Exposure Assessment

In this guide

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Exposure from food

76.　　　The FSA Exposure Assessment Team provided dietary exposure data on mercury for women of childbearing age (16-49 yrs of age) as a proxy for the maternal diet (Table 1). Exposure to mercury was determined using data from the National Diet and Nutrition Survey (NDNS) (Bates et al., 2014, 2016, 2020; Roberts et al., 2018), and 2014 total diet survey (TDS) (FERA, 2015).

77.　　　Exposure estimates are presented as lower- and upper-bound mean and 97.5th percentile. Lower bound: concentration values below the limit of quantification (LOQ) are treated as zero. Upper bound: concentration values below the LOQ are treated as at the LOQ. The food commodities that result in the highest exposures to mercury are fish and seafoods, and non-alcoholic beverages

with mean exposure values of 0.13 and 0.07 µg/kg bw/week, and 97.5th percentile values of 0.62 and 0.17 µg/kg bw/week, respectively.

78.   Mean total exposure (combined exposure from all food groups) to mercury for women of child-bearing age ranges from 0.13-0.29 µg/kg bw/week, whilst exposure in high consumers (97.5th percentile) ranges from 0.62-0.84 µg/kg bw/week.

Table 1. Estimated exposure (in µg/kg bw/day and µg/kg bw/week) to mercury from foods consumed by women of childbearing age (16-49 years).

Food Groups	Mean - Daily exposure to mercury LB to UB (µg/kg bw/day) *	97.5th Percentile - Daily exposure to mercury LB to UB (µg/kg bw/day) *	Mean - Weekly exposure to mercury LB to UB (µg/kg bw/week) *	97.5th Percentile - Weekly exposure to mercury LB to UB (µg/kg bw/week) *
Bread	0-0.00099	0-0.0026	0-0.0069	0-0.018
Misc Cereals	0-0.0010	0-0.0029	0-0.007	0-0.020
Carcass meat	0-0.00034	0-0.0016	0-0.0024	0-0.011
Offal	0.000045	0.00075	0.00032	0.0053
Meat products	0-0.00027	0-0.0011	0-0.0019	0-0.0077
Poultry	0-0.00039	0-0.0014	0-0.0027	0-0.0098
Fish and seafood	0.018	0.089	0.13	0.62
Fats and oils	0-0.000086	0-0.00027	0-0.00060	0-0.0019

Eggs	0-0.00014	0-0.00067	0-0.00098	0-0.0047
Sugars and confectionary	0.00033	0.0013	0.0023	0.0091
Green vegetables	0-0.00028	0-0.0011	0-0.0020	0-0.0077
Potatoes	0-0.0011	0-0.0032	0-0.0077	0-0.022
Other vegetables	0-0.0013	0-0.0043	0-0.0091	0-0.030
Canned vegetables	0-0.00026	0-0.0012	0-0.0018	0-0.0084
Fresh fruit	0-0.0012	0-0.0045	0-0.0084	0-0.032
Fruit products	0-0.00038	0-0.0021	0-0.0027	0-0.015
Non-alcoholic beverages	0-0.010	0-0.024	0-0.07	0-0.17
Milk	0-0.00090	0-0.0033	0-0.0063	0-0.023
Dairy products	0-0.0004	0-0.0015	0-0.0028	0-0.011
Nuts and seeds	0-0.000043	0-0.00037	0-0.00030	0-0.0026
Alcoholic beverages	0-0.00083	0-0.0055	0-0.0058	0-0.039
Meat alternatives	0-0.000024	0-0.00029	0-0.00017	0-0.0020
Snacks	0.000055	0.00025	0.00039	0.0018

Desserts	0-0.000039	0-0.00025	0-0.00027	0-0.0018
Condiments	0-0.00010	0-0.00038	0-0.0007	0-0.0027
Tap water only	0-0.0014	0-0.0061	0-0.0098	0-0.043
Bottled water still or carbonated	0-0.00034	0-0.0028	0-0.0024	0-0.020
Total	0.019-0.041	0.089-0.12	0.13-0.29	0.62-0.84

LB= Lower-bound; UB = Upper-bound.

Exposure from drinking water

79.	The main chemical forms in which mercury occurs in water are elemental mercury, complexes of mercuric mercury with various inorganic and organic ligands, and organic mercury forms, mainly MeHg and dimethylmercury. The chemical form in which mercury occurs depends on pH, redox potential and concentration of inorganic and organic complexing agents. The contribution of MeHg to total mercury is typically less than 5 % in estuarine and marine waters but can be up to 30 % in fresh water (EFSA, 2012).

80.	Concentrations of mercury in water were provided by the Drinking Water Inspectorate for England and Wales, the Drinking Water Quality Regulator for Scotland and Northern Ireland (NI) Water. 2023 median and 97.5th percentile concentrations were provided for England and Wales. 2023 data for NI and Scotland was requested; however, NI had no results greater than the LOQ (0.041 µg/L) and Scotland had no results greater than the limit of detection (LOD) (0.02 µg/L). The LOD and LOQ were therefore used as proxies for 97.5th percentiles for Scotland and NI. For median concentrations, 2016 data from a previous COT paper were used for Scotland and NI (COT, 2018).

81.	The FSA Exposure Assessment Team provided values for water consumption for women of child-bearing age in grams (ml) of water per kg bodyweight per day. These were 8 g/kg bw/day (mean) and 32 g/kg bw/day (97.5

th percentile) using data from the 2014 TDS (FERA, 2015). Using median mercury concentration values in drinking water of 0.04, 0.03 and 0.01 µg/L for England/Wales, Scotland and NI respectively, a 97.5th percentile concentration of 0.12 for England/Wales and LOQ and LOD concentrations of 0.041 and 0.02 µg/L for NI and Scotland, respectively, the calculated exposures to mercury from drinking water are shown in Table 2.

82.　　　The estimated exposures from drinking water in England and Wales are higher than those in NI and Scotland, probably due to a denser population and a longer history of industrial activity particularly in sectors including coal burning, chlor-alkali production, metal refining and waste incineration (Environment Agency., 2021). These activities historically released into the environment mercury which can persist in soils and sediments and leach into water bodies over time. England and Wales also has more extensive environmental monitoring networks which may detect more instances of elevated mercury levels.

Table 2. Calculated mean and 97.5th percentile exposures (in µg/kg bw/day and µg/kg bw/week) for women of childbearing age to Mercury from drinking water.

Region	N (number of samples)	Median (µg/kg bw/day)*	Median (µg/kg bw/week)*	97.5th percentile (µg/kg bw/day)*	97.5th percentile (µg/kg bw/week)*
England and Wales	7944	0.00032	0.00224	0.0038	0.027
Scotland	Median 16424; LOD 585	0.00016	0.00112	0.0013L	0.0091L

| Northern Ireland | Median 395; LOQ 1782 | 0.000080 | 0.00056 | 0.00064L | 0.0045L |

* Average body weight for women of childbearing age = 70.3 kg, value provided by the FSA Exposure Assessment Team from years 1 – 11 of the rolling National Diet and Nutrition Survey, NDNS (Bates et al., 2014, Bates et al., 2016, Roberts et al., 2018). L = calculated using 2023 LOD/LOQ.

Exposure from the air

83.	Mercury is naturally emitted from land and ocean surfaces as elemental mercury. Anthropogenic sources result in the emission of elemental mercury, mercuric mercury, and particle-bound mercury. In general, elemental mercury is the predominant form of mercury in the atmosphere (EFSA, 2012).

84.	The WHO estimates that the average inhalation rate for a 70 kg adult is 20 m3/day (WHO, 2000). The Department for Environment, Food and Rural Affairs (DEFRA) UK-Air Data Selector tool was used to retrieve total mercury air concentrations and the most recent data available were from 2018 at two sites. The average air mercury concentration in London Westminster (urban background) was 2.68 ng/m3 and 15.34 ng/m3 from Runcorn Weston Point (urban industrial site).

85.	As a worst-case scenario, constant exposure of an adult female to an air mercury concentration of 15.34 ng/m3 would result in a daily exposure to 306.8 ng of mercury from the air. For women with an average body weight of 70.3 kg (value provided by the FSA Exposure Assessment Team from years 1 – 11 of the rolling National Diet and Nutrition Survey, NDNS (Bates et al., 2014, Bates et al., 2016, Roberts et al., 2018)), this gives an exposure of 4.36 ng/kg bw/day equivalent to 0.031 µg/kg bw/week.

Exposure from the soil

86.	Mercury is most commonly found in the environment in elemental form, as inorganic mercuric compounds or as monomethylmercury compounds with the general formula, CH_3HgX. Monomethylated mercury compounds are most likely to be found in soil as a result of natural microbial transformation of inorganic

mercury (Environmental Agency, 2009). In surface soils, about 1–3 % of total mercury is in the methylated form with the rest predominantly as Hg2+ compounds (Environment Agency., 2009).

87.   Mercury was measured in topsoil from England from a depth of 0-15 cm as part of a DEFRA-commissioned project (Ander et al, 2013).

88.   Table 3 shows the mercury exposures from soil for women of child-bearing age. Mean and 75th percentile mercury concentrations from soil in regions classified as principal (non-urban) and urban were used to assess potential exposures of adults through soil ingestion (Ander et al, 2013).

89.   An ingestion rate of 50 mg soil/day was assumed based on the rate used by the Environment Agency in their Contaminated Land Exposure Assessment (CLEA) model (Environment Agency., 2009) and was based on a consensus value from studies by the U.S. EPA (1997) and Otte et al. (2001). It is a combined value for soil and dust as most of the evidence used to determine the ingestion rate does not differentiate between soil and household dust. Furthermore, the evidence base for selecting a representative soil ingestion rate for adults is much smaller than that for children; the U.S. EPA (1997) has cautioned that the value is highly uncertain and based on a low level of confidence.

Table 3. Median and 75th percentile exposure values (in µg/kg bw/day and µg/kg bw/week) for women of childbearing age to mercury from soil.

Mercury Concentration and Exposure by Region

Region Type	Percentile	Soil Mercury (mg/kg)	Exposure (µg/kg bw/day)	Exposure (µg/kg bw/week)
Non-urban	Median	0.12	0.000085	0.00060
Urban	Median	0.33	0.00024	0.0017
Non-urban	75th Percentile	0.23	0.00016	0.0011
Urban	75th Percentile	0.65	0.00046	0.0032

Would you like this exported to Excel, Word, or another format? Or perhaps visualized as a chart or graph?

* Average body weight for women of childbearing age = 70.3 kg, value provided by the FSA Exposure Assessment Team from years 1 – 11 of the rolling National Diet and Nutrition Survey, NDNS (Bates *et al*., 2014, Bates *et al*., 2016, Roberts *et al*., 2018).

90.   The data presented are representative of mercury concentrations in the soil in England only.

Pica behaviour

91.   Pica behaviour is described as the craving for and intentional ingestion of substances that are not described as food. The most frequently reported pica behaviours globally are: geophagia, the consumption of earth, soil or clay; amylophagia, the consumption of starch; and pagophagia, the consumption of ice (Miao et al., 2015). Globally, Pica behaviour is thought to affect up to 28 % of pregnant women, though with a high degree of geographic variability (Fawcett et al., 2016). The majority of pica in pregnant women in the UK is geophagia; any risks posed to women of maternal age, therefore, are likely to be from contaminants present in earth, soil or clay .

92.   Geophagia primarily occurs in migrant populations from Africa and South Asia where the practice is commonplace. The soils, chalks and clays consumed by these populations are usually not of UK origin; soils are imported from regions where the practice is prevalent following rudimentary processing such as being oven-baked into blocks (Dean et al., 2004).

93.   The toxicological risk of pica to pregnant women is subject to several uncertainties. These include: the highly variable mineralogical and contaminant profile of the soil and clays consumed; the fact that soils and clays are often imported from a variety of countries, resulting in variation in composition and quality; and the reliance of studies on self-reporting of pica behaviour through questionnaires, which could lead to bias in the data and underreporting of pica potentially due to stigma associated with consuming non-food substances.

94.   In summary, pica presents a potential route of exposure to mercury from soils/clays and is a source of uncertainty in this risk assessment. Exposure to mercury through pica behaviour is not included in the exposure assessment due to the lack of data available on pica behaviour.

Exposure from food supplements

95.   The FSA has no analytical data on the presence of mercury in supplements, but the levels are regulated in the UK under Assimilated Regulation (EC) 629/2008 at a maximum level of 0.1 mg/kg.

96.   The EFSA evaluation of mercury and MeHg in food (EFSA, 2012) conducted a consumer-only exposure assessment and found that the 95th percentile dietary exposure estimations in dietary supplements consumers varied from a minimum LB of 0.00 µg/kg bw per week to a maximum UB of 0.24 µg/kg bw per week in adults. EFSA did not consider dietary supplements a major source of mercury exposure.

Aggregate exposure

97.   Aggregate exposure to mercury from food, drinking water, soil and dust, and air were derived by considering a number of scenarios based on the available data. Table 4 shows scenarios of aggregate exposure from the sources listed above and includes estimate of average and high exposure from these sources as indicated below.

98.   Average and high exposure for food and drinking water represents the mean and 97.5th percentile exposure. Data for exposure from drinking water in England and Wales were used because this represented the highest exposure compared to Scotland and Northern Ireland. The contribution from air in all scenarios is based on average inhalation rates and the average concentration from an urban industrial site in England. For exposure from soil, the average and high exposure represents the mean and 75th percentile exposure respectively for the region with the highest exposure (i.e., urban region as shown in Table 3).

Table 4. Aggregate exposure to Mercury (in µg/kg bw/day and µg/kg bw/week) from food, drinking water, soil and air*.

Scenarios	Aggregate exposure (µg/kg bw/day)	Aggregate exposure (µg/kg bw/week)
Average exposure from all sourcesa	0.045	0.315

High exposure from all sourcesb	0.13	0.91
High exposure from food and mean exposure from all other sourcesc	0.12	0.84
High exposure from drinking water and mean from other sourcesd	0.049	0.34
High exposure from soil and mean from other sourcese	0.046	0.32

a This scenario represents a summation of average exposure from food, water and soil and a value for air*.

b Exposure is based on summation of 97.5th percentile estimates for food and water, 75th percentile for urban soil and a value for air*.

c Exposure is based on summation of 97.5th percentile estimates for food and the averages for water, urban soil and a value for air*.

d Exposure is based on summation of 97.5th percentile estimates for drinking water and the averages for food, urban soil and a value for air*.

e Exposure is based on summation of 75th percentile estimate for urban soil and averages for food, water and a value for air*.

*The contribution from air in all scenarios is based on average inhalation rates and the maximum concentration identified for England and Wales.

NDNS uncertainty

90.　　　　Doubly labelled water (DLW) studies are used to measure total energy expenditure of individuals. These are carried out alongside the NDNS, and the results are compared with the reported energy intakes in the survey. This comparison shows that on average reported energy intakes are around 30% lower than the total energy expenditure. This could arise due to both individual misreporting and survey design.

91.   The NDNS is designed to be as representative as possible, but issues including days of the week sampled in the survey compared to the DLW study may have had an impact, as energy intake has been shown to be higher on weekend days. Misreporting can arise from many factors, such as memory recall bias, social desirability bias (where people consciously or sub- consciously over- or under- report some foods - for example those perceived as healthy or unhealthy) and portion size estimates.

92.   Therefore, exposure estimates are not corrected for underreporting of energy intake, as these figures are averages across population groups, and as there is no information on the degree of misreporting of specific foods. However, exposure assessments at the 97.5th percentile are undertaken to ensure that high consumers are accounted for in the assessment, including those who may have mis-reported their energy intake.