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MEASUREMENT OF THE CONCENTRATIONS OF METALS AND OTHER ELEMENTS FROM THE 2006 UK TOTAL DIET STUDY

Summary

The concentrations of 24 elements including metals in the 2006 UK Total Diet Study (TDS) are reported. Composite samples for the 20 TDS food groups (bread, fish, fruit etc) were collected from 24 UK towns and analysed for their levels of aluminium, antimony, arsenic, barium, bismuth, cadmium, chromium, copper, germanium, indium, lead, manganese, mercury, molybdenum, nickel, palladium, platinum, rhodium, ruthenium, selenium, strontium, thallium, tin and zinc. The results from this survey have been used to estimate dietary exposures to these elements for UK consumers and provide up to date information on their concentrations in foods. Through comparisons with previous TDSs any trends in exposure to these elements in the typical UK diet have been established and the main dietary sources that contribute to these exposure levels have been identified.

The key findings of this survey are:

- The concentrations of each of the elements in the food groups were lower than or similar to those reported in the previous TDS, conducted in 2000, with the exception of aluminium, barium and manganese.
- Population exposures to the elements have generally declined over the course of the TDS programme, and exposures to most of these elements remain at these low levels.
- The Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT) evaluated the results of this survey. They did not identify specific concerns for the health of consumers, but noted a need for more information on aluminium and barium. The COT also stressed that efforts should continue to reduce dietary exposure to inorganic arsenic and to lead.

Background

A number of metals and other elements are present in food and studies on the levels at which they are found and their possible effect on human health is of interest to the Agency. Some elements, such as copper, chromium, selenium and zinc are essential to health but may be toxic at high levels of exposure. Other elements have no known beneficial biological function and long-term, high-level exposures may be harmful to health.

Environmental sources are the main contributors to contamination of food with most metals and other elements. Some elements (e.g. arsenic) are present naturally but the major sources of other elements (e.g. lead) in the environment are because of pollution from industrial and other human activities. The presence of metals and other elements in food can also be the result of contamination by certain agricultural practices (e.g. cadmium from phosphate fertilisers), manufacturing and packaging processes (e.g. aluminium and tin in canned foods). The platinum group metals (which are used in catalytic converters in all new vehicles in the UK since 1993) could contaminate food crops from the emissions of vehicles.

Metals and other elements may enter the food chain at any point during growth and harvesting, through to storage and processing. Food is a major contributor to consumers' overall exposure to metals and other elements, although other routes may also be significant (for example, oral exposure via the drinking water, inhalation exposure via the occupational setting). Furthermore, certain food groups naturally accumulate some elements and consequently contain high concentrations of these elements compared to other foods. For example, fish and shellfish are known to accumulate arsenic and mercury and cereals can accumulate cadmium.

The Total Diet Study (TDS)

The Total Diet Study (TDS) is a continuous market basket-type survey in which foods representing the average UK diet (based on Defra's Expenditure and Food Survey[1] and trade statistics) are purchased, prepared and combined into groups of similar foods for analysis. The TDS has been run on a continuous annual basis since 1966 and has been used as a part of the UK monitoring programme for chemicals in food. It allows the Agency to estimate the general UK population's average exposure to non-nutrients (ie contaminants such as heavy metals, dioxins and pesticides), as well as intakes of some nutrients. Used in conjunction with the Expenditure and Food survey, the TDS has enabled trends over time to be established and assessments on the safety and quality of the food supply to be made.

Food samples representative of the UK diet are purchased throughout the year in 24 towns covering the UK and 119 categories of foods are combined into 20 groups of similar foods (e.g. Bread, Poultry, Milk etc) for analysis. The relative proportion of each food category within a group reflects its importance in the average UK household diet. Foods are grouped so that commodities known to be susceptible to contamination (e.g. offal, fish) are kept separate, as are foods which are consumed in large quantities (e.g. bread, potatoes, milk)[2, 3]. The quantities and relative proportions of each food that make up the total diet are largely based on data from the Expenditure and Food Survey[1] and are updated annually to reflect changing eating habits in the UK. The estimated average weight of food eaten is given in Table 1.

The foods making up the 20 groups were bought from retail outlets in 24 randomly selected towns throughout the UK in the TDS for 2006. The food samples were prepared and cooked according to normal consumer practice. Equal quantities of samples from each town were mixed for each food group to obtain the national composite samples. The composite samples of each food group were homogenised and frozen. Samples were then analysed for a range of metals. The element concentrations for each food group were used together with data on the consumption of these food groups to estimate dietary exposure for both the average UK population and the mean and high level consumer.

Brand names

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

Methodology

Sample preparation

Samples were prepared and cooked (where necessary) according to normal domestic practice. After preparation, constituents of each food group were homogenised and stored frozen at –20^{o}C until required for analysis. The 2006 TDS samples were prepared by the Laboratory of the Government Chemist (LGC).

Analysis

Analyses were carried out by the Central Science Laboratory, York (CSL). UKAS (United Kingdom Accreditation Service) validated methods were used to analyse 20 composite samples provided from the 2006 TDS.

0.5 - 3.0 grams of the samples were digested with a concentrated nitric/hydrochloric acid mixture in a sealed quartz microwave digestion system. The concentrations of metals and other elements in the various food groups were then determined using inductively coupled plasma mass spectrometry (ICP-MS) and high resolution inductively coupled plasma mass spectrometry (HR-ICP-MS). Samples were analysed in batches containing reagent blanks, both spiked reagent blanks and spiked samples (for recovery estimate purposes) plus four certified reference materials.

Analysis of Inorganic Arsenic: The inorganic form of arsenic was separated from the organic form by dissolving the samples in hydrochloric acid, followed by reacting with hydrobromic acid and hydrazinium sulphate and then extracting into chloroform. This was followed by back-extraction into hydrochloric acid and the samples were analysed by ICP-MS and HR-ICP-MS.

Quality Control

Quality control checks were used for instrument stability and spike recovery by using reference material data and replicate agreement. The limits of detection (LODs) achieved are shown in Table 2.

Additional information on methods and quality control criteria used can be found in more detail in the contractor's final report[4].

Results

A summary of the concentrations of metals and other elements in each food group is given in Table 3. Using these values, dietary exposures for the average UK population were estimated. Two kinds of dietary exposures were estimated: consumer exposures and population exposure estimates.

Consumer exposure estimates

Consumption data from the National Diet and Nutrition Survey (NDNS)[5,6] were used to estimate dietary exposures for individuals in the general population who eat average amounts of each food group (i.e. mean consumers) and those who eat significantly more than average amounts (i.e. 97.5th percentile consumers). Total consumer dietary exposures are derived from an average of the individual consumer's exposure patterns with regard to individual foods.

Dietary exposures to the 24 elements from the TDS were estimated for average and high level consumers under the following categories: adults (16 - 64 years), toddlers (1.5 - 4.5 years), young people (4 - 18 years), elderly (over 64 years, free living and institutional) and self-described vegetarians (including some who consume fish) using consumption data from the relevant NDNS[5,6]. Consumer dietary exposures are expressed on a microgram per kilogram body weight per day basis and are summarised in Tables 4a to 4d. Results are expressed as lower bound and upper bound concentrations; that is, where individual sample analyses were less than the limit of detection, the result is expressed as zero (lower bound), or as equal to the limit of detection (upper bound) and the exposure calculated accordingly. Where only one value is shown, this is either because all samples contained concentrations above the LOD (therefore the upper and lower bound mean values are equal) or because the difference between them is negligible.

The estimated dietary exposures for toddlers were in general higher than those for other age groups due to their proportionally higher food consumption on a bodyweight basis. A comparison of intakes by adults, toddlers and young people calculated from the 1997 and 2000 survey results is shown in Tables 5a and 5b.

Population exposure estimates

These can be used to follow trends in exposure as they take into account changes in both consumption of the various foods making up the UK diet and the concentrations of elements in these foods. Population dietary exposures have been estimated by multiplying the amounts of food consumed (based on consumption data from the Expenditure and Food Survey[1] as shown in Table 1) by the corresponding upper and lower bound elemental concentrations in each food group. Comparisons of population dietary exposure for each element from the UK TDS from 1976 to 2000 are given in Tables 6a and 6b (only upper bound means have been consistently recorded in previous years). Population dietary exposures are expressed on a milligram per person per day basis. The percentage contribution to the population exposure by each food group is shown in Tables 7a and 7b.

Dietary Exposures and Risk Assessment

The dietary exposure to metals and other elements can be used to assess the safety of foods consumed. The risk to health is assessed by comparing the estimated dietary exposure with recommended safe guideline levels such as Provisional Tolerable Weekly Intakes (PTWIs) set by the Joint FAO/WHO Expert Committee on Food Additives (JECFA). The PTWI is used by JECFA in identifying tolerable intakes of food contaminants with cumulative properties. In Tables 5a and 5b and in the rest of the discussions, the PTWI has been divided by 7 to provide a tolerable daily intake for comparison with the estimated daily dietary exposures. Previous COT evaluations were also taken into account.[7] Dietary exposures were compared against the reference nutrient intake (RNI) from the Dietary Reference Values (DRV) where these are available.

The presence of each element in the different food groups, the concentrations detected and dietary exposures are discussed in detail below.

Aluminium

Aluminium is the most common metal in the Earth's crust and has many industrial as well as domestic applications. As a result of environmental changes due to intensified agriculture and industrialisation, the availability of aluminium has increased and consequently its uptake by plants and animals has also increased. In addition, it has been used extensively to make cooking and food storage utensils and in food packaging (e.g. aluminium foil). Aluminium compounds are also used as food additives. In 2006, the JECFA reduced the PTWI for all forms of aluminium in food from 7 to 1 milligram per kilogram body weight, because of new evidence that aluminium could have effects on the reproductive system and developing nervous system.[8]

In the 20 food groups of the TDS samples, most groups had aluminium concentrations lower or similar to those reported in the 2000 TDS[9] the exceptions being Bread, Meat Products and Other Vegetables groups. The Miscellaneous Cereals group had the highest concentration of aluminium (17.5 milligrams per kilogram). This is lower than the concentration in the 2000 TDS (19 milligrams per kilogram) but is three times more than the value from the 1997 TDS[10] (5.2 milligrams per kilogram). The levels of aluminium in this group have varied from 4.8 milligrams per kilogram (1988 TDS) to 78 milligrams per kilogram (1994 TDS)[11].

The Miscellaneous Cereals groups is the most significant contributor to the population dietary exposure (42%) (Table 7a). The relatively high aluminium concentration found in this group could be from naturally present aluminium, aluminium-containing additives which are permitted for use in some bakery products included in this group, [12, 13] or as a result of processing and storage of food in aluminium containing utensils.

The population dietary exposure to aluminium is 5.4 milligrams per day, which is higher than the estimates from the 2000 and 1997 TDS (4.7 and 3.4 milligrams per day, respectively, as shown in Table 6a).

The dietary exposure to aluminium estimated for mean adult consumers is 71 micrograms per kilogram bodyweight and 144 micrograms per kilogram body weight for the high-level consumer. From Table 4a it can be seen that with the exception of toddlers, the mean level consumers of all the population groups had intakes within the PTWI of 1 milligram per kilogram body weight (equivalent to a daily exposure of 143 micrograms per kilogram body weight), which was set by JECFA in 2006[8]. The estimates of high-level dietary exposure of toddlers, young people, the elderly and vegetarians exceeded the PTWI by up to 2.4 fold.

The COT noted that whilst the estimates of dietary exposure to aluminium are not markedly higher than previous estimates, they present uncertainty with regard to the safety of aluminium in food in light of new data that led to the recent reduction in the Provisional Tolerable Weekly Intake[14], which is exceeded by some population subgroups. There is a need for further information on possible sources and forms of aluminium in the diet and their bioavailability.

Arsenic

Arsenic is also widely distributed in the Earth's crust and is present in the environment from natural sources, such as rocks and sediments and as a result of human activities such as coal burning, copper smelting and the processing of mineral ores. It occurs in soil, waters - both marine and fresh, and in almost all plants and animal tissues. Levels of arsenic are higher in the aquatic environment than in most areas of land as it is fairly water-soluble and may be washed out of arsenic-bearing rocks. Levels of arsenic in fish and seafood are usually high, because fish absorb arsenic from the water they live in.

The toxicity of arsenic is dependent on the chemical form in which it is present. Most arsenic in the diet is present in the less toxic, organic form. The inorganic form is the more toxic species (it is known to cause cancer). Arsenic occurs in a wide range of foods and the majority of arsenic in the diet comes from fish and fish products; however, more than 97% of the total arsenic in fish is in the organic forms. In the 2006 TDS, the amounts of total arsenic present in the various food groups as well as the inorganic form were measured.

Total Arsenic

As expected, the Fish group contained considerably higher total arsenic concentrations than any other food group (3.99 milligrams per kilogram). This was marginally higher than the values reported for total arsenic in fish in the 2000 TDS[9] (3.4 milligrams per kilogram), and 1999 TDS[15] (3.2 milligrams per kilogram) but lower than the value reported in the 1997 TDS[10] (4.4 milligrams per kilogram). As in the previous study, the Poultry group contained the second highest concentration (0.022 milligrams per kilogram) (Table 3). This is almost half that reported in the 2000 TDS[9] (0.043 milligrams per kilogram).

The population dietary exposure to total arsenic was estimated for the 2006 TDS to be 0.061 - 0.064 milligrams per day which is slightly higher than that found in the 2000 TDS (0.055 milligrams per day) and the 1999 TDS (0.05 milligrams per day) but slightly lower than the 1997 TDS[10] (0.065 milligrams per day) (Table 6a). Since the concentration of arsenic is highest for the Fish group, it is the most significant contributor to dietary arsenic exposure (88%). This is higher than the 2000 TDS (83%), comparable to the 1999 TDS (87%) but lower than the 1997 TDS (94%). Miscellaneous Cereals made the second most significant contribution accounting for 4% of arsenic dietary exposure (Table 7a).

Inorganic Arsenic

The levels of inorganic arsenic were below the limit of detection (LOD) of 0.01 milligrams per kilogram in most of the food groups. Inorganic arsenic was detected only in the case of the Miscellaneous Cereals (0.012 milligrams per kilogram) and Fish (0.015 milligrams per kilogram) food groups. These values are similar to those reported in the 1999 TDS[15] (upper bound mean values of 0.012 and 0.016 milligrams per kilogram respectively). Even though the Fish group had the highest concentration of total arsenic, only a very small fraction (0.36%) is present as inorganic arsenic. In the case of the Miscellaneous Cereals food group, although the percentage of inorganic arsenic is greater, the concentration of total arsenic in these foods is much lower.

The population dietary exposure was 0.0014 - 0.007 milligrams per day and is comparable to the range reported in 1999 (0.0009 - 0.005 milligrams per day)[15]. In the estimation of lower bound consumer dietary exposures, the contribution from the Miscellaneous Cereals and Fish groups alone were considered. In the calculation of upper bound exposures, the concentration of inorganic arsenic in the rest of the food groups was assumed to be equal to the concentration of total arsenic (since this was lower than the LOD for inorganic arsenic) except in the case of the Poultry food group where it was considered to be equal to the LOD. The dietary exposures to inorganic arsenic for the various population groups are given in Table 4a. It can be seen that the dietary exposures for all the population groups are well below the PTWI set by JECFA for inorganic arsenic in 1989, which is equivalent to 2.1 micrograms per kilogram body weight per day[16]. Tables 5a, 5b and 8 show the comparison of estimated dietary exposures to arsenic from the 1997, 1999, 2000 and 2006 TDSs.

Inorganic arsenic is genotoxic and a known human carcinogen and therefore exposure should be as low as reasonably practicable (ALARP)[17]. The estimated total dietary exposure to inorganic arsenic from the 2006 TDS is comparable to that for the 1999 TDS for all population groups. Overall, the results therefore indicate that dietary exposure to inorganic arsenic is consistent with ALARP.

The COT concluded that the data on arsenic appear consistent with previous surveys of total and inorganic arsenic in food, which was reviewed in 2003[17]. They reaffirmed their previous conclusions that current dietary exposure to organic arsenic is unlikely to constitute a risk to health. Their advice remains that exposure to inorganic arsenic should be as low as reasonably practicable (ALARP)[17].

Cadmium

Cadmium has accumulated in the environment as a result of agricultural practices such as using fertilisers and also from historic mining activities. A major use of cadmium is in nickel - cadmium dry cell batteries; the metal also finds some use in the automobile industry.

Cadmium was present at low concentrations in eleven of the food groups, and was below the levels of detection in Carcase Meat, Poultry, Oils and Fats, Eggs, Fresh Fruits, Beverages, Milk and Dairy Products. Cadmium concentrations were highest in the Offal (0.084 milligrams per kilogram) and Nuts (0.065 milligrams per kilogram) groups (Table 3) and were similar to previous years. Food that is consumed in larger quantities makes the greatest contribution to the dietary exposure; Table 7a gives the percentage contribution by each food group. The high contributors are Potatoes (24%), Miscellaneous Cereals (21%) and Bread (19%).

The population dietary exposure to cadmium is 0.011 - 0.013 milligram per day and is similar to those reported for previous years (Table 6a). There has been little change in the dietary exposure of the general UK population to cadmium over the last 20 years. The estimated mean and high-level dietary exposures to cadmium for each consumer group (Table 4b) were within the JECFA PTWI (equivalent to 1 microgram per kilogram body weight per day[18]).

The COT concluded that current dietary exposures to cadmium are not of toxicological concern. They noted that this conclusion might need to be reviewed after the current risk assessment by the European Food Safety Authority (EFSA) is published.

Chromium

Chromium is widely distributed in the Earth's crust and has many industrial uses. It commonly exists in two forms - the trivalent and hexavalent states. Trivalent chromium is essential to human life and plays an important role in carbohydrate, lipid and protein metabolism. Hexavalent chromium compounds do not occur naturally in the environment and are more toxic than trivalent chromium compounds.

Chromium was detected in the various food groups but the concentrations of some were below the LODs (Bread, Offal, Poultry, Beverages and Milk). The Sugars and Preserves group contained the highest chromium concentration (0.08 milligrams per kilogram), and made the greatest contribution (16%) to the population dietary exposure. The other main contributors are the Miscellaneous Cereals, Potatoes and Beverages groups (13%, 12% and 13% respectively) because of their higher levels of consumption (Table 7a). Chromium concentrations have continued to decrease since the 1994 TDS, with population dietary exposure reduced to less than a tenth (from 0.34 milligrams per day in 1994 to 0.029 milligrams per day in 2006, Table 6a).

Although there is no RNI (Reference Nutrient Intake) for chromium, an adequate intake is believed to be above 25 micrograms per day for adults and between 0.1 and 1.0 micrograms per kilogram body weight per day for children and adolescents[19]. The dietary exposures reported in this FSIS are above these values for adults, adolescents and children and are well below the Expert Group on Vitamins and Minerals (EVM) guidance level of 150 micrograms per kilogram body weight per day for total dietary intake of trivalent chromium[20].

The COT concluded that current dietary exposures to chromium are unlikely to be of toxicological concern.

Copper

Copper has been mined and used since ancient times and its ores are widely distributed throughout the world. Copper and its alloys have wide spread domestic, pharmaceutical, industrial and agricultural applications. Copper is an essential element with food being the major source.

Copper was found to be present in all the food groups of the 2006 TDS and Offal (52.5 milligrams per kilogram) and Nuts (9.15 milligrams per kilogram) contained the highest concentrations. The concentration of copper in Offal was higher than the value measured in the 2000 TDS (40 milligrams per kilogram). As shown in Table 3a, the concentrations in the other groups ranged from 0.05 milligrams per kilogram (Milk group) to 2.21 milligrams per kilogram (Miscellaneous Cereals group) and are fairly comparable to the 2000 TDS values.

Miscellaneous Cereals made the most significant contribution (23%) to population dietary exposure to copper, followed by the Bread group (14%) (Table 7a).

The population dietary exposure to copper (1.24 milligrams per day) has changed only marginally since 1982 (Table 6a) and is comparable to the RNI (Reference Nutrient Intake) of 1.2 milligrams per day set by the Committee on Medical Aspects of Food and Nutrition Policy (COMA)[209]. The estimated copper dietary exposures for consumers of all age groups and vegetarians are well below the JECFA PMTDI of 500 micrograms per kilogram body weight per day[21] and the EVM Safe Upper Level of 160 micrograms per kilogram body weight per day for total dietary intake[20].

The COT concluded that current dietary exposures to copper are not of toxicological concern.

Lead

Lead is found everywhere in the environment. Food is one of the major sources of lead exposure in the UK. The Offal group had the highest lead concentration (0.065 milligrams per kilogram) and the greatest contributions to the population dietary exposure were made by the Beverages food group (17%) and the Bread and Other Vegetables groups (16%) (Table 7a).

The population dietary exposure to lead is 0.006 milligrams per day and is similar to the value reported in 2000 (0.007 milligrams per day). Dietary exposures of the general UK population have declined from 0.12 milligrams per day estimated in the 1980 TDS to 0.006 milligrams per day in the 2006 TDS (Table 6a).

All the reported dietary exposures in this survey are well below the JECFA PTWI, which is equivalent to 3.6 micrograms per kilogram body weight per day[22] and are similar to or lower than the exposure levels reported in previous years.

The COT noted that estimates of dietary exposure to lead have not increased since the previous survey. At these dietary intakes, adverse effects, if any, are likely to be very small. However, since it is not possible to identify a threshold for the association between lead exposure and decrements in intelligence quotient, efforts should continue to reduce lead exposure from all sources.

Manganese

Manganese is present both naturally and as a result of contamination in soils, sediments and water. It is an essential element and is present in most foods, particularly green vegetables.

Manganese is present in all the food groups with the highest concentration found in the Nuts group (24.9 milligrams per kilogram). The concentration in other groups ranged from 0.022 milligrams per kilogram (Milk) to 8.01 milligrams per kilogram (Bread) as shown in Table 3b. The concentrations reported are broadly similar to those reported in the 1994 and 2000 TDSs[9,11].

The Beverages group made the highest contribution to the population dietary exposure (41%) followed by the Miscellaneous Cereals (20%) and Bread (16%) groups. The population dietary exposure is 5.24 milligrams per day, as shown in Table 6b. The Expert Group on Vitamins and Minerals concluded that, for guidance purposes, it can be assumed that total manganese intakes up to 200 micrograms per kilogram body weight per day in the general population, or 150 micrograms per kilogram body weight per day in older people, would be unlikely to result in adverse effects[20]. The dietary exposure to manganese for the mean level consumers of all population groups are within these guidelines. The estimated high level toddler exposure exceeded the guidance level by about 50% (305 micrograms per kilogram body weight). Taking into account the precautionary approach taken by the EVM, this small excursion above the guidance level is not expected to be a toxicological concern.

The population dietary exposure to manganese in 2006 (5.24 milligrams per day) has increased marginally since the 1994 and 2000 TDS (4.9 milligrams per day), however, the overall results indicate that dietary exposures to manganese have remained fairly constant since monitoring began in 1983.

The COT concluded that there is insufficient information to determine whether there are risks associated with dietary exposure to manganese. However dietary exposures to manganese in adults have remained fairly constant since monitoring began in 1983, and there is no basis for assuming any concern for health.

Mercury

The sources of mercury contamination are environmental, industrial and agricultural. Exposure to mercury is mainly from the diet and dental amalgam. Mercury can exist in inorganic and organic forms in food, with the organic forms, such as methylmercury, being more toxic following ingestion. In this study, only total mercury was estimated.

Mercury was detected only in the Offal (0.0004 milligrams per kilogram), Fish (0.056 milligrams per kilogram) and Other Vegetables (0.0007 milligrams per kilogram) food groups. The concentration was below the LODs in all other categories (Table 3b). The Fish group is the major contributor (25%) to the population dietary exposure to mercury (Table 7b). The population exposure to mercury is 0.001 - 0.003 milligrams per day. The mean adult daily dietary exposure to mercury is 0.05 micrograms per kilogram body weight.

In 2003 JECFA set a PTWI of 1.6 micrograms per kilogram body weight for methylmercury (equivalent to 0.23 micrograms per kilogram body weight per day)[23] to protect against neurodevelopmental effects in the embryo and fetus. This guideline amount is for methyl mercury. Inorganic mercury is not absorbed as well as methylmercury by the oral route, and therefore comparing dietary exposure to total mercury with the PTWI for methylmercury is a worst case scenario. Taking into account uncertainty related to food groups in which mercury was below the limit of detection, the estimated high-level dietary exposure of children aged 1.5 - 4.5 years is within the range of 0.17 - 0.26 micrograms per kilogram body weight per day, and therefore is in the region of the PTWI. The estimates of dietary exposure to mercury (mean and high-level) for all consumer groups were clearly within the PTWI.

The COT concluded that the current dietary exposures to mercury are unlikely to be of toxicological concern.

Molybdenum

Molybdenum is a relatively rare element and is an essential constituent of several enzymes in the human body. Foodstuffs from above ground plant material contain higher concentrations of molybdenum compared with foods from tubers or animals.

Molybdenum was detected in all food groups of the 2006 TDS except Oils & Fats and Beverages groups. The highest concentration was in the Nuts group (1.26 milligrams per kilogram) and this is slightly higher than the value reported in the 1994 TDS (0.96 milligrams per kilogram). The Offal group had the next highest concentration (1.10 milligrams per kilogram) and the concentrations of all other food groups were below 0.243 milligrams per kilogram (Canned Vegetables). The major contributors to molybdenum intake in the UK diet are the Miscellaneous Cereals (33%) and Bread (19%) food groups.

The population dietary exposure to molybdenum was estimated to be 0.123 - 0.125 milligrams per day and this is slightly higher than the exposures reported in 1994, 1991 and 1985 (0.11 milligrams per day). These are well within the guidance level for molybdenum (0.23 milligram per day) as stated in the EVM report and the WHO estimated daily requirement for molybdenum of 0.1 - 0.3 milligram per day for adults[20]. The mean dietary exposure for adults was estimated to be 1.61 - 1.64 micrograms per kilogram body weight and the high level exposure was 3.03 - 3.08 micrograms per kilogram body weight.

The COT concluded that population dietary exposures to molybdenum are similar to previous studies and although there is uncertainty, the sparse data on the oral toxicity of molybdenum do not suggest that the estimated intakes give cause for toxicological concern.

Nickel

Nickel is another metal that is present in the Earth's crust. It has several industrial applications and is used in the manufacture of batteries, alloys and jewellery. Nickel is present in most foods.

Nickel was detected in most of the food groups except Carcase Meat, Poultry, Oils and Fats, Eggs and Milk, where the concentration was lower than the LOD. Concentrations of nickel in the other food groups varied from 0.02 milligrams per kilogram for the Offal group to 3.2 milligrams per kilogram for the Nuts group (Table 3b). These concentrations were broadly similar to those reported in the 2000 TDS[9].

The population nickel dietary exposure was estimated to be 0.13 milligrams per day and this is the same as that previously reported in 1994, 1997 and in 2000 (Table 6b). The Beverages group contributes the most (21%) to the population dietary exposure followed by the Miscellaneous Cereals group (16%). Mean and high level adult dietary exposures to nickel were 1.49 - 1.63 micrograms per kilogram body weight per day and 3.01 - 3.08 micrograms per kilogram body weight per day respectively, similar to the values reported in 2000 (Tables 5a and 5b).

Population exposures to nickel have decreased since 1976 (0.33 milligrams per day), and have been relatively stable since 1982 (0.13 milligrams per day in the 2006 TDS). Whilst the estimates of dietary exposures to nickel were below or in the region of the WHO TDI (5 micrograms per kilogram body weight per day)[24], for high-level consumers aged 1.5 - 4.5 years the estimate exceeded the TDI by about 60%. The COT had previously noted that ingested nickel may exacerbate contact dermatitis/eczema in pre-sensitised individuals and that toddlers are less likely than adults to be sensitised[7].

The COT concluded that current dietary exposures to nickel are unlikely to be of toxicological concern.

Selenium

Selenium is widely distributed in the Earth's crust and finds use in the electronic, pharmaceutical and agricultural industries. It plays important roles in some enzymes and is an essential element to human health. The Expert Group on Vitamins and Minerals set a Safe Upper Level for total selenium intake of 0.45 milligrams per day[20].

In the 2006 TDS, selenium was detected in most food groups ranging from 0.77 milligrams per kilogram for the Offal group to less than the limit of detection (LOD) in Oils and Fats, Sugar and Preserves, Potatoes, Fresh Fruit, Fruit Products and Beverages groups. The Miscellaneous Cereals group (16%) and the Meat Products group (15%) made the greatest contribution to the population dietary exposure (Table 7b). Selenium concentrations in most food groups were slightly higher than those reported in the 2000 TDS[9] and the concentration in Offal (0.77 milligrams per kilogram) is nearly twice the value reported in the previous survey (0.46 milligrams per kilogram).

The population dietary exposure of 0.048 - 0.058 milligrams per day reported in this survey is slightly higher than the values estimated for the previous years (0.032 – 0.034 milligrams per day in 2000, 0.039 milligrams per day in 1997, 0.043 milligrams per day in 1994) (Table 6b). The reported estimated exposures were well below the WHO upper limit of the safe range for selenium intake (0.4 milligrams per day for adults only)[25], the Tolerable Upper Level (UL) of 0.3 milligrams per day set by EFSA[26] and the EVM Safe Upper Level of 0.45 milligrams per day[20].

The COT concluded that current dietary exposures to selenium are not of toxicological concern.

Tin

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

In the 2006 TDS samples, most of the food groups were found to contain very low concentrations of tin with the concentration of eleven groups below the LOD. As in the previous TDS results, canned foods contained higher concentrations of tin presumably as a result of the slow dissolution of the tin coating. Tin concentrations in a majority of the food groups were below 0.04 milligrams per kilogram, except for the Canned Vegetables

(36.1 milligrams per kilogram) and Fruit Products (11.1 milligrams per kilogram) which also include some canned products (Table 3b). The concentration of tin in the Canned Vegetables group is higher than the 2000 TDS result (25.06 milligrams per kilogram) but lower than the value reported for the 1997 TDS and a previous survey of tin in canned fruit and vegetables (mean 44 milligrams per kilogram)[27]. Canned Vegetables (65%) and Fruit Products (34%) also made the greatest contribution to the population dietary exposure to tin (Table 7b).

The population dietary exposure was estimated as 1.80 - 1.81 milligrams per day, higher than the previous TDS[9] (1.4 milligrams per day) (Table 6b) but comparable to the 1997 TDS. The highest estimated dietary exposure to tin was for high-level consumers aged 1.5 - 4.5 years (341.5 micrograms per kilogram body weight per day). This is lower than the PTWI of 2000 micrograms per kilogram body weight per day[28], but exceeds the EVM guidance level of 220 micrograms per kilogram body weight per day[20].

The COT concluded that current dietary exposures to tin are unlikely to be of toxicological concern.

Zinc

Zinc is an essential element for human health, and is present in plants and animals. It is the key component of a large number of enzymes many of which are important in human metabolism. Zinc was present in all the food groups reported in this survey with concentrations ranging from 0.13 milligrams per kilogram for the Beverages group to 64.8 milligrams per kilogram for the Carcase Meat group (Table 3b). Zinc concentrations were broadly similar to those reported in the earlier TDS surveys[9-11]. Bread (12%), Miscellaneous Cereals (14%), Carcase Meat (15%), Meat Products (16%) and Milk (10%) were the major contributors to the population dietary exposure (Table 7b).

The population dietary exposure was 8.83 milligrams per day, marginally higher than the two previous TDSs (8.4 milligrams per kilogram; Table 6b). This is in good agreement with dietary exposures reported by the NDNS on vitamins and minerals, with mean intakes for men of 10.2 milligrams per day and for women 7 milligrams per day[29] as well as the RNI ranges of 5.5-9.5 milligrams per day for males and 4.0-7.0 milligrams per day for females set by the Committee on Medical Aspects of Food and Nutrition Policy (COMA)[20].

The estimated dietary exposure for all consumer groups was within the JECFA Provisional Maximum Tolerable Daily Intake (PMTDI) of 0.3 - 1 milligram per kilogram body weight per day[30].

The COT concluded that current dietary exposures to zinc are unlikely to be of toxicological concern.

Platinum group metals - Platinum, Palladium, Rhodium and Ruthenium

Since 1993 the internal combustion engines of all new vehicles have been fitted with catalytic converters to control the levels of exhaust emissions. Platinum, palladium and rhodium are used as catalysts and research has shown an increase in the concentration of these metals in roadside dust. There is little information about the biological effects of platinum group metals in food and at present there is no evidence for any adverse health effects from these metals in the general environment[31]. In order to find out if these metals have found their way into the food chain and monitor their levels in various components of the diet, they have been included in this TDS. This is the second time these metals have been included in the TDS, the earlier one being the 1994 TDS.[11]

The concentration of platinum and rhodium were below the levels of detection in all the food groups. The concentrations of palladium were also very low, with a couple below the LOD and other values ranging from 0.00003 milligrams per kilogram (Milk) to 0.002 milligrams per kilogram (Offal). Similarly, the concentration of ruthenium was below the LOD in all the food groups with the exception of the Other Vegetables and Canned Vegetables groups where the concentration was 0.0002 milligrams per kilogram. These values are comparable to those reported for the 1994 TDS.

Taking into account uncertainty related to samples in which these elements could not be detected, the population dietary exposures for these metals have been estimated to be in the region of 0 - 0.002 milligrams per day for platinum and rhodium, 0.0007 milligrams per day for palladium and 0.00003 - 0.00081 milligrams per day for ruthenium. The percentage contribution by each of the food groups to the total population dietary exposures to the platinum group metals is given in Table 7b. No safety guidelines have been established for these metals, but considering the very low levels and that their intake has not increased since 1994, establishing safety guidelines is not considered to be a high priority.

The COT noted that the toxicological database on palladium metal and its compounds is extremely limited. However, they concluded that from the available data, there is no reason to believe that current intakes of palladium from the diet pose a risk to health.

The COT concluded that despite a dearth of information on the effects of low doses of platinum, rhodium and ruthenium, current dietary exposures do not suggest a reason for concern as the levels present in the food samples tested were very low or undetectable.

The Alkaline Earth Metals - Barium and Strontium

Barium and strontium belong to the same family of metals as calcium and have widespread domestic and medicinal applications. This is the first time these metals have been analysed since the 1994 TDS.

Barium and strontium were detected in all the food groups at varying concentrations. The highest concentration was in the Nuts group with a barium concentration of 131 milligrams per kilogram and a strontium concentration of 15.7 milligrams per kilogram. The concentrations of barium and strontium were comparable to the 1994 TDS in all the food groups other than the Nuts group where the concentration is approximately two times the levels reported in 1994.

The mean adult dietary exposure for barium is 9.4 micrograms per kilogram body weight and 45.3 micrograms per kilogram body weight for a high level consumer. The population dietary exposure to barium is 0.847 milligrams per day. This has increased from 0.58 milligrams per day reported in the 1994 TDS. The percentage contribution from various food groups to the population dietary exposures to barium is given in Table 7b and as expected, the Nuts food group is the major contributor (46%).

A Tolerable Daily Intake (TDI) of 20 micrograms per kilogram body weight was derived by the WHO to set guideline limits for drinking water[32]. The mean-level exposures for all population sub-groups were below or in the region of the WHO TDI. The TDI is derived from studies in which no effects were observed and therefore, it is possible that the TDI is highly conservative.

The COT noted that the tolerable daily intake (TDI) for barium is based on studies in which no effects were observed and thus may be over-precautionary. Therefore, they concluded that the estimated exposures, which exceeded the TDI by up to 4-fold, are not necessarily a toxicological concern. They recommended that further research be carried out to allow a TDI to be set with more confidence and to investigate the bioavailability of barium; especially from foods with relatively high levels such as nuts.

In the case of strontium, the population dietary exposure is 1.20 milligrams per day and is lower than the value reported in the 1994 TDS (1.3 milligrams per day). The daily mean adult dietary exposure is 15.6 micrograms per kilogram body weight and that of the high level exposure is 30.6 micrograms per kilogram body weight. The percentage contribution from various food groups to the population dietary exposure is given in Table 7b with Bread making the greatest contribution to the intake (20%).

The COT concluded that current dietary exposures to strontium are unlikely to be of toxicological concern.

Indium and Thallium

These two metals belong to the same group as aluminium in the periodic table. They are used in semi-conductors, LCDs, alloys, pigments and dyes. These metals were found to be present in small quantities in the various food groups. The concentration of indium was below the LOD in all cases except Canned Vegetables and Fruit Products (0.096 and 0.031 milligrams per kilogram respectively). Thallium was present at varying levels (0.00008 milligrams per kilogram in Milk to 0.0028 milligrams per kilogram in Poultry). The results for thallium are lower than or comparable to the 1994 TDS values.[11]

The mean adult dietary exposure to indium is 0.06 - 0.24 micrograms per kilogram bodyweight per day and 0.22 - 0.47 micrograms per kilogram bodyweight per day for the high level consumer. The population dietary exposure is 0. 0.005 - 0.019 milligrams per day. The COT concluded that population dietary exposures to indium are similar to previous studies and although there is uncertainty, the sparse data on the oral toxicity of indium do not suggest that the estimated intakes give cause for toxicological concern.

For thallium, the adult dietary exposure is 0.01 micrograms per kilogram bodyweight per day for the mean level consumer and 0.02 micrograms per kilogram bodyweight per day for the high level consumer. The percentage contribution from various food groups to the population dietary exposure is given in Table 7b. The COT concluded that current dietary exposures to thallium are unlikely to be of toxicological concern.

Antimony, Bismuth and Germanium

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. A Tolerable Daily Intake (TDI) of 6 micrograms per kilogram bodyweight was set by the WHO in 2003[33]. 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.

Antimony was detected in most of the food groups except the Oils and Fats, Eggs and Milk groups where the concentration was below the LOD. The values ranged from below LOD to 0.0099 milligrams per kilogram. The mean adult dietary exposure to antimony was found to be 0.03 micrograms per kilogram bodyweight and the high level exposure was 0.06 micrograms per kilogram bodyweight. This is below the TDI set by WHO (6 micrograms per kilogram body weight)[33]. The population dietary exposure is 0.0025 milligrams per day which is slightly lower than the value reported in the 1994 TDS (0.003 milligrams per day). The Meat Products group which has the highest concentration of antimony contributes the highest percentage (24%) to the total population dietary exposure.

The COT concluded that current dietary exposures to antimony are not of toxicological concern.

Bismuth was detected in eleven of the food groups with concentrations ranging from below LOD to 0.0064 milligrams per kilogram in the Dairy Products food group. The population dietary exposure is 0.002 milligram per day (Table 6a) which is higher than the value reported for the 1994 TDS (0.0004 milligram per day). Dairy Products and Milk contribute most to bismuth exposure (25% and 24% respectively). The mean adult dietary exposure is 0.015 - 0.022 microgram per kilogram bodyweight per day and 0.034 - 0.044 microgram per kilogram bodyweight per day for the high level consumer (Table 4a).

Germanium was detected only in the Offal and Meat Products categories of the TDS samples at concentrations of 0.002 milligrams per kilogram and 0.001 milligrams per kilogram respectively. The population dietary exposure is 0.0001 - 0.0015 milligrams per day which is much lower than the value reported for the 1994 TDS (0.004 milligrams per day). The mean adult dietary exposure is 0.001 - 0.018 microgram per kilogram bodyweight per day and 0.002 - 0.033 microgram per kilogram bodyweight per day for the high level consumer.

The COT concluded that current dietary exposures to bismuth and germanium are unlikely to be of toxicological concern.

Conclusions and further recommendations by the COT

In conclusion, the results from this survey indicate that current population dietary exposures to most of the 24 metals and elements analysed in the 2006 TDS do not raise specific concern for the health of consumers, but there is a need for more information on aluminium and barium. The COT also stressed that efforts should continue to reduce dietary exposure to inorganic arsenic and to lead.

Following a review of these results, the COT recommended that in future research and surveys of elements in food, priorities should include:

- Information on the forms of aluminium in food and their bioavailability.
- Clarification of the large variability in aluminium concentrations in food and whether these represent an increasing trend.
- Assessment of the bioavailability of barium in nuts compared to barium chloride in water.
- A long-term human study with a large number of subjects to examine the effect of barium on blood pressure and to investigate renal end-points

following oral exposure to barium in drinking water, to allow a TDI to be set with more confidence.

- Information on the bioavailability of manganese, particularly from beverages that are the principal contributing food group.

Glossary of terms

ALARP	As Low As Reasonably Practicable
COMA	Committee on Medical Aspects of Food and Nutrition Policy
COT	Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment
EFSA	European Food Safety Authority
EVM	Expert Group on Vitamins and Minerals
HR-ICP-MS	High Resolution Inductively Coupled-Plasma Mass Spectrometry
ICP-MS	Inductively Coupled-Plasma Mass Spectrometry
JECFA	Joint Expert Committee on Food Additives of the Food and Agriculture Organisation of the United Nations and the World Health Organisation International Programme on Chemical Safety
LOD	Limit of Detection
NDNS	National Diet and Nutrition Survey
PTWI	Provisional Tolerable Weekly Intake
TDI	Tolerable Daily Intake
TDS	Total Diet Study
UKAS	United Kingdom Accreditation Service
WHO	World Health Organization

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A copy of the final report of this survey has been placed in the FSA Library - address detailed above. If you wish to consult a copy, please contact the library for an appointment giving at least 24 hours notice or, alternatively, copies can be obtained from the Library: a charge will be made to cover photocopying and postage.

Table 1. Average weight of food eaten as estimated by the Expenditure and Food Survey[1]

	Contribution to household diet as purchased (Kg/person/day)	Loss/gain in preparation and cooking (%) (to nearest 5%)	Estimated average weight of food as eaten (Kg/person/day)
Bread	0.107	0	0.107
Miscellaneous Cereals	0.123	+ 5	0.129
Carcase meat	0.033	- 40	0.020
Offal	0.001	- 35	0.001
Meat products	0.081	- 25	0.061
Poultry	0.035	- 45	0.019
Fish	0.022	- 35	0.014
Oils and fats	0.022	0	0.022
Eggs	0.013	- 10	0.013
Sugar & preserves	0.058	0	0.058
Green vegetables	0.043	- 30	0.030
Potatoes	0.126	- 15	0.107
Other vegetables	0.106	- 15	0.090
Canned vegetables	0.041	- 20	0.033
Fresh fruit	0.111	- 25	0.083
Fruit products	0.055	0	0.055
Beverages	0.298	+ 320	1.252
Milk	0.246	0	0.246
Dairy products	0.082	0	0.082
Nuts	0.003	0	0.003

Table 2. Limits of detection (LOD) for the 2006 Total Diet Study

Element	LOD in milligrams per kilogram
Aluminium	0.01 -0.05
Antimony	0.0001 - 0.0005
Arsenic (Total)	0.001 - 0.005
Arsenic (Inorganic)	0.01
Barium	0.007 0.04
Bismuth	0.0002 - 0.001
Cadmium	0.001 - 0.005
Chromium	0.003 - 0.02
Copper	0.007 -0.04
Germanium	0.0003 - 0.002
Indium	0.003 - 0.02
Lead	0.001 - 0.006
Manganese	0.002 - 0.01
Mercury	0.005 - 0.003
Molybdenum	0.002 - 0.01
Nickel	0.007 - 0.04
Palladium	0.00003 - 0.0002
Platinum	0.0005 - 0.003
Rhodium	0.0005 - 0.003
Ruthenium	0.0002 - 0.001
Selenium	0.005 - 0.03
Strontium	0.003 - 0.02
Thallium	0.00007 - 0.0004
Tin	0.003 - 0.02
Zinc	0.02 - 0.1

Notes Ranges of values are shown as the sample masses taken for analysis varied between the different food matrices examined.

Table 3a. Concentrations (in milligrams per kilogram) of aluminium, antimony, arsenic, barium, bismuth, cadmium, chromium, copper, germanium, indium and lead in the 20 food groups of the 2006 UK Total Diet Study

Food Group	Al	Sb	As		Ba	Bi	Cd	Cr	Cu	Ge	In	Pb
			Inorganic	Total								
Bread	3.59	(0.0014)	<0.01	<0.005	0.81	<0.001	0.023	<0.02	1.66	<0.002	<0.02	(0.011)
Misc. Cereal	17.5	0.0020	(0.012)	0.018	0.74	<0.001	0.021	(0.03)	2.21	<0.002	<0.02	(0.007)
Carcase Meat	0.24	(0.0008)	<0.01	(0.006)	(0.03)	<0.0005	<0.003	(0.03)	1.44	<0.001	<0.01	<0.003
Offal	0.22	(0.0008)	<0.01	(0.008)	0.09	<0.0005	0.084	<0.01	52.5	(0.002)	<0.01	0.065
Meat Product	2.50	0.0099	<0.01	(0.005)	0.33	<0.0005	(0.007)	0.037	1.16	(0.001)	<0.01	(0.005)
Poultry	0.20	(0.0008)	<0.01	0.022	(0.03)	<0.0005	<0.003	<0.01	0.72	<0.001	<0.01	<0.003
Fish	0.81	0.0026	(0.015)	3.99	0.14	(0.0006)	0.015	0.04	0.91	<0.0007	<0.007	(0.004)
Oils & Fats	0.27	<0.0005	<0.01	<0.005	<0.04	(0.001)	<0.005	0.02	(0.08)	<0.002	<0.02	<0.006
Eggs	<0.03	<0.0003	<0.01	<0.003	0.33	<0.0005	<0.003	0.01	0.57	<0.001	<0.01	<0.003
Sugar & Preserves	2.73	0.0044	<0.01	(0.009)	0.49	0.005	(0.006)	0.08	1.80	<0.002	<0.02	<0.006
Green Vegetables	1.12	0.0005	<0.01	0.004	0.465	(0.0005)	0.006	(0.008)	0.580	<0.0003	<0.003	0.004
Potatoes	0.98	(0.0004)	<0.01	(0.005)	0.17	(0.0005)	0.028	0.031	1.12	<0.0007	<0.007	(0.003)
Other Vegetables	2.84	0.0055	<0.01	0.005	0.533	(0.0004)	0.007	0.024	0.808	<0.0004	<0.004	0.013
Canned Vegetables	1.02	0.0005	<0.01	(0.001)	0.249	0.0009	0.006	0.039	1.29	<0.0004	0.096	0.006
Fresh Fruits	0.48	0.0004	<0.01	(0.001)	0.422	(0.0003)	<0.001	(0.007)	0.786	<0.0003	<0.003	(0.002)
Fruit Products	1.17	0.0004	<0.01	(0.003)	0.212	(0.0003)	0.004	0.017	0.544	<0.0003	0.031	0.007
Beverages	1.49	0.0004	<0.01	<0.001	0.036	<0.0002	<0.001	<0.003	0.074	<0.0003	<0.003	(0.001)
Milk	(0.01)	<0.0001	<0.01	<0.001	0.070	0.0020	<0.001	<0.003	0.050	<0.0003	<0.003	(0.001)
Dairy Products	0.50	(0.0004)	<0.01	<0.003	0.22	0.0064	<0.003	(0.01)	0.33	<0.001	<0.01	<0.003
Nuts	3.81	(0.0007)	<0.01	(0.007)	131	<0.001	0.065	(0.03)	9.15	<0.002	<0.02	<0.006

Reported values for inorganic and total As, Bi, Cr, Ge and In are from HR-ICP-MS measurement.

Brackets indicate the measured values are below the LOQ; LODs and LOQs for a given element will vary according to the weight of sample taken.

Table 3b. Concentrations (in milligrams per kilogram) of manganese, mercury, molybdenum, nickel, palladium, platinum, ruthenium, rhodium, selenium, strontium, thallium, tin and zinc in the 20 food groups of the 2006 UK Total Diet Study

Food Group	Mn	Hg	Mo	Ni	Pd	Pt	Rh	Ru	Se	Sr	Tl	Sn	Zn
Bread	8.01	<0.003	0.22	(0.07)	0.0008	<0.003	<0.003	<0.001	(0.06)	2.27	(0.0005)	<0.02	9.9
Misc. Cereal	7.98	<0.003	0.32	0.16	0.0007	<0.003	<0.003	<0.001	(0.07)	1.28	<0.0004	<0.02	9.4
Carcase Meat	0.129	<0.002	(0.016)	<0.02	0.0005	<0.0015	<0.0015	<0.0005	0.14	0.05	(0.0004)	(0.01)	64.8
Offal	2.65	(0.004)	1.10	(0.02)	0.0022	<0.0015	<0.0015	<0.0005	0.77	0.10	0.0023	<0.01	46.5
Meat Product	2.75	<0.002	0.085	0.07	0.0006	<0.0015	<0.0015	<0.0005	0.14	0.61	(0.0006)	0.04	23.0
Poultry	0.180	<0.002	0.050	<0.02	0.0003	<0.0015	<0.0015	<0.0005	0.17	0.16	0.0028	<0.01	16.3
Fish	0.722	0.056	0.024	(0.04)	0.00046	<0.001	<0.001	<0.0003	0.42	2.50	0.0010	(0.021)	7.67
Oils & Fats	0.08	<0.003	<0.01	<0.04	<0.0002	<0.003	<0.003	<0.001	<0.03	0.11	<0.0004	<0.02	0.22
Eggs	0.307	<0.002	0.124	<0.02	<0.0001	<0.0015	<0.0015	<0.0005	0.19	0.38	(0.0003)	<0.01	11.4
Sugar & Preserves	2.05	<0.003	0.06	0.31	(0.0002)	<0.003	<0.003	<0.001	<0.03	1.06	(0.0005)	<0.02	6.49
Green Vegetables	2.06	<0.0005	0.143	0.086	0.00023	<0.0005	<0.0005	<0.0002	(0.007)	2.06	0.00150	<0.003	3.26
Potatoes	1.58	<0.001	0.068	0.07	0.00070	<0.001	<0.001	<0.0003	<0.01	0.625	0.0014	<0.007	3.66
Other Vegetables	1.54	(0.0007)	0.066	0.079	0.00030	<0.0006	<0.0006	(0.0002)	(0.018)	1.39	0.00066	(0.012)	2.62
Canned Vegetables	1.71	<0.0006	0.243	0.338	0.00042	<0.0006	<0.0006	(0.0002)	(0.014)	0.618	(0.00023)	36.1	3.33
Fresh Fruits	1.56	<0.0005	0.019	0.036	(0.00004)	<0.0005	<0.0005	<0.0002	<0.005	0.859	0.00045	(0.005)	0.89
Fruit Products	4.56	<0.0005	0.011	0.066	0.00020	<0.0005	<0.0005	<0.0002	<0.005	0.689	0.00031	11.1	0.61
Beverages	1.71	<0.0005	<0.002	(0.022)	0.00011	<0.0005	<0.0005	<0.0002	<0.005	0.063	(0.00015)	<0.003	0.13
Milk	0.022	<0.0005	0.034	<0.007	(0.00003)	<0.0005	<0.0005	<0.0002	(0.014)	0.273	(0.00008)	<0.003	3.71
Dairy Products	0.224	<0.002	0.065	(0.04)	0.0018	<0.0015	<0.0015	<0.0005	(0.03)	0.83	<0.0002	(0.02)	9.66
Nuts	24.9	<0.003	1.26	3.02	0.0019	<0.003	<0.003	<0.001	0.30	15.7	(0.0012)	(0.02)	31.0

Reported values for Ru, Rh, Pd, Pt and Se are from HR-ICP-MS measurement.

Brackets indicate the measured values are below the LOQ; LODs and LOQs for a given element will vary according to the weight of sample taken.

Table 4a. Estimated total dietary exposure to aluminium, antimony, arsenic (total and inorganic), barium and bismuth from the 2006 Total Diet Study

Population Group	Estimated dietary exposure (µg/kilogram bodyweight/day) [1-3]											
	Al		Sb		Total As		Inorganic As		Ba		Bi	
	Mean	High-level	Mean	High-level	Mean	High-level	Mean	High-level	Mean	High-level	Mean	High-level
Adults	71	144	0.032 - 0.033	0.059 - 0.060	1.65 - 1.68	6.83 - 6.85	0.028 - 0.093	0.071 - 0.165	9.40	45.29	0.015 - 0.022	0.034 - 0.044
Toddlers (1.5-4.5 years)	187	345	0.075 - 0.077	0.132 - 0.135	2.71 - 2.80	12.27 - 12.34	0.075 - 0.246	0.174 - 0.402	22.21 - 22.22	85.01	0.086 - 0.104	0.201 - 0.217
Young people (4-18 years)	123	246	0.049 - 0.050	0.096 - 0.097	1.91 - 1.95	8.19 - 8.24	0.055 - 0.158	0.128 - 0.291	14.36 - 14.37	64.75 - 64.76	0.034 - 0.046	0.090 - 0.107
Elderly (free living)	59	135	0.027	0.054	1.72 - 1.75	6.40 - 6.43	0.024 - 0.079	0.066 - 0.149	6.38 - 6.39	24.53	0.016 - 0.022	0.037 - 0.046
Elderly (Institutional)	58	167	0.023 - 0.024	0.062	1.18 - 1.20	5.02 - 5.05	0.025 - 0.072	0.082 - 0.173	4.64	11.72	0.018 - 0.024	0.049 - 0.061
Vegetarians[4]	87	151	0.035 - 0.036	0.06	1.56 - 1.59	8.68 - 8.70	0.035 - 0.100	0.079 - 0.163	14.21	63.31 - 63.32	0.020 - 0.027	0.048 - 0.056

Notes

1. Exposures have been estimated for the lower and upper bound concentrations and these have been included as ranges where they apply.
2. The dietary exposure (mean and high level) for all foods combined is not equal to the sum of the exposure from the individual food. It refers to the dietary exposure by a consumer consuming one or any combination of the foods containing the metals. These values are derived from a distribution of the individual consumer's consumption patterns with regards to the individual foods.
3. All figures have been rounded off as appropriate.
4. Some of the vegetarian respondents were consumers of fish.

Table 4b. Estimated total dietary exposure to cadmium, chromium, copper, germanium, indium and lead from the 2006 Total Diet Study

Population Group	Estimated dietary exposure (µg/kilogram bodyweight/day) [1-3]											
	Cd		Cr		Cu		Ge		In		Pb	
	Mean	High-level	Mean	High-level	Mean	High-level	Mean	High-level	Mean	High-level	Mean	High-level
Adults	0.14 - 0.17	0.25 - 0.29	0.28 - 0.37	0.50 - 0.62	17.23	34.47	0.001 - 0.018	0.002 - 0.033	0.06 - 0.24	0.22 - 0.47	0.09 - 0.10	0.17 - 0.18
Toddlers (1.5-4.5 years)	0.37 - 0.45	0.65 - 0.75	0.81 - 1.03	1.38 - 1.67	44.71	77.82	0.002 - 0.053	0.006 - 0.085	0.24 - 0.75	0.93 - 1.48	0.21 - 0.25	0.38 - 0.42
Young people (4-18 years)	0.27 - 0.31	0.50 - 0.57	0.51 - 0.65	1.03 - 1.22	29.41	54.92	0.001 - 0.032	0.004 - 0.058	0.13 - 0.44	0.51 - 0.97	0.13 - 0.15	0.26 - 0.30
Elderly (free living)	0.13 - 0.15	0.26 - 0.29	0.25 - 0.32	0.48 - 0.59	16.09	45.70	0.001 - 0.016	0.002 - 0.029	0.05 - 0.21	0.25 - 0.46	0.08 - 0.09	0.16 - 0.17
Elderly (Institutional)	0.11 - 0.13	0.30 - 0.35	0.27 - 0.28	0.56 - 0.70	13.38	43.36	0.001 - 0.015	0.002 - 0.036	0.04 - 0.18	0.19 - 0.45	0.06 - 0.07	0.17 - 0.19
Vegetarians[4]	0.17 - 0.20	0.30 - 0.32	0.31 - 0.40	0.54 - 0.68	18.34	29.96	0 - 0.020	0 - 0.032	0.10 - 0.29	0.36 - 0.57	0.12	0.20 - 0.21

Notes

1. Exposures have been estimated for the lower and upper bound concentrations and these have been included as ranges where they apply.
2. The dietary exposure (mean and high level) for all foods combined is not equal to the sum of the exposure from the individual food. It refers to the dietary exposure by a consumer consuming one or any combination of the foods containing the metals. These values are derived from a distribution of the individual consumer's consumption patterns with regards to the individual foods.
3. All figures have been rounded off as appropriate.
4. Some of the vegetarian respondents were consumers of fish.

Table 4c. Estimated total dietary exposure to manganese, mercury, molybdenum, nickel, palladium and platinum from the 2006 Total Diet Study

Population Group	Estimated dietary exposure (µg/kilogram bodyweight/day) [1-3]											
	Mn		Hg		Mo		Ni		Pd		Pt	
	Mean	High-level	Mean	High-level	Mean	High-level	Mean	High-level	Mean	High-level	Mean	High-level
Adults	67	124	0.02 - 0.05	0.10 - 0.13	1.61 - 1.64	3.03 - 3.08	1.49 - 1.63	3.01 - 3.08	0.009	0.015 - 0.016	0 - 0.029	0 - 0.051
Toddlers (1.5-4.5 years)	168	305	0.04 - 0.12	0.17 - 0.26	4.80 - 4.87	7.54 - 8.32	4.17 - 4.87	7.54 - 8.32	0.027	0.055 - 0.056	0 - 0.082	0 - 0.130
Young people (4-18 years)	106	201	0.03 - 0.08	0.11 - 0.18	3.01 - 3.05	5.77 - 5.82	2.62 - 3.05	5.27 - 5.82	0.016	0.032	0 - 0.048	0 - 0.089
Elderly (free living)	56	112	0.02 - 0.05	0.09 - 0.12	1.43 - 1.46	3.00 - 3.03	1.25 - 1.46	2.58 - 3.03	0.008	0.015	0 - 0.025	0 - 0.045
Elderly (Institutional)	50	121	0.02 - 0.04	0.07 - 0.12	1.33 - 1.36	3.46 - 3.54	1.11 - 1.36	2.80 - 3.54	0.007	0.018	0 - 0.023	0 - 0.055
Vegetarians[4]	78	135	0.02 - 0.05	0.12 - 0.15	2.01 - 2.05	3.34 - 3.37	1.88 - 2.05	3.49 - 3.37	0.010	0.018	0 - 0.031	0 - 0.050

<u>Notes</u>

1. Exposures have been estimated for the lower and upper bound concentrations and these have been included as ranges where they apply.
2. The dietary exposure (mean and high level) for all foods combined is not equal to the sum of the exposure from the individual food. It refers to the dietary exposure by a consumer consuming one or any combination of the foods containing the metals. These values are derived from a distribution of the individual consumer's consumption patterns with regards to the individual foods.
3. All figures have been rounded off as appropriate.
4. Some of the vegetarian respondents were consumers of fish.

Table 4d. Estimated total dietary exposure to rhodium, ruthenium, selenium, strontium, thallium, tin and zinc from the 2006 Total Diet Study

Population Group	Estimated dietary exposure (µg/kilogram bodyweight/day) [1-3]													
	Rh		Ru		Se		Sr		Tl		Sn		Zn	
	Mean	High-level	Mean	High-level	Mean	High-level	Mean	High-level	Mean	High-level	Mean	High-level	Mean	High-level
Adults	0 - 0.029	0 - 0.051	0.0004 - 0.0101	0.001 - 0.0183	0.83 - 0.95	1.65 - 1.79	15.6	30.6	0.011 - 0.012	0.020 - 0.021	23.3 - 23.4	82.1 - 82.2	140.7	267.8
Toddlers (1.5-4.5 years)	0 - 0.082	0 - 0.130	0.0008 - 0.0291	0.0022 - 0.0468	1.97 - 2.27	3.77 - 4.10	42.8	71.1	0.024 - 0.027	0.043 - 0.046	89.3 - 89.8	341.2 - 341.5	387.0	775.7
Young people (4-18 years)	0 - 0.048	0 - 0.089	0.0005 - 0.0169	0.0013 - 0.0315	1.27 - 1.44	2.60 - 2.84	25.9	51.0	0.016 - 0.018	0.032 - 0.035	48.2 - 48.5	191.3 - 191.5	232.3	478.0
Elderly (free living)	0 - 0.025	0 - 0.045	0.0003 - 0.0087	0.0009 - 0.0159	0.73 - 0.82	1.48 - 1.60	14.0	26.6	0.009 - 0.010	0.017 - 0.018	19.7 - 19.9	93.2 - 93.4	121.7	261.2
Elderly (Institutional)	0 - 0.023	0 - 0.055	0.0002 - 0.0081	0.001 - 0.0196	0.59 - 0.68	1.58 - 1.74	12.0	29.2	0.007 - 0.008	0.017 - 0.019	13.1 - 13.2	68.3 - 68.4	103.5	251.5
Vegetarians[4]	0 - 0.031	0 - 0.050	0.0007 - 0.0109	0.0015 - 0.0180	0.64 - 0.76	1.43 - 1.54	20.5	35.9	0.010 - 0.011	0.018 - 0.019	35.0 - 35.1	131.5 - 131.7	93.4	161.6

Notes

1. Exposures have been estimated for the lower and upper bound concentrations and these have been included as ranges where they apply.
2. The dietary exposure (mean and high level) for all foods combined is not equal to the sum of the exposure from the individual food. It refers to the dietary exposure by a consumer consuming one or any combination of the foods containing the metals. These values are derived from a distribution of the individual consumer's consumption patterns with regards to the individual foods.
3. All figures have been rounded off as appropriate.
4. Some of the vegetarian respondents were consumers of fish.

Table 5a. Comparison of the mean and high-level intake of metals and other elements by adult consumers from the 2006, 2000 and 1997 Total Diet Studies with recommended safety guidelines

Element	PTWI or PMTDI[#] (μg/kg bw /day)	Total Dietary Intake (μg/kg bw/day)					
		2006[1-3,5]		2000[1-3,5]		1997[3-6]	
		Mean	High-level	Mean	High-level	Mean	High-level
Aluminium	143	71	144	67 - 68	134 - 135	45.6	81.3
Antimony	6*	0.03	0.06	-	-	0.043	0.057
Arsenic (total)	-	1.65 - 1.68	6.83 - 6.85	1.5-1.6	5.8	1.71	6.00
Arsenic (inorganic)	2.1	0.028	0.071	-	-	-	-
Cadmium	1	0.14 - 0.17	0.25 - 0.29	0.12	0.21	0.20	0.34
Chromium	150‡	0.28 - 0.37	0.50 - 0.62	0.66-0.67	1.0 - 1.1	1.43	2.43
Copper	50 - 500;160†	17.2	34.5	18	33	20.0	45.6
Lead	3.6	0.09 - 0.10	0.17 - 0.18	0.1	0.18	0.34	0.61
Manganese	200 or 150‡	67	124	67	118	-	-
Mercury (methyl mercury)	0.23	0.02 - 0.05	0.10 - 0.13	0.03 - 0.04	0.12 - 0.13	0.04	0.09
Nickel	4.3‡	1.49 - 1.63	3.01 - 3.08	1.5	2.9	1.71	3.00
Selenium	5†	0.83 - 0.95	1.65 - 1.79	0.63 - 0.67	1.2 - 1.3	0.77	1.43
Tin	220‡	23.3 - 23.4	82.1 - 82.2	20	70	27.1	89.9
Zinc	300 - 1000	140.7	267.8	141	252	157	286

The numerical values shown are the tolerable daily intake for a 60 kg person derived from PTWIs or PMTDIs recommended by JECFA unless mentioned otherwise.

* TDI derived by WHO

‡ Expert Group on Vitamins and Minerals - guidance level

† Expert Group on Vitamins and Minerals - safe upper level

Table 5b. Comparison of the mean and high-level intake of metals and other elements by toddlers and young people from the 2006 and 2000 Total Diet Studies with recommended safety guidelines

Element	PTWI or PMTDI[#] (µg/kg bw/day)	Total Dietary Intake (µg/kg bw/day) [1-3,5]							
		Toddlers (1.5 - 4.5 years)				Young people (4 - 18 years)			
		2006		2000		2006		2000	
		Mean	High-level	Mean	High-level	Mean	High-level	Mean	High-level
Aluminium	143	187	345	165	327	123	246	120 - 121	244 - 245
Antimony	6*	0.075 - 0.077	0.132 - 0.135	-	-	0.049 - 0.050	0.096 - 0.097	-	-
Arsenic (total)	-	2.71 -2.80	12.27 - 12.34	2.7	12	1.91 - 1.95	8.19 - 8.24	1.7	7.0
Arsenic (inorganic)	2.1	0.075 - 0.246	0.174 - 0.402	-	-	0.055 - 0.158	0.128 - 0.291	-	-
Cadmium	1	0.37 - 0.45	0.65 - 0.75	0.31 - 0.32	0.56	0.27 - 0.31	0.50 - 0.57	0.22	0.42
Chromium	150[‡]	0.81 - 1.03	1.38 -1.67	1.7	2.7-2.8	0.51 - 0.65	1.03 - 1.22	1.14 - 1.15	2.1
Copper	50 - 500;160[†]	44.71	77.82	46	81	29.41	54.92	30	56
Lead	3.5	0.21 - 0.25	0.38 - 0.42	0.25	0.47	0.13 - 0.15	0.26 - 0.30	0.17	0.32
Manganese	200[‡]	168	305	132	235	106	201	101	195
Mercury (methyl mercury)	0.23	0.04 -0.12	0.17 - 0.26	0.06 - 0.07	0.26 - 0.27	0.03 -0.08	0.11 - 0.18	0.04 - 0.05	0.15 - 0.16
Nickel	4.3[‡]	4.17 - 4.87	7.54 - 8.32	3.9	7.2	2.62 - 3.05	5.27 - 5.82	2.6	5.3
Selenium	5[†]	1.97 - 2.27	3.77 - 4.10	1.3 - 1.4	2.6 - 2.7	1.27 -1.44	2.60 -2.84	0.86 - 0.92	1.9 - 2.0
Tin	220[‡]	89.3 - 89.8	341.2 - 341.5	70	283	48.2 - 48.5	191.3 - 191.5	38	150
Zinc	300 - 1000	387.0	775.7	386	759	232.3	478.0	226	453

\# The numerical values shown are the tolerable daily intake for a 60 kg person derived from PTWIs or PMTDIs recommended by JECFA unless mentioned otherwise.

* TDI derived by WHO

‡ Expert Group on Vitamins and Minerals - guidance level

† Expert Group on Vitamins and Minerals - safe upper limit

<u>Notes for tables 5a and 5b</u>

1. Exposures have been estimated for the lower and upper bound concentrations and these have been included as ranges where they apply.

2. Consumption data taken from the National Diet and Nutrition Survey: adults aged 19 to 64 years. Volume 1: Types and quantities of foods consumed. Henderson L, Gregory J and Swan G. (2002). The Stationery Office, London and Gregory, J., Foster, K., Tyler, H. and Wiseman, M. (1990). The Dietary and Nutritional Survey of British Adults. The Stationery Office, London.

3. The exposure to elements by the mean and high-level (97.5%) consumer for all foods combined is not equal to the sum of the exposure from the individual food. It refers to the dietary exposure by a consumer consuming one or any combination of the foods containing the elements. These values are derived from a distribution of individual consumer's consumption patterns with regards to the individual foods.

4. Exposures have been estimated from upper bound mean concentrations only. Exposures have been converted into μg/kg bw/day (for a 70.1 kg adult) from the 1997 Total Diet Study – Aluminium, Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Tin and Zinc. Food Surveillance Information Sheet No. 191. Ministry of Agriculture, Fisheries and Food (1999). The Stationery Office, London.

5. All figures have been rounded off as appropriate.

6. Consumption data taken from the Dietary and Nutritional Survey of British Adults. J Gregory, K Foster, H Tyler, M Wiseman.(1990). The Stationery Office, London.

Table 6a. Comparison of population dietary exposures of aluminium (Al), antimony (Sb), arsenic (As), barium (Ba), bismuth (Bi), cadmium (Cd), chromium (Cr), copper (Cu), Germanium (Ge), Indium (In) and lead (Pb) from UK Total Diet Studies 1976 to 2006

Year	Population dietary exposure (mg/day)[1-3]											
	Al	Sb	Total As	Inorganic As	Ba	Bi	Cd	Cr	Cu	Ge	In	Pb
1976	n.d.	n.d.	0.075	n.d.	n.d.	n.d.	0.02	0.13	1.8	n.d.	n.d.	0.11
1977	n.d.	n.d.	0.1	n.d.	n.d.	n.d.	0.018	0.17	1.8	n.d.	n.d.	0.1
1978	n.d.	n.d.	0.081	n.d.	n.d.	n.d.	0.02	0.1	1.6	n.d.	n.d.	0.11
1979	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.017	n.d.	n.d.	n.d.	n.d.	0.09
1980	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.026	n.d.	n.d.	n.d.	n.d.	0.12
1981	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.019	n.d.	n.d.	n.d.	n.d.	0.08
1982	n.d.	n.d.	0.09	n.d.	n.d.	n.d.	0.018	n.d.	1.3	n.d.	n.d.	0.069
1983	n.d.	n.d.	0.07	n.d.	n.d.	n.d.	0.018	n.d.	1.2	n.d.	n.d.	0.067
1984	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.019	0.073	1.4	n.d.	n.d.	0.065
1985	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.018	n.d.	1.3	n.d.	n.d.	0.066
1986	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.017	n.d.	n.d.	n.d.	n.d.	0.06
1987	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.018	n.d.	n.d.	n.d.	n.d.	0.06
1988	3.9	n.d.	n.d.	n.d.	n.d.	n.d.	0.019	n.d.	n.d.	n.d.	n.d.	0.06
1991	10	n.d.	0.07	n.d.	n.d.	n.d.	0.018	0.25	1.4	n.d.	n.d.	0.028
1994	11	0.003	0.063	n.d.	0.58	0.0004	0.014	0.34	1.2	0.004	n.d.	0.024
1995	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1997	3.4	n.d.	0.065	n.d.	n.d.	n.d.	0.012	0.1	1.2	n.d.	n.d.	0.026
1999	n.d.	n.d.	0.05	0.0009 - 0.005	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2000	4.7	n.d.	0.055	n.d.	n.d.	n.d.	0.009	0.046	1.3	n.d.	n.d.	0.0073-0.0074
2006[4]	5.4	0.0025	0.061 - 0.064	0.0014 - 0.007	0.847 - 0.848	0.002	0.011 - 0.013	0.022 - 0.029	1.24	0.0001 - 0.0015	0.005 - 0.019	0.006 - 0.007

Table 6b. Comparison of population dietary exposures of manganese (Mn), mercury (Hg), molybdenum (Mo), nickel (Ni), palladium (Pd), platinum (Pt), rhodium (Rh), ruthenium (Ru), selenium (Se), strontium (Sr), thallium (Tl), tin (Sn) and zinc (Zn) from UK Total Diet Studies 1976 to 2006

Year	Population dietary exposure (mg/day)[1-3]												
	Mn	Hg	Mo	Ni	Pd	Pt	Rh	Ru	Se	Sr	Tl	Sn	Zn
1976	n.d.	0.005	n.d.	0.33	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	4.4	10
1977	n.d.	0.005	n.d.	0.26	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	4.2	10
1978	n.d.	0.005	n.d.	0.27	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	3.6	10
1979	n.d.	0.004	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	3.2	n.d.
1980	n.d.	0.005	n.d.	0.27	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1981	n.d.	n.d.	n.d.	0.23	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	2.4	n.d.
1982	n.d.	0.003	n.d.	0.15	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	3.1	10
1983	4.6	n.d.	n.d.	0.15	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	2.3	10
1984	5.3	n.d.	n.d.	0.16	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	2.7	10
1985	5.0	n.d.	0.11	0.14	n.d.	n.d.	n.d.	n.d.	0.063	n.d.	n.d.	1.7	10
1986	n.d.	n.d.	n.d.	0.13	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	2.2	n.d.
1987	n.d.	n.d.	n.d.	0.15	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	2.0	n.d.
1988	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1991	6.2	0.002	0.11	0.17	n.d.	n.d.	n.d.	n.d.	0.060	n.d.	n.d.	5.3	10
1994	4.9	0.004	0.11	0.13	0.001	0.0002	0.0003	0.004	0.043	1.3	0.002	2.4	8.4
1995	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.039[4]	n.d.	n.d.	n.d.	n.d.
1997	n.d.	0.003	n.d.	0.13	n.d.	n.d.	n.d.	n.d.	0.039	n.d.	n.d.	1.8	8.4
2000	4.9	0.0012-0.0015	n.d.	0.13	n.d.	n.d.	n.d.	n.d.	0.032-0.034	n.d.	n.d.	1.4	8.4
2006[4]	5.24	0.001 - 0.003	0.123 - 0.125	0.127 - 0.129	0.0007	0 - 0.0023	0 - 0.0023	0.00003 - 0.00081	0.048 - 0.058	1.20	0.0007 - 0.0008	1.80 - 1.81	8.8

Notes for tables 5a and 5b

1. The population dietary exposures in the previous years were estimated using upper bound mean concentrations for each food group and consumption data taken from the National Food Survey 1997, Ministry of Agriculture, Fisheries and Food (1998). The Stationery Office, London. The exception to this is the 2000 TDS where exposures have been estimated from the lower and upper bound mean concentrations and included as ranges where they apply.
2. Changes in the organisation of the TDS from 1981 onwards mean that exposures from TDSs before 1981 and from 1981 onwards are not directly comparable (Peattie, M.E., Buss, D.H., Lindsay, D.G. and Smart, G.Q. (1983). Reorganisation of the British Total Diet Study for Monitoring Food Constituents from 1981. *Food and Chemical Toxicology* **21**, 503-507).
3. For those years where no values are given, these elements were not included in TDSs for metals and other elements i.e. n.d.= not determined.
4. Dietary exposure estimates for the 2006 TDS and for selenium from the 1995 TDS and are not directly comparable with those from other years as they are based on analyses of composite samples of each food from all the towns in the TDS rather than the upper bound mean concentrations of analyses of each food group from each town.

Table 7a. Contribution (%) by each food group to total population dietary exposures to aluminium (Al), antimony (Sb), arsenic (As), barium (Ba), bismuth (Bi), cadmium (Cd), chromium (Cr), copper (Cu), germanium (Ge), indium (In) and lead (Pb) estimated from the 2006 UK TDS.

Food Group	Contribution to dietary exposure (%)											
	Al	**Sb**	**Inorganic As**	**Total As**	**Ba**	**Bi**	**Cd**	**Cr**	**Cu**	**Ge**	**In**	**Pb**
Bread	7	6	8	1	**10**	5	**19**	7	**14**	**15**	**11**	**16**
Miscellaneous cereals	**42**	**10**	**23**	4	**11**	6	**21**	**13**	**23**	**18**	**13**	**12**
Carcase meat	<1	1	2	<1	<1	<1	<1	2	2	1	1	1
Offals	<1	<1	<1	<1	<1	<1	<1	<1	2	<1	<1	<1
Meat products	3	**24**	5	<1	2	1	3	8	6	4	3	4
Poultry	<1	1	3	1	<1	<1	<1	1	1	1	1	1
Fish	<1	1	3	**88**	<1	<1	2	2	1	1	1	1
Oils and fats	<1	<1	2	<1	<1	1	1	2	<1	3	2	2
Eggs	<1	<1	1	<1	1	<1	<1	<1	1	1	1	1
Sugars and preserves	3	**10**	8	1	3	**14**	3	**16**	8	8	6	5
Green vegetables	1	1	2	<1	2	1	1	1	1	1	<1	2
Potatoes	2	2	8	1	2	3	**24**	**12**	**10**	5	4	4
Other vegetables	5	**20**	7	1	6	2	5	8	6	2	2	**16**
Canned vegetables	1	1	<1	<1	1	1	2	4	3	1	**16**	3
Fresh fruit	1	1	1	<1	4	1	1	2	5	2	1	2
Fruit products	1	1	2	<1	1	1	2	3	2	1	9	5
Beverages	**34**	**20**	**19**	2	5	**12**	**10**	**13**	7	**26**	**20**	**17**
Milk	<1	1	4	<1	2	**24**	2	3	1	5	4	3
Dairy products	1	1	4	<1	2	**25**	2	3	2	6	4	3
Nuts	<1	<1	<1	<1	**46**	<1	2	<1	2	<1	<1	<1
Total	100	100	100	100	100	100	100	100	100	100	100	100

Table 7b. Contribution (%) by each food group to total population dietary exposures to manganese (Mn), mercury (Hg), molybdenum (Mo), nickel (Ni), palladium (Pd), platinum (Pt), rhodium (Rh), ruthenium (Ru), selenium (Se), strontium (Sr), thallium (Tl), tin (Sn) and zinc (Zn) estimated from the 2006 UK TDS.

Food Group	Contribution to dietary exposure (%)												
	Mn	**Hg**	**Mo**	**Ni**	**Pd**	**Pt**	**Rh**	**Ru**	**Se**	**Sr**	**Tl**	**Sn**	**Zn**
Bread	**16**	**10**	**19**	**6**	**12**	**14**	**14**	**13**	**11**	**20**	7	<1	**12**
Miscellaneous cereals	**20**	**12**	**33**	**16**	**13**	**17**	**17**	**16**	**16**	**14**	6	<1	**14**
Carcase meat	<1	1	<1	<1	1	1	1	1	5	<1	1	<1	**15**
Offals	<1	<1	<1	<1	<1	<1	<1	<1	1	<1	<1	<1	<1
Meat products	3	4	4	3	5	4	4	4	**15**	3	5	<1	**16**
Poultry	<1	1	1	<1	1	1	1	1	6	<1	7	<1	4
Fish	<1	**25**	<1	<1	1	1	1	1	**10**	3	2	<1	1
Oils and fats	<1	2	<1	1	1	3	3	3	1	<1	1	<1	<1
Eggs	<1	1	1	<1	<1	1	1	1	4	<1	<1	<1	2
Sugars and preserves	2	6	3	**14**	2	8	8	7	3	5	4	<1	4
Green vegetables	1	<1	3	2	1	1	1	1	<1	5	6	<1	1
Potatoes	3	3	6	6	**11**	5	5	4	2	6	**19**	<1	4
Other vegetables	3	2	5	6	4	2	2	2	3	**10**	7	<1	3
Canned vegetables	1	1	6	9	2	1	1	1	1	2	1	**65**	1
Fresh fruit	2	1	1	2	<1	2	2	2	1	6	5	<1	1
Fruit products	5	1	<1	3	2	1	1	1	<1	3	2	**34**	<1
Beverages	**41**	**20**	2	**21**	**20**	**27**	**27**	**31**	**11**	7	**23**	<1	2
Milk	<1	4	7	1	1	5	5	6	6	6	2	<1	**10**
Dairy products	<1	5	4	3	21	5	5	5	4	6	2	<1	9
Nuts	1	<1	3	7	1	<1	<1	<1	2	4	<1	<1	1
Total	100	100	100	100	100	100	100	100	100	100	100	100	100

Note : The results for food group(s) given in bold are those which contribute 10% or more to the total production dietary exposure for each element. Percentage contribution to population dietary exposure was estimated using upper bound means only.

Table 8. Comparison of the estimated dietary exposures (µg/kilogram bodyweight/day) to arsenic (total and Inorganic) from previous TDSs

Population Group	Estimated total dietary exposure to arsenic (µg/kilogram bodyweight/day) [1, 2]						Estimated total dietary exposure to Inorganic arsenic (µg/kilogram bodyweight/day) [1, 2]			
	Mean			High level			Mean		High level	
	1999 TDS[3]	2000 TDS	2006 TDS	1999 TDS[3]	2000 TDS	2006 TDS	1999 TDS[3]	2006 TDS	1999 TDS[3]	2006 TDS
Adults	1.30	1.5 - 1.6	1.65 - 1.68	4.37	5.8	6.83 - 6.85	0.02 - 0.08	0.03 - 0.09	0.05 - 0.10	0.07 - 0.17
Toddlers (1.5-4.5 years)	2.43 - 2.46	2.7	2.71 - 2.80	11.31 - 11.34	12	12.27 - 12.34	0.05 - 0.20	0.08 - 0.25	0.10 - 0.30	0.17 - 0.40
Young people (4-18 years)	1.60 - 1.61	1.7	1.91 - 1.95	6.65 - 6.66	7.0	8.19 - 8.24	0.03 - 0.10	0.06 - 0.16	0.08 - 0.20	0.13 - 0.29
Elderly (free living)	1.60 - 1.61	1.7	1.72 - 1.75	5.33 - 5.34	5.6	6.40 - 6.43	0.02 - 0.07	0.02 - 0.08	0.04 - 0.10	0.07 - 0.15
Elderly (Institutional)	1.44 - 1.46	1.6	1.18 - 1.20	4.62 - 4.64	4.9	5.02 - 5.05	0.02 - 0.09	0.03 - 0.07	0.05 - 0.10	0.08 - 0.17
Vegetarians[4]	1.24 - 1.25	1.4	1.56 - 1.59	6.98 - 6.99	7.4	8.68 - 8.70	0.02 - 0.07	0.04 - 0.10	0.05 - 0.10	0.08 - 0.16

Notes

1. Exposures have been estimated for the lower and upper bound concentrations and these have been included as ranges where they apply.
2. The dietary exposure (mean and high level) for all foods combined is not equal to the sum of the exposure from the individual food. It refers to the dietary exposure by a consumer consuming one or any combination of the foods containing metals. These values are derived from a distribution of the individual consumer’s consumption patterns with regard to individual foods.
3. Food Standards Agency. 1999 Total Diet Study: Total and inorganic arsenic in food. *Food Surveillance Information Sheet* **51/04**.
4. Some of the vegetarian respondents were consumers of fish.