DIOXINS IN FOOD

Dietary Exposure Assessment and Risk Characterisation

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Executive Summary

'Dioxins' refers to a group of persistent chlorinated chemical compounds that have similar chemical structures and properties, and have similar biological characteristics, including toxicity. Food Standards Australia New Zealand (FSANZ) has conducted an analytical survey of dioxins in a range of food sampled in Australia with the purpose of assessing the level of risk to human health associated with the dietary exposure of the Australian population to dioxins.

The overall conclusion of this report is that, on the basis of the available data, taking into account all the inherent uncertainties and limitations, the public health and safety risk for all Australians from exposure to dioxins from foods is very low.

'Dioxins' includes the polychlorinated dibenzodioxins (PCDDs or dioxins), the closely related polychlorinated dibenzofurans (PCDFs or furans) and polychlorinated biphenyls (dioxin-like PCBs, or PCBs). These compounds can accumulate in the body fat of animals and humans and have a tendency to remain unchanged for prolonged intervals. Long term high levels of exposure to dioxins have the potential to cause a range of toxic effects in animals and humans, including skin lesions, reproductive disorders and cancer. Several hundred of these compounds exist, however, as evaluated by the World Health Organisation (WHO) in 1998, 29 of the compounds (congeners) were considered to have similar 'dioxin-like' toxicity. PCDD/Fs are predominantly generated as unintended by-products of combustion processes and are therefore most usually discharged into the air and then deposited on plant, soil and water surfaces. Environmental PCB contamination has come about through their manufacture for industrial purposes. Dioxins enter the food chain when animals eat contaminated plants. The dioxins are then absorbed into the animal fat, increasing in concentration as they migrate up the food chain. The consumption of animal products with high fat content, such as meat and dairy products, can increase human exposure to dioxins.

FSANZ conducted a survey of both PCDD/Fs and for dioxin-like PCBs in a range of foods representative of the total diet. The food survey analysed composite food samples for each of the 29 PCDD/F and PCBs, for which the WHO developed toxicity equivalency factors (TEFs) to the most toxic dioxin congener TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin). Results are reported for PCDD/F and PCB concentrations and used, with dietary information from the 1995 National Nutrition Survey, in the determination of the dietary exposure. The concentrations of all of the PCDD/F and PCB congeners were summed to give overall dioxin levels. Overall, the concentration of dioxins in the surveyed foods was very low with the highest mean PCDD/F concentrations being found in peanut butter (0.035-0.235 pg TEQ/g fresh weight, lower to upper bound), butter (0.010-0.20 pg TEQ/g fresh weight) and fish fillets (0.08-0.13 pg TEQ/g fresh weight). Highest mean PCB concentrations were found in fish fillets (0.51 pg TEQ/g fresh weight, at the lower and upper bound), although much of this was contributed by a single sample.

The dietary exposure assessment was conducted using FSANZ's dietary modelling computer program, DIAMOND. The results provide information on the mean and 95th percentile dietary exposure to dioxins for various age groups: toddlers aged 2-4 years; children aged 4-15 years; young adults aged 16-29 years; adults aged 30-44 years and 45-59 years; and older adults aged 60 years and above. The results also provide information on lifetime exposure (2 years and above). Separate and combined dietary exposures were determined for PCDD/Fs and PCBs. A dietary exposure assessment was also conducted for infants aged 9 months using a constructed diet based on infant formula.

For all age groups as well as for the lifetime exposure, the mean and 95th percentile monthly dietary exposures were below the Australian tolerable monthly intake for dioxins of 70 pg TEQ/kg body weight (bw)/month. For the population group aged two years and above, representing a lifetime of exposure, mean estimated exposure to dioxins was 3.7-15.6 pg TEQ/kg bw/month (lower to upper bound). Estimated mean 95th percentile exposures for this group was 16.1-40.6 pg TEQ/kg bw/month (lower to upper bound). Toddlers aged 2-4 years were estimated to have the highest exposure to dioxins (mean 6.2-36.7 and 95th percentile 12.1-66.2 pg TEQ/kg bw/month, lower to upper bound respectively) due to their higher food consumption relative to body weight. The mean estimated dietary exposure to dioxins calculated for infants aged 9 months was 11.8-60.8 pg TEQ/kg bw/month (lower to upper bound).

The major foods contributing to PCDD/F exposure and to PCB exposure for the general population (2 years and above) were fish (including crustaceans and molluscs) and milk and dairy products. For toddlers and children, the major foods contributing to both PCDD/F and PCB exposure were milk and dairy products.

In characterising the risk associated with dioxin exposure through food, the uncertainties and limitations in many aspects of the data need to be considered, both in relation to the characterisation of the hazard and determination of the tolerable monthly intake, as well as in relation to the survey data and dietary exposure assessment. In particular, it needs to be recognised that potential adverse effects have only been associated with an elevated dioxin body burden following long-term exposure. Taking these factors into account, it is concluded that the public health and safety risk for all Australians from exposure to dioxins from foods is very low.

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Glossary/Abbreviations

AGAL	Australian Government Analytical Laboratories.
Australian TMI	Australian Tolerable Monthly Intake.
Composite sample	3 or 4 purchases of a given food were combined to form a single sample for analysis of PCDD/F and PCBs.
Congeners	Closely related chemicals derived from the same parent compound.
DEH	Australian Government Department of Environment and Heritage.
DoHA	Australian Government Department of Health and the Ageing.
DIAMOND	Dietary Modelling of Nutritional Data (FSANZ computer software program), based on food consumption data from the 1995 NNS.
Dioxin	Polychlorinated dibenzo-*p*-dioxin.
Dioxins	The group of persistent chlorinated chemical compounds, the polychlorinated dibenzodioxins (PCDDs or dioxins), and including the closely related polychlorinated dibenzofurans (PCDFs or furans) and dioxin-like polychlorinated biphenyls (PCBs), which have certain similar chemical structures and properties, and have similar biological characteristics including toxicity (this document).
EC	European Commission.
Fresh weight concentration	The amount of a food chemical which is present in a given weight of the while food as it is actually eaten. Dioxin concentrations are usually reported on a lipid weight basis. However, fresh weight concentrations are used, combined with dietary survey data, to estimate dietary intake.
Furan	Polychlorinated dibenzofuran.
FSANZ	Food Standards Australia New Zealand.
I-TEQ	International Toxicity equivalencies using NATO-CCMS (1988) toxicity equivalency factors.

LOD	Limit of detection. The lowest concentration of a chemical that can be qualitatively detected using a specified laboratory method and/or item of laboratory equipment (i.e. its presence can be detected but not quantified).
LOQ	Limit of Quantification. The lowest concentration of a chemical that can be detected and quantified, with an acceptable degree of certainty, using a specified laboratory method and/or item of laboratory equipment.
LOR	Limit of reporting. Equivalent to LOQ (this document).
Lower bound TEQ	Toxic equivalencies (TEQ) for which concentration of a congener reported as being less than the LOR is assumed to equal zero. This value is then multiplied by the TEF to achieve a TEQ value.
Middle bound TEQ	Toxic equivalencies (TEQ) for which the concentration of a congener reported as being less than the LOR is assumed to be equal to half the LOR. This value is multiplied by the TEF to achieve a TEQ value.
Upper bound TEQ	Toxic equivalencies (TEQ) for which the concentration of a congener reported as being less than the LOR is assumed to be equal to the LOR. This value is multiplied by the TEF to achieve a TEQ value.
NDP	National Dioxins Program
NHMRC	National Health and Medical Research Council.
FSA	United Kingdom Food Standards Agency.
PTMI	Provisional Tolerable Monthly Intake, as set by JECFA.
JECFA	Joint FAO/WHO Expert Committee on Food Additives.
FFQ	Food Frequency Questionnaire, conducted as part of the NNS.
PCB	Polychlorinated biphenyl.
PCDD/F	Polychlorinated dibenzo-*p*-dioxin and furan.
pg/g	Picogram (10^{-12} g) per gram. Equal to nanogram per kilogram (ng/kg).
pg TEQ/kg bw/ month	Picograms TEQ per kilogram of body weight per month.
ATDS	Australian Total Diet Survey

NNS	National Nutrition Survey. 1995 dietary survey of 13 858 Australians aged 2 years and above. The NNS used a 24-hour food recall methodology.
Core foods	Those foods that are central to the Australian diet.
TCDD	2,3,7,8-tetrachlorodibenzo-*p*-dioxin, the most toxic dioxin congener.
Mapping	The process that assigns the levels of substances detected in survey foods to the appropriate food consumption data to estimate dietary exposure to the substance. Given that a survey cannot analyse all foods in the food supply, a single survey food may be assumed to represent a whole group of foods with appropriate adjustment factors for concentration.
TEQ	Abbreviation of WHO_{98}-TEQ (this document).
TEF	Toxic equivalents factor of a specific dioxin, furan, or PCB. Defines the toxicity of each congener with dioxin-like biochemical and toxic responses, relative to the toxicity of the dioxin 2,3,7,8-TCDD.
WHO_{98}-TEQ	World Health Organization toxic equivalent: the quantified level of each individual congener multiplied by the corresponding TEF. TEQs of each congener are summed to achieve and overall toxic equivalents for a sample (WHO, 1998). In this document WHO_{98}-TEQ is abbreviated to 'TEQ'.
WHO_{98}-TEQ_{DF}	WHO_{98}-TEQ for dioxins and furans.
WHO_{98}-TEQ_{P}	WHO_{98}-TEQ for PCBs.
WHO_{98}-$TEQ_{DF\&P}$	WHO_{98}-TEQ for all analytes.
WHO	World Health Organisation.

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1. Background

The National Dioxin Program (NDP), an Australian Government funded initiative implemented by the Department of Environment and Heritage (DEH), is being conducted in three stages:

- information gathering about the current concentrations of dioxins in Australia;
- risk assessment using the information gathered as a basis to assess the potential risks of dioxins to the environment and human health; and
- development of measures to reduce, and where feasible, to eliminate the release of dioxins in Australia.

Under the information gathering phase of the NDP, the following studies were undertaken:

- Determination of ambient environmental levels of dioxins in Australia (ambient air, aquatic, soils and fauna levels);
- Determination of the levels of dioxin emissions in Australia (bushfire, motor vehicle, wood heater and industrial emissions); and
- Determination of the levels of dioxins in the Australian population (blood serum and human milk studies);

In addition, studies of dioxins in food and agricultural commodities, which also contributed to the NDP, were commissioned separately. Further information on the NDP can be found on the DEH web site at www.deh.gov.au .

Food Standards Australia New Zealand (FSANZ) was commissioned by the Department of Health and Ageing (DoHA), as part of the NDP, to conduct a dietary exposure assessment in order to estimate the dietary exposure of Australians to these chemicals. A survey of dioxins in a range of foods, which are representative of the total diet, was undertaken as a first step in conducting the dietary exposure assessment. This dietary exposure assessment was used to characterise the risk associated with dioxin residues in food. In conjunction with the data collected on exposure to dioxins from other sources in Australia, it contributed to an assessment of the overall impact of dioxins on human health undertaken by the DoHA.

1.1 Dioxins

'Dioxins' refers to a group of persistent chlorinated chemical compounds, the polychlorinated dibenzodioxins (PCDDs or dioxins), and the closely related polychlorinated dibenzofurans (PCDFs or furans), which have certain similar chemical structures and properties, and have similar biological characteristics, including toxicity. Polychlorinated biphenyls (PCBs) are another group of chemicals closely related to dioxins. Some PCB compounds exhibit similar toxicity to the toxic dioxins, and are therefore considered to be 'dioxin-like PCBs'.

For the purposes of this report, the term 'dioxins' was taken to include PCDDs, PCDFs and dioxin-like PCBs.

Several hundred of these closely related PCDD/F and PCB compounds (congeners) exist. The World Health Organization (WHO) (1998), identified twenty-nine of these congeners as having a common mechanism of toxicity and that were persistent and accumulated in the food chain. These compounds can accumulate in the body fat of animals and humans and have a tendency to remain unchanged for prolonged intervals, giving rise to concern for adverse effects in humans.

PCDD/Fs are predominantly generated as unintended by-products of combustion processes (both domestic and industrial) and are therefore most usually discharged into the air. Consequently, air represents the primary route of deposition of dioxins to plant, soil and water surfaces in the environment. PCDD/Fs can then enter the food chain when animals eat contaminated plants. In aquatic environments, filter-feeding animals can absorb PCDD/Fs when they filter sediments or particulate matter floating in the water (NDPa 2003). They are then absorbed into the animal fat. PCDD/Fs increase in concentration as they migrate up the food chain. The consumption of animal products with high fat content, such as meat and dairy products, can increase human exposure to PCDD/Fs (NDPb 2003).

PCBs were manufactured for use in a wide range of industrial applications including electrical insulators or dielectric fluids and specialised hydraulic fluids. Most countries banned the manufacture and use of PCBs in the 1970s. However, PCBs are very difficult to degrade and, due to improper handling, widespread environmental contamination has occurred. As with PCDD/Fs, PCBs are generally be present at very low concentrations in most foods and accumulate in the fatty tissues of animals.

1.2 Previous dietary exposure assessments

Over 90% of human exposure to PCDD/Fs and PCBs is estimated to be through food, predominantly from those foods of animal origin such as meat and dairy products (WHO 1998). However, data on the exposure of Australians to dioxins through food have not previously been collected.

2. Dioxin food survey

2.1 Survey sample selection and preparation

Dioxins concentration data were obtained from the analysis of a range of foods sampled in Australia from retail sources. A total of 168 composite samples of 22 different foods were analysed. Details of these foods are set out in Appendix A.

Food samples were drawn from those collected for the 2002 (20th) Australian Total Diet Survey (ATDS), which were taken from freezer storage. These foods had been randomly collected in all Australian State and Territory capitals, except the ACT, during the 2000-2001 financial year. For some foods, individual composite samples were further combined to provide sufficient sample volume for analysis. Where there were insufficient samples remaining from the 20th ATDS, additional sampling occurred in 2002 in five Australian States (Queensland, New South Wales, Victoria, South Australia and Western Australia).

The Australian Government Analytical Laboratory (AGAL) carried out additional sample collection and preparation and then carried out the analysis of all the samples.

FSANZ ensured that foods likely to have higher levels of dioxins (eg meat, fish and dairy products) were analysed. In addition, those foods that are central to the Australian diet ('core' foods) were analysed. Core foods (eg bread, potatoes, orange juice), are generally consumed by the majority of the population, and often in large amounts, and even though they were expected to contain very low levels of dioxin, were included in the survey.

Margarine (table spread) rather than butter had been sampled as part of the 20th ATDS as Australians consume more margarine than butter. However, overseas data indicates that relatively high concentrations of dioxins can occur in butter. Therefore, ten samples of butter were also collected and analysed as part of this survey.

Each sample analysed for dioxins was made up of a composite of four food purchases for core foods, or three food purchases for all other foods. Where appropriate, the composite food samples were prepared to a 'table ready' state before analysis, thus best representing the amounts of dioxins that would be consumed. For example, meat and eggs were cooked, while no additional preparation occurred for composite milk or bread samples. Details of the preparation undertaken for each food are available in the Supplementary Information (Part 5) to the 20th ATDS on the FSANZ web site (www.foodstandards.gov.au).

2.2 Sample analysis

The methods used for the analysis of dioxins in food were based on the United States Environmental Protection Agency (USEPA) *Method 1613 Revision B* for PCDDs/PCDFs and *Method 1668 Revision A* for PCBs. Both methods use the technique of isotope dilution with high-resolution mass spectrometry for dioxin determination. Details of the analytical methods and quality assurance are at Appendix B.

2.3 Calculation of toxic equivalence (TEQs)

Each composite sample was analysed for the 29 PCDD/F and PCB congeners for which the WHO derived toxic equivalency factors (TEFs) for human risk assessment (set out in Appendix C) (WHO1998). TEFs refer to a weighting factor for each congener that reflects its toxicity relative to that of the most toxic dioxin, 2,3,7,8 tetrachlorodibenzo-p-dioxin (TCDD). The analytical concentration for each congener was multiplied by that congener's TEF to determine a 'weighted' concentration or toxic equivalent (TEQ) (picogram TEQ per gram).

TEQs for each composite food sample were then calculated by summing the weighted concentrations for each of the 17 specified PCDD/F and 12 PCB congeners.

For this survey, TEQs were calculated, on both a fresh weight and lipid weight basis, for each food analysis. For foods with very low levels of lipid (eg orange juice), TEQs were determined on a fresh weight basis only. All dietary modelling was carried out using analytical results for TEQs calculated on a fresh weight basis since this is how the Australian food consumption data are presented.

As food samples were randomly collected nationally and composited prior to analysis, it is likely that only limited conclusions on the possible sources of contamination may be drawn from an examination of individual sample congener profiles. However, raw analytical data showing congener profiles for each food sample analysed has been made available as supplementary information on the FSANZ web site at www.foodstandards.gov.au.

2.4 Lower and upper bound concentrations

In this report the limit of reporting (LOR) is also the limit of quantification, which is the lowest concentration of a chemical that can be detected and quantified, with an acceptable degree of certainty, using a specified laboratory method and/or item of laboratory equipment. Due to the nature of the analytical method for dioxins, based on the isotope dilution technique, variable recoveries between isotopically labelled standards means that there will be differences in the LOR for each individual PCDD/F and PCB congener for each analysis.

As dioxins are ubiquitous in the environment, it may not be reasonable to assume that each congener was not present in the food when the analytical result for that congener was less than the LOR. For this reason, where an analytical result for an individual congener was reported as below the LOR, the actual content could be anywhere between zero and the LOR. To allow for this uncertainty, the results of each food sample analysis were presented as a range, between which the likely concentration of PCDD/F or PCBs would occur. The 'lower bound' of this range was calculated assuming that all congeners reported as being less than the LOR were equal to zero. The 'upper bound' of this range, representing a very conservative 'worst-case' estimate, was calculated assuming that all congeners reported as being below the LOR were present at the LOR for that congener.

Final lower and upper bound TEQs for each composite food sample were derived by summing the weighted concentrations for each of the 17 PCDD/F and 12 PCB congeners, using the assumptions set out above. As the majority of the 29 congeners analysed in the majority of composite food samples were reported as being less than the LOR, the very conservative assumptions used to calculate the upper bound TEQ concentration are compounded by the summing of many analytical values that were reported as being below the LOR.

All lower and upper bound concentrations were calculated in picograms TEQ per gram of food (fresh weight). In order to take into consideration any differences in distribution of PCDD/F and PCBs in foods, lower and upper bound concentrations for PCDD/F and PCBs were calculated separately.

2.5 Food survey analytical results

Where more than one composite sample of a food was analysed (all foods except milk chocolate), a mean upper and lower bound analytical concentration (in picograms TEQ per gram, fresh weight) for PCDD/F and PCBs for that food was derived.

FSANZ normally derives median concentrations for contaminants in food for use in dietary modelling where analytical data for individual samples are available. However, all food samples analysed for this survey were composites of three or four purchases, resulting in some averaging in the analytical result. Therefore, mean rather than median upper and lower bound concentrations of PCDD/F and PCBs were calculated for each food for inclusion in the dietary modelling.

Dietary modelling was then carried out using the mean lower and upper bound concentrations for PCDD/F and PCBs, and the resulting dietary exposure assessments were presented as a range, between which the likely level of exposure would occur.

Peanut butter was selected for inclusion in the dioxin survey as it is a relatively high fat product, and can be a high consumption food in the diet of children. While still at a relatively low level, one peanut butter result was unexpectedly high in PCDD/Fs (0.14-0.32 pg TEQ/gram) compared to other foods analysed in the survey. The high result was still included in the dietary modelling because it was from random samples of peanut butter available on supermarket shelves for purchase and consumption by the general public. The mean value of the four peanut butter analyses was then incorporated in the dietary modelling.

Of the ten composite fish fillet samples analysed, one sample contained much greater amounts of PCBs than all the other composite samples. The high result was still included in the dietary modelling because it was from random samples of fish fillets available in supermarkets for purchase and consumption by the general public. The mean value of the ten fish fillet analyses was used for the dietary modelling.

A summary of the mean PCDD/F and PCB concentrations for each food used in the dietary modelling is shown below in Table 2.1. Individual composite sample PCDD/F and PCB summary results are available at Appendix D.

2.6 Dioxin concentrations in foods from other countries

Comparison of dioxin concentrations in food across different monitoring programs is difficult since there are differences in foods sampled, analytical methodologies and calculation and reporting of TEQs. However, Tables 2.2 and 2.3 give some indication of the measured concentrations of PCDD/Fs and PCBs in selected Australian foods compared with those measured in foods from other areas of the world. Generally, Australian foods have levels of PCDD/Fs and PCBs that appear to be similar to those reported in New Zealand and lower than those reported from other areas of the world.

Table 2.1: Mean levels of PCDD/F and PCBs in food

Food	Number of composite samples	PCDD/F		PCB	
		Lower bound pg/g FW	Upper bound pg/g FW	Lower bound pg/g FW	Upper bound pg/g FW
Bacon	10	0.013	0.061	0.012	0.021
Baked beans	3	0.00018	0.014	0.0011	0.0024
Bread, white	3	0.00039	0.021	0.00028	0.0045
Butter	10	0.011	0.20	0.017	0.070
Chicken breast	11	0.00060	0.016	0.0038	0.0057
Eggs	13	0.0026	0.045	0.0062	0.012
Fish fillets	10	0.080	0.13	0.51	0.51
Fish portions	9	0.0013	0.018	0.017	0.020
Hamburger	10	0.00020	0.020	0.00029	0.0069
Infant formula	5	0.0016	0.015	0.0019	0.0027
Lamb chops	11	0.00042	0.036	0.0040	0.0091
Leg ham	9	0.00039	0.014	0.0012	0.0030
Liver pate	4	0.00047	0.032	0.0020	0.010
Margarine	6	0.00058	0.051	0.0019	0.0071
Milk chocolate	1	0.0029	0.044	0.0048	0.012
Milk, whole	13	0.0010	0.0065	0.0013	0.0060
Minced beef	14	0.00080	0.033	0.0046	0.015
Orange juice	3	0	0.0071	0.00018	0.00042
Peanut butter	4	0.035	0.24	0.00029	0.013
Potatoes	3	0.00023	0.013	0.000060	0.0016
Sausage	11	0.0013	0.041	0.0083	0.017
Tuna, canned	5	0.0024	0.014	0.027	0.027

All samples are composites of three or four purchases.
All results are reported in picograms TEQ per gram of food on a fresh weight basis.
TEQ – WHO Toxic Equivalents (see section 2.3).
Lower Bound – assumes results reported as below the LOR are zero for each congener. The levels of the individual congeners are then summed.
Upper Bound – assumes results reported as below the LOR are at the LOR for each congener. The levels of the individual congeners are then summed.

Table 2.2: Comparison of mean PCDD/F concentrations in selected foods from different areas of the world.

	Mean PCDD/F (pg TEQ/g lipid)						
	Australia	New Zealand[1,2]	UK	Netherlands[3]	Europe[1]	Asia[1,7]	North America[1]
	(This study)	(MFE 1998)	(FSA 2003)	(Freijer et al 2001)	(Codex 2003)	(Codex 2003)	(Codex 2003)
Beef	0.0006-0.24	0-0.11	0.41-0.42[6]	0.82	0.6-1	1.0	0.5-4.1
Pork	0.05-0.22[4]	0-0.20[5]	-	0.24	0.2-1.4	0.8	0.6-23
Lamb	0.004-0.25	0-0.07	-	-	-	-	-
Poultry	0.02-0.53	0.037-0.29	0.13-0.18	1.06	0.6-0.9	0.67	0.03-3.9
Fish	1.56-3.04	0.33-0.41	1.06-1.06	0.181[8,9]	0.01-8.9[9]	0.002-10.2[9]	0.033-0.53[9]
Eggs	0.013-0.42	0.017-0.12	0.24-0.24	1.52	0.5-2.7	-	0.044-0.3[9]
Milk	0.04-0.23	0.019-0.16	0.46-0.47	0.57	0.3-2.5	0.30-1.8	0.3-0.9
Bread	0.00039-0.021	0.0012-0.0059	0.18-0.20	-	-	-	-
Butter	0.013-0.23	0-0.095	-	0.68	-	-	-

[1] Results reported in I-TEQs, that are 10-20% lower than WHO-TEQs
[2] Results reported in the range of lower to middle bound.
[3] Results reported as lower bound only.
[4] Assumes bacon is representative of all pork products.
[5] Pork meat.
[6] Carcas meat.
[7] Whether values represent lower or upper bound means was not reported.
[8] Lean fish.
[9] Reported on a fresh weight basis.

Table 2.3: Comparison of mean PCB concentrations in selected foods from different areas of the world.

	Mean PCBs (pg TEQ/g lipid)						
	Australia	New Zealand[1,2]	UK	Netherlands[3]	Europe[1]	Asia[1,7]	North America[1]
	(This study)	(MFE 1998)	(FSA 2003)	(Freijer et al 2001)	(Codex 2003)	(Codex 2003)	(Codex 2003)
Beef	0.03-0.11	0.0036-0.092	0.25-0.31[6]	1.24	-	-	0.5
Pork	0.04-0.07[4]	0.15-0.43[5]	-	0.23	0.8	-	0.02-1.7
Lamb	0.02-0.06	0.01-0.045	-				
Poultry	0.18-0.24	0.018-0.14	0.47-0.53	1.72	0.7	-	0.3
Fish	9.46-9.5	0.77	3.57-3.57	0.412[8,9]	0.03-9[9]	0.004-2.0[9]	0.11-0.28[9]
Eggs	0.04-0.11	0.05-0.11	0.11-0.20	0.87	0.2-0.6	-	0.029[9]
Milk	0.04-0.11	0.027-0.15	0.34-0.43	0.69	0.2-1.8	-	0.5
Bread	0.0003-0.005	0.00099-0.004	0.06-0.15	-	-	-	-
Butter	0.021-0.086	0.15-0.15	-	0.96	-	-	-

[1] Results reported in I-TEQs, that are 10-20% lower than WHO-TEQs.
[2] Results reported in the range of lower to middle bound.
[3] Results reported as lower bound only.
[4] Assumes bacon is representative of all pork products.
[5] Pork meat.
[6] Carcas meat.
[7] Whether values represent lower or upper bound means was not reported.
[8] Lean fish.
[9] Reported on a fresh weight basis.

2.7 European Union limits for dioxins in food

In 2001 the European Union (EU) introduced maximum levels for dioxins (the sum of PCDDs and PCDFs) in meat and meat products, fish and fishery products, milk and milk products, eggs, fats and oils, fruits, vegetables and cereals (EC 2001). These maximum levels are set out in Appendix E. The maximum levels were fixed at strict but feasible levels while taking into account background contamination, to prevent unacceptably high exposure levels among animals and the human population. In order to actively reduce the presence of PCDD/Fs in feeding stuffs and foodstuffs, the EU recommended that maximum levels should be accompanied by measures stimulating a pro-active approach, including the setting of action levels and target levels, in combination with measures to limit emissions. Therefore, action levels for PCDD/Fs in feeding stuffs and foodstuffs (also included in Appendix E) were introduced in 2002 (EC 2002). Action levels were intended as a tool to highlight those cases were significant levels of PCDD/Fs above the normal background level were found and, where appropriate, to identify a source of contamination and to take measures for its reduction or elimination.

When setting the action levels for dioxins the EU noted that it had introduced maximum and action levels for PCDD/Fs only and not (dioxin-like) PCBs, as there were very limited data available on the prevalence of the latter. However, the EU has undertaken to complete a review of maximum and action levels by 31 December 2004, with a view to including dioxin-like PCBs in the levels to be set.

While the FSANZ dioxin in food survey has analysed foods for which the EU has set regulatory limits, it should be noted that all samples analysed in the FSANZ survey were composite samples made up of three or four purchases. Therefore it is not possible to make a direct comparison of the analytical results with the EU maximum or action levels.

3. Dietary modelling

The dietary exposure assessment was conducted using dietary modelling techniques that combine food consumption data with food chemical concentration data to estimate the exposure to the food chemical from the diet. The dietary exposure assessment was conducted using FSANZ's dietary modelling computer program, DIAMOND.

Dietary exposure = food chemical concentration x food consumption

The exposure was estimated by combining usual patterns of food consumption, as derived from national nutrition survey (NNS) data, with concentrations of dioxins in foods as determined by the FSANZ analytical survey.

3.1 Dietary survey data

DIAMOND contains dietary survey data from the Australian 1995 NNS that surveyed 13 858 people aged 2 years and above. The NNS used a 24-hour food recall methodology.

As there are no data available from the NNS on children under two years, a diet was constructed to estimate dietary exposure to dioxins for infants at nine months of age (see Section 3.3).

Even though no specific high-risk groups for exposure to dioxins were identified, the dietary exposure assessment for dioxins was conducted for a number of age-gender groups for the Australian population in order to determine exposure to dioxins at different stages of the life cycle. The age-gender groups assessed were infants (9 months), toddlers (2-4 years), boys and girls aged 4-15 years, and males and females aged 16-29 years, males and females aged 30-44 years, males and females aged 45-59 years and males and females aged 60 years and over. In addition, exposure to dioxins was estimated for males and females aged from two years, to give an indication of a lifetime of exposure.

These age groups were selected for assessment because of different dietary requirements. For example, infants have a 'milk-based' diet and eat a limited variety of foods; toddlers and children have a low body weight and eat more food per kilogram of body weight than adults, and therefore are at increased risk of exposure. Generally, adults consume less food per kilo of body weight as age increases. In addition, these population groups are similar to those represented in the blood serum study conducted by the DoHA. A close correlation of population groups examined in each survey possibly will aid any comparative analysis and interpretation of these data that may be undertaken as part of the overall Human Health Risk Assessment being undertaken by the DoHA as a part of the NDP.

3.2 How were the estimated dietary exposures calculated?

3.2.1 Mapping

The DIAMOND program assigns dioxin concentrations to food groups. The 22 foods surveyed and analysed were matched (or mapped) to the foods reported as consumed in the food consumption data (the NNS foods). This process assigns the levels of dioxins detected in the survey foods to the appropriate food consumption data to estimate dietary exposure to dioxins.

Given that it is impractical to analyse all foods in the food supply, a single food (for example, potatoes) may be assumed to represent a whole group of foods (for example, all vegetables). Recipes were used for mixed foods to assign their ingredients to the appropriate survey food (for example, the proportion of potato in shepherd's pie).

As dioxins concentrate in the fat, the dioxin concentration for milk fat was used to calculate a dioxin concentration for cheese and ice cream, depending on their average milk fat content (whole milk 4%, cheese 35% and ice cream 10%, derived from nutrient composition tables from the NNS). This mapping technique assumed that dioxins in the raw food (eg milk) end up in the processed food (eg cheese, ice cream) proportional to the amount of fat in the product.

Similarly, the mean dioxin concentration in the fat of fish fillets (4%) was used to calculate a proportional concentration of dioxins in prawns (1%, derived from NNS data). As prawns (and other crustaceans) are filter feeders they tend to have different rates and congener profiles of bioaccumulation to fin fish. However, given the limitations of the survey in terms of budget, sample numbers and foods analysed, this assumption is considered to be reasonable.

Due to their extremely low fat content, some classes of foods were assumed to contain no dioxins and were not mapped to the survey foods. These included such foods as sugar and related products (eg sugar based confectionery), tea and coffee, soft drinks and alcoholic beverages.

This mapping may result in the estimated dietary exposures being overestimated as it is assumed that the analytical level of dioxins in an analysed food, for example white bread, is representative of all foods in that group, for example, cereal based products.

Details of the survey foods and corresponding NNS foods are set out in Appendix F.

3.2.2 Dietary exposure calculations

With each of the population groups assessed, each individual's exposure to PCDD/F and PCBs was calculated using their individual food consumption records from the dietary survey. Food consumption amounts for each individual take into account situations where each food is consumed alone as well as an ingredient in mixed foods. For example, milk consumed as a 'glass of milk' and milk consumed as an ingredient in pancakes.

The DIAMOND program multiplies the specified concentration of dioxin by the amount of food that an individual consumed in order to estimate the exposure to each food. The exposures of each individual were then ranked and population exposures (mean and 95th percentile) were derived. To estimate dietary exposures on a per kilogram of body weight basis, each individuals' total dietary exposure to dioxins from all foods is divided by their own body weight, the results for all individuals are ranked, and population statistics (mean and 95th percentile exposures) are then derived. Some survey respondents did not provide a body weight. These respondents were not included in the ranked exposures for deriving population statistics based on body weight.

The population group 2 years and over, indicative of a lifetime of exposure to dioxins, is representative of the population. However, the data are not weighted according to the population distribution because this can distort the actual amount of food a consumer is reported to have eaten. FSANZ considers it important when estimating the exposure of high consumers to use actual amounts of food consumed not adjusted weights of food.

Exposures to PCDD/F were calculated separately to PCBs for each population group, expressed as picograms TEQ per kilogram of body weight per month. The exposure to dioxins from all foods for each population group was then determined by summing the separate PCDD/F and PCB exposures.

Daily exposures, in picograms TEQ per kilogram of body weight, were multiplied by 30 to estimate monthly exposures, in order to allow direct comparison to the provisional tolerable monthly intake (PTMI), with estimated exposure expressed as a percentage of the PTMI.

3.2.3 Food contribution calculations

Percentage contributions of each food group to total estimated exposures were calculated by dividing the sum of all consumers' exposures from one food group by the sum of all consumers' exposures from all foods containing dioxins, and multiplying this by 100.

3.2.4 Respondents versus Consumers

Dietary exposure assessments usually provide information in terms of 'respondents' and 'consumers only'. Respondents refers to all people included in the NNS survey regardless of whether they were exposed to the food chemical or not; consumers refers to those people who reported consuming food containing the chemical being assessed.

For this dietary exposure assessment all respondents were consumers of dioxins as the foods surveyed represented a wide range of commonly consumed foods that are representative of the Australian diet, and dioxins appear to be ubiquitous in almost all foods.

3.3 Construction of the infant diet

As there were no food consumption data available from the NNS on children under two years, a diet was constructed to enable dietary exposure to dioxins for infants at nine months of age to be calculated. The recommended energy intake for a nine-month-old boy at the 50th percentile weight was used as the basis for the model diet (WHO 1983). Boys' weights were used because boys tend to be heavier than girls at the same age and therefore have higher energy and food requirements. It was assumed that 50 per cent of the energy intake was derived from milk and 50 per cent from solids (Hitchcock et al. 1986). The patterns of consumption of solid foods for a two-year-old child from the NNS were scaled down and used to determine the solid portion of the nine-month-old's diet. Certain foods such as nuts, coffee and alcohol were removed from the infant diet since nuts can be a choking risk (NHMRC 2003) and coffee and alcohol are unsuitable foods for infants (ACT Community Care 2000). Peanut products (peanut butter) were also excluded from the infant diet as it is recommended that the introduction of peanut products be delayed if there is a family history of nut allergy (ACT Community Care 2000) to prevent provoking a nut allergy from developing.

For the diet calculated for infants at 9 months, all milk consumption was assumed to be in the form of infant formula. A study of the concentrations of dioxins in human breast milk in Australia is also being undertaken as a part of the NDP. The results of this study and consideration of the exposure to dioxins for breast fed infants is being considered as a part of the Human Health Risk Assessment being conducted by the DoHA.

Only mean exposure to dioxins for this nine-month-old age group was calculated. The nine-month-old average diet was constructed by making a number of assumptions regarding energy intake and extrapolations from a two-year-old's diet. However, these extrapolations could not be made for a 95th percentile diet for infants as a high consuming infant at nine months is likely to change dietary patterns. For example, a high consuming infant is likely to eat a higher proportion of energy dense foods in order to meet the higher energy intake rather than increase the amount of all foods. There was not enough information from references to enable a diet for a high consuming infant to be derived, and there are no individual food consumption data on high consuming infants from nutrition surveys. Therefore, there was no evidence to validate any extrapolations and assumptions for a high consuming infant. Consequently, estimated 95th percentile exposures for infants at nine months were not calculated.

3.4 Assumptions in the dietary exposure assessment

The aim of the dietary exposure assessment was to make as realistic an estimate of dietary exposure to dioxins as possible. However, where significant uncertainties in the data existed, conservative assumptions were generally used to ensure that the dietary exposure assessment did not underestimate exposure.

In the dietary modelling the following broad assumptions were made:

- consumers eat the same every day of the month;
- that for the upper bound estimates of dioxin exposure, the concentrations of each of the congeners were at the LOR for all the cases where concentrations were reported as less than the LOR;
- where a food containing PCDD/F and PCBs was mapped to a food group, all foods in that group contain the chemicals at the specified concentration for that group;
- consumption of foods as recorded in the NNS represent current food consumption patterns; and
- any foods not analysed or mapped (for example, sugar, tea, coffee, soft drinks and alcoholic beverages), are assumed to contain no dioxins due to their extremely low fat content, except if they were mixed foods and their ingredients were analysed.

In the mapping of food consumption data to the foods for which survey data were available, the following assumptions were made:

- cheese and ice cream have proportional concentrations of PCDD/F and PCBs to milk, relative to the amount of fat in the product;
- crustaceans and molluscs have proportional concentrations of PCDD/F and PCBs to fish fillets, relative to the amount of fat in the product;
- all cereal products have the same PCDD/F and PCB concentration as white bread;
- all vegetables have the same PCDD/F and PCB concentration as potatoes; and
- all fruit and fruit juices have the same PCDD/F and PCB concentration as orange juice.

3.5 Limitations of the dietary modelling

A limitation of estimating dietary exposure over a period of time associated with the dietary modelling is that only 24-hour dietary survey data were available, and these tend to over-estimate habitual food consumption amounts for high consumers. Therefore, predicted high percentile exposures are likely to be higher than actual high percentile exposures over a lifetime.

For commonly consumed foods such as bread, milk and meat, which are generally consumed on a daily basis by the majority of Australians, a 24-hour recall provides a relatively accurate estimate of daily consumption amounts over a longer period of time.

For occasionally consumed foods, the consumption based on 24-hour dietary survey data is not representative of longer-term consumption. Assuming fish consumers have the same fish consumption as they reported for 24 hours each day of the month is an overestimate. The food frequency questionnaire (FFQ) conducted as part of the NNS showed that approximately 75% of respondents aged 12 years and above eat fish less than once per week. Fish are only consumed daily by 6% of Australians (12 years and above). In reality, high consumers of fish on the day of the survey are unlikely to have consumed fish at this level every day. Therefore, assuming the same amount of fish is consumed seven days a week will overestimate exposure to total dioxins for 94% of the population.

A further limitation of the dietary exposure estimate is the small number of foods and samples analysed. This is a result of time and funding restrictions. Foods were selected for analysis to represent the major foods in the Australian diet and foods that were likely to contain dioxins. While there were a small number of samples, the results are considered to be valid due to the random nature of the survey, and it provides a good 'first cut' of estimated exposures for the Australian population.

No analysis of drinking water was carried out as a part of this survey. Levels of dioxins in drinking water are likely to be extremely low as dioxins have very low water solubility.

4. Dietary exposure results

4.1 Estimated dietary exposures to dioxins

4.1.1 Estimated dietary exposures for population groups aged 2 years and above

Mean estimated monthly dietary exposures to dioxins (the sum of PCDD/Fs and PCBs) for each population group two years and above are shown in Figure 4.1. 95th percentile estimated monthly dietary exposures to dioxins for each population group are shown in Figure 4.2. In both figures the estimates from upper bound and lower bound models are presented.

A summary of mean and 95th percentile estimated monthly exposure to dioxins (in pg TEQ/kg bw/month) is set out in Table 4.1. Appendix G has complete mean and 95th percentile exposure results tables for PCDD/F, PCBs and total dioxins.

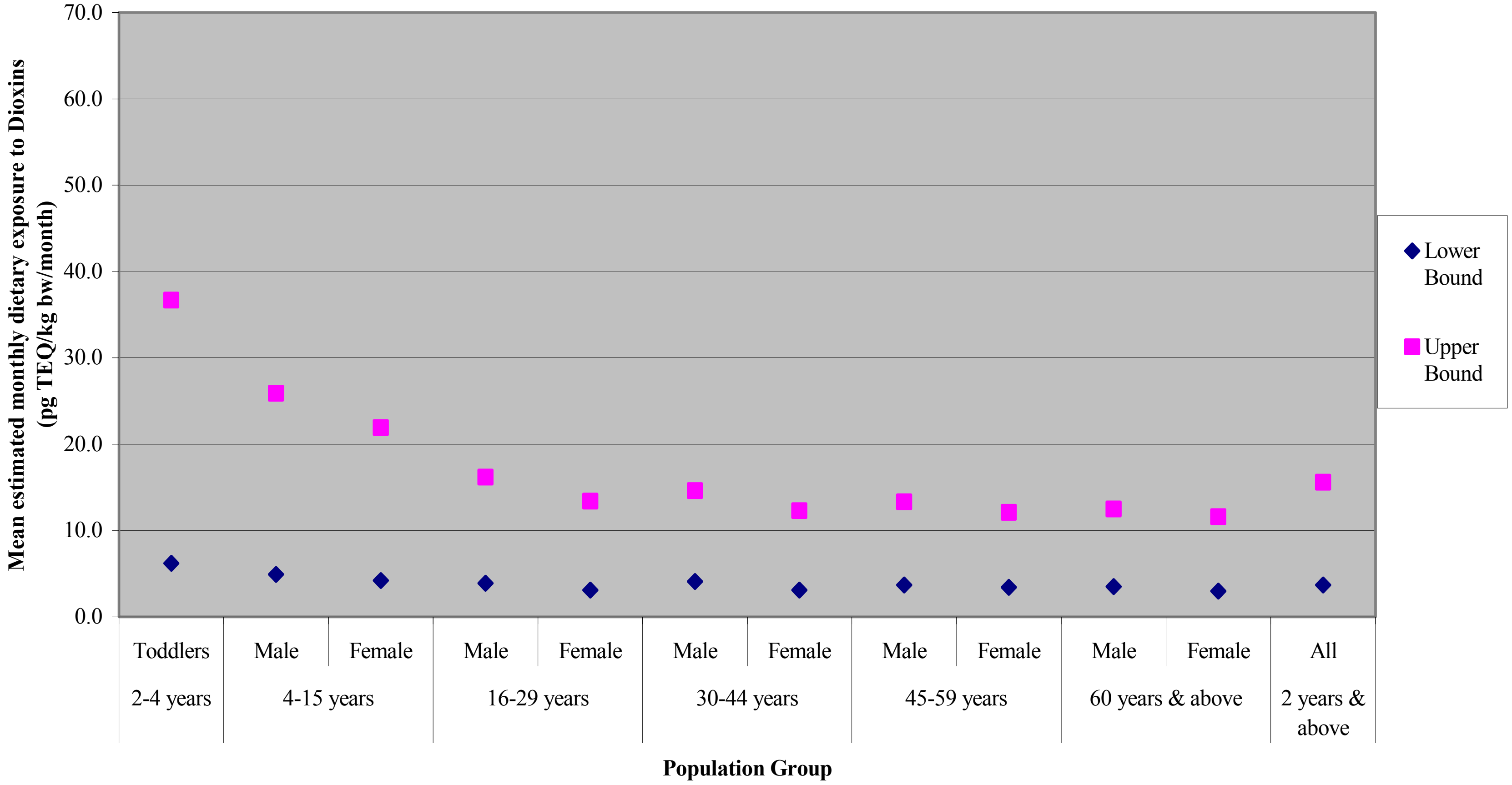
Estimated mean and 95th percentile exposures to dioxins decreased as the age group increased due to food consumption being greater relative to body weight for children.

The large range of reported dietary exposures for each population group results from the high proportion of results that were reported as less than the LOR and the limited sensitivity of the analytical method. The actual dietary exposure to dioxins lies within this calculated range for each population group, and it is not possible, given the limitations of the analytical method, to be more precise.

Table 4.1: Estimated mean and 95th percentile monthly exposures to dioxins

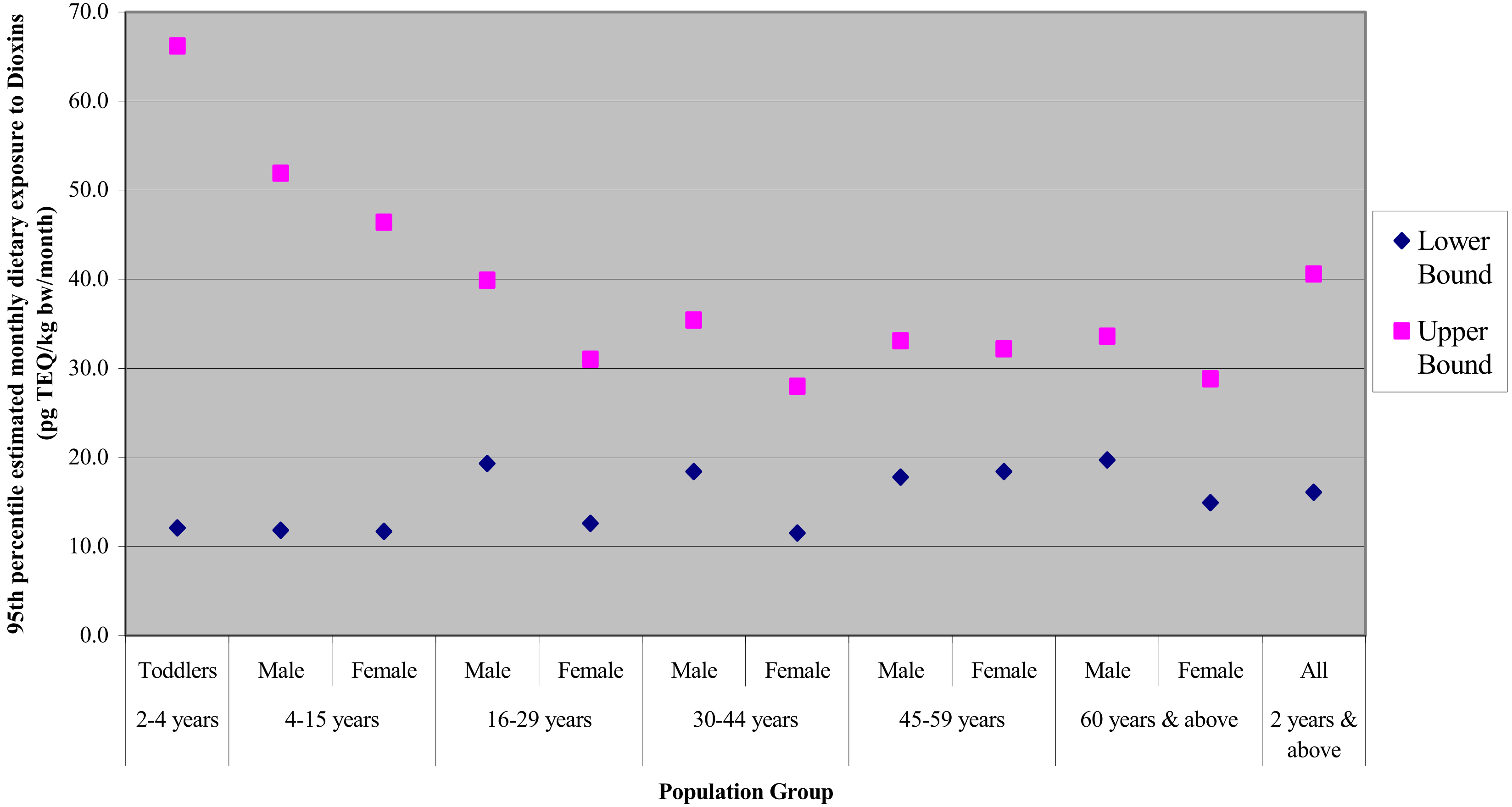
Estimated monthly dietary exposures to dioxins in pg TEQ/kg bw/month					
		Mean Exposure		**95th Percentile Exposure**	
		Lower Bound	Upper Bound	Lower Bound	Upper Bound
All	2+	3.7	15.6	16.1	40.6
Males	2+	4.1	16.9	17.7	43.3
Females	2+	3.4	14.5	14.8	38.4
Toddlers	2-4	6.2	36.7	12.1	66.2
Males	4-15	4.9	25.9	11.8	51.9
Females	4-15	4.2	21.9	11.7	46.4
Males	16-29	3.9	16.2	19.3	39.9
Females	16-29	3.1	13.4	12.6	31.0
Males	30-44	4.1	14.6	18.4	35.4
Females	30-44	3.1	12.3	11.5	28.0
Males	45-59	3.7	13.3	17.8	33.1
Females	45-59	3.4	12.1	18.4	32.2
Males	60+	3.5	12.5	19.7	33.6
Females	60+	3.0	11.6	14.9	28.8

Lower Bound – assumes results reported as being below the LOR are zero.
Upper Bound – assumes results reported as being below the LOR are at the LOR.
PTMI = 70 pg TEQ/kg bw/month
Dioxins = sum of intakes of PCDD/Fs and PCBs.
Estimated dietary exposures are based on food consumption data from the 1995 NNS
Infant estimated dietary exposures are not included in this table as they are based on a constructed infant diet (see Section 3.3) and discussed in Section 4.1.2.



Lower Bound – assumes results reported as being below the LOR are zero.
Upper Bound – assumes results reported as being below the LOR are at the LOR.
TMI = 70 pg TEQ/kg bw/month
Dioxins = sum of intakes of PCDD/F and PCBs.
Estimated dietary exposures are based on food consumption data from the 1995 NNS

Figure 4.1: Mean estimated monthly dietary exposure to dioxins on a per body weight basis



Lower Bound – assumes results reported as being below the LOR are zero.
Upper Bound – assumes results reported as being below the LOR are at the LOR.
TMI = 70 pg TEQ/kg bw/month
Dioxins = sum of intakes of PCDD/F and PCBs.
Estimated dietary exposures are based on food consumption data from the 1995 NNS

Figure 4.2: 95th percentile estimated monthly dietary exposure to dioxins on a per body weight basis

4.1.2 Estimated dietary exposures to dioxins for infants

Estimated dietary exposures for infants aged 9 months were considered separately from other population groups as estimated exposures for infants aged 9 months were derived using a different methodology. 95th percentile exposures were not calculated for this age group for the reasons explained in Section 3.3. In addition, it should be noted that estimated dietary exposures for infants were derived assuming all milk consumption was infant formula. The exposure to dioxins from breast milk is being considered as part of the Human Health Risk Assessment undertaken by the DoHA.

For infants aged 9 months, the mean estimated exposure to dioxins was in the range of 11.8 and 60.8 pg TEQ/kg bw/month (lower to upper bound respectively). Infants aged 9 months had a high calculated mean exposure to total dioxins because of their high food consumption relative to body weight.

4.2 Major contributing foods to total estimated dietary exposures

The foods that contribute to dietary exposure to PCDD/F and PCBs were derived using the exposure assessment where foods with an analytical result reported as below the LOR were assumed to be equal to zero (lower bound). This provided the best indication of the food groups most likely to contribute to dietary exposure as it only included foods where actual PCDD/F or PCB levels were detected.

Percentage contribution to PCDD/F and PCB exposure were determined separately in order to provide an indication of the distribution of PCDD/F and PCBs in different foods and to determine if the same foods were the highest contributors to both PCDD/F and PCB exposure.

While only a limited number of foods were analysed for dioxins, each food was assumed to represent all foods in that group (see Section 3.2.1). When determining the contributions that each food made to dioxin estimated dietary exposures, foods that were mapped together or were assumed to contain the same dioxin concentration of other foods had their contributions summed. For example, milk was summed with contributions from ice cream and cheese.

4.2.1 Major contributing foods to total estimated dietary exposures for toddlers and the population aged 2+ years

The foods with detectable levels of PCDD/F and PCBs that contributed to dietary exposures for toddlers aged 2-4 years are shown in Figures 4.3 and 4.4 respectively, and for the whole population aged 2+ years in Figures 4.5 and 4.6 respectively.

The complete results tables for major contributing foods to estimated dietary exposures for all population groups assessed are included at Appendix H. Only toddler groups are shown separately in the figures because older children and adults tended to have similar foods contributing to exposure as the whole population group 2+ years, whereas toddlers were different. As discussed in Section 3.2.2, the population group 2+ years is a representative sample of the population but data are not weighted according to population distribution. Infants are considered separately in Section 4.2.2.

For toddlers aged 2-4 years the major contributors to PCDD/F exposure were milk and dairy products including cheese and ice cream (55%), fish including crustacean and molluscs (18%), peanut butter (8%) and white bread, including all cereal products (5%). For this population group the major contributors to PCB exposure were fish including crustaceans and molluscs (49%) and milk and dairy products including cheese and ice cream (30%). Other contributing foods included sausages (3%), and beef, veal and game, poultry, orange juice including all fruit and white bread including all cereal products (2% each).

For the whole population aged 2+ years the major contributors to PCDD/F exposure were fish including crustacean and molluscs (39%), milk and dairy products including cheese and ice cream (31%), bacon and pork (7%), white bread including all cereal products and peanut butter (4% each), potatoes including all vegetables (3%) and butter, beef, veal and game and eggs (2% each). Major contributors to PCB exposure for the population aged 2+ years were fish including crustacean and molluscs (72%), milk and dairy products including cheese and ice cream (11%), beef, veal and game (3%) and poultry, bacon and pork, sausages and canned fish (2% each).

The major foods that contributed to PCDD/F exposure were slightly different between adults and children, with milk and dairy products being the major contributor for children (toddlers 2-4 years and males and females 4-15 years), and fish, crustaceans and molluscs for adults (males and females aged 30-44 years, 54-59 years and 60+ years). For males and females in the 16-29 years age group, exposure to PCDD/F was contributed almost equally from fish and milk.

The major contributor to exposure to PCBs for all population groups was fish, crustaceans and molluscs. Of the ten composite fish fillet samples analysed, one sample contained significantly greater amounts of PCBs. FSANZ performed additional dietary modelling using a mean value of PCBs for fish calculated by excluding the one high value. In this scenario, fish remained the highest contributor to PCB exposure for adults. This may be attributed to the fact that people who consumed fish as part of the 24-hour recall in the NNS were assumed to have consumed fish for 30 days, for the dioxin exposure assessment, which is unlikely. However, similar to the PCDD/F exposures, using this scenario, milk was the highest contributor to PCB exposure for children and toddlers.

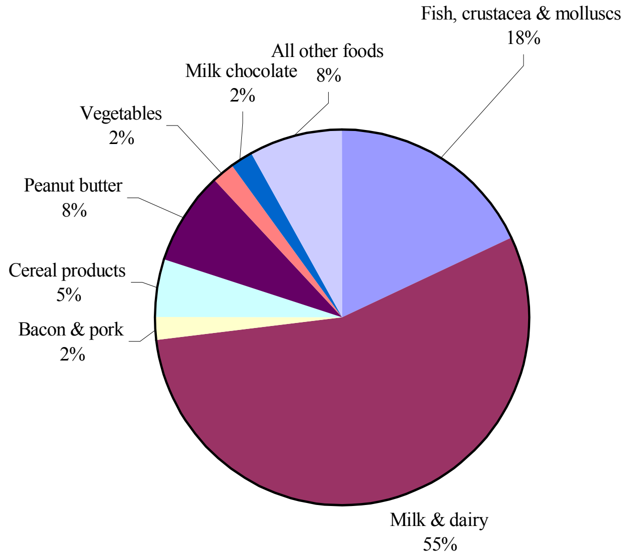


Figure 4.3: Percent contribution of major food contributors to PCDD/F dietary exposures for toddlers aged 2-4 years

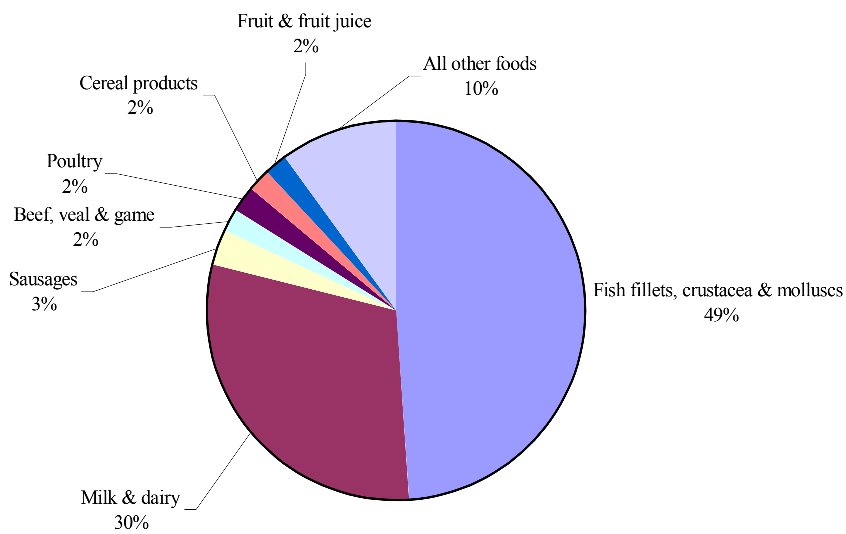


Figure 4.4: Percent contribution of major food contributors to PCB dietary exposures for toddlers aged 2-4 years

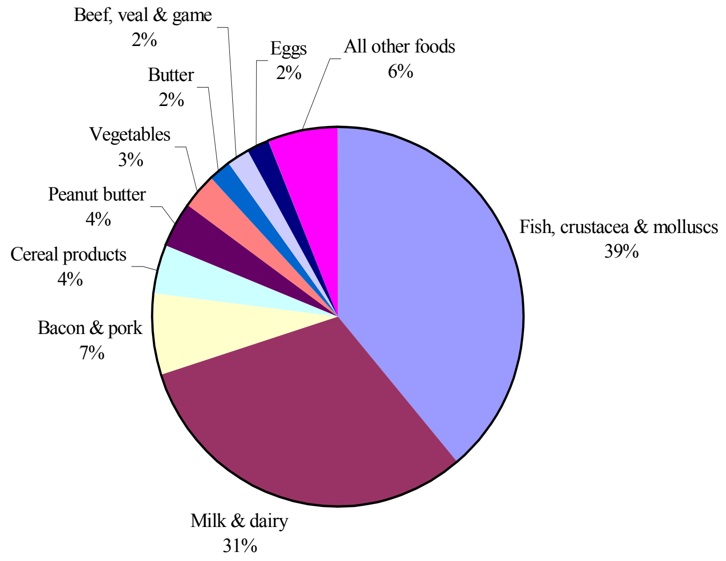


Figure 4.5: Percent contribution of major food contributors to PCDD/F dietary exposures for the whole population aged 2+ years

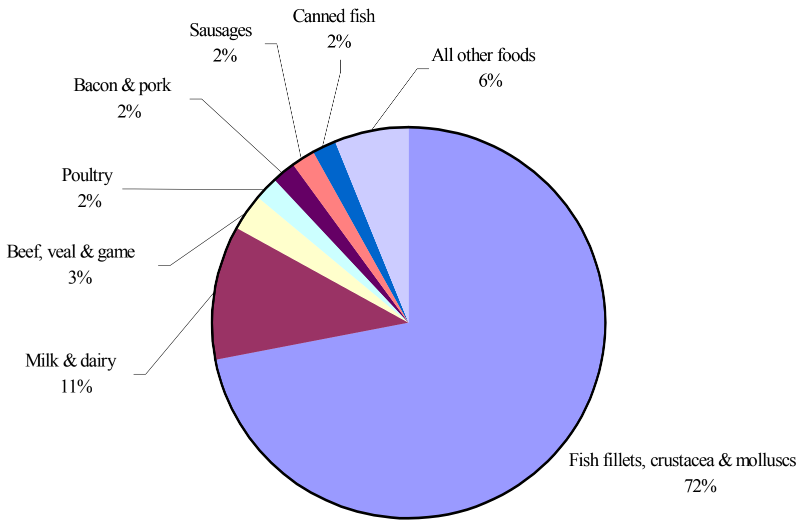


Figure 4.6: Percent contribution of major contributors to PCB dietary exposures for the whole population aged 2+ years

4.2.2 Major contributing foods to total estimated dietary exposures for infants aged 9 months

The foods with detectable levels of PCDD/F and PCBs that contributed to dietary exposures for infants aged 9 months are shown in Figures 4.7 and 4.8 respectively. Exposure to dioxins from breast milk is considered separately in the human health risk assessment being conducted by the DoHA.

For infants aged 9 months the major contributors to PCDD/F exposure (in descending order of contribution) were infant formula (82%), fish including crustacean and molluscs (7%), milk and dairy products including cheese, ice cream and infant dessert (5%), vegetables (2%) and white bread including all cereal products (2%). Major contributors to PCB exposure for this age group were infant formula (61%), fish including crustaceans and molluscs (26%) and milk and dairy products including cheese, ice cream and infant dessert (4%). The high contribution of infant formula to both PCDD/F and PCB exposure can be attributed to the importance of this food in the infants' diet.

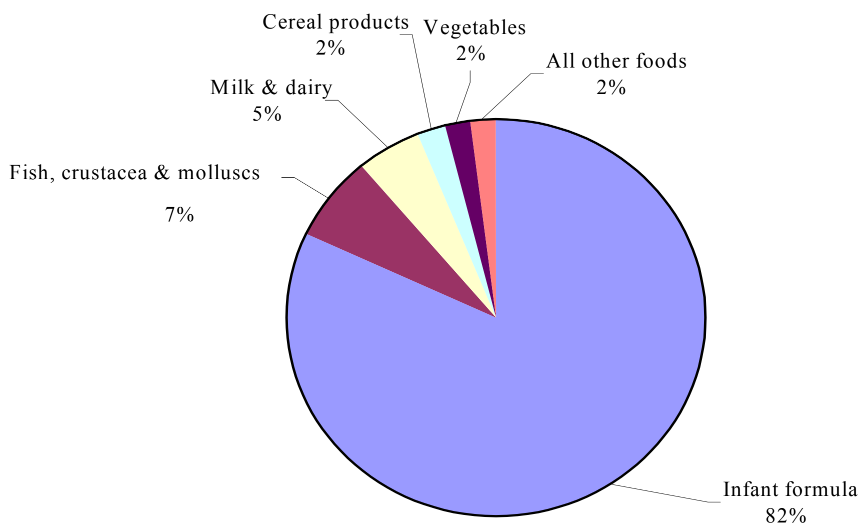


Figure 4.7: Percent contribution of major food contributors to PCDD/F dietary exposures for infants aged 9 months

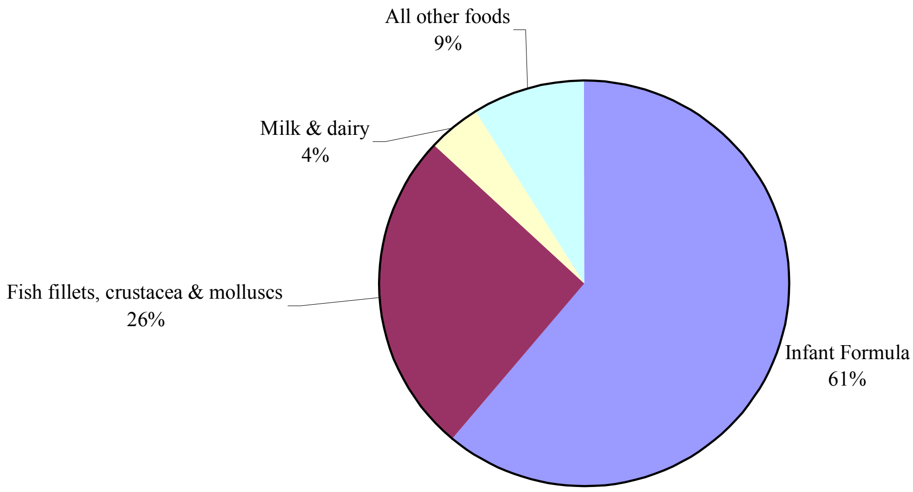


Figure 4.8: Percent contribution of major contributors to PCB dietary exposures for infants aged 9 months

5. Risk characterisation

In characterising the risk associated with dioxins exposure through food, it is necessary to consider the nature of the adverse health effects associated with dioxin exposure, the timeframe in which these effects are observed, whether there is a threshold dose for these effects, the level of exposure for vulnerable sectors of the population, and the limitations and uncertainties inherent in the available data.

5.1 Adverse effects and tolerable intake of dioxins

The nature of the adverse effects associated with dioxins exposure have been well characterised by national and international reviews of the toxicity data on dioxins. In Australia, the National Health and Medical Research Council (NHMRC) considered these reviews in 2002 with a view to establishing an Australian tolerable intake for dioxins (NHMRC, 2002). The NHMRC considered reviews prepared by the WHO European Centre for Environmental Health and International Programme on Chemical Safety (May 1998), the European Community Scientific Committee on Food (May 2001), and the Joint FAO/WHO Expert Committee on Food Additives (JECFA) (June 2001).

Each of these reviews concludes that any potential adverse effect associated with dioxins exposure at the levels normally found in food would only be observed following an elevation in dioxin body burden following long-term exposure (40-50 years). The adverse effects observed in animal models include developmental delays, thyroid hormone alterations and cancer. The dioxin body burden at which these effects occurred has been studied to determine whether a threshold for these effects exists. Upon consideration of the available reviews, the NHMRC concluded that a tolerable intake could be established for dioxins on the basis that a threshold exists (based on body burden) for all observed adverse effects, including cancer. An Australian tolerable monthly intake (TMI) was established for dioxins of 70 pg TEQ/kg of body weight from all sources, including dioxins, furans and dioxin-like PCBs. This is equivalent to the provisional tolerable monthly intake (PTMI) established by JECFA in 2001. The tolerable intake was established on a monthly basis to indicate the long-term nature of any potential dioxin toxicity.

There are a number of uncertainties associated with the determination of a tolerable intake. In the case of dioxins, there are two major uncertainties: firstly, the significance of the toxicity endpoint used to establish the body burden threshold; and secondly, the establishment of a short-term tolerable intake based on long-term body burden data. In considering these uncertainties, the JECFA report stated that: "*the PTMI is not a limit of toxicity and does not represent a boundary between safe intake and intake associated with a significant increase in body burden or risk.*" The report goes on to state: "*Long-term exposure slightly above the PTMI would not necessarily result in adverse health effects but would erode the safety factor built into the calculation of the PTMI. It is not possible, given our current knowledge, to define the magnitude and duration of excess intake that would be associated with adverse health effects.*" These uncertainties will impact on consideration of the data comparing the dietary exposure of dioxins and the TMI.

5.2 Estimated dietary exposures as a percentage of the Australian TMI

As an initial step in characterising the risk associated with dioxins exposure from food, the estimated dietary exposures for various age groups were compared to the Australian TMI. The dietary exposures have been determined on the basis of data from the 1995 National Nutrition Survey, which uses a 24-hour food recall for its data collection. It was necessary, therefore, to multiply the dietary exposure data by 30 in order to allow a direct comparison with the TMI. While this may introduce some uncertainty into the data, the broad range of foods used in the determination of the dietary exposure suggests this uncertainty will be small.

Table 6.1 shows the mean and 95th percentile estimated monthly exposure to dioxins for the range of population groups aged two years and above as a percentage of the TMI. Figures 6.1 and 6.2 show the same data graphically. In both figures, the estimated monthly exposure using the lower bound and upper bound models are presented. Appendix I contains detailed tables of the complete mean and 95th percentile exposure results, as a percentage of the TMI, for PCDD/F, PCBs and total dioxins.

In all cases, the mean and 95th percentile estimated dietary exposure to dioxins for all age-gender categories were below the TMI of 70 pg TEQ/kg bw/month. For the population representing a lifetime of exposure (aged 2+ years), the estimated mean exposure to dioxins was between 5% (lower bound) and 22% (upper bound) of the TMI. The 95th percentile exposure for the same population was between 23% (lower bound) and 58% (upper bound) of the TMI. For the population groups representing the younger members of the population, the mean and 95th percentile dietary exposure estimates were generally a higher percentage of the TMI, as a result of their lower bodyweights and a higher proportion of milk and dairy products in their diets. Given the long-term nature of any potential adverse effects associated with dioxins exposure, there is no increase risk associated with exposure to this population group.

The mean estimated dietary exposure for infants aged 9 months as a percentage of the TMI was considered separately from other population groups since this was derived using a different methodology and cannot be directly compared to other population groups. For this population group, the 95th percentile exposures were not calculated for the reasons discussed in Section 3.3. Estimated mean exposure to dioxins for infants aged 9 months was 17% (lower bound) to 87% (upper bound) of the TMI. Infants at this age had the highest calculated mean exposure to dioxins as a percentage of the TMI because of their high food consumption relative to body weight.

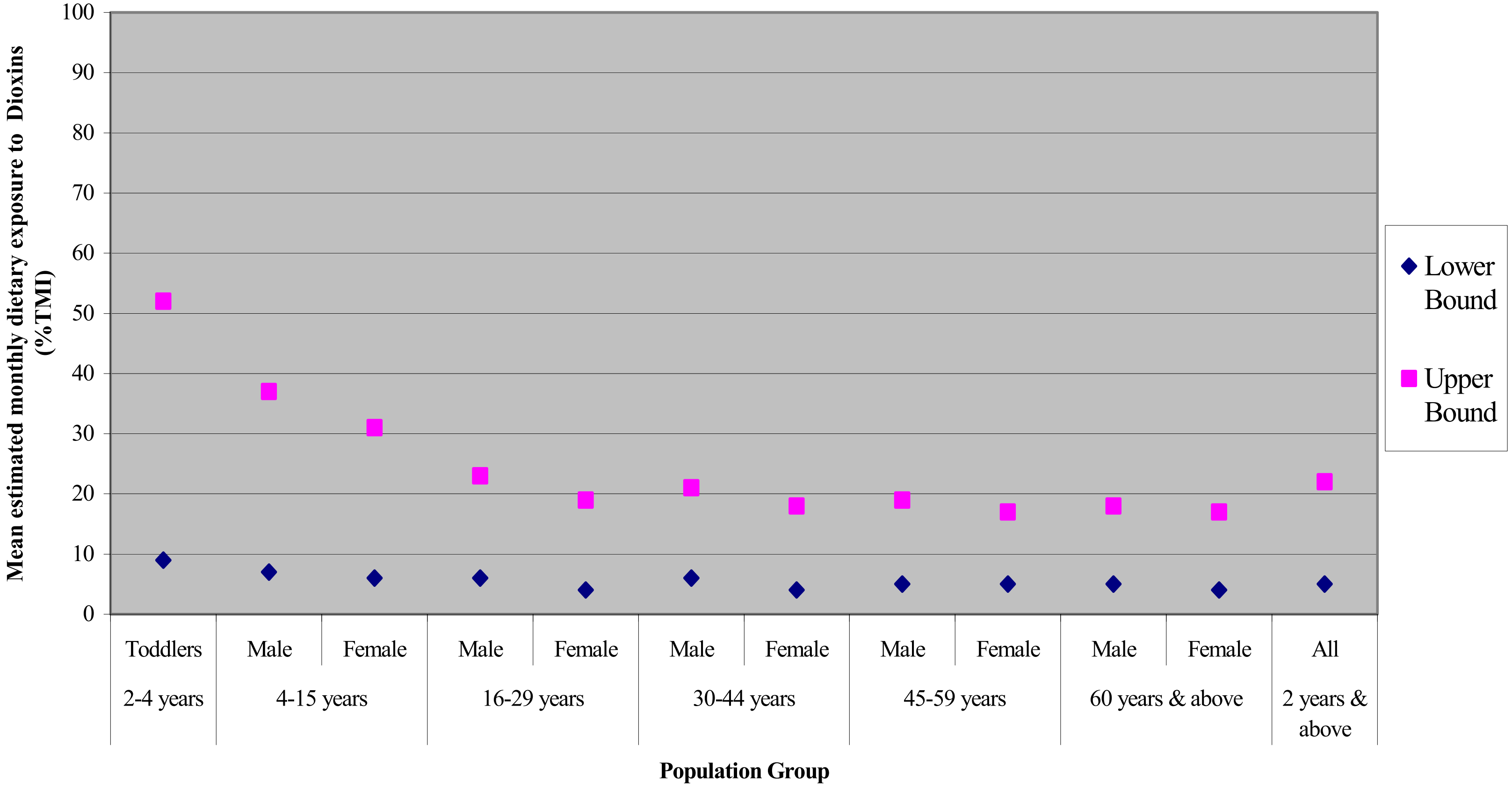
The major sources of uncertainty associated with the determination of dietary exposure for dioxin are: firstly, the use of survey data where the results are below the LOR; and secondly, the dietary modelling methodology. Both of these sources of uncertainty have been discussed in detail in this report. The use of an upper bound (*analytical results below the LOR assumed to be at the LOR*) is a very conservative assumption and gives a highly unlikely 'worst case' scenario for dietary exposure. The actual exposure will lie somewhere between the lower and upper bound but is likely to be closer to the lower bound, given the highly conservative nature of the upper bound determination. In relation to the dietary modelling, the most significant uncertainty is likely to be the determination of the 95th percentile exposures based on 24-hour recall data, which again are likely to be an overestimate, particularly of the longer-term dietary exposure.

A simple comparison of the dietary exposure data on dioxins in foods with the Australian TMI does not raise any public health concerns as the results are all below the TMI. While exposure to dioxins in foods varies with age, any potential risk from dioxins is long-term and related to lifetime body burden rather than to short term dietary exposure. Thus, the overall risk to Australian consumers following the consumption of foods containing dioxins is considered to be very low for individuals in all age groups.

Table 5.1: Estimated mean and 95th percentile monthly exposures to dioxins as a percentage of the Australian TMI

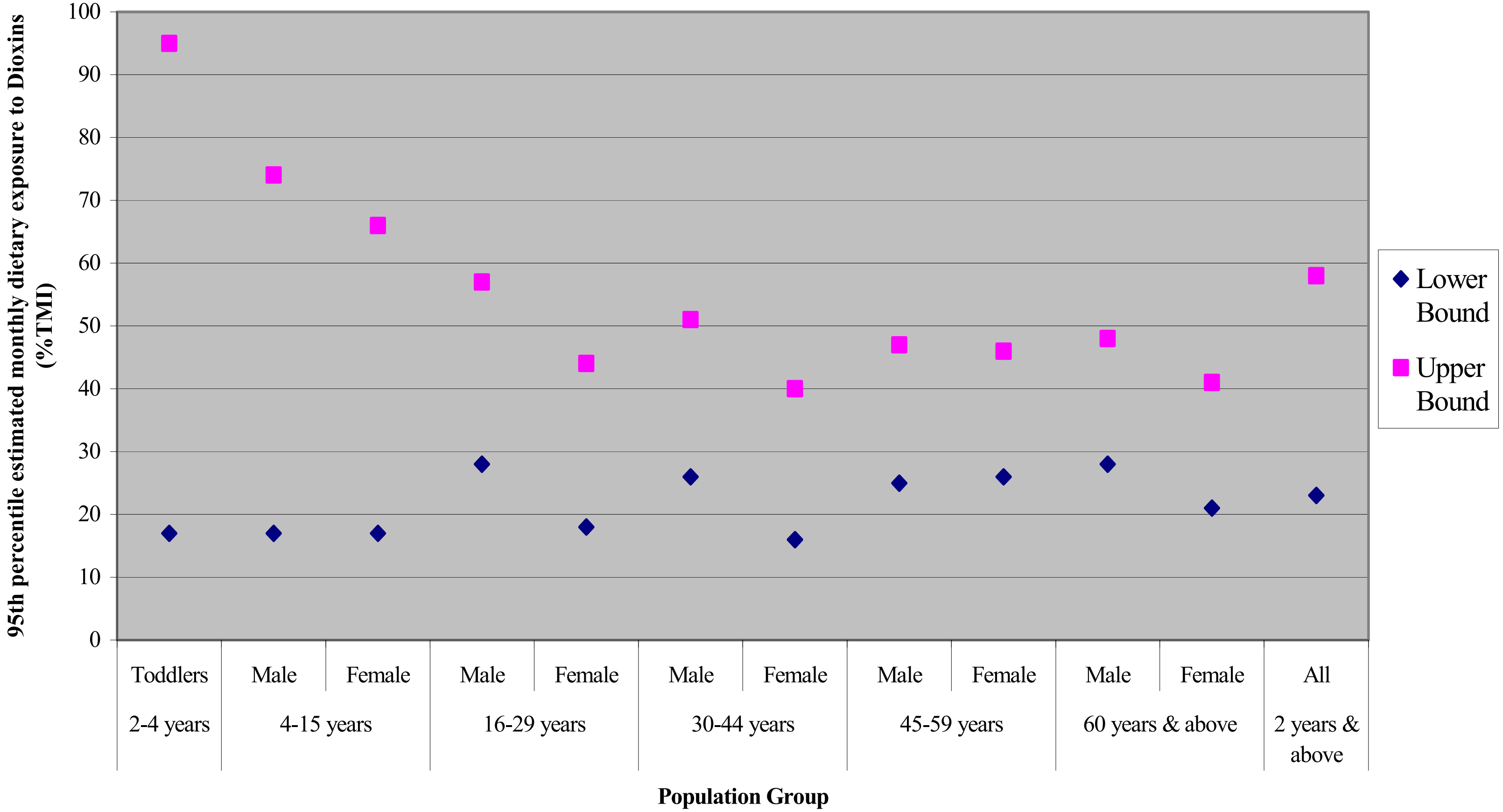
Estimated monthly dietary exposures to dioxins as a percentage of the Australian TMI					
		Mean Exposure		**95th Percentile Exposure**	
		Lower Bound	Upper Bound	Lower Bound	Upper Bound
All	2+	5	22	23	58
Males	2+	6	24	25	62
Females	2+	5	21	21	55
Toddlers	2-4	9	52	17	95
Males	4-15	7	37	17	74
Females	4-15	6	31	17	66
Males	16-29	6	23	28	57
Females	16-29	4	19	18	44
Males	30-44	6	21	26	51
Females	30-44	4	18	16	40
Males	45-59	5	19	25	47
Females	45-59	5	17	26	46
Males	60+	5	18	28	48
Females	60+	4	17	21	41

Lower Bound – assumes results reported as being below the LOR are zero.
Upper Bound – assumes results reported as being below the LOR are at the LOR.
Australian TMI = 70 pg TEQ/kg bw/month.
Dioxins = sum of intakes of PCDD/F and PCBs.
Estimated dietary exposures are based on food consumption data from the 1995 NNS.
Infant estimated dietary exposures are not included in this table as they are based on a constructed infant diet (see Section 3.3).



Lower Bound – assumes results reported as being below the LOR are zero.
Upper Bound – assumes results reported as being below the LOR are at the LOR.
Australian TMI = 70 pg TEQ/kg bw/month.
Dioxins = sum of intakes of PCDD/F and PCBs.
Estimated dietary exposures are based on food consumption data from the 1995 NNS.

Figure 5.1: Mean estimated dietary exposure to dioxins as a percentage of the Australian TMI



Lower Bound – assumes results reported as being below the LOR are zero.
Upper Bound – assumes results reported as being below the LOR are at the LOR.
Australian TMI = 70 pg TEQ/kg bw/month.
Dioxins = sum of intakes of PCDD/F and PCBs.
Estimated dietary exposures are based on food consumption data from the 1995 NNS.

Figure 5.2: 95th percentile estimated dietary exposure to dioxins as a percentage of the Australian TMI

6. Results of other national dioxin dietary surveys

Comparison of dioxin concentrations in foods from different countries and/or monitoring programs was relatively difficult due to differences in foods sampled, analytical methodologies and calculation and reporting of TEQs. Difficulties in making comparisons between dioxin dietary exposure assessments were further compounded due to differences in survey design, age groups surveyed, different methods of determining food consumption for the population and different methods of collecting food data. In addition there can be quite different patterns of food consumption in different areas of the world.

However, in spite of the difficulties in making direct comparisons between different dietary studies, Table 6.1 provides an indication of the calculated dietary exposure to dioxins, on a monthly basis, in selected Australian populations compared with those calculated in populations from other areas of the world.

Specific international dietary studies are discussed in more detail below.

In general terms, the estimated intake of dioxins by Australians is comparable to that of New Zealand and lower than that of other industrialised nations.

6.1 UK Dioxins Total Diet Study

In July 2003 the UK Food Standards Agency (FSA) released the findings of its 2001 Total Diet Study (FSA 2003) on dioxins and dioxin-like PCBs in the UK diet. The FSA found that the estimated average exposure by adults to total dioxins was 0.7-0.9 pg TEQ/kg bw/day (lower to upper bound values respectively). This is equivalent to an estimated monthly exposure of 21-27 pg TEQ/kg bw/month.

For young school children (4-6 years) the FSA estimated average exposure to total dioxins to be in the range of 1.5 (lower bound) to 1.8 pg TEQ/kg bw/day (upper bound). This is equivalent to 45-54 pg TEQ/kg bw/month. For older school children (15-18 years) estimated average exposure to total dioxins was in the range of 0.6-0.7 pg TEQ/kg bw/day (equivalent to 18-21 pg TEQ/kg bw/month).

Direct comparison between the FSA and FSANZ total diet studies was problematic for a number of reasons including different dietary exposure assessments due to differences in survey design, age groups surveyed, different methods of determining food consumption for the population and different methods of collecting food data.

6.2 New Zealand Dioxin Dietary Intake Study

The New Zealand Ministry for the Environment (MFE) undertook a survey and assessment of dietary exposure to PCDD/F and PCBs in a range of retail foods (MFE 1998).

The New Zealand study determined that total exposure to dioxins, furans and PCBs for an adult male (25-44 years) was in the range of 4.5 pg I-TEQ/kg bw/month (lower bound - excluding LOR values), to 9.9 pg I-TEQ/kg bw/month (upper bound - including **half** LOR values). This study assumed a body weight of 80 kg and a median estimated energy diet of 10.8 Mj/day for adult males.

As with the UK study, direct comparison with this New Zealand study was difficult for a number of reasons. The previously widely used International Toxic Equivalents (I-TEQ) for dioxins, furans and PCBs have been used for the New Zealand study, and fewer PCDD/F and PCB congeners were analysed.

In addition to the 1998 assessment of dietary intake of dioxins, the MFE conducted an appraisal of the health risk from dioxins for the New Zealand population (MFE 2001). In this evaluation, estimated dietary exposures previously reported in I-TEQs were recalculated using WHO TEQs. This recalculation resulted in approximately a 10% increase in TEQ levels.

6.3 Netherlands Dioxin Dietary Intake Study

A study of the occurrence and dietary intake of dioxins in the Netherlands was released in 2001 (Freijer et al 2001). This study estimated the mean lifelong-averaged intake of PCDD/Fs in the population to be equivalent to 20.7 pg TEQ/kg bw/month (0.69 pg TEQ/kg bw/day), estimated using lower bound values. PCB mean lifelong-averaged intake was estimated to be 18.6 pg TEQ/kg bw/month (0.62 pg TEQ/kg bw/day), estimated using lower bound values. These estimated intakes represented a reduction in intake of approximately 50% for PCDD/Fs and 60% for non-ortho PCBs, compared to results of a dietary exposure assessment conducted in 1009/91.

6.4 European Dietary Exposure Assessment of Dioxins in Food

The Scientific Committee on Food (SCF) advised the European Commission (EC) Health and Consumer Protection Directorate-General on the establishment of limits relating to PCDD/Fs and PCBs in food (EC 2000). Information on the occurrence of PCDD/Fs and PCBs in food and the dietary exposure to these compounds was compiled from ten participating countries (Belgium, Denmark, Finland, France, Germany, Italy, The Netherlands, Norway, Sweden, and the United Kingdom). Samples were obtained at national levels, from various sites, including rural, and industrial sites and collected in different years, covering the period 1995-1999 for the most recent data. Wherever, available or possible, data on consumption of these foods and the dietary exposure of the general population to these compounds were provided. The SCF noted that there were large differences in the amount, detail and quality of data from the participating countries. In particular inadequate harmonisation of the analytical procedures and lack of sufficient sensitivity of the analytical procedures influenced comparability of results.

Using the data compiled from the participating countries, the average dietary exposure to PCDD/Fs for the average adult person was estimated to be between 12 and 45 pg I-TEQ/kg bw/month (equivalent to 0.4-1.5 pg I-TEQ/kg bw/day). The average dietary exposure to PCBs was estimated to be in the range of 24-45 pg PCB-TEQ/kg bw/month (equivalent to 0.8-1.5 pg PCB-TEQ/kg bw/day).

Table 6.1: An international comparison of mean estimated dietary intakes of dioxins

Country/region	Reference	PCDD/Fs (pg WHO-TEQ/kg bw/month)	PCBs (pg WHO-TEQ/kg bw/month)	Total Dioxins (pg WHO-TEQ/kg bw/month)
Australia[1]	(this study)	0.9-10.2	2.8-5.4	3.7-15.6
New Zealand[2]	Ministry for Environment, 1998 and 2001)	6.6	4.5	11.1
UK[3,4]	Food Standards Agency, 2003	9	9-12	15-21
The Netherlands[4,5]	Freijer et al, 2001	20.7	18.6	39
Europe[6,7]	European Commission, 2000	12-45	24-45	36-90

1-Range is lower bound to upper bound for all persons 2+years of age
2-Medium bound estimate for adult males
3-Range is lower bound to upper bound for the population average
4-Sum of PCDD/F and PCB (total dioxins) may not equal sum of separate intakes due to rounding
5-Lower bound estimate, mean lifelong-averaged (1-70 years) exposure.
6-I-TEQs. WHO-TEQs are 10-20% higher than I-TEQs.
7-Average dietary exposure for an adult person.

7. Conclusion

The data presented in this report represents the most comprehensive analysis of dioxin levels in Australian foods yet undertaken and forms the basis of an analysis of the dietary exposure of the Australian population to dioxins. The dietary exposure analysis has been used in conjunction with the available information on the hazard characterisation of dioxins to assess the human health risk associated with exposure to dioxins in food.

On the basis of the available data, taking into account all the inherent uncertainties and limitations, it can be concluded that the public health risk for all Australians from exposure to dioxins from foods is very low.

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Appendix A: Foods analysed for dioxins

Food	Number of composite samples analysed	Number of Purchases included in each composite sample
Meat & Meat Products		
Bacon	10	3
Beef, minced	14	4
Hamburger	10	3
Lamb chops	11	3
Leg ham	9	3
Sausages, meat, thick	11	3
Liver pate (chicken)	4	3
Dairy Products		
Butter	10	3
Chocolate, milk	1	3
Milk, whole	13	4
Infant formula	5	3
Margarine/Table spread	6	4
Fish		
Fish fillets	10	3
Fish portions	9	3
Tuna, Canned	5	3
Poultry & Eggs		
Eggs	13	4
Chicken breasts	11	3
Cereal Products		
Bread, white	3	4
Other Foods		
Baked beans	3	3
Orange juice	3	4
Peanut butter	4	3
Potatoes	3	4
Total Samples	**168**	
(Total foods)	(22)	

Appendix B: Methods of analysis and quality assurance

Polychlorinated dibenzo-p-dioxins (PCDDs) and Polychlorinated dibenzofurans (PCDFs), 'dioxin-like' Polychlorinated biphenyls (PCBs)

The method is for determination of tetra- through octa-chlorinated dibenzo-p-dioxins (PCDDs) & dibenzofurans (PCDFs) and polychlorinated biphenyl congeners (PCBs) in biological matrices by high resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS).

This method provides data on all toxic 2,3,7,8-chlorinated PCDD (seven) and PCDF (ten) isomers, plus the 12 'dioxin-like' PCB congeners designated as toxic by the World Health Organisation (WHO) (see Appendix C). The PCDD/Fs and PCBs are determined by the isotope dilution quantitation technique. This technique allows determination of the Dioxin toxicity equivalent (TEQ_{DF}) as well as the PCB toxicity equivalent (TEQ_P) for the 'dioxin-like' PCBs in a sample using WHO_{98} toxicity equivalency factors (TEFs). The total toxic equivalents (TEQ_{DFP}) are calculated as the sum of TEQ_{DF} + TEQ_P.

The detection limits and quantification levels in this method are usually dependent on the level of interferences rather than instrumental limitations. The method is 'performance based'. The analytical methodology for the determination of PCDD/Fs and PCBs are based on USEPA methods 1613B and 1668A, respectively.

Samples are composited to produce a homogenous sample. A rendered or extractable portion of fat is removed and spiked with a range of isotopically labelled surrogate standards. Clean up is effected by partitioning with sulfuric acid then distilled water. Further purification is performed using column chromatography on acid and base modified silica gels, neutral alumina and carbon dispersed on celite. After cleanup, the extract is concentrated to near dryness. Immediately prior to injection, internal standards are added to each extract, and an aliquot of the extract is injected into the gas chromatograph. The analytes are separated by the GC and detected by a high-resolution (≥10,000) mass spectrometer. The quality of the analysis is assured through reproducible calibration and testing of the extraction, cleanup, and GC/MS systems.

PCDD/F and PCB Analyses

The following standards were all purchased from Wellington Laboratories (Ontario, Canada) and were used for calibration, quantification and determination of recovery of PCDD/F and PCBs.

PCDD/Fs

- EPA-1613-CVS calibration and verification solutions (CS-1 to CS-5)
- EPA-1613-LCS labelled compound surrogate solution
- EPA-1613-ISS-ST internal standard solution

PCBs

- WP-CVS calibration and verification solutions (CS-1 to CS-7)
- WP-LCS labelled surrogate spiking solution
- WP-ISS internal standard solution

Acetone, dichloromethane, hexane, and toluene were all OmniSolv® grade sourced from Merck KgaA (Darmstadt, Germany). Ethyl acetate and anhydrous sodium sulfate (granular) were both AR grade sourced from Mallinckrodt (Kentucky, USA). AnalaR® sulfuric acid S.G. was sourced from Merck (Victoria, Australia).

All chromatographic columns were purchased from Fluid Management Systems. (Waltham, MA, USA) and were used without any further treatment. They comprised multi-layer (basic/neutral/acidic) silica, basic alumina and PX-21 carbon dispersed on celite which are packed in individual Teflon columns and vacuum sealed in aluminium foil packages.

Sample preparation

Lipid extraction was performed by sample digestion using concentrated hydrochloric acid with dichloromethane solvent extraction on most of the biological samples.

In some cases, accelerated solvent extraction was performed on samples that had been mixed with hydromatrix using a ASE 100 (Dionex, Utah, USA) with ethanol:toluene (68:32) as the extracting solvent and a temperature and pressure of 150°C and 1500 psi, respectively.

Approximately 5-10g of the extracted lipid was accurately weighed and spiked with a known amount of the respective PCDD/Fs and PCB isotopically labelled $^{13}C_{12}$ surrogate spiking solutions. Lipid was dissolved in hexane and subsequently cleaned up using multiple extractions with concentrated sulfuric acid until the acid layer remained colourless. The hexane extracts were washed several times with water and dried through cleaned anhydrous sodium sulfate. The extracts were then concentrated prior to clean-up on the Power-Prep™ system. Elution through the different columns is computer controlled and requires applying the hexane extract first onto the multi-layer silica and using hexane at a flow rate of 10 mL/min onto the alumina column. Dichloromethane:hexane (2:98) at 10 mL/min is used initially and then the solvent strength is modified to dichloromethane:hexane (50:50) and transferred to the carbon column which is eluted with ethyl acetate:toluene (50:50) in the forward direction at 10 mL/min. The flow is then reversed and the carbon column is eluted with toluene at 5 mL/min.

Two fractions are collected. The first fraction is collected from the alumina column during elution using dichloromethane:hexane (50:50) and contains the mono-ortho and di-ortho PCBs. The second fraction containing PCDD/Fs and & non-ortho PCBs are eluted from the carbon column during the reverse elution with toluene. The two fractions are concentrated separately under vacuum and the respective recovery standards (EPA-1613-ISS-ST & WP-ISS) are added and then further concentrated using clean dry nitrogen to a final volume of 10 µL prior to HRGC/HRMS analysis.

High-Resolution Gas Chromatography High-Resolution Mass Spectrometric (HRGC-HRMS) Analysis

All experiments were conducted on a MAT95XL HRMS (ThermoFinnigan MAT GmbH, Bremen, Germany) coupled to an Agilent 6890 GC (Palo Alto, CA, USA) equipped with a CTC A200S autosampler. A DB-5 (J & W Scientific, Folsom, CA, USA) capillary column (60m x 0.25mm i.d., film thickness 0.25µm) was used as the primary analytical column with ultra-high purity Helium as the carrier gas. A flow rate of 1.0 mL/min was maintained throughout the chromatographic run. The temperature program was from 100°C (isothermal for 1 min.) then ramp 1 to 200°C at 40°C/min, ramp 2 to 235°C (isothermal for 10 min) at 3°C/min and then ramp 3 to 310°C (isothermal 9 min) at 5°C/min. A 1µL splitless injection with an injector temperature of 290°C was employed for all standards and sample extracts. The mass spectrometer operating conditions were: ion source and transfer line temperatures, 240°C and 280°C, respectively; ionisation energy 45eV, filament current 0.7mA and electron multiplier voltage set to produce a gain of 10^6. Resolution was maintained at 10,000 (10% valley definition) throughout the sample sequence. Multiple ion detection (MID) experiments were performed in the electron impact mode with monitoring of the exact masses of either M+ [M+2]+ or [M+4]+ ions for native and labelled compounds. Individual congeners are identified using the GC retention time and ion abundance ratios with reference to internal standards. A DB-dioxin (J & W Scientific, Folsom, CA, USA) capillary column (60m x 0.25mm i.d., film thickness 0.15µm) was used for confirmation analysis when necessary.

The MID Windows for PCDD/F.

MID Window	Accurate Mass	*Ion Id	Ion Type	Analyte (I= internal standard)
1	303.9016	M	R	TCDF
	305.8987	M+2	T	TCDF
	315.9419	M	R	TCDF(I)
	317.9389	M+2	T	TCDF(I)
	319.8965	M	R	TCDD
	321.8936	M+2	T	TCDD
	331.9368	M	R	TCDD(I)
	333.9338	M+2	T	TCDD(I)
2	339.8597	M+2	T	PeCDF
	341.8567	M+4	R	PeCDF
	351.9000	M+2	T	PeCDF(I)
	353.8970	M+4	R	PeCDF(I)
	355.8546	M+2	T	PeCDD
	357.8516	M+4	R	PeCDD
	367.8949	M+2	T	PeCDD(I)
	369.8919	M+4	R	PeCDD(I)
3	373.8208	M+2	T	HxCDF
	375.8178	M+4	R	HxCDF
	383.8639	M	R	HxCDF(I)
	385.8610	M+2	T	HxCDF(I)
	389.8156	M+2	T	HxCDD
	391.8127	M+4	R	HxCDD
	401.8559	M+2	T	HxCDD(I)
	403.8529	M+4	R	HxCDD(I)
4	407.7818	M+2	T	HpCDF
	409.7788	M+4	R	HpCDF
	417.8250	M	R	HpCDF(I)
	419.8220	M+2	T	HpCDF(I)
	423.7767	M+2	T	HpCDD
	425.7737	M+4	R	HpCDD
	435.8169	M+2	T	HpCDD(I)
	437.8140	M+4	R	HpCDD(I)
5	441.7428	M+2	T	OCDF
	443.7399	M+4	R	OCDF
	457.7377	M+2	T	OCDD
	459.7348	M+4	R	OCDD
	469.7780	M+2	T	OCDD(I)
	471.7750	M+4	R	OCDD(I)

*T=Target Ion=Quantitation Ion; R=Ratio Ion=Qualifier Ion.

TCDD – tetrachlorodibenzo-*p*-dioxin
PeCDD - pentachlorodibenzo-*p*-dioxin
HxCDD - hexachlorodibenzo-*p*-dioxin
HpCDD - heptachlorodibenzo-*p*-dioxin
OCDD - octachlorodibenzo-*p*-dioxin

TCDF – tetrachlorodibenzofuran
PeCDF – pentachlorodibenzofuran
HxCDF – hexachlorodibenzofuran
HpCDF – heptachlorodibenzofuran
OCDF – octachlorodibenzofuran

Theoretical Ion Abundance Ratios and QC Limits

No. of Chlorine Atoms	*m/z's forming the ratio	Theoretical Ratio	QC limits[1]	
			Lower	Upper
4[2]	M/(M+2)	0.77	0.65	0.89
5	(M+4)/(M+2)	0.65	0.56	0.76
6	(M+4)/(M+2)	0.81	0.70	0.95
6[3]	M/(M+2)	0.51	0.43	0.59
7	(M+4)/(M+2)	0.95	0.83	1.14
7[4]	M/(M+2)	0.44	0.37	0.51
8	(M+2)/(M+4)	0.89	0.76	1.02

[1]QC limits represent ±15% windows around the theoretical ion abundance ratios.
[2]Does not apply to $^{37}Cl_4$-2,3,7,8-TCDD (clean-up standard).
[3]Used for $^{13}C_{12}$-HxCDF only.
[4]Used for $^{13}C_{12}$-HpCDF only.
*The ratio is defined as the Qualifier ion area (R) divided by the Quantitation ion area (T).

The MID windows for non-ortho and mono-ortho PCBs

MID Window	Accurate Mass	*Ion Id	Analyte (I= internal standard)
1	289.9224	M	TeCB
	291.9194	M+2	TeCB
	293.9165	M+4	TeCB
	301.9626	M	TeCB (I)
	303.9597	M+2	TeCB (I)
	323.8834	M	PeCB
	325.8804	M+2	PeCB
	327.8775	M+4	PeCB
	337.9207	M+2	PeCB (I)
	339.9178	M+4	PeCB (I)
2	359.8415	M+2	HxCB
	361.8365	M+4	HxCB
	363.8356	M+6	HxCB
	371.8817	M+2	HxCB (I)
	373.8788	M+4	HxCB (I)
	393.8025	M+2	HpCB
	395.7995	M+4	HpCB
	397.7966	M+6	HpCB
	405.8428	M+2	HpCB (I)
	407.8398	M+4	HpCB (I)

TeCB – tetrachlorobiphenyl
PeCB – pentachlorobiphenyl
HxCB – hexachlorobiphenyl
HpCB – heptachlorobiphenyl

Theoretical Ion Abundance Ratios and QC Limits

No. of Chlorine Atoms	*m/z's forming the ratio	Theoretical Ratio	QC limits[1]	
			Lower	Upper
4	M/(M+2)	0.77	0.65	0.89
5	(M+4)/(M+2)	0.66	0.56	0.76
6	(M+4)/(M+2)	0.82	0.70	0.94
7	(M+4)/(M+2)	0.98	0.83	1.13

[1]QC limits represent ±15% windows around the theoretical ion abundance ratios.
*The ratio is defined as the Qualifier ion area (R) divided by the Quantitation ion area (T).

Analyte identification and quantification criteria

PCDD/Fs and 'dioxin-like' PCBs

For positive identification and quantification, the following criteria must be met:

- The retention time of the analyte must be within 1 second of the retention time of the corresponding $^{13}C_{12}$ surrogate standard.
- The ion ratio obtained for the analyte must be ±15% of the theoretical ion ratio.
- The signal to noise ratio must be greater than 3:1.
- Levels of PCDD/F congeners in a sample must be greater than 3 times any level found in the corresponding laboratory blank analysed.
- Surrogate standard recoveries must be in the range 25-150%.

Quantification using the Isotope Dilution Technique

The naturally occurring (native) compound is determined by reference to the same compound in which one or more atoms has been isotopically enriched. In this method, all carbon atoms for selected PCDD/F and PCB molecules have been substituted with carbon-13 to produce $^{13}C_{12}$-labeled analogs of the chlorinated dibenzo-p-dioxins, dibenzofurans and biphenyls, respectively. The $^{13}C_{12}$-labelled PCDD/Fs and PCBs are spiked into each sample and allow identification and correction of the concentration of the native compounds in the analytical process. Homologue totals for the tetra to octachloro dibenzo-*p*-dioxins and dibenzofurans are calculated by summing the total areas for each positively identified congener within each group and quantifying these totals using the mean relative response factor (RRF) of the determined RRFs for a homologue series.

The proprietary chromatographic integration package supplied with the Thermo Finnigan instrument, (Xcalibur®), was used to target all monitored compounds and create a text file that was further manipulated in Excel to produce the final certificate of analysis.

Quality Assurance

PCDD/Fs and 'dioxin-like' PCBs

- Batch sizes will be typically 6-8 samples.
- A laboratory blank will be analysed with each batch of samples.
- A suitable laboratory control sample (LCS) will be analysed with each batch of samples as a replicate to assess method precision.
- The GCMS resolution (≥10.000), performance and sensitivity will be established for each MS run.
- The recoveries of all isotopically labelled surrogate standards will be calculated and reported.

Data reporting

The bases of reporting for primary and quality control samples are given in the adjacent table.

- PCDD/Fs & 'dioxin-like' PCBs data are corrected for recovery of ^{13}C surrogate standards.
- For all samples, data for quantified analytes are reported to 2 or 3 significant figures.
- Limit of detection data for non-quantified analytes are reported to 1 significant figure.
- Total toxic equivalents will be calculated both excluding limit of detection values (lower bound) and at upper bound concentrations using limit of detection values.

Reporting Basis for Contaminant Concentrations

Contaminant class	Reporting basis
PCDDs and PCDFs	**pg/g on a lipid weight and fresh weight basis**. Total toxic equivalents for PCDD/Fs (WHO_{98}-TEQ_{DF}) will be calculated using the WHO Toxic Equivalents Factors (WHO_{98}-TEFs).
'dioxin-like' PCBs	**pg/g on a lipid weight and fresh weight basis.** Total toxic equivalents for 'dioxin-like' PCBs (WHO_{98}-TEQ_P) will be calculated using the WHO Toxic Equivalents Factors (WHO_{98}-TEFs). Total toxic equivalents for PCDD/Fs and 'dioxin-like' PCBs (WHO_{98}-TEQ_{DFP}) will be calculated from the addition of the respective WHO_{98}-TEQ_{DF} and WHO_{98}-TEQ_P values.

Appendix C: WHO derived toxic equivalency factors for human risk assessment

Dioxins	**WHO_{98}-TEF**
2,3,7,8-TetraCDD	1
1,2,3,7,8-PentaCDD	1
1,2,3,4,7,8-HexaCDD	0.1
1,2,3,6,7,8-HexaCDD	0.1
1,2,3,7,8,9-HexaCDD	0.1
1,2,3,4,6,7,8-HeptaCDD	0.01
OctaCDD	0.0001
Furans	
2,3,7,8-TetraCDF	0.1
1,2,3,7,8-PentaCDF	0.05
2,3,4,7,8-PentaCDF	0.5
1,2,3,4,7,8-HexaCDF	0.1
1,2,3,6,7,8-HexaCDF	0.1
1,2,3,7,8,9-HexaCDF	0.1
2,3,4,6,7,8-HexaCDF	0.1
1,2,3,4,6,7,8-HeptaCDF	0.01
1,2,3,4,7,8,9-HeptaCDF	0.01
OctaCDF	0.0001

CDD – chlorinated dibenzo-*p*-dioxin
CDF – chlorinated dibenzofuran

Polychlorinated biphenyls	**IUPAC No.**	**WHO_{98}-TEF**
Non-ortho PCBs		
3,3',4,4' – tetrachlorobiphenyl	PCB#77	0.0001
3,4,4',5 – tetrachlorobiphenyl	PCB#81	0.0001
3,3',4,4',5 – pentachlorobiphenyl	PCB#126	0.1
3,3',4,4',5,5' – hexachlorobiphenyl	PCB#169	0.01
Mono-ortho PCBs		
2,3,3',4,4' – pentachlorobiphenyl	PCB#105	0.0001
2,3,4,4',5 – pentachlorobiphenyl	PCB#114	0.0005
2,3',4,4',5 – pentachlorobiphenyl	PCB#118	0.0001
2',3,4,4',5 – pentachlorobiphenyl	PCB#123	0.0001
2,3,3',4,4',5 – hexachlorobiphenyl	PCB#156	0.0005
2,3,3',4,4',5' – hexachlorobiphenyl	PCB#157	0.0005
2,3',4,4',5,5' – hexachlorobiphenyl	PCB#167	0.00001
2,3,3',4,4',5,5' – heptachlorobiphenyl	PCB#189	0.0001

(From: WHO 1998).

Appendix D: Individual sample PCDD/F and PCB summary results and mean values.

Table D1: Individual sample analytical results and mean values on a lipid and fresh weight (FW) basis.

			PCDD/F				PCBs			
	Sample	Lipid	Lower Bound		Upper Bound		Lower Bound		Upper Bound	
Food	Number	Content	pg/g Lipid	pg/g FW	pg/g Lipid	pg/g FW	pg/g Lipid	pg/g FW	pg/g Lipid	pg/g FW
Bacon	1	19.0%	0.017	0.0032	0.35	0.066	0.069	0.013	0.11	0.02
Bacon	2	29.0%	0.346	0.0971	0.464	0.125	0.00342	0.000979	0.0714	0.0197
Bacon	3	33.0%	0.00522	0.00177	0.0964	0.0309	0.0903	0.0299	0.136	0.0417
Bacon	4	31.0%	0.00019	0.00006	0.167	0.0494	0.0665	0.0207	0.115	0.0342
Bacon	5	32.0%	0.02	0.0064	0.192	0.0607	0.00291	0.000927	0.0591	0.0191
Bacon	6	30.0%	0.0423	0.0127	0.161	0.044	0.023	0.00691	0.0624	0.0179
Bacon	7	19.0%	0.0414	0.00777	0.128	0.0241	0.017	0.0031	0.0467	0.00922
Bacon	8	24.0%	0.000145	0.0000342	0.136	0.0263	0.0145	0.0035	0.0323	0.00766
Bacon	9	26.0%	0.0236	0.00594	0.102	0.0269	0.035	0.0092	0.0563	0.0148
Bacon	10	36.0%	0	0	0.45	0.16	0.081	0.029	0.082	0.03
Bacon	**Mean**	27.9%	0.05	0.013	0.22	0.061	0.040	0.012	0.077	0.021

Baked beans	1			0		0.0097		0.0015		0.0031
Baked beans	2			0.00048		0.016		0.00082		0.0025
Baked beans	3			0.000047		0.016		0.00089		0.0017
Baked beans	**Mean**			0.00018		0.014		0.0011		0.0024

			PCDD/F				PCBs			
	Sample	Lipid	Lower Bound		Upper Bound		Lower Bound		Upper Bound	
Food	Number	Content	pg/g Lipid	pg/g FW	pg/g Lipid	pg/g FW	pg/g Lipid	pg/g FW	pg/g Lipid	pg/g FW
Bread, white	1			0.00061		0.026		0.00074		0.0079
Bread, white	2			0		0.017		0.000053		0.0032
Bread, white	3			0.00056		0.02		0.000033		0.0025
Bread, white	**Mean**			0.00039		0.021		0.00028		0.0045
Butter	1	82.0%	0.00005	0.000041	0.242	0.197	0.0698	0.057	0.075	0.0615
Butter	2	82.0%	0.00008	0.000065	0.267	0.227	0.0746	0.0609	0.0855	0.0716
Butter	3	77.0%	0	0	0.14	0.11	0.016	0.013	0.11	0.083
Butter	4	81.0%	0	0	0.2	0.16	0.014	0.011	0.086	0.073
Butter	5	85.0%	0.09	0.075	0.38	0.34	0.0023	0.002	0.059	0.047
Butter	6	76.0%	0	0	0.15	0.12	0.0018	0.0014	0.087	0.063
Butter	7	75.0%	0.04	0.03	0.22	0.17	0.014	0.01	0.097	0.073
Butter	8	80.0%	0	0	0.22	0.18	0.016	0.013	0.092	0.078
Butter	9	80.0%	0	0	0.18	0.15	0.0034	0.0027	0.073	0.061
Butter	10	82.0%	0	0	0.35	0.33	0.0024	0.002	0.098	0.086
Butter	**Mean**	80.0%	0.013	0.011	0.23	0.20	0.021	0.017	0.086	0.070
Chicken breast	1	8.7%	0	0	0.43	0.041	0.059	0.0052	0.084	0.0076
Chicken breast	2	2.5%	0	0	0.51	0.014	0.017	0.00044	0.065	0.0016
Chicken breast	3	1.6%	0.004	0.000064	0.77	0.013	0.26	0.0043	0.47	0.0074
Chicken breast	4	1.0%	0.00041	0.0000057	1.8	0.024	0	0	0.15	0.0019
Chicken breast	5	3.2%	0.016	0.00051	0.3	0.0095	0.14	0.0044	0.23	0.0075
Chicken breast	6	6.0%	0.00037	0.000022	0.32	0.018	0.0025	0.00015	0.044	0.0023

			PCDD/F				PCBs			
	Sample	Lipid	Lower Bound		Upper Bound		Lower Bound		Upper Bound	
Food	Number	Content	pg/g Lipid	pg/g FW	pg/g Lipid	pg/g FW	pg/g Lipid	pg/g FW	pg/g Lipid	pg/g FW
Chicken breast	7	1.5%	0.0024	0.000035	0.48	0.0062	1.2	0.018	1.2	0.018
Chicken breast	8	2.8%	0.19	0.0055	0.62	0.017	0.2	0.0057	0.21	0.0059
Chicken breast	9	6.0%	0	0	0.19	0.01	0.033	0.002	0.095	0.0061
Chicken breast	10	5.0%	0	0	0.21	0.012	0.022	0.0012	0.058	0.003
Chicken breast	11	2.9%	0.016	0.00047	0.25	0.0073	0	0	0.044	0.0013
Chicken breast	**Mean**	3.7%	0.021	0.00060	0.53	0.016	0.18	0.0038	0.24	0.0057

Eggs	1	10.0%	0.012	0.0013	0.34	0.034	0.027	0.0029	0.11	0.011
Eggs	2	12.0%	0.008	0.00096	0.36	0.037	0.044	0.0052	0.14	0.016
Eggs	3	12.9%	0.024	0.003	0.3	0.036	0.052	0.0066	0.088	0.011
Eggs	4	11.7%	0.0042	0.00049	0.29	0.031	0.016	0.0019	0.063	0.0075
Eggs	5	12.3%	0.012	0.0014	0.42	0.045	0.0029	0.00035	0.045	0.0048
Eggs	6	12.0%	0.012	0.0014	0.27	0.031	0.072	0.0083	0.086	0.0098
Eggs	7	11.0%	0.026	0.003	0.7	0.072	0.056	0.0063	0.12	0.014
Eggs	8	10.0%	0.01	0.001	0.31	0.031	0.059	0.0059	0.081	0.0082
Eggs	9	12.0%	0.13	0.015	0.55	0.065	0.054	0.0065	0.16	0.017
Eggs	10	12.0%	0.0089	0.001	0.28	0.031	0.13	0.015	0.21	0.024
Eggs	11	11.0%	0	0	0.38	0.04	0.019	0.0022	0.08	0.0084
Eggs	12	10.0%	0.042	0.0044	0.92	0.092	0.11	0.011	0.16	0.016
Eggs	13	12.0%	0.0076	0.00093	0.34	0.036	0.068	0.0083	0.087	0.01
Eggs	**Mean**	11.5%	0.023	0.0026	0.42	0.045	0.055	0.0062	0.11	0.012

			PCDD/F				PCBs			
	Sample	Lipid	Lower Bound		Upper Bound		Lower Bound		Upper Bound	
Food	Number	Content	pg/g Lipid	pg/g FW	pg/g Lipid	pg/g FW	pg/g Lipid	pg/g FW	pg/g Lipid	pg/g FW
Fish fillets	1	11.0%	0.2	0.022	2.2	0.24	4.7	0.51	4.7	0.51
Fish fillets	2	1.1%	0	0	1.7	0.02	4	0.046	4.2	0.048
Fish fillets	3	4.0%	0.15	0.0059	0.37	0.015	1.2	0.049	1.2	0.049
Fish fillets	4	5.9%	12	0.69	12	0.7	68	4	68	4
Fish fillets	5	1.1%	1.3	0.014	6.3	0.065	3.8	0.041	3.8	0.041
Fish fillets	6	1.8%	0.43	0.0076	3.5	0.065	3.1	0.054	3.1	0.054
Fish fillets	7	3.0%	0.23	0.0068	1.6	0.049	2.6	0.079	2.7	0.08
Fish fillets	8	4.8%	0.75	0.036	1.5	0.071	3.4	0.16	3.4	0.16
Fish fillets	9	3.1%	0.2	0.0059	0.65	0.02	1.2	0.038	1.2	0.038
Fish fillets	10	4.4%	0.34	0.015	0.56	0.024	2.6	0.12	2.7	0.12
Fish fillets	**Mean**	4.0%	1.6	0.080	3.0	0.13	9.5	0.51	9.5	0.51
Fish portions	1	18.0%	0.00035	0.000064	0.11	0.017	0.11	0.021	0.12	0.021
Fish portions	2	12.8%	0.022	0.0028	0.28	0.044	0.45	0.057	0.45	0.057
Fish portions	3	14.0%	0.0004	0.000057	0.092	0.012	0.12	0.018	0.13	0.019
Fish portions	4	16.0%	0.0046	0.00072	0.076	0.011	0.018	0.0072	0.041	0.0063
Fish portions	5	15.0%	0.00042	0.000062	0.11	0.015	0.024	0.0035	0.089	0.013
Fish portions	6	15.0%	0.00018	0.000028	0.071	0.011	0.065	0.0099	0.068	0.01
Fish portions	7	13.0%	0.00028	0.000036	0.15	0.018	0.25	0.032	0.25	0.032
Fish portions	8	15.0%	0.0004	0.00006	0.096	0.014	0.026	0.0039	0.094	0.014
Fish portions	9	10.0%	0.077	0.0077	0.23	0.023	0.047	0.0047	0.11	0.011
Fish portions	**Mean**	14.3%	0.012	0.0013	0.14	0.018	0.12	0.017	0.15	0.020

			PCDD/F				PCBs			
	Sample	Lipid	Lower Bound		Upper Bound		Lower Bound		Upper Bound	
Food	**Number**	**Content**	**pg/g Lipid**	**pg/g FW**	**pg/g Lipid**	**pg/g FW**	**pg/g Lipid**	**pg/g FW**	**pg/g Lipid**	**pg/g FW**
Hamburger	1	14.0%	0.00233	0.000315	0.141	0.0187	0.00331	0.00045	0.0701	0.0094
Hamburger	2	5.0%	0	0	0.149	0.00792	0.0158	0.000852	0.0874	0.00433
Hamburger	3	12.0%	0.00052	0.000063	0.141	0.0174	0	0	0.0502	0.00639
Hamburger	4	14.0%	0.00044	0.00006	0.19	0.0243	0.00307	0.000413	0.046	0.00634
Hamburger	5	12.0%	0.00044	0.000054	0.132	0.0161	0.0033	0.0004	0.0577	0.00691
Hamburger	6	15.0%	0.00233	0.000338	0.166	0.0234	0.00002	0.0000029	0.067	0.00939
Hamburger	7	14.0%	0.00749	0.00101	0.209	0.0265	0	0	0.0436	0.00544
Hamburger	8	14.0%	0.00048	0.000066	0.148	0.0195	0.00293	0.000405	0.0705	0.00898
Hamburger	9	14.0%	0.00047	0.000064	0.168	0.0226	0.0028	0.00038	0.0671	0.00845
Hamburger	10	12.0%	0.00064	0.0000795	0.166	0.0202	0.00018	0.000022	0.0278	0.00336
Hamburger	**Mean**	12.6%	0.0015	0.00020	0.16	0.020	0.0031	0.00029	0.059	0.0069

Infant formula	1	3.0%	0.025	0.0008	0.23	0.0072	0.031	0.00099	0.066	0.002
Infant formula	2	2.0%	0.0093	0.00021	0.57	0.013	0.059	0.0013	0.096	0.002
Infant formula	3	2.0%	0.0018	0.000035	0.38	0.008	0.044	0.00086	0.091	0.0017
Infant formula	4	3.0%	0.2	0.0059	0.44	0.013	0.057	0.0017	0.085	0.0024
Infant formula	5	3.0%	0.042	0.0012	1.1	0.034	0.17	0.0048	0.2	0.0054
Infant formula	**Mean**	2.6%	0.056	0.0016	0.54	0.015	0.072	0.0019	0.11	0.0027

			PCDD/F				PCBs			
	Sample	Lipid	Lower Bound		Upper Bound		Lower Bound		Upper Bound	
Food	Number	Content	pg/g Lipid	pg/g FW	pg/g Lipid	pg/g FW	pg/g Lipid	pg/g FW	pg/g Lipid	pg/g FW
Lamb chops	1	20.0%	0	0	0.18	0.04	0.0037	0.00073	0.044	0.0092
Lamb chops	2	15.0%	0	0	0.389	0.0592	0	0	0.0393	0.00597
Lamb chops	3	13.0%	0.00344	0.000436	0.153	0.0199	0	0	0.0444	0.00602
Lamb chops	4	13.0%	0.0084	0.0011	0.49	0.066	0.014	0.0019	0.1	0.013
Lamb chops	5	13.0%	0.0048	0.00062	0.22	0.027	0.027	0.0034	0.082	0.01
Lamb chops	6	15.0%	0.0033	0.0005	0.16	0.027	0.075	0.011	0.076	0.012
Lamb chops	7	8.0%	0.011	0.000924	0.241	0.0203	0.00015	0.000013	0.0429	0.00416
Lamb chops	8	9.0%	0.00873	0.000742	0.213	0.0181	0	0	0.0541	0.0051
Lamb chops	9	20.0%	0.0007	0.00014	0.28	0.058	0.094	0.019	0.1	0.02
Lamb chops	10	16.0%	0	0	0.24	0.041	0.035	0.0056	0.045	0.0077
Lamb chops	11	10.0%	0.0019	0.0002	0.19	0.019	0.02	0.0022	0.064	0.0066
Lamb chops	**Mean**	13.8%	0.0038	0.00042	0.25	0.036	0.024	0.0040	0.063	0.0091
Leg ham	1	5.0%	0.019	0.00086	0.17	0.0072	0.026	0.0012	0.04	0.0018
Leg ham	2	4.0%	0.000029	0.000001	0.13	0.0045	0.008	0.00028	0.027	0.00093
Leg ham	3	4.0%	0.0053	0.0002	0.62	0.028	0.036	0.0014	0.096	0.0041
Leg ham	4	3.4%	0.014	0.00046	0.46	0.016	0.035	0.0012	0.11	0.0034
Leg ham	5	4.0%	0.0074	0.00031	0.42	0.017	0.014	0.0006	0.125	0.0053
Leg ham	6	3.0%	0.026	0.0007	0.45	0.013	0.05	0.0015	0.13	0.0038
Leg ham	7	3.0%	0.021	0.00068	0.35	0.012	0.078	0.0025	0.092	0.003
Leg ham	8	3.0%	0.0087	0.00026	0.37	0.011	0.023	0.00071	0.072	0.0021
Leg ham	9	3.0%	0.0008	0.000024	0.53	0.015	0.059	0.0017	0.095	0.0028
Leg ham	**Mean**	3.6%	0.011	0.00039	0.39	0.014	0.037	0.0012	0.087	0.0030

			PCDD/F				PCBs			
	Sample	Lipid	Lower Bound		Upper Bound		Lower Bound		Upper Bound	
Food	**Number**	**Content**	**pg/g Lipid**	**pg/g FW**	**pg/g Lipid**	**pg/g FW**	**pg/g Lipid**	**pg/g FW**	**pg/g Lipid**	**pg/g FW**
Liver pate	1	16.0%	0.00472	0.000768	0.204	0.0301	0.0228	0.00375	0.0885	0.0151
Liver pate	2	23.0%	0.00042	0.000097	0.211	0.0453	0.0022	0.00051	0.0538	0.0129
Liver pate	3	12.0%	0.0057	0.000683	0.271	0.0298	0.0307	0.00369	0.0764	0.00929
Liver pate	4	11.0%	0.00294	0.000319	0.23	0.0246	0	0	0.0442	0.00434
Liver pate	**Mean**	15.5%	0.0034	0.00047	0.23	0.032	0.014	0.0020	0.066	0.010
Margarine	1	81.0%	0	0	0.098	0.083	0.0026	0.0021	0.0082	0.0063
Margarine	2	66.0%	0	0	0.042	0.028	0.0041	0.0027	0.012	0.008
Margarine	3	69.0%	0.003	0.0021	0.072	0.044	0	0	0.013	0.0098
Margarine	4	76.0%	0	0	0.1	0.081	0.0038	0.0029	0.012	0.0096
Margarine	5	76.0%	0.0018	0.0014	0.056	0.048	0.0025	0.0019	0.0071	0.0051
Margarine	6	74.0%	0	0	0.032	0.021	0.0024	0.0018	0.0052	0.0037
Margarine	**Mean**	73.7%	0.00080	0.00058	0.067	0.051	0.0026	0.0019	0.010	0.0071
Milk chocolate	1	17.2%	0.017	0.0029	0.28	0.044	0.028	0.0048	0.073	0.012
Milk, whole	1	3.0%	0.0037	0.00011	0.15	0.0036	0.033	0.00099	0.09	0.0026
Milk, whole	2	3.0%	0	0	0.16	0.0042	0.064	0.0017	0.14	0.0038
Milk, whole	3	3.0%	0.02	0.00058	0.14	0.0037	0.04	0.0012	0.12	0.0037
Milk, whole	4	3.0%	0.038	0.0012	0.18	0.0055	0.0088	0.00028	0.047	0.0016
Milk, whole	5	3.0%	0.0028	0.000079	0.19	0.0049	0.026	0.00074	0.12	0.0031
Milk, whole	6	3.0%	0	0	0.17	0.0048	0.027	0.00079	0.12	0.0032
Milk, whole	7	3.0%	0.039	0.0011	0.13	0.0037	0.018	0.00051	0.1	0.0029

			PCDD/F				PCBs			
	Sample	Lipid	Lower Bound		Upper Bound		Lower Bound		Upper Bound	
Food	**Number**	**Content**	**pg/g Lipid**	**pg/g FW**	**pg/g Lipid**	**pg/g FW**	**pg/g Lipid**	**pg/g FW**	**pg/g Lipid**	**pg/g FW**
Milk, whole	8	5.0%	0.0044	0.00021	0.18	0.0072	0.033	0.0016	0.11	0.0051
Milk, whole	9	4.0%	0.0031	0.00011	0.13	0.0049	0.012	0.00045	0.039	0.0014
Milk, whole	10	4.0%	0.11	0.0038	0.39	0.014	0.11	0.0039	0.12	0.0045
Milk, whole	11	2.0%	0	0	0.44	0.0086	0.032	0.00058	0.16	0.0024
Milk, whole	12	3.0%	0.059	0.0016	0.41	0.011	0.11	0.003	0.16	0.04
Milk, whole	13	2.0%	0.18	0.0043	0.33	0.0079	0.03	0.00073	0.15	0.0032
Milk, whole	**Mean**	3.2%	0.035	0.0010	0.23	0.0065	0.042	0.0013	0.11	0.0060
Minced beef	1	10.0%	0.00005	0.0000051	0.17	0.017	0.00055	0.000055	0.074	0.0074
Minced beef	2	12.0%	0.0035	0.00042	0.37	0.039	0.0082	0.00098	0.073	0.0084
Minced beef	3	15.0%	0	0	0.25	0.034	0.036	0.0054	0.1	0.015
Minced beef	4	13.0%	0	0	0.19	0.022	0.093	0.011	0.12	0.014
Minced beef	5	16.0%	0	0	0.32	0.052	0.021	0.0033	0.13	0.025
Minced beef	6	8.0%	0	0	0.17	0.013	0	0	0.12	0.0093
Minced beef	7	17.5%	0	0	0.27	0.047	0.0093	0.0016	0.13	0.025
Minced beef	8	11.0%	0	0	0.28	0.03	0.012	0.0013	0.13	0.013
Minced beef	9	15.0%	0.029	0.0043	0.22	0.031	0.0024	0.00035	0.065	0.0094
Minced beef	10	13.0%	0.05	0.0065	0.2	0.025	0.017	0.0021	0.13	0.014
Minced beef	11	16.0%	0	0	0.2	0.032	0.12	0.019	0.14	0.021
Minced beef	12	22.0%	0	0	0.18	0.041	0.002	0.00043	0.064	0.014
Minced beef	13	14.0%	0	0	0.25	0.03	0.12	0.017	0.13	0.017
Minced beef	14	18.0%	0	0	0.23	0.046	0.012	0.0021	0.1	0.014
Minced beef	**Mean**	14.3%	0.0059	0.00080	0.24	0.033	0.032	0.0046	0.11	0.015

			PCDD/F				PCBs			
	Sample	Lipid	Lower Bound		Upper Bound		Lower Bound		Upper Bound	
Food	**Number**	**Content**	**pg/g Lipid**	**pg/g FW**	**pg/g Lipid**	**pg/g FW**	**pg/g Lipid**	**pg/g FW**	**pg/g Lipid**	**pg/g FW**
Orange juice	1			0		0.0047		0.0002		0.00035
Orange juice	2			0		0.0088		0.00019		0.00053
Orange juice	3			0		0.0077		0.00014		0.00037
Orange juice	**Mean**			0		0.0071		0.00018		0.00042
Peanut butter	1	53.2%	0.28	0.14	0.63	0.32	0.00078	0.00041	0.053	0.027
Peanut butter	2	54.0%	0	0	0.44	0.28	0.00055	0.0003	0.013	0.0068
Peanut butter	3	54.0%	0	0	0.27	0.14	0.00035	0.00019	0.014	0.0068
Peanut butter	4	53.0%	0	0	0.39	0.2	0.00049	0.00026	0.023	0.012
Peanut butter	**Mean**	53.6%	0.070	0.035	0.43	0.24	0.00054	0.00029	0.026	0.013
Potatoes	1			0.00031		0.014		0.00012		0.0018
Potatoes	2			0		0.012		0.0000018		0.0014
Potatoes	3			0.00038		0.012		0.000059		0.0016
Potatoes	**Mean**			0.00023		0.013		0.000060		0.0016
Sausage	1	25.0%	0	0	0.13	0.029	0.018	0.0044	0.081	0.015
Sausage	2	21.0%	0.012	0.0024	0.27	0.053	0.009	0.002	0.047	0.01
Sausage	3	28.0%	0.00025	0.000069	0.18	0.046	0.001	0.0003	0.043	0.011
Sausage	4	24.0%	0.019	0.0044	0.17	0.039	0.0019	0.0004	0.048	0.011
Sausage	5	23.0%	0.022	0.005	0.15	0.033	0.003	0.00069	0.11	0.026
Sausage	6	22.0%	0.011	0.0025	0.17	0.038	0.023	0.0053	0.081	0.017
Sausage	7	22.0%	0	0	0.16	0.037	0.11	0.025	0.12	0.025

			PCDD/F				PCBs			
	Sample	Lipid	Lower Bound		Upper Bound		Lower Bound		Upper Bound	
Food	Number	Content	pg/g Lipid	pg/g FW	pg/g Lipid	pg/g FW	pg/g Lipid	pg/g FW	pg/g Lipid	pg/g FW
Sausage	8	17.0%	0.00013	0.000022	0.16	0.027	0.028	0.0047	0.11	0.016
Sausage	9	16.0%	0	0	0.12	0.019	0.008	0.0013	0.05	0.008
Sausage	10	22.0%	0	0	0.27	0.056	0.1	0.022	0.1	0.023
Sausage	11	20.0%	0.002	0.0004	0.38	0.071	0.13	0.025	0.13	0.026
Sausage	**Mean**	21.8%	0.0060	0.0013	0.20	0.041	0.039	0.0083	0.084	0.017
Tuna, canned	1			0		0.013		0.028		0.028
Tuna, canned	2			0.001		0.013		0.028		0.028
Tuna, canned	3			0		0.011		0.0096		0.01
Tuna, canned	4			0.001		0.011		0.015		0.016
Tuna, canned	5			0.0099		0.023		0.054		0.054
Tuna, canned	**Mean**			0.0024		0.014		0.027		0.027

Lower Bound – assumes results reported as being below the LOR are zero.
Upper Bound – assumes results reported as being below the LOR are at the LOR.

Appendix E: European Commission regulatory levels for dioxins in foods

Table E.1: European Commission maximum levels and action levels for dioxins (the sum of PCDDs and PCDFs) in foodstuffs (EC 2001, 2002)

Product	Maximum Level[1, 2] (pg WHO-PCDD/F-TEQ/g fat)	Action Level[1, 2] (pg WHO-PCDD/F-TEQ/g fat)
Meat and meat products from:		
Ruminants (bovine animals and sheep)[3]	3	2
Poultry and farmed game[3]	2	1.5
Pigs[3]	1	0.6
Liver and derived products[3]	6	4
Muscle meat of fish and fishery products[4]	4 (fresh weight)	3 (fresh weight)
Milk and milk products, including butter fat[3]	3	2
Hens eggs and egg products[3]	3	2
Oils and fats:		
Animal fat		
from ruminants	3	2
from poultry and farmed game	2	1.5
from pigs	1	0.6
mixed animal fat	2	1.5
Vegetable oil	0.75	0.5
Fish oil intended for human consumption	2	1.5

1 Maximum and action levels refer to upper bound concentrations, calculated assuming that all values of the different congeners less than the limit of determination are equal to the limit of determination

2 Maximum and action levels to be reviewed by December 2004 in the light of new data on the presence of dioxins and dioxin-like PCBs.

3 Maximum and action levels are not applicable for food products containing less than 1% fat.

4 The maximum level applies to crustaceans excluding the brown meat of crab and to cephalopods without viscera

Appendix F: Dioxin survey foods and corresponding National Nutrition Survey (NNS) foods

FOODS ANALYSED	NNS FOODS REPRESENTED
Bacon	Pork and bacon
Baked beans	Legumes and pulse products and dishes, milk substitutes, and broad, butter and kidney beans
Beef, minced	Beef, veal, game and other carcass meats
Bread, white	White bread, english-style muffins, crumpets, flat breads, buns and yeast-based products, doughnuts, pancakes and crepes, and bread-based stuffings
	Wholemeal, rye, and mixed grain breads, English style muffins, crumpets, flat breads, fancy breads and pancakes
	Savoury biscuits, pastry and croissants
	Sweet biscuits
	Processed and unprocessed brans
	All cereal flours, cereal grains, including oats (except rice), mixed grain breakfast cereals and muesli, tortilla, taco shells, and corn bread
	Single grain corn- or rice- or wheat-based breakfast cereals, and semolina
	Cakes, muffins, scones, slices, and plain dumplings
	Pasta (except filled pasta) and noodles (except rice based)
	Rice, rice products, rice noodles and ground rice
	Infant cereal, infant dinners
Butter	Dairy fats
Chicken breasts	Poultry and feathered game
Eggs	Eggs, quiches, soufflés
Fish fillets, raw, unfrozen	Battered, crumbed or uncoated fin fish (except canned)
	Canned, battered or crumbed crustaceans and molluscs
Fish portion	Fish roe, and fish and seafood products (e.g. fish cakes, seafood sticks)
Hamburgers	Filled rolls and hamburgers
Infant formula	Infant formula
Lamb chops	Lamb
Leg ham	Ham and processed meat
Liver pate (chicken)	Organ meats and offal products and dishes
Margarine, table spread	Margarine, vegetable oils and non-dairy fats
Milk chocolate	Chocolate and chocolate confectionery, chocolate spreads, cocoa powder, cocoa drinks, and carob powder
Milk, full fat	Milk, flavoured milks, yoghurt and cream
	Cheese

FOODS ANALYSED	NNS FOODS REPRESENTED
	Frozen milk products
	Infant custard, yoghurt and gels
Orange juice	All fruit juices and drinks (except vegetable juices, fruit based cordials and fruit-flavoured drink bases and cordial bases), fruit based drinks, and infant juices
	Fruit including: pome fruit and apple sauce bananas, grapes, tropical fruit, avocado, stone fruit, citrus fruit, berry fruit, dried and preserved fruit, and melons
Peanut butter	Peanuts and peanut products
Potato	Potatoes
	Green beans and snake beans
	Broccoli, cauliflower and similar brassica vegetables except cabbage
	Carrot and similar root vegetables, carrot juice and mixed vegetable juice, root and similar brassica vegetables
	Capsicum and other fruiting vegetables (except mushrooms and avocado), and other vegetables
	Celery, leaf and stalk vegetables (except lettuce), and celery juice
	Mushrooms and fungi
	Onion, leek and garlic
	Lettuce
	Green peas and snow peas
	Pumpkin, squash, zucchini
	Tomato and tomato products, and tomato juice
	Tomato and tomato-based sauces, tomato salsa, savoury sauces, pickles, chutneys, relishes and vinegar
Sausages, meat, thick	Sausages, frankfurts and saveloys
Tuna, canned	Canned fish and seafood (except crustacea and molluscs)

Foods assumed to contain no dioxins

FOOD	NNS FOODS REPRESENTED
Beverages, alcoholic	All alcoholic beverages
Beverages, non-alcoholic	All tea, coffee and coffee substitutes
	Soft drinks, flavoured mineral waters and electrolyte drinks, fruit based cordials, and fruit flavoured drink and cordial bases
Sugar/confectionery	Sugar, honey, syrups, jam, toppings, sweet spreads (except chocolate), sugar-based desserts and ice confections, icings, and confectionery
Nuts and seeds	Nuts and nut products and dishes (except peanuts), coconut and coconut products, seed and seed products

Appendix G: Estimated monthly dietary exposures to PCDD/F, PCBs and total dioxins, per kilogram of body weight.

Table G.1: Mean estimated monthly dietary exposure to dioxins per kilogram of body weight

		PCDD/F (pg TEQ/kg bw/month)		PCBs (pg TEQ/kg bw/month)		Total Dioxins (pg TEQ/kg bw/month)	
		Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
All	2+	0.9	10.2	2.8	5.4	3.7	15.6
Males	2+	0.9	10.9	3.1	5.9	4.1	16.9
Females	2+	0.8	9.5	2.6	5.0	3.4	14.5
Infants	9 months	4.5	49.0	7.3	11.8	11.8	60.8
Toddlers	2-4	1.9	25.0	4.3	11.8	6.2	36.7
Males	4-15	1.4	17.4	3.6	8.5	4.9	25.9
Females	4-15	1.2	14.8	3.1	7.1	4.2	21.9
Males	16-29	0.9	10.5	3.0	5.7	3.9	16.2
Females	16-29	0.7	8.8	2.4	4.6	3.1	13.4
Males	30-44	0.9	9.1	3.2	5.4	4.1	14.6
Females	30-44	0.7	8.0	2.4	4.3	3.1	12.3
Males	45-59	0.8	8.5	2.9	4.9	3.7	13.3
Females	45-59	0.7	7.6	2.7	4.5	3.4	12.1
Males	60+	0.7	7.9	2.8	4.6	3.5	12.5
Females	60+	0.6	7.6	2.3	4.1	3.0	11.6

Lower Bound – assumes results reported as being below the LOR are zero.
Upper Bound – assumes results reported as being below the LOR are at the LOR.
PTMI = 70 pg TEQ/kg bw/month
Total dioxins = sum of intakes of PCDD/F and PCBs. Total dioxins may not equal the sum of the separate intakes due to rounding.
Estimated dietary exposures are based on food consumption data from the 1995 NNS
Infant estimated dietary exposures are based on a constructed infant diet (see Section 3.4).

Table G.2: 95th percentile estimated monthly dietary exposure to dioxins per kilogram of body weight.

		PCDD/F (pg TEQ/kg bw/month)		PCBs (pg TEQ/kg bw/month)		Total Dioxins (pg TEQ/kg bw/month)	
		Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
All	2+	2.9	23.7	13.2	16.9	16.1	40.6
Males	2+	3.2	25.0	14.5	18.4	17.7	43.3
Females	2+	2.7	22.4	12.1	16.0	14.8	38.4
Toddlers	2-4	4.0	43.6	8.0	22.6	12.1	66.2
Males	4-15	3.5	33.2	8.3	18.7	11.8	51.9
Females	4-15	3.2	29.0	8.5	17.4	11.7	46.4
Males	16-29	3.5	21.3	15.8	18.6	19.3	39.9
Females	16-29	2.2	17.7	10.4	13.3	12.6	31.0
Males	30-44	3.0	18.1	15.4	17.3	18.4	35.4
Females	30-44	2.2	16.1	9.3	11.9	11.5	28.0
Males	45-59	2.9	16.5	14.9	16.6	17.8	33.1
Females	45-59	2.8	14.8	15.6	17.4	18.4	32.2
Males	60+	3.0	14.9	16.7	18.8	19.7	33.6
Females	60+	2.3	14.8	12.5	14.0	14.9	28.8

Lower Bound – assumes results reported as being below the LOR are zero.
Upper Bound – assumes results reported as being below the LOR are at the LOR.
PTMI = 70 pg TEQ/kg bw/month
Total dioxins = sum of intakes of PCDD/F and PCBs. Total dioxins may not equal the sum of the separate intakes due to rounding.
Estimated dietary exposures are based on food consumption data from the 1995 NNS

Appendix H: Percent contribution of major contributors to PCDD/F and PCB dietary exposure

Table H.1: Percent contribution of major contributors to PCDD/F mean dietary exposures for each population group

Food Name	9 months	2+ years			2-4 years	4-15 years		16-29 years		30-44 years		45-59 years		60+ years	
	All	All	Males	Females	All	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
Fish fillets, including crustacea and molluscs	7	39	40	38	18	26	24	35	35	45	39	44	46	47	44
Milk (full fat) including cheese, icecream and infant dessert	5	31	30	33	55	45	44	33	35	25	31	25	28	24	29
Bacon	1	7	8	6	2	5	6	9	7	8	7	7	7	8	6
White bread, including all cereal products	2	4	4	4	5	5	5	4	5	4	5	4	4	4	4
Peanut butter	0	4	5	4	8	5	7	4	5	5	4	5	3	3	3
Potatoes, including all vegetables	2	3	3	4	2	2	3	3	3	3	4	3	4	3	4
Butter	0	2	2	2	1	1	2	2	2	2	2	2	2	3	3
Beef, minced	0	2	2	2	1	1	1	2	2	2	2	2	1	2	1
Eggs	1	2	2	2	1	2	2	2	2	2	2	2	2	2	2
Milk chocolate	1	1	1	1	2	2	3	2	2	1	2	1	1	0	1
Chicken breasts	0	1	1	1	1	1	1	1	2	1	1	1	1	1	1
Sausages, meat, thick	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Margarine, table spread	0	1	1	1	0	1	1	1	1	0	0	0	0	1	1
Infant formula	82	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Percentage food contributions to PCDD/F and PCB exposure based on 'lower bound' values.
The sum of contributions for each population group may not equal 100% due to rounding.

Table H.2: Percent contribution of major contributors to PCB mean dietary exposures for each population group

Food Name	9 months	2+ years			2-4 years	4-15 years		16-29 years		30-44 years		45-59 years		60+ years	
	All	All	Males	Females	All	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
Fish fillets, including crustacea and molluscs	26	72	73	71	49	60	57	68	68	76	72	75	77	78	76
Milk (full fat) including cheese, icecream and infant dessert	4	11	11	12	30	21	21	13	13	9	11	8	9	8	10
Beef, minced	1	3	3	3	2	3	3	4	3	3	3	3	2	3	2
Chicken breasts	1	2	2	2	2	2	2	3	3	2	2	2	1	1	2
Bacon	1	2	2	2	1	2	2	2	2	2	2	2	2	2	1
Sausages, meat, thick	1	2	2	1	3	3	3	2	1	1	1	2	1	1	1
Tuna, canned	1	2	1	2	1	1	2	1	2	1	2	2	2	1	2
Eggs	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Butter	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
White bread, including all cereal products	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1
Lamb chops	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Orange juice, including all fruit	1	1	1	1	2	1	1	1	1	0	1	1	1	1	1
Milk chocolate	1	1	1	1	1	1	2	1	1	0	1	0	0	0	0
Margarine, table spread	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0
Infant Formula	61	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baked beans	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0

Percentage food contributions to PCDD/F and PCB exposure based on 'lower bound' values.
The sum of contributions for each population group may not equal 100% due to rounding.

Appendix I: Estimated monthly dietary exposures to PCDD/F, PCBs and total dioxins, as a percentage of the Australian TMI.

Table I.1: Mean estimated dietary exposures to dioxins as a percentage of the Australian TMI

		PCDD/F (% TMI)		PCBs (% TMI)		Total Dioxins (% TMI)	
		Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
All	2+	1	15	4	8	5	22
Males	2+	1	16	4	8	6	24
Females	2+	1	14	4	7	5	21
Infants	9 months	6	70	10	17	17	87
Toddlers	2-4	3	36	6	17	9	52
Males	4-15	2	25	5	12	7	37
Females	4-15	2	21	4	10	6	31
Males	16-29	1	15	4	8	6	23
Females	16-29	1	13	3	7	4	19
Males	30-44	1	13	5	8	6	21
Females	30-44	1	11	3	6	4	18
Males	45-59	1	12	4	7	5	19
Females	45-59	1	11	4	6	5	17
Males	60+	1	11	4	7	5	18
Females	60+	1	11	3	6	4	17

Lower Bound – assumes results reported as being below the LOR are zero.
Upper Bound – assumes results reported as being below the LOR are at the LOR.
PTMI = 70 pg TEQ/kg bw/month
Total dioxins = sum of intakes of PCDD/F and PCBs. Total dioxins may not equal the sum of the separate intakes due to rounding.
Estimated dietary exposures are based on food consumption data from the 1995 NNS
Infant estimated dietary exposures are based on a constructed infant diet (see Section 3.4).

Table I.2: 95th percentile estimated dietary exposures to dioxins as a percentage of the Australian TMI

		PCDD/F (% TMI)		PCBs (% TMI)		Total Dioxins (% TMI)	
		Lower Bound	**Upper Bound**	**Lower Bound**	**Upper Bound**	**Lower Bound**	**Upper Bound**
All	2+	4	34	19	24	23	58
Males	2+	5	36	21	26	25	62
Females	2+	4	32	17	23	21	55
Toddlers	2-4	6	62	11	32	17	95
Males	4-15	5	47	12	27	17	74
Females	4-15	5	41	12	25	17	66
Males	16-29	5	30	23	27	28	57
Females	16-29	3	25	15	19	18	44
Males	30-44	4	26	22	25	26	51
Females	30-44	3	23	13	17	16	40
Males	45-59	4	24	21	24	25	47
Females	45-59	4	21	22	25	26	46
Males	60+	4	21	24	27	28	48
Females	60+	3	21	18	20	21	41

Lower Bound – assumes results reported as being below the LOR are zero.
Upper Bound – assumes results reported as being below the LOR are at the LOR.
PTMI = 70 pg TEQ/kg bw/month
Total dioxins = sum of intakes of PCDD/F and PCBs. Total dioxins may not equal the sum of the separate intakes due to rounding.
Estimated dietary exposures are based on food consumption data from the 1995 NNS
Infant estimated dietary exposures are based on a constructed infant diet (see Section 3.4).