Appendix 6: Dietary modelling techniques used to estimate trace element intakes

Dietary modelling is a tool used to estimate exposures (intake) to food chemicals from the diet. Food regulators have used dietary modelling techniques internationally for a number of years to determine if dietary exposure to specific food chemicals represents an unacceptable risk to public health and safety. Dietary modelling is an important part of the ATDS as it translates analytical results for individual foods into dietary exposure estimates that can be compared to established reference health standards. This comparison is crucial in identifying whether the estimated dietary exposure to food chemicals would potentially result in an unacceptable health risk to any population group.

While dietary modelling is a scientific systematic method for estimating the amounts of nutrients a person or population may be eating, the accuracy of these intake estimates depend on the quality of the data used in the dietary models. When there are gaps in available data or uncertainty about their accuracy, assumptions are made, either about the foods eaten or about nutrient levels, based on previous knowledge and experience. The models were set up according to international conventions for nutrient intake estimates, however, each modelling process requires decisions to be made about how to set the model up and what assumptions to make; a different decision may result in a somewhat different answer. DIAMOND (Dietary Modelling of Nutritional Data) is a computer program developed by FSANZ to automate dietary intake calculations. DIAMOND combines food consumption data with nutrient concentration data to estimate the dietary intake to the nutrient for a range of population groups.

Nutrient levels

The trace element levels used in dietary modelling for the ATDS were the mean from the analytical results of the composite samples of each surveyed food.

Assumptions have been made about the concentration of the trace element in the foods where the analytical results were below the limit of reporting (LOR). The limit of reporting LOR is the lowest concentration level at which the laboratory is confident in the quantitative results reported.

In the case of the elements assessed, some results were reported as below the LOR. In order to estimate intakes, a numerical value has to be assigned to these results. It may not be reasonable to assume that the element is not present in the food when the analytical result is below the LOR as the level could be anywhere between zero and the LOR. To allow for this uncertainty, three estimates of dietary intakes were calculated: a possible lower, middle and upper bound estimate. The lower bound estimate was calculated using a mean nutrient concentration based on the assumption that trace element concentrations below the LOR were equal to zero. The middle bound estimate was based on the assumption that trace element concentrations below the LOR were equal to half the LOR. The upper bound estimate was calculated based on the assumption that trace element concentrations below the LOR were all at concentrations equal to the LOR. The results presented in this report are based on the middle bound calculations. Upper and lower bound estimates of intake are presented in Appendix 9.

Food consumption data

Dietary modelling used food consumption data from the 1995 NNS that surveyed 13,858 Australians aged 2 years and above using a 24-hour food recall. There were approximately 4,500 individual foods reported as consumed in the NNS. A second 24-hour recall was also collected on a subset (10%) of NNS respondents on a non consecutive day and used to estimate the usual intake distribution by adjusting for the within-individual variability (see below).

Use of food consumption data for individuals, rather than mean food consumption amounts for the population, greatly improves the reliability and accuracy of the dietary intake estimates for food chemicals as it takes account of the different eating patterns of consumers and enables more precise estimates of the proportion of a population who might have excessive or inadequate intakes.

The food consumption data from each NNS respondent were not weighted according to the number of people in the total Australian population they may represent because this can distort the actual amount of food a consumer is reported to have eaten.

Calculating adjusted intakes

The DIAMOND program multiplies the mean concentration in food of each nutrient by the amount of food that an individual consumed from that food group, using individual food consumption records from the NNS, in order to estimate the intake of the nutrient from each food. The total amount of the nutrient consumed from all foods assessed is summed for each individual.

An individual's nutrient intake may vary substantially from day to day through consumption of a varied diet. More representative estimates of an individual's usual nutrient intake can be developed if more than one day of food consumption data are available. Information for a second (non-consecutive) day of food consumption was collected from approximately 10% of NNS respondents and has been used to adjust each respondent's day one nutrient intake. The adjustment calculation is described in Figure A6.1.

Figure A6.1: Calculating adjusted nutrient intakes

Adjusted value = x + (x1 – x) * (Sb/Sobs)
Where: x is the group mean for the Day 1 sample
x1 is the individual's day 1 intake
Sb is the between person standard deviation; and
Sobs is the group standard deviation for the Day 1 sample

Source: McLennan & Podger, 1998

Population statistics such as low, mean and high percentile intakes for each age-gender group assessed are then derived from the adjusted individual intakes. The use of adjusted individual intakes in turn generates more representative estimates of the extremes, both low and high, of population nutrient intakes and is more appropriate for estimating the likelihood of nutrient adequacy or excess in a population (McLennan & Podger, 1998). Use of adjusted nutrient intakes also facilitates comparison with the NRVs, which describe requirements over the long term and are expressed as values per day for convenience only.

Population groups evaluated

The population groups assessed in the 22nd ATDS were infants aged 9 months (by means of a theoretical diet as described later) and males and females aged:

- 2-3 years
- 4-8 years
- 9-13 years
- 14-18 years
- 19-29 years
- 30-49 years
- 50-69 years and
- 70 years and over.

These population groups correlate with the Nutrient Reference Values (NRVs) for ages 1 to 18 years except that children aged 1-2 years were not assessed as this age group was not included in the NNS.

The NNS only reported an adult's age in five year increments above 19 years of age (e.g. 20-24, 25-29; 30-34 etc), so the cutpoints between age categories in the NNS do not match the age cutpoints in the NRVs. The age groups used for the NRVs are 19-30, 31-50, 51-70 and 70+ years. For reporting purposes the NNS age groups were used. In relation to calculating intakes and comparing them to the NRVs, in the NNS where the age range is specified as 20-24, the people are assigned the age of 22 as the midpoint of that range in DIAMOND, for the aged range 25-29 they were assigned 27, and so on. Therefore, in the intake assessments calculated by DIAMOND, the NRVs used for comparison were wherever 22 and 27 fit etcetera.

Respondents versus consumers

Estimates of dietary intake can be calculated for all survey respondents or only for those respondents who consumed a food containing a nutrient ('consumers'). However because nutrients are distributed across a wide range of foods and are consumed by all members of the population, this study reports intake estimates for all survey respondents. Appendix 11 shows the number of respondents in each age-gender group assessed.

Mapping

A major step in the dietary modelling process is matching (or mapping) the approximately 4,500 foods reported as consumed in the NNS to the 96 ATDS foods that were analysed. This process assigns the levels of substances detected in the ATDS survey foods to the appropriate food consumption data to estimate dietary intake of the substance. Given that the ATDS cannot survey all foods in the food supply, a single ATDS food (for example white bread) may be assumed to represent a whole group of foods (for example white bread, bread rolls, bagels, crumpets, fancy breads and donuts). Recipes are used for mixed foods to assign their ingredients to the appropriate ATDS food (e.g. the proportion of cheese on pizza and in sauces). Details of the survey foods and corresponding NNS foods are set out in Appendix 7.

Food contribution calculations

The percentage contribution each food group makes to total estimated intakes was calculated by dividing the sum of all individuals' intakes from one food group by the sum of all individuals' intakes from all foods containing the nutrients assessed, and multiplying this by 100.

Lower bound results (LOR=0) were used to calculate the percentage contribution of each food group to total estimated intakes. This provides the best indication of the food groups most likely to contribute to dietary intake by including only foods containing levels of the nutrient at or above the LOR. Middle bound results (1/2 LOR) are not used for estimating the percentage contribution of foods to intakes as this would result in all foods being regarded as contributors, reducing the estimated contribution of foods that actually contain quantifiable levels of the nutrient.

Assumptions and limitations in dietary modelling

The aim of the dietary intake assessment is to make as realistic an estimate of dietary intake of the nutrient of interest as possible. However, where significant uncertainties in the data exist, conservative assumptions are generally used to ensure that the dietary intake assessment does not under- or over-estimate nutrient intake. Although improvements have been made to the methods of estimating dietary intake, limitations exist in the methods as well as in the data itself.

Assumptions made in the dietary modelling for the 22nd ATDS include:

- all the foods within the group contain the specified nutrients at the levels shown in Appendix 5;
- all of the nutrient present in food is absorbed by the body;
- where a food has a specified nutrient concentration, this concentration is carried over to mixed foods where the food has been used as an ingredient; and
- for the purpose of this assessment, it was assumed that 1 millilitre is equal to 1 gram for all liquid and semi-liquid foods (e.g. juice).

Particular mention should be made of the assumptions relating to salt in this study. Iodised salt contains, as the name indicates, high levels of added iodine and therefore assumptions about the type of salt consumed has the potential to have a significant impact on estimates of iodine intake.

The NNS did not specifically collect accurate data from all respondents on the amount of salt added at the table or in cooking for their 24 hour recall. In the few cases where respondents have reported consumption of salt or where salt is included as a recipe ingredient in the DIAMOND program, it was assumed that all this salt was iodised, although industry estimates indicate that only about 15% of household table and cooking salt is iodised (FSANZ, 2006). This conservative assumption was made to ensure that the dietary intake assessment did not underestimate iodine intakes, especially since iodine intakes were compared with the UL. The limitations of the NNS consumption for salt increases uncertainty about the accuracy of estimated iodine intakes.

Use of the 1995 NNS food consumption data provides the best available estimate of actual consumption of a broad range of foods across a nationally representative sample of the Australian population. However any significant changes to food consumption patterns since 1995 will not be taken into account in this study. Generally, consumption of staple foods such as fruit, vegetables, meat, dairy products and cereal products, which make up the majority of most people's diet, is unlikely to have changed markedly (Cook et al., 2001a; Cook et al., 2001b).

Infant diet

The 1995 NNS did not include children under two years of age. A theoretical diet was constructed for infants at 9 months of age in order to allow a mean dietary intake of a nutrient to be calculated for infants. The theoretical infant diet was based on an extrapolation from the diet of a child at two years for solid foods, with an adjustment for the proportion of the total diet made up of milk.

The recommended energy intake for a nine-month-old boy (FAO, 2004) at the 50th percentile weight (WHO 2006) was used as the basis for the theoretical diet. Boys' weights were used because boys tend to be heavier than girls at the same age and therefore have higher energy and food requirements. It was assumed that 50 per cent of the energy intake was derived from milk and 50 per cent from solids (Hitchcock et al., 1986).

Certain foods such as nuts, tea, coffee and alcohol were removed from the diet since nuts can be a choking risk (National Health and Medical Research Council, 2003) and coffee and alcohol are unsuitable foods for infants (ACT Community Care (ACTCC), 2007) (see Table A6.1 for further details). Consumption of breakfast cereals was assumed to be in the form of either infant cereal or single grain breakfast cereals, excluding bran-based cereals. All milk consumption was assumed to be in the form of follow-on formula.

The amount of tap and bottled waters that were consumed in the infant diet were determined using the estimated fluid requirements for infants as follows:

Amount of water = Total fluid requirements – (amount of formula + amount of soft drink + amount of juice)
= (135 ml/kg bw x 9.2 kg) – (562 ml + 17 ml +117 ml)
= 1242 ml – 696 ml
= 546 ml

It was assumed that infants consume equal amounts of tap and bottled waters i.e. 273 ml of tap water per day and 273 ml of bottled water per day.

The theoretical diet that was used in the intake assessments for 9 month old infants is outlined in Table A6.2.

Since the theoretical diet for infants produces a mean nutrient intake with no variance, the proportion of the population group with dietary intakes below the EAR or above the UL could not be calculated. As an alternative, the 95th percentile dietary intake was estimated and then compared to the UL, using the internationally accepted formula shown below (WHO, 1985) of:

95^{th} percentile intake = mean intake x 2.5

Table A6.1: Rationale for foods excluded from the 9 month old infant diet

ATDS Food	Rationale
Almonds, raw	Nuts pose a choking hazard to infants and are not recommended for consumption (Hillis & Stone, 1993; The Children's Hospital at Westmead & Sydney Children's Hospital at Randwick, 2003; NHMRC, 2003) thus they were excluded from the infant diet.
Beer	Alcoholic beverages are unsuitable for infants therefore have been excluded from the infant diet (NHMRC, 2003; ACTCC, 2007).

ATDS Food	Rationale
Breakfast cereal, mixed grain	Mixed grain infant cereal was a food analysed in the 22nd ATDS. As standard mixed grain breakfast cereals are not intended for infant consumption they were excluded from the infant diet. It was assumed that the consumption of mixed grain cereals was in the form of infant cereal in the infant diet. The energy value from standard mixed grain cereal was therefore mapped to mixed grain infant cereal. Single grain breakfast cereals were also included to account for the consumption of standard single grain cereals by infants.
Milk	Milk is listed as an unsuitable fluid for babies. Cow's milk contains higher levels of protein, sodium, potassium, phosphorous and calcium. It also contains lower levels of iron, vitamin C and linoleic acid, therefore the composition is not suitable for infants because of the protein and solute load (NHMRC, 2003).
Peanut butter	In the 22nd ATDS peanut butter is mapped to "all peanuts and peanut products". The NHMRC (2003) lists nuts as "foods not suitable for infants or which require care in their use", citing both the choking hazard and the risk of allergy as reasons. A food intake model run on DIAMOND to determine the consumption of forms of foods in 2 year olds diets indicates that all consumption of food in this category was as peanut butter. However, due to the range of ages suggested in the literature for the introduction of peanuts, peanut butter was excluded from the infant diet.
Salt	Low sodium diets are strongly recommended for infants. This is because at birth, infant kidneys are underdeveloped and do not fully develop until several months later. Therefore excretion of excess sodium in the diet is difficult and can be of concern (NHMRC, 2003).
Soy beverage	Soy beverages (excluding soy infant formulas) are inappropriate for the first two years of life as the levels of protein and fat are not suitable for infants (NHMRC, 2003; ACTCC, 2007).
Tea	In the 22nd ATDS tea was mapped to all tea, "instant coffee" and "coffee and coffee substitutes". Tea and coffee contain caffeine and are unsuitable fluids for infants (NHMRC, 2003; ACTCC, 2007).
White wine	Alcoholic beverages are unsuitable for infants therefore have been excluded from the infant diet (NHMRC, 2003; ACTCC, 2007).

Table A6.2: The theoretical diet for a 9 month old infant

ATDS Food	Infant mean consumption amount (g/day)
Almonds	0
Apple, unpeeled	19.1
Avocado	0.25
Bacon	0.17
Baked beans, in tomato sauce, canned	3.2
Bananas	10.0
Beans, green	0.52
Beef steak, rib/ribeye/sirloin, grilled	1.2
Beer, 3.5% alcohol	0
Beetroot, canned	0.41
Biscuits, savoury	1.2
Biscuits, sweet, plain	2.8
Bread, multigrain	1.1
Bread, white	15.5
Bread, wholemeal	3.6
Breakfast cereal, mixed grain	0
Breakfast cereal, single grain	3.4
Broccoli, cooked	2.2
Butter, regular	0.39
Cabbage, cooked	0.33
Cake, chocolate, iced	2.8
Carrots, cooked	2.9
Celery, raw	0.52
Cheese, cheddar, full fat	2.2
Cheese, cottage	0.17
Cheese, processed, cheddar type	1.5
Chicken, breast, fillet	3.5
Chocolate, milk	2.1
Coconut, desiccated	0.54
Cream, pure (not thickened)	0.94
Cucumber, raw	1.1

ATDS Food	Infant mean consumption amount (g/day)
Dairy blend (not reduced fat)	0.09
Eggs, boiled	2.4
Fish fillets	0.33
Fish, battered, takeaway	0.43
Fish, crumbed, oven bake	0.14
Grapes	2.7
Ham	1.8
Hamburger	0.03
Ice cream, full fat, vanilla	5.8
Infant cereal, mixed	3.1
Infant dessert, dairy based	2.3
Infant dessert, fruit based	2.6
Infant dinner, containing meat, chicken or fish	1.9
Infant formula	562
Juice, orange	117.4
Lamb chops, loin, grilled	0.67
Lettuce, raw	0.80
Liver, sheep	0.02
Mango	0.67
Margarine or margarine spread, polyunsaturated	1.5
Milk, full fat	0
Milk, modified, low fat	0
Mushrooms	0.42
Nori sheets	0
Oats, rolled	1.1
Oil, canola	0.33
Olives	0
Onions	1.8
Orange	8.8
Parsley, fresh	0
Pasta, white	7.3
Peach, canned in natural juice	3.5

ATDS Food	Infant mean consumption amount (g/day)
Peach, fresh	2.9
Peanut butter	0
Peas, frozen, cooked	1.3
Pie, meat, individual size	3.3
Pineapple, fresh	1.2
Pizza, meat & vegetable containing	0.47
Pork chops, grilled	0.43
Potato crisps	2.3
Potatoes, cooked	12.8
Prawns, cooked	0.07
Pumpkin, cooked	1.8
Rice, white	9.1
Salmon, canned in brine	0
Salt, iodised	0
Salt, non-iodised	0
Sauce, tomato	0.93
Sausages, beef	2.5
Soft Drink	16.6
Soy Beverage, plain	0
Spinach, fresh, cooked	0.08
Strawberries	0.87
Sugar, white	6.1
Sultanas	1.6
Sweetcorn, kernels, frozen	1.8
Tea	0
Tomatoes, raw	4.4
Tuna, canned in brine	0.35
Water, bottled still	273
Water, tap	273
Watermelon	2.3
Wine, white	0
Yoghurt, fruit, full fat	10.4