Mercurial Madness: Toxic Analysis and Double Standards

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ABSTRACT

Mercury is a known neurotoxin. Current U.S. regulatory efforts through the Environmental Protection Agency (EPA) are directed toward controlling tiny amounts of additional mercury deposition. Treatment of data regarding mercury reveals flawed methods of analysis that can lead to absurd conclusions, yet the conclusions are used to justify draconian, costly regulations of U.S. energy-producing industries. Other sources of mercury, in contrast, particularly in medical applications, are not subjected to a similarly rigorous standard, despite the potential for much greater harm.

Introduction

The phrase "as mad as a hatter" was inspired by symptoms of mercury poisoning suffered by hat makers as a consequence of the use of mercury in the process of curing felt. Isaac Newton probably suffered mercury poisoning from his experiments in alchemy, as described in the book *Newton's Madness: Further Tales of Clinical Neurology* by Harold L. Klawans. Minamata disease, a neurologic syndrome, was caused by severe mercury poisoning from eating shellfish and fish from Minamata Bay into which industrial wastewater had been dumped. Acrodynia or "pink disease" was once a common and sometimes fatal disease in infants before mercury was removed from teething powders, diaper rinses, and laxatives.

Such occupational exposures, public exposures from concentrated industrial dumping, or medical or dental exposures, are not the subject of new regulations. Rather, the U.S. Environmental Protection Agency (EPA) is concerning itself with diffuse tiny amounts of mercury emitted from coal-burning electrical generating stations. Mercury and Air Toxic Standards for power plants have been challenged in court by various industry groups and states, and the case *Michigan v. EPA* has reached the U.S. Supreme Court. The rule would require approximately 1,400 U.S. power plants to emit about 75 percent less mercury starting in 2016.[1] EPA calculates that these rules would save the lives of about 11,000 people per year. However, none of these lives are saved by the reduction of mercury. Instead, they are all due to the "co-benefits" of other reductions resulting from the rule.

Sources of Atmospheric Mercury

About 7,500 tonnes of mercury are emitted into the atmosphere each year from natural and anthropogenic sources. By far, the largest emitter of atmospheric mercury is the ocean. Other huge emitters are various lightly vegetated land areas. In addition, forests, volcanoes, and geothermal events are significant emitters (see Figure 1).

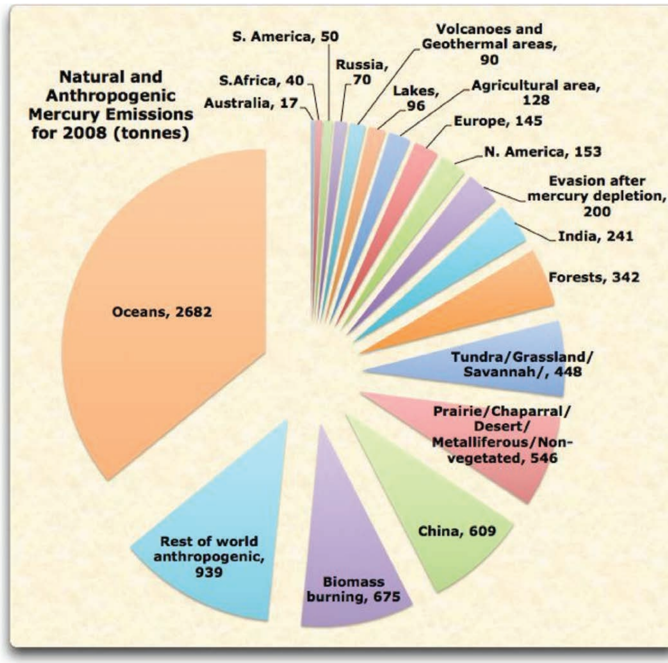

Figure 1. Sources of Atmospheric Mercury. Named countries show anthropogenic emissions for that country

North America contributes a rather small fraction of anthropogenic mercury admissions, as shown in Figure 2. The bar labeled "stationary combustion" is mostly coal-fired power plants. This is what EPA is targeting with its restrictions. U.S. power plants were responsible for about 64.1 tonnes of mercury in 2008, or 1 percent of the total of all mercury emissions.

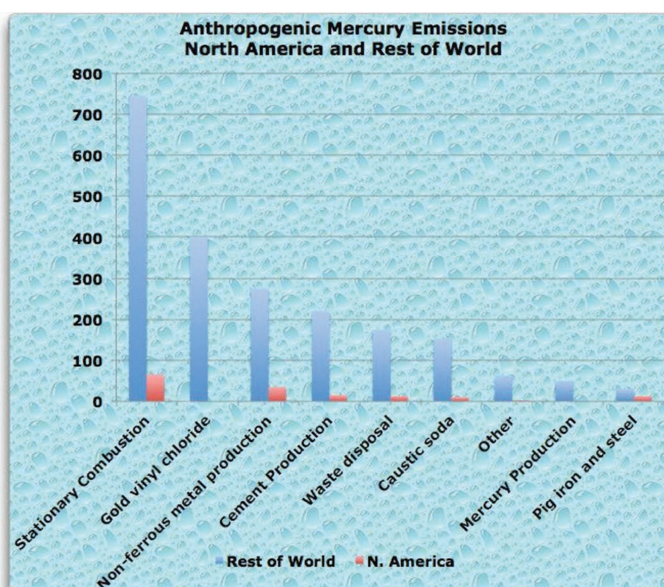

Figure 2. Sources of Anthropogenic Mercury Emissions (tonnes/y)

EPA restrictions will not cut all emissions of mercury from coal-fired power plants, but let's assume that they can cut out 25 tonnes of mercury per year. It's supposed to save 11,000 lives every year. If 11,000 lives could be saved by cutting only 25 tonnes, how many lives could be saved by cutting 100 percent of these mercury emissions? The 25 tonnes are only 1/300 of the total (25/7,500), and 300 times 11,000 gives 3.3 million lives saved every year. No one can imagine that we are losing 3.3 million lives per year from mercury poisoning. Therefore, EPA's assertion that its mercury rule will save 11,000 lives every year is absurd. *Quod erat demonstrandum*.[2] It is only by including the hypothetical "co-benefits" (from reduction of small particulates, PM2.5s) that EPA can make this claim, which means the mercury is irrelevant. In fact there is not one single preventable death attributable to mercury reduction in their projected impacts.

Deposition of Mercury in the Environment

Mercury emitted by power plants, forest fires, automobiles, and so forth is primarily of two kinds: divalent and elemental. Elemental mercury (written as "Hg0") means atoms of mercury vapor. It doesn't combine with much and is insoluble, so it has a fairly long atmospheric half-life, on the order of a year or so. Divalent mercury (written as HgII) exists in the form of compounds such as mercuric chloride ($HgCl_2$). These compounds are both water soluble and chemically reactive, so that they are quickly removed from the atmosphere through deposition by precipitation. Elemental mercury is slowly changed into divalent mercury in the atmosphere. Mercury deposited from the atmosphere or naturally occurring in soil may end up as organic mercury in fish. Fish and shellfish consumption is the route by which mercury emissions into the atmosphere affect the general public. The mercury accumulates as it moves up the food chain.

Areas of the United States where fish have high levels of mercury are shown in Figure 3. The white areas of the map represent those that have not been tested. The EPA threshold of fish safe to eat is 0.3 parts per million (the two lightest shades of red).

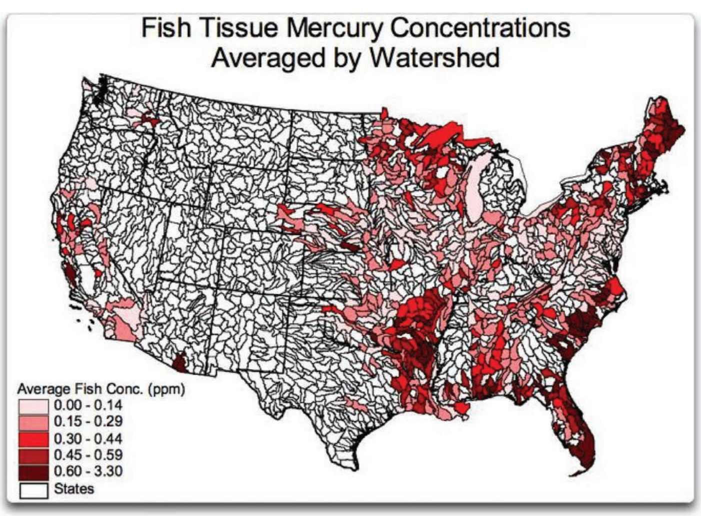

Figure 3. Areas of High Mercury Concentrations in Fish. [Source: EPA's Mercury Maps]

The total mercury concentration in the atmosphere above the U.S. in 2010 is shown in Figure 4. The hot spot in the center of the U.S. reflects natural mercury coming from deserts and croplands.

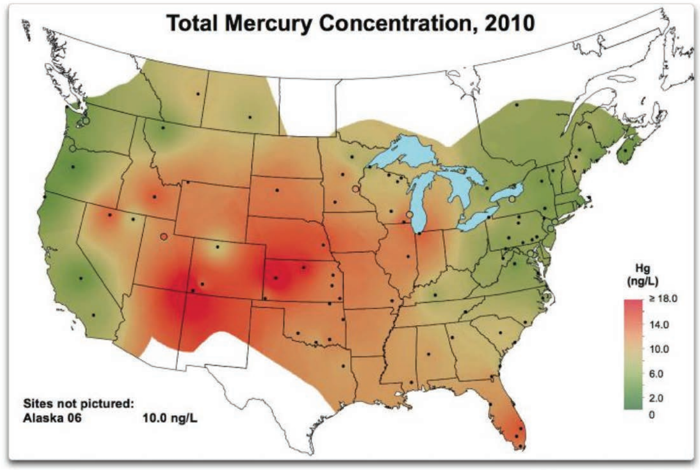

Figure 4. Atmospheric Mercury Concentration above U.S.

The mercury deposited in soil is shown in Figure 5.One might expect that areas downwind from coal-fired power plants would have the highest amount of mercury deposited by precipitation. However, this is not the case. The arrow shows the direction of winds from coal-fired power plants in Ohio to Pennsylvania, which surprisingly does not have high levels of mercury deposition. Deposition is much higher near San Francisco Bay. Basically, the figure is a weather map. Note that the main flow of air in the U.S. is from west to east. When moist air sweeps in from the Pacific and hits the coastal mountains, it rains and deposits the natural mercury from the ocean. Further inland on the east side of California are the western slopes of the Sierra Nevada Mountains. They get the moisture that doesn't fall on the coastal ranges. These high mountains remove most of the moisture from the atmosphere, leaving Nevada with little mercury deposition. The natural hot spot over the Southwestern U.S. precipitates out in the central U.S., aided by moist air flowing in from the Gulf of Mexico. This can be seen all along the Gulf Coast; Florida also has a high level of oceanic mercury deposition.[3]

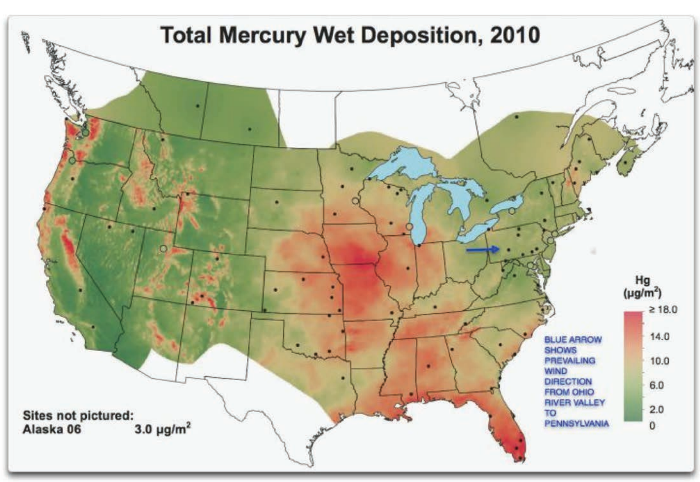

Figure 5. Total Mercury Wet Deposition in U.S., 2010

What's Happening to Mercury Levels in Fish?

When mercury in swordfish was the public scare of the day, a study of swordfish and tuna, by the Smithsonian Institution and other natural-history museums, was published in *Science* in 1972, comparing mercury levels in fish caught between 1878 and 1909, before there were many coal-fired power plants, to tuna caught in 1971. It turned out that the concentrations were about the same.[4] Apparently, the earth is periodically showered with mercury from volcanoes and other sources.[5]

To blame human activity and impose regulations, it is necessary to show an increase in concentration. And the "tuna time bomb" has been found. Over the past 17 years, researchers conclude, writes Brian Palmer in the magazine of the Natural Resources Defense Council, "concentration of mercury in yellowfin tuna has increased by approximately 3.8 percent annually. At the current rate of mercury emission, they could become a very dangerous thing to eat in a decade or two."[6]

Because the authors of the cited study,[7] to their credit, posted the data along with the study, it is possible to assess whether it supports their conclusion.

There were three samples of tuna studied, which were caught in 1971, 1998, and 2008. Figure 6 shows a box plot of the raw data. In the figure, the width of the box is proportional to the number of data points. Boxes show where half of the data is located. The heavy black line is the median of the data. The notches are the error intervals on the median. Units are parts per million (ppm).

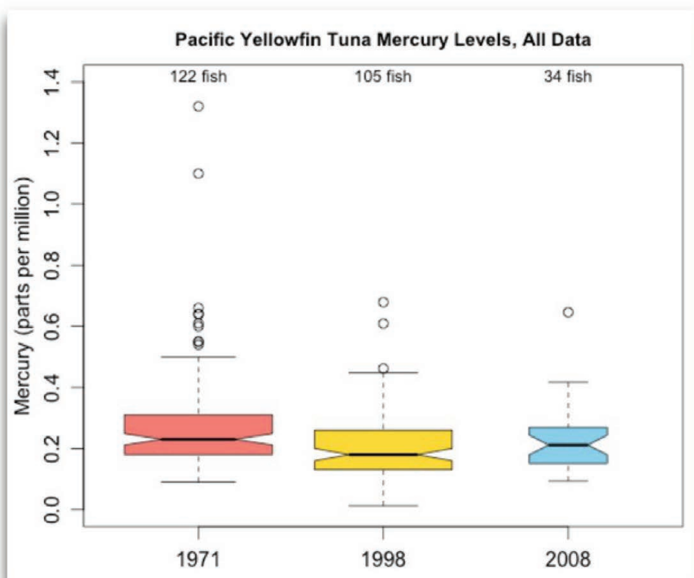

Figure 6. Box Plot of the Tuna Mercury Data by Year of Collection

The authors removed the big fish and the small fish, and the two outliers that have mercury values of 1.32 and 0.15 ppm. Once those are removed, the results are as shown in Figure 7. Note that because of the greatly reduced numbers in the 2008 data, the uncertainty notch has become much wider, and the width of the box is smaller.

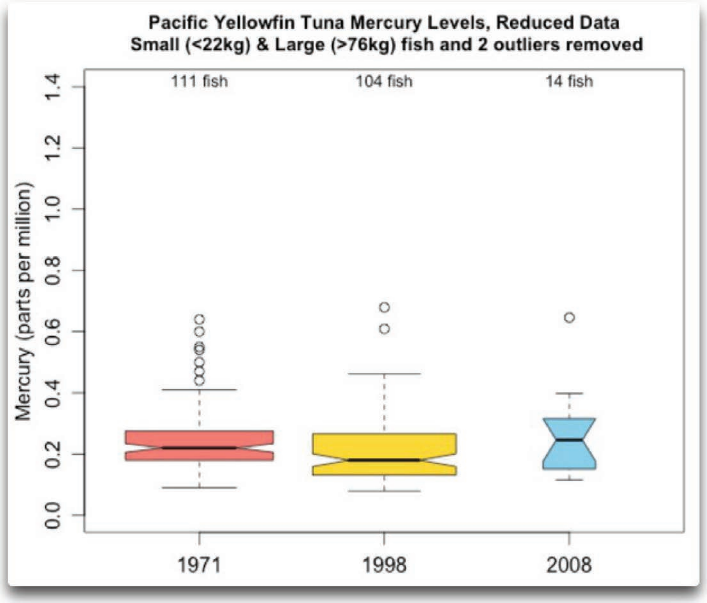

Figure 7. Pacific Yellowfin Tuna Mercury Levels with Reduced Data

The authors' next step is to adjust the mercury content for the weight of the fish. This is important because as the fish gains weight, it bioaccumulates mercury. Figure 8 shows what happens to the reduced data set once the mercury content has been adjusted (either upwards or downwards) depending on the weight of the individual fish. The adjustment is not simple. At a critical body mass, the tuna develops the capability to find prey in deeper, colder water. Below a certain weight, there is not a linear relationship between mercury concentration and size.

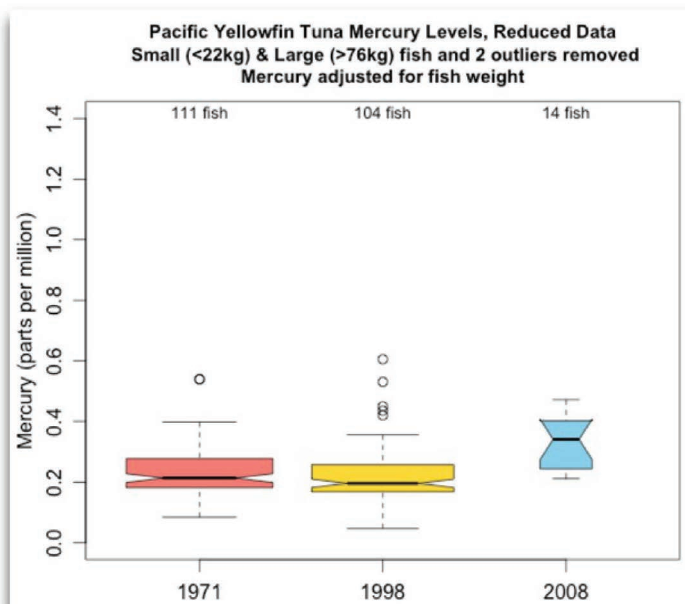

Figure 8. Pacific Yellowfin Tuna Mercury Levels, Reduced Data Set, Adjusted for Fish Weight

This made some obvious changes in the results. First, the outliers have been greatly reduced, as has the range of the data because the outliers were heavy fish with lots of mercury, so that

when they were adjusted, their mercury levels came down. And curiously, while there is not a large change in the median and spread of the 1971 and 1998 data, the mercury concentration in the 2008 data has risen noticeably. While the adjustment process reduced the error of the median in 1971 and 1998 data, it actually increased the error of the median in the 2008 data. The results are still not statistically significant even at the weak P=0.05 level. Now these are the results that they claim to show that the mercury in these tuna is "increasing at a rate of at least 3.8% per year." If anything, the mercury level fell during the period for which we have good data, from 1971 to 1998. This would mean that the entirety of the purported increase occurred over 10 years, after being stable for nearly 30 years. This is simply not plausible.

Why did the results in 2008 move up so much owing to the adjustment by weight? The problem is the weight distribution of the fish in three groups. Figure 9 shows the same three groups, but this time each shows the weights of the fish instead of the mercury levels. The distributions of the weights of the fish caught in 1971 and 1998 are quite similar, but the fish in the 2008 sample are predominantly small.

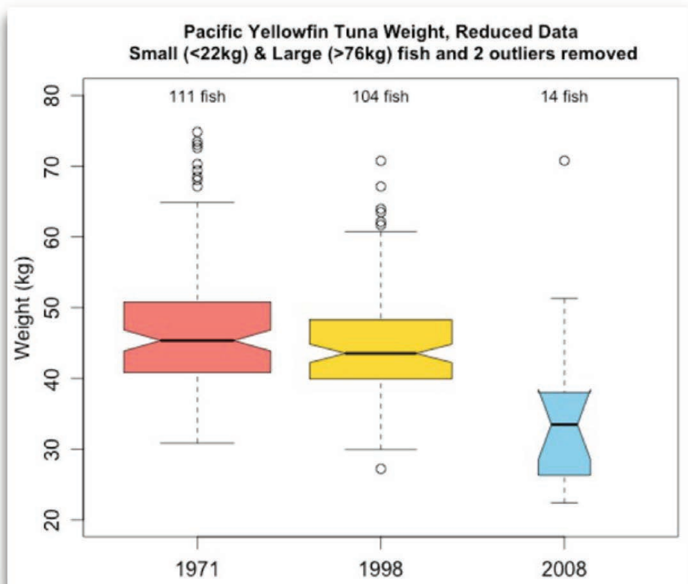

Figure 9. Pacific Yellowfin Tuna Weight, Reduced Data

In summary, these authors have built their entire claim of an increase in mercury on a mere 14 fish, 6 percent of the data, which are lighter in weight than the other 94 percent of the sample.[8] This analysis shows the importance of looking at the raw data before drawing conclusions about one data set, and certainly before extrapolating the results to the whole world.

It's important not to assume that an increase in mercury content of fish, even if genuine, is necessarily due to an increase in anthropogenic emissions. Methylmercury levels in fish do not depend simply on the amount of elemental mercury available for conversion. It's also important that the accumulation of the biologically active form of mercury depends on a variety of factors such as the amount of sulfate, sunlight, and organic matter; pH level; water temperature; and the population of bacteria or zooplankton. A simple change in bacterial activity alone could increase fish mercury concentrations even as atmospheric deposition decreases.[9]

What Is a Safe Level of Mercury?

EPA calculates a reference dose (RfD) using a large number of judgments and very conservative uncertainty factors. From this it calculates that an intake of 0.1 mcg methylmercury per kg per day could be consumed every single day over a lifetime of 70 years without appreciable risk of deleterious effects. This is the most restrictive RfD level for mercury in the world.

When calculating the deleterious effects of exposure to mercury in fish, and hence the hypothetical benefits of regulation, EPA assumes that 6 percent of all pregnant women in the U.S. fish for food and eat as much as 300 pounds of lake fish in a year. It calculates that the exposure to their unborn children will lower the children's IQs by an average of 0.009 points. The average IQ test has a margin of error of about five points. EPA assumes that each IQ point lost would reduce each exposed child's future earnings potential by $892–$1,958 annually. From this it calculates a maximum total benefit of the mercury reductions from its most expensive rule ever of $6 million.[1,7]

Different agencies give different values for the safe cumulative dose of mercury for infants less than 6 months of age. Values for EPA, the Agency for Toxic Substances and Disease Registry (ATSDR), and the U.S. Food and Drug Administration (FDA) are given in Table 1.

Table 1. Exposure Limits for Mercury for Infants Less Than 6 Months Old

Agency	5th Percentile Body Weight	50th Percentile Body Weight	95th Percentile Body Weight
EPA	65 mcg	89 mcg	106 mcg
ATSDR	194 mcg	266 mcg	319 mcg
FDA	259 mcg	354 mcg	425 mcg

Before the removal of thimerosal from vaccines was precipitated by an amendment to the FDA Modernization Act, signed into law Nov 21, 1997, an infant receiving all of the recommended vaccines could have been exposed to a cumulative dose of mercury as high as 187 mcg by six months of age. The vaccines contained 25 mcg of thimerosal, which is 50 percent ethylmercury, per dose. It is simply assumed that ethylmercury is not as dangerous as methylmercury because it is metabolized more quickly.[10]

There is a striking disparity between regulatory policy for the industry that generates 40 percent of America's electricity and that for the pharmaceutical industry. Emissions from coal-fired plants could be responsible for only a tiny fraction of person's mercury exposure from fish, whereas the dose in vaccines is injected in boluses, at a time when the nervous system is developing rapidly. Moreover, vaccines are mandated to be given to most infants.

Public health authorities have not calculated theoretical fractional IQ point losses from increased doses of thimerosal in vaccines, but have stated that its removal was a purely "precautionary" measure and that "the evidence favors rejection of a causal relationship between thimerosal-containing vaccines and autism."[11] A full discussion of this topic is beyond the scope of this article, but note that controversy still exists. For example, there is evidence that the mercury burden is higher in children with autistic spectrum disorders;[12] there is a dose-response

relationship between increasing mercury dose and prevalence of neurodevelopment disorders;[13] and while autism has increased enormously, the possibility that mercury may affect the immune system of certain genetically predisposed children and trigger autism upon their exposure to MMR has never been conclusively ruled out.[14]

In 2000, the late Hilton Terrell, M.D., Ph.D., commented on the double standard:

> Other government agencies have long fulminated against mercury in the environment, making the absurd assumption that there is no threshold exposure beneath which the element is safe.
>
> Recently, an alert somebody noted that the preservative in the vaccine for hepatitis B contains thimerosal, a mercury compound. Calculating the mercury exposure per unit of body weight of newborns, the absurdly low acceptable amounts were transgressed. The vaccine might cause mercury toxicity! We are now told to wait until the infant is two months old before beginning the three shot series. They are working on a mercury-free vaccine.
>
> Now, this collision between two elements of central control is only a fender-bender. We are assured, "...no known harm has occurred...," and that is due to theoretical concerns. It is interesting to stand by and listen to the investigators at the scene of the collision. The U.S. Surgeon-General says, "The risk of devastating childhood diseases from failure to vaccinate far outweighs the minimal, if any, risk of exposure to cumulative levels of mercury in vaccines."
>
> One is tempted to step out into the broken glass in the street and ask these investigating officers, "Why cannot the same reasoning be applied to other minimal risks? … Why can't the industry down the road legally discharge 3 milligrams of mercury into the sewage system each day? Why can't I legally drop an aluminum pull tab from a soft drink can into the Atlantic Ocean nine miles offshore?"[15]

A Fiscal Note

The Regulatory Impact Analysis of the proposed Mercury Toxic Rules says:

> This proposed rule will reduce emissions of Hazardous Air Pollutants (HAP) including mercury from the electric power industry. As a co-benefit, the emissions of certain PM2.5 precursors such as SO_2 will also decline. EPA estimates that this proposed rule will yield annual monetized benefits (in 2007$) of between $59 to $140 billion using a 3% discount rate and $53 and $130 billion using a 7% discount rate.

However, according to Table 1.3 in EPA's own analysis,[16] mercury only has benefits of $.004–$.006 using a 3 percent discount rate, and $0.000005–$0.000009 billion using a 7 percent discount rate.

Now, we have to admire their honesty. They've given all of the monetary values in billions of dollars, with their estimates of total benefit ranging from $50 billion to $140 billion. And they've given their estimate of the benefits from the mercury reduction using a 7 percent discount rate in billions of dollars as well: $0.000005–$0.000009 billion. In human-sized figures, that's a total nationwide benefit spread out across the population of $5,000–$9,000 from the proposed reduction in mercury.

With that kind of trivial benefit, the cost-benefit of including mercury in this regulation must be strongly negative. It should be removed from the bill under the EPA's own requirement that the cost-benefit analysis of a regulation must show a net benefit (positive).

In contrast, the amount spent on autism research is trivial, although the burden of autism will likely mount into trillions of dollars.[14]

Conclusions

U.S. EPA regulatory policies with respect to coal-fired power plants and other industries, which impose enormous costs, are based on questionable methods extrapolated to absurd conclusions. Until fairly recently, mercury in mandated pharmaceutical products was not subjected to scrutiny, and is viewed under a remarkable double standard.

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