SG
UNIVERSITY OF WISCONSIN SEA GRANT INSTITUTE

CONTACTS
James Hurley, Director
hurley@aqua.wisc.edu
608-262-0905

Fred Binkowski, Aquaculture Specialist
sturgeon@uwm.edu
414-382-1723

COURTESY OF U.S. DEPARTMENT OF AGRICULTURE

Early research sponsored by Wisconsin Sea Grant indicates that mercury is not likely an issue for Upper Midwest aquaculture facilities raising yellow perch and other cool- and cold-water food fish.

Mercury, Fish and Aquaculture

Aquaculture in Wisconsin is a diverse industry, including bait fish, stocker fish, aquatic plants, crayfish and more. For those raising yellow perch, trout, walleye and other food fish, questions about possible mercury contamination have mounted during the last 20 years as consumption advisories for wild fish have blanketed waters in the Great Lakes region.

During this same period, advances in measurement techniques have enabled scientists to detect extremely low concentrations of the toxic metal in water. It is now possible to routinely measure concentrations less than one part per trillion. That's less than one drop dispersed throughout an Olympic-sized swimming pool.

Using these powerful measuring techniques to look at mercury in rain, snow, lakes and rivers, scientists have found that some amount of mercury is present virtually everywhere on the planet, from urban centers to remote wildernesses. In fact, the globe-trotting ability of mercury pollution was discovered in northern Wisconsin in the late 1980s, as scientists studying the chemistry and biology of remote lakes were surprised to find that most mercury in fish originated all over the planet and was transported by the atmosphere. Since then, every year has brought increased understanding of where mercury pollution comes from and how it cycles through the environment.

Where Does It Come From?

Mercury is released into the environment by many sources. Human-caused sources include coal-burning electric utilities, incinerators, chlorine and cement manufacturing plants, and leaks and spills from mercury-containing products and disposal sites. In many parts of the world, small-scale gold mining operations are major sources. Natural sources include volcanic eruptions, erosion of rocks and decomposition of soils.

When mercury gets into the atmosphere, it travels anywhere from a few miles to halfway around the world before being deposited on land and water bodies. As a result, major point sources often deliver mercury both to nearby locations and to the global atmosphere. Mercury falls to earth with rainwater and with dry particles. It may also be discharged directly into receiving waters by factories or waste sites, although most of these point sources have been curtailed or eliminated.

Thus, mercury in Wisconsin, as in many places, comes from local, regional and global sources that are both natural and human-created. According to the Madison Conference Declaration on Mercury Pollution (August 2006), human industrial activity has increased atmospheric levels of mercury to three times more than they were about 200 years ago.

The largest sources of human-released mercury in North America are coal-burning electric utilities. Four major electric utility companies exist in Wisconsin. The Wisconsin Department of Natural Resources (WDNR) reports in 2012 that together they emit about 1,800 pounds of mercury annually to the air—a 40 percent reduction from 3,000 pounds in 2010. Further reduction is expected by 2015 when federal and state rules require utilities to meet an 80 to 90 percent reduction, respectively, over baseline levels recorded from 2002 through 2004.

Another major industrial source of mercury comes from chlor-alkali facilities. The sole facility in Wisconsin began using a mercury-free process in 2011, eliminating about 1,000 pounds of mercury emissions annually.

Wisconsin has also reduced mercury releases from commercial products since the implementation of Wisconsin Act 44 in November of 2010. Although new estimates were unavailable at press, the act bans the sale of most mercury-containing products such as thermometers, manometers, thermostats, barometers, switches, replays and other household items unless the only mercury-containing component is a button cell battery.

The U.S. Environmental Protection Agency reports in 2010 that nationally approximately 33.5 tons of mercury are released annually from power plants (down from 48.2 tons in 2005). This amounts to roughly 50 percent of all domestic human-caused mercury emissions. The agency estimates that about one quarter of U.S. emissions from coal-burning power plants are deposited within the contiguous United States, and the remainder enters the global cycle.

Mercury in Fish

When mercury is discharged or deposited into a water body or watershed, bacteria can convert it into a form called methylmercury. It is methylmercury that poses the greatest health risks to humans and wildlife. Methylmer-

cury tends to associate with plankton and other organic (i.e., carbon-containing) material. When fish consume phytoplankton and zooplankton, methylmercury gets passed up the food chain, and tissue concentrations tend to increase, a process called bioaccumulation. In general, the higher an organism is in a food web and the older it is, the higher its mercury tissue concentrations are likely to be.

A 2006 study by the National Academy of Science's Institute of Medicine found that tilefish, shark, swordfish and king mackerel contained the highest concentrations of methylmercury among many commercially available fish. Atlantic salmon and Pacific salmon contained very low levels of mercury.

Another study looked at mercury levels in commercial fish available in Chicago supermarkets. The authors reported that mercury concentrations ranged from 0.03 parts per million (ppm) in salmon to 1.41 ppm in swordfish. Maximum concentrations in orange roughy, swordfish and walleye were above the 1.0 ppm limit set by the U.S. Food and Drug Administration (FDA) for commercially sold fish.

Wisconsin and most other Great Lakes states have issued statewide consumption advisories for sport fish, based partly on their mercury concentrations. The WDNR reports that most sport fish in Wisconsin lakes contain at least 0.05 ppm mercury, the level at which the state issues consumption advice. In addition, the WDNR recommends that, in particular, children under 15 and women of childbearing age avoid eating fish from specific lakes where fish may have higher concentrations of mercury.

The Wisconsin advisory notes that mercury in fish is distributed throughout the fish's muscle tissue, not in the fat or in the skin. Therefore, mercury consumption cannot be reduced by trimming fat, skinning or cooking techniques. The only way to reduce mercury intake is to eat fewer mercury-contaminated fish.

How Does Eating Fish Affect Human Health?

Mercury has been linked to developmental and neurological disorders in adults, children and fetuses. According to the Madison Conference Declaration on Mercury Pollution, "Uncertainties remain in the risk assessment for the neurodevelopmental effects of methylmercury, yet there is sufficient evidence to warrant the prudent selection of fish species in the diet, particularly for pregnant women and children." The same document notes that new evidence indicates methylmercury exposure may increase the risk of cardiovascular disease, particularly in adult men.

At the same time, the many healthful qualities of fish have been widely recognized and promoted. Fish are high in protein but low in cholesterol and fat. The abundant

Although research may still be needed for other contaminants, these results suggest that mercury levels need not be a concern for consumers.

omega-3 fatty acids they contain help control cholesterol and ward off heart disease.

The Institute of Medicine study concluded that for most people the health benefits of eating fish outweigh the risks posed by mercury and other contaminants, and most people should consume seafood regularly. However, the study recommends that children under 13 and women who are or may become pregnant avoid large predatory fish such as shark, swordfish, tilefish and king mackerel, which generally have higher mercury concentrations than other fish.

Mercury and Aquaculture

Many of the questions asked about contaminants and aquaculture have focused on Atlantic salmon (Salmo salar, technically a member of the trout family). A widely publicized study in 2004 by Ronald Hites and colleagues found that concentrations of organic contaminants, such as PCBs and dioxins, were higher in farmed Atlantic salmon than in wild Pacific salmon. However, a companion study of metals in the same fish found approximately equivalent concentrations (less than 0.1 ppm) of mercury in farmed and wild salmon.

Several studies have also looked at farm-raised paddlefish, channel catfish, rainbow trout and crayfish from aquaculture facilities in the southern United States. Mercury levels in these farm-raised fish ranged from 0.0084 ppm to 0.12 ppm, with all fish below the FDA limit of 1.0 ppm.

Despite widespread news coverage and public debate sparked by these studies, little or nothing is known about contaminant levels in farm-raised perch, walleye and other cool-water fish commonly cultured in the Great Lakes region. A recent Wisconsin Sea Grant-sponsored study on mercury in farm-raised yellow perch and rainbow trout is the only published research on contaminants in aquacultured species of the region.

In the Wisconsin study, researchers examined the sources and concentrations of mercury in facilities using three different rearing methods: flow-though, recirculation, and recirculation with hydroponics.

By the time fish were harvested, their mercury concentrations were well below health-advisory limits and the concentrations were also independent of the rearing system used. Concentrations were highest in the young fry and declined as the fish matured—a trend consistent with biodilution (meaning the fish grew faster than they accumulated mercury).

The only significant source of methylmercury to these farm-raised fish was their diet. In general, smaller food pellets had higher concentrations than larger food pellets, which is consistent with the observed growth dilution. Mercury levels in the water were also quite low, and the conversion into methylmercury was negligible—a result of standard operating procedures in which well-oxygenated conditions keep these farm-raised fish alive and hinder the growth of the anaerobic bacteria responsible for the conversion.

Overall, the results from the Wisconsin study suggest that Midwestern farm-raised yellow perch and rainbow trout should be a good choice for consumers seeking fish with low levels of mercury. Due to a continuing lack of data, however, additional research is still warranted on mercury levels in other species of Midwestern farm-raised fish and on organic contaminants in all species of Midwestern farm-raised fish.

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