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2000 Total Diet Study of 12 elements – aluminium, arsenic, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, tin and zinc

The Food Standards Agency has completed a survey of metals and other elements in the 2000 UK Total Diet Study (TDS). This will allow exposure trends to these elements in the typical UK diet to be identified through comparisons with previous TDSs together with identifying the main dietary sources. The results from this survey have been used to estimate dietary exposures to these metals and other elements for UK consumers and provide up to date information on the concentrations in foods.

The key facts 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 1997, with the exception of aluminium and mercury.
- Population exposures to the elements have generally declined over the course of the TDS programme, with exposures to most of these elements now at the lowest level.
- The independent Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT) evaluated the results of this survey and concluded that exposures to aluminium, cadmium, chromium, copper, manganese, nickel, selenium, tin and zinc for each consumer group are unlikely to be of any toxicological concern.
- The Committee also noted that the dietary exposure to arsenic identified in the survey was unlikely to constitute a hazard to health, and that the downward trend for total arsenic was reassuring.
- The Committee looked carefully at consumer exposure to mercury. Comparison of total dietary mercury exposure with the Provisional Tolerable Weekly Intake for methylmercury is highly precautionary, and the COT concluded that the exposures were not of toxicological concern.
- The Committee concluded that dietary exposures to lead are unlikely to result in adverse effects, but that efforts should continue to reduce exposure to lead from all sources.

Background

The metals and other elements in this survey can be present in food adventitiously as a result of human activity, such as cadmium from phosphate fertilisers and lead from industrial pollution, or from natural sources. Although some of these metals and elements are essential, such as copper, chromium, selenium and zinc, all are potentially harmful depending on the exposure.

Metals and other elements may enter the food chain at any point from 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 (inhalation, occupational exposure etc.). 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 an important part of the UK Government's surveillance programme for chemicals in food and has been carried out on a continuous annual basis since 1966. Results from the TDS are used to estimate dietary exposures of the general UK population to chemicals in food, such as nutrients and contaminants, to identify trends in exposure and make assessments on the safety and quality of the food supply.

The design of the UK TDS has been described in detail elsewhere[1] and involves 119 categories of foods combined into 20 groups of similar foods 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)[1, 2].

The foods making up the 20 groups were obtained from retail outlets in 24 towns throughout the UK in the TDS for 2000. The mean element concentrations for each food group are 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. Analysis for metals and other elements in the TDS are carried out every 3 years.

Brand names

Brand names are not available as TDS samples are composites of foods of different types and 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 thoroughly homogenised and stored frozen at –20^{o}C until required for analysis.

Analysis

Analyses were carried out by the Laboratory of the Government Chemist (LGC). A UKAS (United Kingdom Accreditation Service) validated method was used to analyse 480 composite and 20 bulked samples provided from the 2000 TDS.

Samples were digested with concentrated acid using a high-pressure microwave digestion unit, followed by simultaneous determination of metals and other elements using inductively coupled plasma mass spectrometry (ICP-MS). Quantification of the element concentrations were made by direct comparison against NIST (National Institute of Standards and Technology) traceable standard solution calibrants.

Quality Control

The limit of detection (LOD) is the concentration below which an element cannot be accurately measured. LODs were calculated using the 99% confidence limits of the standard deviation of measured values for reagent blanks, analysed simultaneously with

the samples, corrected for typical sample weight and dilution. The LODs achieved are presented in Table 1.

Additional information on methods and quality control criteria used can be found in more detail in the contractor's final report[3].

Results

A summary of the mean concentrations of metals and other elements in each food group is given in Table 2. Results are expressed as lower bound and upper bound means; 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 mean 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 means are equal) or because the difference between them is negligible.

Dietary exposures were estimated for average and high level consumers in different age groups and for vegetarians and for the average UK population (i.e. both consumer and population dietary exposures). Population exposure estimates 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 in concentrations of elements in these foods. Consumer exposures for each food group are estimates of 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 (i.e. 97.5th percentile consumers). Total consumer dietary exposures are derived from a distribution of the individual consumer's exposure patterns with regard to individual foods.

Consumer exposure estimates

Mean and high level dietary exposures to the twelve elements from the TDS were estimated for adults (16 – 64 years), toddlers (1.5 – 4.5 years), young people (4 – 18 years), elderly (over 64 years, free living and institutional) and vegetarians (including some who consume fish) using consumption data from the relevant National Diet and Nutrition Survey (NDNS)[4,5]. 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. Consumer dietary exposures are expressed on a microgram per kilogram body weight per day basis and are summarised in Tables 3a and 3b. A comparison of intakes by adult consumers calculated from the 1997 and 2000 survey results is shown in table 4.

Population exposure

Population dietary exposures have been estimated by multiplying the amounts of food consumed (based on consumption data from the National Food Survey from 1996 to 1998) [6-8] by the corresponding upper and lower bound mean elemental concentration in each food group. Comparisons of population dietary exposure for each element from the UK TDS from 1976 to 2000 are given in Table 5 as upper bound means only (previously only upper bound means have been consistently recorded). 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 Table 6.

Dietary exposures were compared against the reference nutrient intake (RNI) from the Dietary Reference Values (DRV) where these are available.

Estimates of dietary exposure were compared with available tolerable intakes, such as Provisional Tolerable Weekly Intakes (PTWIs) set by the Joint FAO/WHO Expert Committee on Food Additives (JECFA), taking into account previous COT evaluations. The COT evaluation was also informed by a summary of the toxicological data on these metals. The PTWI is used by JECFA in identifying tolerable intakes of food contaminants with cumulative properties. Within this statement, the PTWI has been divided by 7 to provide a tolerable daily intake for comparison with the estimated daily dietary exposures.

The concentrations detected and dietary exposures for each element are discussed in detail below.

Aluminium

Most food groups had aluminium concentrations lower or similar to those reported in the 1997 TDS[9] with the exception of The Miscellaneous Cereals, Sugar and Preserves and Nuts groups. The Miscellaneous Cereals group was reported with the highest mean concentration of aluminium (19 milligrams per kilogram) increasing by three fold from the 1997 TDS[9]. Since the Miscellaneous Cereals groups is the most significant contributor to the population dietary exposure (45%) (Table 6), dietary exposures have also increased from previous surveys by about a third, but were considerably lower than reported in 1994[10] (11 milligrams per day) (Table 5). However, the relatively high aluminium concentrations found in the Miscellaneous Cereals group might be attributed to the presence of aluminium-containing additives which are permitted for use in some bakery products included in this group. The variation in concentrations from previous surveys may be due to different practices involving the use of these additives[11, 12] the different proportion of foods in the group, or, the purchase of different products by the buyer.

The estimated mean and high-level dietary exposures to aluminium for each consumer group were within the JECFA PTWI equivalent to 1000 micrograms per kilogram body weight per day and the COT concluded that these exposures “are unlikely to be of any toxicological concern”.

Arsenic

The Fish group contained considerably higher arsenic concentrations than any other food group (3.4 milligrams per kilogram), although concentrations were similar to those reported for total arsenic in fish in the 1999 TDS[13] (3.2 milligrams per kilogram) and lower than reported in 1997 TDS[9] (4.4 milligrams per kilogram). The Poultry group contained the second highest concentration (0.043 milligrams per kilogram) (Table 2). This was almost half that reported in the 1999 TDS[13] (0.073 milligrams per kilogram).

The population dietary exposure to total arsenic estimated from the 2000 TDS (0.055 milligrams per day) was lower than for the 1997 TDS[9] (0.065 milligrams per day) (Table 5). This is because the arsenic in the Fish group, which is the most significant contributor to dietary arsenic exposure, is lower than that found in the 1997 TDS. As a consequence, fish contributed 83% to arsenic dietary exposure compared to 94% in 1997 TDS[9]. Miscellaneous Cereals made the second most significant contribution accounting for 4% of arsenic dietary exposure (Table 6).

The COT has concluded previously, when considering 1999 TDS of Total and Inorganic Arsenic[13], that there are no relevant tolerable intakes or reference doses by which to assess safety of either inorganic or organic arsenic in the diet. Inorganic arsenic is genotoxic and a known human carcinogen and therefore exposure should be as low as reasonably practicable (ALARP)[14]. Table 7 shows the comparison of estimated dietary exposures to arsenic from the 1999 and 2000 TDS. The COT noted that the data on inorganic arsenic appeared to be consistent with dietary exposure being ALARP, that the dietary exposure to organic arsenic identified in the survey was unlikely to constitute a hazard to health, and that the downward trend for total arsenic was reassuring.

Cadmium

Cadmium is present at low concentrations in most foods, with those that are consumed in larger quantities making the greatest contribution to the dietary exposure. Cadmium concentrations were highest in the Nuts (0.06 milligrams per kilogram) and Offal (0.041 milligrams per kilogram) groups (Table 2) in line with previous years, while Potatoes (31%), Bread (17%) and Miscellaneous Cereals (17%) made the greatest contribution to population dietary exposure (Table 6).

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 were within the JECFA PTWI equivalent to 1 micrograms per kilogram body weight per day[15] and the COT concluded that these exposures “are unlikely to be of any toxicological concern”.

Chromium

The Fish group contained the highest mean chromium concentration (0.11 milligrams per kilogram), but the Potato and Miscellaneous Cereal groups made the greatest contributions (16% and 15% respectively) to population dietary exposure because of the higher levels of consumption of these food groups (Table 6). Chromium concentrations in general have decreased since the 1997 TDS, which is reflected by the population dietary

exposure halving (from 0.1 milligrams per day in 1997 to 0.046 milligrams per day in 2000, Table 5).

Although there is no RNI (Reference Nutrient Intake) for chromium, a safe and 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[16]. The dietary exposures reported are above these values for adults, adolescents and children and are well below the Expert Group on Vitamins and Minerals (EVM) safe upper level of 150 micrograms per kilogram body weight per day for total dietary intake of trivalent chromium[17]. The COT concluded that these exposures “are unlikely to be of any toxicological concern”.

Copper

Copper is present in most foods, with the Offal (40 milligrams per kilogram) and Nuts (12 milligrams per kilogram) groups containing the highest mean concentrations. The mean concentrations in the other groups ranged from 0.06 milligrams per kilogram (Milk group) to 2.8 milligrams per kilogram (Sugar and Preserves group) as shown in Table 2. In general, the concentrations reported are similar to those reported in the 1997 TDS[9].

Miscellaneous Cereals made the most significant contribution (15%) to population dietary exposure to copper, followed by the Sugar and Preserves group (14%) (Table 6).

The population dietary exposure (1.3 milligrams per day) has changed only marginally since 1982 (Table 5). The estimated copper dietary exposures for all age groups and vegetarians are well below the JECFA PMTDI of 500 micrograms per kilogram body weight per day[18] and the EVM Safe Upper Level of 160 micrograms per kilogram body weight per day for total dietary intake[17]. The COT concluded that these exposures “are unlikely to be of any toxicological concern”.

Lead

Food is one of the major sources of lead exposure in the UK. Continuing the trend over the last few years, lead concentrations in all the food groups have decreased. The Offal group had the highest mean lead concentration (0.035 milligrams per kilogram), whilst the Miscellaneous Cereals group made the greatest contribution to the population dietary exposure (21%). The Potatoes and Sugar and Preserves groups closely follow, contributing 12% each (Table 6).

The decrease in lead concentrations in food due to the commitment by the UK and the European Commission to reduce lead exposure (e.g. the phase-out of leaded petrol, etc.) has resulted in the steady decrease in the population dietary exposure to lead since 1980.

Similarly, dietary exposures for mean and high level adult consumers decreased significantly from 0.34 micrograms per kilogram body weight per day and 0.61 micrograms per kilogram body weight per day respectively in 1997, to 0.1 microgram per kilogram body weight per day and 0.18 micrograms per kilogram body weight per day in 2000 (Table 4).

All the reported dietary exposures in this survey are below the JECFA PTWI equivalent to 3.6 micrograms per kilogram body weight per day[19]. Therefore, the dietary exposures to lead identified from the 2000 TDS are unlikely to represent a toxicological concern. The COT confirmed its previous opinion that, because it had not been possible to identify a threshold for the effects of lead, efforts should continue to reduce exposure from all sources[20].

Manganese

Manganese is present in most foods with the highest mean concentration found in the Nuts (26 milligrams per kilogram) and Bread (6.4 milligrams per kilogram) groups. Mean concentrations in other groups ranged from 0.03 milligrams per kilogram (Oils and Fats and Milk groups) to 6.3 milligrams per kilogram (Miscellaneous Cereals group) as shown in Table 2. The concentrations reported are very similar to those reported in the 1994 TDS[10] with the exception of the concentration of manganese in the Nuts group, which almost doubled from the 1994 TDS[10] (15 milligrams per kilogram). Consequently, the population dietary exposure was similar to that reported in 1994, 4.9 milligrams per day, as shown in Table 5. The COT noted that there is currently insufficient information to determine

whether there are risks associated with dietary exposure to manganese and no available safety guideline. However, it concluded that there is no basis for assuming that the current dietary exposure to manganese is a concern for health to consumers.

Mercury

The main sources of exposure to mercury are from the diet and dental amalgam. Mercury is present in most foods naturally, and concentrations found in this survey ranged from 0.0001 milligrams per kilogram (for the Canned Vegetables, Fresh Fruit, Fruit Products, Beverages and Milk groups) to 0.071 milligrams per kilogram (for the Fish group) (Table 2). Mercury concentrations were similar or lower than those reported in the 1997 TDS[9] except for the Fish group, in which the mean level was just over a third higher (0.071 milligrams per kilogram compared to 0.043 milligrams per kilogram). The Fish group contributed 65% of the population dietary exposure to mercury (Table 6).

Mercury can exist in inorganic and organic forms in food, with the organic forms, such as methylmercury, being more toxic following ingestion. With the exception of high-level consumption by children aged 1.5-4.5 years, the estimates of dietary exposure to mercury (mean and high-level) for all consumer groups were within the PTWI for methylmercury set by JECFA in 2003 to protect against neurodevelopmental effects (equivalent to 0.23 micrograms per kilogram body weight per day)[21]. While the estimate for high-level consumption by children aged 1.5-4.5 years exceeded the JECFA PTWI for methylmercury by 17%, it is highly unlikely that all the mercury in the diet is in the form of methylmercury. Inorganic mercury is less well-absorbed than methylmercury by the oral route, and therefore comparing dietary exposure to total mercury to the PTWI for methylmercury is a worst case scenario. Furthermore, the COT has previously noted that toddlers are likely to be less sensitive to the neurodevelopmental effects of methylmercury than the fetus or infant[22]. Therefore, it concluded that the dietary exposures to mercury do not give rise to toxicological concerns for consumers. The Committee also noted that the population exposures to mercury have decreased since 1976 (0.005 milligrams per day), with the current dietary exposure at its lowest level (0.0015 milligrams per day).

Nickel

Nickel is present in most foods, with concentrations varying from 0.007 milligrams per kilogram for the Eggs group to 2.9 milligrams per kilogram for the Nuts group (Table 2). With a few exceptions, nickel concentrations in most food groups were similar or lower than those reported in the 1997 TDS[9].

The Sugar and Preserves group with nickel concentrations of 0.49 milligrams per kilogram contributed the most (25%) to the population nickel dietary exposure, which was estimated as 0.13 milligrams per day, the same as that previously reported in 1994 and in 1997 (Table 5). Mean and high level adult dietary exposures to nickel were 1.5 micrograms per kilogram body weight per day and 2.9 micrograms per kilogram body weight per day respectively, slightly lower than reported in 1997 (Table 4).

Population exposures to nickel have decreased since 1976 (0.33 milligrams per day), with the current dietary exposure at its lowest level (0.13 milligrams per day). The estimates of dietary exposures to nickel for high-level consumers aged 1.5-4.5 years and 4-18 years marginally exceeded the WHO TDI (5 micrograms per kilogram body weight per day)[23]. Taking into account the low toxicity of nickel, and the precautionary nature of the TDI, the COT concluded that the estimated nickel exposures were “unlikely to result in any adverse health effects”.

Selenium

Selenium was detected in all food groups ranging from 0.46 milligrams per kilogram for the Offal group to 0.001 milligrams per kilogram for Fresh Fruit, Fruit Products and Beverages groups. The Bread group (19%) and the Meat Products group (14%) made the greatest contribution to the population dietary exposure (Table 6). Selenium concentrations in most food groups were similar to or lower than those reported in the 1997 TDS[9] with Miscellaneous Cereals being reported as four times lower (0.002 – 0.012 milligrams per kilogram) than in the previous survey (0.039 milligrams per kilogram).

A continuing decline in the population dietary exposure was also observed (0.032 – 0.034 milligrams per day) for this TDS compared to that for previous years (e.g. 0.039 milligrams per day, 0.043 milligrams per day and 0.063 milligrams per day in 1997, 1994 and 1985

respectively) (Table 5). The reported estimated exposures were below the WHO upper limit of the safe range (400 micrograms per day for adults only)[24] and the EVM Safe Upper Level of 220 micrograms per kilogram body weight per day for total dietary intake[17]. The COT evaluated these exposures and concluded that these “are unlikely to be of any toxicological concern”.

Tin

Most foods contain very low concentrations of tin, although canned foods may contain higher concentrations as a result of the slow dissolution of the tin coating used on the inside of some food cans to protect the steel body of the can. Tin concentrations in most food groups were below 0.1 milligrams per kilogram, except for the Canned Vegetables (25 milligrams per kilogram), Fruit Products (11 milligrams per kilogram) and Meat Products (0.13 milligrams per kilogram) groups, which also include some canned products (Table 2). These concentrations are considerably lower than reported in a previous survey of tin in canned fruit and vegetables (mean 44 milligrams per kilogram)[25]. Canned Vegetables (61%) and Fruit Products (37%) also made the greatest contribution to the population dietary exposure to tin (Table 6).

The population dietary exposure was estimated as 1.4 milligrams per day, lower than in the previous TDS[9] (1.8 milligrams per day) (Table 5). The estimates of dietary exposures to tin for high-level consumers aged 1.5 - 4.5 years were lower than the PTWI of 2000 micrograms per kilogram body weight per day[26], but exceeded the EVM guidance level of 220 micrograms per kilogram body weight per day[17]. The COT noted that the EVM guidance level is more applicable than the PTWI to long term dietary exposures. However, taking into account the precautionary approach of the EVM, the committee concluded that the small exceedance of this guidance level is within an area of uncertainty, but is not expected to result in adverse effects.

Zinc

Zinc is an essential element for human health, and is present in all foods reported in this survey with concentrations ranging from 0.23 milligrams per kilogram for the Beverages

group to 55 milligrams per kilogram for the Carcase Meat group (Table 2). Zinc concentrations were very similar to those reported in the 1997 TDS[9]. Milk contributes 15% of the population dietary exposure whilst the Meat Products and Carcase Meat groups each contribute 14% (Table 6).

The population dietary exposure was 8.4 milligrams per day, the same as that reported in the 1997 TDS[9] (Table 5). This is in good agreement with dietary exposures reported by a FSA survey on vitamins and minerals, with mean intakes for men of 10.2 milligrams per day and for women 7 milligrams per day[27].

The estimated dietary exposure for all consumer groups were within the JECFA Provisional Maximum Tolerable Daily Intake (PMTDI) of 1000 micrograms per kilogram body weight per day[28]. The Committee on Toxicity concluded that the estimated zinc intakes were unlikely to result in any adverse health effects.

Review of the results by the COT

The COT was asked to consider the results of this survey. Its conclusions are summarised below.

- Current dietary exposures to aluminium, cadmium, chromium, copper, mercury, nickel, selenium, tin and zinc are unlikely to be of any toxicological concern for consumers.

- The survey measured total arsenic only, but the data appear consistent with a survey of total and inorganic arsenic in food, which the Committee reviewed recently. It reaffirms its previous conclusions that current dietary exposure to organic arsenic is unlikely to constitute a hazard to health, and exposure to inorganic arsenic should be as low as reasonably practicable (ALARP).

- Estimates of total exposure to lead, including that from the diet, do not exceed the PTWI. The Committee concludes that current dietary intakes are unlikely to result in adverse effects, but that efforts should continue to reduce exposure to lead from all sources.

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

- In future surveys of elements in food, priority should be given to those of greatest toxicological concern, such as arsenic, mercury and lead. Speciation of metals such as mercury, arsenic and chromium would be helpful for the risk assessment.

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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. Limits of detection

Element	2000 Total Diet Study LOD / mg/kg
Aluminium	0.0006 – 0.013
Arsenic	0.0002 – 0.003
Cadmium	0.0001 – 0.0013
Chromium	0.0005 – 0.011
Copper	0.0003 – 0.006
Lead	0.0001 – 0.0012
Manganese	0.0001 – 0.0021
Mercury	0.00005 – 0.001
Nickel	0.0002 – 0.004
Selenium	0.0005 – 0.011
Tin	0.0001 – 0.0016
Zinc	0.0003 – 0.006

Notes

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

Table 2. Lower and upper bound mean concentrations of aluminium, arsenic, cadmium, chromium, copper, lead, manganese, mercury, nickel, selenium, tin and zinc in the 20 food groups of the 2000 UK Total Diet Study

Food Group	Mean concentrations (mg/kg fresh weight)											
	Al	As	Cd	Cr	Cu	Pb	Mn	Hg	Ni	Se	Sn	Zn
Bread	2.8	0.009	0.015	0.031	1.4	0.007	6.4	0.0005-0.0006	0.053	0.06	0.006	8.2
Miscellaneous Cereals	19	0.021	0.014	0.06	1.7	0.013	6.3	0.0003-0.0012	0.12	0.002-0.012	0.03	7.3
Carcase Meat	0.24	0.012	0.001	0.052	1.6	0.001	0.13	0.0009-0.001	0.01	0.1	0.008	55
Offal	0.25	0.02	0.041	0.037	40	0.035	2.9	0.003	0.022	0.46	0.007	46
Meat Product	2.3	0.01	0.007	0.084	1.6	0.006	1.5	0.0008-0.0009	0.066	0.1	0.13	26
Poultry	0.16	0.043	0.001	0.083	1.3	0.001	0.17	0.0005-0.0006	0.021	0.2	0.003	17
Fish	2.8	3.4	0.013	0.11	1.1	0.014-0.015	1.1	0.071	0.065	0.32	0.028	8.3
Oils & Fats	0.98	0.016	0.001-0.002	0.10-0.11	0.11	0.003-0.004	0.03	0-0.001	0.026-0.027	0.001-0.011	0.004-0.005	0.38
Eggs	0.03	0.002-0.003	0.0001-0.0003	0.041	0.49	0.0001-0.0004	0.28	0.0001-0.0003	0.007	0.14	0.0002-0.0005	11
Sugar & Preserves	4.1	0.014	0.011	0.079	2.8	0.014	2.5	0.0002-0.0003	0.49	0.006-0.007	0.055	8.1
Green Vegetables	1.1	0.002	0.014	0.008	0.88	0.011	2.3	0.0001-0.0002	0.083	0.005	0.0009	3.5
Potatoes	1.1	0.002	0.025	0.063	1.1	0.003	1.7	0-0.0003	0.075	0.001-0.005	0.001	3.2
Other Vegetables	1.5	0.007	0.009	0.016	0.96	0.011	1.3	0.0001-0.0002	0.044	0.015	0.008	2.4
Canned Vegetables	0.91	0.002	0.005	0.03	1.2	0.004	1.8	0-0.0001	0.31	0.012	25	3.8
Fresh Fruits	0.3	0.001	0.001	0.003	1.2	0.002	3.2	0.0001	0.032	0-0.001	0.012	0.87
Fruit Products	1.1	0.001	0.001	0.025	0.64	0.01	4.2	0.0001	0.064	0-0.001	11	0.71
Beverages	1.4	0.001	0.00015-0.00019	0.005	0.1	0.001	2.2	0-0.0001	0.027	0-0.001	0.001	0.23
Milk	0.02	0.002	0.00007-0.0001	0.005	0.06	0.001	0.03	0-0.0001	0.008	0.012	0.0008-0.0009	4.8
Dairy Products	0.55	0.006	0.001-0.002	0.026	0.52	0.001-0.002	0.22	0-0.0005	0.041	0.019-0.021	0.034	11
Nuts	5.7	0.029	0.06	0.077	12	0.012	26	0.0002-0.0011	2.9	0.37	0.022	39

All figures have been rounded off as appropriate.

Table 3a. Estimated total consumer dietary exposure to aluminium, arsenic, cadmium, chromium, copper and lead from the 2000 Total Diet Study

Population Group	Estimated dietary exposure (µg/kilogram bodyweight/day) [1-4]											
	Al		As		Cd		Cr		Cu		Pb	
	Mean	High-level	Mean	High-level	Mean	High-level	Mean	High-level	Mean	High-level	Mean	High-level
Adults	67-68	134-135	1.5-1.6	5.8	0.12	0.21	0.66-0.67	1.0-1.1	18	33	0.1	0.18
Toddlers (1.5-4.5 years)	165	327	2.7	12	0.31-0.32	0.56	1.7	2.7-2.8	46	81	0.25	0.47
Young people (4-18 years)	120-121	244-245	1.7	7.0	0.22	0.42	1.14-1.15	2.1	30	56	0.17	0.32
Elderly (free living)	59	126-127	1.7	5.6	0.12	0.21	0.60-0.61	0.98-0.99	18	40	0.094-0.095	0.17
Elderly (Institutional)	81-82	162-163	1.6	4.9	0.14	0.24	0.72	1.1	20	41	0.12	0.19
Vegetarians[5]	71-72	133-134	1.4	7.4	0.13	0.23	0.55	0.92-0.93	16	29	0.1	0.18-0.19

Notes

1. Exposures have been estimated from a range (lower - upper bound) of mean 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 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 patter with regards to the individual foods.

4. All figures have been rounded off as appropriate.

5. Some of the vegetarian respondents were consumers of fish.

Table 3b. Estimated total consumer dietary exposure to manganese, mercury, nickel, selenium, tin and zinc from the 2000 Total Diet Study

Population Group	Estimated dietary exposure (µg/kilogram bodyweight/day) [1-4]											
	Mn		Hg		Ni		Se		Sn		Zn	
	Mean	High-level	Mean	High-level	Mean	High-level	Mean	High-level	Mean	High-level	Mean	High-level
Adults	67	118	0.03-0.04	0.12-0.13	1.5	2.9	0.63-0.67	1.2-1.3	20	70	141	252
Toddlers (1.5-4.5 years)	132	235	0.06-0.07	0.26-0.27	3.9	7.2	1.3-1.4	2.6-2.7	70	283	386	759
Young people (4-18 years)	101	195	0.04-0.05	0.15-0.16	2.6	5.3	0.86-0.92	1.9-2.0	38	150	226	453
Elderly (free living)	57	100	0.04	0.12	1.3	2.5	0.57-0.60	1.1	17	76	133	250
Elderly (Institutional)	67	113	0.03-0.04	0.11-0.12	1.6	2.8	0.57-0.62	1.0-1.1	17	61	156	250
Vegetarians[5]	65	123	0.03	0.16	1.5	3.0	0.36-0.40	0.94-0.98	26	101	84	149

Notes

1. Exposures have been estimated from a range (lower - upper bound) of mean 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 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.

4. All figures have been rounded off as appropriate.

5. Some of the vegetarian respondents were consumers of fish.

Table 4. Comparison of the mean and high-level exposures of metals and other elements by adult consumers from the 2000 and 1997 Tota Diet Study

Element	2000 Total Dietary Exposure (mg/kg bw/day) [1-3,5]		1997 Total Dietary Exposure (mg/kg bw/day) [3-6]	
	Mean	High-level	Mean	High-level
Aluminium	67-68	134-135	45.6	81.3
Arsenic[7]	1.5-1.6	5.8	1.71	6.00
Cadmium	0.12	0.21	0.20	0.34
Chromium	0.66-0.67	1.0-1.1	1.43	2.43
Copper	18	33	20.0	45.6
Lead	0.1	0.18	0.34	0.61
Manganese	67	118	-	-
Mercury	0.03-0.04	0.12-0.13	0.04	0.09
Nickel	1.5	2.9	1.71	3.00
Selenium	0.63-0.67	1.2-1.3	0.77	1.43
Tin	20	70	27.1	89.9
Zinc	141	252	157	286

Notes

1. Exposures have been estimated from a range (lower - upper bound) of mean 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 th dietary exposure by a consumer consuming one or any combination of the foods containing the elements. These values are derived from a distribution of the 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 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.

7. Consumer dietary exposure to arsenic is also shown in Table 7 compared to values from the 1999 Total Diet Study.

Table 5. Comparison of population dietary exposures of aluminium (Al), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), manganese (Mn), mercury (Hg), nickel (Ni), selenium (Se), tin (Sn) and zinc (Zn) from UK Total Diet Studies 1976 to 2000

Year	Population dietary exposure (mg/day)[1-3]											
	Al	As	Cd	Cr	Cu	Pb	Mn	Hg	Ni	Se	Sn	Zn
1976	n.d.	0.075	0.02	0.13	1.8	0.11	n.d.	0.005	0.33	n.d.	4.4	10
1977	n.d.	0.1	0.018	0.17	1.8	0.1	n.d.	0.005	0.26	n.d.	4.2	10
1978	n.d.	0.081	0.02	0.1	1.6	0.11	n.d.	0.005	0.27	n.d.	3.6	10
1979	n.d.	n.d.	0.017	n.d.	n.d.	0.09	n.d.	0.004	n.d.	n.d.	3.2	n.d.
1980	n.d.	n.d.	0.026	n.d.	n.d.	0.12	n.d.	0.005	0.27	n.d.	n.d.	n.d.
1981	n.d.	n.d.	0.019	n.d.	n.d.	0.08	n.d.	n.d.	0.23	n.d.	2.4	n.d.
1982	n.d.	0.09	0.018	n.d.	1.3	0.069	n.d.	0.003	0.15	n.d.	3.1	10
1983	n.d.	0.07	0.018	n.d.	1.2	0.067	4.6	n.d.	0.15	n.d.	2.3	10
1984	n.d.	n.d.	0.019	0.073	1.4	0.065	5.3	n.d.	0.16	n.d.	2.7	10
1985	n.d.	n.d.	0.018	n.d.	1.3	0.066	5.0	n.d.	0.14	0.063	1.7	10
1986	n.d.	n.d.	0.017	n.d.	n.d.	0.06	n.d.	n.d.	0.13	n.d.	2.2	n.d.
1987	n.d.	n.d.	0.018	n.d.	n.d.	0.06	n.d.	n.d.	0.15	n.d.	2.0	n.d.
1988	3.9	n.d.	0.019	n.d.	n.d.	0.06	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
1991	10	0.07	0.018	0.25	1.4	0.028	6.2	0.002	0.17	0.060	5.3	10
1994	11	0.063	0.014	0.34	1.2	0.024	4.9	0.004	0.13	0.043	2.4	8.4
1995	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.039[4]	n.d.	n.d.
1997	3.4	0.065	0.012	0.1	1.2	0.026	n.d.	0.003	0.13	0.039	1.8	8.4
2000	4.7	0.055	0.009	0.046	1.3	0.0073-0.0074	4.9	0.0012-0.0015	0.13	0.032-0.034	1.4	8.4

Notes

1. Population dietary exposures have been estimated using upper bound mean concentrations for each food group and consumption data taken from the National Food Survey 1996, 1997 and 1998, Ministry of Agriculture, Fisheries and Food (1997, 1998 and 1999 respectively). 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 selenium from the 1995 TDS 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 6. Contribution (%) by each food group to total population dietary exposures to aluminium, arsenic, cadmium, chromium, copper, mercury, manganese, nickel, lead, selenium, tin and zinc estimated from the 2000 UK Total Diet Study

Food Group	Contribution to dietary exposure (%)											
	Al	As	Cd	Cr	Cu	Pb	Mn	Hg	Ni	Se	Sn	Zn
Bread	7	2	**17**	7	**12**	**10**	**14**	4	5	**19**	<1	**10**
Miscellaneous Cereals	**45**	4	**17**	**15**	**15**	**21**	**14**	9	**11**	4	<1	**10**
Carcase meat	<1	<1	<1	2	3	<1	<1	1	<1	6	<1	**14**
Offal	<1	<1	<1	<1	2	<1	<1	<1	<1	1	<1	<1
Meat products	2	1	4	9	6	4	1	3	2	**14**	<1	**14**
Poultry	<1	2	<1	4	2	0	<1	1	<1	**12**	<1	4
Fish	1	**83**	2	3	1	3	<1	**65**	1	**13**	<1	1
Oils and fats	1	1	<1	5	<1	1	<1	2	1	1	<1	<1
Eggs	<1	<1	<1	1	<1	<1	<1	<1	<1	5	<1	2
Sugar & preserves	5	2	7	**11**	**14**	**12**	3	1	**25**	1	<1	6
Green vegetables	1	<1	5	1	2	5	2	<1	2	1	<1	1
Potatoes	3	<1	**31**	**16**	**10**	4	4	2	7	2	<1	4
Other vegetables	3	1	8	3	6	**12**	2	1	3	3	<1	2
Canned vegetables	1	<1	2	2	3	2	1	<1	9	1	**61**	2
Fresh fruit	<1	<1	1	1	7	2	5	1	2	<1	<1	1
Fruit products	1	<1	<1	3	2	7	4	<1	3	<1	**37**	<1
Beverages (no mineral water)	**30**	1	2	**11**	8	**13**	**47**	4	**22**	2	<1	3
Milk	<1	1	<1	3	1	2	<1	2	2	**10**	<1	**15**
Dairy products	1	1	1	3	3	1	<1	2	2	4	<1	8
Nuts	<1	<1	1	<1	2	<1	1	<1	5	2	<1	1
Total	100	100	100	100	100	100	100	100	100	100	100	100

Notes

The food group(s) 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 7. Comparison of the estimated consumer dietary exposures (µg/kilogram bodyweight/day) to arsenic from the 1999 and 2000 Total Diet Study

Population Group	Estimated total dietary exposure to arsenic (µg/kilogram bodyweight/day) [1, 2]			
	Mean		High level	
	1999 TDS[3]	2000 TDS	1999 TDS[3]	2000 TDS
Adults	1.30	1.5-1.6	4.37	5.8
Toddlers (1.5-4.5 years)	2.43 - 2.46	2.7	11.31-11.34	12
Young people (4-18 years)	1.60 - 1.61	1.7	6.65-6.66	7.0
Elderly (free living)	1.60 - 1.61	1.7	5.33-5.34	5.6
Elderly (Institutional)	1.44 - 1.46	1.6	4.62-4.64	4.9
Vegetarians[4]	1.24 – 1.25	1.4	6.98-6.99	7.4

Notes

1. Exposures have been estimated using lower and upper bound means 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 exposure patterns with regard to individual foods.

3. Food Standards Agency. 1999 Total Diet Study: Total and inorganic arsenic in food. Food Surveillance Information Sheet **47/04.**

4. Some of the vegetarian respondents were consumers of fish.