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Radiation Doses from the Average Australian Diet

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Executive summary

All food products in the human diet contain radionuclides. Many factors influence the concentration of radionuclides in food products, including: their physical and chemical properties, abundance in the environment, biological uptake from the environment and how the food is cooked and prepared for consumption. Although most radionuclides consumed in our diet are of natural origin, some of these, known as anthropogenic radionuclides, are due to human activities.

Australia has previously introduced public health actions to manage radionuclides in some food products. In the 1950's and 60's radionuclides in milk were monitored and reported in response to concerns about wide spread contamination from atmospheric nuclear weapons testing in Australia and the South Pacific. Imported food monitoring programs and food restrictions were introduced in response to the 1986 Chernobyl and the 2011 Fukushima Dai-ichi nuclear power plant accidents. Although programmes like these provide an appropriate level of action to mitigate public exposure to radiation, little is known about the baseline level of radionuclides in food products in Australia and the risk to the population from consumption.

In collaboration with Food Standards Australia New Zealand (FSANZ), ARPANSA assessed the health risk to the Australian population from exposure to both anthropogenic and naturally occurring radionuclides in food products consumed in Australia. This assessment required the measurement of radionuclides in the food followed by a radiation dose assessment from their consumption.

The key findings were:

- anthropogenic radionuclides ^{60}Co, ^{134}Cs and ^{241}Am were not detected in any food product, while low levels of ^{137}Cs were detected in some foods
- naturally occurring radionuclides were detected in most foods, at varying concentrations
- radiation dose estimates were much less than the reference level of 1 mSv/year for existing radiation exposure situations
- consumption of these food products by the Australian population is not expected to have any long term health impacts.

The benefit of this baseline exposure study of radionuclides in food products consumed in Australia is in providing a better understanding of the dose to people from a typical diet. Further, more informed decisions can be made on the management of radionuclides in food.

This study was done as part of the 25th Australian Total Diet Study (ATDS) undertaken by FSANZ in surveying Australian food to determine exposure to contaminants. Water was not included in the measurements and assessment but may be considered in future studies.

1. Introduction

Exposure to ionising radiation in our daily lives occurs via a number of different pathways. One pathway is the ingestion of food containing radionuclides. The exposure and subsequent radiation dose to people is dependent on the radionuclides consumed, the activity concentration of these radionuclides, the age of the person and the quantity of food ingested. Food consumption rates are influenced by a number of factors including climate, cultural preferences and agriculture (FSANZ, 2019; UNSCEAR, 2000, 2013). Radionuclides that are present in the food chain originate from human activity, known as anthropogenic radionuclides, or are naturally occurring.

Anthropogenic radionuclides are present in the environment predominantly as a result of fallout due to atmospheric nuclear weapons testing conducted between 1945 and 1980 and from nuclear power plant reactor accidents such as the Chernobyl accident in 1986 and, more recently, the Fukushima Dai-ichi accident in 2011 (UNSCEAR, 2000, 2013).

Naturally occurring radionuclides originate from cosmic or terrestrial sources. Cosmogenic radionuclides form in the upper atmosphere or in space. These radionuclides (including ^{7}Be and ^{14}C) may attach to particles and be deposited onto the earth's surface. The terrestrial radionuclides include the long-lived uranium and thorium radionuclides and their decay products, and radioactive potassium (^{40}K). The decay products of uranium and thorium include radioactive isotopes of uranium (U), thorium (Th), protactinium (Pa), radium (Ra), radon (Rn), polonium (Po), lead (Pb), bismuth (Bi) and actinium (Ac). These radionuclides have half-lives that range from microseconds to billions of years and have existed in the environment since the formation of the earth. Due to the shorter half-lives of the decay products, the radionuclides in the decay chain exist in a state of secular equilibrium (equal activities) unless natural or anthropogenic processes disrupt this equilibrium (L'Annunziata, 2012; Longworth and Geoff, 1998).

Radionuclides make their way into the food chain via a range of processes. Plants take up radionuclides via direct deposition or, through transfer mechanisms from the soil, water or the atmosphere. Animals take up radionuclides from their environment or from feed materials. Humans ingest radionuclides via the consumption of food and water.

The transport mechanisms of the radionuclides, once inside the body, are dependent on the properties of the element. Once ingested, the digestive system will partially break down food into a suitable form for the body to use. Soluble radionuclides contained within the food may transfer to the bloodstream and be carried throughout the body. The chemical properties of each radionuclide influences where it deposits in the body (Martin and Harbison, 1996). For example, radium (Ra) is chemically similar (analogous) to calcium and will deposit in bone while caesium (Cs) and its isotopes will deposit in all body tissues. Once the body incorporates the radionuclide, the radiation emitted will interact with the surrounding tissues and organs. The radiological effect will vary for each organ or tissue exposed depending on the radiation type, the radionuclide's retention time and the sensitivity of the tissue or organ to the radiation exposure.

1.1 Radionuclides in Australian food

Food Standards Australia New Zealand (FSANZ) regularly undertakes surveys of Australian food to determine exposure to contaminants such as pesticide residues and heavy metals. The focus of the 25th Australian Total Diet Study (ATDS) was to determine the levels of agricultural and veterinary chemical residues, metal contaminants and anthropogenic radionuclides in food consumed in Australia. The inclusion of anthropogenic radionuclides in the study provided important information about their current concentrations in Australian food as this information was not previously available.

The anthropogenic radionuclides in this study were chosen based on past and potential releases into the environment from nuclear weapon detonations, nuclear power plant accidents or other industrial processes. Cobalt-60 (^{60}Co), caesium-137 (^{137}Cs), caesium-134 (^{134}Cs) and americium-241 (^{241}Am) were used as indicators of the levels of anthropogenic radionuclides in the environment. Caesium-137, due to its relatively long half-life, was expected to be present in low levels in the food. A recent study of radioactivity in seafood sourced from northern Australia had shown the presence of ^{137}Cs at low levels in Australian seafood (Urban et al., 2015). Strontium-90 (^{90}Sr), also with a long half-life may be present at low levels due to fallout from past nuclear weapons detonations. However, the analysis for ^{90}Sr is complex and lengthy and was therefore not included in this study. A conservative assumption commonly used is that the level of ^{90}Sr in the environment is the same as that of ^{137}Cs based on historical fallout monitoring results (AIRAC, 1975).

In addition to the anthropogenic radionuclides specified, the study was expanded to include the analysis of a selection of important naturally occurring radionuclides in the food. Studies of radionuclides in food consumed in other countries have shown the important contribution of naturally occurring radionuclides to the overall ingestion dose (Al-Masri et al., 2004; Choi et al., 2008; Patra et al., 2014; Pearson et al., 2016b; Pietrzak-Flis et al., 1997). In Australia, there have been studies of naturally occurring radionuclides in northern Australian bushfoods consumed by the indigenous people living in the Alligator Rivers Region of the Northern Territory (Martin et al., 1998; Ryan et al., 2008; Ryan et al., 2005). Prior to the current study there was little information on the activity concentrations of these naturally occurring radionuclides in the typical Australian diet.

1.2 A risk based approach

A risk based approach provides a process of systematically assessing the potential impact of a hazard on a defined individual or population. Risk assessments are required where there is a plausible chance that there could be an increased risk of harm to people (enHealth, 2012). An important role of the risk assessment process is to clearly document key assumptions and uncertainties to establish the credibility of results and allow decision makers, including the public, to make informed decisions about any risks taken.

The United Nations Scientific Committee on the Effects of Atomic Radiation estimates a global ingestion dose range from 0.2 to 1.0 mSv/year and recognises that this dose range will depend on the radionuclide composition of foods (UNSCEAR, 2008). In Australia, an effective dose to a person from consuming food should not generally exceed a value of 1 mSv/year (ARPANSA 2017).

In this study a risk assessment was undertaken to evaluate the potential health effects resulting from exposure to radionuclides found in food products consumed in Australia. The hazard was quantified by estimating radionuclide activity concentrations in targeted food products. A range of factors including age groups and food consumption rates were taken into account to develop an exposure scenario based on ingestion of radionuclides in the Australian diet.

The information gained through this study provides vital information of the base line concentration of radionuclides in food consumed in a typical Australian diet. This information may be used in managing food safety in Australia and allows radiation risks to be compared to other risks encountered in everyday life. The base line data can assist in optimising radiation protection and communicate risk in the unlikely event of a radiological or nuclear emergency that causes contamination of food in Australia.

1.3 Objective

In collaboration with Food Standards Australia New Zealand (FSANZ), the objective of the study was to characterise the potential health effects to the Australian population from exposure to radionuclides found in typical food products consumed in Australia.

1.4 Scope of the study

The scope of this study was to:

- determine reference activity concentrations adequate to ensure that the dose could be calculated at or below the reference level
- ensure that analytical methods were selected to obtain measurements at or below the derived activity concentrations
- screen all the ATDS food samples collected for the 25th ATDS for the anthropogenic radionuclides ^{137}Cs, ^{134}Cs, ^{60}Co and ^{241}Am to determine current levels in Australian foods
- select a representative sample of foods from the ATDS and determine the levels of the naturally occurring radionuclides ^{234}U, ^{238}U, ^{230}Th, ^{226}Ra, ^{210}Pb and ^{210}Po from the ^{238}U decay chain, and ^{232}Th and ^{228}Ra from the ^{232}Th decay chain
- estimate the radiological dose and health impact to the Australian population from the radionuclide levels determined in this study.

The contribution from cosmogenic radionuclides was not considered within this study. Water and other beverages were analysed as part of the ATDS screening process for anthropogenic radionuclides but were not included in the assessment of naturally occurring radionuclides.

2. Calculation of dose and population dose

After ingestion, radionuclides incorporated in the human body irradiate organs in the body over time. The dose received depends on the radionuclide's physical half-life and its biological retention (biological half-life) within the body. Therefore radionuclides may deliver radiation doses to organs for many months or years after the intake. To estimate the accumulation of radiation dose over extended periods of time requires the calculation of the committed effective dose. The commitment period is taken to be 50 years for adults, and to age 70 years for children (ICRP, 2012).

2.1 Calculation of committed effective dose

The total committed effective dose due to the ingestion of radionuclides present in all types of food, for a particular age group, may be determined using equation 1:

$$Dose_{ing,j} = \sum_{ik}\left(DC_{ing,ij} \times R_{jk} \times C_{ik} \times 1000\right) \quad (1)$$

Where:

$Dose_{ing,j}$	is the committed effective dose (mSv/year) due to the ingestion of all radionuclides for all food types for the age group (*j*)
$DC_{ing,ij}$	is the ingestion dose coefficient (Sv/Bq) for radionuclide (*i*) for each age group (*j*)
R_{jk}	is the consumption rate (kg/year) for the age group (*j*) for food type (*k*)
C_{ik}	is the activity concentration of the radionuclide in the food (Bq/kg) for radionuclide (*i*) and food type (*k*)

2.1.1 Dose coefficients

The International Commission on Radiological Protection (ICRP) has published dose coefficients for each radionuclide which take into account the sensitivity of organs and tissues in the body, the biological half-life of the radionuclide and the type of radiation emitted (ICRP, 2012).

The dose coefficients for the anthropogenic and naturally occurring radionuclides are shown in Appendix 1. Generally, the dose coefficient is higher in younger age groups. This relationship is especially evident for ^{241}Am, which has the highest dose coefficient for the selected anthropogenic radionuclides (Table A1.1).

The four naturally occurring radionuclides with the highest dose coefficients are ^{210}Po, ^{228}Ra, ^{210}Pb and ^{226}Ra with ^{228}Ra being the highest for an infant of 3 months according to the ICRP age groups. Further, the dose coefficients for these four radionuclides are higher than any of the dose coefficients for the anthropogenic radionuclides.

Potassium-40 is not included in the determination of committed effective dose. The human body maintains a relatively constant level of potassium, and hence a constant level of ^{40}K. Therefore, an increase in the amount of ^{40}K ingested does not result in accumulation and, consequently, the dose due its presence has been determined to be 0.165 and 0.185 mSv/year for adults and children, respectively (UNSCEAR, 2000).

2.2 Population weighted dose

The population weighted dose, in mSv/year, is the sum of all the individual doses to members of the population divided by the total population. Although the population weighted dose does not represent any single age group, it represents the average dose across the entire population.

The population weighted dose is calculated using equation 2:

$$Population\ weighted\ dose = \sum_j \frac{Dose_{ing,j} \times Pop_j}{Pop_{tot}} \quad (2)$$

Where:

$Dose_{ing,j}$	is the total committed effective dose (mSv/year) due to the ingestion of all radionuclides for all food types for the age group (*j*)
Pop_j	is the population of age group (*j*)
Pop_{tot}	is the total population

3. Reference activity concentrations applied for method selection

For the naturally occurring radionuclides, a reference level for exposure was set as a total committed effective dose of 1 mSv/year. This value is consistent with the recommendation by the International Atomic Energy Agency (IAEA) in Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, General Safety Requirements Part 3 (IAEA, 2014) adopted within the Australian Guide for Radiation Protection in Existing Exposure Situations, Radiation Protection Series G-2 (ARPANSA, 2017).

For the anthropogenic radionuclides a less sensitive approach was applied. In Australia it is expected that anthropogenic radionuclides in food would be at trace levels, largely because there has been no significant radiological or nuclear accident in Australia that would contaminate the food chain. Therefore a reference level for exposure to each of the radionuclides was set as a committed effective dose of 1 mSv/year. This is consistent with the guidance developed jointly by the Food and Agriculture Organisation of the United Nations (FAO) and the World Health Organisation (WHO) and described within the international "Food Code", *The Codex Alimentarius* (FAO/WHO, 1995).

It is important to select analytical methods for radionuclide measurements that are sufficiently sensitive to allow estimates of dose contribution below the described reference levels of 1 mSv/year.

To achieve sufficient measurement performance, reference activity concentrations were determined to assist with the selection of appropriate analytical methods. These analytical methods were needed to achieve a minimum detectable activity concentration for the radionuclides that would allow the calculation of doses below the reference level.

Therefore, the reference activity concentration for each radionuclide was determined by taking into account the reference level for the committed effective dose, the food consumption rate and ingestion dose coefficient.

Using this method of deriving the reference activity concentrations has some limitations. In particular, it was assumed that radionuclides had no preferential uptake in certain foods and that naturally occurring radionuclides were present in secular equilibrium.

3.1 Consumption data

For the determination of reference activity concentrations, international studies were used as the source of information on food consumption rates. Table 1 shows these consumption rates. At the time of determining reference activity concentrations, detailed consumption data for Australia was not available. Consumption data for an infant (1 year), child and adult were sourced from the UNSCEAR 2000 report (UNSCEAR, 2000), while the consumption for an infant (3 months) was based on 'mixed' infant formula consumption at a rate of 800 mL/day, matched to the intake rate for breast milk (ICRP, 2005).

Table 1. Food consumption rate data (kg/year) derived from international publications

Food type	Infant (3 months)	Infant (1 year)	Child	Adult
Milk products	290	120	110	120
Meat products		15	35	50
Grain products		45	90	140
Leafy vegetables		20	40	60
Roots and fruits		60	110	170
Fish products		5	10	15
Total	290	265	395	555

3.2 Age groups

The ICRP have determined dose coefficients for a range of age groups. Age group consumption data, sourced from international studies, was matched as closely as possible to the ICRP age groups (Table 2) to calculate the reference activity concentrations.

Table 2. ICRP dose coefficients age group mapping to international studies

ICRP age groups	Age groups from international studies
Infant (3 months)	Infant (3 months)
1 year	Infant (1 year)
5 years	Child
10 years	N/A
15 years	N/A
Adult	Adult

3.3 Calculation of reference activity concentrations

The reference activity concentrations for the radionuclides were determined by rearranging equation 1 to form equation 3:

$$C_{ij} = \frac{Dose_{ing,ij}}{DC_{ing,ij} \times R_j \times 1000} \qquad (3)$$

Where: $Dose_{ing,ij}$ is the committed effective dose (mSv/year) (reference level for exposure) due to the ingestion of radionuclide (*i*) for all food types for the age group (*j*)

$DC_{ing,ij}$ is the ingestion dose coefficient (Sv/Bq) for radionuclide (*i*) for each age group (*j*)

R_j is the consumption rate (kg/year) for all food types the age group (*j*)

C_{ij} is the activity concentration of the radionuclide in the food (Bq/kg) for radionuclide (*i*) and age group (*j*)

Infant formula was treated separately to other foods due to its almost exclusive consumption by the infant (3 months) age group. Consequently, it was considered to contribute very little to the consumption in any other age group. Example calculations are illustrated in Appendix 2.

3.4 Naturally occurring radionuclides

The calculation of reference activity concentrations assumed that the radionuclides in the uranium and thorium decay chains were in secular equilibrium. Taking into account all age groups, the concentration giving a dose equal to the reference level of 1 mSv/year was selected as the reference activity concentration for each radionuclide. The reference level for exposure of 1 mSv/year was for the contribution of all naturally occurring radionuclides in the average diet.

Table 3 shows that the reference activity concentration for infant formula was determined to be 0.041 Bq/kg, while the reference activity concentration for other foods was determined to be 0.18 Bq/kg.

Table 3. Calculated reference activity concentrations for naturally occurring radionuclides

Radionuclide	Concentration (Bq/kg) for 1 mSv/year				Reference activity concentrations (Bq/kg)	
	Infant (3 months)	Infant (1 year)	Child	Adult	**Infant formula**	**Other foods**
Naturally occurring	0.041	0.18	0.21	0.52	**0.041**	**0.18**

3.5 Anthropogenic radionuclides

The reference level for exposure was set to 1 mSv/year for each of the anthropogenic radionuclides in this study. The reference activity concentration was calculated in the same way as for the naturally occurring radionuclides. Table 4 shows that the reference activity concentration was lowest for ^{241}Am in infant formula at 0.9 Bq/kg, other food at 5 Bq/kg. Reference activity concentrations for the other radionuclides were much higher than those for ^{241}Am.

Table 4. Calculated reference activity concentrations for anthropogenic radionuclides

Radionuclide	Concentration (Bq/kg) for 1 mSv/year				Reference activity concentrations (Bq/kg)	
	Infant (3 months)	Infant (1 year)	Child	Adult	**Infant formula**	**Other foods**
^{60}Co	64	140	150	540	**50**	**100**
^{134}Cs	132	235	195	97	**100**	**50**
^{137}Cs + ^{90}Sr	25	45	44	44	**10**	**10**
^{241}Am	0.93	10	9	9	**0.9**	**5**

4. Sample preparation and analysis

4.1 Sample collection

FSANZ provided the food samples for analysis based on the sampling regime and sample preparation protocols for the 25th ATDS (FSANZ, 2019). These detailed the processes for purchasing, transporting, preparing and storing foods for the study. Foods were categorised as being either ‘national’ or ‘regional’. National foods comprised largely processed foods where variations within the country were not expected. Regional foods were grown or produced in different regions of Australia and therefore variation in activity concentrations of radionuclides within the food could be expected.

The project covered two sampling periods: autumn 2013 and summer 2014. Eighty-eight different food sample types were collected, with individual food purchases composited into a total of 248 samples for the autumn period and 260 samples for the summer period. All foods were screened for anthropogenic radionuclides and a selection of foods were analysed for naturally occurring radionuclides.

4.2 Selection of foods for determination of naturally occurring radionuclides

From the range of foods sampled for the ATDS, ARPANSA selected representative foods to determine the levels of naturally occurring radionuclides. A variety of foods were selected to represent the expected consumption rates by all ICRP age groups. Table 5 shows the food categories and selected foods in each category. These foods are also consistent with the food categories shown in the UNSCEAR report (UNSCEAR, 2000). Using this criteria, twenty-two foods across both sampling periods, were selected for analysis.

Table 5. Food and food categories for analysis of natural radionuclides

Food category	Food type
Milk products	Milk, infant formula
Meat products	Beef mince, chicken, eggs
Grain products	Bread, breakfast cereal, pasta, rice
Leafy vegetables	Broccoli, lettuce
Roots and fruits	Carrot, onion, peanut butter, potatoes, apples, bananas, mango, nectarine, tomato, fruit juice
Fish products	Fish

4.3 Sample preparation

Foods collected were prepared and/or cooked with oversight by FSANZ, so that they were in a ‘ready to eat’ state prior to being received by ARPANSA.

The samples were frozen prior to shipping and stored frozen until sample preparation and analysis commenced. Any remaining sample was stored for further analysis. The samples received were either unprocessed portions or pre-ground and homogenised. Samples received in the unprocessed state were ground and homogenised using a laboratory grade or commercial blender depending on the food. Pre-ground samples were thoroughly mixed prior to subsampling for analysis. Approximately 500 g of the homogenised sample was subsampled for analysis of anthropogenic radionuclides by high-resolution gamma spectrometry.

For the analysis of the naturally occurring radionuclides, a larger mass was required. Composite samples were prepared by mixing equal amounts of all original samples of a given food type. For example, if four different regional samples were collected, equal amounts of the four regional samples were combined to produce one composite sample. The composite samples were dried at 90°C to a constant mass and ground, using a knife mill, to a fine powder. Some of the dried sample was reserved for analysis of specific radionuclides and another portion was further subsampled for pre-treatment (ashing) using a muffle furnace at 400°C or 500°C for additional radionuclide analysis.

4.4 Analysis for anthropogenic radionuclides

The samples were analysed for anthropogenic radionuclide activity concentrations using high-resolution gamma spectrometry. High purity germanium detectors, calibrated for energy and efficiency using NIST (National Institute of Standards and Technology) traceable multi-radionuclide sources, were used for gamma counting.

Samples were dispensed into medium (450 mL) Marinelli beakers: a geometry suitable for the measurement of gamma emitting radionuclides. Samples were counted for a minimum of eight hours for this screening. The composite samples (twenty-two samples in total) were also analysed for anthropogenic radionuclides, following drying and grinding.

4.5 Analysis for naturally occurring radionuclides

The methods used for the determination of activity concentrations of naturally occurring radionuclides from the ^{238}U and ^{232}Th decay chain are summarised in Table 6 and details of the procedures are provided in Appendix 3.

Table 6. Summary of procedures used in the analysis of natural radionuclides

Radionuclides	^{210}Po	^{210}Pb	U/Th	Ra
Sample preparation	Dried	Ashed @ 400°C	Ashed @ 500°C	Ashed @ 500°C
Dissolution	HNO_3, HNO_3/H_2O_2	HNO_3 plus additional ashing	HNO_3 plus additional ashing	HNO_3 plus additional ashing
Separation	Manganese dioxide (MnO_2) precipitation	Sr resin, MnO_2 precipitation for separation of ingrown ^{210}Po	Co-precipitated with Ca_2PO_4, U: separation using UTEVA resin Th: separation using TEVA resin	Co-precipitated with $PbSO_4$, purification with $BaCl_2$ ^{228}Ra: ^{228}Th allowed to grow in, TEVA resin separation
Source preparation	Autodeposition (silver disc)	Autodeposition (silver disc)	Electrodeposition (stainless steel discs)	^{226}Ra: dissolved in EDTA, scintillant added ^{228}Ra: Electrodeposition of Th
Counting technique	Alpha spectrometry	Alpha spectrometry	Alpha spectrometry	^{226}Ra: LSC ^{228}Ra: alpha spectrometry

5. Dose assessment inputs

5.1 Food consumption data

FSANZ provided a report detailing the consumption data for the twenty-two food groups analysed for naturally occurring radionuclides. The data was based on the 2011-12 Australian National Nutrition and Physical Activity Survey (ABS, 2014). This survey was a 24-hour recall survey and for 64% of respondents, a second 24 hour recall survey was undertaken. Only the consumption information, where two days of data was available (n=7735), was used for this study and for the estimation of dose.

Where possible, the foods consumed in the nutrition survey were matched to the twenty-two food types selected for testing. Where no exact matches were possible, the foods were matched as closely as possible to the items for which data existed to provide a suitable approximation or 'mapping' for dietary consumption and radionuclide intake. For example, 'broccoli' captures broccoli, broccoflower, cauliflower, stalk and stem vegetables, based on the assumption that similar types of foods would have similar radionuclide concentrations. This broad mapping was done in order to capture as many foods from the diet as possible. Recipes were used to break down mixed foods or dishes that didn't match directly to one food type into its major ingredients. These ingredients were then matched to the foods analysed e.g. hamburgers that are composed of meat, bread, tomato, cheese and lettuce could be better matched by this component breakdown. Some foods were not able to be included in this matching process and they were not classified (e.g. coffee, sugar, confectionary). Table A1.1 in Appendix 4 shows the twenty-two 'ARPANSA' food groups, the foods matched to the food group and the consumption data for the different age groups.

The data from FSANZ covered the following age groups: 2 years, 3–7 years, 8–12 years, 13–17 years and 18 years and above. For infants, the consumption rate used was the same as that used to determine the reference activity concentration given by the ICRP (ICRP, 2005) of 800 mL/day.

5.2 Dose coefficients

The provided age group data for Australian food consumption was matched to the ICRP age groups, shown in Table 7, in order to undertake the detailed dose assessments.

Table 7. ICRP dose coefficients age group mapped to Australian consumption data

ICRP age groups	Age groups used in this study
Infant (3 months)	<1 year
1 year	2 years
5 years	3–7 years
10 years	8–12 years
15 years	13–17 years
Adult	More than 18 years

6. Results

The activity concentration results are shown in Appendix 5 and Appendix 6. The results are reported in Bq/kg based on the sample "as received". As detailed in section 4.3, foods collected had either been prepared and/or cooked so that they were in a 'ready to eat' state, so are not reported as wet weight or dry weight. The reported uncertainty is the combination of the standard uncertainties and is reported with a coverage factor of k=1, giving a confidence factor of approximately 68%. A result less than the minimum detectable activity concentration (MDC) has been reported as "ND" (not detected). This is consistent with current IAEA recommendations (IAEA, 2017). There is some variation in MDC, due to differences in factors such as the measurement technique used, mass of sample used for analysis, counting time and recovery of the radionuclide during the assay.

6.1 Activity concentrations – anthropogenic radionuclides

Appendix 5 (Tables A5.1 and A5.2) lists the results of all the samples screened for anthropogenic radionuclides. For comparison, these tables also list the results for ^{40}K obtained during the screening process.

Some radionuclides, ^{60}Co, ^{134}Cs and ^{241}Am, were not detected in any of the food samples. The radionuclide ^{137}Cs was detected in twelve samples at an activity concentration ranging from 0.061 to 0.389 Bq/kg. As previously discussed, ^{137}Cs is present at low levels in the environment due to the deposition of global fallout and because of its longer half-life. Therefore, the presence of ^{137}Cs in some food was expected.

There was insufficient data available to make any comparisons of the anthropogenic radionuclide content of the foods between the autumn and summer periods.

Where the radionuclide was not detected, the MDC was well below the most restrictive reference activity concentrations for ^{241}Am of 0.9 Bq/kg for infant formula and 5 Bq/kg for other foods, refer to Table 4.

6.2 Committed effective dose – anthropogenic radionuclides

The committed effective dose from the intake of anthropogenic radionuclides, ^{60}Co, ^{134}Cs and ^{241}Am could not be calculated because the radionuclides were not detected in any of the samples analysed. ^{137}Cs was detected in only a small number of samples.

All the radionuclide levels were below the reference activity concentrations for all foods. Therefore the committed effective dose was less than 1 mSv/year for each radionuclide across all the age groups. In the case of ^{60}Co, ^{134}Cs and ^{137}Cs the MDCs were considerably less than the reference activity concentrations. For the composite samples, the dose for each radionuclide was estimated using the MDC if the radionuclide was not detected. This data is shown in Table 8.

Table 8. Estimated dose contribution for each radionuclide in all composite foods.

Age Group	Dose contribution from anthropogenic radionuclides (mSv/year)			
	^{241}Am	^{60}Co	^{134}Cs	^{137}Cs + ^{90}Sr
Infant	<0.03	<0.01	<0.01	<0.01
2 years	<0.03	<0.01	<0.01	<0.01
3–7 years	<0.03	<0.01	<0.01	<0.01
8–12 years	<0.03	<0.01	<0.01	<0.01
13–17 years	<0.03	<0.01	<0.01	<0.01
>18 years	<0.03	<0.01	<0.01	<0.01

6.3 Activity concentrations – naturally occurring radionuclides

The measured activity concentrations and the uncertainties (k=1) for the uranium and thorium decay chain radionuclides in the composite samples are shown in Appendix 6. The results, except for infant formula, are shown graphically in Figures 1-8. Where a radionuclide was not detected, the MDC is shown as a black bar. A black dashed line on the graph indicates the reference activity concentration. The activity concentrations for the selected radionuclides in infant formula are shown in Figure 9 where the dashed line shows the calculated reference activity concentration for an infant (< 3 months).

All the MDCs were well below the reference activity concentrations indicating that the methods of analysis provided suitable results to establish that the calculated committed effective dose was below the reference level of 1 mSv/year.

The activity concentrations for the naturally occurring radionuclides varied depending on the radionuclide and the food type. Thorium-232 was not detected in any of the composite samples and ^{230}Th was detected in five samples only. Comparison of Figures 2-9 shows that the radionuclides were not in secular equilibrium. The radionuclides in the ^{238}U decay chain showed varied activity concentrations in the same food type, indicating some disequilibrium. This can be explained by the decay product having become separated from its parent radionuclide by different processes within the environment (UNSCEAR, 2000).

All activity concentration values for the naturally occurring radionuclides were below 0.3 Bq/kg, with isotopes of radium generally being the dominant contributor. Radium-228 results showed the highest activity concentrations in cereal, eggs and peanut butter. Radium-226 showed a similar relative activity concentration trend, although the values are lower within each comparable food.

The ^{40}K activity concentrations are shown in Appendix 5. The ^{40}K activity was not considered for dose calculations.

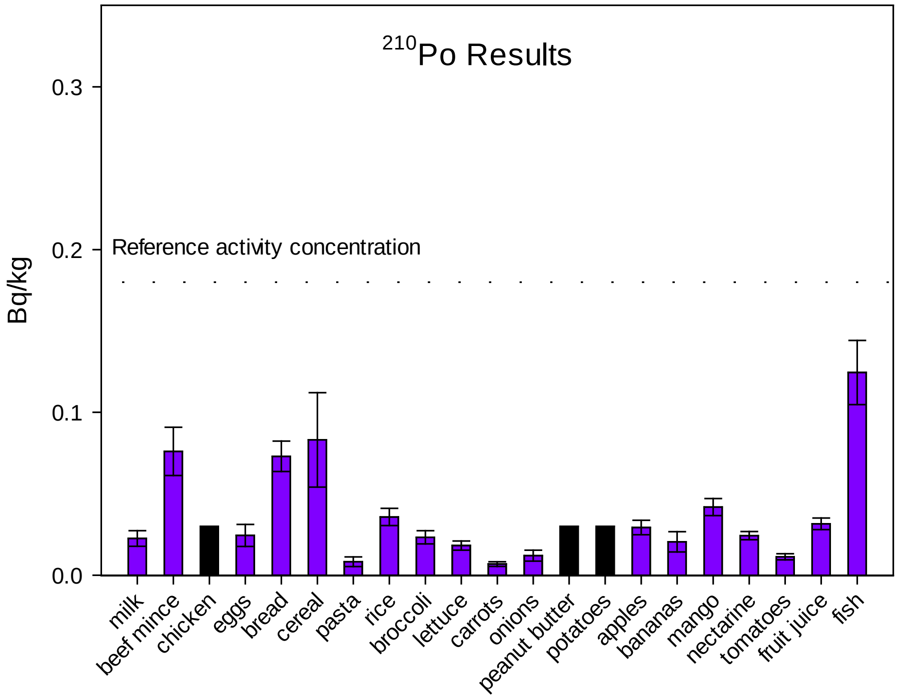

Figure 1. Activity concentrations for ^{210}Po for the composite samples

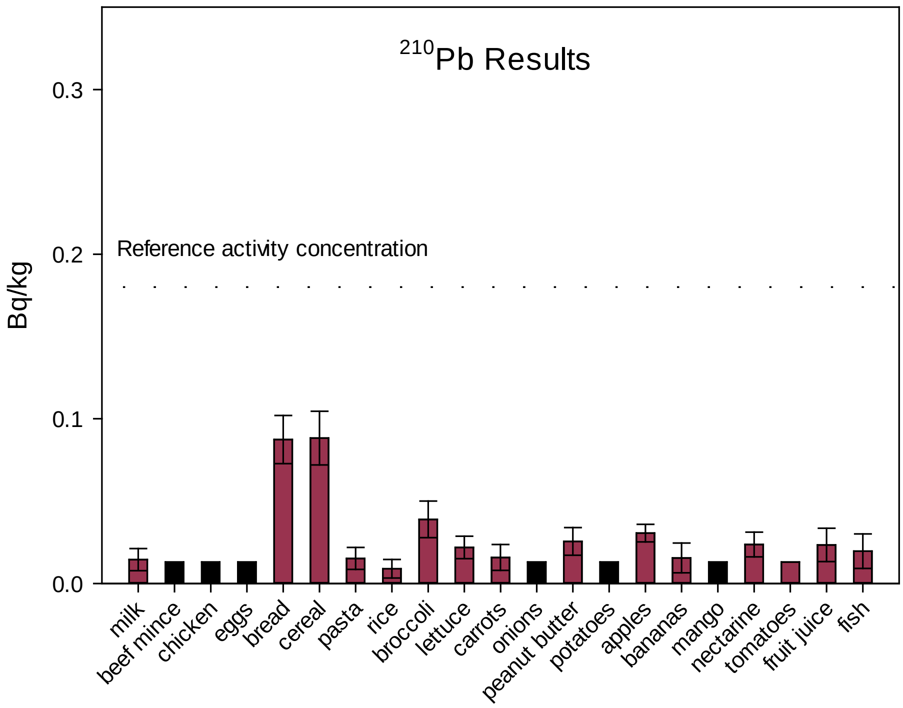

Figure 2. Activity concentrations for ^{210}Pb for the composite samples

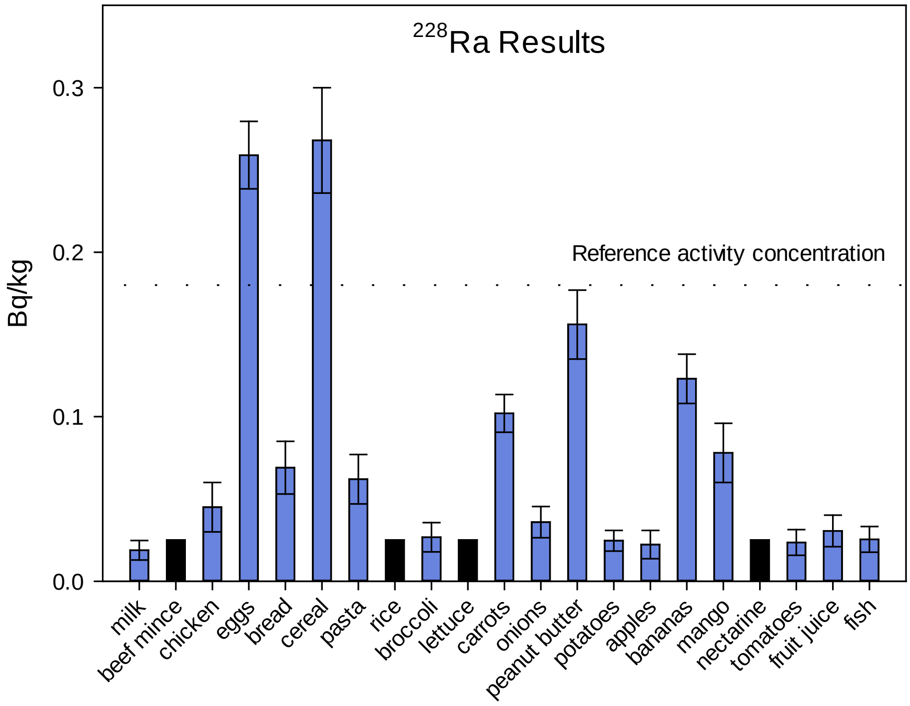

Figure 3. Activity concentrations for ^{228}Ra for the composite samples

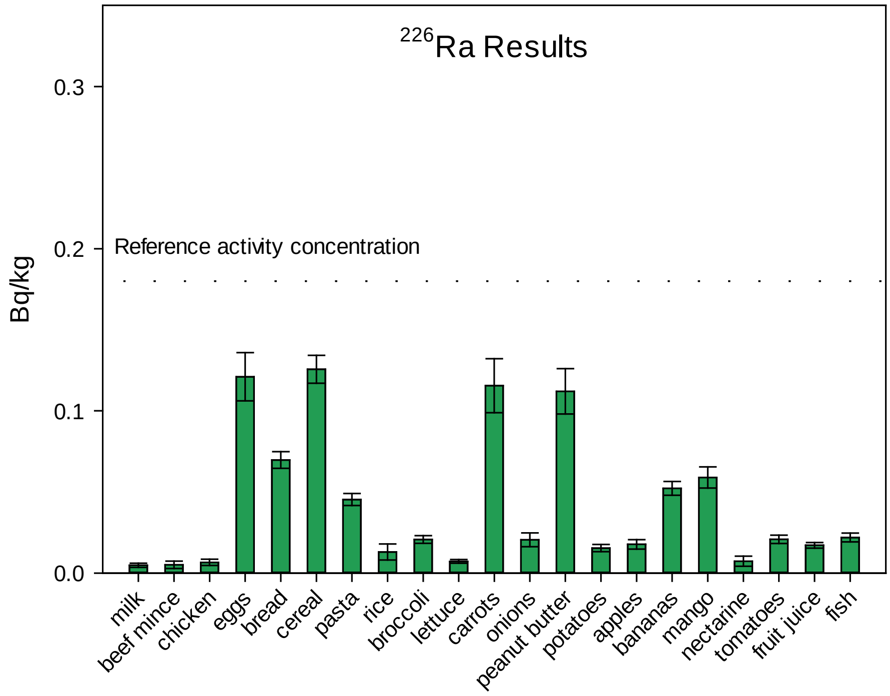

Figure 4. Activity concentrations for ^{226}Ra for the composite samples

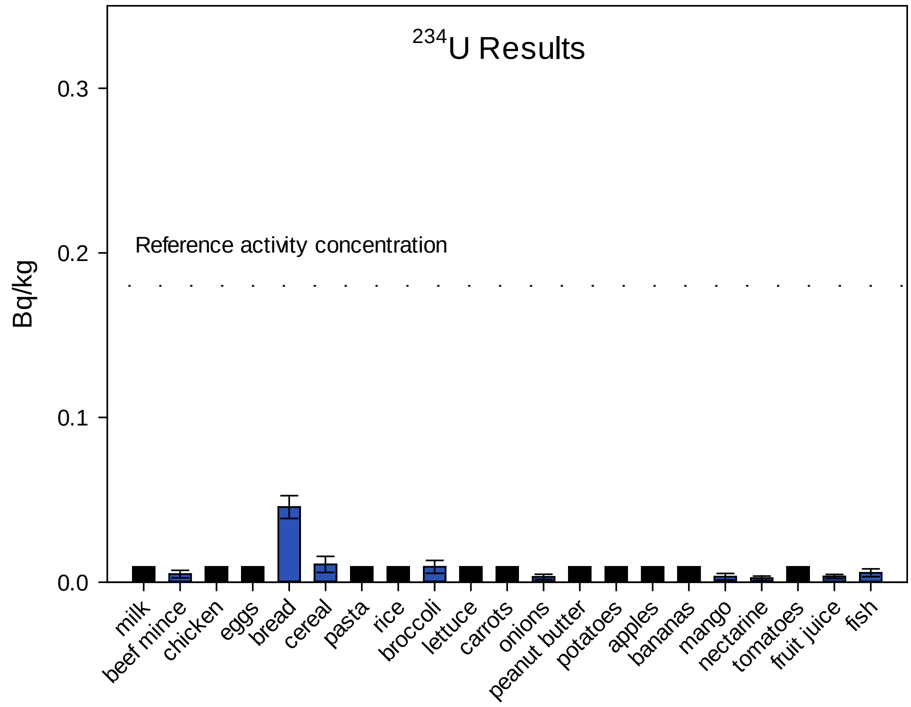

Figure 5. Activity concentrations for ^{234}U for the composite samples

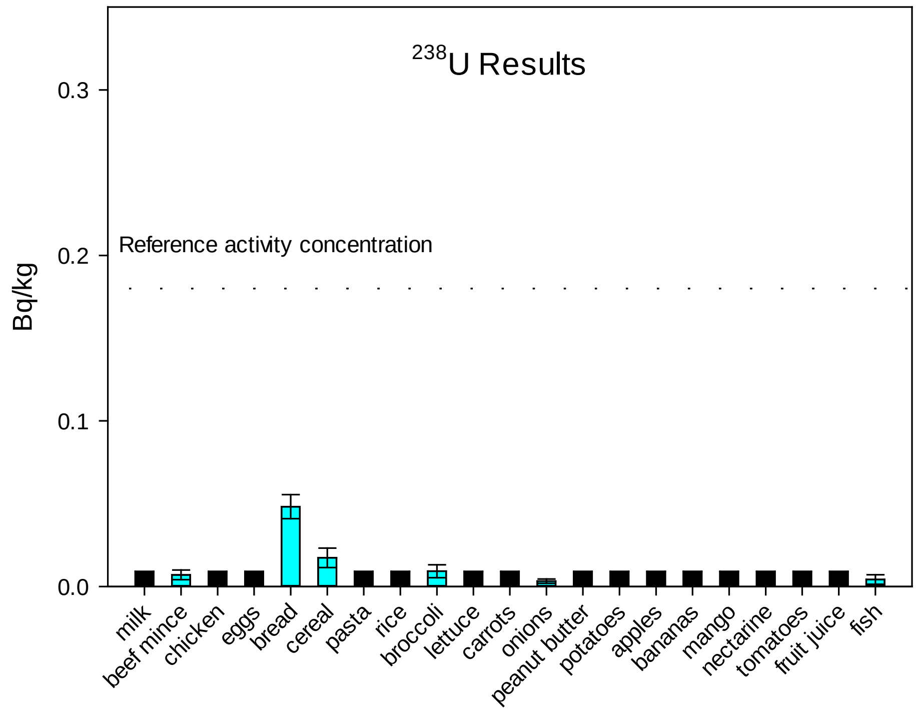

Figure 6. Activity concentrations for ^{238}U for the composite samples

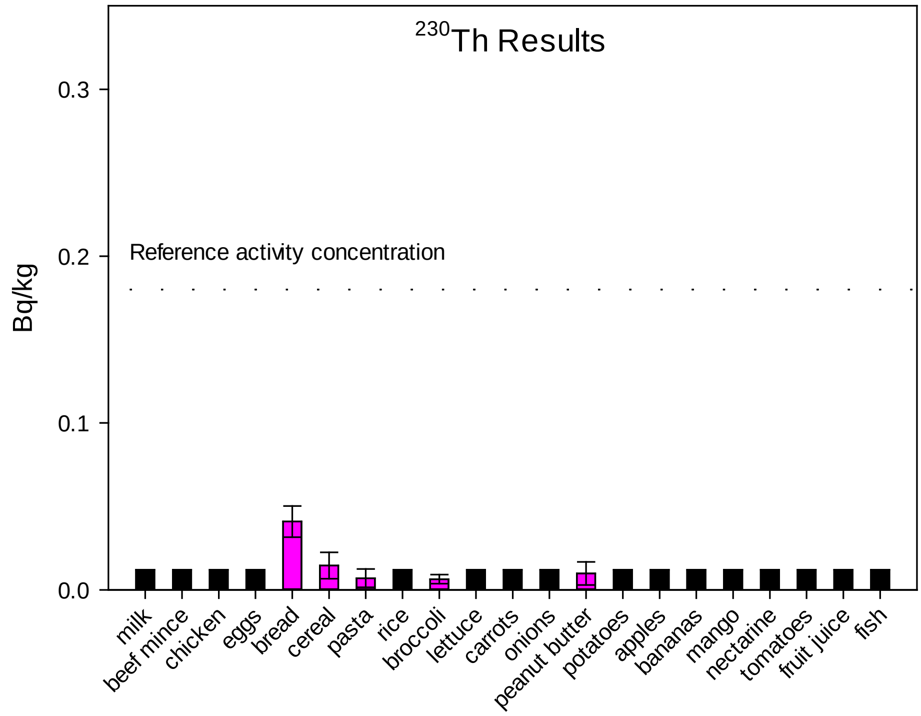

Figure 7. Activity concentrations for ^{230}Th for the composite samples

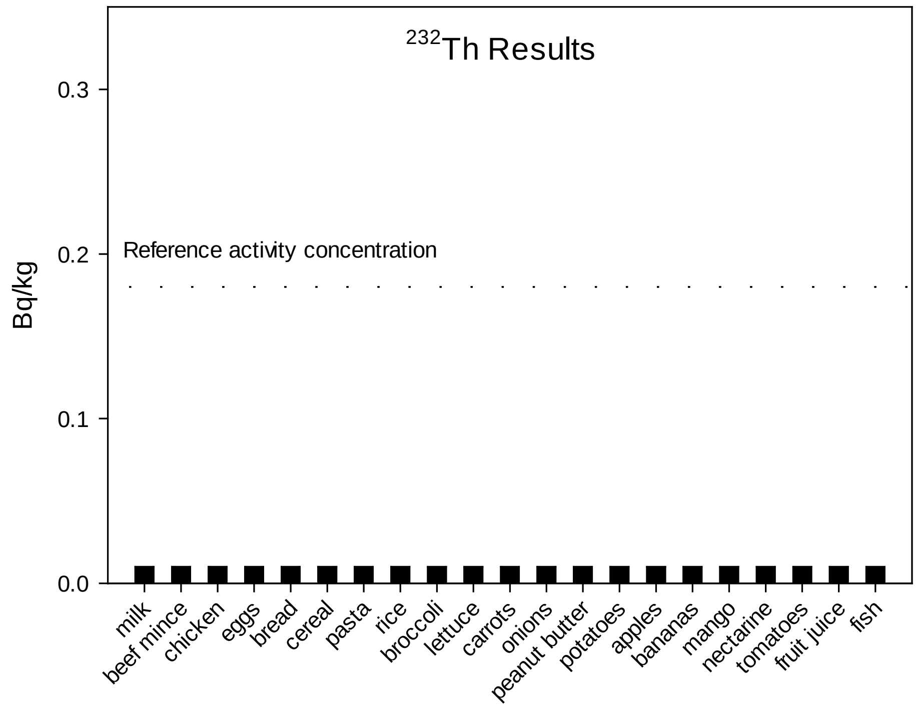

Figure 8. Activity concentrations for ^{232}Th for the composite samples

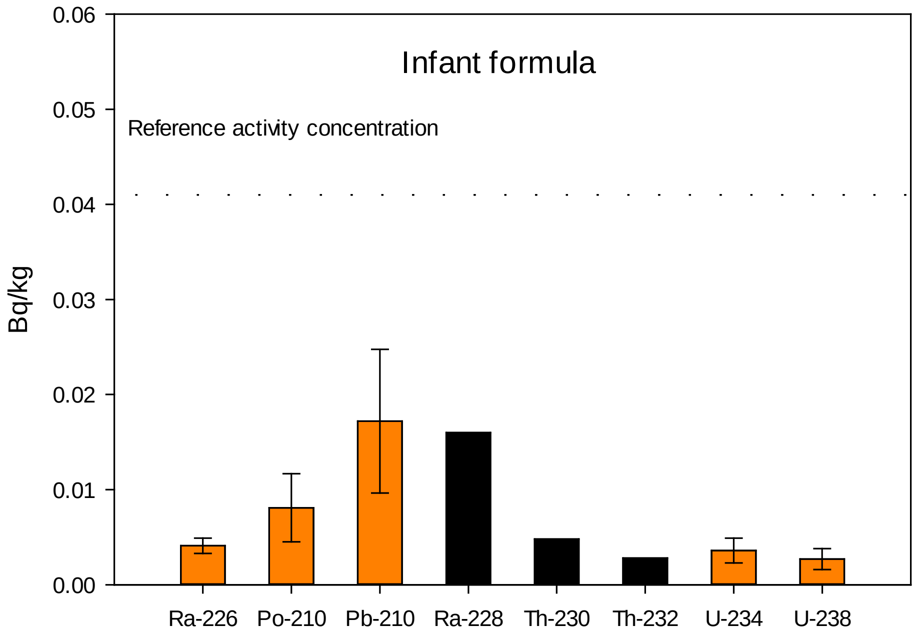

Figure 9. Activity concentration for the selected radionuclides in infant formula.

6.4 Committed effective dose - naturally occurring radionuclides

The committed effective dose was calculated for each age and food group. An example of the calculation (for the consumption of ^{226}Ra by a two-year-old) is detailed in Table A7.1 in Appendix 7. The committed effective dose was determined using two methods:

1. if the radionuclide was not detected the activity concentration was deemed to be zero
2. if the radionuclide was not detected, the MDC for the radionuclide was used as an activity concentration for that sample.

Figures A7.1 to A7.6 in Appendix 7 show the committed effective dose for each food group and includes the dose contributed by each radionuclide (calculated using the MDC as an activity concentration where there was no detection).

The committed effective doses were calculated for the food and age groups and are shown in Table 9 with and without including the MDC in the calculation. The total committed effective doses for the different age groups are shown in Figure 10. The reference level for exposure of 1 mSv/year is indicated by a dotted line. For most of the age groups the committed effective dose did not show a significant difference when the two different calculation methods were applied. The exception was for infant formula where the activity concentration for ^{228}Ra was below the detection limit. In this case the use of the MDC in the calculation resulted in a much higher dose than if the activity concentration was assumed to be zero.

The dose coefficients given in ICRP Publication 95 (ICRP, 2005) for chronic exposure were used to estimate the committed effective dose for an infant consuming breast milk. The dose coefficients model the exposure pathway based on the radionuclide intake by the mother (adult), radionuclide transfer into breast milk and subsequent consumption of breast milk by the infant.

Table 9. Committed effective dose (mSv/year), due to the naturally occurring radionuclides, for the age groups and food categories and the total committed effective dose

Age groups	MDC included in calculation of dose	Food categories						Total committed effective dose (mSv/y)
		Milk products	Meat products	Grain products	Leafy vegetables	Root vegetables and fruit	Fish products	
Infant (formula)	No	0.11						0.11
	Yes	0.26						0.26
Infant (breast milk)	No	0.015						0.015
	Yes	0.017						0.017
2 years	No	0.091	0.016	0.086	0.0028	0.078	0.0039	0.28
	Yes	0.094	0.022	0.088	0.0032	0.089	0.0039	0.30
3–7 years	No	0.046	0.011	0.063	0.0014	0.045	0.0020	0.17
	Yes	0.048	0.014	0.065	0.0017	0.053	0.0021	0.18
8–12 years	No	0.042	0.013	0.069	0.0012	0.049	0.0024	0.18
	Yes	0.044	0.017	0.071	0.0017	0.056	0.0025	0.19
13–17 years	No	0.044	0.017	0.085	0.0017	0.051	0.0018	0.20
	Yes	0.045	0.023	0.088	0.0025	0.057	0.0018	0.22
>18 years	No	0.012	0.0051	0.017	0.0009	0.014	0.0018	0.051
	Yes	0.014	0.0071	0.018	0.0011	0.018	0.0018	0.059

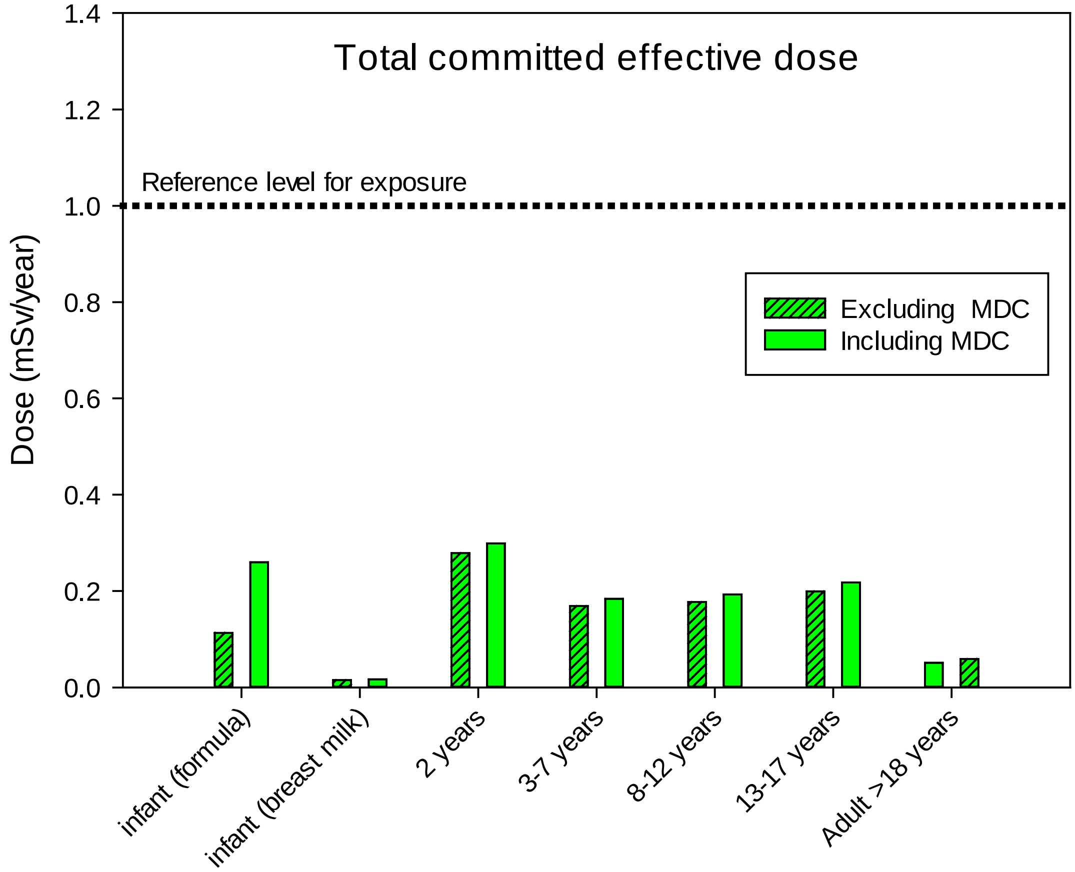

Figure 10. Total committed effective dose ranges for the consumption of food containing radionuclides from the U and Th decay series.

6.5 Population weighted committed effective dose

The population weighted committed effective dose was calculated using equation 2 and is shown in Table 10.

Table 10. Population weighted committed effective dose (mSv/year), due to the naturally occurring radionuclides.

Age groups	Total committed effective dose (mSv/year)		Percentage of the Australian population*	Contribution to population weighted dose (mSv/year)	
	No MDC	MDC		No MDC	MDC
Infant (formula)	0.11	0.26	0.65^	**0.00074**	**0.0017**
Infant (breast milk)	0.015	0.017	0.65^	**0.0001**	**0.0001**
2 years	0.28	0.30	2.7	**0.0075**	**0.0081**
3-7 years	0.17	0.18	6.5	**0.011**	**0.012**
8-12 years	0.18	0.19	6.3	**0.011**	**0.012**
13-17 years	0.20	0.22	6.5	**0.013**	**0.014**
>18 years	0.051	0.059	76.8	**0.039**	**0.045**
Population weighted average dose (mSv/year)				**0.083**	**0.094**

***Sourced from 2011 census (ABS, 2011)**

^50/50 ratio of breast milk and formula milk infants (AIHW, 2011)

7. Discussion

In a worldwide context, the activity concentrations of naturally occurring radionuclides can vary by many orders of magnitude depending on region. Consequently, radionuclide concentrations in foods vary widely because of these regional differences. These differences arise from variations in radionuclide background levels in soil, the climate and the agricultural conditions that prevail. There are also differences in the types of local food included in categories such as vegetables, fruits and fish. Reference values have been documented by UNSCEAR, which are based on the most widely available data (UNSCEAR, 2000).

In this study the measured activity concentrations of the naturally occurring radionuclides varied by two orders of magnitude. However, the results were generally consistent with the reference values reported by UNSCEAR and other authors (Choi et al., 2008; Pearson et al., 2016b; UNSCEAR, 2000). For example, in this study the ^{228}Ra and ^{226}Ra activity concentrations in the composite carrot sample were four to five times higher than the average reported by UNSCEAR for root vegetable and fruits, but were within the range reported across a range of countries, noting that the data for ^{228}Ra was very limited (UNSCEAR, 2000).

The UNSCEAR reference value for ^{210}Po in fish products of 2 Bq/kg is much higher than the results obtained in this study of 0.125 Bq/kg. Polonium is known to accumulate in seafood and activity concentrations may be high when compared to concentrations in other food types. A study by Urban et al (2015) showed the levels in different types of fish were significantly higher than found in this study, ranging from less than 0.02 Bq/kg to 10.9 Bq/kg. The activity concentration may have also depended on the species of fish. Polonium-210 is generally higher in shellfish and large pelagic predators and may not be in secular equilibrium with the parent, ^{210}Pb (Carvalho, 2011; Pearson et al., 2016a).

The consumption rates used in this study were different to UNSCEAR values. A comparison table can be found in Appendix 4, Table A.4.2. In particular, the consumption rates for the categories of 'milk products' and 'roots and fruits' were higher in this study, while 'leafy vegetable' and 'fish products' consumption rates were lower. The UNSCEAR consumption rate dataset was useful as a reference and as a way to compare studies. However, the differences demonstrate the importance of having country specific consumption rates to obtain a more accurate representation of dose for a given population.

The committed effective dose due to the consumption of food containing radionuclides was considerably less than the reference level of 1 mSv/year. Generally the ingestion dose for children was higher than for adults due to the higher dose coefficients for children. In this case, the differences were most notable for the ingestion of ^{228}Ra, ^{210}Po and ^{210}Pb. The calculated doses were generally consistent with results obtained in other studies (Choi et al., 2008; Landstetter et al., 2013; UNSCEAR, 2000).

A comparison table of various studies reporting the activity concentrations of natural radionuclides in infant formula is presented in Appendix 6, Table A6.3. There was some consistency with international studies for ^{234}U and ^{238}U. The reported value in this study of 0.065 Bq/kg for ^{210}Po was similar to the studies reported in Slovenia and India. The greatest difference was in the reported values for ^{226}Ra. The reported values from this study of 0.033 Bq/kg were similar to those reported in the Slovenian study but were 1 to 2 orders of magnitude lower than the studies in Malaysia and Saudi Arabia. Further, the studies from Malaysia and Saudi Arabia included infant formula sourced from Australia. This may indicate that further investigation of radionuclide content of infant formula may be warranted to understand the differences in ^{226}Ra activity concentrations. However, it is important to note that even if the ^{226}Ra activity concentration from the Malaysian and Saudi Arabian data were applied, the dose to a formula fed infant would not be above 1 mSv/year.

When the doses were calculated with and without including the MDC comparison showed that there was generally no notable difference in the results (Table 9). A notable exception is the formula fed infant. The calculated dose to a formula fed infant which used the MDC values for ^{228}Ra was more than double than the dose for when the activity concentration was assumed to be zero.

The dose contribution from anthropogenic radionuclides was found to be much lower than the 1 mSv/year reference level. In the majority of cases anthropogenic radionuclides were not detected. Where MDCs were used for dose estimates, the contributions were below 0.03 mSv/year for ^{241}Am and below 0.01 mSv/year for the other radionuclides analysed.

Overall, the study showed that, based on the average Australian diet, the committed effective dose from the ingestion of food (excluding water) was very low at 0.059 mSv/year for adults. The total committed effective dose ranged from 0.017 for a breast fed infant to 0.30 mSv/year for a 2-year-old child. The differences in the dose with age group was dependent predominately on dose coefficients and rate of food consumption. The dose coefficients are generally higher in younger age groups, however, the food consumption increases with age resulting in some complexity with dose estimates.

There have been many large scale studies worldwide of cancer risk arising from ionising radiation exposure (UNSCEAR, 2006). The risk from exposure to high radiation doses is relatively well quantified, but for low radiation exposures the scientific evidence for increased health risk is more limited. While there is a possible increased risk of cancer at low radiation doses or for radiation delivered over a long period of time, scientific studies show that these effects are not always detectable within populations (UNSCEAR, 2017). However, the current Linear No Threshold (LNT) model for radiation protection indicates that the likelihood of effects increases as dose increases.

In order to differentiate between magnitudes of exposure of the whole body, it is useful to consider:

- very low doses (below 10 mSv), which corresponds to the range of exposure any member of the public may experience under normal circumstances on a yearly basis
- low doses (10 to 100 mSv), that may be incurred by a few individuals as a result of their profession, or from medical examinations
- moderate doses (100 mSv to 1 Sv), harmful tissue reactions may be detected if the dose is incurred under relatively short time periods, and where, at the higher dose end, acute effects of short-term exposures are to be expected
- high doses (more than 1 Sv), where acute effects from short-term exposures will occur.

Harmful tissue reactions, ranging from skin burns to vomiting, reduced blood cell counts and death, occur when doses are moderate to high (greater than about 500 mSv). Doses that may result in harmful tissue reactions are not a concern in food consumed in Australia, except in the event of a potential extreme accident situation.

8. Conclusion

This study was conducted to evaluate the levels of anthropogenic and naturally occurring radionuclides in Australian foods that form the largest part of a typical Australian diet. The study was run in conjunction with the FSANZ as part of the 25th Australian Total Diet Survey. A total of 508 food samples were collected during autumn of 2013 and the summer of 2014. This sample set represented 88 different food types from different regions of the country. All of these foods were screened for anthropogenic radionuclides and

22 food types (as composites) were analysed for naturally occurring radionuclides. There were 248 samples collected during autumn and 260 samples were collected in summer to investigate seasonal impacts of food growing in Australia.

The study showed that the anthropogenic radionuclides, ^{60}Co, ^{134}Cs and ^{241}Am were not detectable in any of the food samples analysed. Caesium-137 was detected at very low activity concentrations in only 2.4% of the samples. This meant that there was insufficient data to make comparisons between samples collected during the autumn and the summer sampling periods. Caesium-137 has a relatively long half-life and is present in the environment at trace levels in the southern hemisphere, primarily due to global fallout.

To ensure sufficient analytical sensitivity in measuring naturally occurring radionuclides, food samples of the same food type were combined to create composite samples. These composite samples were predominately from the summer sampling period. Naturally occurring radionuclides were detectable in all 22 composite food samples. The need for composites combined with the dominant representation from the autumn sampling period meant that seasonal comparisons in radionuclide content could not be made in this case.

The calculated committed effective dose due to the consumption of food containing radionuclides was estimated at less than 0.4 mSv/year for all age groups. Naturally occurring radionuclides contained within food contributed more to the overall dose than anthropogenic radionuclides. The highest contribution to the dose was from exposure to ^{228}Ra, ^{210}Po and ^{210}Pb. The calculated population weighted average dose was less than 0.1 mSv/year. This dose represents a small fraction of the average background dose of 1.5 mSv/year to the Australian public (excluding medical exposures) (Webb et al., 1999). Therefore, the dose due to the consumption of food containing anthropogenic or naturally occurring radionuclides contributes only a very small portion of the overall dose to the population.

It was noted that there were some differences in the activity concentrations reported for infant formula when compared to international studies. Further investigation into infant formula may be warranted, although doses are not expected to be above 1 mSv/year for formula fed infants.

The focus of this study was food and excluded the contribution from the consumption of water. The average adult in Australia was estimated to consume approximately 2 litres of water in a day. Therefore this is an important consideration in the ingestion pathway and may contribute significantly to the overall dose. Further work is required to investigate the levels of radionuclides, especially the naturally occurring fraction, in water. These levels are expected to vary depending on the source of water. For example, there may be large differences if the water is obtained from a reservoir compared to an underground aquifer or between different geographical regions. Data on radionuclide levels in water and information on water consumption rates and water sources will be required to be able to determine the dose from the ingestion of drinking water.

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Appendix 1 Dose coefficients

Table A1.1 Age related dose coefficients (selected anthropogenic radionuclides).

Radionuclide	Ingestion dose coefficient (Sv/Bq)						
	Infant – Breast milk (from adult intake)	Infant	1-year-old	5-year-old	10-year-old	15-year-old	Adult
^{241}Am	8.5E-11	3.7E-6	3.7E-7	2.7E-7	2.2E-7	2.0E-7	2.0E-7
^{60}Co	2.0E-9	5.4E-8	2.7E-8	1.7E-8	1.1E-8	7.9E-9	3.4E-9
^{134}Cs	3.1E-9	2.6E-8	1.6E-8	1.3E-8	1.4E-8	1.9E-8	1.9E-8
^{137}Cs	2.6E-9	2.1E-8	1.2E-8	9.6E-9	1.0E-8	1.3E-8	1.3E-8
^{90}Sr	1.5E-8	2.3E-7	7.3E-8	4.7E-8	6.0E-8	8.0E-8	2.8E-8

Table A1.2 Age related dose coefficients (naturally occurring radionuclides)

Radionuclide	Ingestion dose coefficient (Sv/Bq)						
	Infant – Breast milk (from Adult intake)	Infant	1-year-old	5-year-old	10-year-old	15-year-old	Adult
^{238}U	3.4E-11	3.4E-7	1.2E-7	8.0E-8	6.8E-8	6.7E-8	4.5E-8
^{234}U	3.6E-11	3.7E-7	1.3E-7	8.8E-8	7.4E-8	7.4E-8	4.9E-8
^{230}Th	3.9E-11	4.1E-6	4.1E-7	3.1E-7	2.4E-7	2.2E-7	2.1E-7
^{226}Ra	2.8E-8	4.7E-6	9.6E-7	6.2E-7	8.0E-7	1.5E-6	2.8E-7
^{210}Pb	2.2E-7	8.4E-6	3.6E-6	2.2E-6	1.9E-6	1.9E-6	6.9E-7
^{210}Po	7.1E-8	2.6E-5	8.8E-6	4.4E-6	2.6E-6	1.6E-6	1.2E-6
^{232}Th	6.0E-11	4.6E-6	4.5E-7	3.5E-7	2.9E-7	2.5E-7	2.3E-7
^{228}Ra	1.8E-7	3.0E-5	5.7E-6	3.4E-6	3.9E-6	5.3E-6	6.9E-7

Appendix 2 Determination of reference activity concentration

Relevant equation - $C_{ij} = \frac{Dose_{ing,j}}{DC_{ing,ij} \times R_j \times 1000}$

Table A2.1 Age related dose coefficients (naturally occurring radionuclides)

Quantity	Dose criteria per nuclide (*i*) per age group (*j*)	Food consumption per age group (*j*)	Ingestion dose coefficient per nuclide (*i*) per age group (*j*)	Derived activity concentration per nuclide (*i*) per age group (*j*)
Variable	$Dose_{ing,ij}$	R_j	$DC_{ing,ij}$	$C_{i,j}$
Unit	mSv/year	kg/year	Sv/Bq	Bq/kg
Assumption	For the naturally occurring radionuclides (NORM), a reference level for exposure is set as the total committed effective dose of 1 mSv/year. For the anthropogenic radionuclides, a reference level for exposure to each of the radionuclides was set as a committed effective dose of 1 mSv/year.	Total consumption per year is used. No preferential nuclide uptake for food types. Food consumption data based on international data from UNSCEAR. Infant formula treated separately due to it being a potential dominant pathway for infants, 800ml/day.	Age dependant ingestion dose coefficients from the ICRP. In the case of NORM, the assumption is that the ^{238}U & ^{232}Th series are in equilibrium, this allows the dose coefficients to be summed.	The assumption of equilibrium for NORM materials means that the derived activity concentration can be applied to each NORM isotope within the ^{238}U and ^{232}Th series.
Examples				
Anthropogenic: ^{241}Am				
Infant (formula)	1	290	3.7E-6	0.9
Infant	1	265	3.7E-7	10
Child	1	395	2.7E-7	9
Adult	1	555	2.0E-7	9
NORM: ^{238}U & ^{232}Th series				
Infant (formula)	1	290	8.5E-5	0.041
Infant	1	265	2.1E-5	0.18
Child	1	395	1.2E-5	0.21
Adult	1	555	3.5E-6	0.52

Appendix 3 Analysis details – naturally occurring radionuclides

Information on sample preparation procedures and measurement, for the naturally occurring radionuclides, is provided below. Quality control samples, including check samples and method blanks were analysed with each batch of samples. Sample spikes and duplicate samples were also included randomly.

A3.1 Potassium-40

Potassium-40 is a naturally occurring gamma emitter. Information on the activity concentration of ^{40}K was obtained for all samples as part of the screening for anthropogenic radionuclides using high-resolution gamma spectrometry.

A3.2 Polonium-210

The dried composite samples were used for the analysis of ^{210}Po. A subsample (5–10 g) was weighed into a glass beaker, a known amount of tracer (^{209}Po) was added and the sample digested using concentrated nitric acid and refluxed overnight. The following day the digestion was continued using a nitric acid/hydrogen peroxide mixture. The digested solution was evaporated to near dryness. Water was added and a manganese dioxide precipitation was used to separate the polonium from the matrix. The precipitate was dissolved using hydroxylamine hydrochloride (20% w/v) and hydrochloric acid. Ascorbic and citric acids were added, the pH adjusted to 1.5 - 2 and the polonium was then auto deposited onto a pre-cleaned silver disc. The discs were counted using alpha spectrometry.

A3.3 Lead-210

Ashed composite samples were used for the analysis of ^{210}Pb. A known amount of stable lead was added to the samples. The samples were digested using nitric acid. If the dissolution was not complete additional ashing was undertaken. In this case, the solution was allowed to evaporate to dryness and the beaker was placed into a heated muffle furnace (300–400^{o}C). This treatment was repeated until the remaining residue could be easily dissolved in dilute nitric acid.

The solution was passed through a column containing 3 g of Eichrom Sr resin rinsed with 70 mL of 2 M HCl. After the sample was loaded, the resin was rinsed with 60 mL of 2 M HCl to remove the radium fraction. The column was then rinsed using 50 mL of 6 M HNO_3, separating the polonium from the column. The lead was eluted using 50 mL of 6 M HCl and collected in a small bottle. A small subsample of the eluate was taken for the analysis of lead, using flame atomic absorption spectrometry, to determine the recovery of the added lead. Polonium tracer (^{209}Po) was added to the eluate and the sample allowed to sit for six months for in-growth of the decay product (^{210}Po).

Following the in-growth period, the sample was transferred to a glass beaker. The sample bottle was rinsed with a small amount of concentrated nitric acid and this rinse was also added to the beaker. The polonium was separated using the manganese dioxide precipitation method previously described in section A3.2 and auto deposited onto a silver disc. The discs were counted using alpha spectrometry.

A3.4 Uranium/thorium

Separate subsamples were prepared for uranium and thorium radionuclides. Portions of the ashed composite samples were taken through an additional ashing step at 500^{o}C. Tracer (^{232}U or ^{229}Th) and nitric acid were added to the ash. The acid was evaporated and, if necessary, samples re-ashed in a muffle furnace. This process was repeated until the sample easily dissolved in a solution of nitric acid.

The uranium/thorium was separated from the matrix by co-precipitation using calcium phosphate. This was then dissolved in 3 M HNO_3-1 M $Al(NO_3)_3$ and loaded onto Eichrom resins, UTEVA resin for the separation of uranium and TEVA resin for the separation of thorium. The resins were rinsed to remove interfering radionuclides. The uranium was eluted using 0.5 M HCl and the thorium was eluted using 6 M HCl. The eluted radionuclides were evaporated and electrodeposited onto stainless steel discs from a sulphate solution. The discs were counted using alpha spectrometry.

A3.5 Radium

Separate subsamples were prepared for ^{226}Ra and ^{228}Ra. Ashed composite samples were re-ashed at 500^{o}C. Tracer (^{133}Ba) was added and the samples were dissolved, with additional ashing steps if required. The residue was dissolved in a dilute nitric acid solution. The radium and barium were separated using a lead sulphate precipitation. This precipitate was dissolved in DTPA and a barium sulphate precipitation was used to separate the radium/barium from other radionuclides. The radium/barium sulphate precipitate was counted using high resolution gamma spectrometry to determine the recovery of the added ^{133}Ba tracer.

For ^{226}Ra analysis, the precipitate was dissolved in EDTA and then a toluene based naphthalene scintillation cocktail was added to the solution. The samples were sealed and allowed to sit for a minimum of two weeks for the ingrowth of ^{222}Rn decay products, before being measured using liquid scintillation counting with alpha/beta discrimination.

For the ^{228}Ra, analysis the precipitate was left for a minimum of six months to allow for the ingrowth of ^{228}Th. Tracer (^{229}Th) was added and the precipitate was dissolved in EDTA. The thorium was then separated using an iron hydroxide precipitation. The precipitate was dissolved in a nitric acid solutions and TEVA Eichrom resin was used to purify the thorium. Electrodeposition onto stainless steel discs was used to prepare the source for counting by alpha spectrometry. The result for ^{228}Ra was calculated based on the result of the ^{228}Th.

A3.6 Alpha spectrometry/liquid scintillation counting

Canberra passivated implanted planar silicon (PIPS) detectors were used for alpha spectrometry measurements. The detectors have active area of 450 mm^2 and a nominal resolution of 20 keV. Banks of twelve chambers are dedicated to different radionuclides (polonium, thorium and uranium) to reduce interferences. A layer of air and an applied bias voltage were applied to reduce contamination from recoil.

The detectors were calibrated using a mixed radionuclide electrodeposited source containing ^{238}U, ^{234}U, ^{239}Pu and ^{241}Am. The samples were placed on the highest shelf to maximise the efficiency. Apex-Alpha software was used for the treatment of data and calculation of results.

A Quantulus liquid scintillation counter was used for the determination of ^{226}Ra. A set of calibrated standards (traceable to NIST), were prepared and used for the efficiency determination.

Appendix 4 Food mapping and consumption rates

Table A4.1 Food consumption data provided by Foods Standards Australia and New Zealand

'ARPANSA' foods	Food represented in diet	Mean consumption (grams/person/day)				
		2 years	3–7 years	8–12 years	13–17 years	>18 years
Apples	Pome fruits (excludes juice; includes dried)	64	70	90	55	49
Bananas	Bananas, plantains, citrus fruits, kumquats, pineapple, jackfruit and melons. Excludes juice; includes dried	71	71	75	46	54
Beef mince	Meat, offal and fat from mammals (cattle, non-bird game, pork, deli meats (except poultry-based), lamb, mutton, goat, kangaroo and rabbit)	36	43	65	80	86
Bread	Breads (all types), buns, crumpets, English-style muffins	65	81	100	110	91
Cereal	Breakfast cereals, oats, flours and rice crackers	43	58	66	60	53
Broccoli	Broccoli, broccoflower, cauliflower, stalk and stem vegetables. Includes juices from these vegetables	12	9.4	8.4	12	18
Carrots	Root vegetables (non-starchy)-includes carrots, ginger, radishes, celeriac, horseradish, wasabi, sarsaparilla, chicory root, angelica root, gentian root, liquorice, ginseng and orris root. Includes juices from these vegetables	19	17	19	19	25
Chicken	Meat, offal and fat from poultry and game birds	26	24	37	52	50
Eggs	Eggs	7.1	10	13	14	18
Fish	All seafood including plain/crumbed/battered/smoked/canned fish, crustacea and molluscs	7.9	8.1	14	12	26
Infant formula	Infant formula	2.7	0.2	0	0	0

Fruit juice	Fruit juices, ciders and perry, wine	76	79	95	100	140
Lettuce	Cabbages, and Brussels sprouts; leafy vegetables and herbs	6	7.6	12	15	25
Milk	Milk, cream, butter, cheeses and yoghurt	690	640	710	700	660
Onions	Onions, shallots, spring onions, leeks and garlic; mushrooms	6.2	5.5	6.5	12	14
Pasta	Pasta, noodles (except rice) and couscous	36	37	44	65	45
Peanut butter	Seeds and tree nuts (including coconut); peanuts and peanut butter	3	2.3	4.1	4.3	9.1
Potatoes	Potatoes, Jerusalem artichokes, cassava, parsnips, swedes, sweet potatoes, taro, turnips	35	56	80	110	94
Rice	Rice and rice products (excluding rice crackers) and rice-based breakfast cereals	20	34	32	51	51
Tomatoes	Avocadoes and olives; capsicums, chillies and spices; cucumbers and chokos; fresh beans and bean sprouts; peas (fresh, dried and sprouts); pumpkins, squash, marrows and zucchini; sweetcorn; tomatoes/eggplant/okra (cooked or processed), tomatoes/eggplant/okra/pepino (raw or sun-dried)	69	64	73	86	120
Mango	Tropical fruits (smooth-skinned, except bananas, plantains, avocadoes & olives); tropical fruit (rough or furry skin, except pineapples and jackfruit)	8.7	7.1	13	5.4	11
Nectarine	Canned fruits (excluding pineapples); stone fruits and fresh figs; grapes; berries	59	64	42	36	61
Not classified	Coffee, teas (includes herbal), water (all sources) and intensely sweetened soft drinks, oils, chocolates and fudge; honey; sugars, confectionery and syrups	690	940	1300	1600	2100

Table A4.2. Comparison of Australian consumption data with data in UNSCEAR (2000)

Food group	UNSCEAR (kg/y)			Australian data (kg/y)				
	Infant	Children	Adults	2 years	3–7 years	8–12 years	13–17 years	>18 years
Milk products	120	110	120	253	234	259	256	241
Meat products	15	35	50	25	28	42	53	56
Grain products	45	90	140	60	77	88	104	88
Leafy vegetables	20	40	60	7	6	7	10	16
Roots and fruits	60	110	170	150	159	182	173	211
Fish products	5	10	15	3	3	5	4	9
Water and beverages	150	350	500	Not classified				

Appendix 5 Anthropogenic radionuclides plus ^{40}K

Table A5.1 Autumn sampling program: activity concentration results. ND: not detected. The MDC for ^{60}Co, ^{134}Cs, ^{137}Cs and ^{241}Am was lower than 1 Bq/kg, for ^{40}K lower than 5 Bq/kg and for infant formula, the MDC was 0.6 Bq/kg.

ARPANSA sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA13-126-0266	234811-D-16 apples	30.6 ± 2.0	ND	ND	ND	ND
FA13-126-0267	237568-D-13 apples	29.7 ± 2.0	ND	ND	ND	ND
FA13-126-0268	234762-D-13 apples	33.2 ± 2.1	ND	ND	ND	ND
FA13-126-0269	234910-D-1 apples	31.4 ± 2.0	ND	ND	ND	ND
FA13-126-0270	Composite apple	33.3 ± 1.9	ND	ND	ND	ND
FA13-126-0271	234811-D-17 bananas	96.0 ± 5.6	ND	ND	ND	ND
FA13-126-0272	234762-D-30 bananas	145.6 ± 8.5	ND	ND	ND	ND
FA13-126-0273	234910-D-2 bananas	106.2 ± 6.2	ND	ND	ND	ND
FA13-126-0274	237568-D-14 bananas	100.2 ± 5.9	ND	ND	ND	ND
FA13-126-0275	Composite bananas	111.1 ± 6.2	ND	ND	ND	ND
FA13-126-0276	234746-D-13 beef mince	115.9 ± 7.4	ND	ND	ND	ND
FA13-126-0277	235141-D-23 beef mince	153.5 ± 9.4	ND	ND	0.197 ± 0.057	ND
FA13-126-0278	236936-D-15 beef mince	132.8 ± 8.1	ND	ND	ND	ND
FA13-126-0279	235756-D-21 beef mince	122.6 ± 7.5	ND	ND	ND	ND
FA13-126-0280	Composite beef mince	137.8 ± 7.7	ND	ND	0.0847 ± 0.0073	ND
FA13-126-0281	234811-D-11 bread	30.5 ± 3.0	ND	ND	ND	ND
FA13-126-0282	234762-D-14 bread	37.4 ± 2.9	ND	ND	ND	ND

ARPANSA sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA13-126-0283	234910-D-23 bread	39.7 ± 3.3	ND	ND	ND	ND
FA13-126-0284	237568-D-16 bread	47.4 ± 3.2	ND	ND	ND	ND
FA13-126-0285	Composite bread	38.4 ± 2.2	ND	ND	ND	ND
FA13-126-0286	234811-D-2 cereal	105.9 ± 6.1	ND	ND	ND	ND
FA13-126-0287	234910-D-11 cereal	93.1 ± 6.1	ND	ND	ND	ND
FA13-126-0288	Composite cereal	107.2 ± 6.0	ND	ND	ND	ND
FA13-126-0289	234746-D-15 broccoli	95.3 ± 5.6	ND	ND	ND	ND
FA13-126-0290	235141-D-13 broccoli	97.3 ± 5.6	ND	ND	ND	ND
FA13-126-0291	236936-D-17 broccoli	125.7 ± 7.3	ND	ND	ND	ND
FA13-126-0292	235756-D-4 broccoli	95.6 ± 5.6	ND	ND	ND	ND
FA13-126-0293	Composite broccoli	102.4 ± 5.9	ND	ND	ND	ND
FA13-126-0294	234746-D-16 carrots	38.0 ± 2.4	ND	ND	ND	ND
FA13-126-0295	235141-D-14 carrots	56.5 ± 3.3	ND	ND	ND	ND
FA13-126-0296	236936-D-18 carrots	42.3 ± 2.6	ND	ND	ND	ND
FA13-126-0297	235756-D-5 carrots	39.6 ± 2.4	ND	ND	ND	ND
FA13-126-0298	Composite carrots	46.4 ± 2.6	ND	ND	0.0123 ± 0.0024	ND
FA13-126-0299	234746-D-18 chicken	151.2 ± 9.0	ND	ND	ND	ND
FA13-126-0300	235141-D-24 chicken	147.2 ± 9.0	ND	ND	ND	ND
FA13-126-0301	236936-D-20 chicken	118.0 ± 7.2	ND	ND	ND	ND
FA13-126-0302	235756-D-22 chicken	110.8 ± 6.9	ND	ND	ND	ND

ARPANSA sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA13-126-0303	Composite chicken	133.0 ± 7.4	ND	ND	0.0175 ± 0.0025	ND
FA13-126-0304	234746-D-19 eggs	34.8 ± 2.6	ND	ND	ND	ND
FA13-126-0305	235141-D-16 eggs	33.1 ± 2.5	ND	ND	ND	ND
FA13-126-0306	236936-D-21 eggs	38.1 ± 2.7	ND	ND	ND	ND
FA13-126-0307	235756-D-7 eggs	38.8 ± 2.8	ND	ND	ND	ND
FA13-126-0308	Composite eggs	36.5 ± 2.0	ND	ND	ND	ND
FA13-126-0309	234746-D-4 fish	58.9 ± 3.9	ND	ND	ND	ND
FA13-126-0310	235756-D-13 fish	74.5 ± 4.7	ND	ND	0.133 ± 0.034	ND
FA13-126-0311	Composite fish	71.5 ± 4.0	ND	ND	0.0523 ± 0.0042	ND
FA13-126-0312	234762-D-6 infant formula	23.0 ± 2.0	ND	ND	ND	ND
FA13-126-0313	237568-D-6 infant formula	15.8 ± 1.2	ND	ND	ND	ND
FA13-126-0314	Composite infant formula	21.7 ± 1.2	ND	ND	0.0055 ± 0.0015	ND
FA13-126-0315	234811-D-5 fruit juice	31.9 ± 2.1	ND	ND	ND	ND
FA13-126-0316	234910-D-15 fruit juice	45.1 ± 2.7	ND	ND	ND	ND
FA13-126-0317	Composite fruit juice	41.4 ± 2.3	ND	ND	ND	ND
FA13-126-0318	234811-D-26 lettuce	51.2 ± 3.2	ND	ND	ND	ND
FA13-126-0319	234762-D-21 lettuce	62.2 ± 3.8	ND	ND	ND	ND
FA13-126-0320	234910-D-29 lettuce	49.5 ± 3.0	ND	ND	ND	ND
FA13-126-0321	237568-D-24 lettuce	40.0 ± 2.6	ND	ND	ND	ND
FA13-126-0322	Composite lettuce	51.1 ± 2.9	ND	ND	ND	ND

ARPANSA sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA13-126-0323	234746-D-23 milk	40.9 ± 2.9	ND	ND	ND	ND
FA13-126-0324	235141-D-27 milk	39.6 ± 2.7	ND	ND	0.137 ± 0.039	ND
FA13-126-0325	236936-D-25 milk	38.7 ± 2.8	ND	ND	ND	ND
FA13-126-0326	235756-D-9 milk	40.0 ± 2.6	ND	ND	ND	ND
FA13-126-0327	Composite milk	43.1 ± 2.4	ND	ND	0.0332 ± 0.0035	ND
FA13-126-0328	234811-D-12 onions	59.9 ± 4.1	ND	ND	ND	ND
FA13-126-0329	234762-D-23 onions	62.0 ± 4.1	ND	ND	ND	ND
FA13-126-0330	234910-D-30 onions	67.8 ± 4.3	ND	ND	ND	ND
FA13-126-0331	237568-D-26 onions	59.9 ± 3.9	ND	ND	ND	ND
FA13-126-0332	Composite onions	63.6 ± 3.7	ND	ND	ND	ND
FA13-126-0333	234762-D-8 pasta	17.1 ± 1.5	ND	ND	ND	ND
FA13-126-0334	237568-D-8 pasta	18.3 ± 1.4	ND	ND	ND	ND
FA13-126-0335	Composite pasta	17.9 ± 1.0	ND	ND	ND	ND
FA13-126-0336	235141-D-7 peanut butter	193 ± 11	ND	ND	ND	ND
FA13-126-0337	236936-D9 peanut butter	191 ± 11	ND	ND	ND	ND
FA13-126-0338	Composite peanut butter	193 ± 11	ND	ND	0.0451 ± 0.0094	ND
FA13-126-0339	234811-D-13 potatoes	57.9 ± 3.6	ND	ND	ND	ND
FA13-126-0340	234762-D-24 potatoes	50.4 ± 3.2	ND	ND	ND	ND
FA13-126-0341	234910-D-31 potatoes	106.6 ± 6.2	ND	ND	ND	ND
FA13-126-0342	237568-D-27 potatoes	99.8 ± 5.8	ND	ND	ND	ND

ARPANSA sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA13-126-0343	Composite potatoes	82.6 ± 4.6	ND	ND	ND	ND
FA13-126-0344	234762-D-10 rice	4.82 ± 0.94	ND	ND	ND	ND
FA13-126-0345	237568-D-10 rice	6.66 ± 0.86	ND	ND	ND	ND
FA13-126-0346	Composite rice	7.57 ± 0.44	ND	ND	ND	ND
FA13-126-0347	234811-D-30 tomatoes	72.0 ± 4.3	ND	ND	ND	ND
FA13-126-0348	234762-D-27 tomatoes	57.5 ± 3.4	ND	ND	ND	ND
FA13-126-0349	237568-D-30 tomatoes	68.4 ± 4.1	ND	ND	ND	ND
FA13-126-0350	237568-D-30 tomatoes	62.7 ± 3.7	ND	ND	ND	ND
FA13-126-0351	Composite tomatoes	66.1 ± 3.7	ND	ND	ND	ND
FA13-134-0364	234746-D-1 Bacon	84.4 ± 5.0	ND	ND	ND	ND
FA13-134-0365	235756-D-11 Bacon	138.3 ± 8.4	ND	ND	ND	ND
FA13-134-0366	234811-D-24 Beans, green	67.5 ± 4.1	ND	ND	ND	ND
FA13-134-0367	234762-D-20 Beans, green	49.3 ± 3.0	ND	ND	ND	ND
FA13-134-0368	234910-D-27 Beans, green	71.4 ± 4.6	ND	ND	ND	ND
FA13-134-0369	237568-D-22 Beans, green	84.2 ± 5.2	ND	ND	ND	ND
FA13-134-0370	234811-D-18 Bok choi	76.3 ± 5.1	ND	ND	ND	ND
FA13-134-0371	234762-D-31 Bok choi	56.9 ± 3.6	ND	ND	ND	ND
FA13-134-0372	234910-D-22 Bok choi	95.8 ± 5.6	ND	ND	ND	ND
FA13-134-0373	237568-D-15 Bok choi	127.3 ± 7.4	ND	ND	ND	ND
FA13-134-0374	234746-D-14 Bread, multigrain	63.7 ± 4.1	ND	ND	ND	ND

ARPANSA sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA13-134-0375	235141-D-12 Bread, multigrain	60.0 ± 3.8	ND	ND	ND	ND
FA13-134-0376	236936-D-16 Bread, multigrain	51.3 ± 3.2	ND	ND	ND	ND
FA13-134-0377	235756-D-3 Bread, multigrain	51.3 ± 3.8	ND	ND	ND	ND
FA13-134-0378	235141-D-20 Butter	3.94 ± 0.78	ND	ND	ND	ND
FA13-134-0379	236936-D-3 Butter	6.64 ± 0.93	ND	ND	ND	ND
FA13-134-0380	234746-D-3 Cake, chocolate, iced	72.2 ± 4.3	ND	ND	ND	ND
FA13-134-0381	235756-D-1 Cake, chocolate, iced	65.1 ± 4.0	ND	ND	ND	ND
FA13-134-0382	234811-D-19 Capsicum	53.3 ± 3.6	ND	ND	ND	ND
FA13-134-0383	234762-D-15 Capsicum	60.1 ± 4.0	ND	ND	ND	ND
FA13-134-0384	234910-D-24 Capsicum	54.0 ± 3.3	ND	ND	ND	ND
FA13-134-0385	237568-D-17 Capsicum	67.1 ± 4.0	ND	ND	ND	ND
FA13-134-0386	234811-D-20 Cauliflower	76.2 ± 4.6	ND	ND	ND	ND
FA13-134-0387	234762-D-16 Cauliflower	50.3 ± 3.1	ND	ND	ND	ND
FA13-134-0388	234910-D-3 Cauliflower	91.6 ±5.3	ND	ND	ND	ND
FA13-134-0389	237568-D-18 Cauliflower	78.6 ± 5.1	ND	ND	ND	ND
FA13-134-0390	234746-D-17 Celery	80.3 ± 4.7	ND	ND	ND	ND
FA13-134-0391	235141-D-15 Celery	84.9 ± 5.5	ND	ND	ND	ND
FA13-134-0392	236936-D-19 Celery	86.7 ± 5.5	ND	ND	ND	ND
FA13-134-0393	235756-D-6 Celery	104.2 ± 6.4	ND	ND	ND	ND
FA13-134-0394	234811-D-21 Cheese, cheddar, full fat	22.0 ± 1.8	ND	ND	ND	ND

ARPANSA sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA13-134-0395	234762-D-17 Cheese, cheddar, full fat	17.7 ± 1.5	ND	ND	ND	ND
FA13-134-0396	234910-D-25 Cheese, cheddar, full fat	21.2 ± 1.6	ND	ND	ND	ND
FA13-134-0397	237568-D-19 Cheese, cheddar, full fat	22.7 ± 1.6	ND	ND	ND	ND
FA13-134-0398	234762-D-3 Chocolate, milk	119.8 ± 7.4	ND	ND	ND	ND
FA13-134-0399	237568-D-3 Chocolate, milk	138.8 ± 8.4	ND	ND	ND	ND
FA13-134-0400	235141-D-3 Coffee, instant	10.52 ± 0.94	ND	ND	ND	ND
FA13-134-0401	236936-D-4 Coffee, instant	24.1 ± 2.0	ND	ND	ND	ND
FA13-134-0402	234811-D-22 Cucumber	51.5 ± 3.5	ND	ND	ND	ND
FA13-134-0403	234762-D-18 Cucumber	56.6 ± 3.8	ND	ND	ND	ND
FA13-134-0404	234910-D-26 Cucumber	45.2 ± 3.1	ND	ND	ND	ND
FA13-134-0405	237568-D-20 Cucumber	45.0 ± 2.8	ND	ND	ND	ND
FA13-134-0406	234811-D-23 Fish fillets, plain from takeaway	104.2 ± 6.2	ND	ND	ND	ND
FA13-134-0407	234762-D-19 Fish fillets, plain from takeaway	83.6 ± 4.9	ND	ND	ND	ND
FA13-134-0408	234910-D-7 Fish fillets, plain from takeaway	114.5 ± 6.6	ND	ND	ND	ND
FA13-134-0409	237568-D-21 Fish fillets, plain from takeaway	105.8 ± 6.8	ND	ND	ND	ND
FA13-134-0410	234762-D-4 Garlic	180 ± 10	ND	ND	ND	ND
FA13-134-0411	237568-D-4 Garlic	181 ± 10	ND	ND	ND	ND

ARPANSA sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA13-134-0412	234746-D-20 Grapes	70.7 ± 4.5	ND	ND	ND	ND
FA13-134-0413	235141-D-17 Grapes	67.4 ± 4.0	ND	ND	ND	ND
FA13-134-0414	236936-D-22 Grapes	80.7 ± 5.1	ND	ND	ND	ND
FA13-134-0415	235756-D-8 Grapes	81.3 ± 5.0	ND	ND	ND	ND
FA13-134-0416	234811-D-14 Ham, sliced delicatessen style	163.5 ± 9.5	ND	ND	ND	ND
FA13-134-0417	234910-D-13 Ham, sliced delicatessen style	169.6 ± 9.7	ND	ND	ND	ND
FA13-134-0418	234746-D-21 Hamburger	59.5 ± 4.0	ND	ND	ND	ND
FA13-134-0419	235141-D-25 Hamburger	63.9 ± 3.8	ND	ND	ND	ND
FA13-134-0420	236936-D-23 Hamburger	55.7 ± 3.3	ND	ND	ND	ND
FA13-134-0421	235756-D-23 Hamburger	53.9 ± 3.6	ND	ND	ND	ND
FA13-134-0422	234746-D-5 Hot chocolate beverage	17.2 ± 1.5	ND	ND	ND	ND
FA13-134-0423	235756-D-14 Hot chocolate beverage	54.6 ± 3.6	ND	ND	ND	ND
FA13-134-0424	234910-D-33 Ice cream, full fat, vanilla	49.7 ± 3.2	ND	ND	ND	ND
FA13-134-0425	237568-D-5 Ice cream, full fat, vanilla	40.0 ± 2.9	ND	ND	ND	ND
FA13-134-0426	234811-D-4 Infant cereal, mixed	11.72 ± 0.85	ND	ND	ND	ND
FA13-134-0427	234910-D-14 Infant cereal, mixed	8.23 ± 0.76	ND	ND	ND	ND
FA13-134-0428	235141-D-5 Infant dessert, milk based	28.7 ± 1.9	ND	ND	ND	ND
FA13-134-0429	236936-D-6 Infant dessert, milk based	22.8 ± 1.8	ND	ND	ND	ND
FA13-134-0430	234746-D-6 Infant dinner	67.0 ± 4.2	ND	ND	ND	ND

ARPANSA sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA13-134-0431	235756-D-15 Infant dinner	50.2 ± 3.1	ND	ND	ND	ND
FA13-134-0432	234811-D-25 Kiwifruit	81.5 ± 4.9	ND	ND	ND	ND
FA13-134-0433	234762-D-32 Kiwifruit	87.1 ± 5.4	ND	ND	ND	ND
FA13-134-0434	234910-D-28 Kiwifruit	83.6 ± 5.0	ND	ND	ND	ND
FA13-134-0435	237568-D-23 Kiwifruit	88.5 ± 5.1	ND	ND	ND	ND
FA13-134-0436	234746-D-22 Lamb chops, loin	93.7 ± 5.5	ND	ND	ND	ND
FA13-134-0437	235141-D-26 Lamb chops, loin	105.9 ± 6.2	ND	ND	0.248 ± 0.040	ND
FA13-134-0438	236936-D-24 Lamb chops, loin	98.3 ± 5.6	ND	ND	ND	ND
FA13-134-0439	235756-D-24 Lamb chops, loin	85.9 ± 5.3	ND	ND	ND	ND
FA13-134-0440	235141-D-21 Liver pate (chicken)	48.3 ± 3.2	ND	ND	ND	ND
FA13-134-0441	236936-D-7 Liver pate (chicken)	85.0 ± 5.1	ND	ND	ND	ND
FA13-134-0442	234762-D-7 Margarine, monounsaturated	24.1 ± 1.9	ND	ND	ND	ND
FA13-134-0443	237568-D-7 Margarine, monounsaturated	21.6 ± 1.6	ND	ND	ND	ND
FA13-134-0444	234811-D-27 Mushrooms	101.5 ± 6.2	ND	ND	ND	ND
FA13-134-0445	234762-D-22 Mushrooms	97.7 ± 5.8	ND	ND	ND	ND
FA13-134-0446	234910-D-8 Mushrooms	107.8 ± 6.3	ND	ND	ND	ND
FA13-134-0447	237568-D-25 Mushrooms	108.6 ± 6.6	ND	ND	ND	ND
FA13-134-0448	234811-D-15 Mussels	25.0 ± 1.6	ND	ND	ND	ND
FA13-134-0449	234910-D-16 Mussels	21.0 ± 1.8	ND	ND	ND	ND

ARPANSA sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA13-134-0450	235141-D-6 Oats, rolled	12.9 ± 1.1	ND	ND	ND	ND
FA13-134-0451	236936-D-8 Oats, rolled	15.7 ± 1.0	ND	ND	ND	ND
FA13-134-0452	234746-D-24 Orange	52.4 ± 3.2	ND	ND	ND	ND
FA13-134-0453	235141-D-18 Orange	52.7 ± 3.2	ND	ND	ND	ND
FA13-134-0454	236936-D-26 Orange	53.3 ± 3.2	ND	ND	ND	ND
FA13-134-0455	235756-D-10 Orange	50.0 ± 3.4	ND	ND	ND	ND
FA13-134-0456	234746-D-8 Peas, frozen	30.6 ± 2.2	ND	ND	ND	ND
FA13-134-0457	235756-D-17 Peas, frozen	43.8 ± 2.8	ND	ND	ND	ND
FA13-158-0503	235141-D-1 Almonds	225 ± 13	ND	ND	ND	ND
FA13-158-0504	236936-D-1 Almonds	235 ± 14	ND	ND	ND	ND
FA13-158-0505	234762-D-1 Baked beans in tomato sauce	77.4 ± 4.6	ND	ND	ND	ND
FA13-158-0506	237568-D-1 Baked beans in tomato sauce	86.0 ± 5.0	ND	ND	ND	ND
FA13-158-0507	234811-D-1 Beer, full strength	5.56 ± 0.90	ND	ND	ND	ND
FA13-158-0508	234910-D-10 Beer, full strength	7.5 ± 1.0	ND	ND	ND	ND
FA13-158-0509	235141-D-2 Beetroot, canned	56.2 ± 3.3	ND	ND	ND	ND
FA13-158-0510	236936-D-2 Beetroot, canned	61.2 ± 3.7	ND	ND	ND	ND
FA13-158-0511	234746-D-2 Biscuits, savoury	55.7 ± 4.0	ND	ND	ND	ND
FA13-158-0512	235756-D-12 Biscuits, savoury	50.2 ± 3.5	ND	ND	ND	ND

ARPANSA sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA13-158-0513	234762-D-2 Breakfast cereals, rice based	32.7 ± 2.0	ND	ND	ND	ND
FA13-158-0514	237568-D-2 Breakfast cereals, rice based	27.1 ± 1.6	ND	ND	ND	ND
FA13-158-0515	234811-D-3 Coconut, desiccated	236 ± 14	ND	ND	ND	ND
FA13-158-0516	234910-D-12 Coconut, desiccated	230 ± 14	ND	ND	ND	ND
FA13-158-0517	235141-D-4 Honey	16.8 ± 1.0	ND	ND	ND	ND
FA13-158-0518	236936-D-5 Honey	19.9 ± 1.6	ND	ND	ND	ND
FA13-158-0519	234746-D-7 Oil, canola and olive	ND	ND	ND	ND	ND
FA13-158-0520	235756-D-16 Oil, canola and olive	ND	ND	ND	ND	ND
FA13-158-0521	234811-D-6 Peach, natural juice	43.3 ± 3.0	ND	ND	ND	ND
FA13-158-0522	234910-D-17 Peach, natural juice	37.3 ± 2.5	ND	ND	ND	ND
FA13-158-0523	234762-D-9 Pie, meat, individual size	72.9 ± 4.6	ND	ND	ND	ND
FA13-158-0524	237568-D-9 Pie, meat, individual size	41.7 ± 2.6	ND	ND	ND	ND
FA13-158-0525	234811-D-7 Pineapple, canned in natural juice	29.5 ± 1.8	ND	ND	ND	ND
FA13-158-0526	234910-D-18 Pineapple, canned in natural juice	26.7 ± 2.2	ND	ND	ND	ND
FA13-158-0527	235141-D-22 Pizza, meat and vege topping	63.7 ± 4.2	ND	ND	ND	ND
FA13-158-0528	236936-D-10 Pizza, meat and vege topping	59.8 ± 4.0	ND	ND	ND	ND

ARPANSA sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA13-158-0529	234746-D-9 Potato crisps	369 ± 22	ND	ND	ND	ND
FA13-158-0530	235756-D-18 Potato crisps	398 ± 22	ND	ND	ND	ND
FA13-158-0531	234746-D-25 Prawns, cooked	38.0 ± 2.5	ND	ND	ND	ND
FA13-158-0532	235141-D-28 Prawns, cooked	50.6 ± 3.2	ND	ND	ND	ND
FA13-158-0533	236936-D-27 Prawns, cooked	45.1 ± 2.8	ND	ND	ND	ND
FA13-158-0534	235756-D-25 Prawns, cooked	11.92 ± 0.88	ND	ND	ND	ND
FA13-158-0535	234762-D-25 Pumpkin	68.7 ± 4.2	ND	ND	ND	ND
FA13-158-0536	234910-D-4 Pumpkin	103.5 ± 6.1	ND	ND	ND	ND
FA13-158-0537	237568-D-28 Pumpkin	82.8 ± 4.9	ND	ND	ND	ND
FA13-158-0538	234811-D-28 Pumpkin	77.6 ± 5.0	ND	ND	ND	ND
FA13-158-0539	234811-D-8 Sauce, savoury, non-tomato	27.4 ± 2.0	ND	ND	ND	ND
FA13-158-0540	234910-D-19 Sauce, savoury, non-tomato	70.8 ± 4.4	ND	ND	ND	ND
FA13-158-0541	235141-D-8 Sauce, tomato	83.2 ± 5.0	ND	ND	ND	ND
FA13-158-0542	236936-D-11 Sauce, tomato	49.0 ± 3.0	ND	ND	ND	ND
FA13-158-0543	234746-D-26 Sausages, beef	77.1 ± 4.8	ND	ND	ND	ND
FA13-158-0544	235141-D-29 Sausages, beef	84.4 ± 5.3	ND	ND	ND	ND
FA13-158-0545	236936-D-28 Sausages, beef	63.1 ± 3.8	ND	ND	ND	ND
FA13-158-0546	235756-D-26 Sausages, beef	69.3 ± 4.2	ND	ND	ND	ND
FA13-158-0547	234746-D-10 Soft drink	ND	ND	ND	ND	ND

ARPANSA sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA13-158-0548	235756-D-19 Soft drink	1.37 ± 0.32	ND	ND	ND	ND
FA13-158-0549	234762-D-11 Soy beverage, full fat	36.4 ± 2.7	ND	ND	ND	ND
FA13-158-0550	237568-D-11 Soy beverage, full fat	44.0 ± 3.0	ND	ND	ND	ND
FA13-158-0551	234811-D-29 Strawberries	53.3 ± 3.3	ND	ND	ND	ND
FA13-158-0552	234762-D-26 Strawberries	53.1 ± 3.2	ND	ND	ND	ND
FA13-158-0553	234910-D-9 Strawberries	55.6 ± 3.8	ND	ND	ND	ND
FA13-158-0554	237568-D-29 Strawberries	56.9 ± 3.8	ND	ND	ND	ND
FA13-158-0555	234811-D-9 Sugar, white	ND	ND	ND	ND	ND
FA13-158-0556	234910-D-20 Sugar, white	ND	ND	ND	ND	ND
FA13-158-0557	235141-D-9 Sultanas	283 ± 16	ND	ND	ND	ND
FA13-158-0558	236936-D-12 Sultanas	256 ± 15	ND	ND	ND	ND
FA13-158-0559	234746-D-27 Sushi roll, nori	44.9 ± 3.1	ND	ND	ND	ND
FA13-158-0560	235141-D-30 Sushi roll, nori	36.7 ± 2.6	ND	ND	ND	ND
FA13-158-0561	236936-D-29 Sushi roll, nori	44.9 ± 2.8	ND	ND	ND	ND
FA13-158-0562	235756-D-27 Sushi roll, nori	25.2 ± 1.8	ND	ND	ND	ND
FA13-158-0563	234746-D-11 Sweetcorn, kernels, frozen	48.0 ± 3.2	ND	ND	ND	ND
FA13-158-0564	235756-D-20 Sweetcorn, kernels, frozen	71.5 ± 4.5	ND	ND	ND	ND
FA13-158-0565	234762-D-12 Tea	3.80 ± 0.60	ND	ND	ND	ND
FA13-158-0566	237568-D-12 Tea	3.36 ± 0.54	ND	ND	ND	ND

ARPANSA sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA13-158-0567	234811-D-10 Tomatoes, canned	76.1 ± 4.8	ND	ND	ND	ND
FA13-158-0568	234910-D-21 Tomatoes, canned	95.6 ± 5.6	ND	ND	ND	ND
FA13-158-0569	235141-D-10 Tuna, canned in brine	51.8 ± 3.2	ND	ND	ND	ND
FA13-158-0570	236936-D-13 Tuna, canned in brine	64.7 ± 3.9	ND	ND	ND	ND
FA13-158-0571	234746-D-28 Water, tap	ND	ND	ND	ND	ND
FA13-158-0572	235141-D-31 Water, tap	ND	ND	ND	ND	ND
FA13-158-0573	236936-D-30 Water, tap	ND	ND	ND	ND	ND
FA13-158-0574	235756-D-28 Water, tap	ND	ND	ND	ND	ND
FA13-158-0575	234811-D-31 Watermelon	36.8 ± 2.4	ND	ND	ND	ND
FA13-158-0576	234762-D-28 Watermelon	38.3 ± 2.8	ND	ND	ND	ND
FA13-158-0577	234910-D-6 Watermelon	39.9 ± 2.5	ND	ND	ND	ND
FA13-158-0578	237568-D-31 Watermelon	32.0 ± 2.0	ND	ND	ND	ND
FA13-158-0579	234746-D-29 Wine, red and white	23.9 ± 1.8	ND	ND	ND	ND
FA13-158-0580	235141-D-19 Wine, red and white	21.7 ± 1.5	ND	ND	ND	ND
FA13-158-0581	236936-D-31 Wine, red and white	20.9 ± 1.5	ND	ND	ND	ND
FA13-158-0582	235756-D-29 Wine, red and white	25.7 ± 1.6	ND	ND	ND	ND
FA13-158-0583	234811-D-32 Yoghurt, fruit, full fat	51.9 ± 3.4	ND	ND	ND	ND
FA13-158-0584	234762-D-29 Yoghurt, fruit, full fat	57.7 ± 3.6	ND	ND	ND	ND
FA13-158-0585	234910-D-32 Yoghurt, fruit, full fat	52.3 ± 3.3	ND	ND	ND	ND
FA13-158-0586	237568-D-32 Yoghurt, fruit, full fat	51.8 ± 3.2	ND	ND	ND	ND

ARPANSA sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA13-163-0593	234746-D-12 Avocados	175 ± 10	ND	ND	ND	ND
FA13-163-0594	235141-D-11 Avocados	126.5 ± 7.8	ND	ND	ND	ND
FA13-163-0595	235756-D-2 Avocados	116.5 ± 7.0	ND	ND	ND	ND
FA13-163-0596	236936-D-14 Avocados	151.7 ± 8.8	ND	ND	ND	ND

Table A5.2 Summer sampling program: activity concentration results. ND: not detected. The MDC, for ^{60}Co, ^{134}Cs, ^{137}Cs and ^{241}Am, was lower than 1 Bq/kg, for ^{40}K lower than 5 Bq/kg and for infant formula, the MDC was 0.6 Bq/kg.

ARPANSA Sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA14-066-0134	FS275857-1 apples	34.6 ± 2.2	ND	ND	ND	ND
FA14-066-0135	FS275886-1 apples	42.0 ± 2.6	ND	ND	ND	ND
FA14-066-0136	FS275900-1 apples	32.0 ± 2.1	ND	ND	ND	ND
FA14-066-0137	FS275925-1 apples	28.1 ± 1.8	ND	ND	ND	ND
FA14-066-0138	FS275857-2 bananas	109.2 ± 6.5	ND	ND	ND	ND
FA14-066-0139	FS275886-2 bananas	105.4 ± 6.1	ND	ND	ND	ND
FA14-066-0140	FS275900-3 bananas	92.3 ± 5.7	ND	ND	ND	ND
FA14-066-0141	FS275925-3 bananas	91.3 ± 5.4	ND	ND	ND	ND
FA14-066-0142	FS275857-13 beans, green	103.8 ± 6.1	ND	ND	ND	ND
FA14-066-0143	FS275886-13 beans, green	73.5 ± 4.4	ND	ND	ND	ND
FA14-066-0144	FS275900-14 beans, green	80.5 ± 4.6	ND	ND	ND	ND
FA14-066-0145	FS275925-14 beans, green	109.5 ± 6.4	ND	ND	ND	ND
FA14-066-0146	FS275857-5 bread, white	34.5 ± 2.6	ND	ND	ND	ND
FA14-066-0147	FS275886-5 bread, white	39.1 ± 2.7	ND	ND	ND	ND
FA14-066-0148	FS275900-5 bread, white	35.3 ± 2.4	ND	ND	ND	ND
FA14-066-0149	FS275925-5 bread, white	37.9 ± 2.5	ND	ND	ND	ND
FA14-066-0150	FS275857-6 cereal	93.1 ± 5.6	ND	ND	ND	ND
FA14-066-0151	FS275886-6 cereal	87.6 ± 5.1	ND	ND	ND	ND
FA14-066-0152	FS275813-6 broccoli	91.7 ± 5.7	ND	ND	ND	ND

ARPANSA Sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA14-066-0153	FS275876-6 broccoli	90.0 ± 5.5	ND	ND	ND	ND
FA14-066-0154	FS275919-6 broccoli	100.6 ± 5.8	ND	ND	ND	ND
FA14-066-0155	FS275932-6 broccoli	86.2 ± 5.1	ND	ND	ND	ND
FA14-066-0156	FS275813-8 carrots	54.1 ± 3.0	ND	ND	ND	ND
FA14-066-0157	FS275876-8 carrots	51.8 ± 3.0	ND	ND	ND	ND
FA14-066-0158	FS275919-8 carrots	36.6 ± 2.1	ND	ND	ND	ND
FA14-066-0159	FS275932-8 carrots	43.7 ± 2.5	ND	ND	ND	ND
FA14-066-0160	FS275813-10 chicken	106.9 ± 6.4	ND	ND	ND	ND
FA14-066-0161	FS275876-10 chicken	98.7 ± 5.9	ND	ND	ND	ND
FA14-066-0162	FS275919-10 chicken	109.0 ± 6.4	ND	ND	ND	ND
FA14-066-0163	FS275932-10 chicken	106.5 ± 6.2	ND	ND	ND	ND
FA14-066-0164	FS275813-11 eggs	33.7 ± 2.6	ND	ND	ND	ND
FA14-066-0165	FS275876-12 eggs	38.8 ± 2.8	ND	ND	ND	ND
FA14-066-0166	FS275919-12 eggs	35.7 ± 2.6	ND	ND	ND	ND
FA14-066-0167	FS275932-11 eggs	38.7 ± 2.6	ND	ND	ND	ND
FA14-066-0168	FS275813-12 fish	52.3 ± 3.2	ND	ND	ND	ND
FA14-066-0169	FS275932-12 fish	59.0 ± 3.6	ND	ND	ND	ND
FA14-066-0170	FS275900-16 infant formula	25.1 ± 1.7	ND	ND	ND	ND
FA14-066-0171	FS275925-16 infant formula	24.7 ± 1.6	ND	ND	ND	ND
FA14-066-0172	FS275857-16 fruit juice	41.9 ± 2.9	ND	ND	ND	ND

ARPANSA Sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA14-066-0173	FS275886-16 fruit juice	36.2 ± 2.6	ND	ND	ND	ND
FA14-066-0174	FS275857-18 lettuce	43.0 ± 3.1	ND	ND	ND	ND
FA14-066-0175	FS275886-18 lettuce	60.5 ± 4.0	ND	ND	ND	ND
FA14-066-0176	FS275900-18 lettuce	32.7 ± 2.4	ND	ND	ND	ND
FA14-066-0177	FS275925-18 lettuce	49.8 ± 3.3	ND	ND	ND	ND
FA14-066-0178	FS275813-18 mango	41.1 ± 2.8	ND	ND	ND	ND
FA14-066-0179	FS275857-19 mango	45.8 ± 3.1	ND	ND	ND	ND
FA14-066-0180	FS275886-19 mango	43.6 ± 2.8	ND	ND	ND	ND
FA14-066-0181	FS275932-18 mango	45.1 ± 3.2	ND	ND	ND	ND
FA14-066-0182	Composite mango	45.1 ± 2.5	ND	ND	ND	ND
FA14-066-0183	FS275813-19 milk	42.2 ± 2.6	ND	ND	0.103 ± 0.028	ND
FA14-066-0184	FS275876-19 milk	43.9 ± 2.7	ND	ND	ND	ND
FA14-066-0185	FS275919-19 milk	57.1 ± 3.6	ND	ND	ND	ND
FA14-066-0186	FS275932-19 milk	43.2 ± 2.7	ND	ND	ND	ND
FA14-066-0187	FS275876-20 nectarine	70.7 ± 4.3	ND	ND	ND	ND
FA14-066-0188	FS275813-20 nectarine	77.1 ± 4.6	ND	ND	ND	ND
FA14-066-0189	FS275919-20 nectarine	76.0 ± 4.5	ND	ND	ND	ND
FA14-066-0190	FS275925-21 nectarine	64.1 ± 3.8	ND	ND	ND	ND
FA14-066-0191	FS275932-20 nectarine	82.2 ± 5.1	ND	ND	ND	ND
FA14-066-0192	FS275900-21 nectarine	61.4 ± 3.9	ND	ND	ND	ND

ARPANSA Sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA14-066-0193	FS275857-22 nectarine	73.7 ± 4.6	ND	ND	ND	ND
FA14-066-0194	FS275886-22 nectarine	76.2 ± 4.4	ND	ND	ND	ND
FA14-066-0195	Composite nectarine	71.9 ± 4.0	ND	ND	ND	ND
FA14-066-0196	FS275857-23 onions	48.6 ± 3.4	ND	ND	ND	ND
FA14-066-0197	FS275886-23 onions	45.0 ± 3.0	ND	ND	ND	ND
FA14-066-0198	FS275900-22 onions	49.2 ± 3.2	ND	ND	ND	ND
FA14-066-0199	FS275925-22 onions	51.6 ± 3.4	ND	ND	ND	ND
FA14-066-0200	FS275900-23 pasta	8.78 ± 0.96	ND	ND	ND	ND
FA14-066-0201	FS275925-23 pasta	14.8 ± 1.2	ND	ND	ND	ND
FA14-066-0202	FS275876-23 peanut butter	157.8 ± 8.8	ND	ND	ND	ND
FA14-066-0203	FS275919-23 peanut butter	179 ± 10	ND	ND	ND	ND
FA14-066-0204	FS275813-24 potato crisps	419 ± 24	ND	ND	ND	ND
FA14-066-0205	FS275932-24 potato crisps	355 ± 20	ND	ND	ND	ND
FA14-066-0206	FS275857-28 sauce savoury	68.2 ± 4.2	ND	ND	ND	ND
FA14-066-0207	FS275886-28 sauce savoury	61.8 ± 3.8	ND	ND	ND	ND
FA14-066-0208	FS275857-32 tomatoes	47.5 ± 3.0	ND	ND	ND	ND
FA14-066-0209	FS275886-32 tomatoes	55.6 ± 3.4	ND	ND	ND	ND
FA14-066-0210	FS275900-31 tomatoes	68.5 ± 4.1	ND	ND	ND	ND
FA14-066-0211	FS275925-31 tomatoes	54.8 ± 3.4	ND	ND	ND	ND
FA14-080-0232	FS275813-1 avocados	133.1 ± 7.8	ND	ND	ND	ND

ARPANSA Sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA14-080-0233	FS275876-2 avocados	148.1 ± 8.6	ND	ND	ND	ND
FA14-080-0234	FS275919-2 avocados	134.4 ± 7.7	ND	ND	ND	ND
FA14-080-0235	FS275932-1 avocados	172.7 ± 9.9	ND	ND	ND	ND
FA14-080-0236	FS275813-2 bacon	85.9 ± 5.5	ND	ND	ND	ND
FA14-080-0237	FS275932-2 bacon	81.2 ± 5.1	ND	ND	ND	ND
FA14-080-0238	FS275857-3 beer	10.0 ± 1.0	ND	ND	ND	ND
FA14-080-0239	FS275886-3 beer	9.7 ± 1.0	ND	ND	ND	ND
FA14-080-0240	FS275857-4 bok choi	77.4 ± 5.0	ND	ND	ND	ND
FA14-080-0241	FS275886-4 bok choi	89.4 ± 5.5	ND	ND	ND	ND
FA14-080-0242	FS275900-4 bok choi	82.6 ± 5.1	ND	ND	ND	ND
FA14-080-0243	FS275925-4 bok choi	44.3 ± 3.0	ND	ND	ND	ND
FA14-080-0244	FS275813-5 bread, multigrain	59.0 ± 3.4	ND	ND	ND	ND
FA14-080-0245	FS275876-5 bread, multigrain	62.7 ± 3.6	ND	ND	ND	ND
FA14-080-0246	FS275919-5 bread, multigrain	59.9 ± 3.4	ND	ND	ND	ND
FA14-080-0247	FS275932-5 bread, multigrain	52.5 ± 3.0	ND	ND	ND	ND
FA14-080-0248	FS275876-7 butter	6.41 ± 0.72	ND	ND	ND	ND
FA14-080-0249	FS275919-7 butter	6.88 ± 0.73	ND	ND	ND	ND
FA14-080-0250	FS275813-7 cake, chocolate	51.9 ± 3.4	ND	ND	ND	ND
FA14-080-0251	FS275932-7 cake, chocolate	73.9 ± 4.4	ND	ND	ND	ND
FA14-080-0252	FS275857-7 capsicum	63.1 ± 4.6	ND	ND	ND	ND

ARPANSA Sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA14-080-0253	FS275886-7 capsicum	55.0 ± 4.0	ND	ND	ND	ND
FA14-080-0254	FS275900-7 capsicum	51.9 ± 3.9	ND	ND	ND	ND
FA14-080-0255	FS275925-7 capsicum	61.9 ± 4.0	ND	ND	ND	ND
FA14-080-0256	FS275857-8 cauliflower	93.6 ± 5.8	ND	ND	ND	ND
FA14-080-0257	FS275886-8 cauliflower	82.1 ± 5.1	ND	ND	ND	ND
FA14-080-0258	FS275900-8 cauliflower	74.3 ± 4.6	ND	ND	ND	ND
FA14-080-0259	FS275925-8 cauliflower	66.4 ± 3.9	ND	ND	0.149 ± 0.025	ND
FA14-080-0260	FS275813-9 celery	75.9 ± 4.9	ND	ND	ND	ND
FA14-080-0261	FS275876-9 celery	90.5 ± 5.6	ND	ND	ND	ND
FA14-080-0262	FS275919-9 celery	97.5 ± 5.9	ND	ND	ND	ND
FA14-080-0263	FS275932-9 celery	78.8 ± 4.9	ND	ND	ND	ND
FA14-080-0264	FS275857-9 cheese, cheddar	19.3 ± 1.4	ND	ND	ND	ND
FA14-080-0265	FS275886-9 cheese, cheddar	18.1 ± 1.4	ND	ND	ND	ND
FA14-080-0266	FS275900-9 cheese, cheddar	22.2 ± 1.5	ND	ND	ND	ND
FA14-080-0267	FS275925-9 cheese, cheddar	17.0 ± 1.2	ND	ND	ND	ND
FA14-080-0268	FS275900-10 chocolate	110.7 ± 6.6	ND	ND	ND	ND
FA14-080-0269	FS275925-10 chocolate	106.4 ± 3.4	ND	ND	ND	ND
FA14-080-0270	FS275876-11 coffee, instant	11.73 ± 0.92	ND	ND	ND	ND
FA14-080-0271	FS275919-11 coffee, instant	6.81 ± 0.69	ND	ND	ND	ND
FA14-080-0272	FS275857-11 cucumber	43.1 ± 3.2	ND	ND	ND	ND

ARPANSA Sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA14-080-0273	FS275886-11 cucumber	48.7 ± 3.4	ND	ND	ND	ND
FA14-080-0274	FS275900-11 cucumber	43.7 ± 3.0	ND	ND	ND	ND
FA14-080-0275	FS275925-11 cucumber	48.6 ± 3.3	ND	ND	ND	ND
FA14-080-0276	FS275857-12 fish fillets	106.4 ± 6.2	ND	ND	0.144 ± 0.028	ND
FA14-080-0277	FS275886-12 fish fillets	85.9 ± 5.0	ND	ND	ND	ND
FA14-080-0278	FS275900-12 fish fillets	52.5 ± 3.2	ND	ND	ND	ND
FA14-080-0279	FS275925-12 fish fillets	95.8 ± 5.5	ND	ND	ND	ND
FA14-080-0280	FS275900-13 garlic	182 ± 10	ND	ND	ND	ND
FA14-080-0281	FS275925-13 garlic	188 ± 11	ND	ND	ND	ND
FA14-080-0282	FS275813-13 grapes	64.0 ± 4.1	ND	ND	ND	ND
FA14-080-0283	FS275876-13 grapes	67.0 ± 4.2	ND	ND	ND	ND
FA14-080-0284	FS275919-13 grapes	62.5 ± 4.0	ND	ND	ND	ND
FA14-080-0285	FS275932-13 grapes	65.5 ± 4.0	ND	ND	ND	ND
FA14-080-0286	FS275857-14 ham, sliced	115 ± 7.0	ND	ND	ND	ND
FA14-080-0287	FS275886-14 ham, sliced	156 ± 9.0	ND	ND	ND	ND
FA14-080-0288	FS275813-14 hamburger	68.4 ± 4.1	ND	ND	ND	ND
FA14-080-0289	FS275876-14 hamburger	61.1 ± 3.6	ND	ND	ND	ND
FA14-080-0290	FS275919-14 hamburger	57.9 ± 3.5	ND	ND	ND	ND
FA14-080-0291	FS275932-14 hamburger	57.3 ± 3.4	ND	ND	ND	ND
FA14-080-0292	FS275813-15 hot chocolate	73.5 ± 4.7	ND	ND	ND	ND

ARPANSA Sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA14-080-0293	FS275932-15 hot chocolate	58.2 ± 3.8	ND	ND	ND	ND
FA14-080-0294	FS275900-15 ice cream	27.5 ± 2.0	ND	ND	ND	ND
FA14-080-0295	FS275925-15 ice cream	24.6 ± 1.7	ND	ND	ND	ND
FA14-080-0296	FS275857-15 infant cereal	48.4 ± 3.0	ND	ND	ND	ND
FA14-080-0297	FS275886-15 infant cereal	9.20 ± 0.80	ND	ND	ND	ND
FA14-080-0298	FS275876-16 infant dessert	37.8 ± 2.3	ND	ND	ND	ND
FA14-080-0299	FS275919-16 infant dessert	35.1 ± 2.2	ND	ND	ND	ND
FA14-080-0300	FS275813-16 infant dinner	56.2 ± 3.3	ND	ND	ND	ND
FA14-080-0301	FS275932-16 infant dinner	50.3 ± 2.9	ND	ND	ND	ND
FA14-080-0302	FS275857-17 kiwifruit	66.7 ± 4.4	ND	ND	ND	ND
FA14-080-0303	FS275886-17 kiwifruit	74.7 ± 4.6	ND	ND	ND	ND
FA14-080-0304	FS275900-17 kiwifruit	81.2 ± 5.1	ND	ND	ND	ND
FA14-080-0305	FS275925-17 kiwifruit	83.1 ± 5.1	ND	ND	ND	ND
FA14-080-0306	FS275813-17 lamb chops, loin	93.0 ± 5.5	ND	ND	ND	ND
FA14-080-0307	FS275876-17 lamb chops, loin	90.8 ± 5.3	ND	ND	ND	ND
FA14-080-0308	FS275919-17 lamb chops, loin	96.5 ± 5.6	ND	ND	0.406 ± 0.046	ND
FA14-080-0309	FS275932-17 lamb chops, loin	89.0 ± 5.1	ND	ND	0.347 ± 0.035	ND
FA14-080-0310	FS275876-18 liver pate	40.6 ± 2.6	ND	ND	ND	ND
FA14-080-0311	FS275919-18 liver pate	52.0 ± 3.3	ND	ND	ND	ND
FA14-080-0312	FS275900-19 margarine	8.0 ± 1.1	ND	ND	ND	ND

ARPANSA Sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA14-080-0313	FS275925-19 margarine	5.74 ± 0.84	ND	ND	ND	ND
FA14-080-0314	FS275857-20 mushrooms	89.8 ± 5.3	ND	ND	ND	ND
FA14-080-0315	FS275886-20 mushrooms	91.7 ± 5.4	ND	ND	ND	ND
FA14-080-0316	FS275900-20 mushrooms	82.5 ± 5.1	ND	ND	ND	ND
FA14-080-0317	FS275925-20 mushrooms	75.5 ± 4.7	ND	ND	ND	ND
FA14-080-0318	FS275857-21 mussels	23.0 ± 1.6	ND	ND	ND	ND
FA14-080-0319	FS275886-21 mussels	23.6 ± 1.6	ND	ND	ND	ND
FA14-080-0320	FS275876-21 oats, rolled	12.4 ± 1.0	ND	ND	ND	ND
FA14-080-0321	FS275919-21 oats, rolled	19.5 ± 1.2	ND	ND	ND	ND
FA14-080-0322	FS275813-22 orange	43.6 ± 2.9	ND	ND	ND	ND
FA14-080-0323	FS275876-22 orange	47.8 ± 3.2	ND	ND	ND	ND
FA14-080-0324	FS275919-22 orange	46.5 ± 2.8	ND	ND	ND	ND
FA14-080-0325	FS275932-22 orange	47.9 ± 3.0	ND	ND	ND	ND
FA14-080-0326	FS275813-23 peas, frozen	52.2 ± 3.2	ND	ND	ND	ND
FA14-080-0327	FS275932-23 peas, frozen	35.3 ± 2.2	ND	ND	ND	ND
FA14-098-0378	FS275876-1 almonds	204 ± 11	ND	ND	ND	ND
FA14-098-0379	FS275919-1 almonds	208 ± 11	ND	ND	ND	ND
FA14-098-0380	FS275900-2 baked beans	70.4 ± 4.2	ND	ND	ND	ND
FA14-098-0381	FS275925-2 baked beans	68.6 ± 4.1	ND	ND	ND	ND
FA14-098-0382	FS275813-3 beef mince lean	108.9 ± 6.4	ND	ND	ND	ND

ARPANSA Sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA14-098-0383	FS275876-3 beef mince lean	117.6 ± 6.8	ND	ND	ND	ND
FA14-098-0384	FS275919-3 beef mince lean	127.5 ± 7.4	ND	ND	0.389 ± 0.050	ND
FA14-098-0385	FS275932-3 beef mince lean	106.2 ± 6.1	ND	ND	0.267 ± 0.035	ND
FA14-098-0386	FS275876-4 beetroot, canned	50.8 ± 2.3	ND	ND	ND	ND
FA14-098-0387	FS275919-4 beetroot, canned	60.4 ± 2.5	ND	ND	ND	ND
FA14-098-0388	FS275813-4 biscuits, savoury	49.0 ± 3.5	ND	ND	ND	ND
FA14-098-0389	FS275932-4 biscuits, savoury	48.5 ± 2.8	ND	ND	ND	ND
FA14-098-0390	FS275900-6 breakfast cereals-rice based	32.9 ± 2.6	ND	ND	ND	ND
FA14-098-0391	FS275925-6 breakfast cereals-rice based	29.9 ± 2.4	ND	ND	ND	ND
FA14-098-0392	FS275857-10 coconut	224 ± 13	ND	ND	ND	ND
FA14-098-0393	FS275886-10 coconut	220 ± 12	ND	ND	ND	ND
FA14-098-0394	FS275876-15 honey	23.6 ± 1.7	ND	ND	ND	ND
FA14-098-0395	FS275919-15 honey	19.1 ± 1.4	ND	ND	ND	ND
FA14-098-0396	FS275813-21 oil	ND	ND	ND	ND	ND
FA14-098-0397	FS275932-21 oil	ND	ND	ND	ND	ND
FA14-098-0398	FS275857-24 peach	39.2 ± 1.5	ND	ND	ND	ND
FA14-098-0399	FS275886-24 peach	37.8 ± 1.5	ND	ND	ND	ND
FA14-098-0400	FS275900-24 pie, meat	50.7 ± 3.5	ND	ND	ND	ND
FA14-098-0401	FS275925-24 pie, meat	44.8 ± 3.0	ND	ND	ND	ND

ARPANSA Sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA14-098-0402	FS275857-25 pineapple	32.8 ± 2.4	ND	ND	ND	ND
FA14-098-0403	FS275886-25 pineapple	26.5 ± 1.8	ND	ND	ND	ND
FA14-098-0404	FS275876-24 pizza	66.9 ± 4.3	ND	ND	ND	ND
FA14-098-0405	FS275919-24 pizza	63.0 ± 3.9	ND	ND	ND	ND
FA14-098-0406	FS275857-26 potato	103.7 ±6.3	ND	ND	ND	ND
FA14-098-0407	FS275886-26 potato	107.5 ± 6.3	ND	ND	ND	ND
FA14-098-0408	FS275900-25 potato	95.7 ± 5.6	ND	ND	ND	ND
FA14-098-0409	FS275925-25 potato	108.6 ± 6.2	ND	ND	0.087 ± 0.023	ND
FA14-098-0410	FS275813-25 prawns	60.0 ± 4.2	ND	ND	ND	ND
FA14-098-0411	FS275876-25 prawns	36.0 ± 2.8	ND	ND	ND	ND
FA14-098-0412	FS275919-25 prawns	44.3 ± 3.0	ND	ND	ND	ND
FA14-098-0413	FS275932-25 prawns	31.3 ± 2.1	ND	ND	ND	ND
FA14-098-0414	FS275857-27 pumpkin	79.3 ± 4.8	ND	ND	ND	ND
FA14-098-0415	FS275886-27 pumpkin	77.2 ± 4.6	ND	ND	ND	ND
FA14-098-0416	FS275900-26 pumpkin	53.7 ± 3.5	ND	ND	ND	ND
FA14-098-0417	FS275925-26 pumpkin	110.3 ± 6.5	ND	ND	ND	ND
FA14-098-0418	FS275900-27 rice	8.5 ± 1.0	ND	ND	ND	ND
FA14-098-0419	FS275925-27 rice	6.5 ± 1.0	ND	ND	ND	ND
FA14-098-0420	FS275876-26 sauce tomato	83.0 ± 5.1	ND	ND	ND	ND
FA14-098-0421	FS275919-26 sauce tomato	98.8 ± 5.8	ND	ND	ND	ND

ARPANSA Sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA14-098-0422	FS275813-26 sausages beef	72.3 ± 4.4	ND	ND	ND	ND
FA14-098-0423	FS275876-27 sausages beef	61.4 ± 3.7	ND	ND	ND	ND
FA14-098-0424	FS275919-27 sausages beef	66.1 ± 4.0	ND	ND	ND	ND
FA14-098-0425	FS275932-26 sausages beef	64.3 ± 3.8	ND	ND	0.061 ± 0.020	ND
FA14-098-0426	FS275813-27 soft drink	2.35 ± 0.46	ND	ND	ND	ND
FA14-098-0427	FS275932-27 soft drink	ND	ND	ND	ND	ND
FA14-098-0428	FS275900-28 soy beverage	42.6 ± 2.9	ND	ND	ND	ND
FA14-098-0429	FS275925-28 soy beverage	39.3 ± 2.6	ND	ND	ND	ND
FA14-098-0430	FS275857-29 strawberries	46.5 ± 3.2	ND	ND	ND	ND
FA14-098-0431	FS275886-29 strawberries	48.2 ± 3.2	ND	ND	ND	ND
FA14-098-0432	FS275900-29 strawberries	53.3 ± 3.3	ND	ND	ND	ND
FA14-098-0433	FS275925-29 strawberries	50.6 ± 3.4	ND	ND	ND	ND
FA14-098-0434	FS275857-30 sugar white	ND	ND	ND	ND	ND
FA14-098-0435	FS275886-30 sugar white	ND	ND	ND	ND	ND
FA14-098-0436	FS275876-28 sultanas	265 ± 15	ND	ND	ND	ND
FA14-098-0437	FS275919-28 sultanas	256 ± 15	ND	ND	ND	ND
FA14-098-0438	FS275813-28 sushi roll, nori	33.0 ± 2.1	ND	ND	ND	ND
FA14-098-0439	FS275876-29 sushi roll, nori	38.0 ± 2.3	ND	ND	ND	ND
FA14-098-0440	FS275919-29 sushi roll, nori	40.2 ± 2.8	ND	ND	ND	ND
FA14-098-0441	FS275932-28 sushi roll, nori	44.4 ± 3.0	ND	ND	ND	ND

ARPANSA Sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA14-098-0442	FS275813-29 sweetcorn, kernels	85.3 ± 5.0	ND	ND	ND	ND
FA14-098-0443	FS275932-29 sweetcorn, kernels	60.2 ± 3.5	ND	ND	ND	ND
FA14-098-0444	FS275900-30 tea	2.37 ± 0.61	ND	ND	ND	ND
FA14-098-0445	FS275925-30 tea	4.49 ± 0.61	ND	ND	ND	ND
FA14-098-0446	FS275857-31 tomatoes, canned	86.8 ± 5.5	ND	ND	ND	ND
FA14-098-0447	FS275886-31 tomatoes, canned	85.6 ± 5.5	ND	ND	ND	ND
FA14-098-0448	FS275876-30 tuna, canned	66.5 ± 4.3	ND	ND	ND	ND
FA14-098-0449	FS275919-30 tuna, canned	60.7 ± 3.9	ND	ND	ND	ND
FA14-098-0450	FS275813-30 water, tap	ND	ND	ND	ND	ND
FA14-098-0451	FS275876-31 water, tap	ND	ND	ND	ND	ND
FA14-098-0452	FS275919-31 water, tap	ND	ND	ND	ND	ND
FA14-098-0453	FS275932-30 water, tap	ND	ND	ND	ND	ND
FA14-098-0454	FS275857-33 watermelon	40.0 ± 2.7	ND	ND	ND	ND
FA14-098-0455	FS275886-33 watermelon	37.9 ± 2.6	ND	ND	ND	ND
FA14-098-0456	FS275900-32 watermelon	39.3 ± 2.4	ND	ND	ND	ND
FA14-098-0457	FS275925-32 watermelon	32.8 ± 2.1	ND	ND	ND	ND
FA14-098-0458	FS275813-31 wine	18.6 ± 1.4	ND	ND	ND	ND
FA14-098-0459	FS275876-32 wine	14.3 ± 1.2	ND	ND	ND	ND
FA14-098-0460	FS275919-32 wine	23.0 ± 1.6	ND	ND	ND	ND
FA14-098-0461	FS275932-31 wine	19.6 ± 1.3	ND	ND	ND	ND

ARPANSA Sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1				
		^{40}K	^{60}Co	^{134}Cs	^{137}Cs	^{241}Am
FA14-098-0462	FS275857-34 yogurt	47.1 ± 2.9	ND	ND	ND	ND
FA14-098-0463	FS275886-34 yogurt	55.3 ± 3.8	ND	ND	ND	ND
FA14-098-0464	FS275900-33 yogurt	63.0 ± 4.0	ND	ND	ND	ND
FA14-098-0465	FS275925-33 yogurt	61.8 ± 3.5	ND	ND	0.084 ± 0.015	ND

Appendix 6 Naturally occurring radionuclides

Naturally occurring radionuclides (^{210}Po, ^{210}Pb, ^{226}Ra and ^{228}Ra)

Table A6.1 Activity concentrations: naturally occurring radionuclides ^{210}Po, ^{210}Pb, ^{226}Ra and ^{228}Ra

ARPANSA Sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1			
		^{210}Po	^{210}Pb	^{226}Ra	^{228}Ra
FA13-126-0270	Composite apples	0.0293 ± 0.0045	0.0306 ± 0.0054	0.0177 ± 0.0029	0.0223 ± 0.0086
FA13-126-0275	Composite bananas	0.0205 ± 0.0062	0.0155 ± 0.0090	0.0522 ± 0.0043	0.123 ± 0.015
FA13-126-0280	Composite beef mince	0.076 ± 0.015	ND	0.0051 ± 0.0023	ND
FA13-126-0285	Composite bread	0.0730 ± 0.0094	0.087 ± 0.015	0.0697 ± 0.0051	0.069 ± 0.016
FA13-126-0288	Composite cereal	0.083 ± 0.029	0.088 ± 0.016	0.1256 ± 0.0086	0.268 ± 0.032
FA13-126-0293	Composite broccoli	0.0233 ± 0.0041	0.039 ± 0.011	0.0207 ± 0.0024	0.0267 ± 0.0089
FA13-126-0298	Composite carrots	0.0068 ± 0.0014	0.0158 ± 0.0079	0.116 ± 0.017	0.102 ± 0.012
FA13-126-0303	Composite chicken	ND	ND	0.0066 ± 0.0019	0.045 ± 0.015
FA13-126-0308	Composite eggs	0.0244 ± 0.0068	ND	0.121 ± 0.015	0.259 ± 0.020
FA13-126-0311	Composite fish	0.125 ± 0.020	0.020 ± 0.010	0.0219 ± 0.0027	0.0254 ± 0.0078
FA13-126-0314	Composite infant formula	0.0081 ± 0.0036	0.0172 ± 0.0076	0.0041 ± 0.0008	ND
FA13-126-0317	Composite fruit juice	0.0316 ± 0.0036	0.023 ± 0.010	0.0171 ± 0.0017	0.0306 ± 0.0096
FA13-126-0322	Composite lettuce	0.0182 ± 0.0028	0.0219 ± 0.0068	0.0072 ± 0.0011	ND
FA13-126-0327	Composite milk	0.0225 ± 0.0048	0.0145 ± 0.0067	0.0048 ± 0.0013	0.0188 ± 0.0059
FA13-126-0332	Composite onions	0.0120 ± 0.0034	ND	0.0205 ± 0.0043	0.0359 ± 0.0093

ARPANSA Sample no.	Sample	Activity concentration (Bq/kg) uncertainties k=1			
		^{210}Po	^{210}Pb	^{226}Ra	^{228}Ra
FA13-126-0335	Composite pasta	0.0082 ± 0.0030	0.0152 ± 0.0067	0.0453 ± 0.0037	0.062 ± 0.015
FA13-126-0338	Composite peanut butter	ND	0.0255 ± 0.0084	0.112 ± 0.014	0.156 ± 0.021
FA13-126-0343	Composite potatoes	ND	ND	0.0154 ± 0.0022	0.0246 ± 0.0063
FA13-126-0346	Composite rice	0.0358 ± 0.0053	0.0089 ± 0.0057	0.0130 ± 0.0049	ND
FA13-126-0351	Composite tomatoes	0.0113 ± 0.0019	ND	0.0208 ± 0.0026	0.0236 ± 0.0078
FA14-066-0182	Composite mango	0.0418 ± 0.0052	ND	0.0590 ± 0.0065	0.078 ± 0.018
FA14-066-0195	Composite nectarine	0.0243 ± 0.0025	0.0237 ± 0.0075	0.0073 ± 0.0031	ND
MDC (MDC infant formula)		*0.030*	*0.013*		*0.025 (0.016)*

Naturally occurring radionuclides (uranium and thorium)

Table A6.2 Activity concentrations: naturally occurring radionuclides uranium and thorium

ARPANSA sample no.	Sample	Activity concentration (Bq/kg) Uncertainties k=1			
		^{234}U	^{238}U	^{230}Th	^{232}Th
FA13-126-0270	Composite apples	ND	ND	ND	ND
FA13-126-0275	Composite bananas	ND	ND	ND	ND
FA13-126-0280	Composite beef mince	0.0049 ± 0.0023	0.0070 ± 0.0029	ND	ND
FA13-126-0285	Composite bread	0.0456 ± 0.0069	0.0482 ± 0.0073	0.0409 ± 0.0093	ND
FA13-126-0288	Composite cereal	0.0108 ± 0.0049	0.0173 ± 0.0059	0.0146 ± 0.0079	ND
FA13-126-0293	Composite broccoli	0.0093 ± 0.0039	0.0092 ± 0.0039	0.0064 ± 0.0027	ND
FA13-126-0298	Composite carrots	ND	ND	ND	ND
FA13-126-0303	Composite chicken	ND	ND	ND	ND
FA13-126-0308	Composite eggs	ND	ND	ND	ND
FA13-126-0311	Composite fish	0.0057 ± 0.0024	0.0042 ± 0.0029	ND	ND
FA13-126-0314	Composite infant formula	0.0036 ± 0.0013	0.0027 ± 0.0011	ND	ND
FA13-126-0317	Composite fruit juice	0.0034 ± 0.0013	ND	ND	ND
FA13-126-0322	Composite lettuce	ND	ND	ND	ND
FA13-126-0327	Composite milk	ND	ND	ND	ND
FA13-126-0332	Composite onions	0.0032 ± 0.0016	0.0032 ± 0.0013	ND	ND
FA13-126-0335	Composite pasta	ND	ND	0.0070 ± 0.0055	ND
FA13-126-0338	Composite peanut butter	ND	ND	0.0098 ± 0.0069	ND
FA13-126-0343	Composite potatoes	ND	ND	ND	ND

ARPANSA sample no.	Sample	Activity concentration (Bq/kg) Uncertainties k=1			
		^{234}U	^{238}U	^{230}Th	^{232}Th
FA13-126-0346	Composite rice	ND	ND	ND	ND
FA13-126-0351	Composite tomatoes	ND	ND	ND	ND
FA14-066-0182	Composite mango	0.0033 ± 0.0020	ND	ND	ND
FA14-066-0195	Composite nectarine	0.0024 ± 0.0013	ND	ND	ND
MDC (MDC infant formula)		*0.0092*	*0.0090*	*0.012 (0.0048)*	*0.010 (0.0028)*

Table A6.3 Comparison of data from studies of radionuclides in infant formula.

[1] Formula has been scaled to dry powder based on a ratio of 13% dry formula to 87% water to make up a liquid formula (Trdin & Benedik, 2017) with negligible contribution from water.

Study	Activity concentration (Bq/kg) in Infant formula							
	^{210}Po	^{210}Pb	^{226}Ra	^{228}Ra	^{234}U	^{238}U	^{230}Th	^{232}Th
Australia (This study)	0.0081	0.0172	0.00410	ND	0.0036	0.0027	ND	ND
Australia (This study) Scaled to dry powder[1]	0.065	0.14	0.033	ND	0.029	0.0216	ND	ND
Slovenia (Trdin and Benedik, 2017)	0.16 – 0.36	NA	NA	NA	0.007 – 0.037	0.0097 – 0.034	0.29 – 0.58	NA
Slovenia (Strok and Smodis, 2009)	0.055 – 0.082	0.29 – 0.65	0.057 – 0.063	NA	0.074 – 0.091	0.065 – 0.071	NA	NA
Malaysia (Uwatse et al., 2014)	NA	NA	1.36 – 7.1	NA	NA	NA	NA	0.31 – 8.6
India (Prabhath et al., 2015)	0.08 – 0.23	NA	NA	NA	NA	NA	NA	NA
Saudi Arabia (Jemii and Alharbi, 2018)	NA	NA	0.26 – 1.06	NA	NA	NA	NA	0.21 – 0.84

Appendix 7 Committed effective dose

Table A7.1 Example of the calculation of committed effective dose for ^{226}Ra for a 2–year–old.

Food type/category	Consumption kg/year	^{226}Ra Bq/kg	Intake Bq/year	Dose coefficient Sv/Bq	Dose mSv/year
Milk products					
Milk	252	0.0048	1.21	$9.6E10^{-7}$	$1.16E10^{-3}$
Infant formula	0.986	0.0041	0.00404	$9.6E10^{-7}$	$3.88E10^{-6}$
Meat products					
Beef mince	13.1	0.0051	0.0671	$9.6E10^{-7}$	$6.44E10^{-5}$
Chicken	9.50	0.0066	0.0627	$9.6E10^{-7}$	$6.02E10^{-5}$
Eggs	2.59	0.121	0.314	$9.6E10^{-7}$	$3.01E10^{-4}$
Grain products					
Bread	23.7	0.070	1.65	$9.6E10^{-7}$	$1.59E10^{-3}$
Breakfast cereal	15.7	0.126	1.97	$9.6E10^{-7}$	$1.89E10^{-3}$
Pasta	13.1	0.0453	0.596	$9.6E10^{-7}$	$5.72E10^{-4}$
Rice	7.30	0.013	0.0950	$9.6E10^{-7}$	$9.12E10^{-5}$
Leafy vegetables					
Broccoli	4.38	0.0207	0.0907	$9.6E10^{-7}$	$8.71E10^{-5}$
Lettuce	2.19	0.0072	0.0158	$9.6E10^{-7}$	$1.51E10^{-5}$
Roots and fruits					
Carrot	6.94	0.116	0.802	$9.6E10^{-7}$	$7.69E10^{-4}$
Onion	2.26	0.0205	0.0464	$9.6E10^{-7}$	$4.46E10^{-5}$
Peanut butter	1.10	0.112	0.123	$9.6E10^{-7}$	$1.18E10^{-4}$
Potatoes	12.8	0.0154	0.197	$9.6E10^{-7}$	$1.89E10^{-4}$
Apples	23.4	0.0177	0.414	$9.6E10^{-7}$	$3.97E10^{-4}$
Bananas	25.9	0.0522	1.35	$9.6E10^{-7}$	$1.30E10^{-3}$
Mango	3.18	0.0590	0.187	$9.6E10^{-7}$	$1.80E10^{-4}$
Nectarine	21.5	0.0073	0.157	$9.6E10^{-7}$	$1.51E10^{-4}$
Tomato	25.2	0.0208	0.524	$9.6E10^{-7}$	$5.03E10^{-4}$
Fruit juice	27.8	0.0171	0.475	$9.6E10^{-7}$	$4.56E10^{-4}$
Fish products					
Fish	2.89	0.0219	0.0632	$9.6E10^{-7}$	$6.07E10^{-5}$
Total					**$1.00E10^{-2}$**

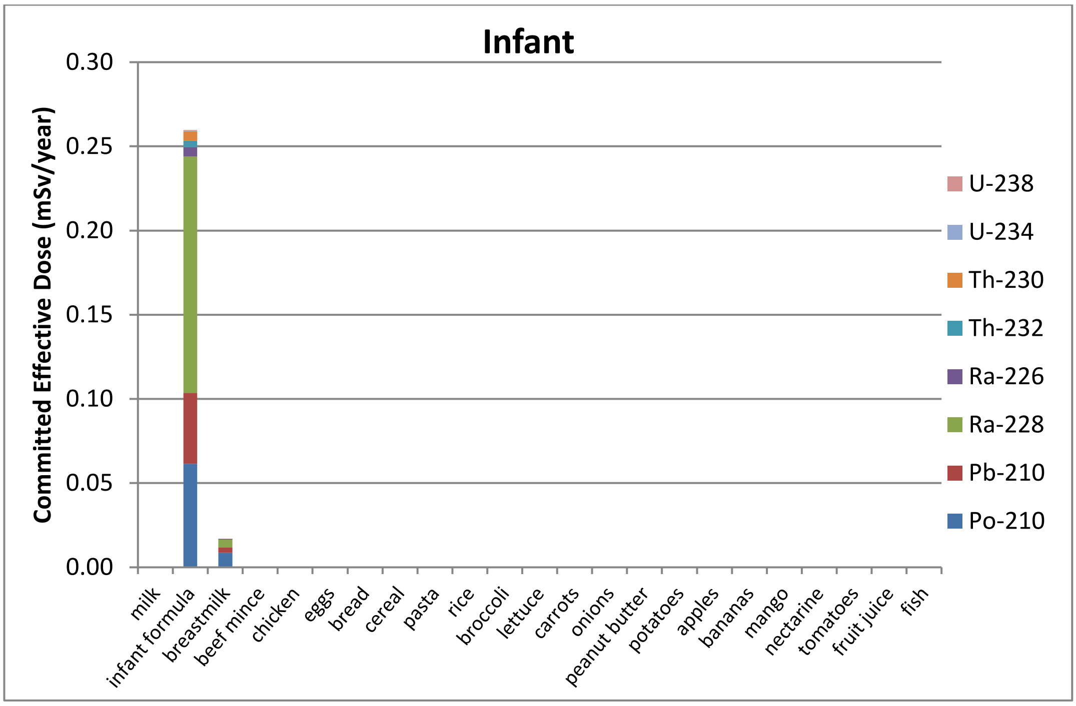

Figure A7.1. Committed effective dose for infants (MDC included).

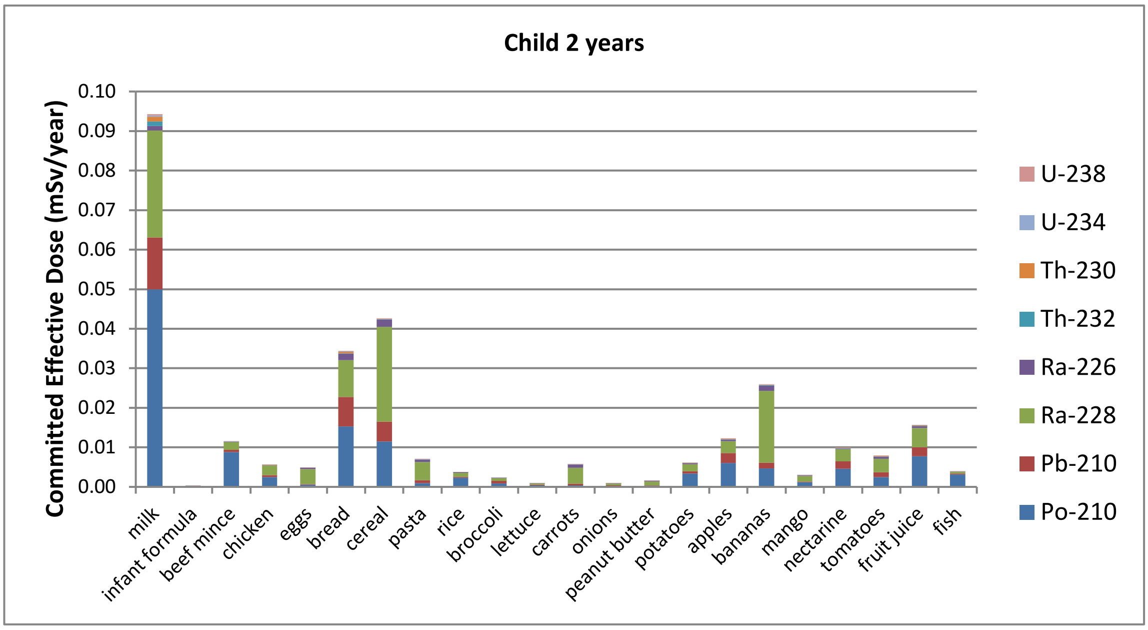

Figure A7.2. Committed effective dose for a child of 2 years old (MDC included)

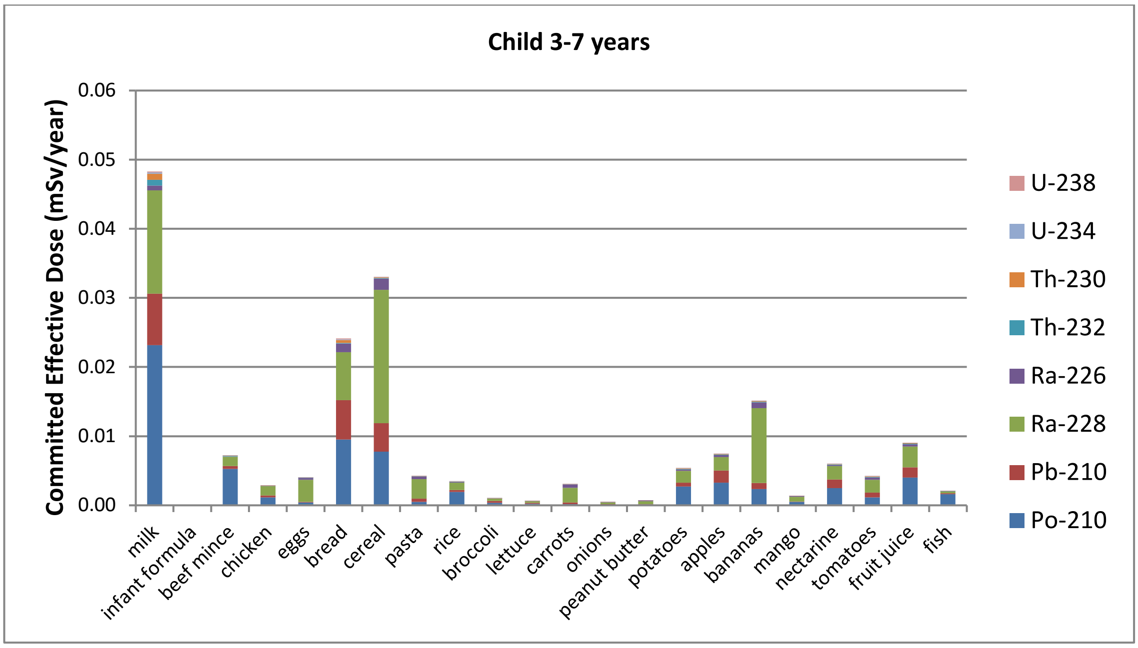

Figure A7.3. Committed effective dose for a child, 3–7 years old (MDC included)

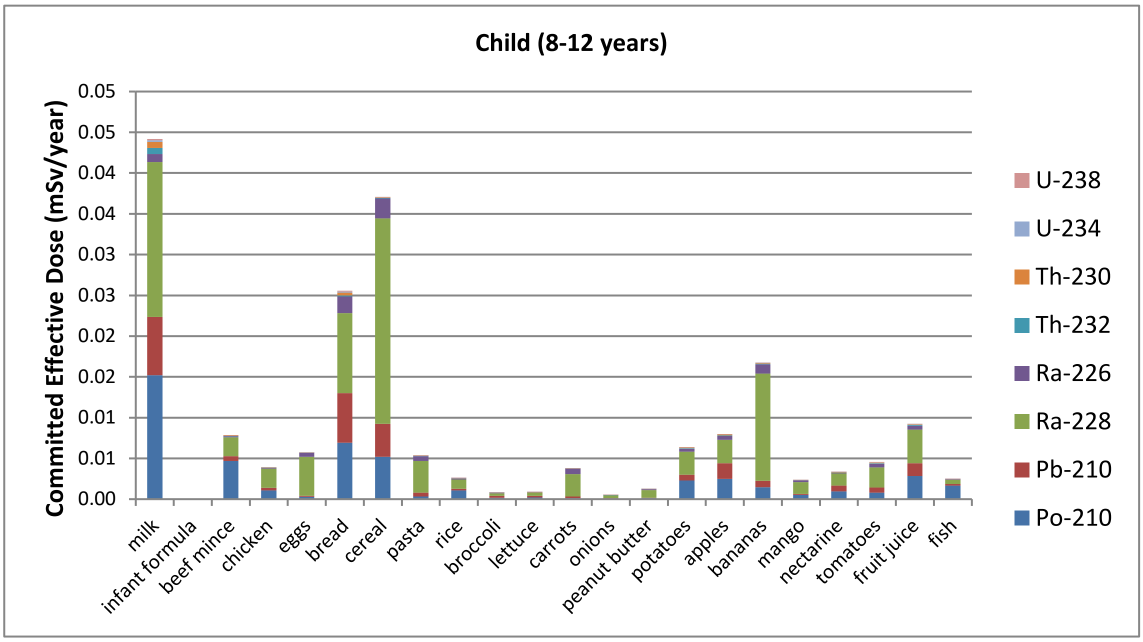

Figure A7.4. Committed effective dose for a child, 8–12 years old (MDC included)

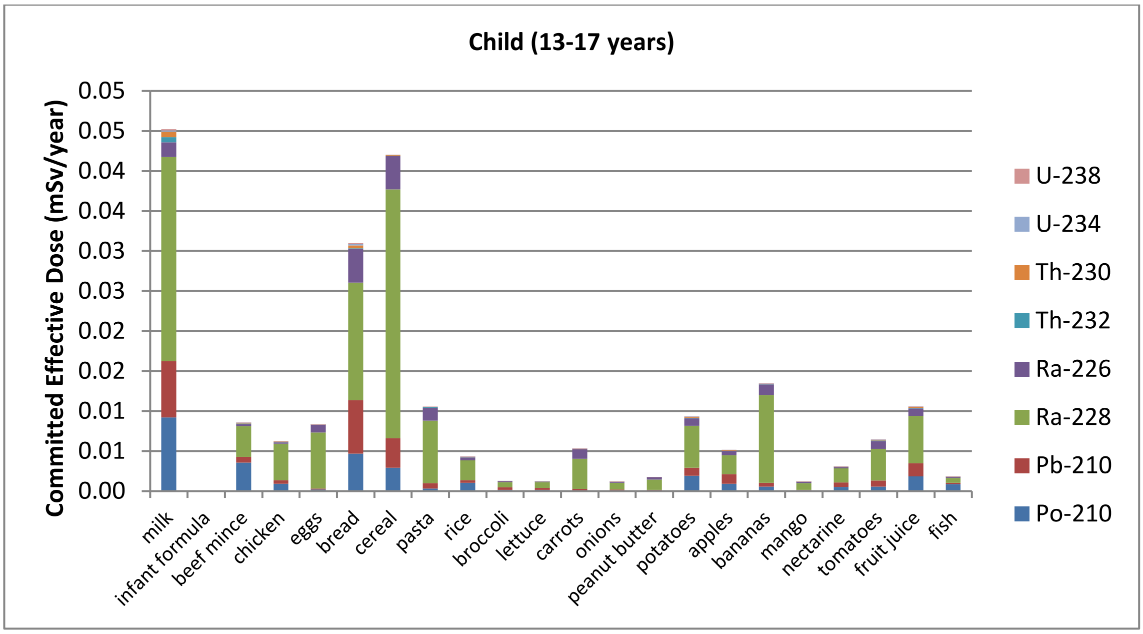

Figure A7.5. Committed effective dose for a child, 13–17 years (MDC included)

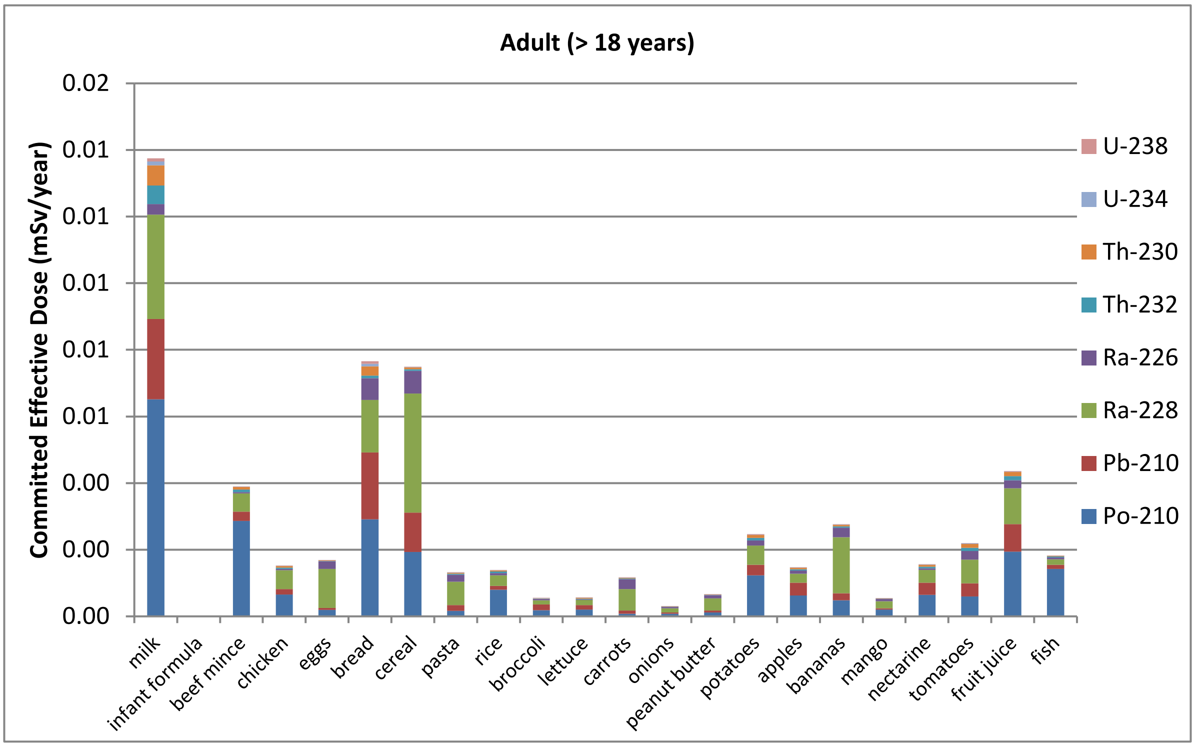

Figure A7.6. Committed effective dose for an adult (MDC included)