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Metals in commonly eaten groceries in Western Australia: a market basket survey and dietary assessment

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Metals in commonly eaten groceries in Western Australia – a market basket survey and dietary assessment

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Abstract

Children's dietary exposure to metals has received limited attention in Australia. This study undertook a market basket survey and analysed 253 food and beverages for metals. This data was used in conjunction with recent average diet data for children in Western Australia to model dietary metals exposure, with mean metals intakes for boys and girls aged 8, 12, 13 and 16 years calculated.

Results show that for some metals, including cadmium, nickel and manganese, dietary intake guidelines have been exceeded in younger children. The mean modelled cadmium intake in children aged 8 years was almost 60% of the World Health Organisation guideline and exceeded the European Food Safety Authority guideline. Nickel and manganese intake was higher in younger children than reported in international studies. Modelling based on the 95% percentile of dietary consumption exceeded the respective guidelines or upper level of intake for several of the metals studied.

The findings from this study support the need for further investigation into the exposure of children to metals from diet and the health implications of exposure.

Key words

Metals, food, exposure, children, dietary, cadmium, nickel, manganese

Introduction

For many persistent chemicals in the environment, including metals, diet forms the major exposure pathway in non-smoking, non-occupationally exposed individuals. In Australia, the Australian Total Diet Survey (ATDS) is conducted by Food Standards Australia and New Zealand (FSANZ) every two years and is used to assess the Australian population's dietary intake of a range of pesticide residues and food contaminants including metals. This is achieved by the testing of food samples representative of the total diet. Food consumption data collected in a National Nutrition Survey (ABS, 1999; Commonwealth Department of Health and Ageing, 2010) is then used to calculate dietary intake of contaminants based on the measured concentration in the foods and the average consumption of that food or food type by the population.

The 23rd ATDS examined the presence of a number of metals including aluminium, arsenic, cadmium, chromium, cobalt, copper, lead, manganese, mercury, selenium and zinc in a range of food samples collected in 2008 (FSANZ, 2011). This ATDS used data from the 2007 National Nutrition Survey (Commonwealth Department of Health and Ageing, 2010) to model the dietary metals exposure of Australian children based on the results of two 24hr dietary recall. The ATDS calculations were undertaken for boys and girls aged 2-3 years, 4-8 years, 9-13 years and 14-16 years for essential metals and children 2-5 years, 6-12 years and 13-16 years for metals with no known biological function. Based upon the dietary modelling methodology utilised it was concluded that intake of these metals was within acceptable health standards (FSANZ, 2011). However metals such as nickel and uranium were not included in the 23rd ATDS analysis and the intake of non-essential metals was not examined by gender which is important as both dietary intake and average body weight may differ between girls and boys. The use of a single mean bodyweight for children aged 6-12 years and 13-16 years in the FSANZ study for adjustment of metal intake may also underestimate the exposure of children at the lower end of those age ranges.

Low concentrations of metals have been implicated in a range of health effects in recent years, placing a focus on the need to better estimate intakes to reduce exposure risk, particularly in young children. Assessing diet is therefore imperative given the significance of this source for children. This study aimed to measure a range of metals in commonly eaten groceries purchased in the Perth metropolitan region. The selection of foods analysed for metals was based on a small survey of children's diets. Modelling was then undertaken on children aged 7-16 years using data collected in the most recent survey of typical diet of children in Western Australia (Martin et al., 2010).

Materials & Methods

Study Design

This study was in two parts, with the first being a market basket survey of a range of food products identified from a small group of children with concentrations of metals analysed in a variety of food types, this was followed by modelling of dietary metals intake using data collected from the Child and Adolescent Physical Activity and Nutrition Survey (CAPANS) 2008, (Martin et al., 2010).

Selection of food types for metals analysis

Twenty two families with young children aged 5-6 years completed a 24 diet diary and food frequency questionnaire, and this data provided guidance as to the types of foods consumed by children in Perth and helped inform the choices of food products for analysis for metal content. Participants were recruited using advertisements placed in the local media and also at community centres, health centres, child care centres and local businesses. Written informed consent was received from the parents of participating children prior to data collection. This study was approved by the Human Research Ethics Committee at Edith Cowan University.

Sample collection and preparation

Samples of foods and beverages were collected between April and July 2011. Two hundred and fifty three food items were purchased from a number of major supermarkets including each of the leading Australian supermarket chains at outlets in the city centre and Joondalup regions of metropolitan Perth. Food samples were selected on the basis of being commonly consumed groceries identified in the 24 hour diet diaries and food frequency questionnaires, as well as a range of other food products and were readily available from major retailers. Food samples that would normally be prepared prior to consumption by washing or by the removal of inedible portions were treated in this way. Food samples were not cooked prior to analysis. At least 100 g of each food item was transferred to a plastic zip lock bag. Liquid food samples were collected into 500 ml polyethylene bottles washed in 2% nitric acid prior to sample collection. Samples of tea and coffee were prepared according to manufacturers' instructions, allowed to cool and then transferred into the polyethylene sample collection bottle. A sample of the drinking water used to brew these beverages was also analysed and the metals concentrations in the water were subtracted from the concentrations obtained in the tea and coffee samples. All samples were frozen at −20 °C prior to analysis.

Metals analysis of food samples

All samples were analysed for the thirteen metals Al, As, Cd, Co, Cu, Pb, Mn, Hg, Ni, Se, Sn, U, Zn at the National Measurement Institute (NSW, Australia), a National Association of Testing Authorities (NATA) accredited facility using an accredited (for all food matrices) and validated method. NMI participates regularly in inter–laboratory proficiency testing for a range of food matrices. Solid food samples were homogenised in a blender (Braun, Multiquick). All samples types (solid and liquid foods) were digested with concentrated instrument grade nitric acid (Seastar Chemicals) by boiling over a water bath, prior to analysis using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS, Perkin Elmer Elan DRC II). For quality control purposes, for every batch of 20 samples or less, at least one blank (nitric acid), one duplicate, one blank spike and one sample spike. Two types of certified reference material were used for QA/QC procedures: Prawn Tissue Reference (AGAL3) and Bovine Liver Reference (AGAL4) (Supplementary data Table 1) with detection between 80 and 116% of all analyses. Duplicate analyses are also shown in the Supplementary data (Supplementary data Table 2).

Blank spike recoveries were between 83-102% and sample spike recoveries were within 85-103%. The limit of reporting was determined by replicate analysis of low level spiked matrix. The method detection limit was defined as 3.14 times the standard deviation of at least seven replicates of low level spiked matrix. The practical quantitation limit was calculated as 10 times the standard deviation of the low level spiked matrix replicates and this was rounded up to give the limit of quantification (LOQ). The LOQ for metals in solid food and liquid samples was 0.01 µg/g for all metals, with the exceptions of Al, Sn and Se in solid food samples for which the limits of quantification were 0.5, 0.02 and 0.05 µg/g, respectively. Reporting limits have been validated by the laboratory in a wide variety of food matrices to check for any interference in the presence of high salt concentrations.

Statistical Methods and Analysis

All descriptive analyses were conducted using SPSS version 19.0 (IBM© 2010). The concentrations of metals in foods were positively skewed and not normally distributed as assessed by histogram and Kolomogorov-Smirnov testing. Concentrations below the detection limits were assigned of zero for the purposes of dietary modelling to avoid overestimating exposure. Foods were assigned to one of 16 categories based on the major food groupings used in the 1995 National Nutritional Survey (ABS, 1999). In addition to the National Nutritional Survey major food groups (Cereals and cereal products, Fruit and fruit products, Vegetables and vegetable products, Legumes and pulses, Fish and seafood, Fats and oils, Egg and egg products, Milk and milk products, Meat, poultry and game, Seed and Nut products, Snack foods, Sugar products, Savoury sauces and condiments and Confectionary), a group for dairy substitutes was included in this study as well as a category of 'Other' for miscellaneous foods not readily categorised. Prepared or multiple ingredient foods were assigned to the food group based on the major ingredient in that food, for example pizza would be categorised as a cereal based dish.

Calculation of metal content of foods by serving

In order to present the concentration data in the form of intake of a given metal per portion of food, a typical adult serving of each food was determined using data from either the AUSNUT database (Food Standards Australia New Zealand, 2007), Australian Guide to Healthy Eating portion size guidelines and the manufacturers' guidance provided on food packaging. The amount of each metal present per serving was calculated by multiplying the metal concentrations by the typical serving size in grams, as shown below.

Metal per serving (µg) = Concentration in food sample (µg/g) × typical adult serving size (g)

In order to avoid overestimating the metal content of foods, the quantity per serving was only calculated if the concentration was above the limit of quantification, otherwise the metal content per portion was reported as below the LOQ. Metal concentrations in the foods were reported based on adult portion sizes due to lack of available standard child portion sizes. The adult portion sizes were not used in the subsequent modelling of children's dietary metals intake.

Modelling Dietary Metals Intake in Children

To estimate the daily dietary metals intake in children the concentrations of metals analysed in foods were combined with the recent state based averaged dietary data collection from the Western Australia, 2008 Child and Adolescent Physical Activity and Nutrition Survey (CAPANS) (Martin et al., 2010). The CAPANS 2008 collected one 24 hour diet recall from 653 children residing in Perth, Western Australia between July and December 2008. These children were recruited through schools across the metropolitan and non-metropolitan region and were in school years 3, 5 and 7 (Primary School), corresponding to ages of 8-9 years, 10-11 years and 12-13 years, respectively, and school years 8, 10 and 11 (Secondary School), corresponding to children aged 13-14, 15-16 and 16-17. Diet recalls were completed by children with the assistance of their parents. Data on the average diet of primary and secondary school CAPANS participants, stratified by gender, in mean grams per food group per day was presented in the final report (Martin et al., 2010). Raw data was accessed in order to calculate the 5th and 95th percentiles of consumption of each of the food groups in grams per food group per day.

The mean, 5th and 95th percentile consumption in grams by CAPANS participants of each food group was multiplied by the geometric mean concentration of analysed metals in foods that belonged to each food group.

Mean Metals Intake from a food group = Mean consumption of food group (g) * GM Metals concentration, where GM is the geometric mean.

Calculations were performed separately for boys and girls and also for primary and secondary school children, based on the consumption of food groups reported in these categorical variables (Martin et al., 2010). For adjustments based on body weight, CAPANS 2008 raw data was accessed to calculate the mean weight of children in each of the age and gender categories which was then was used to adjust the modelled metals intake. Beverages and foods included in the food group ‘other’, were not included in the modelling of children’s dietary intake.

Results

Metals concentrations in food and beverage samples and metal content by (adult) portion

The concentrations of 11 metals in 253 food samples tested are presented by food group (Table 1). The majority of food samples tested had concentrations of mercury and uranium that were below the limit of quantification. Mercury, however, was detected in 76% of the fish and seafood samples analysed and exceeded the maximum limit of 1 mg/kg (or 1 µg/g) (FSANZ, 2012) in one sample, swordfish (1.7 µg/g) with wobbegong shark just below the limit at 0.99 µg/g (Table 2). Uranium was only detected in 11 of the 253 samples analysed (4%) and was found in tinned smoked oysters and mussels, nori seaweed, dried herbs and spices, in one brand of each of sliced luncheon meats, yoghurt and malted food drink, albeit at low concentrations, range 0.01 - 0.04 µg/g (Supplementary Data Table 3).

Aluminium and manganese demonstrated the most variability in concentration in the foods analysed (Table 1), with standard deviations across the samples tested of 25 and 29 µg/g, respectively. Many of the foods with the highest concentrations of aluminium (dried herbs and spices) were found to also have high manganese concentrations. Tinned smoked mussels and oysters had the highest aluminium content by 100 g portion (15,000 and 6300 µg, respectively) (Table 3). Canned tomatoes and tomato based pasta sauce (in glass jars) also had high aluminium content by 125 g portion (1250 -2125 µg), as did beef sausages and meat products (sausage roll and meat pie) prepared with beef and/or mutton (731 – 1218 µg per serving) calculated for a 100 g, 140 g and 174 g serving of sausage, sausage roll and meat pie, respectively. Beverages, and specifically teas, were found to contain relatively high concentrations of both aluminium and manganese, with green tea found to contain an average of 887 µg aluminium and 674 µg manganese per 250 ml serving, black tea on average had

837 µg aluminium and 399 µg manganese and the black tea blend Earl Grey 1024 µg aluminium and 574 µg manganese per 250 ml serving (Figure 1).

Total arsenic concentrations were highest in fish and seafood, as anticipated (Table 1) and also in cereals, specifically rice and rice products, including rice crackers and cakes and rice based breakfast cereals (Table 1). By portion, fish and seafood had the highest arsenic content, with the highest concentrations in wobbegong shark (3800 µg per 100 g portion) (Table 3), however, this is likely to be predominantly organic arsenic (Jackson et al., 2012). Rice and rice products had arsenic content per serving of between 2.9 – 31 µg, with the highest concentrations found in brown rice.

The highest cadmium concentrations were found in seaweed, seafood, nuts and seeds, cocoa powder and chocolate (Table 1). By serving, seafood contained the most cadmium, with smoked oysters providing 430 µg per 100 g serving, smoked mussels 70 µg, squid 57 µg, mackerel 10 µg and crab meat 9 µg. Tinned beetroot contained 7.5 µg of cadmium per 75 g serving and potatoes contained 6.1 µg per 122 g serving (1 medium potato). In the food group confectionary, chocolate and cocoa powder were found to contain 0.52 - 6.16 µg per serving (Table 3), with dark chocolate (70% cocoa) containing an average of 5.8 µg of cadmium per 28 g portion.

Lead concentrations in the food samples tested were generally low (Table 1), with the highest concentrations found in teas (both green and black). The highest lead content by serving was found in tinned products (oysters, mussels, fruit salad, crab meat and peaches, 4 - 36 µg lead per serving). One brand of honey analysed was found to contain 4.9 µg per 29 g (~1 tablespoon), however, a second brand tested was found to have lead concentrations below the limit of quantification.

The highest tin concentrations were found in canned fruits, beans and vegetables, however, concentrations did not exceed the maximum levels set by the Food and Agriculture Organisation of the United Nations (FAO)/World Health Organisation (WHO) Food Standards Program of 150 mg/kg for canned beverages, 50 mg/kg cooked tinned meats and 250 mg/kg for tinned citrus fruits and other tinned foods (FAO/WHO, 1989).

Nuts, seeds, dried herbs and spices, cocoa and chocolate were found to contain the highest concentrations of nickel (Table 1). By portion, nuts (peanuts, cashews, mixed nuts, walnuts and pine nuts), dark (70% cocoa) chocolate, quinoa and some soy based products (milk and tofu) had the highest nickel content, contributing 69 - 330 µg per portion (Supplementary Data Table 3). Oats, previously identified as a source of nickel exposure contained 60 µg nickel per 40 g serving.

Copper was found in most foods with the highest average concentration in seeds and nuts and the highest maximum concentration in seafood (Table 1). Highest concentrations of selenium were found in eggs, seafood and meat (Table 1). Cobalt concentrations were low across all groups with a range of <0.01 -2.00 µg/g (Table 1).

Modelled Dietary Metals Intake in Children

The modelling of metals intakes of children in this study revealed that mean intakes were generally low and below the relevant guidelines with the exception of cadmium, copper, manganese, nickel and zinc for younger children (Table 4). The 95th percentile modelled intakes were above the intake guidelines for aluminium, cadmium, mercury, nickel, selenium and zinc, particularly for the younger age groups (Table 4).

The Provisional Tolerable Monthly Intake (PTMI) for cadmium set by the Joint FAO/WHO Expert Committee on Food Additives and Contaminants is 25 µg Cd/kg body weight/month

(FAO/WHO, 2011), equivalent to ~0.8 µg/kg bw/day. The mean intake modelled in Western Australian children in this study did not exceed this value. The European Food Safety Authority (EFSA) have revised their guideline for dietary cadmium intake and their Tolerable Weekly Intake (TWI) is based on modelling of dietary intake required to maintain urinary cadmium concentrations below 1 µg/g creatinine after 50 years of exposure. This has been set at 2.5 µg/kg bw/week, equivalent to ~0.36 µg/kg bw/day (EFSA, 2009). The modelled mean Cd intake in children aged 7 years exceeded this value and suggests that a large proportion of young children will have Cd intakes that exceed this value (Table 4). The mean intakes modelled of girls at the age of 7 was calculated to be almost 60% of the FAO/WHO value, again indicating that a proportion of children are also likely to be exceeding this guideline, particularly those consuming many chocolate based food items. The modelled 95th percentile Cd intake exceeded both the FAO/WHO and EFSA guidelines for children of both genders in all age groups.

The mean modelled nickel intake in children aged 7 was close to 8 µg/kg bw/day, the level of intake at which eczema can be aggravated in susceptible individuals (Nielsen et al., 1990; EFSA, 2005). The 95th percentile Ni intakes were above 8 µg/kg bw/day for all age groups. The results of this study suggest that dietary intake of nickel is high in Western Australian children (Table 4).

Intake of the nutritionally essential metals copper, manganese, selenium and zinc are usually assessed in intake per day without adjustment for body weight. The mean intake of copper in 7 years olds was estimated to be 1.6 mg/day in girls and 1.7 mg/day in boys, with intake increasing to 1.9 mg/day in boys aged 13 and 16 but decreasing to 1.5 mg/day in girls of those age groups (data not shown). These values all exceed the Adequate Intake for copper for children in those age groups but are below the Upper Level of intake (NHMRC, 2006). The 95th percentile intake was 6.4 mg/day in both boys and girls aged 8-12 years and this exceeded the Upper Level of Intake of 5 mg/day for this age group (NHMRC, 2006). The mean intakes for selenium across the age groups were in the range of 91 - 123 µg/day, with the lowest mean intake of 91 µg/day identified for girls at age 13 and 16 (data not shown). The mean selenium intakes also exceeded the Recommended Dietary Intakes established for children, although they are below the Upper Level of Intake (NHMRC, 2006). The mean modelled selenium intakes in this study were similar to those obtained in the 23rd ATDS (FSANZ, 2011). The 95th percentile of Se intake exceeded the respective Upper Level of Intake for all age and gender groups (NHMRC, 2006), with the exception of girls aged 13 and 16 years. Mean zinc intakes were estimated to be between 15.6 - 16.9 mg/day in girls and 18.7 - 21.7 mg/day in boys. These values all exceed the Recommended Dietary Intakes, even when the greater requirements of those following a vegetarian diet are taken into account (NHMRC, 2006). The respective Upper Levels of Intake for zinc (boys and girls 9-13 years 25 mg/day, boys and girls 14-18 years 35 mg/day, NHMRC, 2006) were exceeded in all age groups at 95th percentile of dietary intake, with 95th percentile intake more than double the Upper Level of intake for primary children. Mean manganese intakes were estimated to be between 6.3 - 6.8 mg/day in girls and 7.1 - 7.9 mg/day in boys. These mean intakes are approximately double the Adequate Intake of children aged 14-18 years (3.5 mg boys, 3.0 mg girls) (NHMRC, 2006), with the mean intakes of younger children exceeding their respective Adequate Intakes (2.5 mg/day children 4 – 8 years old and girls 9 – 13 years old, 3.0 mg boys 9 – 13 years old) to a greater extent. No Upper Level of Intake has been established for manganese (NHMRC, 2006).

Fish and seafood were estimated to contribute 78 and 100% of a child's arsenic and mercury intake, respectively (Figure 2). Other metals were more evenly spread across food groups, such as Cd where 36% of average intake is provided by fish and seafood and 31% by cereals, with the remaining intake distributed across vegetables, nuts and seeds, snack foods and confectionary (Figure 2). Cereal and cereal products and fruit combined provided over 60% of a child's dietary lead exposure (Figure 2). For the dietary intake of uranium it was determined that the majority of exposure was occurring from milk and dairy products, with fish and seafood contributing the remaining exposure (Figure 2), however exposure to this metal was low (mean intake of 0.01 µg/kg bw/day for all age and gender groups).

Discussion

The measured concentrations of metals in food samples were generally low. Specific food items were shown to have elevated concentrations such as teas which were found to have high concentrations of aluminium and manganese. Information on the consumption of tea by population groups is often lacking in total diet studies, and therefore this potential source of metals exposure may be overlooked, although it is unlikely to account for substantial exposure in children due to limited tea consumption, but it may influence exposure in other age groups. Tea and other beverage consumption was not included in the modelling of children's dietary metals intake as data on consumption was not available.

Rice and rice based products, were found to be significant sources of arsenic in the diet, which is in keeping with findings in international literature (Jackson et al., 2012). Although arsenic speciation was not addressed in this study, previous work has revealed that the major species of arsenic in rice based products is generally the more toxic inorganic form (Jackson et al., 2012), however the ratio of organic to inorganic arsenic will vary in different food products.

Fish and seafood intake and seeds and nuts on a per portion basis were the food groups with the highest concentrations across the range of metals tested. However, for most metals tested the food group cereals and cereal products contributed most metal exposure to the diet, with the notable exceptions of arsenic, mercury, tin and uranium. For both arsenic and mercury, fish and seafood were the predominant sources of exposure, whereas for tin, fruit and fruit products contributed most exposure (as a result of tinned fruit), and milk and milk products resulted in the majority of dietary exposure to uranium. For cadmium, fish and seafood and cereals both contribute about a third each of a child's exposure, with the remaining dietary intake distributed between vegetables and vegetable products, nuts and seeds, snack foods and confectionary.

Cadmium concentrations in all food samples were below the specified maximum levels (ML) for metal contaminants in foods set out in Standard 1.4.1 of the Food Standards Code (FSANZ, 2012), with the exception of cocoa powder which had concentration of 0.64 µg/g, which exceeded the ML of 0.5 µg/g. The only other incidence of a food sample exceeding the ML was for mercury concentrations in a sample of swordfish, however, ML for mercury in fish apply as an average per batch of sample units, rather than for individual samples (FSANZ, 2012), and therefore the limited number of samples of each food type analysed in this study means that these findings should be interpreted with caution.

The mean modelled cadmium intake for both boys and girls 7 years of age in this study was similar to that reported in a German study (0.49 µg/kg bw) of children (mean age 3.8 years) residing in an industrial area (Wilhelm et al., 2002) and is similar to the limited other studies of dietary intake in young children conducted in Europe and the United States (Mykkänen et al., 1986; Smart et al., 1988; Gunderson, 1995, Wilhelm et al.,1995; Schrey et al, 2000; Leblanc et al., 2005). The results of the modelled mean dietary cadmium intake for children in this study were also higher than those reported in the 23rd ATDS where the 90th percentile of cadmium intake was 0.34 µg/kg bw/day and 0.23 µg/kg bw/day for children aged 6-12 years and 13-16 years, respectively (FSANZ, 2011). This may reflect the use of a single mean body weight to adjust for each age group in the FSANZ study, which may under estimate exposure in the younger members of each range. Also the fact that some high cadmium foods (such as dark chocolate) were not included in the ATDS may have resulted in exposure being underestimated.

The mean modelled dietary intake of cadmium by children aged 7 in this study exceeded 0.36 µg/kg bw/day, indicating that a significant proportion of 7 year olds may be estimated to exceed this (EFSA) guideline. The mean modelled cadmium intake of older children was below 0.36 µg/kg bw/day, however, there intake was 50-75% of this guideline. Modelling of dietary intake at the 95th percentile revealed that both FAO/WHO and EFSA guidelines for cadmium intake were exceeded in all age and gender groups. These results suggest that a large number of children in Western Australia have dietary cadmium intakes that may result in urinary cadmium concentrations >1µg/g creatinine and hence be susceptible to the associated health risks, such as increased risk of decreased bone density and kidney dysfunction (Åkesson et al., 2006; Gallagher et al., 2008) later in life and risks of adverse health outcomes in early life (de Burbure et al., 2006). Low cadmium exposure in children has recently been associated with neurodevelopmental outcomes in children (Ciesielski et al., 2012).

The modelled mean dietary lead intake in this study was low and generally comparable with dietary lead intakes for children reported internationally (Gulson et al., 1997; Wilhelm et al., 2003a). The modelled mean intake of lead is very similar to the previous estimated intake for Australian children (FSANZ, 2011). The mean modelled arsenic intakes for children in this study exceeded those seen in Germany and Australia (Wilhelm et al., 2003b; FSANZ, 2011), however, were similar to those determined for children in the United States (Pellizzari et al., 1999). The higher modelled intake in this study may reflect a greater breadth of rice and rice products included in this study.

There is limited recent comparative data available on dietary uranium intake. The modelled mean uranium intakes for children were low in this study (0.01 µg/kg bw/day, data not shown) and were below the estimated dietary intake of uranium for toddlers calculated by the UK 2001 total diet survey (Food Standards Agency, 2004) as well as the WHO Tolerable Daily Intake (TDI) of 0.6 µg/kg bw (WHO, 2004). Mean modelled nickel intakes were high in this study, especially for younger children, with intake at all ages exceeding median dietary intake reported for 4 - 7 years old in Germany (Wittsiepe et al., 2009) and 3 - 14 year olds in France (LeBlanc et al., 2005). Nickel intake exceeding 8 µg/kg bw/day has been reported to have the ability to aggravate eczema symptoms in susceptible individuals (Nielsen et al., 1990; EFSA, 2005).

A number of metals are required in small concentrations for optimal biological function however these may pose increased risks of health effects if exposure is high. Mean modelled intakes of copper, selenium, manganese and zinc were all meeting the respective Adequate Intake or Recommended Dietary Intake for children based on the age and gender (NHMRC, 2006). Indeed mean copper, manganese, selenium and zinc intakes estimated in this study were higher than those reported internationally (Aung et al, 2006; Schrey et al., 2000; Thomas et al., 1999; Wilhelm et al., 2003b; Wittsiepe et al., 2009). The modelled mean dietary intakes of copper and zinc were also greater in this study than previously determined nationally (FSANZ, 2003; FSANZ, 2011). Modelling of dietary intake at 95th percentile indicated that intake of copper, selenium and zinc exceeded Upper Levels of intake (NHMRC, 2006) in some, or all, of the age groups included in this study.

There is a paucity of literature regarding the assessments of dietary manganese intake in children, however, mean modelled manganese intake in children in this study were four fold greater than those estimated for young children in the United States (Bouchard et al., 2011) and Japan (Aung et al., 2006) and also exceeded the estimated mean dietary exposure reported for adults in the total diet study in the UK (Ysart et al., 1999). Mean manganese exposure in children in this study, particularly in boys aged 13 and 16 years (7.9 mg/day), was closer to the estimated upper range of dietary exposure for adults calculated in the UK study (8.2 mg/day) (Ysart et al., 1999). Exposure to manganese through drinking water and other sources of environmental exposure has been found to be associated with hyperactivity and increased oppositional behaviour (Bouchard et al., 2007) with negative impacts on children's learning and memory also suggested (Torres-Agustin et al., 2012). To date there is no information as to whether dietary exposure could be causing these effects in children and given the high mean dietary exposure in children in Western Australia further research in this area is warranted.

There are a number of limitations of the study, notably the small number of samples of each food type, therefore the concentrations of food samples may not be representative. The modelled dietary intakes have been generated using the geometric mean metals concentrations in order to minimise the potential for over estimation of intake due to the skewed nature of the metals concentrations in food, however as geometric means are less sensitive to lower and higher values this may have introduced error in the estimation of exposure for some metals. Nevertheless, the variety of food types covered in the study provides an indication of the extent of variation of metals exposure across commonly eaten food items and the potential sources of specific metals intake by children.

Conclusions

This study provides an assessment of typical dietary intake using the most up to date dietary information available for Australian children. This study indicates that dietary exposure to some metals, notably cadmium, nickel and manganese, may be of concern for children given recent studies demonstrating health effects at relatively low concentrations. Further research is required to determine the range of modelled intake based on a more comprehensive assessment of food types and consumption patterns of children, including the use of individual consumption data. There also needs to be some efforts at establishing whether these low exposures may contribute to risks of adverse health effects. Measures to reduce cadmium, nickel and manganese exposures in children are necessary, hence better information on specific dietary contributors to that exposure are required.

Disclosure statement

The authors have nothing to disclose.

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Table 1: Concentrations of metals in foods by food groups (µg/g) n=253

Food Group		Al	As	Cd	Co	Cu	Pb	Mn	Ni	Se	Sn	Zn
Beverages (n =16)	**% <LOD**	6.3	87.5	93.8	93.8	18.8	93.8	18.8	50.0	93.8	93.8	31.3
	GM	0.30	0.01	0.01	0.01	0.04	0.01	0.27	0.01	0.01	0.01	0.03
	Minimum	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Maximum	12.0	0.05	0.07	0.16	4.90	0.03	10.0	1.60	0.10	0.14	17.0
Cereals (n=34)	**% <LOD**	20.6	20.6	55.9	17.6	0.0	64.7	0.0	0.0	5.9	64.7	2.9
	GM	1.10	0.02	0.01	0.02	1.83	0.01	11.8	0.17	0.09	0.03	17.2
	Minimum	<0.50	<0.01	<0.01	<0.01	0.51	<0.01	1.10	0.04	<0.05	<0.02	4.40
	Maximum	8.10	0.37	0.05	0.11	5.40	0.06	75.0	2.50	0.24	1.10	95.0
Fats & oils (n=4)	**% <LOD**	100	100	100	100	75.0	100	75.0	75.0	100	100	0.0
	GM	<0.50	<0.01	<0.01	<0.01	0.01	<0.01	0.01	0.01	<0.05	<0.02	0.22
	Minimum	<0.50	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.05	<0.02	0.03
	Maximum	<0.50	<0.01	<0.01	<0.01	0.02	<0.01	0.01	0.02	<0.05	<0.02	0.58
Fish and seafood (n=17)	**% <LOD**	58.8	0.0	47.1	88.2	0.0	70.6	0.0	5.9	0.0	70.6	0.0
	GM	0.81	0.94	0.03	0.01	0.72	0.01	0.33	0.05	0.42	0.02	7.31
	Minimum	<0.50	0.04	<0.01	<0.01	0.14	<0.01	0.04	<0.01	0.13	<0.02	2.60
	Maximum	150.0	38.0	2.80	0.39	85.0	0.36	22.0	0.65	2.30	0.43	230
Fruit (n=27)	**% <LOD**	74.1	81.5	92.6	81.5	0.0	74.1	0.0	25.9	96.3	77.8	0.0
	GM	0.51	0.01	0.01	0.01	0.76	0.01	0.88	0.03	<0.05	0.02	0.97
	Minimum	<0.50	<0.01	<0.01	<0.01	0.22	<0.01	0.17	<0.01	<0.05	<0.02	0.25
	Maximum	14.0	0.03	0.01	0.07	4.40	0.05	11.0	0.61	0.06	65.0	6.70
Eggs	**% <LOD**	100	100	100	100	0.0	100	0.0	100	0.0	100	0.0
	GM	<0.50	<0.01	<0.01	<0.01	0.67	<0.01	0.32	<0.01	0.45	<0.02	13.3

(n=3)	**Minimum**	<0.50	<0.01	<0.01	<0.01	0.62	<0.01	0.27	<0.01	0.38	<0.02	12.0
	Maximum	<0.50	<0.01	<0.01	<0.01	0.71	<0.01	0.41	<0.01	0.56	<0.02	14.0
Meat	**% <LOD**	41.2	58.8	100	76.5	0.0	76.5	0.0	0.0	0.0	88.2	0.0
	GM	0.90	0.01	<0.01	0.01	0.89	0.01	0.82	0.09	0.11	<0.02	16.2
(n=17)	**Minimum**	<0.50	<0.01	<0.01	<0.01	0.49	<0.01	0.08	0.02	0.05	<0.02	5.70
	Maximum	8.70	0.02	<0.01	0.03	1.60	0.04	6.50	0.18	0.26	0.03	54.0
Milk	**% <LOD**	0.0	90.0	100	80.0	0.0	100	0.0	55.0	5.0	95.0	0.0
	GM	0.22	0.01	<0.01	0.01	0.11	<0.01	0.11	0.01	0.05	<0.02	9.43
(n=20)	**Minimum**	0.02	<0.01	<0.01	<0.01	0.02	<0.01	0.02	<0.01	<0.01	<0.02	1.60
	Maximum	2.60	0.02	<0.01	0.01	0.40	<0.01	0.48	0.07	0.30	0.05	49.0
Dairy substitutes (n=3)	**% <LOD**	0.0	66.7	100	66.7	0.0	100	0.0	0.0	33.3	100	0.0
	GM	0.40	0.01	<0.01	0.01	0.37	<0.01	0.94	0.10	0.01	<0.02	1.04
	Minimum	0.26	<0.01	<0.01	<0.01	0.09	<0.01	0.48	0.04	<0.01	<0.02	0.40
	Maximum	0.52	0.02	<0.01	0.03	0.90	<0.01	2.40	0.65	0.02	<0.02	2.90
Seeds & Nuts (n=12)	**% <LOD**	8.3	50.0	41.7	0.0	0.0	83.3	0.0	0.0	33.3	0.0	0.0
	GM	1.44	0.01	0.02	0.10	13.7	0.01	32.7	1.61	0.08	0.07	52.7
	Minimum	<0.50	<0.01	<0.01	0.04	8.80	<0.01	13.0	0.11	0.03	0.01	34.0
	Maximum	31.0	0.12	1.20	0.52	26.0	0.06	110	11.0	0.58	0.18	88.0
Savoury sauces and condiments (n=7)	**% <LOD**	14.3	57.1	71.4	28.6	0.0	57.1	0.0	0.0	14.3	57.1	0.0
	GM	0.93	0.01	0.01	0.04	0.68	0.01	1.77	0.31	0.03	0.02	4.93
	Minimum	<0.50	<0.01	<0.01	<0.01	0.03	<0.01	0.05	0.04	<0.01	<0.02	0.15
	Maximum	4.10	0.14	0.02	1.10	6.80	0.01	19.00	1.40	0.17	0.16	43.0
Vegetables (n=42)	**% <LOD**	64.3	97.6	54.8	69.0	0.0	97.6	0.0	19.0	88.1	85.7	0.0
	GM	0.57	0.01	0.01	0.01	0.77	0.01	1.72	0.03	<0.05	0.02	2.97
	Minimum	<0.50	<0.01	<0.01	<0.01	0.16	<0.01	0.36	<0.01	<0.05	<0.02	0.84

	Maximum	17.0	0.01	0.10	0.04	7.30	0.02	4.50	0.22	0.19	3.70	10.0
Legume (n=8)	**% <LOD**	62.5	87.5	100	25.0	0.0	100	0.0	0.0	50.0	12.5	0.0
	GM	0.43	0.01	<0.01	0.02	2.82	<0.01	4.57	0.25	0.05	0.20	8.67
	Minimum	<0.50	<0.01	<0.01	<0.01	1.90	<0.01	2.80	0.06	<0.05	<0.02	4.70
	Maximum	2.10	0.01	<0.01	0.08	7.10	<0.01	8.70	1.20	0.20	11.0	31.0
Snack (n=8)	**% <LOD**	25.0	37.5	25.0	25.0	0.0	75.0	0.0	0.0	37.5	87.5	0.0
	GM	1.43	0.02	0.02	0.02	1.99	0.01	8.20	0.14	0.06	<0.02	9.47
	Minimum	<0.50	<0.01	<0.01	<0.01	0.95	<0.01	3.90	0.04	<0.05	<0.02	5.00
	Maximum	4.80	0.26	0.09	0.10	3.10	0.04	22.0	0.96	0.13	0.03	16.0
Sugar (n=2)	**% <LOD**	50.0	50.0	100	50.0	50.0	100	0.0	50.0	50.0	100	0.0
	GM	0.45	0.01	<0.01	0.02	0.02	<0.01	0.35	0.02	<0.05	<0.02	0.08
	Minimum	<0.50	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	<0.01	<0.05	<0.02	0.02
	Maximum	0.81	0.01	<0.01	0.11	0.09	<0.01	3.00	0.05	<0.05	<0.02	0.33
Confectionary & cereal bar (n=19)	**% <LOD**	31.6	57.9	47.4	31.6	0.0	63.2	0.0	15.8	57.9	94.7	0.0
	GM	2.15	0.01	0.02	0.04	1.41	0.01	2.43	0.27	<0.05	<0.02	5.14
	Minimum	<0.50	<0.01	<0.01	<0.01	0.04	<0.01	0.02	<0.01	<0.05	<0.02	0.10
	Maximum	140	0.09	0.64	2.00	43.0	0.47	100	7.10	0.16	0.06	86.0
Other (n=14)	**% <LOD**	0.0	35.7	35.7	28.6	14.3	14.3	0.0	0.0	7.1	50.0	0.0
	GM	17.0	0.05	0.04	0.05	1.55	0.09	12.8	0.28	0.06	0.05	8.54
	Minimum	0.19	<0.01	<0.01	<0.01	<0.01	<0.01	0.10	0.01	<0.05	<0.02	0.14
	Maximum	200	27.0	5.20	0.76	18.0	1.70	350	3.00	0.35	2.00	43.0

Limit of detection 0.01μg/g for all liquid samples for all metals and for solid samples for the metals As, Cd, Co, Cu, Pb, Mn, Ni and Zn. For Al, Sn and Se in solid food samples the limits of reporting were 0.5, 0.02 and 0.05 μg/g, respectively.

Table 2: Mercury concentrations in fish and seafood (in µg/g and µg per 100g serve)

Description	**Hg µg/g**	**Hg µg per 100g serve**
Swordfish	1.70	170
Shark -Wobbegong	0.99	99
Hake Fillet	0.15	15
Pink Snapper fillet	0.08	8
Barramundi fillet	0.07	7
Crab Meat (tinned)	0.05	5
Fish Finger (Frozen crumbed Hoki)	0.05	5
Tuna (tinned)	0.04	4
Mackerel Fillets (tinned)	0.03	3
Oysters (smoked tinned)	0.02	2
Sardines (smoked tinned)	0.02	2
Tasmanian Salmon	0.02	2
Mussels (smoked tinned)	0.01	1
Squid	<0.01	<0.01
Prawns (cooked and peeled)	<0.01	<0.01
Fish (Frozen battered white fish)	<0.01	<0.01
Basa Fish Fillet	<0.01	<0.01
Geometric Mean	**0.04**	**1.20**

Table 3: Metals content in foods per serve (µg) n=253. Adult serving sizes determined by data from AUSNUT database, Australian Guide to Health Eating and food packaging.

		Al per serve	As per serve	Cd per serve	Co per serve	Cu per serve	Pb per serve	Mn per serve	Se per serve	Sn per serve	Ni per serve	Zn per serve
Beverages (n=16)	**GM**	45.9	0.01	0.01	0.01	2.78	0.01	20.6	0.01	0.01	0.19	1.29
	Minimum	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	Maximum	1024	2.50	1.40	3.20	98.0	0.60	699	2.00	2.80	32.00	340
Cereals (n=34)	**GM**	27.4	0.55	0.06	0.59	106	0.03	689	4.29	0.11	10.2	1000
	Minimum	<0.50	<0.01	<0.01	<0.01	23.6	<0.01	44.0	0.03	0.01	1.50	125
	Maximum	456	30.7	3.00	4.40	540	3.00	3800	17.0	100	125	3800
Fats & oils (n=4)	**GM**	<0.50	<0.01	<0.01	<0.01	0.10	<0.01	0.01	<0.03	0.01	0.01	1.74
	Minimum	<0.50	<0.01	<0.01	<0.01	0.08	<0.01	<0.01	<0.03	0.01	<0.01	0.24
	Maximum	<0.50	<0.01	<0.01	<0.01	0.16	<0.01	0.08	<0.03	0.01	0.16	4.64
Fish and seafood (n=17)	**GM**	5.42	94.04	0.30	0.01	72.20	0.05	32.91	42.06	0.06	4.01	730.86
	Minimum	<0.50	4.00	<0.01	<0.01	14.00	<0.01	4.00	13.00	0.01	<0.01	260
	Maximum	15000	3800	280	39.0	8500	36.0	2200	230	43.0	65.0	23000
Fruit (n=27)	**GM**	1.11	0.01	0.01	0.01	49.65	0.02	56.99	<0.03	0.06	0.61	62.76
	Minimum	<0.50	<0.01	<0.01	<0.01	6.00	<0.01	12.00	<0.03	0.01	<0.01	6.60
	Maximum	437	0.30	0.15	3.71	300	11.4	1782	0.60	14755	37.26	276
Eggs (n=3)	**GM**	<0.50	<0.01	<0.01	<0.01	29.43	<0.01	13.98	19.67	0.01	<0.01	585

	Minimum	<0.50	<0.01	<0.01	<0.01	27.28	<0.01	11.88	16.72	0.01	<0.01	528
	Maximum	<0.50	<0.01	<0.01	<0.01	31.24	<0.01	18.04	24.64	0.01	<0.01	616
Meat (n=17)	**GM**	9.74	0.03	0.01	0.02	58.35	0.02	53.75	7.26	0.02	5.72	106
	Minimum	<0.50	<0.01	<0.01	<0.01	14.28	<0.01	3.24	2.64	0.01	0.46	120
	Maximum	1218	2.00	<0.01	4.20	244	2.00	910	27.00	4.20	27.84	4500
Milk (n=20)	**GM**	3.76	0.01	0.01	0.01	6.18	0.01	6.08	1.02	0.01	0.05	518
	Minimum	<0.50	<0.01	<0.01	<0.01	0.80	<0.01	0.30	<0.01	<0.01	<0.01	36.0
	Maximum	455	0.21	<0.01	0.21	21.0	<0.01	88.0	7.50	8.75	5.00	1250
Dairy substitutes (n=3)	**GM**	99.0	0.05	<0.01	0.06	93.2	<0.01	234	0.50	<0.01	25.3	260
	Minimum	65.0	<0.01	<0.01	<0.01	22.5	<0.01	120	<0.01	<0.01	10.0	100
	Maximum	130	5.00	<0.01	7.50	225	<0.01	600	5.00	<0.01	163	725
Seeds & Nuts (n=12)	**GM**	27.9	0.07	0.15	2.51	353	0.01	845	0.80	1.00	41.7	1362
	Minimum	<0.50	<0.01	<0.01	1.00	132	<0.01	390	0.03	0.01	2.75	855
	Maximum	930	3.60	14.4	15.6	780	1.80	3300	17.4	5.40	330	2640
Savoury sauces and condiments (n=7)	**GM**	7.76	0.04	0.02	0.21	8.76	0.02	22.7	0.10	0.07	3.92	63.2
	Minimum	<0.50	<0.01	<0.01	<0.01	0.15	<0.01	1.00	<0.01	0.01	0.80	3.00
	Maximum	77.9	1.40	0.30	11.0	136	0.20	361	1.70	1.60	26.6	430
Vegetables (n=42)	**GM**	2.51	0.01	0.06	0.03	43.8	0.01	98.2	0.05	0.03	0.66	170
	Minimum	<0.50	<0.01	<0.01	<0.01	3.30	<0.01	6.00	0.03	0.01	<0.01	19.2

	Maximum	2125	0.75	7.50	3.60	438	2.50	524	16.7	463	16.5	1833
Legume (n=8)	**GM**	2.05	0.01	<0.01	0.55	220	<0.01	356	0.48	10.5	19.3	676
	Minimum	<0.50	<0.01	<0.01	<0.01	54.0	<0.01	138	0.03	0.01	4.80	192
	Maximum	151	0.48	<0.01	3.33	337	<0.01	495	18.5	1513	67.4	1473
Snack (n=8)	**GM**	14.7	0.13	0.21	0.23	43.2	0.01	178	0.40	0.02	3.08	205
	Minimum	<0.50	<0.01	<0.01	<0.01	18.0	<0.01	96.0	0.03	0.01	0.60	100
	Maximum	130	6.50	1.62	1.70	83.7	0.68	374	3.00	0.54	16.3	364
Sugar (n=2)	**GM**	0.79	0.01	<0.01	0.04	0.04	<0.01	1.25	<0.03	0.01	0.03	0.29
	Minimum	<0.50	<0.01	<0.01	<0.01	<0.01	<0.01	0.17	<0.03	0.01	<0.01	0.08
	Maximum	2.51	0.03	<0.01	0.34	0.28	<0.01	9.30	<0.03	0.01	0.16	1.02
Confectionary & cereal bar (n=19)	**GM**	23.5	0.03	0.10	0.42	37.2	0.04	64.1	0.17	0.01	4.13	136
	Minimum	<0.50	<0.01	<0.01	<0.01	0.18	<0.01	0.18	0.03	0.01	<0.01	0.77
	Maximum	1022	0.66	6.16	14.6	448	3.43	870	7.92	0.44	148	840
Other (n=14)	**GM**	54.1	0.07	0.05	0.10	4.79	0.16	40.8	0.14	0.08	0.89	27.3
	Minimum	0.40	<0.01	<0.01	<0.01	<0.01	<0.01	0.07	<0.01	0.01	0.03	0.06
	Maximum	600	13.5	2.60	3.00	180	4.93	980	35	3.80	94.0	1200

Table 4: Calculated dietary intake of metals for primary and secondary school children, mean (5th – 95th percentile), adjusted for mean body weight (μg/kg body weight/day) n=653.

	Boys				Girls				Tolerable daily intake
	Primary		Secondary		Primary		Secondary		
	Age 8 (mean weight 30.5kg)	Age 12 (mean weight 47.5kg)	Age 13 (mean weight 51.7kg)	Age 16 (median 68.8kg)	Age 8 (mean weight 30.9kg)	Age 12 (mean weight 47.2kg)	Age 13 (mean weight 50.1kg)	Age 16 (mean 61.1kg)	
Al	69.2 (3.3-267)	44.4 (2.1-171)	45.6 (1.4-166)	34.2 (1.1-124)	66.6 (2.0-257)	43.7 (1.3-168)	38.0 (0.0-151)	31.2 (0.0-124)	143[1]
As	2.5 (0.1-17.3)	1.6 (0.0-11.1)	1.3 (0.0-9.1)	1.0 (0.0-6.8)	2.7 (0.0-15.5)	1.8 (0.0-10.2)	1.1 (0.0-8.6)	0.9 (0.0-7.1)	
Cd	0.4 (0.0-2.2)	0.3 (0.0-1.4)	0.2 (0.0-1.3)	0.2 (0.0-1.0)	0.4 (0.0-2.0)	0.3 (0.0-1.3)	0.2 (0.0-1.2)	0.2 (0.0-1.0)	0.8/0.36[2]
Co	0.6 (0.1-2.3)	0.4 (0.0-1.4)	0.4 (0.0-1.5)	0.3 (0.0-1.1)	0.6 (0.0-2.3)	0.4 (0.0-1.5)	0.3 (0.0-1.3)	0.3 (0.0-1.1)	
Cu	54.9 (3.6-211)	35.3 (2.3-135)	36.1 (1.6-137)	27.1 (1.2-103)	52.9 (2.2-208)	34.6 (1.4-136)	31.4 (0.0-126)	25.8 (0.0-104)	50 – 500[3]
Pb	0.2 (0.0-0.7)	0.1 (0.0-0.4)	0.1 (0.0-0.4)	0.1 (0.0-0.3)	0.2 (0.0-0.6)	0.1 (0.0-0.4)	0.1 (0.0-0.4)	0.1 (0.0-0.3)	[4]
Mn	234 (25.8-818)	150 (16.6-525)	153 (11.1-532)	115 (8.4-400)	219 (15.6-800)	144 (10.2-524)	126 (0.0-462)	103 (0.0-379)	

Hg	0.1 (0.0-0.8)	0.1 (0.0-0.5)	0.0 (0.0-0.4)	0.0 (0.0-0.3)	0.1 (0.0-0.7)	0.1 (0.0-0.5)	0.0 (0.0-0.4)	0.0 (0.0-0.3)	0.23[5]
Ni	7.4 (0.6-27.2)	4.7 (0.4-17.5)	5.0 (0.2-18.7)	3.8 (0.2-14.0)	6.9 (0.3-26.9)	4.5 (0.2-17.6)	4.2 (0.0-16.7)	3.4 (0.0-13.7)	8[6]
Se	3.5 (0.2-13.5)	2.3 (0.1-8.7)	2.4 (0.1-8.5)	1.8 (0.1-6.4)	3.3 (0.1-12.7)	2.1 (0.1-8.3)	1.8 (0.0-7.3)	1.5 (0.0-6.0)	7[7]
Sn	22.5 (0.2-72.8)	14.5 (0.1-46.7)	14.0 (0.1-48.1)	10.5 (0.1-36.1)	25.4 (0.1-82)	16.7 (0.1-53.8)	17.0 (0.0-58.9)	14.0 (0.0-48.3)	2000[8]
Zn	614 (37.9-2038)	394.0 (24.3-1308)	418.9 (16.3-1290)	315 (12.3-968)	548 (22.9-1902)	359 (15.0-1246)	311.4 (0.0-1100)	255 (0.0-902)	1000[9]

[1]Al Provisional Tolerable Weekly Intake (PTWI) 1 mg/kg bw FAO/WHO 2007
[2]Cd Provisional Tolerable Monthly Intake (PTMI) 25 µg/kg bw (i.e. ~0.8 µg/kg bw/day) (FAO/WHO 2011). EFSA PTWI 2.5µg/kg bw i.e.~ 0.36µg/kg bw/day (EFSA, 2009).
[3]Cu Provisional Maximal Tolerable Daily Intake (PMTDI) 50-500 µg/kg bw (FAO/WHO, 1982).
[4]Previous Pb PTWI 25 µg/kg bw (~3.6µg/kg bw/day) withdrawn as found to be associated with a decrease of at least 3 IQ points in children (FAO/WHO, 2011). No safe intake for children established.
[5]Hg PTWI Methylmercury 1.6 µg/kg bw/week (FAO/WHO, 2007), equivalent to ~0.23 µg/kg bw/day.
[6]Ni 8 µg/kg bw/day intake at which eczema can be aggravated (Nielson et al., 1990; EFSA, 2005).
[7]Se Upper Level of Intake 7 µg/kg bw/day (NHMRC, 2006).
[8]Sn PMTDI 2 mg/kw bw (FAO/WHO, 1989).
[9]Zn PMTDI 1.0mg/kg bw (FAO/WHO, 1982).