Mercury in fish

https://doi.org/10.1038/s43016-024-01062-2

Regional variation in fish mercury

Amina T. Schartup & C. Anela Choy

The bioaccumulation of methylmercury in fish and its biomagnification through the food chain is a major public health concern. Differences in fish methylmercury concentration observed between China and the United States highlight the need for a better understanding of region-specific factors that drive its formation and biological uptake.

CREDIT: YASSER AL-ZAYYAT/CONTRIBUTOR/AFP/GETTY

Mercury is a heavy metal with unique chemical and physical properties that have led to its use and mining by humans for thousands of years[1]. Historically, human exposure to mercury was mostly occupational: alchemists manipulated it in attempts to turn it into gold and chemists and biologists explored its bactericidal and herbicidal properties for treatment and preservation[2,3]. Empires exploited mercury's volatility and its ability to form amalgams with gold and silver to amass wealth. When these amalgams are heated, mercury is released into the air, leaving behind pure gold and silver — but also spreading the toxic metal fumes globally. In the 19th and 20th centuries, the burning of mercury-enriched coal for power generation became a major source of atmospheric mercury, which ended up deposited worldwide in inorganic form. In the late 1960s, it was discovered that some of this inorganic mercury could be converted into methylmercury — a highly neurotoxic and bioaccumulative organic mercury form — in aquatic sediments[4]. This discovery has fundamentally changed our understanding of mercury pollution and its effects on the environment and human health; it is now known that most modern mercury exposure does not come from direct occupational contact but from consuming fish containing methylmercury[5].

Writing in *Nature Food*, Xiang and colleagues[6] compiled global data on fish mercury levels, including data from China and the USA. They found compelling evidence that wild-caught freshwater fish in China have significantly lower mercury levels than similar fish in the USA. Notably, the proportion of mercury in its most toxic form, methylmercury, is below 50% in Chinese fish, compared with more than 80% in US fish. These findings suggest that the Chinese population, which also tends to consume more freshwater fish and farmed fish per capita, is generally exposed to lower levels of methylmercury from fish consumption than the US population, which is more reliant on wild-caught marine fish.

From a public health perspective, globally, prenatal exposure to methylmercury is responsible for nearly 250,000 new cases of intellectual disability each year[5]. Although mostly mild, these cases collectively result in nearly 2 million disability-adjusted life years[5]. Additional evidence indicates that dietary methylmercury exposure may be linked to cardiovascular impairments in adults[7]. This is particularly concerning given the growing global issue of micronutrient deficiencies, which increased fish consumption could help alleviate. In many countries, all micronutrient needs could be met by sustainable fish catches within 100 km of their coasts[8]. However, the increasing presence of contaminants such as mercury pose a food security concern, potentially offsetting the health benefits of fish consumption. Although many risk–benefit analyses suggest that the health advantages of fish consumption outweigh the risks of contaminant exposure[9], it remains uncertain when these thresholds might be crossed. There is a clear consensus that efforts must be made to reduce mercury and other contaminants in fish to safeguard public health[10].

On 16 August 2017, the Minamata Convention entered into force with the goal to protect human health and the environment from human mercury emissions and releases[11]. Its underlying principle is straightforward: by reducing mercury input into the environment, we can lower methylmercury levels in fish and, consequently, reduce human exposure to it. However, as Xiang and colleagues demonstrate in their study, nature is rarely that simple; despite substantially higher mercury emissions in China compared with the USA, fish methylmercury levels are actually lower in China. This raises two important questions: why is this the case, and what does it mean for future methylmercury levels in Chinese fish?

Although the role of temporal and environmental variability on fish methylmercury concentrations were not explicitly accounted for, the authors used structural equation modelling to attribute the observed differences between China and the USA to the ecological structure of Chinese ecosystems and human activities. Methylmercury is bioaccumulative, meaning that organisms absorb more of it than they can excrete, leading to increasing levels as the animal ages. Therefore, older fish tend to have higher methylmercury levels than younger fish of the same species in the same ecosystem. Methylmercury also biomagnifies through the food chain; because it is slowly eliminated, predators that consume prey higher up the trophic chain accumulate even higher concentrations of methylmercury[12]. This is why apex predators, such as sharks, orcas and humans, are at greater risk. Moreover, longer food chains and more complex food webs result in higher methylmercury levels at the top. Xiang and colleagues show that food chains in Chinese ecosystems are shorter on average, and the fish harvested are generally younger than those in the USA. This difference is attributed to factors such as faster growth rates, overfishing and changing landscapes in China due to rapid industrialization. The authors caution that environmental restoration efforts in China could inadvertently increase methylmercury levels in fish, thus raising exposure risks for consumers. However, it is important to note that the same mechanisms of accumulation and magnification that can increase methylmercury levels in fish also enhance the levels of beneficial micronutrients, whose presence or absence may have a much greater impact on human health than methylmercury[9,13].

Much of our current understanding of the mercury cycle and biological uptake of the toxic form is based on research conducted primarily in developed countries with a long history of mercury contamination and land-use changes[14]. As a result, knowledge of these processes — as well as empirical data from ecosystem compartments and fish species — is limited in the southern hemisphere and developing countries[14]. The work by Xiang and colleagues illustrates why there is a need for a region-specific understanding of the factors that drive methylmercury formation and biological uptake.

Future research, especially as we evaluate the effectiveness of the Minamata Convention, should consider the potential impacts of, and interactions with, rapid environmental and climatic changes. Additionally, it is important to recognize that economic and cultural differences in fishing practices and consumption preferences substantially influence exposure to methylmercury. Any discussion or recommendation regarding dietary exposure to methylmercury should be culturally and economically sensitive to avoid unintended harm to communities[15,16].

Amina T. Schartup & C. Anela Choy
Scripps Institution of Oceanography, Scripps Center for Oceans and Human Health, University of California San Diego, La Jolla, CA, USA.
e-mail: aschartup@ucsd.edu

Published online: 07 October 2024

References

1. Martín-Gil, J., Martín-Gil, F. J., Delibes-de-Castro, G., Zapatero-Magdaleno, P. & Sarabia-Herrero, F. J. *Experientia* **51**, 759–761 (1995).
2. Quantitative and qualitative analysis of mercury compounds in the list. *FDA* https://go.nature.com/4eBgMz3 (2018).
3. Grandjean, P., Satoh, H., Murata, K. & Eto, K. *Environ. Health Perspect.* **118**, 1137–1145 (2010).
4. Jensen, S. & Jernelov, A. *Nature* **223**, 753–754 (1969).
5. Bellinger, D. C., Devleesschauwer, B., O'Leary, K. & Gibb, H. J. *Environ. Res.* **170**, 416–421 (2019).
6. Xiang, Y. et al. *Nat. Food* https://doi.org/10.1038/s43016-024-01049-z (2024).
7. Roman, H. A. et al. *Environ. Health Perspect.* **119**, 607–614 (2011).
8. Hicks, C. C. et al. *Nature* **574**, 95–98 (2019).
9. Calder, R. S. D., Bromage, S. & Sunderland, E. M. *Environ. Res.* **168**, 496–506 (2019).
10. Kessler, R. *Environ. Health Perspect.* **121**, A304–a309 (2013).
11. *Minamata Convention on Mercury* (United Nations, 2013); https://go.nature.com/4eF366o
12. Schartup, A. T. et al. *Nature* **572**, 648–650 (2019).
13. Velichka, J. et al. *Environ. Pollut.* **336**, 122375 (2023).
14. Schneider, L. et al. *Ambio* **52**, 897–917 (2023).
15. Boyd, A. D. & Furgal, C. M. *Health Commun.* **34**, 1564–1574 (2019).
16. Calder, R. S. D. & Schartup, A. T. *GeoHealth* **7**, e2023GH000858 (2023).

Acknowledgements

A.T.S. and C.A.C. acknowledge support from the U.S. National Science Foundation and National Institute of Environmental Health Sciences grant 1P01ES035541-01.

Competing interests

The authors declare no competing interests.