Metals

In this guide

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Heavy metals

27. Heavy metals are persistent organic pollutants that can bioaccumulate in animals and plants. For tea plants, metal content is attributed to two main routes: a) the tea processing procedure (possible contamination from processing equipment, packaging or storage materials), and b) to the acidic soils in which they are grown in. Other sources such as rainfall, atmospheric dust, pesticides and biocides, fertilisers can also contribute to the metal contamination in tea. Although some heavy metals, such as manganese, copper, zinc, and iron, play an essential role in metabolism, others, such as mercury, cadmium, lead, and arsenic, are non-essential and can cause adverse health effects, even in trace quantities (Fan et al., 2025b).

28. Shah et al., (2022) analysed the adverse effects of heavy metals in tea on pregnant mothers (n=400; n=200 non-tea drinkers and n=200 tea drinkers) and foetal outcomes. Maternal blood was analysed for the concentration of aluminium, copper, lead, cadmium, mercury and zinc, as well as iron, total iron binding capacity and ferritin. A “structured questionnaire” was used to collect data from pregnant women in personal interviews at hospital. The frequency of tea of cups (150 mL) drank by mothers in the tea drinker group was: one = 20/200, two = 41/200, three = 69/200, four = 18/200, five = 52/200.The authors observed gestational hypertension, maternal iron deficiency and maternal gestational weight gain in the tea drinking group. Higher plasma concentrations of aluminium, copper, lead, cadmium, and mercury in pregnant tea drinkers than the pregnant non-tea drinkers were also observed. The authors noted a limitation as they were unable to measure the amount of caffeine that tea drinkers consume and thus limits the connection between caffeine and preterm deliveries.

29. Colapinto et al., (2016) examined the association between tea intake during pregnancy and maternal and infant metal exposures. Data from the MIREC Study cohort were used for these analyses. Participants with a gestational age of ⩾20 weeks (n=1954) with available biomarker data for metal exposure were included. Intake of regular (black), green and herbal tea was evaluated in the first and third trimesters via a questionnaire. Women reported their frequency of consumption for each type of tea in terms of number of 6-ounce (~180 mL) cups per day, week or month.

30. Metal concentrations of lead, cadmium, arsenic, total mercury and manganese in maternal whole blood were measured in the first and third trimester visits. Cord blood concentrations of these metals were also measured. Urine analysis for speciated arsenic was conducted in the first trimester.

31. The proportions of women consuming regular, green or herbal tea during the first and third trimesters of pregnancy were described by GM of each metal in the maternal whole blood collected at these time points. Where significant differences in GM metal concentrations were observed between tea drinkers and non-tea drinkers, adjusted least squares geometric means (LSGMs), and their confidence intervals, were calculated by frequency of tea intake for each type of tea consumed.

32. In the first trimester, concentrations of all metals were above the limits of detection (LOD): lead (GM: 0.62 μg/dL) 100% of participants, mercury (GM: 2.99 nmol/L) 90% of participants; cadmium (GM 1.93 nmol/L) 97% of participants, arsenic (GM 9.75 nmol/L) 92% of participants and manganese (GM

160.1 nmol/L) 100% of participants. Adjusted LSGMs for lead in the first trimester were higher for tea drinkers than for those who were non-tea drinkers (LSGM 0.65 µg/dL, 95%CI: 0.62, 0.69 and 0.61 µg/dL, 95%CI: 0.59, 0.62), and there was evidence of a dose–response relationship for green and herbal tea. Those who consumed herbal tea in the third trimester had significantly higher third trimester maternal and cord blood lead concentrations than non-herbal tea drinkers. The authors were of the opinion that these results provided evidence of an association between blood lead concentrations and green or herbal tea consumption. However, they acknowledged that the GM blood lead concentrations of the highest tea consumers were still less than 1 µg/dL and within the normal range of blood lead concentrations in the Canadian population.

Arsenic

33. A discussion paper on the effects of arsenic in the maternal diet (TOX/2023/20) was presented to the COT in March 2023. Following this, an additional paper was presented containing information on epigenetic effects (TOX/2023/54) and the draft statement (TOX/2023/55).

34. The publication of the statement has been put on hold due to the recent assessments by EFSA and JECFA, and the need to consider which health-based guidance values to take forward for use in risk assessment.

Cadmium

35. In 2022, the COT published their statement on the potential risks from cadmium in the maternal diet (COT, 2022). Exposures considered cadmium levels that have been measured in the composite food samples of the Total Diet Study (TDS) (Bates et al., 2014, 2016; Roberts et al., 2018).

36. The food groups providing the highest cadmium exposures were miscellaneous cereals, potatoes, and bread. As stated above, high intakes of rice can occur, especially in certain groups, but there are no separate concentration data for cadmium in rice in the TDS. Although the TDS data can be used for exposure in specific sub populations (e.g. vegetarian or ethnic origin), the data sets are small and therefore not sufficiently robust to provide separate, statistically reliable exposure estimates in these sub-populations.

37. The COT concluded that “food is the main source of cadmium for non-smoking women of maternal age who have never smoked. In their assessment, breads, miscellaneous cereals and potatoes make the highest dietary

contribution. Cadmium intake via other routes such as water, soil, and dust only contribute a small amount to total exposure. Taking the total amount of exposure from the TDS, the mean percentage and 97.5th percentile when compared to the EFSA tolerable weekly intake (TWI) of 2.5 µg/kg bw per week were 22-58% and 58-100% respectively."

38. Overall, cadmium in the maternal diet does not appear to be a health concern.

Chromium

39. Chromium (Cr) is a hard, highly lustrous metal that exists in various mineral forms and is present throughout the environment. The most prevalent natural ionic form of chromium is Cr(III). Some Cr(VI) is present in the environment, largely due to industrial activity. The general population is primarily exposed to chromium via food and drinking water. The International Agency for Research on Cancer (IARC) reviewed Cr(III) and Cr(VI) and their compounds. Cr(VI) and its compounds have been classified as human carcinogens that cause cancers of the lung, and paranasal sinuses after inhalation (IARC, 2012). However, the potency of the carcinogenic effect varies with the physicochemical properties of the compound. There is no consistent evidence to suggest that Cr(III) compounds cause cancer in humans at concentrations to which people are exposed in food or the wider environment.

40. Little to no data could be found that specifically correlated the risk to health from chromium due to consumption of tea as part of the maternal diet.

41. In 2014, the FSA completed a survey of metals and other elements, this included chromium. Chromium was below the limit of detection (0.04 mg/kg) in tea (n=24) (FSA, 2014a).

42. In 2014, EFSA published a scientific opinion on the risks to public health related to the presence of chromium in food and drinking water (EFSA, 2014). The EFSA Panel on Contaminants in the Food Chain (CONTAM) considered the additional contribution to the exposure to Cr(VI) from water used to prepare certain foods including tea. A worst-case scenario assumed that there was no reduction of Cr(VI) into Cr(III) occurred when these foods were ingested immediately after their preparation. The scenario led to an increase up to two-fold in the exposure levels to Cr(IV), in comparison to those estimated via the consumption of only drinking water. However, the CONTAM Panel was not able to consider this additional contribution to the exposure to Cr(VI) when deriving

margin of exposures (MOEs) since no reliable data to quantify Cr(VI) in food exist. The Panel derived a Tolerable Daily Intake (TDI) of 300 µg Cr(III)/kg bw per day from the relevant no observed adverse effect level of 286 mg/kg bw per day identified in a long-term rat study, applying the default uncertainty factor of 100 to account for species differences and human variability, and an additional uncertainty factor 10 to account for the absence of adequate data on reproductive and developmental toxicity.

43. Guidance from the UK Health Security Agency (UKHSA), states that there is some limited evidence to suggest that Cr(VI) compounds for example potassium dichromate may be toxic to reproductive system and the unborn child. Cr(III) compounds were not considered to be harmful to the unborn child at levels not harmful to the mother (UKHSA, 2022).

Lead

44. In 2014, the FSA performed an analysis of lead levels in tea (FSA, 2014b), i.e. in samples of black (n=42) and green tea (n=9) leaves. These samples were also analysed as tea liquid (drink), after steeping the tea leaves for both a shorter (15 seconds) and a longer brew time (20 minutes).

45. Results showed that the levels of lead in dried tea varied significantly, ranging from 0.125 to 2.56 mg/kg. The highest levels were found in green tea varieties, where n=5/9 samples contained lead levels above 1 mg/kg. The levels of lead found in the brewed teas were low with half the results being less than the LOD (0.2µg/L). Teas brewed for a longer period of time resulted in only a slight increase in the level of lead. The report concluded that exposure to lead from the consumption of the analysed brewed teas was not a concern for consumer health compared to levels of exposure to lead from all dietary sources.

46. Studies by Gustin et al., (2020), Tagne-Fotso et al., (2016) and Wennberg et al., (2017) found an association between a mothers’ lead exposure increasing with increased consumption of coffee and/or tea.

47. In 2024, the COT published a statement on the effects of lead on the maternal health (COT, 2024). The FSA Exposure Assessment Team provided dietary exposure data on lead for women of childbearing age (16 – 49 years of age) as a proxy to maternal diet using data from the TDS food groups (Bates et al., 2014, 2016; Roberts et al., 2018). Tea (green and black) was included in the non-alcoholic beverages food group. The mean and 97.5th percentile exposure to lead (lower bound; LB to upper bound; UB) from this food group was 0-0.039 and

0-0.091 µg/kg bw per day, respectively.

48. The COT concluded that any risk of toxicity from lead in food is likely to be small. However, the COT acknowledged that “toxicity will depend on total exposure to lead from all sources”. As such the COT also considered aggregate exposures and concluded that “any aggregate risk of toxicity from lead in relation to the maternal diet together and other potential sources of maternal exposure is likely to be small.”

Mercury

49. In 2025, the COT published a statement on the effects of mercury on maternal health (COT, 2025). The FSA Exposure Assessment Team provided dietary exposure data on lead for women of childbearing age (16 – 49 years of age) as a proxy for maternal diet. 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 TDS (FERA, 2015).

50. Tea (green and black) was included in the non-alcoholic beverages food group. Non-alcoholic beverages resulted in a mean and 97.5th percentile exposure values of 0.07 and 0.17 µg/kg bw per week, respectively. This food category was the second highest contributor for exposure to mercury (the first was fish and seafoods).

51. The COT concluded that the high individual and aggregate exposure assessments to mercury from food, water, soil and air all estimated exposures were below the EFSA TWIs for both methylmercury and inorganic mercury. For the UK population, therefore, the risk to women of maternal age and their foetuses is low.

Trace elements

52. Trace elements such as aluminium, copper, fluoride, manganese and nickel are present in tea, as they are naturally absorbed from soil and water, with higher absorption rates in tea plants grown in acidic soil conditions. These elements can also be from anthropogenic sources (e.g. addition of pesticides, fertilisers) and have shown to influence the absorption by tea plants. The final concentration in tea is dependent on the soil, growth location, harvest time and processing (e.g. contamination from machinery) (Han et al., 2006; Rai, 2025).

53. Długaszek et al., (2025) determined the content of calcium, copper, iron, potassium, magnesium, manganese, sodium, zinc, and aluminium in infusions of black tea, including bagged and loose leaf. The amount of each element extracted from 1 g of tea was: calcium- ND (not detected)-7.23 mg, potassium- 15.1–32.3 mg, magnesium- 0.11–0.86 mg, sodium- ND-2.85 mg, and aluminium- ND- 1028 µg, copper- 1.24–11.02 µg, iron- ND-36.13 µg, manganese- 97.3–541.6, and zinc- 6.18–22.43 µg.

54. Tao and Mai (2017) determined the metal content in tea leaves (n=19; for further processing into green tea) grown in two Vietnam provinces. A total of 18 elements was determined including aluminium, calcium, potassium, magnesium, manganese, sodium, barium, iron, copper, tin, zinc, selenium, nickel, boron and heavy metal (lead, mercury, cadmium and arsenic). The results showed that potassium was present at the highest range at 12,203.49 – 21,762.47 mg/kg), followed by calcium (2,807.84 – 6,810.78 mg/kg), aluminium (237.96 – 2,454.48 mg/kg), magnesium (1,418.88 – 2,160.74 mg/kg), and manganese (409.21 – 2,149.15 mg/kg). Levels of heavy metals in most of the samples were either non detects or below the "acceptable level" as required by food law.

55. Podwika et al., (2017) investigated the concentrations of copper, manganese, zinc and cadmium in tea leaves (n=27 total; n=8 black, n=8 green) purchased from a market in Southern Poland. The mean levels of manganese, zinc, cadmium and copper in black tea were: 1,094.1, 21.8, 31.4 and 21.3 mg/kg, respectively. The mean levels of manganese, zinc, cadmium and copper in green tea were: 814.3, 21.6, 60.7 and 17.5 mg/kg, respectively.

56. Karak and Bhagat (2010) published a systematic review of the recent findings on different trace elements in tea leaves, made tea (black, green and oolong tea) and tea infusions from various non-EU countries. The range of trace elements aluminium, arsenic, cadmium, chromium, copper, iron, manganese, nickel and lead in tea infusions were 0.06 – 16.82 mg/L, trace – 1.53 µg/L, trace – 0.79 µg/L, below detectable limit (BDL) – 43.2 µg/L, 0.02 – 40.0 mg/L, 0.2 – 4.54 mg/L,– 250 mg/L and BDL – 0.16 mg/L, respectively. The authors concluded that the presence of trace elements in all analysed tea samples was within the safe limits for human consumption when comparing with health based guidance values from FAO/WHO (where available). However, they also noted that tea consumption "provides a significant additional source of trace elements" but that "toxicity of trace elements depends not only on the total amount of the metal but also on the existing species. Therefore, total element determination is not

adequate for risk assessment."

Fluorine – Fluoride

57. Fluorine is a trace element which is ubiquitous in the environment and is present at low levels in all plants and animals. Elemental fluorine is a highly reactive gas, and the ionic form, fluoride is present in food. Any references to fluorine in this section should be interpreted as fluoride i.e. since tea is a beverage/food. It was noted that the majority of information on fluoride was based on drinking water.

58. When considering drinking/tap water (typically used in tea making), fluoride is naturally present at low levels in most drinking water in England and Wales. Some drinking water is fluoridated; whereby drinking water is dosed to bring the fluoride level up to a target level of 1 mg/L as a public health measure intended to prevent tooth decay The maximum permitted level in drinking water is 1.5 mg/L. The Department of Health and Social Care is responsible for national policy on fluoridation (DHSC, 2025). The Drinking Water Inspectorate ensures that water companies comply with all drinking water regulations such that water supplies do not contain more than 1.5 mg/L of fluoride.

59. Pattaravisitsate et al., (2021) investigated the concentrations of fluoride in five different types of tea and herbal products purchased from a market in Bangkok. Teas were brewed for five minutes. The highest average concentration was detected in black tea (n=5/16) at 2.54 mg/L. The average concentration for green tea (n=3/16) was 1.19 mg/L. The concentrations of detected fluoride were inversely associated with the leaf size and the type of water (distilled ultrapure, water treated by reverse osmosis membrane system, tap, bottled and, bottled mineral) used for the brewing process.

60. Ruxton and Bond (2015) determined the fluoride content of UK retail tea and compared the levels between tea bags and infusions. The authors stated that tea provided ~70% of adult fluoride intake in the UK, with estimated daily mean tea intakes of 542 and 648 mL for all adults and older adults, respectively. Retail samples of tea bags (n=27 black; n=11 decaffeinated; n=11 speciality/single estate teas (white, green and black)). Mean fluoride/kg dry weight was 1,164 mg black blended, 877 mg speciality and 1,464 mg decaffeinated. Samples were brewed in 240 mL of boiled de-ionised water, 40 seconds later the bags were gently squeezed against the side of the beakers and removed. Infusions contained 4.91 mg/L black blended, 3.0 mg/L speciality and 7 mg/L decaffeinated equating to 0.72–1.68 mg of F- per serving.

61. Chan et al., (2013) reported a risk of high exposure to fluoride if consuming 1L/day of “UK supermarket economy black tea”, which contained levels of fluoride ranging from 3.60 to 7.96 mg/L in a two-minute brewing infusion (using deionised water).

62. Walters et al., (1983) reviewed the dietary intake of fluoride in the UK and fluoride content of some foodstuffs and noted that in some individuals fluoride intakes from tea could be as high as 8.9 mg/day. The authors estimated that tap water containing 1 mg fluoride/L could increase normal dietary intakes by 54%.

63. Sonnenburg et al., (2025) presented several scenarios which resulted in different levels of exposure to fluoride by varying the extent of oral intake of contributing sources. For tea consumption (black or green), the following serving sizes per day were used: 75 mL (0.5 cup), 150 mL (1 cup), 300 mL (2 cups), 600 mL (4 cups), and 1,200 mL (8 cups). The fluoride concentration was measured in the prepared infusions, considering the fluoride concentration in the water used for brewing. Results indicated that drinking black or green tea may result in fluoride exposure between 0.24 mg/d and 3.76 mg/d, based on a mean infusion concentration of 3.13 mg/L.

64. Kampouri et al., (2022) evaluated the impact of gestational fluoride exposure on birth outcomes (birth size and gestational age at birth). Maternal urinary fluoride (MUF) concentrations (n=558 gestational week 29, n= 463 4 months postpartum) were positively correlated with tea intake ($p = 0.001$), with the correlation of urinary fluoride being stronger with black tea ($p = 0.000$) than with green tea ($p = 0.013$).

65. Krishnankutty et al., (2021) examined maternal exposure to fluoride through tea consumption in a low-fluoride water region (Western Jutland, Denmark; fluoride range: 0.10 to 0.18 mg/L, mean 0.12 mg/L) by measuring fluoride released from commercially available teas (tea bags (n=33) and loose teas n=57)). The fluoride concentration from tea bags ranged from 0.34 to 2.67 mg/L. In loose teas the levels for black and green tea were 0.72 – 4.50 and 1.28 – 1.50 mg/L, respectively. MUF concentrations were measured in spot urine samples (n=118) from first-trimester pregnant women and in prepared tea infusions made with deionised water. MUFs from pregnant tea drinkers were higher than those with no tea consumption ($p=0.002$).

66. The UK first reviewed the safety of fluorine in 2000, based on the findings of a TDS conducted by the FSA in 1997 (FSA, 2000). The TDS collected

food samples which were analysed for the presence of halogen elements, including fluorine (COT, 2000). The highest mean fluoride concentrations were found in fish (1.9 mg/kg) and beverages (1.1 mg/kg). The high fluoride levels in fish are thought to originate mainly from the skeleton, as fluoride accumulates in the bones of fish. Some canned fish contains small bones which may result in a higher fluoride exposure if eaten whole. The fluoride content of beverages largely reflects the fluoride content of the water used in their preparation. However, tea contains higher amounts of fluoride than other beverages, as fluoride is selectively taken up from the soil by the tea plant (COT, 2003a).

67. The United States Department of Health and Human Services National Institutes of Health Office of Dietary Supplements (US NIH ODS) state that “brewed tea typically contains higher levels of fluoride than most foods, depending on the type of tea and its source, because tea plants take up fluoride from soil.” Fluoride levels can range from 0.3 to 6.5 mg/L (0.07 to 1.5 mg/cup) in brewed tea made with distilled water. Other sources of dietary fluoride were provided, and most foods not prepared with fluoridated water was described to provide less than 0.05 mg/100g (US NIH, 2025).

68. There is an upcoming piece of work for COT to review toxicity information with respect to fluoride in relation to neurotoxicity, effects on bone and effects on the thyroid, and to consider the potential risks in the context of UK exposure levels through dental products, drinking water, and other exposure sources. Tea will be considered as one of the other exposure sources. Specific evaluation of the impact of tea in the maternal diet will be made following this wider COT review.

Manganese

69. Manganese (Mn) is a silver-grey metal that is naturally present in the earth’s crust. It is found in water, soil and rocks combined with sulphur, oxygen and chlorine (UKHSA, 2024). The general public may be exposed to low levels of manganese due to its natural presence in the environment. Manganese is involved in the formation and activation of several enzymes in the human body.

70. The main exposure pathway of manganese is from dietary sources (food and drinking water). Nuts, grains, beans and tea are rich in manganese, and as such, vegetarians and tea drinkers may have higher intakes than the average person, but such levels are unlikely to cause adverse health effects (DWI, undated). The maximum concentration of manganese in UK drinking water is 50 µg/L (DWI, undated). An individual should be able to get all the manganese they

require by eating a varied and balanced diet. For the majority of the population, taking 4 mg or less of manganese from supplements a day is unlikely to cause harm (NHS, 2020).

71. Özdemir and Güçer (1998) developed a speciation scheme for the identification of manganese in tea leaves and tea infusions. The range of manganese in five different groups of tea leaves was 1,107–2205 μg/g (dry weight). It was noted that 30% of Mn (II) was passed into the water of tea infusions.

72. Extremely high manganese exposure in children may affect brain development. However, it is not known whether children are more sensitive than adults. Exposure to manganese during pregnancy is not likely to cause damage to the unborn child at doses where the mother appears unaffected (UKHSA, 2024). However, some studies suggest that higher manganese levels were associated with an increased odds ratio for maternal complications (Iqbal et al., 2020), increased the risk of preterm delivery (Bakouei et al., 2015), and were associated with the risk of preeclampsia (Liu et al., 2020).

73. The COT updated their assessment on the safety of manganese following the availability of an updated TDS conducted by the FSA in 2000 (COT, 2003b).There was insufficient information to determine whether there were toxicological risks associated with dietary exposure to manganese and the COT did not specifically consider sub-population groups such as pregnant, lactating or breastfeeding women. In their assessment on the potential risks from manganese in the diets of infants aged 0-12 months and children aged 1 to 5 years, their review included data that considered adverse neurological effects from *in utero* exposure but the COT concluded that “it was not possible to relate the adverse effects observed in humans to dietary exposures and therefore it is not possible to draw firm conclusions on the effects of current dietary exposures on the neurodevelopment of children ages 0-5 years” (COT, 2018).

74. In 2023, the EFSA Panel on Nutrition, Novel Food and Food Allergens (NDA) published a scientific opinion on the tolerable upper intake level for manganese. Based on the available human and animal studies, neurotoxicity was identified as the critical effect; however, the data were not sufficient nor suitable to characterise a dose-response relationship and identify a reference point for manganese induced neurotoxicity. EFSA noted that the main contributors to manganese intake from the background diet are grain-based products (mainly bread (and similar products), and breakfast cereals), tea and other manganese-rich beverages (e.g. hibiscus, maté infusions). High consumers of tea and other

manganese-rich beverages, or vegetarians, may have habitual intakes of manganese in the higher range of the intake distribution in the general population. For vegetarians, this ranges from 1.5 to 2.4-fold higher intakes of manganese compared to those with omnivorous diets. For tea drinkers, in a 'UK food composition database' a value of 0.14 mg manganese /100 g of tea was found. The mean intake was 5.5 mg/day (range 2–12 mg/day) or 10 mg/day (range 5–20 mg/day), whilst the mean for non-tea drinkers was 3.2 mg/day (range 0.5–6.5 mg/day). For pregnant and lactating women the 95th percentile estimated background intake of manganese from natural food sources was up to 8.27 mg/day and 8.97 mg/day in lactating women, respectively (data were based on surveys included in EFSA's intake assessment).

75. The EFSA NDA Panel utilised the estimated background dietary intakes (i.e. manganese intakes from natural dietary sources only) for the 95th percentile of consumers EFSA established a safe level of intake of 8 mg/day for adults ≥18 years (including pregnant and lactating women) and a range of 2 to 7 mg/day for other population groups.

76. In 2021, WHO performed a reassessment of the risk posed by manganese in drinking water in support for the development of WHO Guidelines for drinking-water quality (WHO, 2021). The WHO reviewed studies relating to prenatal exposures of manganese and risks to foetus health/development. Specific maternal effects were not considered. The WHO reviewed a number of epidemiological studies that have identified associations between neurotoxic effects in children and increased exposure to manganese in drinking water and established a provisional HBGV (pHBGV) of 80 µg/L for total manganese, based on "identified health considerations for bottle-fed infants." Bottle-fed infants were identified to be the most susceptible subpopulation; however, the WHO noted that the pHBGV is also applicable to the general population. In 2022, the WHO derived a TDI of 0.024 mg/kg bw by applying an uncertainty factor of 1,000 to a lowest-observed adverse effect level of 25 mg/kg bw per day identified from studies that reported neurological effects in rats exposed to manganese from birth to postnatal day 21 (WHO, 2022).