Mercurial risks from acid's reign: tainted fish may pose a serious human health hazard - includes information on methylmercury, health tips for anglers, affects on animals, and appreciation of methylmercury's threat

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Mercurial Risks From Acid's Reign

Alerted by local health advisories, anglers in North America increasingly find that the catches they pull from their favorite lakes aren't fit to be fried, at least not in generous quantities. Most of those warnings focus on fish tainted with methylmercury, the form of mercury most toxic to humans.

Environmental chemists once viewed serious methylmercury contamination of fish as a threat only in waters downstream from large industrial polluters, such as pulp and paper mills, smelters or chloralkali plants. In the past decade, however, researchers have extended their lake-metals surveys to "pristine" waters in the northern woods of the United States, Canada and Scandinavia. And many of those surveys have unexpectedly turned up high levels of methylmercury in fish.

Today, one of the few features common to waters having a methylmercury problem is low pH or a steady rain of acidic deposition. Though researchers still labor to tease out precisely why fish in these waters are especially vulnerable to methylmercury contamination, the mercury-pH link remains fairly unassailable, according to James G. Wiener, a research biologist with the Fish and Wildlife Service's National Fisheries Contaminant Research Center in La Crosse, Wis.

Scientists have a better understanding of where the mercury originates: Some is natural, and some enters as fallout from distant air polluters--largely incinerators smelters and coal-fired power plants.

Regardless of the source, the hazard remains the same. Adults eating large amounts of methylmercury-contaminated fish can suffer irreversible nerve damage, starting with a chronic numbness or tingling around the mouth or in the arms and legs. Children exposed in utero to even low doses of mercury can develop a range of more serious problems--from psychomotor retardation (including delays in speech or walking) to birth defects involving severe brain damage.

Because of the special vulnerability of children and developing fetuses, state health advisories on the consumption of local fish typically emphasize the risk to pregnant women and youngsters. But methylmercury also threatens adults, especially Native Americans living on subsistence diets in which protein comes mostly from local fish or from game animals that eat those fish.

"No known instances of mercury poisoning among humans have so far been reported from eating fish caught in lakes that do not receive a known discharge of the metal [in industrial wastes]," states a report issued last August by the Electric Power Research Institute (EPRI) in Palo Alto, Calif.

But the risk is there.

In epidemiologic studies of residential communities poisoned by industrial mercury discharges, Thomas W. Clarkson of the University of Rochester (N.Y.) and others have detected a risk of fetal brain damage among pregnant women receiving daily exposures of 600 to 1,100 nanograms of mercury per kilogram of body weight. FDA diet surveys indicate that the average American adult consumes only 50 nanograms of mercury per kilogram of body weight daily. Clarkson points out, however, that studies conducted in communities that depend on fish for their dietary protein (including ones in Canada and Sweden) have identified individuals whose diets apparently provide 200 times the federally permissible mercury limit for fish sold in the United States -- and 23 times the amount considered "tolerable" by the World Health Organization.

Acknowledging the potential for such extreme exposures, health departments in at least 21 U.S. states and two Canadian provinces have now issued advisories on methylmercury-contaminated freshwater fish. These warnings typically list affected waters by name and estimate how much fish from each can be safely consumed each week, and by whom. For instance, New York's latest advisory recommends that infants, children under 15 and women of childbearing age not eat any fish from the waters listed.

Researchers who study the methylmercury problem point to combustion pollutants in the air as the primary source of mercury in most highly contaminated lake fish, says Greg Mierle, a biophysical ecologist at the Dorset (Ontario) Research Center.

Yet as recently as a decade ago, scientists had all but discounted air pollution as an important source of the metal.

Why the turnabout? The few tests conducted in the early 1980s to measure mercury in rainwater turned up only scant amounts, Mierle recalls. Because mercury contamination plagued so many lakes -- including ones in remote, nonindustrial regions -- some reserchers reasoned that the metal must have come from natural geologic deposits.

"The problem," mierle says, "is that the analytical techniques used in the early '80s were not very good." That realization led Mierle and his co-workers to spend several years improving mercury assay methods. The Dorset team then set about measuring all of the mercury entering one Ontario lake, as the metal trickled in with rain and with drainage from surrounding lands.

"And somewhat to our surprise," Mierle says, "it turned out that the direct deposition from rain accounted for about half the mercury coming into the lake."

He adds that these data, published in the September 1990 ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY (ET&C), also indicate that "there's more than enough mercury in rain falling on the watershed [lands draining into the lake] to account for what enters the lake from runoff."

"The scary thing," Mierle says, is that the "very low levels" of mercury typically found in rain can cause such dramatic contamination. Industrial mercury fallout, generally measured at only a few parts per trillion in rain, could add as little as 0.3 gram of mercury a year to a 25-acre lake, according to the August EPRI report. Yet this "is more than enough to account for all the mercury that we're seeing in fish and other biota," Mierle says.

And aquatic ecologists are indeed seeing a lot of it. In the mid-1970s, after dramatically reducing mercury levels in industrially contaminated waterways, the Ontario government initiated a survey of fish in seemingly pristine lakes. The study sought to establish a baseline by determining natural, background levels of the metal in nonindustrial areas. But project scientists have turned up far more than background levels in most of the 1,400 sites they have sampled thus far. Fish retrieved from 90 to 95 percent of these Ontario lakes have proved so heavily tainted with methylmercury that they have triggered health adivosries, Mierle observes.

In recent years, several other jurisdictions have uncovered similarly disturbing trends. Methylmercury findings in

Florida have led officials there to issue fish-consumption advisories for one-third of the state's rivers, lakes and streams. Minnesota has published consumption advisories for 285 bodies of water (more than half of those sampled), and Wisconsin has done the same for 154. Michigan has extended a blanket warning on methylmercury-tainted fish to cover all of its estimated 10,000 inland lakes.

And in Sweden, "more than 9,400 lakes ought to be blacklisted due to levels of methylmercury in fish higher than 1 milligram per kilogram," according to a report in the September 1990 ET&C by Ying-Hua Lee and Hans Hultberg of the Swedish Environmental Research Institute.

In its gaseous, elemental state -- the form typically emitted by combustion sources -- mercury poses little environmental hazard, says Wiener. Though elemental mercury is toxic, it has difficulty passing through a fish's gills and gut membranes, he explaines. And when it does sneak in, fish tend to eliminate it rather quickly.

Methylmercury is another matter. Even more toxic to humans, this compound accumulates rapidly and efficiently in a fish's edible muscle. In fact, Wiener notes, data reported in the September 1990 ET&C by researchers at EPRI and four other institutions show that even though most lake-water mercury remains in inorganic forms, the organic, methylated species of this metal constitute 95 to 99 percent of what ends up in fish.

Since methylmercury itself rarely deposits directly into lakes, toxicity problems seldom develop unless microbes or chemical conditions within the lake transform elemental mercury into methylmerucy (see box, p.152), notes biogeochemist John W.M. Rudd of the Freshwater Institute in Winnipeg, Manitoba. Researchers are now trying to figure out how microbes and ambient water chemistry can methylate mercury so prodigiously in one lake and ignore the metal in another.

Ambient pH appears to be one of the most important factors.

For years, says Wiener, aquatic ecologists in the United States, Canada, Sweden Finland and the Soviet Union observed a similar trend: Fish from acidic lakes tended to show substantially higher methylmerucry levels than did fish from neutral or alkaline lakes. Wiener and his colleagues decided to investigate the role of pH by experimentally acidifying a portion of Little Rock Lake in northern Wisconsin.

By installing two "sea curtains," the researchers partitioned part of the lake into two nearly identical basins. At two-year intervals beginning in 1985, they have added sulfuric acid -- the pH-lowering agent formed by the sulfates in acid rain -- to one basin. This incrementally increased its acidity from an initial pH of 6.1 to a very inhospitable 4.7. The other basin has remained untreated.

Last year, the team published comparisons of methylmercury levels in fish caught from the basins during the first two years, when researchers maintained the treated basin at a pH of 5.6. And by the end of the second year, they report in the September 1990 Et&C, year-old perch from the acidified basin contained 16 percent more methylmercury than did perch of the same age from the untreated water. Because the adjacent basins derive nearly all their water from rain and should receive nearly identical doses of air pollution, Wiener now concludes that the experimental lake acidification somehow fostered the increased contamination in fish from the treated basin.

Rudd, who has conducted his own studies of freshwater systems, has found that any of three factors can increase mercury methylation and the subsequent contamination of fish. Those factors, he says, are waterway acidification, increased deposition of mercury into a waterway, and flooding of previously wooded land.

Since combustion pollutants can not only acidify surface waters but also enrich their mercury concentration, Rudd suspects that acid rain packs a double whammy. "In some of our experiments," he says, "if we both decreased [a water's] pH and increased its mercury concentrations, we got kind of a double effect" on methylation rates, compared with the effect of either factor alone.

Moreover, other findings suggest that independent of their pH-altering role, sulfates may foster the methylation of mercury in some waterways. Because the lake studied in those investigations -- led by Cynthia C. Gilmour at the Benedict (Md.) Estuarine Research Laboratory -- tended to have an acidic pH, Rudd says it's possible that sulfates may represent yet another additive factor contributing to the methylmercury problem in regions beset by acid rain.

It's possible that the remote waters identified as methylmercury problem sites over the last five or 10 years have actually held contaminated fish for decades. Ecologists essentially stumbled onto the discovery that these waters are far from pristine; and few of the lakes have been assayed regularly enough or long enough to reveal whether the methylmercury levels of their inabhitants are stable or increasing. But Rudd suspects that a growing acid-deposition problem is raising both the number of affected lakes and the methylmercury levels of the fish that swim in their waters.

Because mercury is so ubiquitous, and because so many factors can foster its methylation, "once you have a [methylmercury] problem it tends to stay with you" -- especially in acidic waters, observes Ronald J. Sloan of New York's Department of Environmental Conservation in Albany.

But a number of researchers are investigating possible remedies for acid-prone lakes contaminated by airborne mercury.

Research undertaken by Rudd 10 years ago suggested, for instance, that adding selenium to freshwater systems would inhibit methylmercury uptake by susceptible fish. Swedish researchers are now conducting lake-scale experiments to explore the safety and effectiveness of such treatments. These new studies, says Rudd, indicate that "if you add a little selenium to a lake, it not only decreases the uptake of methlmercury by fish, but also reduces the toxicity of the mercury that has bioaccumulated in the fish."

However, concerns that the selenium might adversely affect fish reproduction leave the treatment's merits still in question, says Ralph Turner, a geochemist at Oak ridge (Tenn.) National Laboratory. Selenium can be highly toxic (SN: 7/4/87, p.8), and its therapeutic dose may be close to, if not overlapping, its toxic dose, Turner notes. "It certainly doesn't give you much margin of safety," he says.

Turner's own tactics for countering methylmercury buildup in freshwater fish focus on stimulating the activity of several detoxifying bacteria. In the water, elemental mercury can undergo a host of chemical transformations. Many of the resulting compounds render the metal ripe for methylation. Turner, who admits he's taking "a long-shot sort of approach," is participating in an EPRI-sponsored project to identify factors that might spur certain naturally occurring bacteria to reduce such oxidized compounds back to elemental mercury.

During the 1950s, classified defense activities at Oak Ridge resulted in extensive mercury contamination of a nearby creek. Yet despite the hundreds of thousands of pounds of mercury now present in this water systems, "our levels of methylmercury in fish are similar to what you find in background, pristine lakes," Turner says. Part of the reason, his data suggest, "is that bacteria have intervened and reduced the production of methylmercury."

Bacteria don't methylate mercury on purpose. They apparently accomplish these transformations only inadvertitently, "as a consequence of doing something else," Turner notes. For this reason, enticing them to methylate less hasn't proved easy, he says.

High levels of mercury-based compounds appear to stimulate the "reduction" activity Turner has seen in the waters around Oak Ridge. The challenge, he says, is to enhance the level of that activity through mechanisms that don't involve adding more mercury. This summer, Turner will work with researchers from EPA's microbial ecology lab in Gulf Breeze, Fla., to investigate how changing water pH or bacterial nutrient levels affects mercury's methylation rates.

In another EPRI-funded project, scientists at the University of California, Irvine, are exploring ways to spur the activity of demethylating bacteria. These microbes vary in their innate genetic ability to convert methylmercury back to the gaseous elemental metal. However, like athletes, demethylators can improve their skills with a training regimen that involvesovercoming a succession of challenges.

Environmental scientist Betty Olson has established an Olympic-style training camp for such microbes in her lab, where the organisms exercise against mercury-contaminated river sediment from Oak Ridge in a microcosm of the natural environment.

When her organisms first arrived for training, they achieved "no measurable [mercury] demethylation," Olson recalls. Today, her recruits can transform 20 nanograms of methylmercury (per gram of sediment) back to elemental mercury daily. If they can sustain this "really exciting" rate ocne they return to their home waters, she calculates, it might be possible to naturally "clean up" Oak Ridge's contamination in just eight years. To test the idea, she plans to return her mighty microbes to their Oak Ridge home for mciro-scale field exercises in just a few weeks.

Of course, unless the volatile, elemental mercury is subsequently trapped by activated charcoal or other filtering systems, the demthylated metal remains susceptible to remethylation, she notes. While such filtering at the lake surface is conceptually feasible, it's a long way from routine, Olson says.

For most of these scientists, the big hurdle has been winning national and international appreciation for the magnitude of the problem they're tackling. That hard-earned recognition -- along with critical research funding -- is coming, Rudd says. And that's fortunate, adds Turner, because there's still so much about the problem that "we just don't know."