Which delivers more mercury, dental amalgam or a tuna fish sandwich?

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Introduction

The debate concerning mercury (Hg) exposure from dental amalgam continues in North America (see, for example: Richardson et al., 2011; Richardson, in press). One response to this debate has been the assertion that one receives more mercury from eating a tuna fish sandwich than from dental amalgam fillings (Greger, 2012). Greger (2012) even suggests that a total of 29 amalgam-filled teeth are required to deliver the same mercury dose as eating 1 tuna fish sandwich per week. Of course, the validity of this assertion requires consideration of a number of factors and assumptions, none of which are defined or described by Greger (2012). These considerations include:

1. How much tuna fish is contained in a typical sandwich?
2. How much Hg is contained in the tuna fish being consumed?
3. How much Hg exposure occurs from a dental amalgam filling and how was this determined?

The number of amalgam fillings present will determine just how much Hg exposure arises from those fillings. It is obvious that a person with no amalgam (and thus no amalgam-related Hg exposure) will receive greater Hg exposure from eating a tuna fish sandwich. Likewise, however, a person with one or more amalgam fillings will receive more Hg from that source than from tuna fish if that person does not eat tuna fish sandwiches.

Exposure alone is only half of the risk equation. Risk is determined by comparing that exposure to the level of exposure that is deemed, for all intents and purposes, to be 'safe'. The other major issue to consider is the toxicity of the Hg in tuna (methyl Hg) versus the toxicity of the Hg in dental amalgam (Hg vapor or Hg^0). Greger (2012) fails to mention that these are two different forms of mercury with differing toxicity. Various North American environmental and health regulatory agencies provide definitions of what constitutes a reference exposure level (REL). The US Environmental Protection Agency (USEPA) uses the acronyms RfD (reference dose) and RfC (reference concentration) rather than REL. The EPA defines the RfD (and RfC) as *the estimated level of daily oral exposure (or continuous inhalation exposure) to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime*" (see USEPA's Glossary of risk assessment terms at: http://www.epa.gov/risk_assessment/glossary.htm). A detailed discussion of the derivation of RfDs is provided by USEPA (1993).

Therefore, it is essential to compare exposure to these RELs in order to ascertain the presence or absence of risk. Also, the relative risk of one chemical exposure versus another (such as Hg vapor (Hg^0) from amalgam versus methyl Hg from tuna fish) is best ascertained, not by comparing exposures, but by comparing the ratios of exposure:REL. This ratio is generally termed the hazard quotient (HQ) and is computed by dividing the exposure by the REL. The chemical substance with the highest HQ value has the highest relative risk, irrespective of the exposure levels that are encountered.

The purpose of this paper is to examine the relative exposures and the relative risks posed by Hg exposure in the US population from dental amalgam versus the exposure that arises from the consumption of tuna fish sandwiches. The issues influencing exposure, and the relative toxicity and risk of methyl Hg from tuna versus Hg^0 from amalgam, are discussed herein.

RELs for Hg^0 and methyl Hg

The toxicology of Hg^0 and methyl Hg will not be reviewed herein. This is thoroughly reviewed by the US Agency for Toxic Substances and Disease Registry (USATSDR, 1999), as well as by the US National Research Council (USNRC, 2000) and various journal reviews (see, for example: Richardson et al. 2009; Clarkson and Magos, 2006).

RELs for methyl Hg are published as a daily dose, given that exposure is as a result of food consumption, and almost exclusively due to fish and shellfish consumption. Various international environmental health agencies have published RELs for methyl Hg; these are summarized in Table 1.

Regulatory RELs for Hg^0 are presented as a reference air concentration (or synonymous term). The various published RELs for Hg^0 are summarized in Table 2. These RELs span an order of magnitude between 0.03 $\mu g/m^3$ (CalEPA, 2008) and 0.3 $\mu g/m^3$ (USEPA, 1995); various RELs from other agencies and sources fall between these 2 extremes. The REL-associated dose for Hg^0 is derived by multiplying the RfC by daily inhalation rate and then dividing by body weight to establish the daily dose associated with the airborne concentration that is deemed to be ‘safe’. Also, a further adjustment of 0.8 is applied owing to the fact that only approximately 80% of Hg^0 is absorbed when inhaled into the lungs. These absorbed REL-associated Hg doses for Hg^0 are also presented in Table 2.

Table 1: Published RELs for methyl mercury.

Agency or Author	Year of publication	Terminology	REL (µg Hg/kg-day)
USEPA	2001	Reference dose (RfD)	0.1
Health Canada	2007	Tolerable daily intake (TDI)	0.2
WHO	2003	pTDI [1]	0.23 [2]
USATSDR	1999	Minimum risk level (MRL)	0.3

1. pTDI = provisional tolerable daily intake.
2. Based on a provisional tolerable weekly intake of 1.6 µg/kg body weight per week

Table 2: Published RELs for Hg^0 and their equivalent doses.

Agency or Author	Year of publication	Terminology	REL (µg Hg^0/m^3)	REL-associated absorbed dose (µg Hg/kg-day) [1]
California EPA	2008	Chronic reference air concentration (RfC)	0.03	0.005
Richardson et al	2009	Chronic reference exposure level (REL)	0.06	0.01
Lettmeier et al	2010	Chronic reference air concentration (RfC)	0.07	0.011
US ATSDR	1999	Chronic minimal risk level (MRL)	0.2	0.032
US EPA	1995	Chronic reference air concentration (RfC)	0.3	0.048

1. Calculated as (see Richardson et al. 2011): REL (µg Hg^0/m^3)* 15.85 m^3/day * 80% Hg^0 absorbed ÷ 80 kg adult body weight. Body weight and inhalation rate from US EPA (2011); Hg^0 absorption rate after WHO (1991). Derived for adults because toxicological data underlying all RELs for Hg^0 were drawn from studies on adults.

Exposure to Hg^0 from dental amalgam

The exposure to Hg^0 from dental amalgam is dependent on the number of amalgam fillings in a person's teeth. Dose increases as the number of amalgam-restored tooth surfaces increases (Richardson et al. 2011; Richardson in press). For the US adult population with restored teeth, the average number of restored tooth surfaces is 14 (Richardson et al. 2011). Assuming that all of these fillings are composed of dental amalgam, then the average daily dose of Hg received by this amalgam-bearing population is 0.12 µg Hg/kg body weight per day, with the maximum reaching 0.39 µg/kg-day for those persons with > 65 amalgam-filled tooth surfaces (Richardson et al. 2011). From these studies, the average dose associated with a single amalgam-filled tooth surface is 0.01 µg/kg body weight per day. Greger (2012) suggests that 29 teeth completed covered with amalgam, is required to deliver a dose equivalent to that from a single tuna fish sandwich. This would amount to a total of 116 amalgam-filled tooth surfaces (16 molars that have 5 surfaces each; and 13 non-molar teeth with 4 surfaces each). 116 amalgam-filled tooth surfaces deliver an average dose of Hg^0 of 1.16 µg/kg body weight per day.

Exposure to Methyl Hg from eating tuna fish

The chronic (long term) daily dose associated with the consumption of tuna fish is a function of the following factors:

1. The average concentration of methyl Hg contained in the tuna fish;
2. The quantity (mass) of tuna fish consumed per week;

The vast majority of tuna consumed by the US population is canned tuna (Groth 2010). Recent surveys of methyl Hg levels in canned tuna are summarized in Table 3. Overall, canned light tuna has an average methyl Hg concentration of 0.12 µg Hg/g fish (or 3.4 µg Hg/oz of fish). Canned albacore (white) tuna has higher Hg levels, with an overall average of about 0.4 µg Hg/g fish (11.3 µg/oz). Fresh or frozen whole tuna, such as tuna steaks that might comprise a restaurant meal, have average methyl Hg levels that exceed those found in canned albacore (white) tuna (Groth 2010; Burger and Gochfeld, 2006; USFDA 2012). For the purposes of this article, focus is placed on consumption of canned tuna, but it should be realized that persons regularly consuming fresh tuna will have much higher methyl Hg intakes than derived here.

Table 3: Summary of recent surveys of Hg in tuna.

Reference	Canned white/ albacore tuna	Canned light tuna
	[Mean Hg] (µg/g)	[Mean Hg] (µg/g)
Mercury Policy Project (2012)	0.560	0.125 (chunk light) 0.058 (light skipjack)
Holloman & Newman (2012)	0.327	0.056
Gerstenberger et al. (2010)	0.502 (chunk white) 0.576 (solid white)	0.137
Groth (2010)	0.353	0.118
Burger & Gochfeld (2006)	0.31	0.10
Burger & Gochfeld (2004)	0.407	0.118
FDA 2006 (cited by Burger & Gochfeld 2006)	0.35	0.12
USFDA (2012)	0.350	0.128

With respect to average tuna consumption in the US, this will vary widely based on personal food preferences, income and other factors. The USEPA (http://www.fda.gov/food/foodsafety/product-specificinformation/seafood/foodbornepathogenscontaminants/methylmercury/ucm115662.htm) recommends no more than 12 oz of canned light tuna be consumed per week, whereas only 6 oz of canned albacore (white) tuna be consumed per week (either alone or in combination with up to 6 oz of light tuna). These recommendations from USEPA will be employed herein for purposes of comparative dose estimates from canned tuna consumption.

Assuming the consumption of 12 oz of canned light tuna per week, the average adult daily methyl Hg exposure will be:

$$\text{Dose} = [\text{Tuna}_{\text{Hg}}] \times M_{\text{Tuna}} / (7\ \text{days/week}) / \text{BW}$$

Where,

Dose = average daily dose of methyl Hg from eating tuna fish (µg Hg/kg bw/day);

$[\text{Tuna}_{\text{Hg}}]$ = average concentration of methyl Hg in tuna fish (µg/oz)

M_{Tuna} = mass of tuna consumed per week (oz/week)

BW = average adult body weight (80 kg).

For canned light tuna, the average daily dose is:

Dose = (3.4 μg Hg/oz × 12 oz/week) / (7 days/week) / 80 kg

= 0.073 μg Methyl Hg/kg bw/day.

Considering one meal per week of canned albacore (white) tuna, the resulting average daily dose would be:

Dose = (11.3 μg Hg/oz × 6 oz/week) / (7 days/week) / 80 kg

= 67.8 μg Hg/week] / (7 days/week) / 80 kg

= 0.12 μg Methyl Hg/kg bw/day

Considering one meal per week of canned albacore (white) tuna, combined with one meal of canned light tuna, the resulting average daily dose would be:

Dose = [(3.4 μg Hg/oz × 6 oz/week) + (11.3 μg Hg/oz × 6 oz/week)] / (7 days/week) / 80 kg

= [(20.4 + 67.8) μg Hg/week] / (7 days/week) / 80 kg

= 0.16 μg Methyl Hg/kg bw/day

Results and Discussion

Estimated exposures to Hg from dental amalgam and from tuna consumption are summarized in Table 4. Also included in Table 4 are the ratios (hazard quotients) for exposures to methyl Hg (from tuna) and Hg0 (from amalgam) divided by their respective RELs.

It is apparent from Table 4 that average Hg exposure from dental amalgam in the US population exceeds the average exposure that results from eating canned light tuna at the rate of consumption recommended by the USEPA. The dose of methyl Hg received by consumption of albacore tuna alone (6 oz/week), or in combination with light tuna (total of 12 oz/week) (both consumption scenarios considered acceptable by the USEPA) is still lower than the maximum dose of Hg received from dental amalgam fillings in the US population.

Were a person to have 29 amalgam-restored teeth, as suggested by Greger (2012), the Hg dose from that amalgam would be 1.16 μg/kg body weight per day. The equivalent dose of Hg from tuna fish would require the consumption of 32 sandwiches per week using canned light tuna, or 10 sandwiches per week using canned albacore tuna, to deliver this same Hg dose of 1.16 μg/kg body weight per day. Looking at it differently, it requires only 12 amalgam surfaces (or only about 3 amalgam-restored molar teeth) to deliver the same dose as eating just 1 sandwich per week of canned albacore tuna; and it would require just 4 amalgam-filled surfaces (or just 1 amalgam-restored molar) to deliver the same dose as eating just 1 sandwich per week of canned light tuna.

Population exposures to all forms of mercury are presented graphically in Figure 1. Even considering consumption of all fish species, including fin fish and shellfish, Hg exposure from dental amalgam is greater, on average, than from fish and shellfish consumption in the US population.

As previously mentioned, comparative risk can only be effectively achieved by comparing the hazard quotients (dose divided by respective REL), not simply comparing the doses. The HQ for average Hg exposure from dental amalgam is more than three times greater than that for routine consumption of canned light tuna (12 oz/week), and is almost 60% greater than for the exposure resulting from tuna consumption that includes the more contaminated albacore (white) tuna. The hazard quotient for the maximum amalgam-related Hg exposure reported for the amalgam-bearing US adult population is some 5 times greater than the greatest methyl Hg exposure resulting from tuna consumption at the rates recommended by the USEPA.

It is apparent that Hg exposure from canned tuna fish consumption will exceed the Hg exposure and risk from dental amalgam only in instances of high tuna intake, well beyond consumption rates recommended by the US government, in combination with low incidence of amalgam fillings, well below the national average for amalgam load.

Table 4. Population exposures and risks posed by Hg exposure from amalgam, and from canned tuna consumption.

Source	Exposure dose	REL	HQ [1]
	µg/kg bw/day	µg/kg bw/day	
Dental amalgam [2]	0.01 (1 filled surface) 0.12 (mean) 0.39 (maximum)	0.048 [3]	2.5 (mean) 8.1 (maximum)
Light tuna (12 oz/wk) [5]	0.073	0.1 [4]	0.73
Albacore tuna (6 oz/wk) [5]	0.12	0.1	1.2
Light + albacore (6 oz each/wk) [5]	0.16	0.1	1.6

1. HQ = hazard quotient = exposure dose ÷ REL dose.
2. As reported by Richardson et al. (2011)
3. REL-associated dose based on the RfC published by the USEPA (see Table 2).
4. as published by the USEPA (see Table 1).
5. Consumption rate recommended by the USEPA.

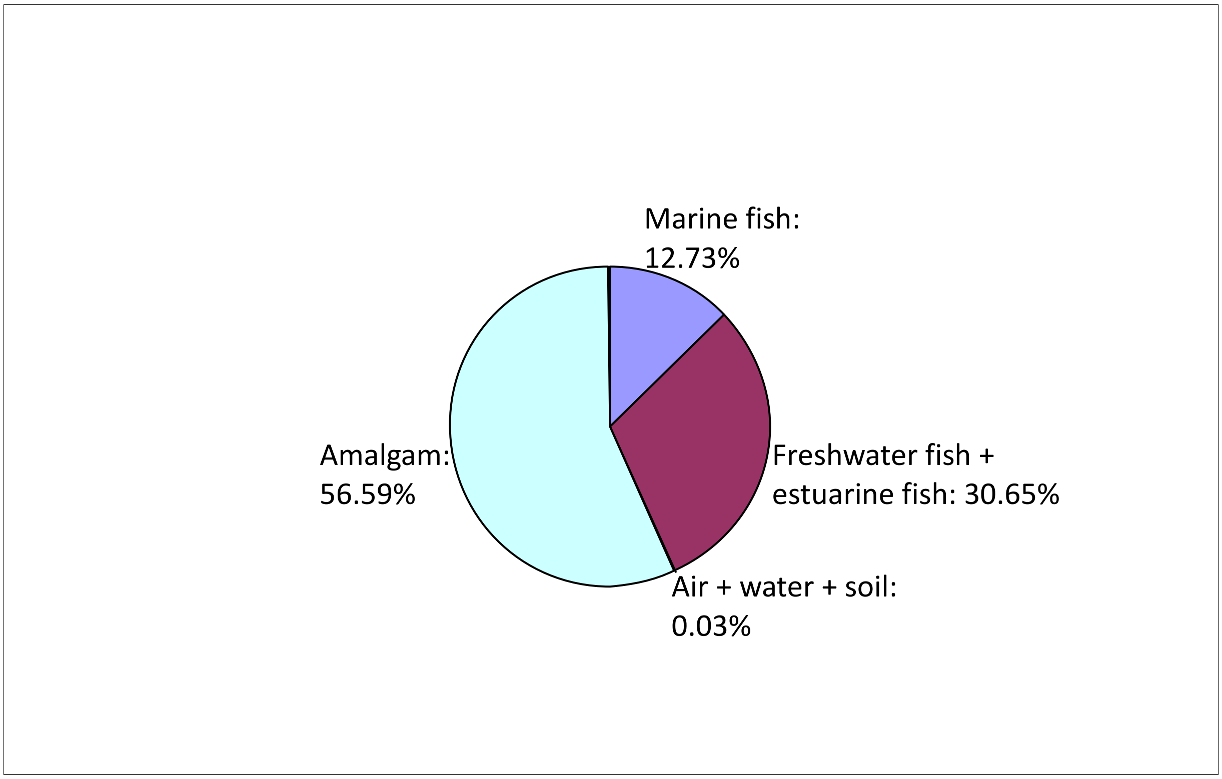

Figure 1: Relative (%) source contributions to average daily adult intake of total Hg in the US population with amalgam fillings. Amalgam intake adjusted for 80% absorption; methyl Hg intake adjusted for 100% absorption; other sources assumed 100% absorption. Amalgam data from Richardson et al. (2011). Other data from USEPA (2001). Figure from Richardson (2010).

References

Burger J and M Gochfeld. 2006. Mercury in fish available in supermarkets in Illinois: Are there regional differences. Sci Total Environ 367: 1010–1016.

Burger J and M Gochfeld. 2004. Mercury in canned tuna: white versus light and temporal variation. Environ Res 96: 239–249.

CalEPA (California Environmental Protection Agency). 2008. Mercury, inorganic — chronic reference exposure level and chronic toxicity summary. Office of Environmental Health Hazard Assessment, California EPA; 2008. Dated December 2008. Summary on line at: http://www.oehha.ca.gov/air/allrels.html.

Clarkson TW and L Magos. 2006. The toxicology of mercury and its chemical compounds. Crit Rev Toxicol, 36(8): 609-662.

Gerstenberger SL, A Martinson and JL Kramer. 2010. An evaluation of mercury concentrations in three brands of canned tuna. Environ Toxicol Chem, 29(2): 237–242.

Greger, M. 2012. Amalgam Fillings, Canned Tuna, & Mercury. Video online at: **http://www.care2.com/greenliving/amalgam-fillings-canned-tuna-mercury.html**

Groth III, E. 2010. Ranking the contributions of commercial fish and shellfish varieties to mercury exposure in the United States: Implications for risk communication. Environ Res, 110: 226–236.

Health Canada. 2007. Human Health Risk Assessment of Mercury in Fish and Health Benefits of Fish Consumption. Bureau of Chemical Safety, Food Directorate, Health Products and Food Branch, Health Canada, Ottawa, ON. Dated March 2007.

Holloman EL and MC Newman. 2012. Expanding perceptions of subsistence fish consumption: Evidence of high commercial fish consumption and dietary mercury exposure in an urban coastal community. Sci Total Environ, 416: 111-120.

Lettmeier B, Boese-O'Reilly S, Drasch G. 2010. Proposal for a revised reference concentration (RfC) for mercury vapour in adults. Sci Total Environ, 408:3530–3535.

Mercury Policy Project. 2012. Tuna Surprise: Mercury in School Lunches. Prepared by Edward Groth, PhD, for the Mercury Policy Project, Montpelier, VT. Online at: http://mercurypolicy.org/wp-content/uploads/2012/09/es915final.pdf

Richardson GM. In press. Mercury exposure and risks from dental amalgam in Canada: the Canadian Health Measures Survey 2007-2009. Human and Ecological Risk Assessment, An International Journal, DOI: 10.1080/10807039.2012.743433

Richardson GM, R Wilson, D Allard, C Purtill, S Douma and J Gravière. 2011. Mercury exposure and risks from dental amalgam in the US population, post-2000. *Science of the Total Environment,* 409: 4257-4268.

Richardson, GM, R Brecher, H Scobie, J Hamblen, K Phillips, J Samuelian and C Smith. 2009. Mercury vapour (Hg^0): Continuing toxicological uncertainties, and establishing a Canadian reference exposure level. Regulatory Toxicology and Pharmacology, 53: 32-38

Richardson, GM. 2010. Mercury Exposure and Risks from Dental Amalgam. Presented to the Dental Products Panel – Medical Devices Advisory Committee, US Food and Drug Administration, Washington, DC, December 14-15, 2010.

USATSDR (US Agency for Toxic Substances and Disease Registry). 1999. Toxicological Profile for Mercury. ATSDR, U.S. Department Of Health And Human Services, Public Health Service, Washington, DC. Dated March 1999.

USEPA (US Environmental Protection Agency). 1993. Reference Dose (RfD): Description and Use in Health Risk Assessments. Background Document 1A. Dated March 15, 1993. Available online at: http://www.epa.gov/iris/rfd.htm

USEPA (US Environmental Protection Agency). 2001. Methylmercury (MeHg) (CASRN 22967-92-6). USEPA, Integrated Risk Information System (IRIS). RfD posted 07/27/2001. Online at: http://www.epa.gov/iris/subst/0073.htm

USEPA (United States Environmental Protection Agency). 1995. Mercury, elemental (CASRN 7439-97-6). Integrated Risk Information System. Last updated June 1, 1995. On-line at: http://www.epa.gov/ncea/iris/subst/0370.htm.

USEPA (United States Environmental Protection Agency). 2001. Water Quality Criterion for the Protection of Human Health: Methylmercury – FINAL. Report EPA-823-R-01-001, Office of Science and Technology, Office of Water, US EPA, Washington, DC. Dated January 2001.

USFDA (US Food and Drug Administration). 2012. Mercury Levels in Commercial Fish and Shellfish (1990-2010). USFDA, Washington, DC. Accessed December 4, 2012. Online at: http://www.fda.gov/food/foodsafety/product-specificinformation/seafood/foodbornepathogenscontaminants/methylmercury/ucm115644.htm

USNRC (US National Reseach Council). 2000. Toxicological Effects of Methylmercury. Committee on the Toxicological Effects of Methylmercury, Board on Environmental Studies and Toxicology, National Research Council. National Academy Press, Washington, DC.

WHO (World Health Organization). 2003. Joint FAO/WHO Expert Committee on Food Additives, Sixty-first meeting 10-19 June 2003, Summary and Conclusions. Available on-line: ftp://ftp.fao.org/es/esn/jecfa/jecfa61sc.pdf