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Understanding the Paradox of Mercury Pollution in China: High Concentrations in Environmental Matrix yet Low Levels in Fish on the Market

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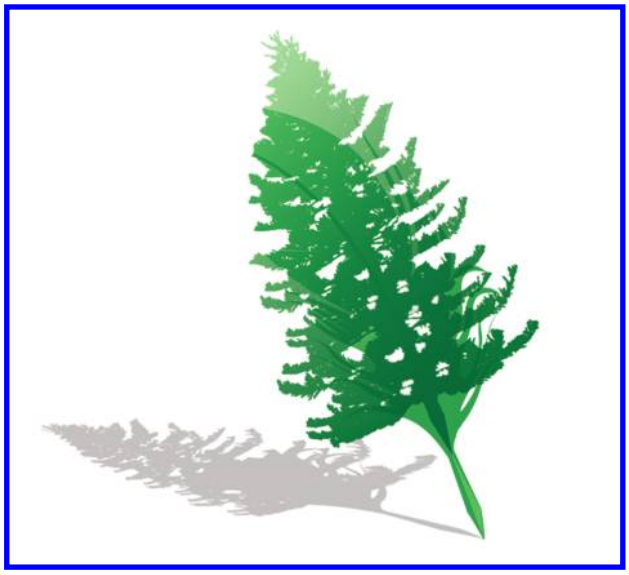

Being a persistent toxic substance, mercury, in both inorganic and organic forms, poses significant threats to public health and the environment. Mercury occurs naturally in the earth's crust and is released into the environment through both natural (e.g., volcano eruption, rock weathering, and forest fires) and anthropogenic processes (e.g., fossil fuel combustion, mining, and cement production). In particular, elemental mercury, which is highly volatile, can be redistributed globally after emissions by local, regional, and global atmospheric circulations.

As the largest developing country with fast industrial growth, China consumes about half of the global mercury supply and contributes to approximately a quarter of the total anthropogenic mercury emissions.[1] Coal combustion, metal smelting, artisanal gold mining, and cement production are the major sources of atmospheric mercury emissions in China. Mercury pollution is widespread and has occurred in various environmental compartments in China. Many sites with heavy mercury pollution have been reported, primarily caused by activities related to mercury and gold mining, metal smelting, and chemical production.[2] The atmospheric mercury levels in China are much higher than the global background level (1.5−2.0 ng/m^3) and the atmospheric mercury deposition rate is approximately three times of the global average (23−25 μg/m^2/year).[1] Because of the prevalent mercury emissions from coal combustion, mercury concentrations in the river water in northern China (0.24−5.7 μg/L) were even hundreds of times higher than those found in southern and southwestern China (0.031−0.069 μg/L).[2] It should be noted that mercury pollution has significant spatial variation because of the large geographical span of China.

Varying levels of mercury, which is mostly present in the most toxic and bioaccumulative form (72−100%), methylmercury, are found in fish. Eating fish and seafood products is an important mercury exposure route in North America and Europe, and numerous advisories on consumption of fish caught from lakes, rivers, and coastal areas have been issued, particularly for fertile women and young children.[3] Fish mercury limits in the ranges of 0.2−1.0 mg/kg for total mercury and 0.3−1.0 mg/kg for methylmercury have been established in various countries.[3] Despite the widespread mercury pollution, the mercury contents in fish from China were generally below the international marketing limit (0.5 mg/kg), with some marine fish containing higher concentrations of mercury.[2] The mercury levels in river fish from north China were generally higher than those from south China, while the opposite trend was observed for marine fish,[2] which probably resulted from the higher mercury concentrations in the rivers in the north and the more intense industrial development in the south. It has been shown that the major exposure pathway to methylmercury in population in mercury mining areas in Guizhou, China is through consumption of rice, instead of fish.[4] Overall, the human body loadings of mercury, as indicated by blood and hair mercury concentrations, were generally low, exception for the coastal populations with heavy fish consumptions in China.[2]

The generally low mercury levels in fish despite of the elevated mercury levels in environmental matrix in China pose an apparent paradox. We believe this can be explained from the fact that the fish market in China is dominated by farmed freshwater fish (Figure 1), which have lower potentials for mercury bioaccumulation. Wild freshwater fish populations have declined drastically over the past several decades due to overfishing, pollution, and habitat destruction. Fish farming, which involves stocking and rearing fish commercially in natural waters (ponds, lakes, and rivers) or artificial systems (cages, tanks, pools, and reservoirs), offers an alternative to meet the increasing market demand for fish and fish protein. Farmed fish convert feed into body tissue efficiently, and are bred to grow fast and reproduce often, in relatively small amounts of water. As a result, they are produced in larger quantities and cost less than the fish caught from wild stocks. Meanwhile, recreational

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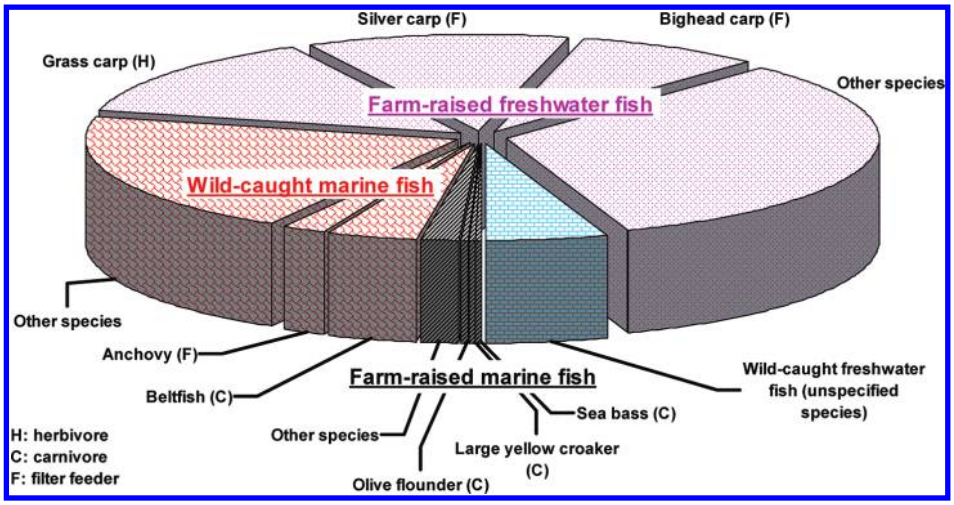

Figure 1. Breakdown of fish production (31.32 million tonnes) in China in 2010.[5] Freshwater fish, which are primarily vegetarians with low potentials for mercury bioaccumulation, account for >70% of the fish production. Marine fish on the consumer market are essentially carnivores and can have relatively high concentrations of mercury.

fishing occurs primarily in fish farms except for the remote and sparsely populated areas in China.

The bioaccumulation of methylmercury in fish is influenced by the trophic level and the age and body size of the fish. Being fat-soluble, methylmercury is efficiently absorbed by fish but is excreted very slowly, resulting in bioaccumulation of mercury during growth. Predatory fish also accumulate the mercury in the fish they eat, and the mercury concentrations in their bodies can be up to an order of magnitude higher than those of the consumed species (biomagnifications). As a result, fish that are long-lived and on the higher levels of the food chain bear elevated levels of mercury. Farmed carnivorous fish thrive on "trash fish" (less valuable fish species from the wild catch, such as anchovies) or fishmeal derived primarily from trash fish, often in combination with vegetable proteins, cereal grains, and minerals. In contrast, vegetarian fish are fed with diets consisting primarily of plant food and require only minimal amounts of fishmeal. The vast majority of fish grown in fish farms in China are vegetarians, which have much lower potential for biomagnifications of mercury than the carnivores. In addition, farmed fish are typically fast growing and short-lived, which means that growth dilution could significantly reduce the methylmercury concentrations in their bodies while they could only bioaccumulate mercury for relatively short time periods.

Sufficient land space and a continuous supply of high quality water are essential for fish farms. As a result, large-scale commercial fish farming typically occurs in rivers, lakes, reservoirs, and coastal zones located far away from the large industrial and urban centers, which reduces the fish's mercury exposure. To the consumers, healthy farmed fish raised in clean water are not only cheaper but also more desirable compared to wild fish from potentially polluted waters.

Overall, the freshwater fish in China are expected to have low mercury levels, while marine fish on the consumer market are primarily carnivores and may contain higher concentrations of mercury. To minimize the potential health risks from mercury in fish, it is necessary to develop consumption guidelines for pregnant or nursing women and young children with diets heavy in marine fish in the coastal areas.

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Notes

The authors declare no competing financial interest.

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