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What Quantity of Fish do I need to eat to have enough Mercury for a Thermometer?

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Abstract
The presence of elevated mercury levels in ecosystems and farmed fish has been of great concern since the 1970s, due to the severe neurotoxin effects. This paper will investigate how mercury works its way up food chains into the fish we consume, why mercury levels differ between regions of water and species, and how many fish would give us enough mercury for a thermometer.

Keywords: *Health; Earth Sciences; Environmental pollution; Mercury poisoning; Fish*

Introduction

Mercury (Hg) is a toxic heavy metal present in the environment and accompanied ecosystems, known as "one of the 10 leading chemicals of concern" [1]. From large-scale poisoning epidemics, mercury has been derived as a potent neurotoxin at sufficient concentrations, with side effects being nervous system impairment i.e. tremors [2]. Approximately 80-90 % of human exposure towards mercury is through the consumption of fish, with levels of mercury present in fish varying based on the trophic level in the food chain, size and location of habitat [3]. This begs the question, how much mercury do we absorb from the fish we ingest?

Mercury bioaccumulation in food chains

Mercury enters the environment in its inorganic form (Hg^{+}/Hg^{2+}), it then undergoes methylation by anaerobic bacteria present in the water to form methylmercury (CH_3-Hg^{+}). Methyl mercury in its organic form has a high affinity towards sulphur-containing compounds such as the -SH side chain present in cysteine proteins [4]. Thus, mercury bioaccumulates in aquatic organisms as it is able to readily bind to proteins. By doing so, it works up the trophic levels of the food chain, as seen in Figure 1. Mercury levels are augmented through anthropogenic (human-based) processes of coal combustion and mining, alongside natural processes of volcanic eruptions and the degassing of Earth's crust [5].

Another contributing practice more prevalent in the past is pesticide leaching however due to successful waste management agreements in place [6], pesticide leaching is less of a concern.

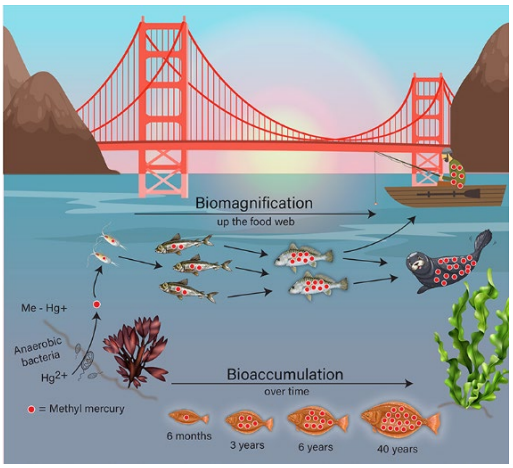

Figure 1 – Transportation of mercury [7].

Concentrations of mercury detected vary across regions of the earth as shown in Appendix A [8]. Elevated Hg levels are present in the Eastern tropic Pacific and the Southern Ocean. Research shows higher mercury levels in water sources with acidic pH values (pH < 7). Other factors such as temperature and microbial activity of the habitat also play a role [5]. Global warming has been shown to increase methyl mercury levels in fish; In tropical areas with higher water temperatures, the fish consume more due to a larger energy demand [9]. An increase of 1 ˚C

in water temperature has been shown to have a 32 % increase in CH_3-Hg in a 15 kg Cod [10].

Variation of mercury in fish species

Levels detected vary in freshwater and marine species due to their position in the food chain and the complexity of their environments [11]. Biomagnification is the accumulation of mercury through the food chain leading to predatory fish higher up in the food chain such as marine species of Tuna and Swordfish having greater levels of mercury [12]. Alongside those with a larger lifespan inevitably accumulating more mercury over time. Research undertaken for native European species has indicated higher mercury levels in marine species in comparison to freshwater [11]. This distinction may differ in water sources of other continents based on proximity to polluting sources. Another crucial element impacting variation is that freshwater habitats (e.g. rivers) are smaller and have less diverse ecosystems compared to marine habitats (e.g. oceans), therefore bioaccumulation is limited. This is seen by the lower mercury concentrations of freshwater species i.e. Trout and Catfish. Table 1 below shows differences in mercury levels of several fish species.

Species [specifications included]	Quantity of mercury [ppm]	Quantity of mercury [µg/g]	Category of level
Shark	0.979	0.979	High
Swordfish	0.995	0.995	High
Tuna [Skipjack]	0.144	0.144	Medium
Cod (Fresh/Frozen)	0.111	0.111	Medium
Trout (Freshwater)	0.071	0.071	Low
Mackerel [Atlantic]	0.050	0.050	Low
Sardine	0.013	0.013	Low

Table 1 – Varied species and mercury levels (ppm is equivalent to µg/g) [13].

Mercury in a thermometer equates to how much fish?

Despite its bad reputation as a chemical, Mercury is used in industry for cosmetics, batteries and dental amalgams [14]. The paper will focus on its use in thermometers, assuming the same form of the element is in the thermometers and the fish. Mercury-based thermometers (Figure 2) are used to detect temperature in medical settings and weather stations, with the average oral thermometer containing approximately 0.61 g of mercury [15]. Therefore, how much of different fish species must we consume to have enough mercury for a single thermometer? For cod, you will need to consume 5.5 million grams to have the required mercury amount (1). For Sharks, due to the higher mercury concentration, consumption is less at 0.62 million grams (2).

$$\left(\frac{0.61\text{g}}{(0.111 \times 10^{-6}\ \text{g})}\right) = 5.50 \times 10^{6}\text{g}\ \ (eq^{n}\ 1)$$

$$\left(\frac{0.61\ \text{g}}{(0.979 \times 10^{-6}\ \text{g})}\right) = 6.23 \times 10^{5}\ \text{g}\ (eq^{n}\ 2)$$

Figure 2 – A mercury-based thermometer [16].

With a cod approximant size of 212 g in a regular portion of cod and chips [17], dividing the 5.5 million grams required by this amount allows us to determine the 25,943 portions needed to have the mercury for a single thermometer. By having cod and chips every Friday (52 Fridays in a normal year), it would take around 499 years to consume the required mercury.

Conclusion

The paper highlights the mechanism of methylation by which mercury accumulates and notes variations of levels due to factors of pH, temperature and habitat. In associating mercury pollution with a well-known context, the paper calculates 499 years of weekly cod and chips for an individual to obtain the 0.61 g needed for a single thermometer, highlighting the present trace amounts. However, with methylmercury being detected 7,000-11,000 m deep in ocean trenches [18], the extent of this pollution is worse than we realise, and greater in-depth research is needed in the future to see the effects of such extensive pollution.

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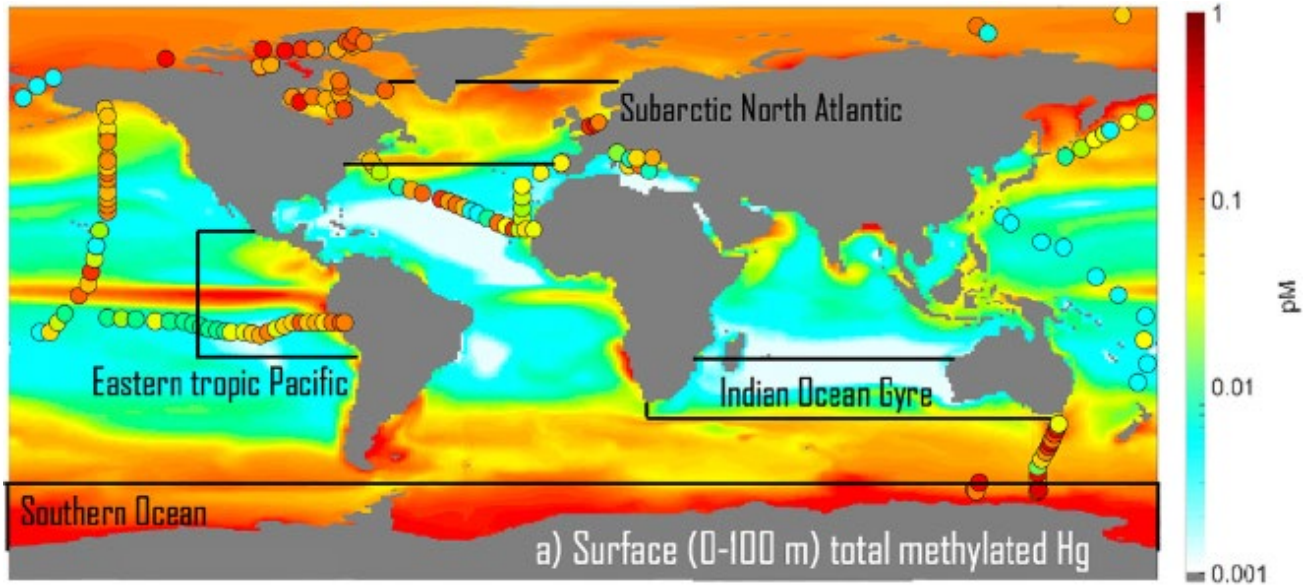
Appendix A:



Supplementary Figure 1 – Concentration of methylated mercury (pM) across the surface of the Earth [8].