Measurement of the concentrations of metals and other elements from the 2014 UK Total Diet Study

The following technical reports will be published with the food safety information sheet. They provide further information on the analytical methods used, tabulate the analytical results and describe the sampling plan used to collect the samples.

Sampling for UK Total Diet Study HallMark Veterinary & Compliance Services.

Total Diet Study of metals and other elements in food. Report for the UK Food Standards Agency (FS102081), Fera.

Introduction

1. Metals and other elements can be present in food and studies on levels and possible effects on human health are of interest to the Food Standards Agency (FSA). Some elements, such as copper, chromium, selenium and zinc are essential to health but may be toxic at high levels. Others such as lead have no known biological function and are harmful to human health at very low levels of exposure.

2. These elements may be naturally present in the environment and can enter the food chain at any point during the growth and harvesting stages of food production through to storage and processing. Food is a major source of exposure although other exposure routes may also be important e.g. drinking water and occupational exposure. In addition, some foods tend to have relatively high concentrations of particular elements. For example, fish and shellfish are known to accumulate arsenic and mercury from the marine environment and cereals readily take up and store cadmium from the soil.

The Total Diet Study (TDS)

3. The Total Diet Study (TDS) represents the average UK diet and as such is used to estimate dietary exposure for the UK population to a range of elements present in food, to identify trends in dietary exposure levels and make assessments on the safety and/or nutritional quality of food.

4. The previous 2006 TDS comprised one hundred and nineteen food categories pooled into twenty food groups. The 2014 TDS study included nineteen additional food categories and a further eight food groups.

5. For the 2014 TDS retail samples for one hundred and thirty-eight categories of food were purchased from twenty-four Local Authority areas distributed across the UK. The food categories were classified under twenty-eight food groups.

6. The twenty-eight food groups included in the 2014 TDS study were as follows: bread, miscellaneous cereals, carcass meat, offal, meat products, poultry, fish, oils and fats, eggs, sugars and preserves, green vegetables, potatoes, other vegetables, canned or jarred vegetables, fresh fruit, fruit products, non-alcoholic beverages, milk, dairy products, nuts, alcoholic drinks, meat substitutes, snacks, non dairy desserts, sandwiches, condiments, tap water and bottled waters.

7. The food items comprising the various food categories were prepared and cooked for consumption, according to specified instructions agreed between the FSA and the analytical laboratory Fera (York).

8. The prepared samples were analysed for the following metals and elements: aluminium, antimony, total arsenic, inorganic arsenic, barium, bismuth, cadmium, chromium, copper, germanium, indium, iodine, lead, manganese, mercury, molybdenum, nickel, palladium, platinum, rhodium, ruthenium, selenium, strontium, thallium, tin and zinc.

9. The 2014 TDS measured contaminant levels in one hundred and thirty-eight food categories, to give a finer level of analysis for the exposure assessment.

10. Brand names are not reported as TDS samples are composites of foods of different types from a variety of sources.

11. Each age class had a discrete National Diet and Nutrition Survey (NDNS) data set. The age classes for the 2014 TDS comprised: toddlers (1.5 to 3 years), young people (4 to 10 years), (11 to 18 years) and adults (19 years and above). Unlike previous TDS the over 64 years (free living and institutional) age class was not included in the 2014 TDS because the consumption data was taken from the NDNS Rolling Programme[1] which did not include this age group. Therefore, the scope of the NDNS consumption data differed for the 2006 and 2014 TDS surveys.

[1] National Diet and Nutrition Survey Rolling Programme https://www.gov.uk/government/collections/national-diet-and-nutrition-survey#archive-ndns-reports

Methodology
Sampling

12. The sampling method is documented in the contractor's report[2]. The 2014 TDS comprised one hundred and thirty-eight food categories. Each category consisting of food items sampled from twenty-four different UK towns, giving a total of three thousand three hundred and twelve samples. The one hundred and thirty-eight food categories were pooled into twenty-eight food groups. The meat substitutes, sandwiches, tap water and bottled waters food groups each contained a single food category. The proportion of each food category making up the corresponding food group composite sample, is shown in Annex 2 of the contractor's report[3].

13. The food items for the various food categories were prepared and cooked according to specified instructions agreed between the FSA and the analytical laboratory Fera (York).

Analysis

14. Further details of the analytical method and quality procedures used in the study can be found in the contractor's technical report[4]. The multi-element analysis was carried out using inductively coupled plasma-mass spectrometry (ICP-MS). All analytical methods used in the survey were UKAS accredited (IS017025). To minimise background contamination, deionised water, analytical grade reagents and acid cleaned plastic ware were used throughout. The technical report includes a detailed description of the analytical methodology, including the specific methods for iodine and inorganic arsenic.

15. Quality control procedures were employed throughout the analytical investigation with each batch containing a minimum of three procedural blanks, a spiked sample (for recovery estimate purposes) and reference materials (both certified and in-house).

Results

16. The element concentrations for each food group are reported in Table 5 of the contractor's technical report.

17. The analytical results for the food categories corresponding to each food group are presented in Tables 6 - 29 of the technical report.

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[2] Final Report UK Total Diet Study FS102081 Dec 2014, HallMark Veterinary & Compliance Services

[3] Total Diet Study of metals and other elements in food, Report for the UK Food Standards Agency (FS102081), Fera

[4] Total Diet Study of metals and other elements in food. Report for the UK Food Standards Agency (FS102081)

18. A summary for each element providing context to its occurrence in food together with the food groups which featured the highest occurrence levels, is provided below.

Aluminium

19. Aluminium is the most common metal in the Earth's crust and has many industrial uses as well as domestic applications and is used extensively to make cooking and food storage utensils and in food packaging (e.g. aluminium foil). Aluminium compounds have been used historically as food additives.

20. The highest concentrations of aluminium were detected in the dairy products (8.59 mg/kg), bread (4.01 mg/kg), snacks (3.97 mg/kg), miscellaneous cereals (3.67 mg/kg) and sugars and preserves (3.55 mg/kg) food groups. The highest concentration in the 2006 TDS was 17.5 mg/kg recorded in the miscellaneous cereals food group.

Arsenic

21. Arsenic is present in rocks and sediments. It also occurs due to human activities such as coal burning, copper smelting and processing of mineral ores. It is found in soil, marine and fresh water environments, and in almost all plant and animal tissues. Arsenic levels are highest in the aquatic environment.

22. The toxicity of arsenic is dependent on its chemical form. Most arsenic in the diet is the less toxic organic species. Inorganic arsenic is the more toxic form. Arsenic occurs in a wide range of foods but is predominantly found in fish and fish products. More than 97% of the total arsenic in fish is the organic form.

23. The TDS considered both total arsenic (sum of inorganic and organic species) and inorganic arsenic with results presented for each.

24. The highest concentration of total arsenic was detected in the fish food group (2.0 mg/kg), with low levels being measured in snacks (0.011 mg/kg), condiments (0.011 mg/kg) and sandwiches (0.038 mg/kg). Levels in the remaining food groups were below the Limit of detection (LOD) or Limit of quantification (LOQ) for the analytical method. The highest concentration in the 2006 TDS was 3.99 mg/kg also detected in the fish food group.

25. Inorganic arsenic levels were below the LOD or LOQ for all food groups tested in the 2014 TDS. Levels were also below the LOD or LOQ in the 2006 TDS.

Barium and strontium

26. Barium and strontium belong to the same family of metals as calcium and have widespread domestic and medicinal applications.

27. Barium was detected in all food groups with the highest levels found in the nuts (2.53 mg/kg) and miscellaneous cereals (0.88 mg/kg) food groups.

28. Strontium was detected in most foods with the highest concentrations found in the nuts (5.41 mg/kg), meat substitutes (3.37 mg/kg), bread (3.26 mg/kg), sandwiches (2.83 mg/kg), miscellaneous cereals (1.74 mg/kg) and other vegetables (1.46 mg/kg) food groups.

29. The highest concentrations of barium and strontium in the 2014 TDS were lower than those recorded in the 2006 TDS. Barium was measured at 2.53 mg/kg (2014 TDS) compared with 131 mg/kg for the nuts food group (2006 TDS). The nuts food group had the highest concentration of strontium at 5.41 mg/kg (2014 TDS) compared to 15.7 mg/kg in the earlier TDS.

Cadmium

30. Cadmium is present in the environment due to intensive agricultural practices and historic mining activity. A major use of cadmium is in nickel cadmium dry cell batteries and the metal is also used in the car industry.

31. The highest cadmium concentrations were recorded in the offal (0.067 mg/kg) and snacks (0.059 mg/kg) food groups. Cadmium levels were low or below the LOD for the remaining food groups in the 2014 survey. Similar cadmium levels were measured in the 2006 TDS with the highest concentrations found in the offal (0.084 mg/kg) and nuts (0.065 mg/kg) food groups.

Chromium

32. Chromium is widely distributed in the Earth crust and has many industrial uses. The metal commonly exists in trivalent and hexavalent states. Trivalent chromium is essential to human life and plays an important role in carbohydrate, lipid and protein metabolism. Chromium (VI) is mostly man made with a very small proportion present naturally in the environment.

33. The highest concentration (0.12 mg/kg) was measured in the miscellaneous cereals food group. Chromium levels were low or below the LOD for the remaining food groups of the 2014 TDS. The highest concentration in the 2006 TDS was 0.08 mg/kg measured in the sugar and preserves food group.

Copper

34. Copper has been mined since ancient times and its ores are widely distributed throughout the world. Copper and its alloys are used in domestic, pharmaceutical, industrial and agricultural applications. Copper is an essential element for health with the diet being the major source of exposure.

35. The offal and nuts food groups had the highest concentrations of copper (23.2 mg/kg) and (10.1 mg/kg) respectively. The offal food group also recorded the highest concentration in the 2006 TDS with a level of 52.5 mg/kg. The nuts food group had a similar concentration of 9.15 mg/kg compared to the 2014 TDS result.

Antimony, bismuth and germanium

36. Antimony and bismuth belong to the same family as arsenic in the periodic table. Antimony is used in alloys and in fireproofing materials, paint, glazes and pigments. Bismuth is also used in alloys and paints as well as in some pharmaceutical and cosmetic products. Germanium, which belongs to the same group as tin and lead, has been used extensively in electronic and optical devices. Germanium is present in trace amounts in a wide range of foods including beans, tomato juice, oysters, tuna and garlic.

37. Antimony was detected at low levels the highest concentration being (0.0092 mg/kg) in the condiments group. The highest concentration in the 2006 TDS was 0.0099 mg/kg measured in the meat products group.

38. Bismuth was below the LOD or LOQ for most food groups tested. The highest concentration (0.014 mg/kg) was measured in the dairy products group. The highest concentration (0.0064 mg/kg) in the 2006 TDS was also measured in the dairy products group.

39. Germanium levels were below the LOD for all food groups tested in both the 2014 and 2006 TDS.

Iodine

40. The highest iodine concentrations were detected in the fish (0.811 mg/kg), eggs (0.378 mg/kg), milk (0.263 mg/kg), dairy products (0.242 mg/kg) and desserts (0.158 mg/kg) food groups. The 2006 TDS did not include iodine.

Lead

41. Lead is widely distributed in the environment due to mining and other anthropogenic activities with the diet being an important source of exposure in the UK.

42. Lead was detected at low levels or below the LOD in the food groups tested. The highest concentration in the 2014 TDS was 0.042 mg/kg measured in the offal group. For the 2006 TDS the offal group also had the highest concentration at 0.065 mg/kg.

Manganese

43. Manganese occurs both naturally in the environment and as a contaminant of soils, sediments and water. It is an essential element and is present in most foods, particularly green vegetables.

44. The highest concentrations in the 2014 TDS were measured in the meat substitutes (18.3 mg/kg), nuts (17.9 mg/kg), bread (7.79 mg/kg) and miscellaneous cereals (6.79 mg/kg) food groups. The highest concentrations in the 2006 TDS were in the nuts (24.9 mg/kg) and bread food groups (8.01 mg/kg).

Mercury

45. Exposure to mercury is mainly from the diet and dental amalgam. Mercury can exist as both inorganic and organic species in food, with the organic form methylmercury being more toxic. In the 2014 TDS total mercury was measured (sum of inorganic mercury and methylmercury).

46. Mercury was detected at low levels or below the LOD. The highest concentration was 0.0497 mg/kg measured in the fish group. For the 2006 TDS the highest concentration of mercury was also detected in the fish group (0.056 mg/kg).

Molybdenum

47. Molybdenum is a relatively rare element and an essential constituent of several enzymes required for health.

48. The highest concentrations of molybdenum were measured in the nuts (0.915 mg/kg), miscellaneous cereals (0.218 mg/kg) and bread (0.208 mg/kg) food groups. The nuts food group also had the highest concentration (1.26 mg/kg) followed by the offal group (1.10 mg/kg) in the 2006 TDS.

Nickel

49. Nickel has various industrial applications and is used in the manufacture of batteries, alloys and jewellery. Nickel is present in most foods albeit at low levels.

50. For the 2014 TDS nickel was detected in the nuts (2.14 mg/kg) and poultry (0.29 mg/kg) food groups with low levels detected in the remaining groups. The nuts food group also had the highest concentration in the 2006 TDS with a level of 3.02 mg/kg.

Palladium

51. Palladium was below the LOD in all food groups except the sandwiches group (0.002 mg/kg). For the 2006 TDS levels were also low with the highest

concentrations being 0.0019 mg/kg in the nuts and 0.0018 mg/kg in the dairy products food groups.

Platinum, rhodium and ruthenium

52. Platinum, rhodium and ruthenium were below the LOD in all food groups. The levels in the 2006 TDS were also below the LOD except for the ‘other vegetables’ and ‘canned vegetables’ groups which had very low levels of ruthenium (0.0002 mg/kg).

Selenium

53. Selenium is used in the electronic, pharmaceutical and agricultural industries. It plays an important role in some enzymes and is essential for human health.

54. The offal (0.59 mg/kg) and fish (0.29 mg/kg) food groups had the highest concentrations of selenium. Levels were low or below the LOD for the remaining food groups. The 2006 TDS also recorded the highest concentrations of selenium in the offal (0.77 mg/kg) and fish (0.42 mg/kg) food groups.

Indium and thallium

55. Indium and thallium belong to the same group as aluminium in the periodic table. They are used in semi-conductors, LCD (liquid crystal display), alloys, pigments and dyes.

56. Indium and thallium levels were below the LOD or LOQ for all food groups tested in the 2014 TDS. For the 2006 TDS the highest concentration of indium was 0.096 mg/kg in the canned vegetables food group and for thallium 0.0028 mg/kg in the poultry food group.

Tin

57. Tin has been used to make utensils since ancient times with bronze and pewter being well known alloys of tin used to make dishes and other culinary equipment. Tin cans have been used for canning food for nearly 200 years. Tin cans are made from steel sheets with a coating of tin to prevent rusting.

58. For the 2014 TDS the highest concentration of tin was measured in the canned or jarred vegetables group (30.1 mg/kg) with lower levels detected in the fruit products (6.16 mg/kg) and miscellaneous cereals groups (1.26 mg/kg). The highest concentrations of tin in the 2006 TDS were also in the canned vegetables (36.1 mg/kg) and fruit products (11.1 mg/kg) food groups.

Zinc

59. Zinc is an essential element for human health and is present in plants and animals. Highest concentrations were reported for the carcass meat (39.2

mg/kg), offal (36.7 mg/kg), meat substitutes (34.1 mg/kg) nuts (33.4 mg/kg), meat products (19.7 mg/kg), poultry (11.2 mg/kg), sandwiches (10.6 mg/kg), bread (10.3 mg/kg), snacks (8.83 mg/kg) and miscellaneous cereals (8.27 mg/kg) food groups. The highest concentrations of zinc in the 2006 TDS were measured in the carcass meat (64.8 mg/kg), offal (46.5 mg/kg) and nuts (31.0 mg/kg) food groups.

Exposure Assessment

60. The 2014 metals and other elements TDS occurrence data were used to estimate dietary exposure. The consumption data were taken from the National Diet and Nutrition Survey Rolling Programme (NDNS) (Bates et al 2014).

Risk Assessment

61. The risk assessment for each element has been carried out using the dietary exposure estimates for children aged 1.5 to 3 years. This age group had the highest exposures, compared to other age groups, for every element analysed. The risk assessments for this age group will therefore be conservative for all other populations included in the TDS.

Metals and other elements essential to human health

Antimony

62. The highest total mean and 97.5th percentile exposures were in the age class 1.5 to 3 years and were 0.031 – 0.073 µg/kg bw/day and 0.065 – 0.12 µg/kg bw/day, respectively. The highest contributing food group to total mean exposure was the ‘Milk’ group with a total mean exposure of 0.0098 µg/kg bw/day.

63. The current estimates of mean and 97.5th percentile dietary exposures to antimony are well below the World Health Organisation (WHO) TDI of 6 µg/kg bw (WHO, 2003). The current estimated dietary exposures did not indicate excessive antimony intake and are not of toxicological concern.

Copper

64. The highest total mean and 97.5th percentile exposures were in the 1.5 to 3 years age class and were 36 µg/kg bw/day and 59 µg/kg bw/day, respectively. The highest contributing food group to total mean exposure was the ‘miscellaneous cereals’ group with a mean exposure of 2.5 µg/kg bw/day.

65. The current estimates of mean and 97.5th percentile dietary exposure to copper are below all the available health-based guidance values (HBGV)[5].

66. The current estimated dietary exposures did not indicate excessive copper intake and are not of toxicological concern.

Iodine

67. The highest total mean and 97.5th percentile exposures were in the 1.5 to 3 years age class and were 9.2 µg/kg bw/day and 20 µg/kg bw/day, respectively. The highest contributing food group to total mean exposure was the 'milk' group with a mean exposure of 5.2 µg/kg bw/day.

68. The current estimates of mean and 97.5th percentile dietary exposures to iodine are below or marginally greater than (~ 20%) the Scientific Committee on Food (SCF) Upper Level (UL) of 200 µg/day for 1 - 3 year olds (SCF,2002), equivalent to 16.7 µg/kg bw/day.

69. The current estimated dietary exposures did not indicate excessive iodine intake and are not of toxicological concern.

Manganese

70. The highest total mean and 97.5th percentile exposures were in the 1.5 to 3 years age class and were 160 µg/kg bw/day and 270 µg/kg bw/day, respectively. The highest contributing food group to total mean exposure was the 'non-alcoholic beverages' group with a mean exposure of 43 µg/kg bw/day.

71. The Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT) reviewed the data from the FSA 2014 Infant Metals Survey and as part of this, considered that the way in which the currently available health based guidance value (HBGV)[6] for manganese had been derived was not sufficiently robust for the risk characterisation of dietary exposure. The Committee is due to revisit the issue of manganese HBGVs and exposures in this age group in a statement at a later date.

Molybdenum

72. The highest total mean and 97.5th percentile exposures were in the 1.5 to 3 years age class and were 4.5 – 4.6 µg/kg bw/day and 7.6 – 7.7 µg/kg bw/day,

[5] Joint FAO/WHO Expert Committee on Food Additives (JECFA) provisional maximum TDI of 50 – 500 µg/kg bw (FAO/WHO, 1982a); The Expert Group on Vitamins and Minerals (EVM) safe upper level (SUL) of 160 µg/kg bw/day (EVM, 2003); and The Scientific Committee on Food (SCF) upper level (UL) of 1000 µg/day for 1-3 year olds (equivalent to 83 µg/kg bw/day (SCF, 2003a).

[6] The EVM considered that 12.2 mg/day (equivalent to 1.22 mg/kg bw/day for infants aged 4 to 18 months would not result in adverse health effects (EVM, 2003); The WHO derived a TDI of 60 µg/kg bw (WHO, 2004).

respectively. The highest contributing food group to total mean exposure was the 'miscellaneous cereals' group with a mean exposure of 1.4 μg/kg bw/day.

73. There is no HBGV for molybdenum against which to compare exposures. The COT evaluated the 2006 metals survey (COT, 2008) and concluded that the exposures to molybdenum were unlikely to be of toxicological concern. Mean exposure is at a similar level to that calculated for the 2006 metals survey (approximately 4 μg/kg bw/day, based on a 60 kg adult). Exposure at the 97.5th percentile was not mentioned previously but is 167% of the calculated mean exposure.

74. The current estimated dietary exposures did not indicate excessive molybdenum intake and are unlikely to be of toxicological concern.

Selenium

75. The highest total mean and 97.5th percentile exposures were in the 1.5 to 3 years age class and were 1.3 – 2.9 μg/kg bw/day and 2.5 – 4.9 μg/kg bw/day, respectively. The highest contributing food group to total mean exposure was the 'fish' group with a mean exposure of 0.27 μg/kg bw/day.

76. The current estimates of mean and 97.5th percentile dietary exposures to selenium were below the Expert Group on Vitamins and Minerals (EVM) and SCF's upper levels of 7.5 μg/kg bw/day (EVM, 2003), and 60 μg/kg bw/day for 1-3 year olds (SCF, 2000), respectively.

77. The current estimated dietary exposures do not indicate excessive selenium intake and are not of toxicological concern.

Zinc

78. The highest total mean and 97.5th percentile exposures were in the 1.5 to 3 years age class and were 320 μg/kg bw/day and 530 μg/kg bw/day, respectively. The highest contributing food groups to total mean exposure were the 'miscellaneous cereals' and 'dairy products' groups with a mean exposure of 51 μg/kg bw/day.

79. The current estimate of mean dietary exposure to zinc was below all the available HBGVs. The current estimate of 97.5th percentile dietary exposure was approximately 10% greater than the SCF UL, equivalent to 580 μg/kg bw/day for 1 - 3 year olds (bodyweight of 12 kg) (SCF, 2003b). However, these exposures were below the Joint FAO/WHO Expert Committee on Food Additives (JECFA) provisional maximum tolerable daily intake (PMTDI) of 0.3 – 1.0 mg/kg bw/day (FAO/WHO, 1982b) and the EVM SUL of 25 mg/day (equivalent to 2500 μg/kg bw/day for a 10 kg infant) (EVM, 2003).

80. The current estimated dietary exposures did not indicate excessive zinc intake and are not of toxicological concern.

Metals and other elements non-essential to human health

Aluminium

81. The highest total mean and 97.5th percentile exposures were in the 1.5 to 3 years age class and were 100 µg/kg bw/day and 170 µg/kg bw/day, respectively. The highest contributing food group to total mean exposure was the 'non-alcoholic beverages' group with a mean exposure of 27 µg/kg bw/day.

82. The current estimates of mean and 97.5th percentile dietary exposure to aluminium were well below the JECFA provisional tolerable weekly intake of 2000 µg/kg bw (equivalent to 286 µg/kg bw/day) (FAO/WHO, 2012). The current estimated dietary exposures are not of toxicological concern.

Arsenic (total and inorganic)

83. For total arsenic, the highest total mean and 97.5th percentile exposures were in the 1.5 to 3 years age class and were 1.9 – 2.2 µg/kg bw/day and 7.1 – 7.4 µg/kg bw/day, respectively. The highest contributing food group to total mean exposure was the 'fish' group with a mean exposure of 1.8 µg/kg bw/day.

84. The highest total mean and 97.5th percentile exposures to inorganic arsenic were in the 1.5 to 3 years age class and were 0.13 – 0.68 µg/kg bw/day and 0.28 – 1.1 µg/kg bw/day, respectively. The highest contributing food group to total mean exposure was the 'miscellaneous cereals' group with a mean exposure of 0.081 µg/kg bw/day.

85. The inorganic form of arsenic is carcinogenic and of most concern to health. Using the JECFA benchmark dose modelling ($BMDL_{05}$) of 3.0 µg/kg bw/day (FAO/WHO, 2011), the inorganic arsenic range of mean exposures generates Margins of Exposure (MOEs) of 23 – 4.4. For total high-level exposures MOEs of 11 – 2.7 were calculated. For values greater than 10, these exposures would be considered low concern but for those less than 10 there could be a small risk to consumers. Therefore, for both mean and 97.5th percentile consumers there could be a small risk to health.

Cadmium

86. The highest total mean and 97.5th percentile exposures were in the 1.5 to 3 years age class and were 0.32 – 0.54 µg/kg bw/day (2.24 – 3.78 µg/kg bw/week) and 0.54 – 0.85 µg/kg bw/day (3.78 – 5.95 µg/kg bw/week), respectively. The highest contributing food group to total mean exposure was the 'miscellaneous cereals' group with a mean exposure of 0.099 µg/kg bw/day.

87. Although the European Food Safety Authority (EFSA) tolerable weekly intake (TWI) of cadmium was exceeded by toddlers in some cases, these exceedances were small in magnitude (140% maximum) and would not be expected to remain at this level over the decades of bio-accumulative exposure considered by EFSA in setting the HBGV. These levels are not a major cause for concern.

Chromium

88. No speciation was performed as part of the current survey, therefore the dietary exposure presented is for total chromium which is assumed to be Cr (III).

89. The highest total mean and 97.5th percentile exposures were in the 1.5 to 3 years age class and were 1.6 – 3.1 µg/kg bw/day and 3.0 – 5.2 µg/kg bw/day, respectively. The highest contributing food group to total mean exposure was the ‘miscellaneous cereals’ group with a mean exposure of 0.74 µg/kg bw/day.

90. The current estimates of mean and 97.5th percentile dietary exposure to chromium are well below the EFSA TDI for Cr (III) of 0.3 mg/kg bw (EFSA, 2014). The current estimated dietary exposures are not of toxicological concern.

Lead

91. The highest total mean and 97.5th percentile exposures to lead were in the 1.5 to 3 years age class and were 0.15 – 0.28 µg/kg bw/day and 0.25 – 0.46 µg/kg bw/day, respectively. The highest contributing food group to total mean exposure was the ‘milk’ group with a mean exposure of 0 – 0.039 µg/kg bw/day.

92. EFSA calculated that the $BMDL_{01}$ for lead, derived from blood levels associated with a decrease of 1 intelligence quotient (IQ) point, corresponded to a dietary intake of 0.5 µg/kg bw/day (EFSA, 2010). The range of mean exposures for lead generates margins of exposure between 0.5 µg/kg bw/day and the calculated exposures, of 3.3 – 1.8. For total 97.5th percentile exposures, MOEs of 2 – 1.1 were calculated. MOE values of 10 or greater should be sufficient to ensure that there is no appreciable risk of a clinically significant effect on IQ. At lower doses, but greater than 1 it can be taken to imply that at most, any risk from the diet is likely to be small in relation to that from background sources. It should be noted that food is not the only source of exposure to lead in this age group; other potentially important sources of exposure include water and soil. Any risks posed by the current estimated dietary exposures to lead were small.

Mercury

93. In their assessment EFSA regarded total mercury as inorganic mercury for all food categories apart from ‘fish and other seafood’. The mean and high-level total dietary exposure estimates, including ‘fish and other seafood’ were below

the EFSA TWI of 4 µg/kg bw for inorganic mercury. The exposure calculated for the ‘fish food group is below the methylmercury TWI of 1.3 µg/kg bw (EFSA, 2012).

94. The current estimated dietary exposures are not of toxicological concern.

Nickel

95. The highest total mean and 97.5th percentile nickel exposures were in the 1.5 to 3 years age class and were 4.4 – 5.2 µg/kg bw/day and 7.1 – 8.1 µg/kg bw/day, respectively. The highest contributing food group to total mean exposure was the ‘miscellaneous cereals’ group with a mean exposure of 1.1 µg/kg bw/day.

96. All mean and 97.5th percentile exposures for children less than 10 were below the toddler-specific TDI of 20 µg/kg bw/day (Haber *et al.*, 2017). For adolescents and adults aged over 11 years, the mean exposures were below the EFSA TDI of 2.8 µg/kg bw/day, but 97.5th percentile exposures ranged from 1.1- to 1.5 - fold the EFSA TDI (EFSA, 2015).

97. The current average and high level chronic dietary exposure estimates to nickel are unlikely to be of concern for UK infants and young children. Although high-level exposures for adolescents and adults aged over 11 years exceeded the TDI established by EFSA it is unlikely that they will be of toxicological concern.

98. The current estimated dietary exposures do not indicate excessive nickel intake and are unlikely to be of toxicological concern.

Barium

99. The highest total mean and 97.5th percentile exposures were in the 1.5 to 3 years age class and were 20 µg/kg bw/day and 33 µg/kg bw/day, respectively. The highest contributing food group to total mean exposure was the ‘miscellaneous cereals’ group with a mean exposure of 5.5 µg/kg bw/day.

100. The mean exposure estimate was equal to the WHO TDI of 20 µg/kg bw for barium (WHO, 2001) and although the 97.5th percentile dietary exposure was up to 165% of the TDI it is unlikely that there would be a concern. The TDI represents the estimated maximum exposure over a lifetime without appreciable risk to health. The period of time for which the barium exposures exceed the TDI is relatively short.

101. The current estimated dietary exposures are unlikely to be of toxicological concern.

Bismuth

102. The highest total mean and 97.5th percentile exposures were in the 1.5 to 3 years age class and were 0.10 – 0.19 µg/kg bw/day and 0.33 – 0.43 µg/kg bw/day, respectively. The highest contributing food group to total mean exposure was the ‘dairy products’ group with a mean exposure of 0.085 µg/kg bw/day.

103. There is no HBGV for bismuth against which to compare exposures. The COT evaluated the 2006 metals survey (COT, 2008) and concluded that the exposures to bismuth were unlikely to be of toxicological concern. Mean exposures are up to approximately 2-fold those calculated for pre-school children (1.5 – 4.5 years) in the 2006 metals survey (approximately 0.086 – 0.10 µg/kg bw/day). Current 97.5th percentile exposures are also approximately 2-fold higher than those (0.20 – 0.22 µg/kg bw/day) of the similar age group in the 2006 TDS. However, the bodyweights used to calculate exposures for children aged 1.5 – 4.5 years in the 2006 TDS would have been higher than those used to calculate exposures for children aged 1.5 to 3 years. This would lead to higher exposures being calculated for children aged 1.5 – 3 years. It is therefore likely that there is less than a 2-fold difference between exposures from 2006 and 2014.

104. The current estimated dietary exposures to bismuth are unlikely to be of toxicological concern.

Germanium

105. The highest total mean and 97.5th percentile exposures were in the 1.5 to 3 years age class and were 0.0002 – 0.10 µg/kg bw/day and 0.0023 – 0.17 µg/kg bw/day, respectively. The highest contributing food groups to total mean exposure were the ‘meat substitutes’ and ‘nuts’ groups, each with a mean exposure of 0.00010 µg/kg bw/day.

106. There is no HBGV for germanium against which to compare exposures. The COT evaluated the 2006 metals survey (COT, 2008) and concluded that the exposures to germanium were unlikely to be of toxicological concern. The upper bound (UB) mean exposures are approximately double those calculated for pre-school children (1.5 – 4.5 years) in the 2006 metals survey (approximately 0.002 – 0.053 µg/kg bw/day). Current UB 97.5th percentile exposures are also approximately 2-fold those of the 2006 TDS (0.006 – 0.085 µg/kg bw/day). However, the bodyweights used to calculate exposures for children aged 1.5 – 4.5 years in the 2006 TDS would have been higher than those used to calculate exposures for children aged 1.5 to 3 years. This would lead to higher exposures being calculated for children aged 1.5 – 3 years. It is therefore likely that there is less than a 2-fold difference between exposures from 2006 and 2014.

107. The current estimated dietary exposures for germanium are unlikely to be of toxicological concern.

Indium

108. The highest total mean and 97.5th percentile exposures were in the 1.5 to 3 years age class and were 0.0014 – 0.052 µg/kg bw/day and 0.0059 – 0.086 µg/kg bw/day, respectively. The highest contributing food group to total mean exposure was the ‘canned vegetables’ group with a mean exposure of 0.00040 µg/kg bw/day.

109. There is no HBGV for indium against which to compare exposures. The COT evaluated the 2006 metals survey (COT, 2008) and concluded that although there is uncertainty, the sparse data available did not suggest that the indium dietary exposures were a cause for concern. UB mean exposures are less than 10% of those calculated for pre-school children (1.5 – 4.5 years) in the 2006 metals survey (approximately 0.24 – 0.75 µg/kg bw/day). Current UB 97.5th percentile exposures are approximately 5 - 10% of those of the similar age group (0.93 – 1.48 µg/kg bw/day). The current estimated dietary exposures are not of toxicological concern.

Palladium

110. The highest total mean and 97.5th percentile exposures were in the 1.5 to 3 years age class and were 0.01 – 0.11 µg/kg bw/day and 0.042 – 0.18 µg/kg bw/day, respectively. The highest contributing food group to total mean exposure was the ‘tap water’ group with a mean exposure of 0.0045 µg/kg bw/day.

111. There is no HBGV for palladium against which to compare exposures. The COT evaluated the 2006 metals survey (COT, 2008) and concluded that there was “no reason to believe that current dietary intakes of palladium would pose a risk to human health”. Mean exposures from the 2014 survey are approximately 4-fold those calculated for pre-school children (1.5 – 4.5 years) in the 2006 metals survey (0.027 µg/kg bw/day). Current 97.5th percentile exposures are approximately 3-fold those of the similar age group (0.055 – 0.056 µg/kg bw/day). This increase in exposure could be due to differences in the age range and therefore bodyweight of toddlers considered in 2006 (1.5 to 4.5 years) and 2014 (1.5 to 3 years). Additionally, there were differences in the number of food groups in 2006 (20 groups) and 2014 (28 groups). Palladium levels were not detected in the vast majority of food groups and any calculated exposures are based on the LOD rather than detected levels.

112. The main group contributing to total exposure in the 2014 TDS is tap water. Potential exposure from tap water in 2006 may have been masked by the presence of tap water in the same beverages food group as soft drinks, resulting in a dilution of any contribution from this source. The current estimated dietary exposures are unlikely to be of toxicological concern.

Platinum

113. The highest total mean and 97.5th percentile exposures to platinum were in the 1.5 to 3 years age group and were 0 – 0.10 µg/kg bw/day and 0 – 0.17 µg/kg bw/day, respectively. It is not possible to know which food groups are contributing to total mean exposure as there were no measured values for platinum and all exposures are calculated based on zero for the LB and the LOD for the UB.

114. The COT (2008) used a no observed adverse effect level (NOAEL) of 13 mg/kg bw/day to calculate MOEs for platinum. They concluded that the MOE of 100000 between the NOAEL and the 2006 TDS dietary platinum exposures were of low concern. The range of mean exposures for platinum generates MOEs of at least 130000. For total high-level exposures MOEs of at least 76000 were calculated. However, the maximum exposures calculated for the 2014 TDS are based on the LOD and not measured values. It is therefore likely that these are conservative. In addition, the bodyweights used to calculate exposures for children aged 1.5 – 4.5 years in the 2006 TDS would have been higher than those used to calculate exposures for children aged 1.5 to 3 years in the 2014 TDS. This would lead to higher exposures being calculated for children aged 1.5 – 3 years and the corresponding MOE values would be lower. Therefore, the MOE values calculated for platinum indicate a low concern for human health.

115. The current estimated dietary exposures to platinum are not of toxicological concern.

Rhodium

116. The highest total mean and 97.5th percentile exposures were in the 1.5 to 3 years age group and were 0 – 0.051 µg/kg bw/day and 0 – 0.086 µg/kg bw/day, respectively. It is not possible to know which food groups are contributing to total mean exposures as there were no measured values for rhodium and all exposures are calculated based on zero for the LB and the LOD for the UB.

117. There is no HBGV for rhodium against which to compare exposures. The COT evaluated the 2006 metals survey (COT, 2008) and concluded that “the very low dietary exposures to rhodium did not suggest a reason for concern”. Mean exposures from the 2014 survey are approximately 62% of those calculated for pre-school children (1.5 – 4.5 years) in the 2006 metals survey (0 – 0.082 µg/kg

bw/day). Current 97.5th percentile exposures are approximately 66% of those of the similar age group (0 – 0.13 µg/kg bw/day).

118. The current estimated dietary exposures do not suggest a reason for toxicological concern.

Ruthenium

119. The highest total mean and 97.5th percentile exposures were in the 1.5 to 3 years age group and were 0 – 0.10 µg/kg bw/day and 0 – 0.17 µg/kg bw/day, respectively. Because the total mean lower bound exposure to ruthenium is zero, we cannot say which food groups are contributing to total exposure.

120. There is no HBGV for ruthenium against which to compare exposures. The COT evaluated the 2006 metals survey (COT, 2008) and concluded that "the very low dietary exposures to ruthenium did not suggest a reason for concern". Mean exposures from the 2014 survey are approximately 350 % of those calculated for pre-school children (1.5 – 4.5 years) in the 2006 metals survey (0.0008 – 0.029 µg/kg bw/day). Current 97.5th percentile exposures are approximately 360% of those of the similar age group (0.0022 – 0.047 µg/kg bw/day).

121. However, ruthenium was not detected in any of the food groups and thus any calculated exposures are based on LODs rather than 'detected' levels in food. As with palladium, the bodyweights of the 1.5 to 3 year old toddlers' used in the 2014 calculations will be lower than those of the 1.5 – 4.5 year olds used in the 2006 assessment resulting in higher calculated exposures for the 2014 TDS. There are also differences in the number of food groups between 2006 and 2014.

122. The current estimated dietary exposures to ruthenium are unlikely to pose a risk to human health.

Strontium

123. The highest total mean and 97.5th percentile exposures were in the 1.5 to 3 years age class and were 61 µg/kg bw/day and 98 µg/kg bw/day, respectively. The highest contributing food groups to total mean exposure were the 'bread' and 'miscellaneous cereals' groups each with a mean exposure of 11 µg/kg bw/day.

124. The COT (2008) used a margin of exposure approach compared to a therapeutic dose of 1700 mg/day (equivalent to 28 mg/kg bw/day for a 60 kg adult) for strontium. The MOE between this therapeutic dose and the highest exposure level in the 2006 TDS was 400 and the COT concluded that "current dietary exposures to strontium were unlikely to be of toxicological concern" (COT, 2008). Using this therapeutic value and the mean exposure for strontium an MOE of 460 was generated. For the total 97.5th percentile exposure an MOE of

286 was calculated. The mean MOE value is higher than that calculated for the dietary exposures for the 2006 TDS and indicates a lower concern for human health. The MOE calculated for 97.5th percentile consumers was lower than 400. However, the bodyweights used to calculate exposures for children aged 1.5 – 4.5 years in the 2006 TDS would have been higher than those used to calculate exposures for children aged 1.5 to 3 years. This would lead to higher exposures being calculated for children aged 1.5 – 3 years and correspondingly, a lower MOE value.

125. The current estimated dietary exposures to strontium are unlikely to be of toxicological concern.

Thallium

126. The highest total mean and 97.5th percentile exposures were in the 1.5 to 3 years age group and were 0.021 – 0.22 µg/kg bw/day and 0.073 – 0.36 µg/kg bw/day, respectively. The highest contributing food group to total mean exposure was the ‘sugar’ group with a mean exposure of 0.015 µg/kg bw/day.

127. The COT (2008) used a margin of exposure approach to assess the risk associated with dietary intake of thallium. It was noted that the WHO had estimated that the daily oral intake of 10 µg/day (equivalent to 0.17 µg/kg bw/day for a 60 kg adult) corresponded to a urinary thallium concentration of 5 µg/L, above which the magnitude of the risk and severity of adverse effects was uncertain. When compared to the highest dietary exposure for thallium, of 0.046 µg/kg bw/day (high level intake by children aged 1.5 – 4.5 years) calculated in the 2006 TDS, the MOE was approximately 4. The Committee concluded that “current dietary exposures to thallium were unlikely to be of toxicological concern”.

128. The range of mean exposures calculated for thallium in the 2014 TDS generated MOEs of 0.77 - 8 when compared to the therapeutic dose. For total high-level exposures MOEs of 0.47 - 2.3 were calculated. However, the bodyweights used to calculate exposures for children aged 1.5 – 4.5 years in the 2006 TDS would have been higher than those used to calculate exposures for children aged 1.5 to 3 years. This would lead to higher exposures being calculated for children aged 1.5 – 3 years.

129. The intakes appear higher than in 2006, but some may be due to methodological issues, however we cannot exclude that the MOEs are inadequate. Given that this exceedance is for only a portion of life and given the uncertainties, the current estimated dietary exposures to thallium are unlikely to be of toxicological concern.

Tin

130. The highest total mean and 97.5th percentile exposures were in the 1.5 to 3 years age class and were 95 - 96 µg/kg bw/day and 300 µg/kg bw/day, respectively. The highest contributing food group to total mean exposure was the ‘canned vegetables’ group with a mean exposure of 61 µg/kg bw/day.

131. Overall, the total mean exposure estimate to tin was well below the EVM guidance level of 220 µg/kg bw/day (EVM, 2003), and would therefore not be of toxicological concern. Although the total 97.5th percentile estimate was approximately 40% above the EVM guidance level, this is a relatively minor exceedance and would be unlikely to result in adverse effects. The current estimated dietary exposures are not of toxicological concern.

Discussion

132. The risk assessments were based on the estimated dietary exposures calculated for the 1.5 to 3 years age group. Toddlers and young children’s energy requirements and food consumption are on average higher relative to their body weight than older children and adults. This means that they can have a relatively higher dietary exposure to chemicals in food compared to other age groups, when expressed on a body weight basis. Therefore, the risk assessments are cautious in terms of the risk to health for the general population because dietary exposures will be lower for the older age groups.

133. The contribution of the food groups to dietary exposure varied with the age groups considered in the TDS. Food groups identified in the risk assessment as the largest contributors to dietary exposure are based on the toddlers and young children 1.5 to 3 years age group.

134. Dietary exposure to lead was compared to the reference point set by EFSA of 0.5 µg/kg bw/day. This reference level represents a deficit in neurodevelopment, measured as a decrease in IQ of 1 point at the population level. There is strong evidence to suggest that lead can impair intelligence (as measured by IQ).

135. The Margin of Exposure (MOE) is a measure of how close to the reference point the estimated exposure value is. Risk assessors consider a MOE greater than 1 for lead to not be of concern for health. The lead dietary exposures in this survey had a MOE greater than 1.

136. However, when considering total lead exposure from all sources such as the important contribution from soil and dust, there may be a small risk to health. People are exposed to lead through food, drinking water, air, soil and dust. Food and water are the major sources of exposure, although in toddlers and young children, ingestion of soil and dust can also be an important source of lead exposure.

137. The toxicity of arsenic is dependent on its chemical form. It is generally accepted that inorganic arsenic is more toxic than the arsenic compounds that are commonly found in seafood and other marine organisms.

138. Dietary exposure to inorganic arsenic was compared to the reference point set by JECFA of 3 µg/kg bw/day. The COT concluded that dietary exposure to inorganic arsenic with a MOE of 10 or more would not be a health concern. A MOE of less than 10 was calculated, within the range of dietary exposures to inorganic arsenic calculated for the 1.5 to 3 years age class. Therefore, for some individuals in this age class there may be a small risk to health from dietary exposure to inorganic arsenic.

139. Dietary exposure to cadmium was compared to the TWI set by EFSA of 2.5 µg/kg bw. The range of dietary exposures for the 1.5 to 3 years age group exceeded the tolerable weekly intake (TWI) by a small margin. However, the TWI of 2.5 µg/kg bw is based on 50 years of bioaccumulation of cadmium in the body and exposures are highest for the 1.5 to 3 years age group when expressed on a body weight basis compared to the older age groups. Therefore, dietary exposure would not be expected to remain at this level over the decades of bio-accumulative exposure considered by EFSA when setting the HBGV. Dietary exposure to cadmium is not considered to be a major cause for concern.

Conclusion

140. The lead dietary exposures for toddlers and young children were such that any risks posed would be small. However, when considering total lead exposure from all sources there may be a small risk to health for the 1.5 to 3 years age group. The ingestion of soil and dust can be an important source of lead exposure for this age group, although this route of exposure is outside the scope of the TDS.

141. Dietary exposure to inorganic arsenic was compared to the reference point set by JECFA of 3 µg/kg bw/day. For some individuals of the 1.5 to 3 years age group there could be a small risk to health.

142. The range of cadmium dietary exposures calculated for the 1.5 to 3 years age group exceeded the EFSA TWI of 2.5 µg/kg bw for cadmium. However, the

HBGV was set in the context of 50 years of bio-accumulation of cadmium in the body. The dietary exposures of toddlers and young children can be higher than older age groups when expressed on a body weight basis and cadmium dietary exposure would not be expected to remain at this level over the decades of bio-accumulative exposure considered by EFSA in setting the HBGV.

143. Dietary exposures for the remaining elements analysed in the study did not pose a health concern. An updated risk assessment for manganese will be published on the COT website in due course.

Summary of units

Microgram (µg): one thousandth of a milligram (mg)

Milligram (mg): one thousandth of a gram

Kilogram (kg): one thousand grams

Micrograms per kilogram (µg/kg)

Micrograms per kilogram body weight per day (µg/kg bw/day)

Glossary

Limit of detection (LoD)

The lowest concentration at which the analyte can be reliably detected by a particular measurement procedure.

Limit of quantification (LoQ)

The lowest concentration of an analyte that can be determined with acceptable precision and accuracy under the stated conditions of the test.

Lower bound exposure (LB)

The measure of exposure based on a concentration where the analytical result is below the limit of detection and is assumed to have a value of zero.

Upper bound exposure (UB)

The measure of exposure based on a concentration where the analytical result is below the limit of detection and is assumed to have a value equal to the limit of detection or where the analytical result is above the limit of detection but below the limit of quantification is assumed to have a value equal to the limit of quantification.

Upper Level (UL)
The upper level is not a recommended intake level but is the maximum level that can be consumed daily with no appreciable adverse effects to human health.

Health based guidance value (HBGV)

A value derived by dividing a point of departure (a no observed-adverse-effect level (NOAEL), benchmark dose (BMD) or benchmark dose lower confidence limit (BMDL)) by an uncertainty factor to determine a level that can be ingested over a defined time period with no appreciable risk to human health.

Benchmark dose (BMD)

A dose or concentration of a substance that produces a predetermined change in the response rate of an adverse effect. This predetermined change in response is called the benchmark response (BMR). Normally the BMR is for a 5 or 10% change relative to the control group response.

Benchmark dose lower confidence limit (BMDL)

The lower boundary of the confidence interval on the benchmark dose. The BMDL accounts for the uncertainty in the estimate of the dose–response, due to characteristics of the experimental design. The BMDL can be used as the point of departure for derivation of a health-based guidance value or a margin of exposure.

Margin of exposure (MOE)

Ratio of the no observed adverse effect level (NOAEL) or benchmark dose lower confidence limit (BMDL) for the critical effect to the estimated exposure concentration.

No-observed-adverse-effect level (NOAEL)

The highest concentration of a substance, found by experiment or observation, that causes no adverse effects on morphology, functional capacity, growth, development or lifespan of the target organism compared to those of the control organisms.

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