MERCURY:

Sources in the Environment, Health Effects, and Politics

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BLUE OCEAN INSTITUTE
Inspiration, Information, Action

Introduction to Mercury; Not The Planet

By Carl Safina

And we care about mercury because…?

Because if you're eating seafood, it's got mercury. And because mercury poisoning is rare, but the risks are real. And mainly because if you understand the risks—you don't have to worry.

Richard Gelfond is the CEO of IMAX movie theaters. A few years ago he noticed that when he was running, he was suddenly having trouble with balance. He dismissed it until he began having difficulty even walking. His wife had to hold his hand while stepping off curbs. He thought it was stress, until one day—he simply fell down.

Mr. Gelfond's doctors couldn't figure out what his problem was. First they suspected a brain tumor. Then they simply suspected that Mr. Gelfond was lying when he insisted he wasn't an alcoholic. Months of frustration and worsening health ensued. It was an article in the New York Times—not the physician's training—that finally caused his frustrated doctor to ask his frustrated patient, "Do you eat a lot of fish?"

"What kind of question is that?," Gelfond thought. He replied that in fact he had a very healthy diet—he ate fish about 14 times a week. The doctor arranged for yet another blood test; this time, they'd be looking for mercury. A blood mercury concentration over 5 milligrams per liter is cause for concern; Mr. Gelfond's was 76. Diagnosis: severe mercury poisoning.

And yet, Mr. Gelfond could not locate a doctor in all of New York City who knew what to do for him. The only thing they could offer was, "Don't eat any more fish; you'll probably get better." (See very informative video on You Tube: "Medical Masquerade: One Man's Experience with Methylmercury Poisoning", Gelfond begins at 4 minutes)

So part of the reason we're interested in mercury is to help create a better-informed medical community, and to spread the word to nutritionists and seafood lovers to be on the lookout for mercury, to understand about mercury in seafood, and to stay healthy.

Another reason: it's close to home for me too. As a lifelong avid fisherman, 30 years ago I started eating fish I caught instead of buying meat. It was a big part of my diet; I ate fish probably five or six nights a week. And because I caught a lot, I served large portions. As my fishing skills improved I sought bigger and bigger fish, until a very large proportion of my diet was tuna steaks and shark—some of the highest-mercury fish around. But at the time, I didn't know much about mercury. Then I noticed that when I was driving, I was having trouble staying in the lane even on straight roads. I had to really concentrate, and do a lot of correcting with the wheel. Like Mr. Gelfond's physicians, I simply did not think about mercury poisoning, or make the connection between my driving and what I was eating. The problem went undiagnosed, but it's likely that I'd given myself mercury poisoning. Over time my fishing and eating habits changed; I went back to catching smaller fish. About 10 years after those weird driving episodes, I found myself talking to the physician who was quoted in the article that first alerted Mr. Gelfond's doctor to the possibility of mercury. He tested my hair and found a mercury concentration of 1.3 parts per million. That's a lot higher than most people's, which usually ranges from about 0.3 to 0.8 parts per million, but it was well below the level at which most people would become sick. (The concentration in hair can't be compared to that in blood; the levels differ and are measured differently).

The thing is, when I got my hair tested I was probably still eating fish several times a week. But I was eating small fish, one-to-two pounders that I caught from my kayak along the shore. That's a lot different than eating big, open-ocean fish that were 100 times larger; because with mercury, size matters. It makes the difference; the bigger the fish, the bigger the mercury dose. And a big part of what I hope you get from all this is: it's not about avoiding fish; it's about avoiding mercury.

We've put together this report intending to shed light on a topic that can seem confusing. I hope you find it enlightening and clarifying. And I hope it helps to keep you healthy.

Carl Safina

Summary

By Carl Safina

Think of it this way: fish is good for you; mercury is bad for you. Fish carry mercury, but some fish have a lot and some have very little. So choose fish low in mercury. We'll tell you how.

For most of us, most of the time, mercury is something we need to think about, but not worry about. (We pay our agencies—like the Environmental Protection Agency (EPA) and the Food and Drug Administration (FDA)—to do the worrying for us; but they don't always do the best job possible.)

If you know what you're doing, you can avoid seafood-related health problems involving mercury. Here are the questions to think about: are we eating fish high in mercury, how much are we eating, and will we be exposing a developing child to mercury?

This report summarizes a lot of what scientists and medical researchers have learned about mercury in the environment, in food, and in people. And, if you want to know, "*Where did these people get this bit of information from?"* this report tells you that, too, with extensive footnotes. If you want to know, *Which fish are low in mercury?,* there's a helpful graphic on page 28, and a list showing low-, medium-, and high-mercury fish on page 33.

Mercury's Sources and Destinations

Mercury is tricky. It's the only metal that is liquid at room temperature. It's an element. It exists in several forms and various compounds. All are toxic. Some forms are lethal in very small quantities. Mercury effortlessly penetrates cell membranes and gets deep into living tissue, including the brain, and crosses the placenta of mammals where it can interfere with fetal development.

Fortunately, most people never come into contact with the most dangerous forms. But mercury is everywhere. In 2009 the U.S. Environmental Protection Agency tested game fish in 500 lakes nationwide; every single fish from every lake tested positive for mercury.

Mercury gets into the air from natural sources such as volcanoes, and human sources such as burning coal. Nowadays, human sources put about ten times as much mercury into the air as do volcanoes. Some mercury coming from the land and sea is natural; but today some of it is mercury that was first introduced through past human activities and is now recycling through living systems. About a third of the mercury getting into the living environment these days is being brought up by people from deep, locked-away sources such as coal, in which mercury is a common impurity.

If you know what you're doing, you can avoid seafood-related health problems involving mercury.

People use mercury in various industrial processes, such as manufacture of chlorine, lye, and plastics, and to separate gold from stream sediments (in certain river systems, gold mining is a significant cause of mercury pollution). But the largest single human-generated source of mercury comes from burning coal to create electricity. And that is greatly increasing.

In the U.S., 40 percent of human-generated mercury comes from coal-burning power plants. Existing technology could remove about 95 percent of the mercury from coal plant smokestacks, but few plants currently have this technology.

It's a truly global issue. The amount of mercury emitted in the U.S. is a small part of world emissions. Two-thirds of human-generated mercury originates in Asia; China is now the world's largest mercury polluter. Air currents carry mercury around the planet. More than half of the mercury that falls in America originates in Asia and elsewhere outside the country. Similarly, about two-thirds of the mercury generated in the United States falls outside the U.S.

After mercury falls to Earth, much of it either settles on water or gets washed into water. In water, bacteria convert mercury into a compound called methylmercury. That's where most of the trouble starts. Methylmercury is the form most commonly absorbed by living things. In streams, lakes, rivers, and the ocean, methylmercury easily enters the food-web, getting into plankton and then plankton-eating fish, and whatever eats them.

Mercury from natural sources has always entered the living environment. But what's different now is that human industrial activities are greatly raising the amount of mercury getting into soils, water, wildlife, and people.

The largest single human-generated source of mercury comes from burning coal to create electricity.

Today, the quantity of mercury in soil is about three times greater

Like people who eat too much fish, fish-eating wildlife—including birds such as herons, and aquatic mammals—can suffer neurological and developmental effects.

than before the Industrial Revolution. Teeth, fur and feather samples dating back 800 years show that pre-industrial mercury concentrations in Arctic marine animals were only about one-tenth of present-day levels. North Pacific Ocean water samples taken in 2006 had mercury concentrations 30 percent higher than just 10 years earlier. Much of that is from increasing coal-burning as developing countries industrialize, and human populations grow.

Like people who eat too much fish, fish-eating wildlife—including birds such as herons, and aquatic mammals—can suffer neurological and developmental effects. Mercury has recently been implicated in egret declines in south Florida, with the birds suffering liver and kidney damage. Even insect-eating songbirds such as thrushes and tree swallows are experiencing mercury-induced reproductive problems and lower survival. Otters in Maine and Vermont and mink in Massachusetts and Connecticut carry mercury concentrations at potentially fatal levels.

When humans become the last link in the ocean food chain by consuming top predators such as sharks, swordfish, or tunas, they get a high mercury dose.

Is this just a scare, or can mercury really make you sick? Answer: It can make you sick. Mercury is a particular concern for child-bearing-aged women and growing children.

Mercury Magnified

Mercury that we send into the air and water comes back to us in seafood. And because mercury gets into living things easier than it leaves, it accumulates more with each rung of the food chain.

So just imagine a simple food chain: Mercury gets into water. Bacteria convert it to methylmercury, which gets into single-celled algae, which are eaten by tiny drifting animals called copepods. Soon one million copepods each carry an infinitesimally small amount of mercury. They're eaten by, say, a thousand herring. Now those thousand herring have the mercury of a million copepods. Over a summer, a tuna eats the thousand herring; getting all the mercury that was in all those herring, mercury that's been gathered by millions of smaller living things from a vast quantity of seawater. That's how all the mercury from many creatures funnels into one.

The longer the food chain, the more toxified the top predators. Animals in each link in the food chain can have between two and seven times the mercury of their prey in the previous link. Levels in these top predators can be more than a million-fold higher than in the little creatures at the bottom of the same food chain.

When humans become the last link in the ocean food chain by consuming top predators such as sharks, swordfish, or tunas, they get a high mercury dose. Arctic peoples such as North American Inuit and the Faroe Islanders, who still eat a lot of seals, dolphins, and whale-meat, carry some of the highest mercury loads. But so do some people who eat a small piece of a big fish many times a week.

Fish Size and Your Health

How much does it take to cause health problems? The thing is: experts disagree. Even so, there's an easy, sensible path through this maze.

Mercury that we send into the air and water comes back to us in seafood.

Fish-eating fishes like bass, snappers, or groupers have higher mercury concentrations than do low-on-the-food-chain shell bearing mollusks (clams, oysters, scallops), crustaceans (shrimp, lobsters, crabs), or mainly vegetarian fishes like tilapia. A grilled shark steak has a relatively high concentration of mercury; a baked clam has very little. (It doesn't matter how you cook it or whether it's raw; the mercury stays.)

So the first rule of thumb about which seafoods are high or low in mercury is: the more predatory the fish, the higher on the food chain—the more mercury. And that's also pretty much the only rule of thumb. Big fish eat little fish, so the bigger, the more mercury. The relevant question becomes: Was it a big fish or a little one? The solution: eat small.

But how dangerous is any given meal to your health? That depends on how big a piece you eat relative to your body weight, whether you're still growing, and whether you're pregnant or likely to become pregnant—and whether you want to eat swordfish, shark, tuna, or other big fish once a year or several times a week.

Mount Sinai Hospital calculated yearly U.S. health costs from mercury pollution at $5.1 billion.

If exposure stops, blood mercury levels drop to half within two months of exposure as mercury passes out of the body. If we habitually eat foods with mercury, mercury accumulates, and with age our mercury level increases.

High Exposure Can Make You Sick

High and chronic exposures have been responsible for some horrible cases of mass poisonings. In the 18th and 19th centuries, factory workers making felt hats using mercury-soaked fabric slowly developed twitches, tremors, and dementia, hence the term: "mad as a hatter." For nearly 40 years in the mid-20th Century, a factory dumped mercury compounds into Minamata Bay, Japan. By the mid 1950s, thousands of residents of nearby fishing communities were stricken with neurological problems and with trouble seeing, speaking, and walking. Worse, many babies were born paralyzed and with gross deformities, and mental retardation. Well over 10,000 people were poisoned.

High doses of mercury can be fatal. But chronic, low-level exposure may cause permanent nervous system damage, affecting the brain and impairing sight, hearing, speech, learning abilities and IQ, attention span, and muscle coordination, fatigue, difficulty concentrating, thinning hair, digestive problems, muscle and joint pain, sleep disorders, immune system problems, and heart and vascular trouble. (Of course, those problems can arise from other causes too, making it difficult to determine when mercury is the cause.) Serious methylmercury poisoning can cause tingling, difficulty walk¬ing, skin rashes, mood swings, memory loss, liver and hormonal problems, and, in extreme cases, coma, convulsions, and death. A cost analysis by researchers at New York City's Mount Sinai Hospital calculated yearly U.S. health costs from mercury pollution at $5.1 billion.

A U.S. government study of over 6,000 women between 1999 and 2006 found that 8 percent of women of childbearing age had blood mercury levels exceeding the Environmental Protection Agency's guidelines for potential injury to an unborn child.

If a fish cannot fit on a platter whole, it's probably high in mercury.

Mercury exposure in the womb or during infancy, can disrupt complex, fragile development, causing irreversible damage to a child's brain—at much lower exposures than those affecting adults. Over 600,000 children annually are born with mercury levels that put them at risk for learn¬ing problems and impaired intelligence, according to an Environmental Protection Agency analysis of in-the-womb mercury exposure.

And yet—seafood is the best source of the omega-3 fatty acid DHA, which is critical for a baby's brain and eye development, both before and after birth.

This has sparked unhelpful debating of yes-or-no questions: "Should I eat fish because it's healthy?" Should I avoid seafood because it's dangerous?" "Do the benefits of eating fish outweigh the risks?" Those are the wrong questions.

Because seafood is both nutritious and our main source of mercury, the answer isn't, "avoid seafood;" the answer is, "avoid mercury."

Eating Fish But Avoiding Mercury

Here's how to do it: First, change the questions to, "What fish should I eat? How much? And how often?"

But remember our rule of thumb: the bigger the fish, the more mercury. A large, old 500-pound mako shark that has been eating tunas and swordfish is going to contain all the mercury that has concentrated up the line, from swarms of plankton to many thousands of smaller fish like mackerel, then into the tuna and swordfish and on to the shark. Similarly, a 5-pound cod has eaten less food than has a 50-pound cod, so it has accumulated less mercury. Our rule of thumb holds: eat small.

If a fish cannot fit on a platter whole, it's probably high in mercury. For instance, some of the lowest-mercury seafoods include shrimps, salmon, catfish, and pollock. You could fit them on a platter whole. But tuna? It would take a mighty large platter to fit a whole tuna, since yellowfin, bigeye, and bluefin tuna often exceed 100 pounds (bluefin can reach well over 1,000). That's why fresh tuna comes in steaks. Canned tuna is usually yellowfin, skipjack, or albacore tuna. Most Americans eat so much canned tuna, in fact, that over one-third of the U.S. population's mercury comes from canned tuna. And beware of fish sold as steaks; those are big fish, so limit your eating.

But what kind of advice is "beware," or "limit?" In 2010 the Environmental Protection Agency and the Food and Drug Administration issued a joint consumer advisory. The guidance, directed at women who may become pregnant, pregnant women, nursing mothers, and young children, boils down to this: "Eat up to 12 ounces (2 average meals) a week of a variety of fish and shellfish that are lower in mercury… If you eat a lot of fish one week, you can cut back for the next week or two. Just make sure you average the recommended amount per week." Because tuna steaks have more mercury than canned tuna, they recommend not exceeding 6 ounces per week of tuna steaks (http://1.usa.gov/eEK3jn).

So it's pretty easy to stay within government-recommended guidelines and to keep your mercury blood-level low. However, the guidelines don't speak to men, or to women who aren't potentially child-bearing. And the agencies' list of fish low in mercury is poor and partially inaccurate. To clarify this, we include a very informative graphic on page 28 and a table on page 33. The good news: some of the most popular and best-tasting seafood is also low in mercury.

Fishing industry lobbyists and publicists want you to believe there's nothing at all to worry about.

Denial and Spin

Blue Ocean Institute wants to give you the full information picture so you don't have to worry. But fishing industry lobbyists and publicists want you to believe there's nothing at all to worry about. Their Orwellian-named Center for Consumer Freedom's mercuryfacts.com tells consumers that they can eat fish containing ten times the EPA recommended maximum dose. Fishscam.com contends that mercury concerns are a "scare." A U.S. based seafood industry lobbying group, National Fisheries Institute, actually wrote, "What published science shows is that higher blood mercury among moms may actually be a marker of optimal brain development in babies, because it indicates regular seafood consumption."

To keep fish safe, we need to reduce the release of mercury.

Corporate profits in the energy industry have also affected our health by influencing mercury regulation. Companies operating the nation's worst-polluting coal-power plants raised millions of dollars to create pro-industry mercury rules while the George W. Bush administration ignored professional and scientific staff and advice from a federal advisory panel.

Cause for Optimism

To keep fish safe, we need to reduce the release of mercury. That's quite doable. Existing pollution-control technology could lower global mercury discharges by up to 60 percent. The European Mercury Strategy, launched in 2005, includes a 2011 ban on mercury exports, a phase-out of mercury in goods and industrial applications, new rules for safe storage, and reductions in mercury emissions from fossil-fuel power plants and industrial facilities.

In the U.S., there's been a sharp drop in mercury use in batteries, fungicides, and paints. Mercury emissions from U.S. municipal and medical waste incinerators have gone down by 90 percent.

But what about coal? New regulations enacted by the Obama Administration in December, 2011 will, for the first time, regulate emissions from coal-fired power plants under the Clean Air Act. These new rules will remove over 90 percent of the mercury when power plants burn coal. More than half of all coal-fired power plants already use the proposed technologies. Compliance will cost about $11 billion yearly, but the EPA estimates benefits of up to $140 billion each year. In other words, every dollar spent reducing power plant pollution can yield up to $13 in health and economic benefits.

Every dollar spent reducing power plant pollution can yield up to $13 in health and economic benefits.

That's the way forward, and cause for optimism.

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I. Mercury Basics

Mercury comes from both natural and anthropogenic sources and has many pathways to ecosystems and humans.

Quick facts

- Atomic number: 80
- Symbol: Hg
- Also known as quicksilver
- Only metal that is liquid under standard pressure/temperature conditions

Source: UNEP Chemicals Branch, 2008: The Global Atmospheric Mercury Assessment: Sources, Emissions and Transport. UNEP Chemicals Branch, Geneva, Switzerland.

Mercury, also known as quicksilver, is a rare, naturally occurring, silvery-white metal in the Earth's crust. It is found throughout the world, but constitutes less than 1/100,000,000 of one percent of the planet. Since it does not blend geochemically with the crust's main elements, mercury sometimes concentrates in rock, sometimes as elemental mercury (Hg) but most commonly as cinnabar (mercury sulfide, HgS), a bright red mineral.[1] The element was named after the Roman god Mercury, the messenger god who wore winged sandals, known for speed and mobility.

Mercury exists in three forms, all of which are toxic and considered potentially dangerous: elemental, inorganic and organic. Each has distinct properties that affect its distribution, uptake and toxicity, but all forms can be converted to toxic organic compounds. Some are poisonous even in very small quantities.[2] Most atmospheric mercury is elemental mercury vapor, while most mercury in water, soil, sediments, or plants and animals is found within compounds and inorganic salts.[3]

Mercury atoms in their pure metallic form are known as elemental mercury (Hg). The metal can exist as both a gas and a liquid at room temperature. Elemental mercury vapor, or gaseous elemental mercury, is the predominant form in the atmosphere. In this form, it may deposit locally or can remain airborne for up to a year, traveling globally before being deposited on land or water. Gaseous elemental mercury is toxic to air-breathing creatures at high concentrations—much higher levels than exist in the outdoor environment.[4] Exposure occurs when elemental mercury is spilled or products containing elemental mercury break, posing particular risk in warm or poorly ventilated spaces.[5]

Sunlight-induced reactions can convert gaseous elemental mercury to atmospheric compounds known as reactive gaseous mercury (RGM), some of which is bound to particles as total particulate mercury. Both forms are more water-soluble than gaseous elemental mercury and fall to Earth quicker, usually within hours or days of emission, often creating regional mercury hotspots. But under the right atmospheric conditions, RGM can be transported long distances, even between continents.[6]

After emission to the air, inorganic mercury (bound to airborne particles or in a gaseous form) eventually falls back to Earth in rain, snow or as dry particles and settles on or is washed into water.[7] It is the form most commonly found in the environment in compounds that include mercuric chloride, mercuric acetate, mercuric sulfide, and others. Inorganic mercury is not as easily absorbed by living organisms as other forms.[8]

Organic mercury is most commonly found as methylmercury (CH3Hg+ or MeHg), a potent neurotoxin.[9] Mercury is transformed into methylmercury by bacteria living in aquatic systems: rivers, lakes, wetlands, sediment, soil and the ocean.[10] Any form of mercury that makes its way into an aquatic system has the potential to be converted into organic mercury—and into methylmercury.[11,12]

Methylmercury compounds are highly stable and are soluble both in water and in the fats of organisms. This form of mercury is the most toxic to humans and wildlife, easily penetrating cell membranes and absorbing into tissues. Aquatic plants and animals readily take up mercury from their environment (either from air or water or by eating food contaminated with mercury) that bioaccumulates, with levels generally increasing with each step up the food chain. The highest mercury concentrations are found in top predators.[13, 14, 15]

Various chemical processes can return mercury to its elemental form that can then be easily re-emitted.

II. Uses of Mercury

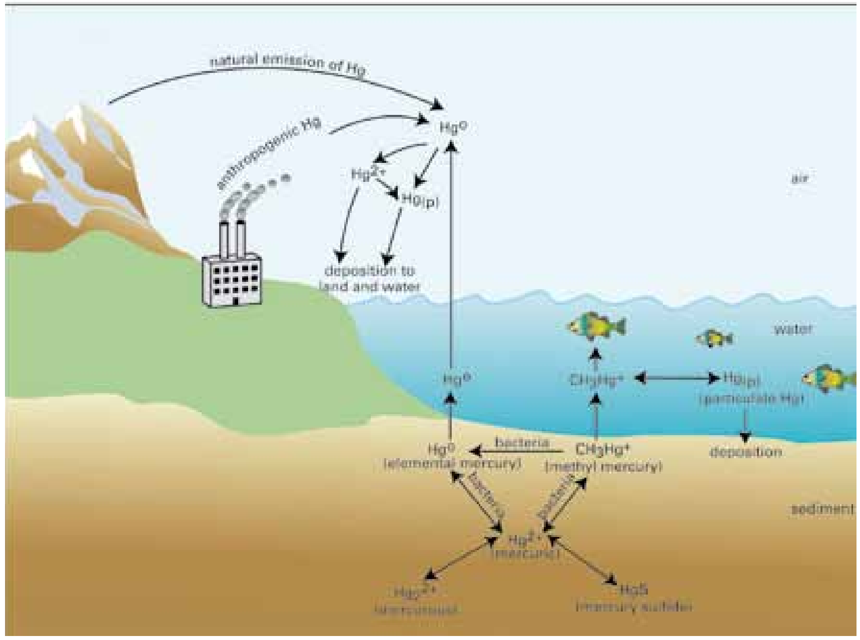
Because mercury responds to change in temperature and pressure, it has long been used in thermometers, barometers and navigational instruments. Good conductivity makes it useful in electrical wiring and switches, batteries, and thermostats. Mercury-vapor lamps light highways at night. A plethora of consumer products contain

Mercury may deposit locally or can remain airborne for up to a year, traveling globally before being deposited on land or water.

mercury, from paints, switches, fluorescent bulbs, and electronic devices, to pesticides, fungicides (used in seeds and bulbs) and cosmetics (mascara, eyeliner and skin-lightening creams).

In medicine, mercury is an ingredient in dental amalgam, acts as a preservative in pharmaceuticals and is used in blood pressure machines.

Major species and transformations of mercury in the environment (modified from Wood, 1974; Mason and others, 1994).



Conversion to methylmercury is most important because it is bioavailable and is transferred to water and biota.

Source: USGS: Geologic Studies of Mercury by the U.S. Geological Survey

In industry, it is used in the smelting process, in nuclear reactors, as an antifouling agent in paper, and in the production of chlorine, lye and plastic—and is used to recover gold from stream sediments.[1]

Mercury-free alternatives are available for many products, so in some regions, use is declining. One exception is the growing market for energy-saving light bulbs. Although compact fluorescent (CFL) bulbs use less energy—a way to combat climate change—they contain mercury. The European Union's call for mandatory use of compact fluorescents by 2012 has prompted China to reopen cinnabar mines and ramp up factory production of CFL bulbs with attendant environmental cost.[2] However, each CFL bulb contains only a small amount of mercury (5 milligrams), less than a watch battery, but still requires safe recycling.[3]

Burning of fossil fuels, primarily coal, is the largest single source of mercury pollution.

Another exception is polyvinyl chloride (PVC). China's booming construction industry has sparked a huge PVC demand, which uses a mercury catalyst.[4]

III. Sources of Mercury

Mercury is one of the more highly toxic persistent chemicals on Congress's list of Hazardous Air Pollutants.[1] Many natural sources of mercury create background environmental levels that were present long before humans walked the planet. However, global concentrations have increased substantially over the last two centuries with inputs from a range of human activities. Sediment, peat and ice core data have shown that today, sediment contains about three times as much mercury as it did before the Industrial Revolution.[2]

Emissions estimates vary, but Hans Friedli, a chemist at the National Center for Atmospheric Research and an international consortium estimated in 2010 that yearly emissions from natural sources average 5,207 metric tons (about 11,500,00 pounds) or 69 percent of total emissions. Human inputs added an additional 2,320 metric tons (about 5,114,700 pounds), for a total of 7,527 (about 6,594,200 pounds).[3]

Ocean mercury levels in 2006 were approximately 30 percent higher than those measured in the mid-1990s.

Recent sediment and ice core samples also show that on a global scale, new mercury deposition is about one-third human-caused, another third comes from natural sources, and one-third is "legacy" mercury. Such legacy mercury re-enters the environment from previous deposition, often in a time scale of decades or longer—and originates from a combination of natural and human-produced sources.[4]

Mercury concentrations vary greatly between locations, influence by proximity to pollution sources, wind, tides, and other factors. While mercury is a "persistent pollutant" that does not break down over time, its dangers slowly lessen as it settles into the beds of rivers, lakes and oceans, buried under layers of sediment.[5]

1. Natural Sources of Mercury

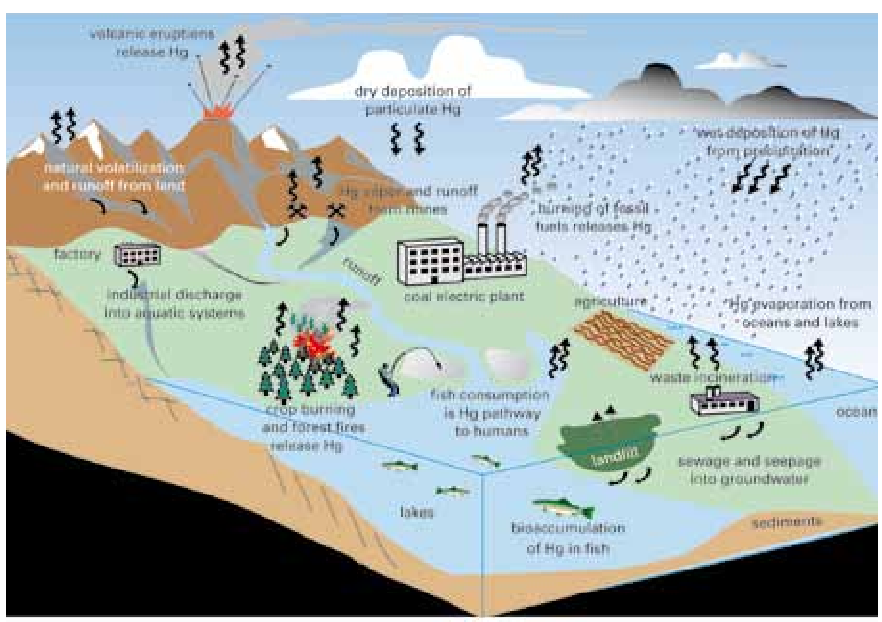
Concentrated mercury ores are usually found where high-density rocks are forced to the surface in hot springs or volcanic regions[1]. It naturally enters the environment through volcanic eruptions, forest fires, evaporation from oceans and topsoil, weathering of mercury-containing rocks, erosion,[2] and through tens of thousands of uncontrolled coal bed fires.[3]

Most of yearly natural source emissions (5,207 metric tons or about 11,500,00 pounds)[4] come from surface waters—2,778 metric tons (6,124,000 lbs.). Another 2,429 metric tons (5,355,000 lbs.) per year come from terrestrial surfaces. Periodic volcanic eruptions and geothermal activities account for about 2 percent of all natural releases—about 90 metric tons (200,000 lbs.) per year but can be much higher.[5] These estimates include both primary emissions from natural reservoirs and re-emissions of previously deposited mercury that originated from both human and natural sources.[6]

Global concentrations have increased substantially over the last two centuries with inputs from a range of human activities.

Mercury in the ocean comes from both natural and human-produced sources. University of Connecticut mercury expert Robert Mason estimates total mercury in the ocean to be 350,000 metric tons (772,000,000 lbs.).[7] Precipitation carries airborne mercury to the ocean's surface, and melting snow and ice, runoff from

Mercury Cycle showing important contributions of mercury to the environment from land, water, air and anthropogenic sources



Source: USGS: Geologic Studies of Mercury by the U.S. Geological Survey

Concentrations of mercury in the atmosphere and contributions of mercury to the atmosphere from natural and anthropogenic sources

[Mercury concentrations given (ng/m^3) are those in air above the sources listed, which are provided to give a relative comparison of various sources contributing mercury to the atmosphere. Estimated mercury contributed to the atmosphere represents that from all like sources combined throughout the world, for example, all oceans worldwide are estimated to contribute as much as 2,000 t of mercury per year to the atmosphere. ≈, approximated; ng/ m^3, nanograms/cubic meter; kg/yr, kilograms/year; t/yr, metric tons/year]

Source	Hg concentration or emission*	Estimated Hg contributed to atmosphere worldwide	References
Atmosphere	1 – 2 ng/m^3	4,400 – 6,000 t/yr	Fitzgerald (1986); Porcella (1994); Lamborg and others (2002).
Volcanoes	28 – 1,400 ng/m^3	60 t/yr #	Fitzgerald (1986); Varekamp and Buseck (1986); Ferrara and others (1994).
Land	1 – 6 ng/m^3	~ 1,000 t/yr	Varekamp and Buseck (1986); Gustin and others (1994); Mason and others (1994).
Mines	2 – 5,000 ng/m^3	~10 – 100 t/yr	Ferrara and others (1991; 1998) Gustin and others (1994; 1996; 2000).
Oceans	1 – 3 ng/m^3	800 – 2,000 t/yr	Mason and others (1994); Lamborg and others (2002).
Anthropogenic	~10->900 kg/yr *	2,000 – 2,600 t/yr	Mason and others (1994); Environmental Protection Agency (2000); Lambor g and others (2002).

Mercury emissions from some explosively erupting volcanoes indicate that this source of mercury to the atmosphere could be several times higher than shown here (Varekamp and Buseck, 1986).

*Range of mercury emissions in 1999 from numerous power plants in the U.S.A. as reported to the EPA (Environmental Protection Agency, 2000).

Source: USGS: Geologic Studies of Mercury by the U.S. Geological Survey

Environmental Mercury Fluxes from Global Mercury Models

	Lamborg et al., 2002	Mason and Sheu, 2002	Selin et al., 2007	Mason, 2008	Friedl et al., 2008
Hg Fluxes (kt/yr)					
Natural emissions from land	1.0	0.81	0.5		
Re-emissions from land		0.79	1.5		
Emissions from biomass burning					0.675
(A) Total emissions from land	1.0	1.6	2.0	1.85[a]	
Natural emissions from ocean	0.4	1.3	0.4		
Re-emissions from ocean	0.4	1.3	2.4		
(B) Total oceanic emissions	0.8	2.6	2.8	2.6	
(C) Primary anthropogenic emissions	2.6	2.4	2.2		
Total emissions (A+B+C)	**4.4**	**6.6**	**7.0**		
(D) Deposition to land	2.2	3.52			
(E) Deposition to ocean	2.0	3.08			
Total deposition (D+E)	**4.2**	**6.6**	**7.0**	**6.4**	
Net load to land	1.2	1.72			
Net load to ocean (burial in sediments)	1.2 (0.4)	0.68 (0.2)			
Total net load (land+ocean)	**2.4**	**2.4**	**2.2**		
Other parameters					
Mercury burden in the troposphere (kt)	5.22	5.00	5.36		
GEM lifetime (yr)	1.3	0.76	0.79		

[a]Including Hg^0 emissions (0.2 kt/yr) in response to Atmospheric Mercury Depletion Events (AMDE's) in polar regions. Biomass burning is not included in the emissions from land in this Table. For table references see the technical background report.

Source: UNEP Chemicals Branch, 2008: The Global Atmospheric Mercury Assessment: Sources, Emissions and Transport. UNEP Chemicals Branch, Geneva, Switzerland.

rivers and coastal erosion brings more. Currents transport mercury between oceans, and carry upwells from deep waters to the surface.[8] Ocean mercury levels measured 30 percent higher in 2006 than mid-1990s concentrations.[9]

Atmospheric mercury emissions from forest fires (and other naturally-occurring biomass burning) have only recently been considered in local and global estimates. Using averages from 1997-2006, recent studies place those outputs at about 675 metric tons (1,488,000 lbs.) per year, some 13 percent of total natural mercury outputs.[10]

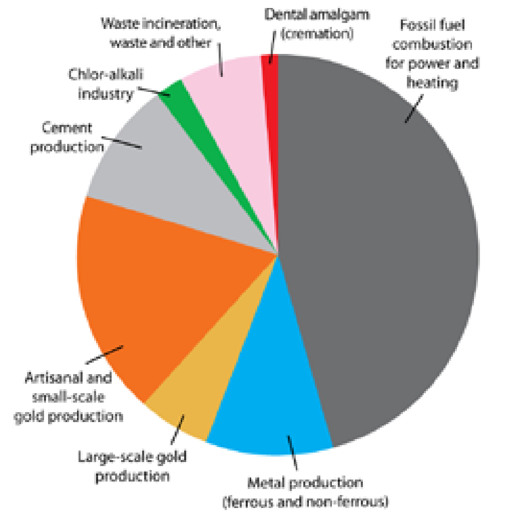
2. Human (Anthropogenic) Sources of Mercury Emissions

The main human sources of mercury come from burning coal to generate electricity, mining activities, waste incineration and industrial processes used in smelting or cement production. UNEP estimates that 45 percent of human-generated mercury worldwide comes from burning fossil

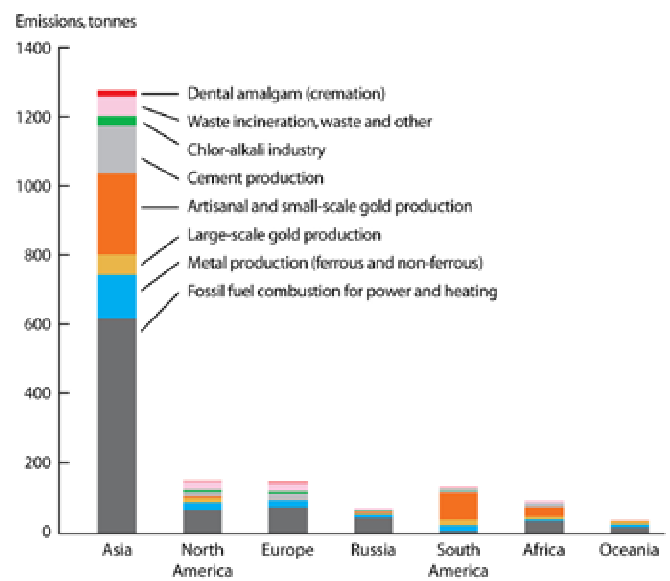
Nearly 70 percent of human-generated mercury emissions globally come from burning coal and the mining and processing of gold.

fuels, with coal-fired power plants being the largest single source.[1] In the U.S., 40 percent of mercury emissions come from coal-fired power plants.[2] Small-scale gold mining contributes about 18 percent, with industrial gold production adding an additional 6 to 7 percent. Mining, smelting, and producing metals other than gold or mercury account for some 10% of all anthropogenic emissions.[3]

UNEP quantifies global anthropogenic inputs in the graphics below:



Proportion of global anthropogenic emissions to air in 2005 from different sectors.



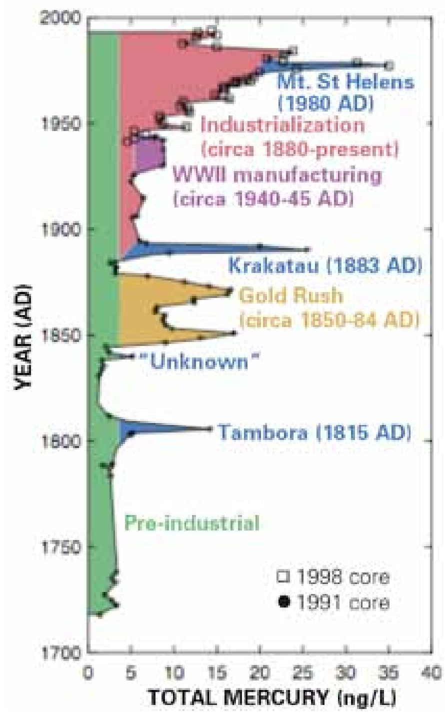
Emission factors for HG used to estimate the 2005 emissions

Category	Unit	Emission factor
Coal combustion:		
· Power plants	g/tonne coal	0.1–0.3
· Residential and commercial boilers	g/tonne coal	0.3
Oil combustion	g/tonne oil	0.001
Non-ferrous metal production		
· Cu smelters	g/tonne Cu produced	5.0
· Pb smelters	g/tonne Pb produced	3.0
· Zn smelters	g/tonne Zn produced	7.0
Cement production	g/tonne cement	0.1
Pig iron & steel production	g/tonne steel	0.04
Waste incineration	g/tonne wastes	
· Municipal wastes		1.0
· Sewage sludge wastes		5.0
Mercury Production (Primary)	kg/tonne ore mined	0.2
Gold production (Large-scale)	g/g gold mined	0.025–0.027

Note: The emission factor denotes the average mercury emission rate from various sources, relative to the intensity of each specific activity.
Source (three graphics above): UNEP Chemicals Branch, 2008: The Global Atmospheric Mercury Assessment: Sources, Emissions and Transport. UNEP Chemicals Branch, Geneva, Switzerland.

According to 2002 U.S. Geological Survey (USGS) estimates, metal production, typically smelters, contributed 6.8 percent of global mercury emissions and 6.4 percent came from cement production. Another 3 percent comes from waste disposal, including municipal and hazardous waste, crematoria and sewage sludge incineration; however, with limited data, this may be underestimated by somewhere between a factor of two to five. Three percent comes from chlor-alkali production; 1.4 percent from production of pig iron and steel and 1.1 percent from mercury production, mainly for batteries.[4,5]

Human-generated sources have increased the amount of mercury in the environment across the globe. Many studies have estimated human contributions, with varying estimates. Using 2005 data, the United Nations Environment Programme (UNEP) estimates total human emissions at approximately 1,930 metric tons per year (TYP), (about 4,255,000 pounds), with a possible range of 1,220 to 2,900 tpy (2,690,000 to 6,393,000 lbs.).[6] Friedli and Mason's estimate is 2,320 metric tons (5,115,000 lbs.). These figures do not include emissions from home cook-fires, slash-and-burn farming or other biomass burning.[7]



Atmospheric mercury deposition corresponds to volcanic and anthropogenic events over the past 270 years. Preindustrial deposition rates can be conservatively extrapolated to present time (4ng/L; in green) to illustrate the increase during the past 100 years (in red) and significant decreases in the past 15-20 years.

Source: UNEP Chemicals Branch, 2008: The Global Atmospheric Mercury Assessment: Sources, Emissions and Transport. UNEP Chemicals Branch, Geneva, Switzerland.

Arctic ice core, sediment and peat samples document the rise in mercury since pre-industrial times. They reveal a rapid rise in gaseous elemental mercury after World War II, which peaked around 1970 and then fell sharply after the widespread introduction of clean air policies in some parts of the world. Levels have remained relatively stable since around the mid-1990s.[8] Geographically, about two-thirds of human-induced mercury releases to the atmosphere come from Asia. China, with its rapidly expanding economy, is now the number one mercury polluter worldwide, accounting for nearly half of global emissions.

The bulk of China's emissions come from coal-fired power plants and coal burning for heat and cooking in individual households. The U.S. and India rank second and third, but together equal about one-third of China's emissions. Russia ranks fourth. Fossil fuel-powered electric plants are

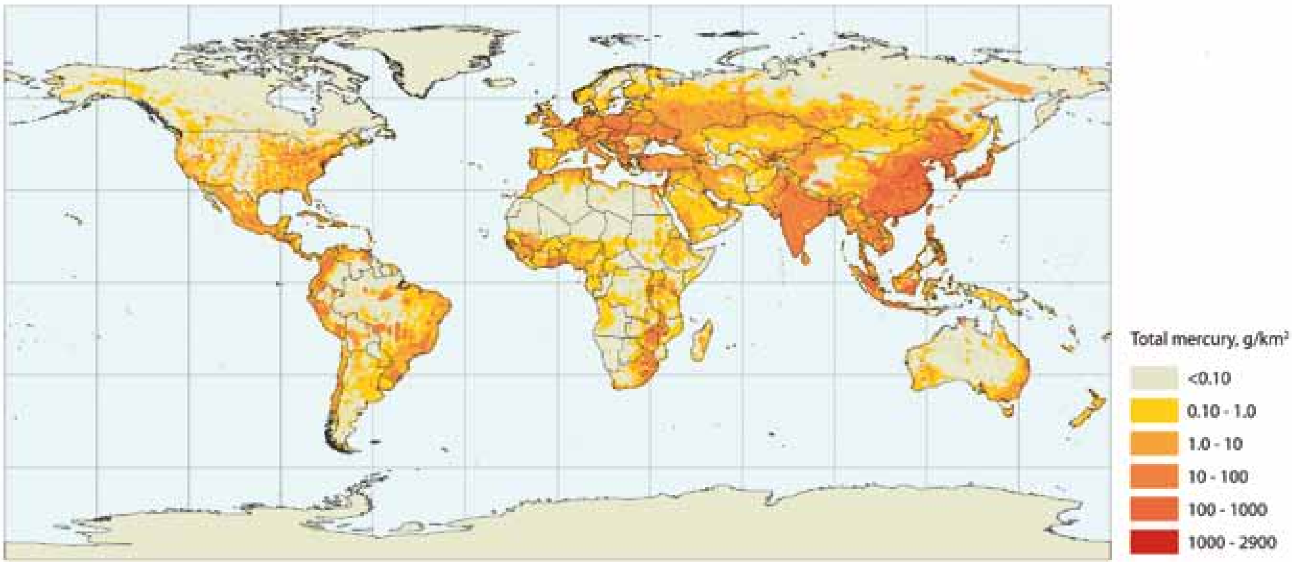
Global anthropogenic emissions to air in 2005 from different regions

Continent	2005 emission, tonnes	% of 2005 emission	Low-end estimate	High-end estimate
Africa	95	5.0	55	140
Asia	1281	66.5	835	1760
Europe	150	7.8	90	310
North America	153	7.9	90	305
Oceania	39	2.0	25	50
Russia	74	3.9	45	130
South America	133	6.9	80	195
Total	1930	100	1220	2900

Source: UNEP Chemicals Branch, 2008: The Global Atmospheric Mercury Assessment: Sources, Emissions and Transport. UNEP Chemicals Branch, Geneva, Switzerland.

Geographically, about two-thirds of anthropogenic releases of mercury to the atmosphere come from Asia.

Global mercury emissions to air from human activities in 2005



Source: Arctic Monitoring and Assessment Programme, Arctic Pollution 2011

the main source of emissions from all four countries.[10]

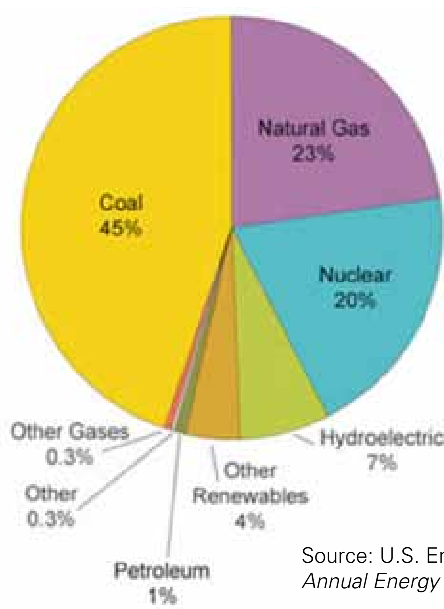
Despite some fluctuation, human-caused mercury emissions to the atmosphere have remained fairly constant since around 1990 despite a growing global population with expanding energy needs. In 1990, estimates totaled 1,910 metric tons (4,211,000 lbs.); output rose to 2,050 tons (4,519,000 lbs.) in 1995, but then fell back to near-1990 levels in 2000: 1,930 tons (4,255,000 lbs.) in 2000. This drop was mostly due to emissions control in Europe and North America.[11]

U.S. anthropogenic mercury emissions account for roughly 3 percent globally.

Illinois offers a U.S. success story. After instituting stringent state regulations, mercury emissions from Illinois coal plants dropped from 3,894 pounds in 2005 to 2,532 in 2009—while generating the same amount of electricity.[12]

However, emissions increased in

U.S. Electric Power Industry Net Generation by Fuel, 2009



Source: U.S. Energy Information Administration, *Annual Energy Review 2009* (August 2010)

Emission factors for Mercury used to estimate the 2005 emissions

Category	Unit	Emission factor
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Source: UNEP Chemicals Branch, 2008: The Global Atmospheric Mercury Assessment: Sources, Emissions and Transport. UNEP Chemicals Branch, Geneva, Switzerland.

South America, Africa, Oceania—and particularly in Asia,[13] which as of 2005, contributed an estimated 65 percent of emissions from human activities.[14]

The U.S. contribution totals about 242 metric tons (534,000 lbs.), dropping to less than 160 (353,000 lbs.) per year by the end of the decade.[15] U.S. anthropogenic mercury emissions account for roughly 3 percent globally.[16]

In 2005, coal-fired power plants contributed just under half of global human-generated mercury pollution,[2] an estimated 810 metric tons (1,785,000 lbs.).[3] China is both the largest coal producer and biggest consumer. In 2003, Chinese mercury emissions were estimated at 609 metric tons (1,343,000 lbs.), with 44 percent coming from coal combustion.[4]

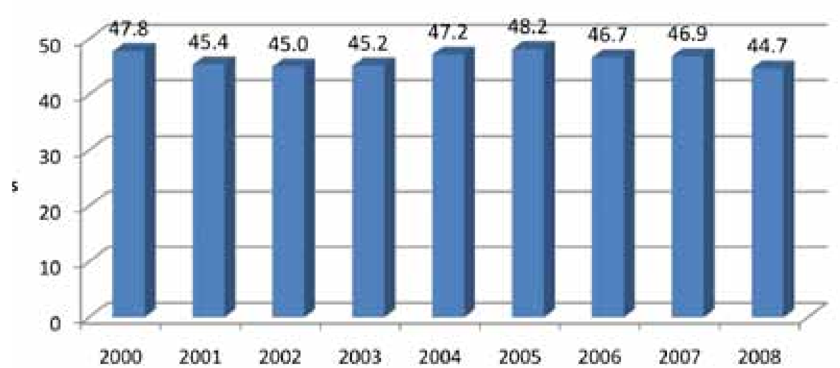
The U.S. Environmental Protection Agency (EPA) estimated that coal-fired power plants are responsible for about 40 percent of total U.S. anthropogenic mercury emissions; some 1,200 coal-fired units at more than 450 power plants generate about half of the nation's electricity.[5]

Pollution controls (such as electrostatic precipitators and fabric filters) remove up to one-third of the mercury emitted by coal burning plants. When combined with sulfur dioxide

A. Human Sources: Energy Production

Burning of fossil fuels, primarily coal, is the largest single source of human-generated mercury pollution. Mercury is a natural impurity in coal. When it is burned to generate electricity, mercury is released into the air through a plant's smokestacks. Coal combustion creates mercury emissions between one and two orders of magnitude higher than those from oil combustion, depending on the country.[1]

U.S. Power Plant HG Emissions 2000-2008



Source: Dirty Kilowatt report

Global historic primary production of Hg, and the total contribution from the two main mining sites in Europe, Almadén in Spain and Idrija in present-day Slovenia.

L.D. Hylander, M. Meilli/The Science of the Total Environment 304 (2003) 13-27

Source: 500 years of Mercury Production

and nitrogen oxide control devices, up to 95 percent of the mercury can be captured.[6] However, many plants lack these pollution controls, globally and in the U.S.[7]

Many U.S. plants have installed pollution-control devices, but some older plants without controls emit large amounts of mercury. In their 2007 report, "Dirty Kilowatts: America's Most Polluting Power Plants," the Environmental Integrity Project (EIP) reported that U.S. mercury emissions from the nation's 1400-plus fossil fuel-fired power plants have remained fairly steady since 2000, hovering between 44 and 48 tons per year.[8] Together, the 50 highest-polluting plants emitted 16 tons of mercury—one–third of all power plant mercury pollution—but generated less than 18 percent of the electricity.[9] Though total mercury emissions from coal-fired power plants fell by 4.71 percent between 2007 and 2008, 27 of the top 50 emitters increased emissions, in one case, by more than 100 percent.[10]

In their May 2011 Proposed Rules, the EPA projected that power plant mercury emissions in 2010 would reach approximately 60 tons; 1990 levels were 46 tons.[11]

B. Human Sources: Mining

Big human-induced mercury inputs began with mining.[1] Globally, nearly one million tons of metallic mercury has been produced for human use throughout recorded history. Currently, mercury releases from artisanal and small-scale gold mining activities are among the most critical environmental issues.

Mercury ore has been mined for over 2,000 years in China, where mercury was originally used as an amalgamation agent. [2] Qin Shihuang, founder of China's Qin Dynasty (246-221 BC), was killed by drinking a mercury mixture concocted by Qin alchemists that was meant to bestow eternal life.[3] Cinnabar was used over 1,000 years ago as a drug, a preservative and as vermillion and orange pigment in temples and palaces. The mines in Almaden, Spain employed 1,000 laborers in the early 12th century, under the Arabic Empire.[4] The ancient Greeks used mercury in ointments and the Romans used it in cosmetics that sometimes deformed the face.[5]

The 1554 invention of the "patio

Figure 11. Mercury mineral belts in North America. Mercury mines shown have significant mercury production (> 1,000 flasks or 34 t), and mercury occurrences have little or no production. Modified from Rytuba (2003).

Source: USGS: Geologic Studies of Mercury by the U.S. Geological Survey process" that used mercury to extract silver from ore made it an extremely valuable resource for Spain and its American colonies, with demand continuing into the late 19th century.

Around the world, the largest mercury mines have been in Spain, Italy, Slovenia, Peru, China, the former U.S.S.R., Algeria, Mexico, Turkey, and the U.S. (California).[6] Many others are scattered across the planet, but most are closed due to low demand and sagging prices sparked by environmental and health concerns.[7] Remaining mines operate in Algeria, Kyrgyzstan, and China.[8]

Mercury has been mined in North America since the early 1800s, with about 130,000 tons produced from several mercury mineral belts. The largest producer, the California Coast Ranges mineral belt, contains over 50 mines. Much of the mercury produced in North America was used in gold mining, using the mercury amalgamation process. Large-scale mercury mining ceased by about 1990 in North America; the last U.S. mine, McDermitt Mine in Nevada, closed in 1992.[9]

Mercury released from artisanal and small-scale gold mining activities is among the most critical current environmental issues.

Legacy mercury pollution remains in riverbanks, soils, and drainages throughout historic gold mining regions, posing potential health hazards to humans and wildlife: drainage from mines pollutes streams, rivers, local watersheds and ecosystems.[10] Significant mine wastes containing cinnabar ore and elemental mercury exist at abandoned mercury mines scattered across southwestern Alaska, California, Nevada, Texas, Arkansas and throughout the Pacific Northwest.[11]

Another substantial source is the chlor-alkali industry that uses mercury to convert salt to chlorine gas and lye, which is used in soaps, detergents, plastics, and in the paper-making process.

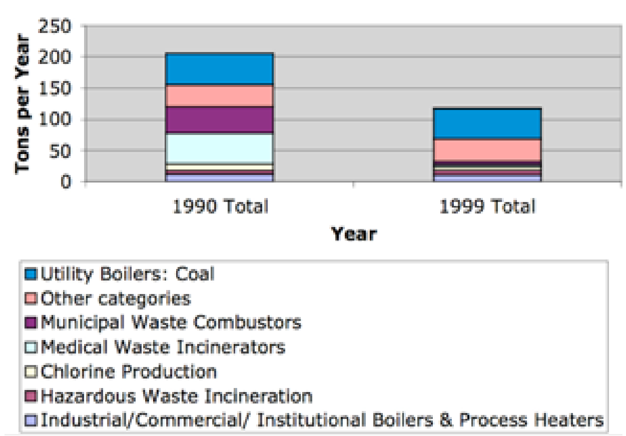
Across the globe, widespread artisanal and small-scale gold mining activities create serious environmental and health issues. Some 10-15 million people work in artisanal/small-scale gold mining[12] producing 20 to 30 percent of the world's gold.[13] The largest mercury emissions from three of the top 10 global emitters—Brazil, Indonesia and Colombia—come from artisanal mining.[14]

The practice is often illegal and unregulated, operates in 70 nations (many of them developing countries), and releases somewhere between 650 and 1,000 tons (1,433,000 and 2,205,000 lbs.) of mercury a year.[15] Most of this goes directly into waterways. Miners are also exposed to toxic vapor when using mercury in pans to amalgamate gold particles.

The quest for other metals also has mercury impacts. Mercury is a common impurity in copper, zinc, lead and nickel ores;[16] smelting processes to obtain these metals release large amounts of mercury into the atmosphere, especially in developing countries[17], but metal production also accounts for most of the mercury emissions in Canada and Mexico.[18] Mining, smelting and producing metals other than gold and mercury contribute about one-tenth of anthropogenic emissions to air and water.[19]

C. Other Sources of Anthropogenic Mercury Emissions

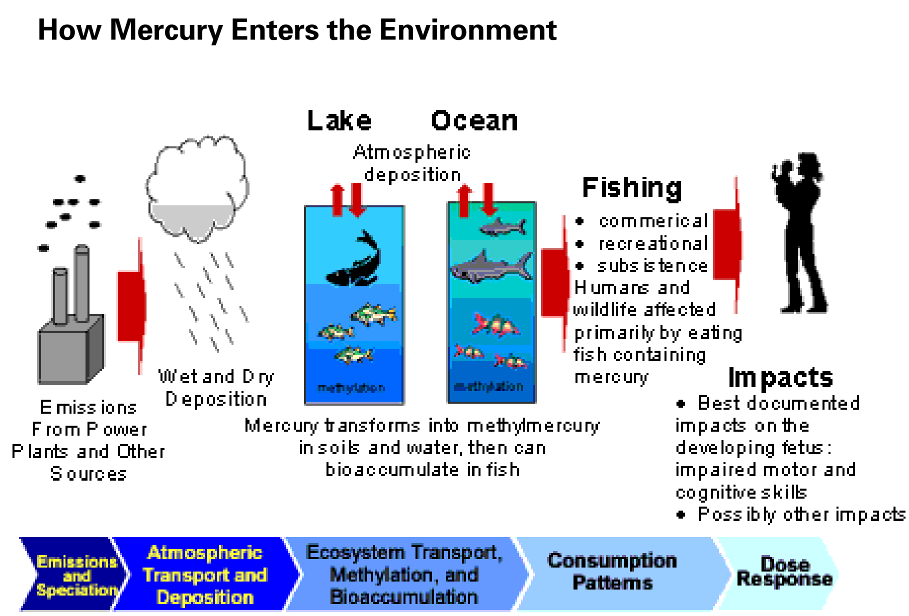
Change in Mercury Emissions by Source Categories



Source: Environmental Protection Agency

Cement plants, which burn coal to heat the materials used to make cement, are the fourth largest emitter of airborne mercury in the U.S. Both coal and limestone—a raw material used in the process—contain mercury.[1]

Another substantial source is the chlor-alkali industry that uses mercury to convert salt to chlorine gas and lye, which are ingredients in soaps, detergents, plastics, and in the paper-making process.[2] These plants are among the biggest industrial mercury users; it's not uncommon for a plant to house about 200 tons of mercury on site. Globally, chlor-alkali plants have "lost" dozens of tons of mercury in the manufacturing process and cannot account for where that mercury went.[3] However, the chlorine industries in India and the European Union have made voluntary commitments to completely eliminate the mercury process. Modern chlor-alkali plants use mercuryfree technology.[4]



Source: Environmental Protection Agency

Discarded mercury-laden consumer products that ultimately end up in landfills or waste incinerators create[5] up to 7 percent of total human-produced emissions. Incineration is the larger of the two sources, but mercury leaches slowly from landfills to contaminate soil, air and water.

Most countries do not measure the mercury content of medical waste, and emissions are often lumped into overall waste incinerator estimates. About 5,000 medical waste incinerators are currently operating in the U.S., with most of them releasing 50 times more mercury than that released by a municipal solid waste incinerator, according to 2008 EPA estimates.[5]

Other anthropogenic sources of mercury include industrial runoff, seepage, and discharges6 and, in some countries, cremation of human remains that have mercury amalgam dental fillings; the production of dental amalgam and use of mercury fillings causes additional releases.[7]

IV. How Mercury Moves and Persists in the Environment

Mercury released through human activities has increased over the past 150 years[1]: Since pre-industrial times, the amount of mercury dispersed across the globe has at least doubled.[2] This has increased the amount of mercury in the ocean by 25 percent at the surface and 11 percent in the deep sea.[3]

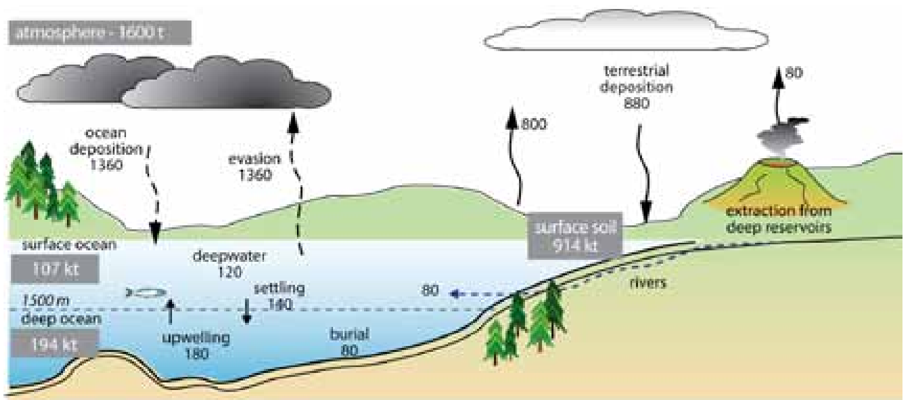
Over the course of the 20th century, mercury in Canadian lake sediments has increased three-fold, with the greatest contamination in lakes at lower latitudes that sit close to major emission sources. Similar increases have occurred in lake sediments across Eurasia and North America.[4]

No matter where on Earth it originates, airborne mercury gas mixes throughout the troposphere (lower atmosphere) and can potentially travel great distances. In this form, it normally circulates in the atmosphere from 6 months to 2 years, long enough to be carried thousands of miles across continents and around the globe.[5] (Other forms of mercury tend to be deposited closer to their sources.) Its movement is determined by chemical changes in the mercury and on the physics of wind and precipitation.

Mercury redistributes around the world, eventually falling to earth or into the ocean or freshwaters, on local, regional, continental and/or global scales. Mercury that remains airborne for extended time periods and travels

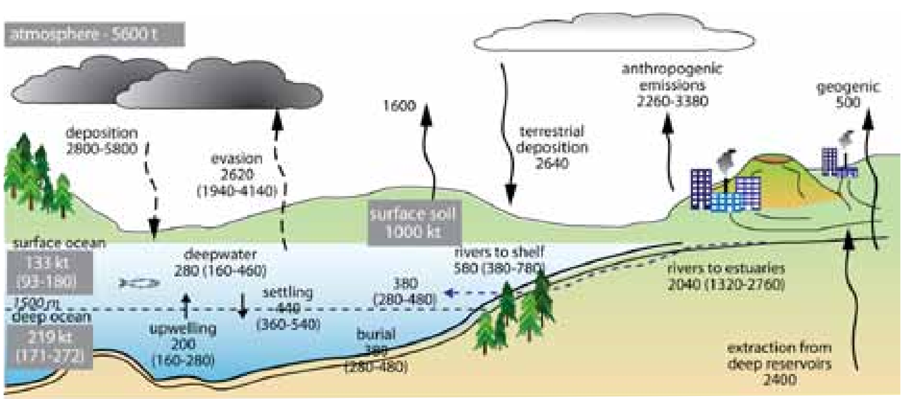
Since pre-industrial times, global atmospheric mercury deposition rates have at least doubled, distributing mercury across the globe.

Pre-industrial budget



Results of box models showing changes in mercury cycling from pre-industrial times to the present (all fluxes in t/yr).

Present-day budget



Source: UNEP Chemicals Branch, 2008: The Global Atmospheric Mercury Assessment: Sources, Emissions and Transport. UNEP Chemicals Branch, Geneva, Switzerland.

across continents is said to be in "the global cycle."

EPA has estimated that about one-third of U.S. emissions are deposited within the continental U.S., with the remainder entering the global cycle and contributing a total of 5 percent to the global load. In all, less than half of all mercury deposition within the U.S. comes from U.S. sources.[6]

Coal-fired power plants emit about 40 percent of U.S. mercury pollution.[7] and that mercury deposits in high quantities close to emission sources, concentrating at up to 3 times average regional levels.[8] An EPA-funded study traced almost 70 percent of the mercury in Ohio Valley rainwater to local coal-fired power plants.[9] But U.S. emissions also pollute other parts of the country. Heavy concentrations of U.S.-sourced mercury land in the Northeast, driven from Midwest power plants on easterly winds.[10]

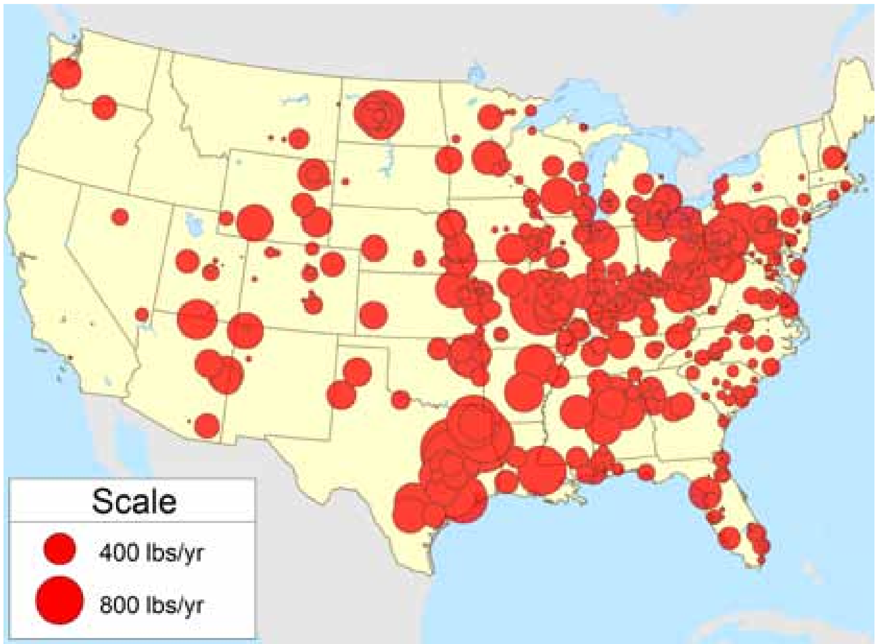
Global air currents transport substantial quantities of mercury to the Arctic: a 2011 study found that between 80 and 140 tons of man-made mercury emissions are deposited in the Arctic Ocean yearly.

Wind and water patterns sometimes carry pollutants to remote regions far removed from population centers or industrial zones.[11] Global air currents transport substantial amounts of mercury to the Arctic: a 2011 study found that between 80 and 140 tons (176,000 and 309,000 lbs.) of human-made mercury emissions reach the Arctic Ocean yearly. A similar quantity arrives on ocean currents (particularly from the Atlantic Ocean), flowing in on river currents and released by coastal erosion.[12]

Airborne mercury can travel from a power plant in the mid-latitudes to the high Arctic within days or weeks. Ocean currents move far slower; it can take years or even decades for mercury

EPA has estimated that about one-third of U.S. emissions are deposited within the contiguous U.S., with the remainder entering the global cycle and contributing a total of 5 percent to the global load…less than half of all mercury deposition within the U.S. comes from U.S. sources.

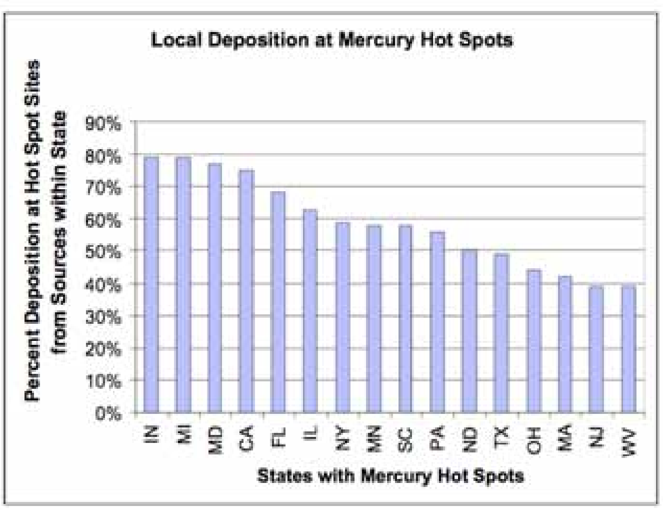
Power Plant Sources of Airborne Mercury Pollutions, 2010



Each circle in this map represents a power plant that reported mercury pollution in 2010. The area of the circle is directly proportional to the amount of mercury the plant emitted.

Source: Environment America Research and Policy Center

Recent modeling shows that local emissions can have local impacts



Source: EPA Office of Water --Draft analysis 2003

to flow from the mid-latitudes to the Arctic Ocean.[13]

Most of the mercury released to the environment is repeatedly cycled within and between "environmental reservoirs": air, surface soils, sediments, oceans, rivers, and lakes. This "historical mercury", which comes from both natural and human sources, is continually re-emitted into air and re-deposited onto land and surface waters.[14]

For example, rain or flooding washes mercury in soil or sediment back into oceans or rivers, impacting aquatic ecosystems—and then evaporation returns mercury to the atmosphere. Mercury absorbed by trees and other vegetation is re-released during forest fires. Rain and snow eventually conveys atmospheric mercury back to land, completing the cycle. In this way, mercury can move between regions in a series of hops called "the grasshopper effect," which spreads pollutants farther than expected.[15]

Rain or flooding washes mercury in soil or sediment back into oceans or rivers, impacting aquatic ecosystems--and then evaporation returns mercury to the atmosphere.

Half of re-emissions originate from natural sources, with the other half coming from human inputs. Eventually, deep burial in soils and sediments removes mercury from circulation. Surface soils and oceans store the most mercury. Exchange between oceans, soil and atmosphere eventu-

Once deposited into the sea… mercury is absorbed by phytoplankton and attaches to dead organic matter that then "rains" a steady supply of mercury through the water column and into sediments.

ally create steady levels within each of these sectors when inputs stabilize.[16]

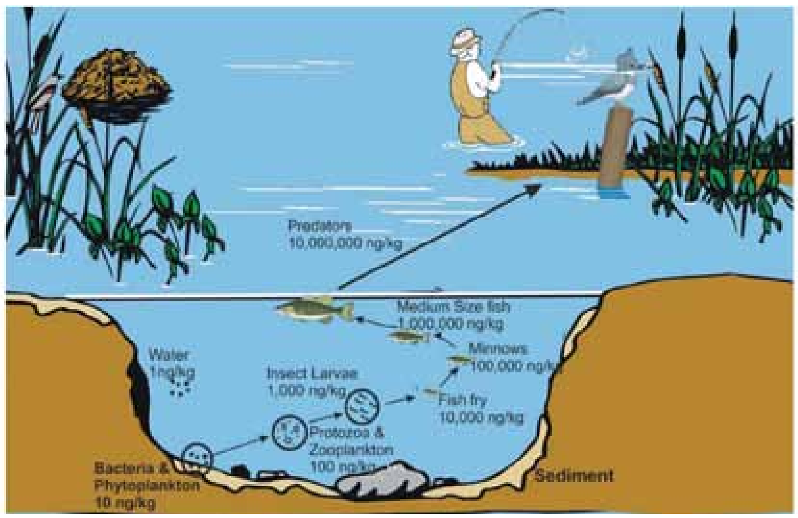
Once deposited into the sea, mercury can be transformed into its most toxic form, methylmercury. In productive marine areas, mercury is absorbed by phytoplankton and naturally attaches to dead organic matter; as that matter sinks, it "rains" a steady supply of mercury through the water column and into ocean sediments.[17]

A landmark U.S. Geological Survey (USGS) study in the North Pacific Ocean documented for the first time how this "ocean rain" process converts mercury into methylmercury. They tracked mercury emissions from Asia to deposition points in the North Pacific. There, they observed the life cycle of various species of algae that thrive in sunlit waters near the surface. These algae are short-lived, and "rain" downward when they die. At depth, bacteria decompose the settling algae. The researchers found that this decomposition process transforms mercury into methylmercury.[18]

V. How Mercury Moves from the Environment to People and Animals

When mercury falls in rain or snow as dust-like particles, it is eventually washed into waterways or the sea. Within these aquatic environments, bacteria convert inorganic mercury into an extremely toxic form, methymercury that is easily and rapidly absorbed by fish and other aquatic organisms. Although mercury and most of its compounds are toxic to all living organisms, methylmercury poses the greatest health risk to both animals and to people who eat mercury-laden seafood.[1]

Biomagnification of Mercury



The concentration of a pollutant can increase from one link in a food chain to the next hightest trophic level through the process of biomagnification. This diagram illustrates a typical pathway for biomagnification of merucry.

Source: USGS: Geologic Studies of Mercury by the U.S. Geological Survey

Methylmercury accumulates in tissues and organs. It also biomagnifies, increasing in concentration up the food chain. At each successive step (trophic level) up the food web, methylmercury levels jump between two and seven times higher, moving from prey to predator. The longer the food chain, the more poisoned top predators become.[2]

As a result, the predatory fish that humans and marine mammals consume, such as swordfish, king mackerel, shark, and certain tuna species, as well as wild freshwater fish like pike or bass, have the highest concentrations of mercury.[3] Levels in these top predators can be over a million-fold higher than in the small creatures at the bottom of the food chain that live in or near the same waters.[4]

The greatest source of human exposure to methylmercury comes through consumption of fish, marine mammals, and crustaceans.[5] Exposure depends on a variety of factors, including the frequency of seafood meals, a person's body weight, portion size and type of fish or shellfish eaten. EPA

The greatest source of human exposure to methylmercury comes through consumption of fish, marine mammals, and crustaceans.

EPA's 500 sampling locations for their National Lake Fish Tissue Study

Source: Environmental Protection Agency

guidelines established a maximum mercury dose of .1 microgram per kilogram of body weight per day to be the level shown to be without appreciable risk over the course of a lifetime. This "reference dose" (RfD) corresponds to a blood mercury level of 5.8 micrograms per liter (µg/l).[6]

Americans consumed 15.8 pounds of fish per person in 2009, according to the National Marine Fisheries Service, spending an estimated $75.5 billion on seafood. Most, about 84 percent, was imported.[7]

Over 50 types of fish and shellfish make up 97 percent of the seafood Americans eat. Mercury concentrations in those species span at least two orders of magnitude, with, herring—a low-mercury fish—containing about 0.01 parts per million (ppm), while shark may carry more than 1 ppm.[8] Many of the largest sources, such as tuna and swordfish, are caught in far-off waters before being sold in domestic markets.[9]

A 2011 study by GotMercury.org evaluated mercury levels in fish sold in grocery stores in Florida, California, New York, Iowa, and Nevada. Nearly three-quarters of swordfish samples registered high levels of mercury, and 13 of them were more than two hundred times the maximum acceptable levels set by federal food safety officials.[10]

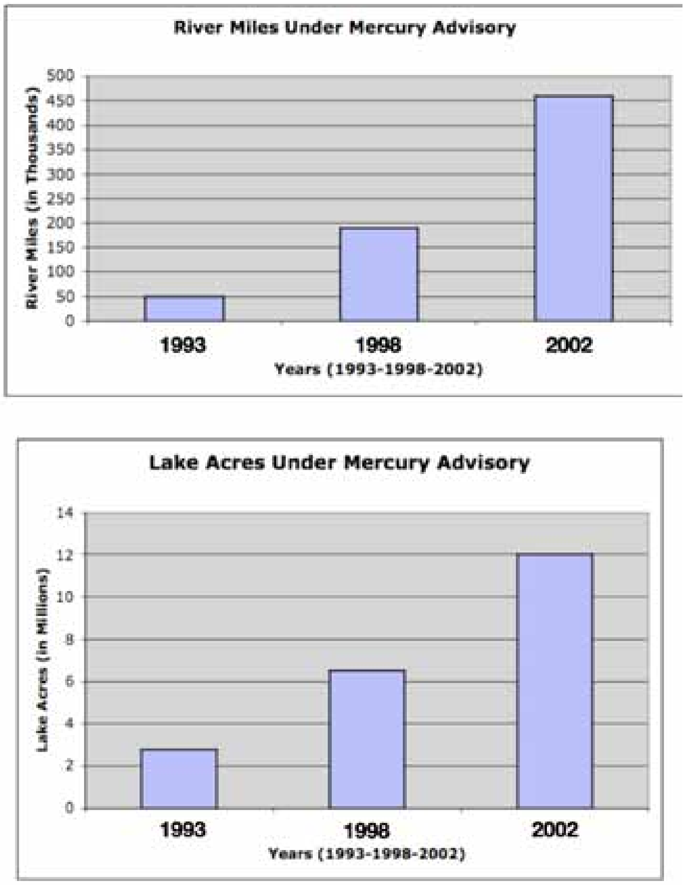
Only 1/70th of a teaspoon of mercury is needed to contaminate a 25-acre lake to the point where fish are unsafe to eat.

Ocean-caught fish account for over 90 percent of Americans' mercury intake.[11] Some people believe that seafood fished from the sea are safer to eat than those caught in lakes or rivers because selenium in ocean fish offsets mercury, but that premise is not widely accepted among experts.[12]

Unsafe mercury levels are carried by both commercial and sport fish caught in ocean waters as well as locally-caught freshwater fish. Subsistence and sport fishermen who eat their catch can be at a particularly high risk of mercury poisoning if they fish regularly in contaminated waters. Most states' health departments have issued advisories regarding methylmercury contamination in sport fish, but few departments offer advice on commercially-caught fish.

In 2009, the EPA tested predator and bottom-dwelling game fish species at 500 lakes and reservoirs nationwide as part of the National Lake Fish Tissue Study. Every fish tested from every water body contained mercury. Fish fillets from 49 percent of the sampled lakes contained over 0.3 ppm, exceeding EPA standards for human consumption. The agency estimates that these results represent the conditions in 36,422 lakes across the country.[13] Only 1/70th of a teaspoon of mercury is needed to contaminate a 25-acre lake to the point where fish are unsafe to eat.[14]

In 2001, 41 states issued 2,259 advisories for mercury contamination in a wide variety of fish species, with over half of those advisories applying to all water bodies in the state.[15] All 50 states issued fish consumption advisories in 2008, warning citizens to limit how often they eat certain types of fish caught in state waters because of mercury content.[16] In certain locations, like California, some contamination is related to past mining activities, but most advisories are not related to mining or nearby industrial discharges. In these cases, atmospheric mercury



Source: Environmental Protection Agency

deposition is the probable culprit.[17]

Across the U.S., mercury pollution has contaminated 18 million acres of lakes, estuaries, and wetlands (43 percent), and 1.4 million miles of river. Trends show the situation is worsening. Between 2006 and 2008, lake acreage under advisory increased by 18 percent and river miles went up by 52 percent. Despite those increases, many waterways have never even been tested.[18]

In some downwind locations, waters can be highly polluted. In 2009, 96 percent of the lakes in New York's Adirondack Mountains exceeded the recommended government action level for methylmercury in fish.[19]

Mercury emitted by power plants over the last decade is still impacting fish today.

Within the last few years, research has proven that mercury atmospheric emissions end up in fish in as little as three years.[20] Mercury emitted by power plants over the last decade is still impacting fish today.[21]

VI. Health Effects of Mercury Exposure

Mercury is toxic to all living things and serves no known metabolic function. As methylmercury, it is easily absorbed and not easily eliminated, it readily breaches the blood-brain barrier, and since it also passes to the placenta, women of childbearing age and unborn children are of greatest concern.[1] High concentrations in humans impact the central nervous system, especially the sensory, visual, and auditory parts of the brain that affect coordination.[1]

Although high doses of mercury can prove fatal, recent research suggests that chronic, low-level exposure may cause nervous system damage, lower immunity, impair reproduction, and raise heart attack risk.[2]

The greatest exposure comes from eating mercury-laden fish. Acute health affects are also triggered by exposure to elemental mercury vapor from sources like broken thermometers or fluorescent light bulbs. Exposure to inorganic mercury is rare, and usually occurs in the workplace.

A range of factors influences the severity of health effects from exposure, including the dose, duration of exposure and the chemical form of mercury, the age and health of the individual, and the route of exposure (inhalation, ingestion, or skin contact)[3]. Blood mercury levels seem to increase with age, generally peaking in a person's 50s or 60s.[4]

High concentrations in humans impact the central nervous system, especially the sensory, visual, and auditory parts of the brain that affect coordination.

Although higher blood mercury levels do not guarantee harm, they do increase risk of damage to the developing brain in unborn babies and young children. Symptoms of toxic effects have been seen in adults and children whose blood mercury levels exceed the EPA's reference dose.[5]

A 2011 cost analysis by researchers at New York City's Mount Sinai Hospital calculated yearly U.S. health costs from mercury pollution to be $5.1 billion when factoring in medical care and indirect costs such as income lost while caring for sick children.[6]

1. Neurological Damage in Children

Mercury's adverse affects on developing neurological systems are well established and known to be permanent.[1] Studies of widespread mercury poisoning in Minamata, Japan from the 1930s through the 1960s indicate that prenatal exposure causes damage throughout the fetal brain. Epidemiological data from Minamata and other historic poisonings, particularly Iraq, have demonstrated the developmental effects of methylmercury on the fetal brain. In some cases, children were born with serious congenital methylmercury poisoning although the mother had appeared unaffected during pregnancy.[2]

A 2011 cost analysis by researchers at New York City's Mount Sinai Hospital calculated yearly U.S. health costs from mercury pollution at $5.1 billion.

The consequences of methymercury exposure are largely determined by the timing and degree of exposure, with the fetal and newborn periods being the most critical. Optimal brain development requires specialized cells to form patterns that make specific connections with other cells, all in a precise sequence and within a tight timeframe. Toxic insults during this set of complex, delicate processes can result in substantial, irreparable damage to the developing brain—at much lower exposures than those affecting adult brain functions.[3]

In-utero exposure can impair children's ability to think and learn. Mothers who are exposed to methylmercury while breast-feeding their babies may also expose their infants through their milk.[4] Deficits have been found in areas ranging from language skills, ability to focus, and cognitive thinking to fine motor function and visual-spatial skills.[5]

There is a wide range of estimates on the incidence of mental retardation caused by methylmercury toxicity, ranging from 115 to 2,675 cases in the U.S. each year.[6] Chronic, low-level exposure can also decrease birth weight.[7] The cost of caring for these children is estimated at somewhere between $28 million and $3.3 billion.[8]

The EPA-funded National Academy of Sciences (NAS) Methylmercury Study, published in 2000, explored methylmercury's toxicological effects. Animal studies confirmed the sensory effects and impacts on brain development and memory function documented in epidemiology studies.[9] Other lab studies that exposed rodents to short-term, high-dose methylmercury documented increased infant mortality and birth defects, smaller litter size, and lowered sperm counts.[10]

Dangers extend beyond the womb in a number of ways. Both prenatal and early childhood exposure may impair cognition throughout life, contributing to behavioral problems and affecting learning potential.[11] Infant and early childhood exposure has been linked to lower IQ, poor motor function, and attention deficit hyperactivity disorder (ADHD).[12] A 2006 study in Hong Kong found significantly higher mercury levels in 52 children diagnosed with ADHD compared with 59 controls.[13]

A 2004 Harvard School of Public Health study found that continued mercury exposure into adolescence may cause further brain damage.[14] Chronic mercury exposure is also associated with elevated risks for autism,[15] and high prenatal exposure can cause cerebral palsy and severe mental retardation.

To quantify the extent of mercury risk to American children, the U.S. National Health and Nutrition Examination Survey (NHANES) analyzed blood mercury levels in 6,174 women aged 18 to 49 in continouse studies from 1999-2006, with data released every two years.

Data from the first two years revealed that approximately 8 percent of women of childbearing age (some 4 million women) had blood mercury concentrations exceeding the EPA reference dose, levels that could injure an unborn child. About 1 percent (580,000 women) carried high methylmercury levels that were three to four times the recommended maximum concentration.[16, 17]

In-utero exposure can impair children's ability to think and learn. In the U.S., methylmercury toxicity is estimated to cause between 115 and 2,675 cases of mental retardation per year.

Using 1999-2000 NHANES data, the EPA estimated that more than 300,000 newborns each year may risk learning disabilities associated with in utero methylmercury exposure.[18] In February 2004, an EPA analysis revealed that "about 630,000 children are born each year at risk for lowered intelligence and learning problems caused by exposure to high levels of mercury in the womb." This nearly doubled the previous EPA estimate.[19]

However, there are important benefits to eating seafood. Seafood is the best source of the long-chain omega-3 fatty acid DHA, which is critical for a baby's brain and eye development, both in utero and in the "fourth trimester"—the first three months after birth—while the brain is still developing. Additionally, seafood is a prime protein source for many. Therefore, choice of low-mercury species is key to minimizing mercury-related health effects, while maximizing the benefits of omega-3 consumption.[21]

2. Mercury Poisoning in Adults

But mercury also impacts adult health. In certain cases, symptoms may not appear for some time after exposure and may appear in various combinations. Chronic low-level exposure can trigger ailments not easily linked to mercury, such as fatigue, difficulty concentrating, thinning hair, digestive problems, muscle and joint pain, and sleep disturbance. Classic symptoms of serious methylmercury poisoning include problems with peripheral vision, pins and needles in hands, feet, and around the mouth, coordination difficulties, impaired speech and hearing, difficulty walking and muscle weakness, mental disturbances, skin rashes, mood swings, memory loss, and, in extreme cases, coma, convulsions, and death. However, individual sensitivity varies widely: in a review of 24 symptomatic patients, blood mercury levels ranged from 7 to 125 micrograms per liter.[1,2]

Mercury exposure has also been linked to heart health. The NAS Methylmercury Study concluded that "the cardiovascular system appears to be a target for MeHg toxicity in humans and animals." The study noted that methylmercury exposure can adversely affect both the developing and adult cardiovascular systems at exposure levels lower than those known to cause neurodevelopmental effects.[3] More recent studies have linked methylmercury exposure to thickening of the carotid artery (a measurement of atherosclerosis), a condition that raises blood pressure and increases the risk of heart attack or stroke.[4,5]

Other research conducted at the University of California, Los Angeles (UCLA), found that chronic mercury exposure impacts the pituitary gland, the immune system and the liver. Since the pituitary secretes thyroid-regulating hormones, impaired function could trigger hypothyroidism. Disturbed pituitary function also increases susceptibility to infection and inflammatory or autoimmune disease.[6] At the same time, mercury exposure compromises immunity by suppressing white blood cells and lowering white blood cell count.[6]

Other impacts may create a legacy that extends over generations. The 1997 EPA Mercury Study reported that methylmercury is capable of causing chromosomal damage. One study of adults living in Brazil's Tapajo River region correlated high methylmercury concentration in hair to DNA damage in white blood cells and aberrations in chromosomes—at blood mercury levels seen in population studies conducted in the Faroes Islands and the Seychelles.[7]

3. Absorption and Removal in the Body

Methylmercury is efficiently absorbed into the body: more than 95 percent of methylmercury consumed in fish is absorbed through the digestive tract. In contrast, less than 10 percent of elemental mercury is absorbed.[1] The blood stream then quickly transports mercury through-

More recent studies have linked methylmercury exposure to thickening of the carotid artery (a measurement of atherosclerosis), a condition that raises blood pressure and increases the risk of heart attack and stroke.

Seafood is the best source of the long-chain omega-3 fatty acid DHA, which is critical for a baby's brain and eye development… Therefore, choice of low-mercury species is key to minimizing mercury-related health effects, while maximizing the benefits of omega-3 consumption.

out the body, distributing it into organs and tissues within 30 to 40 hours of ingestion.[2]

Blood mercury levels match concentrations in the tissues that are known to be targets for the toxin. Certain organs have a high affinity for methylmercury, and chief among them is the brain. After penetrating the blood-brain barrier, mercury accumulates in the brain where it can damage the central nervous system.[3] About 10 percent of the total methylmercury body burden sits in the brain.[4]

Animal studies with monkeys have provided insight into what happens from long-term exposure. Researchers observed a process where mercury slowly demethylates inside the body, transforming into inorganic mercury deposits in the brain.[5] Since inorganic mercury is slow to cross the blood-brain barrier, demethylated mercury can remain trapped in the brain for nearly two years, unlike organic methylmercury, which easily permeates cells and has a half-life in the brain of just one month.[6]

The largest storehouse for inorganic mercury seems to be the pituitary, with concentrations 200 to 300 percent higher than those in the brain. Additional deposits form in the liver and kidneys.[7,8] The UCLA study offered compelling evidence that mercury accumulates in the body in a cumulative process that increases with age.[9]

All forms of mercury gradually pass out of the body in liver bile and feces. Smaller amounts are excreted in urine, sweat and breast milk and it is stored in hair and nails. Within 50 to 70 days of exposure, adult blood levels drop to half, but the process takes longer in newborns.[10]

VII. History of Mercury Health Impacts

1. Mad Hatters of England

In 18th and 19th century England, mercury salts were used to produce felt for hats. Factory workers who handled mercury-soaked fabric each day developed uncontrollable twitches and tremors that made them appear demented. This may be the origin of the phrase “mad as a hatter.”[1] Workplace exposure to mercury was common in the 19th century and many people died young as a result of mercury poisoning.[2]

2. The Poisoning of Minamata

Between 1932 and 1968, the Chisso Corporation dumped mercury compounds they used in plastics production into the sea near Minamata, Japan. Fish from Minamata Bay was a major protein source for most local residents. By 1953, cats, dogs, fish, and pigs began acting strangely, and birds started falling from the sky. Then, in 1956, people were also stricken, with many experiencing numbness, slurred speech, constricted vision, or tremors. Some developed serious brain damage, while others lapsed into unconsciousness or lost motor control. Babies were born with mental retardation and/or grossly deformed limbs, with little muscle coordination and contorted, paralyzed bodies.

By 2001, the Japanese government had officially recognized 2,955 “Minamata Disease” patients, 1,784 of whom had already died. Another 10,072 people received medical expenses and an allowance for chronic conditions associated with mercury poisoning. It remains unknown how many people in all were affected, but estimates range much higher than official numbers.[1,2,3]

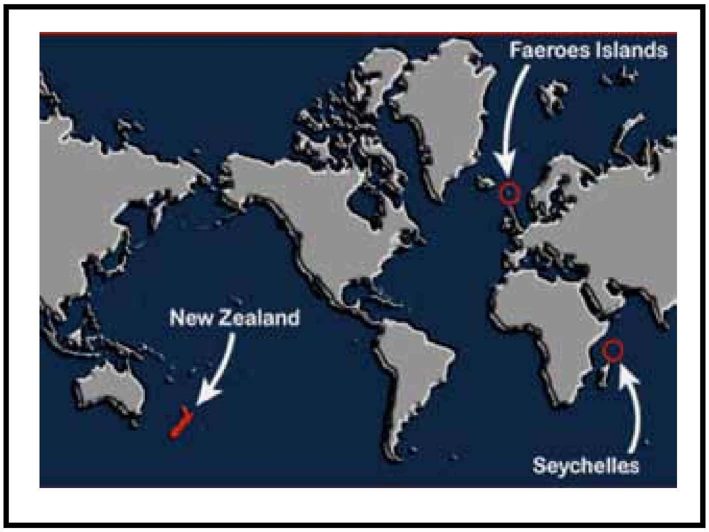
3. The Iraq Poison Grain Disaster

From December 1971 to March 1972, unknown numbers of people in rural Iraq ate bread made from grain that was meant for planting. The grain had been treated with a methylmercury fungicide. They also fed the grain to livestock, which further increased their exposure through milk and meat.[1]

Symptoms began to appear after a latent period that lasted between 16 and 38 days. In all, 6,148 people were admitted to hospitals suffering from methylmercury poisoning in the largest such epidemic in history. The recorded death toll was 452, but some suggest the true death toll may have been up to 10 times higher.[2] Some individuals only experienced mild symptoms, such as paresthesia—numbness of hands, feet, lips and tongue. But many developed far more serious symptoms, including loss of balance, vision problems, blindness, or total central nervous system failure. Prenatal exposure caused irreversible brain damage; some children were born with or developed blindness, deafness, severe motor dysfunction, paralysis or mental retardation.[3,4]

4. Global Reach

Since the 1950s, notable mercury poisonings of both humans and wildlife have also occurred in Scandinavia, Iraq, Europe, the United States, Canada, the Philippines, and South America's Amazon River region, among other places. In each of these locations, exposure came from highly contaminated aquatic systems. The pollution came from a range of sources, from industrial discharges and agricultural products to atmospheric deposition, mining activities and elemental mercury.[1]



In the U.S. NHANES study, blood mercury levels proved higher among certain demographics, specifically people with higher incomes, ethnic groups that eat a lot of seafood such as Native American, Asian and Pacific Island populations, and coastal residents.[2] Children in minority and low income communities who subsist on locally-caught fish also face greater risk.[3]

5. Health Impact on Arctic Indigenous Peoples

Arctic indigenous peoples rely on subsistence hunting and fishing to survive in the frozen north, eating a diet of marine fish and mammals, some species of seabird and freshwater fish. These animals are extremely high in mercury. Residents of native Arctic communities carry some of the highest mercury loads of anyone on the planet because of high accumulation in the fish and marine mammals that are the mainstays of their traditional diet.[1]

Although there has been an overall decline in the proportion of Arctic people that exceed U.S. and Canadian blood mercury levels, concentrations in over 90 percent of women of child-bearing age in some areas of Greenland exceed safe guidelines. A study on Inuit pre-school children in Nunavut, Canada, found that 59 percent of those surveyed ingested methylmercury at unacceptable levels.[2]

VIII. Population Studies

Risk assessments for mercury by the U.S. Environmental Protection Agency, the joint Food and Agriculture Organization of the United Nations/World Health Organization Expert Committee on Food Additives, and other national and international organizations have been largely based on epidemiological studies from New Zealand, the Faroe Islands and the Seychelles (as well as information from the Iraqi and Minamata poisonings).[1]

The three population studies used differing methods. The Faroe study tested mercury levels in umbilical cord blood and mother's hair samples while the Seychelles and New Zealand studies used only maternal hair samples. Each calculated exposure at various stages of fetal development during the second or third trimester.[2] The studies differed in outcome, fueling debate over medical uncertainties.[3]

Whether any study accurately pictures methylmercury's neurotoxic effects depends on how reliable exposure data is, and adjustments for possible confounding factors such as the impacts of other chemical exposures or the benefits of seafood nutrients.[4,5,6] For example, when Faroes data was later re-analyzed, the benefits of low-mercury fish consumption during pregnancy were highlighted, with children of mothers who ate healthy fish species earning higher test scores for motor and spatial functions. Edward Groth and other researchers emphasize that studies of benefits and risks regarding fish consumption during pregnancy must carefully take into account factors that may skew results.[7]

However, scientific uncertainties remain and environmental health researchers continue to debate why one study can show clear deleterious effects of mercury from a seafood diet—and another study does not.

1. New Zealand

In 1978, researchers screened mercury levels in 11,000 pregnant women in New Zealand, and tested hair mercury levels for those who ate fish three times per week during pregnancy. Performance on standard child development tests linked higher hair mercury concentrations with lower test performance. A later reanalysis of the data replicated these results.[3]

2. Faroe Islands

In 1986-87, Danish scientists examined the impact of prenatal methylmercury exposure on cognitive development in the Faroe Islands, a fishing community in the North Atlantic between Iceland and Norway where traditional foods include high-mercury pilot whale meat. The researchers assessed prenatal methylmercury exposure in 1,022 children by testing cord blood and maternal hair samples. They continued testing the children's cognitive development into their teenage years.

When these children were evaluated at age seven, deficiencies were identified in memory, learning and attention that were proportional to the level of mercury recorded in umbilical cord blood and maternal hair.[1,2] Researchers found that electrical signals in the brains of highly-exposed children transmitted slower than normal along a particular brain circuit. At age 14—after a continued diet that included fish and whale meat—the disruption had worsened: the harm done by mercury before birth or in early childhood had not been repaired as the children grew up, and continued exposure caused further damage.[3]

3. Seychelles

A study begun in 1989 evaluated the effects of prenatal methylmercury exposure in 779 children in the Seychelles, an island nation in the Indian Ocean. Their mothers reported eating ocean fish at least 12 times per week during pregnancy, but fish were not specified. Researchers took hair samples from those mothers a few months after they gave birth. The children were then evaluated four times at preschool age.[1]

At first, there was no firm evidence that prenatal exposure caused neuro-developmental damage. However, when statistically determined "outliers" were removed from the analyses, researchers identified problems with auditory comprehension. A subsequent study of 229 Seychelles mother–child pairs in 2007[2] that factored in the confounding beneficial effects of omega-3 fish nutrition found an adverse effect of methylmercury exposure on child cognitive development.[3] Despite eating about four times as much seafood as U.S. women, after adjusting for the effect of fish nutrients, the negative effect was still smaller than that seen in the Faroe Islands and other studies.[4,5]

The researchers theorized that one key difference in results between the Faroe Islands and Seychelles studies was not the amount of fish consumed—but the mercury content of fish consumed: a major part of the Faroese diet is heavily contaminated pilot whale meat, while the Seychellois eat ocean fish carrying low to medium levels of mercury. [6]

4. Project Viva Study, Boston

Researchers associated with an OB-GYN practice in the Boston area are conducting a long-term epidemiological study looking for associations between numerous dietary and environmental factors that might affect babies during gestation. In 2005, they tested 135 six month-old babies for mercury effects suffered during gestation, gauged by maternal hair samples taken during pregnancy. Visual recognition memory (VRM) tests evaluated the infants' ability to recognize and remember faces and shapes—tests that indicate intelligence. The study affirmed previous research, showing that the omega-3 fatty acid DHA in fish boosts brain development—and exposure to mercury harms the developing brain. Results showed that for each additional weekly fish serving eaten by their mothers during pregnancy, children's (VRM) scores jumped by 4 points. But, each increase of 1 ppm [part per million] of mercury in mothers' hair samples lowered VRM scores by 7.5 points. Infants whose mothers ate fish more than twice a week but had hair mercury levels below 1.2 ppm scored the highest. A second study in 2008 that tested 341 three year-old children had similar findings.[1]

IX. Federal Guidelines on Seafood Consumption

As EPA was preparing their "1997 Mercury Study Report to Congress,"[1] new data on the health effects of methylmercury was emerging. Based on research conducted in the Faroe Islands, the EPA calculated that ingesting .1 microgram of mercury per kilogram of body weight per day was the level shown to be without appreciable risk over the course of a lifetime. This "reference dose" (RfD) corresponds to a blood mercury level of 5.8 micrograms per liter (μg/l).

EPA's safety level for human consumption is 0.5 parts per million (ppm); The U.S Food and Drug Administration's (FDA) also established a benchmark for the acceptable level of mercury in food: the FDA "action level," where the agency may step in to pull mercury-laden products off the shelves, is 1 ppm.[2]

To establish that reference dose, EPA began with the mercury level in umbilical cord blood known to affect brain development in children. Then the agency doubled the blood mercury level of Faroes Island children who tested in the lowest 5 percent in neurodevelopment screenings. That "benchmark" was 58 micrograms of methylmercury per liter of blood (58 µg/l). EPA then estimated a 10-fold "uncertainty factor" to keep fetal mercury blood levels at least 10 times below that level.[3] However, there is still wide scientific uncertainty about what dose actually causes harm, and individual sensitivity varies.[4]

The EPA reference dose has been criticized on numerous counts. First among these criticisms is the fact that EPA guidelines for acceptable daily exposure were based on 1999 data, which predates studies that have since shown that symptoms can occur at lower doses. As Susan Silbernagel and colleagues note in a 2011 Journal of Toxicology paper, more recent studies suggest that greater caution is justified, especially for pregnant and nursing women and children—but given uncertainties around various health impacts, more protective guidelines could be prudently applied to other seafood consumers as well.[5]

Emerging evidence suggests that an important reason why the EPA 5.8 µg/l RfD limit is too high is because it was calculated with the assumption that mercury levels in fetal blood match that of the mother. However, studies have shown that umbilical cord blood levels are, on average, about 1.7 times higher—meaning that maternal blood levels actually need to be below 3.5 micrograms per liter.[6]

A 2005 report by Oceana and the Mercury Policy Project cites another shortfall. Over the last decades, the accepted margin of safety for most toxic substances has been a dose that is 100-fold lower than the level where there are no adverse effects in animal experiments. With some substances, such as pesticides, the EPA, has applied much larger safety factors, up to 1,000-fold. However, the uncertainty factor for mercury is just 10-fold.

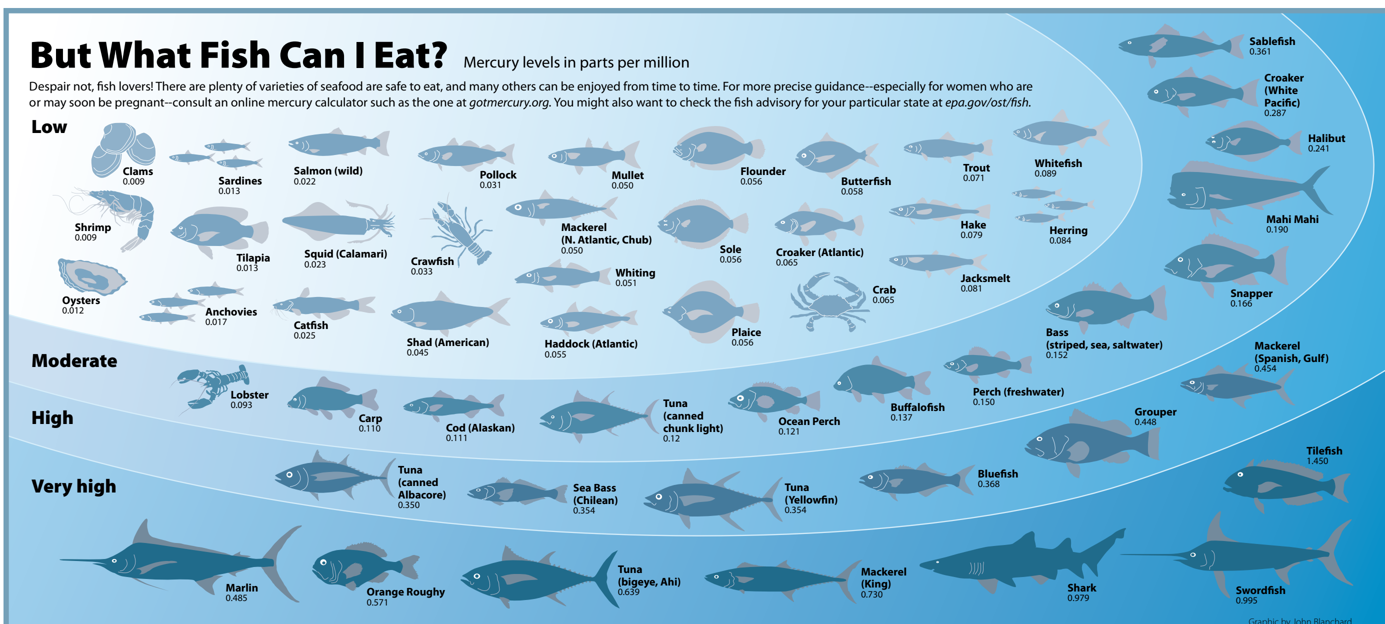
While the EPA reference dose targets women of childbearing age and children under 6 years old, anyone who eats several meals of fish per week, or who eats predatory fish high in mercury could easily exceed the EPA reference dose. Although blood mercury levels that spike above the reference dose do not guarantee harm, they do increase risk of damage to the developing brain in unborn babies and young children.[6] In adults, symptoms of toxic effects ordinarily do not occur unless one exceeds the EPA RfD for an extended period.[8]

In 2004, the FDA and EPA issued a joint consumer advisory about mercury in fish and shellfish[9], offering the following consumption guidelines for women and young children:

-Do not eat Shark, Swordfish, King Mackerel, or Tilefish because they contain high levels of mercury.

-Eat up to 12 ounces (2 average meals) a week of a variety of fish and shellfish that are lower in mercury.

-Five of the most commonly eaten fish that are low in mercury are shrimp, canned light tuna, salmon, pollock, and catfish.



Source: John Blanchard (Sources: FDA and EPA), Sierra Magazine, Nov/Dec 2011

-Another commonly eaten fish, albacore ("white") tuna has more mercury than canned light tuna. So, when choosing your two meals of fish and shellfish, you may eat up to 6 ounces (one average meal) of albacore tuna per week.

-Check local advisories about the safety of fish caught by family and friends in your local lakes, rivers, and coastal areas. If no advice is available, eat up to 6 ounces (one average meal) per week of fish you catch from local waters, but don't consume any other fish during that week.

-Follow these same recommendations when feeding fish and shellfish to your young child, but serve smaller portions.

-Generally speaking, the fish to avoid are large predators. Peak predators act as concentrators for bioaccumulative toxics: their bodies absorb the methylmercury from their prey, which, in turn, have absorbed methylmercury from living things lower on the food chain.[10]

1. Federal Advisories Generate Confusion

Though the advisory is posted on the EPA and FDA websites, the agencies do not require that it be posted in places where fish are sold. As a result, many consumers may be uninformed or confused. Should they eat more fish because it's good for their heart? Or should they avoid specific fish because mercury (and other pollutants) they contain could be bad for them or their children?

The consumption advisory fails to specify how much children can safely consume, stating only that parents should "serve smaller portions." Some data suggests that safety messages about mercury should also mention potential danger for older children.[1] In adults, even low mercury levels may raise heart attack risk.[2]

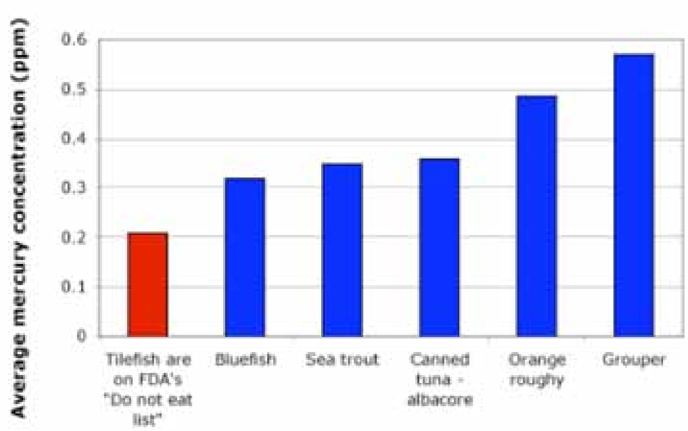
Drafts of a highly-criticized 350-page report issued by the FDA in 2008[3] and 2009[4], caused additional confusion. The report, "Quantitative Risk and Benefit Assessment of Consumption of Commercial Fish," concluded that health benefits gleaned from eating large quantities of seafood outweighed health risks from neurotoxic methylmercury exposure. It omitted a more logical course from its analysis: eat more fish, but choose low-mercury fish.

Mercury contamination in fish has continued to rise, and is higher than the 2003 FDA data used to develop consumption guidelines. Some fish species not mentioned in the advisory carry higher mercury levels than those on the "do not eat" list.

An EPA review stated that the report was "not a product EPA should endorse as it does not reach the level of scientific rigor routinely demonstrated by the Agency." [5] The agency's comments on the next version noted that, "While some changes have been made in response to EPA comments on the earlier draft, the analyses themselves are essentially unchanged, and in the opinion of EPA, scientifically flawed." They further note that FDA relied on science regarding neurodevelopmental risks that "had been completely abandoned by the scientific community as a basis for risk assessment for more than a decade," and conclude that "a fish consumption advisory strategy based on the design of the FDA draft analysis would be highly inconsistent with what is generally considered to be proper public health practice." [6]

In 2010, the FDA and EPA issued

New FDA data show that five fish, including canned albacore tuna, have higher levels of mercury than tilefish, a fish on the FDA "Do Not Eat" list for pregnant women



Source: Environmental Working Group, compiled from FDA 2003 mercury testing data.

a joint consumer advisory on mercury in fish with their "Dietary Guidelines for Americans." It also urged Americans to increase seafood consumption—which is appropriate if those meals include low-mercury fish—but also makes the controversial suggestion that women who are pregnant or breastfeeding can eat all types of tuna—which are high-mercury fish.[7, 8]

2. Independent Studies Show Mercury is Still in Seafood

Mercury contamination in certain fish has continued to rise, and is higher than levels present in data used by the 2003 FDA to develop consumption guidelines. Some fish species not mentioned in government advisories carry higher mercury levels than those on the "do not eat" list. Among them is tuna.

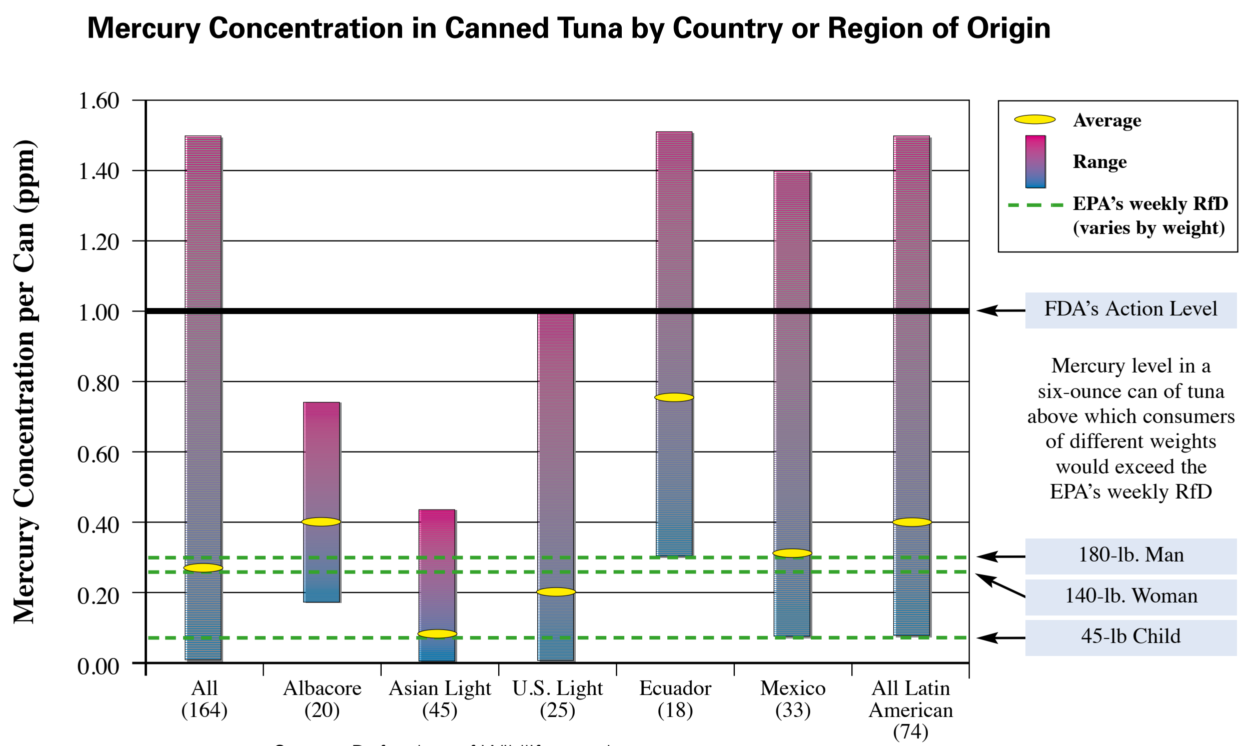
Instead, advisories classify canned light tuna as "low mercury" despite evidence that tuna—a large predatory fish atop the food chain—carries substantial mercury levels that vary depending on the species, the ocean it came from and the size of the fish, information that is not always available to consumers.[1]

The April 2010 edition of *Environmental Research* published a study showing that in 2005, Americans ate about one billion pounds of canned tuna—and that tuna accounts for over 37 percent of mercury exposure in the American diet.[2]

In 2005-06, University of Las Vegas researchers tested 300 cans of tuna collected from stores across the country; more than half exceeded the 0.5 parts per million EPA safety level for consumption. Five percent exceeded the FDA action level of 1.0 ppm—where the FDA may take legal action to remove a product from the shelves. The researchers recommended that regulatory agencies require the tuna industry to provide information on mercury content on the label.[3] Another study by Defenders of Wildlife found that 35 percent of light tuna samples had mercury levels above 0.3 ppm.[4]

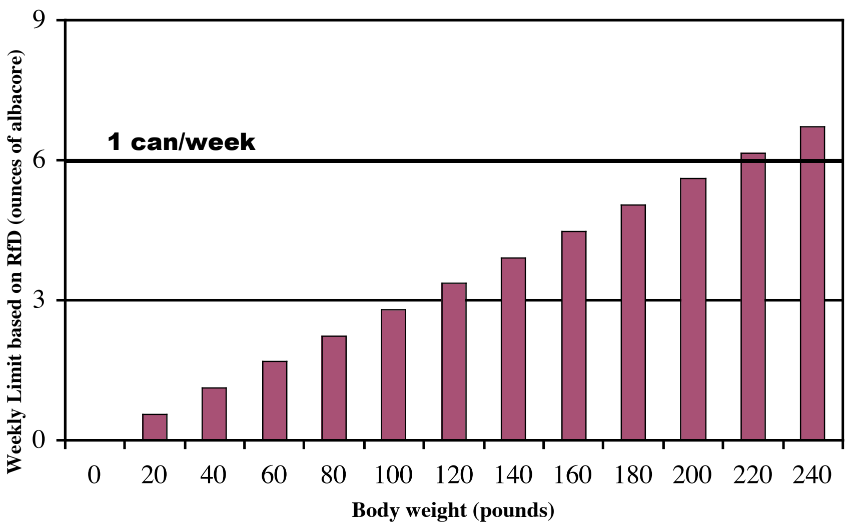
Since tuna is a staple in the Special Supplemental Nutrition Program for Women, Infants and Children (WIC) and is also offered in federal school lunch programs—and is the only animal meat protein source offered by the U.S. Department of Agriculture and state WIC programs, except in Alaska and Hawaii—the government may be placing low-income women and children at risk of high mercury exposure.[5]

To put seafood choices in context, eating two 5-ounce servings of salmon



Source: Defenders of Wildlife, et. al.

Maximum weekly consumption of albacore tuna (0.401 ppm) that does not exceed the EPA reference dose for people of different weights



Source: Defenders of Wildlife, et. al.

in a week would yield a 4 microgram intake of methylmercury. Two servings of canned light tuna (average 0.118 ppm, from skipjack tuna, a smaller species), would bring a 33 microgram dose; the same sized serving of canned albacore tuna (at 0.353 ppm) would triple the dose to 100 micrograms. With two swordfish meals, the dose would jump to 277 micrograms.[6]

If a 120-pound (54.4-kilogram) woman was pregnant or breastfeeding, one six-ounce portion of fresh tuna would bring that week's intake to about 144 percent above government exposure guidelines.[7] But for pregnant women, staying within safe limits may be more subtle than that: ingesting a big dose of mercury one day—that may even be within EPA guidelines for the week—could endanger a fetus at critical stages in development.[8]

Studies show that low-income families and people of color are exposed to higher levels of mercury than wealthier families. African and Mexican-American children had higher hair mercury levels than Caucasian children, corresponding to the amount of fish consumed per week.[9]

3. Screening and Enforcement

Other criticism targets the FDA's screening, monitoring and enforcement efforts. The 1 ppm FDA action level is among the least protective mercury guidelines adopted by any developed country or international health body. For example, across the border, Health Canada's guideline is 0.5ppm.[1]

Critics of FDA policies and enforcement have included the National Academy of Sciences, who wrote in 1991 that "the present monitoring and inspection program carried out by all federal agencies lacks both the frequency and the direction sufficient to ensure effective implementation of the nation's regulatory limits for seafood safety." Between 1991 and 2006, the only enforcement of the FDA 1.0 ppm limit was eight recalls of shark and swordfish. There were no tuna recalls.[2]

A *New York Times* report revealed that importers of swordfish, a high mercury fish, use smaller, younger swordfish to pass the FDA mercury tests. One FDA seafood expert said that over half of all imported swordfish probably contains unacceptable mercury levels.[3]

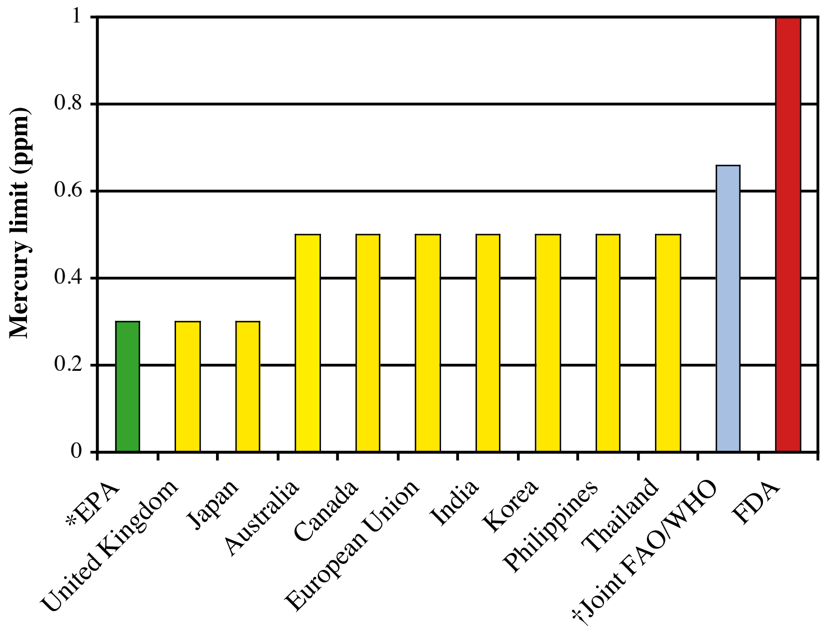
In 2008, Oceana, a nonprofit ocean conservation organization, tested fish samples from grocery stores and sushi restaurants for mercury. Two-thirds of those swordfish fillets and one-third of sushi tuna samples exceeded the FDA action level.[4] The problem could be easily solved, critics say, by requiring FDA mercury testing of fish with rapid testing technology.

Easy to use online calculators are available that estimate safe intakes based on the EPA RfD and offer information on healthy seafood choices. Those sites include Got Mercury.org,[5] the National Resources Defense Council,[6] and a new iPhone application, Fish4Health.[7]

Consumers should beware of misinformation sites like HowMuchFish.com—a Center for Consumer Freedom project funded by the food-and -beverage industry seeking to counter scientific evidence on the dangers of

One FDA seafood expert said that over half of all imported swordfish probably contains unacceptable mercury levels.

Maximum allowed/recommended mercury levels in fish in selected countries and by IGOs



Source: Defenders of Wildlife, et al.

mercury levels in fish—which states that consumers can safely intake 10 times the EPA's RfD.[8]

4. Efforts to Strengthen Advisories

In 2010, a coalition of 30 scientists, medical doctors and consumer advocates wrote to U.S. Food and Drug Administration Commissioner Margaret Hamburg and Environmental Protection Agency Administrator Lisa Jackson requesting that they strengthen consumer guidelines.[1] They detailed a litany of problems with the current advisory:

"It urges women of childbearing age to consume no more than 12 ounces of fish and shellfish per week, needlessly limiting potential nutritional benefits."

"It assumes that no one eats more than 12 ounces of seafood a week, ignoring several percent of the population who currently do exceed that intake level and offering no advice for high- end consumers, despite the obvious likelihood that such high-end consumers bear the greatest risk of excessive methylmercury exposure."

"It lists only five high-mercury fish varieties as choices for women to avoid or limit intake of, and names just five "lower-mercury" choices, offering no advice about the rest of the seafood market except to "eat a variety of other fish." That "other fish" category includes 41 seafood items that range from 0.010 to 0.554 ppm mercury, and which of those the items one chooses to eat can profoundly affect a consumer's methylmercury exposure."

"It recommends canned light tuna as a "lower-mercury" choice, although canned light tuna has an above average methylmercury level and is the largest single source of mercury exposure in the U.S. diet. FDA has acknowledged that it included canned light tuna in the "lower-mercury" category to avoid harming the market for this staple item."

"It is addressed only to women of childbearing age and parents of young children, ignoring other population subsets' needs for guidance to manage methylmercury exposure."[2]

The letter's signatories urged that benefits and risks of fish consumption be addressed in a balanced way, highlighting the benefits of eating low-mercury fish—citing advice offered by many states to "Eat fish, be smart, choose wisely." They also suggested categorizing fish species for both mercury and omega-3 content, removing canned light tuna as a recommended low-mercury choice, directing consumption advice to everyone who eats seafood regularly, and better monitoring commercially-caught seafood.[3]

Last year's U.S. Department of Agriculture Dietary Guidelines for Americans 2010 backtracked on informing the public about methymercury risks, writing that: *"Moderate, consistent evidence shows that health benefits derived from the consumption of a variety of cooked seafood in the US in amounts recommended by the Committee outweigh the risks associated with methyl mercury (MeHg) and persistent organic pollutants (POPs) exposure, even among women who may become or who are pregnant, nursing mothers, and children who are ages 12 and younger. Overall, consumers can safely eat at least 12 oz. of a variety of cooked seafood per week provided they pay attention to local seafood advisories and limit their intake of large, predatory fish."*[4] *Those guidelines also stated that pregnant women can eat "all types of tuna."*

In a letter to Secretary of Agri-

Guide to mercury levels in different varieties of fish and shellfish

LOW-MERCURY FISH AND SHELLFISH

VERY LOW < 0.043 ppm	BELOW AVERAGE 0.044-0.086 ppm
Shrimp	Pollock
Sardines	Atlantic Mackerel
Tilapia	Anchovies, Herring & Shad
Oysters & Mussels	Flounder, Sole & Plaice
Clams	Crabs
Scallops	Pike
Salmon	Butterfish
Crayfish	Catfish
Freshwater Trout	Squid
Ocean Perch & Mullet	Atlantic Croaker
	Whitefish

MODERATE-MERCURY FISH AND SHELLFISH

ABOVE AVERAGE 0.087-0.172 ppm	MODERATELY HIGH 0.173-0.344 ppm
Pacific Mackerel (Chub)	Carp & Buffalofish
Smelt	Halibut
Atlantic Tilefish	Sea Trout
Cod	Sablefish
Canned Light Tuna	Lingcod & Scorpionfish
Spiny Lobster	Sea Bass
Snapper, Porgy, Sheepshead	Pacific Croaker
Skate	American Lobster
Freshwater Perch	Freshwater Bass
Haddock, Hake, Monkfish	Bluefish

HIGH-MERCURY FISH

HIGH 0.345-0.688 ppm	VERY HIGH > 0.688 ppm
Canned Albacore Tuna	King Mackerel
Spanish Mackerel	Swordfish
Fresh/Frozen Tuna	Shark
Grouper	Gulf Tilefish
Marlin	Tuna Sushi/Bluefin Tuna
Orange Roughy	

Source: Letter to Tom Vilsac and Kathleen Sebelius, Groth, et. al.

culture Tom Vilsack and Secretary of Health and Human Services Kathleen Sebelius in 2011, 12 scientists asked the EPA and FDA to revise Dietary Guidelines.[5] They reasoned that recent studies show adverse health effects at doses near or even below the RfD, making it even more important to inform pregnant women to eat very low-mercury fish.

The letter also called attention to press materials issued with the guidelines stating that the advisory committee "emphasized that, even for pregnant women, the benefits of consuming seafood far outweigh the risks." The authors note that this statement "sweeps aside the Committee's nuanced explanation that fish consumption by pregnant women is beneficial *if women choose lower-mercury fish,* and transforms a complex risk/risk balancing exercise into a simple-minded either/or choice in which risks are minimized and benefits exaggerated. It also manufactures a conclusion that the committee never reached."[6]

The scientists requested a public retraction of this interpretation of the guidelines that detailed risks versus benefits. For example, though fish consumption may reduce heart attack and stroke,[7, 8] several well-designed epidemiological studies show that methylmercury accumulated by eating high-mercury fish can increase the risk of cardiovascular disease, cancelling out much or all of the expected benefit.[9] They also note that while fish contain omega-3 fatty acids that are essential for prenatal brain development, prenatal methylmercury exposure has well-documented adverse effects on cognitive development.

In June 2011, environmental and consumer organizations filed a legal petition asking the FDA to implement and enforce stricter regulations for mercury in seafood. The petition requested that seafood sellers be required to distribute or post mercury warnings and that the agency enforce its action level of 1 ppm of methlymercury in fish and resume testing seafood for mercury. It also emphasized the need to update mercury concentrations in fish, presenting recent data on potentially unsafe levels in certain fish species.[10]

The petition also charged the FDA and other government agencies, including the National Marine Fisheries Service, with promoting increased consumption of seafood without clearly flagging the high-mercury species as a health hazard.[11]

So far, these petitions have gone unheeded.

Research shows that public warnings work—which is why the advisories need to provide accurate information taken from current scientific findings: The key is to eat low mercury fish. One study examined women's fish-eating habits before and after the first FDA mercury advisory as part of the Project Viva Study in Boston. Researchers monitored the diets of 2,235 women before and 11 months after the FDA warned women who were or might become pregnant to avoid four high-mercury fish species. Overall, those women lowered their fish intake

The key is to eat low mercury fish.

17 percent, from 7.7 to 6.4 meals per month after the advisory. Though it was not on the FDA advisory list, most of that came from eating less canned tuna and from species known to carry high levels of mercury.[12]

However, most physicians encourage fish consumption by pregnant women because of beneficial omega fatty acids. The key is to eat low mercury fish.[40]

X. Ecosystem Impacts of Mercury

Mercury is toxic to all living things. It is passed to young mammals across the placenta and through mother's milk and crosses the blood-brain barrier. In wildlife, a diet that includes mercury impacts behavior, reproduction, and the survival of offspring and longevity of adults. It impairs cell development, impacts growth and neurological development, and can cause weight loss or early death.[3]

Mercury poisons many species, including fish and any fish-eating species. Affected animals include crayfish, salamanders, eagles, osprey, loons, white ibis, turtles, mink, otters, bears, seals, whales, and the Florida panther, and others. Some are endangered species. Since the toxic load grows with each step up the food chain, predatory species are most at risk,[4,5] and with greater quantities of mercury circulating throughout the global environment, risk is greater with increased exposure.[2,3]

Various symptoms endanger basic behaviors that undermine nutrition, breeding and overall survival. Mercury-laden fish have difficulty schooling, making them easy prey. Likewise, impaired motor skills in mammals dull escape and avoidance behaviors making them vulnerable,[4] while also making it harder for them to hunt and forage for food.[5] Lab studies show that methylmercury also weakens immunity, making animals susceptible to disease.[6,7]

Mercury is readily excreted into bird's eggs, causing birth defects or killing embryos before they hatch.[8] Mercury-poisoned birds frequently fail to nest, lay smaller clutches or are unable to brood their eggs or care for hatchlings. Even at low levels, mercury toxicity in adult birds results in central nervous system damage affecting vision, mobility and muscle coordination.[9]

The common loon *(Gavia immer)*, a long-lived fish-eating bird found throughout New England and Eastern Canada, has become a sentinel species for aquatic methylmercury pollution. Among birds, it is among the worst affected, with some of the highest mercury levels of any animal in the world.[10]

Nearly 40 percent of the loon's range falls within areas of high mercury deposition.[11] One-fifth of loons tested in a U.S. Fish and Wildlife Service (USFWS) study in New York State's Adirondack Mountains had mercury levels high enough to endanger breeding success,[12] and in Maine, 22 percent of the population is considered at risk. A study conducted throughout loon range from 1996 to 2005 showed that the birds' mercury body burden increased 8.4 percent each year. The most impacted pairs were lethargic, had asymmetrical wings and fledged 41 percent fewer chicks than unaffected loons.[13]

Other fish-eating bird species such as the white ibis and great snowy egret suffer from the same symptoms.[14] One study estimated that mercury contamination could result in a 50 percent reduction in white ibis fledglings, and mercury has recently been implicated in egret declines in south Florida,[17, 18] with the birds suffering from liver and kidney damage.[15]

Even insect-eating songbirds such as Bicknell's thrush, tree swallows, and the great tit are experiencing mercury-induced reproduction problems and lower survival rates,[16, 17] as well as reduced singing behavior (affecting communication with other birds) and smaller song repertoires (which impacts mating).[18,19]

Species group and representative species


Loons
Common loon, red-throated loon


Wading birds
Common egret, great blue heron, black-crowned night heron


Pelicans
Brown pelican, white pelican, gannets


Cormorants
Double-crested cormorant


Mergansers
Common merganser, red-breasted merganser


Gulls and terns
Herring gull, common tern

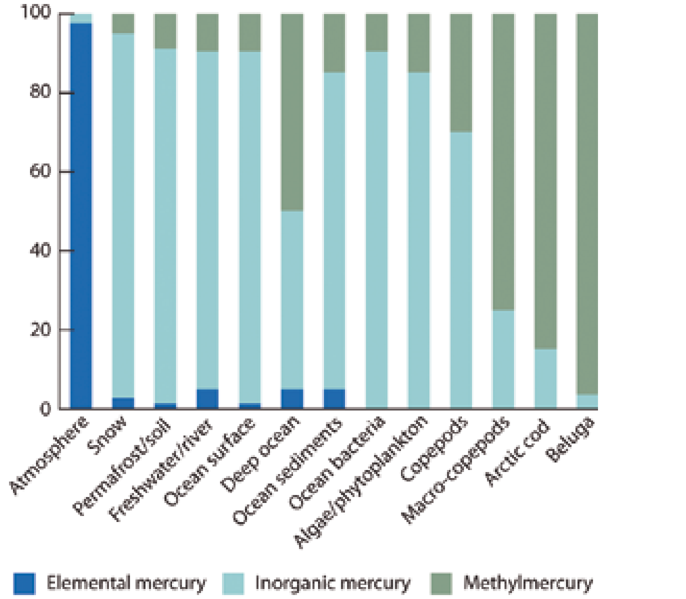

Pelagic seabirds
Fulmars, shearwaters


Raptors
Bald eagle, osprey, golden eagle, owls


Gallinaceous birds
Ring-necked pheasant, chukar partridge, grouse, quail

Source: Field Manual of Wildlife Diseases: Birds

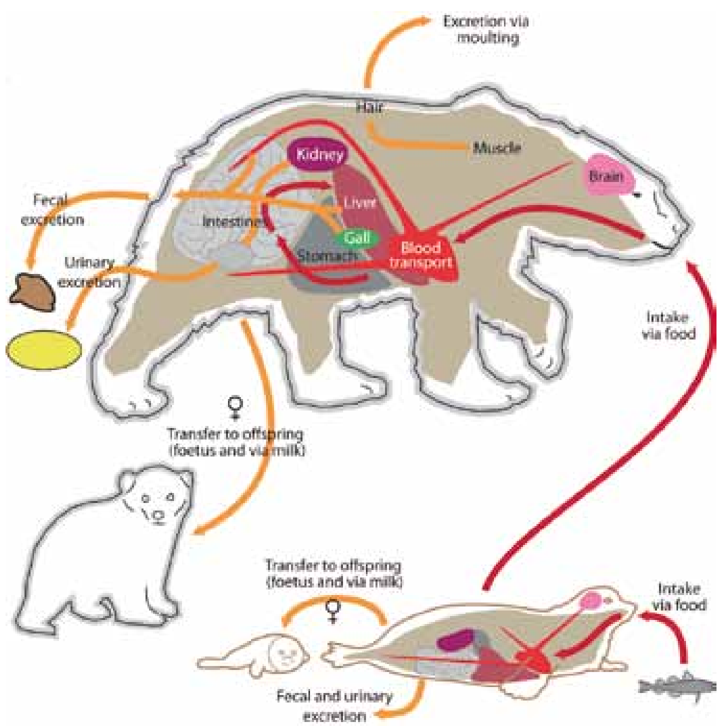
Mercury species



The proportion of methylmercury increases through the food chain. In top predators such as beluga, the mercury is almost entirely present as methylmercury.

Source: Arctic Monitoring and Assessment Programme, Arctic Pollution 2011

Routes of uptake, transfer and excretion of mercury in Arctic seals and polar bears.



Source: Arctic Monitoring and Assessment Programme, Arctic Pollution 2011

Animals in the northeastern U.S. have particularly high mercury exposure because of wind currents that carry emissions to the coast from Midwest power plants. Otters in Maine and Vermont and mink in Massachusetts and Connecticut carry mercury concentrations that equal or exceed levels that can prove fatal.[20]

Globally, Arctic animals carry the heaviest mercury loads. Teeth, fur and feather samples dating back 800 years show that mercury concentrations are now about 10 times higher than pre-industrial levels in marine animals that top the Arctic food web: beluga, ringed seal, polar bear, and marine birds that breed there. [21]

Over 90 percent of the present-day mercury in the tissues of Arctic species is believed to have come from human sources, with concentrations increasing between 1 percent and 4 percent each year over the past 150 years. In some species, levels continue to rise despite reductions in human-generated emissions over the past three decades in some parts of the world.[22]

Teeth, fur and feather samples dating back 800 years show that mercury concentrations are now about 10 times higher than pre-industrial levels in marine animals that top the Arctic food web.

Recent studies on polar bears have shown a correlation between mercury concentrations in the brain stem and levels of a key brain chemical, NMDA, that is responsible for almost half of brain activity—and controls

Every dollar spent reducing power plant pollution will yield up to $13 in health and economic benefits, according to EPA estimates, with a total benefit of up to $140 billion annually. Yearly compliance costs are approximately $10.9 billion.

all aspects of the bruins' behavior and reproduction. Researchers are now analyzing other brain regions—some of which sequester up to six times more mercury.[23]

Mercury passes out of the body in urine, feces and mother's milk, but polar bears also get rid of large amounts in fur and marine birds excrete mercury through feathers. Toothed whales, which lack hair and feathers and lack this additional pathway to rid themselves of toxins, are among the most vulnerable, carrying high accumulations of mercury in brain tissue.[24]

XI. Impact of Climate Change on Mercury in the Environment

Climate change could significantly affect many of the processes driving the global mercury cycle. Melting glaciers, ice sheets and permafrost are releasing mercury that has been stored for thousands of years, potentially raising mercury levels in nearby water bodies.[1] That mercury could pack a powerful impact: mercury deposited from the air and stored atop frozen ground 'fast tracks' into the Arctic food chain.[2]

A warmer climate will also alter the conditions that spark reactions involving mercury. As temperatures rise, warmer seas and melting sea ice could induce higher emissions—and re-emissions—from the oceans. This would change the present ratio between ocean and atmospheric mercury.[3]

These conditions could also change the relationship between ocean methylmercury levels and the amount of organic carbon in seawater, according to a 2009 Harvard University study. Organic carbon may provide additional surfaces where microbes can methylate mercury: lead researcher Elsie Sunderland believes that the methylation process may be linked to the biological pump in the ocean. High methylmercury concentrations have been measured where biological activity is highest. With climate change potentially increasing the amount of phytoplankton in the seas, the mercury cycle could accelerate, producing more methylated mercury.[4,5]

Since inorganic mercury can only be converted to methylmercury when it is not frozen, earlier thaws and later freezes could boost production of methylmercury in far northern and southern latitudes.[6] The effects of increased mercury on wildlife may be particularly important for endangered species.[7]

XII. Mercury Legislation

1. The EPA's New Mercury Rule

On December 21, 2011, in response to a court deadline, the Environmental Protection Agency announced the nation's first national standards regulating mercury and other toxic emissions from coal-fired power plants. The emissions limits were mandated in amendments made in 1990 to the Clean Air Act. The new rule (titled "National Emission Standards for Hazardous Air Pollutants From Coal- and Oil-Fired Electric Utility Steam Generating Units and Standards of Performance for Fossil-Fuel-Fired Electric Utility, Industrial-Commercial- Institutional, and Small Industrial- Commercial-Institutional Steam Generating Units") requires plants to limit mercury emissions and other air toxics by installing pollution controls. According to EPA estimates,

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TABLE 28—SUMMARY OF THE MONETIZED BENEFITS, SOCIAL COSTS, AND NET BENEFITS FOR THE PROPOSED RULE IN 2016

[Millions of 2006$][a]

	3% Discount rate	7% Discount rate
Total Monetized Benefits[b]	$59,000 to $140,000	$53,000 to $130,000.
Hg-related Benefits[c]	$4.1 to $5.9	$0.45 to $0.89.
CO_2-related Benefits	$570	$570.
$PM_{2.5}$-related Co-benefits[d]	$59,000 to $140,000	$53,000 to $120,000.
Total Social Costs[e]	$10,900	$10,900.
Net Benefits	$48,000 to $130,000	$42,000 to $130,000.
Non-monetized Benefits	Visibility in Class I areas. Cardiovascular effects of Hg exposure. Other health effects of Hg exposure. Ecosystem effects. Commercial and non-freshwater fish consumption.	

[a] All estimates are for 2016, and are rounded to two significant figures. The net present value of reduced CO_2 emissions are calculated differently than other benefits. The same discount rate used to discount the value of damages from future emissions (SCC at 5, 3, 2.5 percent) is used to calculate net present value of SCC for internal consistency. This table shows monetized CO_2 co-benefits at discount rates at 3 and 7 percent that were calculated using the global average SCC estimate at a 3 percent discount rate because the interagency workgroup on this topic deemed this marginal value to be the central value. In section 6.6 of the RIA we also report the monetized CO_2 co-benefits using discount rates of 5 percent (average), 2.5 percent (average), and 3 percent (95th percentile).

[b] The total monetized benefits reflect the human health benefits associated with reducing exposure to MeHg, $PM_{2.5}$, and ozone.

[c] Based on an analysis of health effects due to recreational freshwater fish consumption.

[d] The reduction in premature mortalities account for over 90 percent of total monetized $PM_{2.5}$ benefits.

[e] Social costs are estimated using the MultiMarket model, in order to estimate economic impacts of the proposal to industries outside the electric power sector. Details on the social cost estimates can be found in Chapter 9 and Appendix E of the RIA.

these technologies are already in use by 60 percent of the nation's 1,400 coal- and oil-fired power plants. The rule requires that the rest reduce emissions by 2015.[1] This can be achieved by pre-treating coal to remove mercury before combustion or by 'capturing' the mercury at the end of the process before it is released.[2] When fully implemented, 91 percent of mercury in coal will be removed from emissions.[3]

In July, the Republican-led House passed a bill (H.R. 2018) that sought to postpone the regulations by at least 18 months. The Democrat-led Senate did not approve the measure.[4]

Power plants are the largest unregulated source of U.S. mercury emissions, comprising about 40 percent of human-produced atmospheric emissions. EPA noted in their analysis that emissions can be cut without affecting service or raising electricity costs, and compliance will create more jobs than it will eliminate.[5] The agency's economic analysis showed that every dollar spent reducing power plant pollution will yield up to $13 in health and economic benefits, according to EPA estimates, with a total benefit of up to $140 billion annually.[6] Yearly compliance costs are approximately $10.9 billion.[7]

Some of the worst polluting power plants were constructed in the 1950s and 1960s using obsolete, inefficient technologies; according to some estimates, between 32 and 58 of these will close.[8] The rule levels the playing field for a U.S. electric market that has been skewed in favor of higher polluting plants. New plants use fuel and produce electricity more efficiently and pollute far less.[9]

XIII. U.S. Legislative History: Mercury Regulations

Before the 1990 Clean Air Act (CAA) Amendments, EPA regulated hazardous air pollutants one chemical at a time, based on human health risk. During the 1970s and 1980s, the agency was embroiled in legal, scientific, and policy debates over which pollutants to regulate—and what safe levels were. From 1970 when Richard Nixon established the Act, with broad bipartisan support, through 1990, EPA created National Emissions Standards for Hazardous Air Pollutants for just seven toxics.[1]

In 1990, Congress revised section 112 of the Clean Air Act. The Amendment mandated EPA to identify *categories* of industrial sources for 187 listed toxic air pollutants and develop pollution-control standards for them based on technologies or practices already in use within that industry. This streamlined approach made much more sense because many industrial sources release more than one toxic chemical.[2]

To establish these so-called "Maximum Achievable Control Technology" (MACT) standards, EPA identifies the least-polluting sources within an industry. MACT standards must equal the average emissions of the best-controlled 12 percent of those pollution sources if there are 30 or more, or the best-performing five if there are fewer than 30. Industries must then install controls or change production processes to reduce emissions to meet those standards. EPA normally does not mandate use of a specific control technology, but instead sets a performance level based on practices and technologies already in use by the best-controlled industrial sources. To meet MACT standards, industries must install controls or change production processes to reduce emissions within an "ample margin of safety."[3,4]

At that time, Congress also directed the EPA to report on mercury. That included assessing the magnitude of U.S. mercury emissions by source, calculating the availability and cost of emissions control technologies, and evaluating the health and environmental impacts. Congress commissioned a second study to evaluate the health hazards posed by emissions from fossil fuel-fired power plants (also known as utility steam generating units, or EGUs).[5]

The Mercury Study[6] was due in 1993 and the Utility Study[7] the following year. The National Institute of Environmental Health Sciences (NIEHS) provided an additional study to Congress in 1995 to help determine a safe mercury threshold for humans—an amount, ingested daily over a lifetime, that should not cause human health problems even in subpopulations that consume large amounts of seafood.[8] Congress then requested an independent evaluation from the National Academy of Sciences (NAS) on a safe mercury reference dose.[8]

But power plants escaped regulation in 1991 when the EPA excluded them from a list of industrial categories (the section 112(c) source category list) intended for regulation under MACT. The Natural Resources Defense Council (NRDC) filed suit, and under a 1994 settlement, EPA was required to complete their study and report to Congress by November 1995. EPA failed to deliver these reports until 1998. Under threat of an "unreasonable delay" lawsuit by NRDC and the Sierra Club, EPA agreed to make regulatory determinations by Dec. 15, 2000.[9, 10]

In 2000, the NAS National Research Council issued their "The Toxicological Effects of Methylmercury" report. Based on the latest scientific evidence, they upheld EPA's mercury guideline as justifiable, but noted that some children of women who consume large amounts of fish and seafood during pregnancy may be at particular risk of neurological problems.[11]

EPA concluded in December 2000 that coal- and oil-fired power plant emissions posed a significant threat to human health and to the environment. Then-EPA Administrator Carol Browner determined that it was "appropriate and necessary" to reduce toxic air pollutants from fossil fuel-fired power plants under MACT standards, and placed the plants on the section 112(c) source category list. In 2001, an industry group sued the EPA in the DC Circuit Court, challenging their position and the case was thrown out.[12, 13]

In March, 2005, EPA reversed their conclusion that regulation was needed and de-listed coal- and oil-fired power plants under the Section 112(n) Revision Rule. The agency also instituted the Clean Air Mercury Rule, or Clear Skies Act,[14] a cap and trade program that allowed even the dirtiest plants to buy pollution credits from places as far away as Alaska or Hawaii. The plan claimed significant power plant mercury reductions, but in fact delayed any mercury regulation for 13 years.[15]

Sixteen states, several cities and a coalition of American Indian tribes and environmental and public health groups challenged both the 2005 Action and the Clean Air Mercury Rule in a federal lawsuit, *New Jersey v. EPA.* They contended that under the Clean Air Act, toxic substances must be regulated, not traded.[16]

In February 2008, the U.S. Court of Appeals for the D.C. Circuit unanimously struck down both initiatives. The Court ruled that EPA sidestepped the law by failing to require prompt, substantial cuts in mercury emissions from coal-fired power plants—and were unable to prove that emissions allowed by the rule would not adversely affect health and the environment.[17]

They also ruled that EPA had illegally substituted mercury pollution trading for protections required by the Clean Air Act, that it was illegal to remove industries from the section 112(c) source category list, and emphasized that it was EPA's legal obligation to adopt MACT standards for power plants.[18]

The Court noted that the violations were not mere legal technicalities, but defied Clean Air Act requirements, and the judge's comments went so far as to invoke Lewis Carroll's "Alice in Wonderland," saying that the agency's reasoning recalled "the logic of the Queen of Hearts, substituting the EPA's desires for the plain text" of the law.[19]

On December 18, 2008, environmental and public health organizations[20] filed a complaint against EPA in DC District Court, charging that they had failed to establish standards for hazardous air pollutants from coal- and oil- fired EGUs.[21] EPA settled the case by agreeing to produce a proposal by March 16, 2011 and a final rule by November 2011.[22] Although the new regulation was not finalized until December 21st, EPA has now met its Congressional mandate under the 1990 Clean Air Act to regulate emissions from these plants.[23]

Los Angeles Times interviews with EPA employees revealed that political appointees at the agency completely ignored both professional and scientific staff and a federal advisory panel in writing the new rules.

Other regulations have also had positive impact. Mercury use in batteries, fungicides and paints has dropped sharply, and municipal and medical waste incinerators have cut mercury emissions by 90 percent.[25] Additionally, the number of chlor-alkali plants declined from about 20 in 1990 to 12 in 2000 and even those reduced their mercury use.[26]

XIV. Industry Fights Rules with Denial and Influence

1. The Power Plant Industry: Influence on the Clean Air Mercury Rule

The 30 companies that own most of the nation's heaviest-polluting power plants and their trade association raised $6.6 million for President Bush and the Republican National Committee from 1999-2004, according to Public Citizen, a consumer advocacy group, and the Environmental Integrity Project, an environmental watchdog organization. The administration's 2005 Clean Air Mercury Rule saved those contributors billions of dollars in compliance costs.[6]

In a recorded April 2001 speech, a utility industry lobbyist told his coal industry audience they need not fear impending EPA MACT regulations: he and friends in the Bush administration planned to create the "next generation of regulatory programs" for power plants. The lobbyist stated that eliminating MACT standards would be the highest priority for the utility industry.[2]

The Bush Administration's Clean Air Mercury Rule was heavily influenced by industry. The rule included 12 paragraphs that were lifted—some verbatim—from a legal document prepared by industry lawyers.[3]

Los Angeles Times interviews with EPA employees revealed that political appointees at the agency completely ignored both professional and scientific staff and a federal advisory panel in writing the new rules.[4] And the EPA's inspector general reported that agency scientists were pressured to change their scientific findings in order to support the Administration's pro-industry rules.[5, 6]

2. The Power Plant Industry vs. the 2011 EPA Mercury Rule

The EPA Mercury Rule sparked intense lobbying efforts by the power plant industry. According to NRDC, lobbyists for the American Petroleum Institute, American Chemistry Council, the Business Roundtable and others mounted a big push to stop EPA Administrator Lisa Jackson from finalizing the new standards, appealing to her, President Obama, House Energy & Commerce Committee Chairman, Fred Upton (R-MI), and Energy & Power Subcommittee Chairman, Ed Whitfield (R-KY).[1]

On July 12, 2011, the U.S. House Energy and Commerce Committee approved a bill that would delay implementation of the EPA Mercury and Air Toxics standards by at least 18 months. H.R. 2401 would require Cabinet-level officials to analyze the effects on employment and the economy of eight Clean Air Act regulations. The bill was never voted on in the Senate.[2]

Additionally, an amendment by Rep. Cynthia Lummis (R-WY) was tagged to H.R. 2584, the House appropriations bill for EPA and the Interior Department that would block implementation of the standards. Rep. Lois Capps (D-CA) sponsored an amendment to the House EPA-Interior spending bill that would strike the Lummis amendment.[3]

Despite intense lobbying efforts, the Obama administration has finalized these long-overdue regulations.

On July 12, 2011, the U.S. House Energy and Commerce Committee approved a bill that would delay implementation of the proposed EPA Mercury and Air Toxics standards for power plants by at least 18 months.

3. "Clean Coal"

The 2010 documentary "Dirty Business: 'Clean Coal' and the Battle for Our Energy Future" notes that many Americans are unaware that about one-half of the nation's energy comes from burning coal—using what they call "dirty, 19th-century technology." The film investigates the coal lobby's $40 million dollar public relations/advertising campaign aimed at pushing cleaner energy alternatives aside and convincing the public that coal is a clean energy source.[1]

4. The Fishing Industry Spins and Denies

Consumer misinformation on safe mercury levels in fish has been exacerbated by messages from commercially interested parties, most notably, the tuna industry.

When the EPA and USDA began warning consumers about methylmercury risks in fish, the National Fisheries Institute (NFI), a U.S. seafood industry trade group, launched public relations campaigns denying health risks and promoting fish consumption.[1, 2, 3]

Tuna companies have spent millions on advertising, urging consumers to "eat more tuna." Some ads have specifically targeted women of childbearing age in an effort to counter the impact of government advice regarding mercury directed at that demographic.[4] Burston Marstellar, the PR firm representing the U.S. Tuna Foundation (now the Tuna Council), ran ad campaigns to persuade people—including pregnant women—that eating all kinds of tuna is beneficial and poses no health hazard.[5]

Tuna companies have recently launched a multi-million dollar campaign marketing canned tuna products as a "wonderfish" that never mentions the word "mercury."[6] In March 2011, GotMercury.org and five other organizations sent a letter to the heads of StarKist, Chicken of the Sea and Bumble Bee rquesting that they include information about mercury levels in canned tuna in the "Tuna the Wonderfish" campaign.[7]

Part of the strategy has been to change perceptions of benefit versus risk by reframing the debate—so that consumer decisions are seen as either eating fish or not eating fish. When public health officials have advised Americans to eat more fish—but to choose low-mercury types—the industry has fought back as if the dictum was to abstain from eating fish. The industry has repeatedly claimed that "the benefits far outweigh the risks," dismissing risks from methylmercury exposure as unproven or minuscule and attacking the 2004 FDA/EPA Advisory as "excessively risk-averse" [8]

Internal blog posts from Burston Marstellar's CEO in 2006 stated that his company pitched "ideas for how to act like a political campaign by neutralizing the negatives and bringing out the heart healthy benefits of tuna."[9]

Fishing lobbies aggressively neutralize "bad publicity" from news stories on methylmercury risk, incorporating opinions from industry-backed organizations like the Center for Consumer Freedom. The center runs two mercury-disinformation websites. Mercuryfacts.com hosts a "mercury calculator" that tells consumers they can eat fish containing ten times the EPA reference dose. Fishscam.com contends that mercury concerns are a "scare" created by environmentalists. RealMercuryFacts.org is another disinformation site.[10]

Lobbies typically respond to media reports by attacks discrediting coverage, alleging inaccurate, one-sided reporting that harms the public by scaring people away from eating fish. Another tactic is to overwhelm reporters and editors with letters, e-mails, press releases and comments on their web sites and blogs.[10] Sometimes these efforts prompt follow-up stories that give more play to their arguments. Particular targets have included New York Times food reporter Marian Burros, Newsweek science editor Sharon Begley, Houston Chronicle writer David Ellison, Chicago Tribune reporters Sam Roe and Michael Hawthorne, among others. Mercuryfacts.org has a "Fearmongers" tab on their website denouncing some reporters' coverage—and 21 nonprofit health and environmental organizations.[11]

One example of this type of media harassment took place in 2009.[12] For a report on mercury, reporter Sue Kwon of KPIX-TV in San Francisco ate one can of albacore tuna each day for 20 days. She noted in her broadcast that after three weeks, regular lab tests documented a spike in blood mercury levels that climbed from 4 micrograms per liter to 17—three times the EPA reference dose.

Kwon interviewed Dr. Jane Hightower on the segment, a San Francisco-based physician who discussed the health risks associated with mercury exposure. In a long email to KPIX's station manager, the National Fisheries Institute attacked Hightower's credibility and argued that Kwon's report was full of errors. They wrote, "what published science shows is that higher blood mercury among moms may actually be a marker of optimal brain development in babies, because it indicates regular seafood consumption."[13]

NFI sent at least two more letters to the station and posted a rebuttal video on YouTube[14]; both the original letter and the original version of the YouTube video claimed that the "level of mercury in blood that approaches risk" was 580 micrograms per liter. When this was noticed and reported by other media outlets, NFI claimed a "decimal-point error" and revised the safe level in its video to 58 micrograms per liter—which is still 10 times the EPA guideline level of 5.8 micrograms per liter.

Their video also stated that, "The scientific literature does not support an overall harm to baby brain development as a result of moms eating fish," a distortion that omits the fact that the fish type and mercury level of fish consumed is the determining factor regarding harm. Kwon spent days justifying the accuracy of her reporting to her managers.

The major researchers who study the health effects of methylmercury

When the EPA and USDA began warning consumers about methylmercury risks in fish, the National Fisheries Institute (NFI), a U.S. seafood industry trade group, launched public relations campaigns denying health risks and promoting fish consumption.

have also been attacked, including Phillippe Grandjean, the Harvard University scientist who conducted the Faroe Island Study, the late Kathryn Mahaffey, the EPA's leading expert on heavy metal toxicity that helped shape U.S. policy,[15] and others.[16]

XV. Global Legislative History

Currently, the world's two largest emitters of mercury pollution, China and the U.S. (number one and two, respectively), do not regulate mercury emissions from coal-fired power plants. In China, the Law of the People's Republic of China on the Prevention and Control of Air Pollution does not address mercury and has a loophole where polluters may opt out of compliance through payment of a "discharge fee."[1]

However, the European Union (EU) has made regulatory progress. Following the preparation of the EU Position Paper on Ambient Air Pollution by Mercury, the Union launched the European Mercury Strategy[2] in 2005. The strategy encompasses 20 actions, including a phase-out of mercury in goods and industrial applications, new rules for safe storage, a ban on mercury exports enacted in 2011, reductions in mercury emissions from fossil-fuel power plants and industrial facilities, efforts to promote international action, and more.[3,4]

International negotiations to limit global mercury pollution are moving forward. In 1998, the United Nations Economic Commission for Europe (one of five regional United Nations commissions that includes 56 countries in Europe, central Asia and North America) added a Heavy Metals Protocol to their Convention on Long-range Transboundary Air Pollution.[5] Part of that Protocol targeted mercury, requiring signatories to cut their emissions below 1990 levels. As of 2011, 36 nations have signed on, but it is not yet official: Arctic countries have ratified, except for Iceland (which has signed but not ratified), the United States (which has 'accepted' but not ratified), and the Russian Federation.

In 2008, the Arctic Council of Ministers endorsed the Arctic Contaminants Action Program to identify the main sources of mercury within the Arctic and suggest reduction measures.[6]

At the 2009 meeting of the United Nations Environment Programme (UNEP) Governing Council, more than 140 countries agreed to negotiate a legally binding international agreement by 2013 to limit mercury emissions and discharges. After Obama administration officials announced that the U.S. would reverse the position taken by the Bush administration and sign on, China, India, Canada, Australia and other nations also endorsed the treaty.[7, 8]

At that meeting, UNEP decided that an interim plan was necessary while awaiting the treaty because "the risk to human health was so significant that accelerated action... is needed." Those measures include safe mercury storage and reducing mercury use both among artisanal miners and in products.[9] Even without a legally-binding global agreement, many countries are acting to lower their emissions.[10]

XVI. Future Scenarios

Future global mercury emissions depend on a range of variables: national and regional economic development, regulatory changes, and use of emission-reducing technologies, and the impact of global climate change.[1,2]

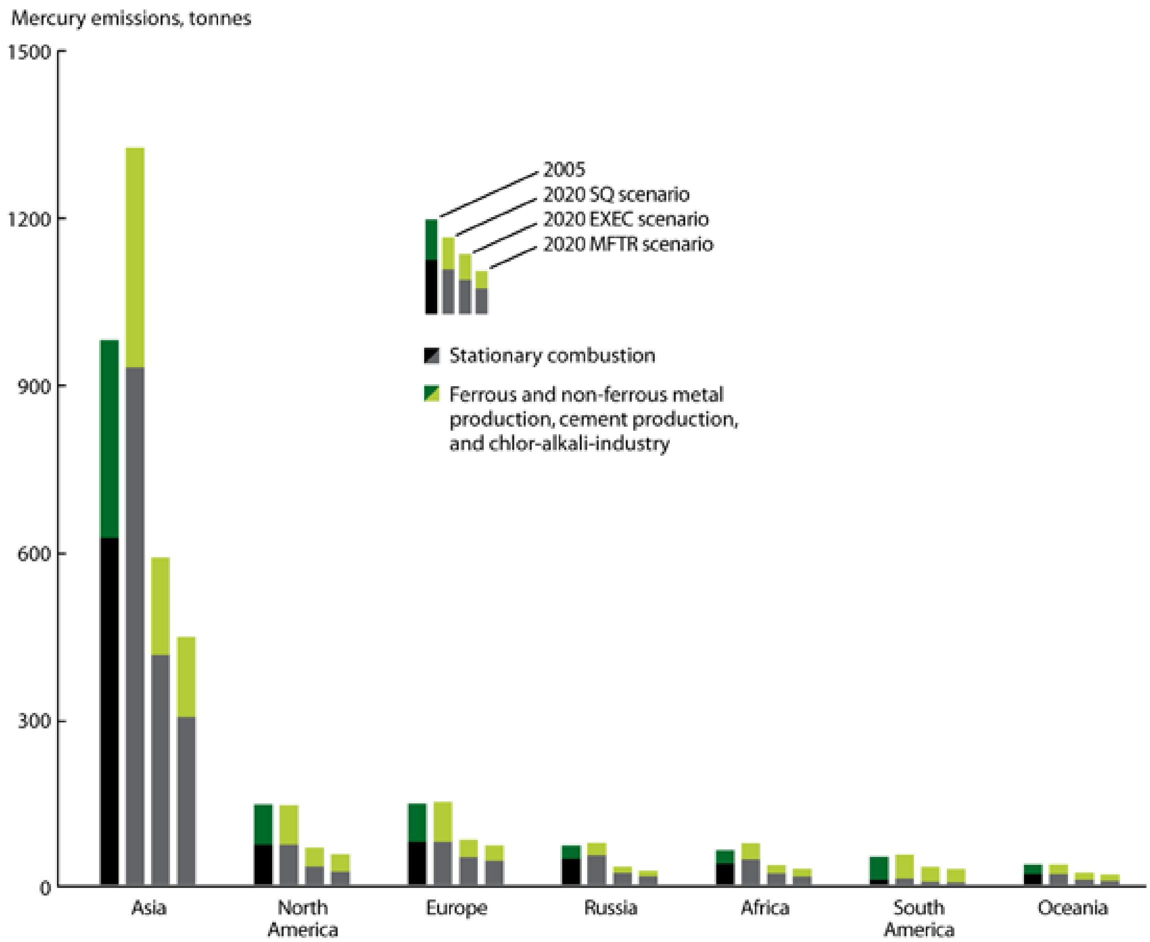
Mercury moves slowly in and out of both the soil and oceans that hold large reservoirs of the metal. There may be significant lag time—tens of decades—before cuts in mercury pollution impact levels in oceans, freshwaters, soils, sediments, ice—and in both wildlife and humans. For example, ocean models suggest that a 5 percent global reduction in mercury emissions would bring a 2.4 percent drop in methylmecury in the western Arctic Ocean and a 2.1 percent drop in the eastern Arctic Ocean by 2020. Even with substantial cuts in emissions, significant recovery in the oceans could take up to 35 years.[3]

Ocean concentrations are still rising. Water samples taken in the North Pacific Ocean in 2006 were approximately 30 percent higher than those measured in the mid-1990s. Computer models predict that if mercury emission rates continue at current rates, by 2050 concentrations in the Pacific will increase by about 50 percent[4] and may double in some parts of the open ocean (as compared with the mid-1990s).[5, 6]

The METAALICUS study concluded that cutting mercury emissions from coal-fired power plants and other industrial activities would lower methylmercury in fish within a decade.

Since mercury has a relatively short lifetime in the atmosphere, the atmosphere responds much more

Continental breakdown of mercury emissions, current and under the three scenarios.



SQ=status quo scenario; EXEC=extended emissions control scenario; MFTR= maximum feasible technological reduction scenario.

Source: UNEP, The Global Atmospheric Mercury Assessment: Sources, Emissions and Transport

quickly to changes in emissions.[7] The Mercury Experiment to Assess Atmospheric Loading in Canada and the United States study (METAALICUS) concluded that cutting mercury emissions from coal-fired power plants and other industrial activities would lower methylmercury in fish within a decade.[8]

Researchers have modeled a range of projections for future human-caused mercury emissions. The Arctic Monitoring and Assessment Program (AMAP) noted that without action, global mercury emissions could grow by 25 percent by 2020, raising average concentrations globally.[9,10] Such a rise could cost the global economy $3.7 billion a year because of health costs associated with diminished IQ alone. But with widespread use of the best existing pollution-control technology, global discharges could be lowered by up to 60 percent.[11] A 50 percent reduction in emissions would also deliver a hefty global economic benefit, estimated at between $1.2 and $1.8 billion a year.[12]

Implementing new technologies could have significant impact.[13] An AMAP assessment,[14] modeled three different possibilities for 2020 mercury levels: If nothing is done, yearly emissions will reach 1850 tons, a 25 percent increase over 2005 levels. Under that scenario, current patterns, practices and uses of mercury continue against a backdrop of economic growth in various regions.

Under the “extended emissions control” scenario, emissions would drop to 850 tons, less than half of “status quo” emissions. Those gains would require global adoption of both North American and European mercury-reduction technologies combined with Europe's strict emissions control measures.

The best possibility, "maximum feasible technological reduction", would implement all available ways to reduce mercury, producing dramatic reductions. This approach would cut emissions to 670 tons, just two-fifths of the "status quo."[15]

However, none of these scenarios have factored in any of the potential impacts of global climate change on mercury transformation, transport, and deposition. Both climate change and other factors, including economics and geopolitics, may change energy use. Rising oil prices could bring wider use of coal-powered electricity that would increase mercury emissions—or, if other means of energy production are developed, mercury emissions could decline.[16]

Main assumptions applied for some sectors under the three scenarios

Sector	Status quo (SQ) 2020	Extended emissions control (EXEC) 2020	Maximum feasible technological reduction (MFTR) 2020
Large combustion plants	Increase in coal consumption in Africa (20%), South America (50%) and Asia (50%). Application of current technology	SQ 2020 assumptions plus: De-dusting: fabric filters and electrostatic precipitators operated in combination with FGD. Activated carbon filters. Sulphur-impregnated adsorbents. Selenium impregnated filters.	SQ 2020 assumptions plus: Integrated gasification combined cycle (IGCC). Supercritical polyvalent technologies. 50% participation in electricity generation by thermal method.
Iron and steel production	Application of current technology.	In sintering: fine wet scrubbing systems or fabric filters with addition of lignite coke powder. In blast furnaces: scrubbers or wet ESPs for BF gas treatment. In basic oxygen furnace: dry ESPs or scrubbing for primary de-dusting and fabric filters or ESPs for secondary de-dusting. In electric arc furnaces: fabric filters and catalytic oxidation.	EXEC 2020 techniques in existing installations plus: Sorting of scrap. New iron-making techniques. Direct reduction and smelting reduction.
Cement industry	Increase in global cement production (50%). Application of current technology	SQ 2020 assumptions plus: De-dusting: fabric filters and electrostatic precipitators.	SQ 2020 and EXEC 2020 assumptions plus: All plants with techniques for heavy metals reduction.
Chlor-alkali industry	Phase-out of mercury cell plants by 2010		

Source: Arctic UNEP

Given the slow timescale of mercury circulation through the ocean, the Arctic Monitoring and Assessment Programme notes that emissions reductions should be implemented as soon as possible.[22]

New analysis published last year in *Environmental Science and Technology*[17] modeled projected human-caused mercury emissions out to 2050, based on a special report by the U.N. Intergovernmental Panel on Climate Change.[18] In four possible scenarios, they found that at best, human emissions would remain constant—and at worst, they would double, depending on industrial growth, increases in coal combustion and use of environmental controls. Mercury emissions coming from Asia—mostly from India and China—account for more than half of global anthropogenic emissions in all 2050 scenarios. Projections for Asia span a wide range from near constant output to a 240 percent increase.[19]

Since most new emissions are expected to come from coal combustion in Asia, cleaning up power plants is key.[20] In a 2008 report, the United Nations Environment Programme noted that, "Mercury control technology for coal-fired power plants capable of capturing up to 95 percent of the mercury has only recently become commercially available and very few governments require it. Thus currently it is found on only a handful of plants [worldwide]."[21]

Given the slow timescale of mercury circulation through the ocean, the Arctic Monitoring and Assessment Programme notes that emissions reductions should be implemented as soon as possible.[22]

Note: all tonnage measurements are in metric tons.

XVII. Useful Links

Food and Drug Administration data on mercury concentrations in different species of fish: http://www.fda.gov/Food/FoodSafety/Product-SpecificInformation/Seafood/FoodbornePathogensContaminants/Methylmercury/ucm115644.htm

National Listing of Fish and Wildlife Advisories: http://www.epa.gov/mercury/advisories.htm

The Mercury Study Report to Congress (Volume IV: An Assessment of Exposure to Mercury in the United States) 1997 http://www.epa.gov/ttn/oarpg/t3/reports/volume4.pdf

FDA Mercury dockets: http://www.fda.gov/OHRMS/DOCKETS/ac/02/briefing/3872b1.htm

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