AUSTRALIAN EXPOSURE FACTOR GUIDANCE

Guidelines for assessing human health risks from environmental hazards

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The *Australian exposure factor guidance* handbook (2012) is intended to provide risk assessors with sets of tabulated data on human factors that may be used as inputs to the exposure assessment component of an environmental health risk assessment. The handbook should be read in conjunction with Chapter 4 of the main enHealth guidance document, in which summary Tables E1, E5, E6 and E7 from this handbook have been reproduced.

Toxikos Pty Ltd, under the direction of its principal toxicologist Dr Roger Drew, were the principal authors of the *Australian exposures factors guidance* handbook, substantially expanding on an initial draft prepared by Dr Andrew Langley in 2003. Toxikos employees Mr John Frangos and Ms Tarah Hagen provided significant input into the revised handbook.

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Summary

The information in this document is not intended to be a comprehensive compendium of exposure parameters. It has been produced to provide guidance. While a number of ‘recommendations’ have been made regarding parameter values in the text (summarised in Tables E1–E7), risk assessors and others using the information should check to ensure the suggestions presented are suitable for the scenarios they are evaluating. Australian data should be used where it is available. It is important the risk assessor consult the text and, if necessary, the primary information source prior to using any of the information contained in Tables E1–E7.

In Australia it is generally assumed that the most sensitive individual is the 2–3 year old child (enHealth 2003, 2004; NEPC 1999). Data is provided throughout the document for a 2–3 year old child. However, in Table E6, information is also provided for a 1–2 year old child. The risk assessor should determine which age bracket most closely resembles the most sensitive individual for their exposure scenario.”

Australian exposure factor information has been sought and juxtaposed with overseas data to allow an appreciation of the fact that not all overseas data reflects sectors of the current Australian population. If Australian information is not available, overseas data may be used but will require justification in the risk assessment why they are applicable in Australia.

It should also be appreciated that the information may not be current at the time the risks assessor consults this document; indeed, some values may be more than a decade old and Australian demographics and behaviour may have changed from the time the information was first gathered. For example, there are currently many more people of Asian, Indian and African descent residing in Australia, people are more mobile and, due to water restrictions in most states, shower durations and garden irrigation are different than 10–20 years ago. These examples highlight the necessity to make certain exposure parameter values used in any given risk assessment are contemporary and ‘fit for purpose’. It is the risk assessor’s responsibility to ensure this is so.

The recommended exposure factor values in this document are envisaged to be used primarily for screening (i.e. Tier 1) risk assessments. More detailed risk assessments should use circumstance and scenario specific data where possible.

In some of the tables an arithmetic mean has been provided. It should be noted that for many of the tabulated data, the underlying distribution may be skewed, with the arithmetic mean distorted by high end values. The geometric mean or median (where available) may be a better representation of the central tendency in such cases.

In many tables, the figures have been represented as published in the source data. In using such data, the risk assessor needs to be mindful of the precision inherent in such estimates and that it is advisable to consider how many significant figures should be used when using these data sources, as well as in the expression of the outcomes of calculations based on the data.

The information provided in Tables E1–E7 is provided for convenience, it is not intended that these exposure parameter values be used in isolation of the text nor, more importantly, the scientific literature. Table E1 provides a summary of suggested exposure factors for adults. Summary physiological information for children is provided for a range of ages in Table E2, with intake values for environmental media and food summarised in Table E3, and activity factors summarised

in Table E4. For screening risk assessments and setting guideline values the default sensitive receptor is a 2–3 year old child (Table E5), or it could be a 1–2 year old child (Table E7). Non-age dependent exposure parameters are summarised in Table E7.

Table E1: Summary of suggested exposure factors for adults[a]

Parameter	Suggested value Average (95th percentile)[a]	Units	Comment
Anatomical and physiological parameters (Sections 2.1.4 & 2.2.4)			
Body weight	78 (107)	kg	M & F combined*
	85 (114)	kg	M
	70 (100)	kg	F
	70	kg	Lifetime average M & F combined
Body height	169 (181)	cm	M & F combined
	176 (188)		M
	162 (174)		F
* Note these heights and weights may differ for uniform populations of a specific race (Sections 2.2.1 & 2.2.2).			
Dermal exposure parameters (Section 3.2.4)			
Total skin surface area	20,000 (24,000)	cm^2	M & F combined See Table 3.2.3 for surface area of specific body parts.
	21,000 (25,000)		M
	19,000 (23,000)		F
Exposed skin surface area	6,300 (7,900)	cm^2	M & F combined*
	6,700 (8,100)		M*
	5,900 (7,500)		F*
* These defaults approximate the sum of forearms, hands, lower legs and feet. The actual exposed body parts should be used as indicated by the exposure scenario (Section 3.2.4).			
Oral exposure parameters			
Drinking water intake M & F combined (gender specific data not available)	2 1.2 (2.8)	L/d	Life time tap water (i.e. community supply) intake. Includes water used in food preparation. Excludes commercially purchased bottled water and water intrinsic to purchased food and beverages (i.e. milk). Less than lifetime tap water intakes. (Water intake may be much larger with high activity ± tropical or arid areas). Can be used for pregnancy but 50% increase during lactation (Section 4.2.3).

Parameter	Suggested value Average (95th percentile)[a]	Units	Comment
Anatomical and physiological parameters (Sections 2.1.4 & 2.2.4)			
Food intake	1,400	g/day	M & F combined *
	1,550		M*
	1,200		F*
* Average food intakes not including beverages (e.g. juices, tap water, coffee) but including milk for ≥19 yrs; upper intakes from recent Australian food surveys are not readily available. For intakes of individual food groups see section 4.4.4 and Tables 4.4.1a,b,c.			
Soil ingestion	50 (60)	mg/day	Section 4.5.3
Incidental water ingestion while swimming	25 (125)	mL/hr	Average (upper estimate) (Section 4.6.3)
Inhalation exposure parameters			
Inhalation rate (long term exposures)	15 (20)	m^3/day	M & F combined (Section 5.1.3). For specific inhalation rates by activity or for short term exposures, see Section 5.1 (Table 5.1.2)
Activity Patterns			
Total time indoors	20 (24)	hr/day	Average (upper estimate) (Section 6.2.3.2)
Time indoors *(At home)*	20 (24)	hr/day	Average (upper estimate) (Section 6.2.3.2)
Time spent outdoors	3	hr/day	Approximate average value for Australian adults (Section 6.2.3.2). Upper estimate not available.
Time spent swimming	0.5	hr/day	For general population *
	1.5		For people who swim regularly *
* Estimates for Australians assuming all outdoor sports activity is swimming (Section 6.2.4.3).			

M = Male (adult)

F = Female (adult)

The summary tables provide suggestions for possible values for use in screening risk assessments. An average (i.e. central) and reasonable maximum value is provided. The latter is in parenthesis and when data permit is the 95th percentile, otherwise it will be an 'upper' estimate as indicated. In general an 'upper estimate' is a reasonable maximum value. The specific sections in this guidance document should be consulted for additional explanations. It is the ultimate decision of the risk assessor to choose the most appropriate value to use on a case-by-case basis. Wherever possible, data which is specific for the risk assessment scenario, chemicals and receptors of concern should be used ahead of the values in this table. When separate values for males or females are not provided in the summary tables the recent data used for generating the tables did not contain this information. Older agency publications (e.g. from Australia, US EPA, Canada, the Netherlands) may have such data and the risk assessor should seek and justify the use of this information as needed.

Table E2: Summary of suggested physiological parameters for children and adolescents (male and female combined). Values are average or 95th percentile (in parenthesis)[a]

Parameter	Units	Age bracket (years)															Comment
		0–<1	1–<2	2–<3	3–<4	4–<5	5–<6	6–<7	7–<8	8–<9	9–<10	10–<11	11–<12	12–<13	13–<14	14–<15	15–<16	16–<18	
Anatomical and physiological parameters																			
Body weight	kg	7[d] (8)	11[d] (13)	15 (17)		24 (33)				37 (58)				56 (83)				69 (97)	Section 2.2.4
Body height	cm	64[d] (67)	81[d] (86)	96 (106)		120 (132)				141 (156)				162 (176)				171 (180)	Section 2.1.4
Dermal exposure parameters																			
Skin surface area	cm^2	4,500 (5,100)[b]	5,300 (6,100)	6,100 (7,000)	7,600 (9,500)			10,800 (14,800)				15,900 (20,600)						Use adult values	Section 3.2.4; Table 3.2.5 for specific body parts.
Exposed skin surface area	cm^2	1,300 (1,500)	1,600 (1,900)	1,800 (2,100)	2700 (3,300)			3,500 (5,000)				5,600 (7,300)						Use adult values	Section 3.2.4
Inhalation exposure parameters																			
Inhalation rate (long term)	m^3/d	5.4 (8.1)[c]	8.0 (12.8)	9.5 (15.9)	10.9 (16.2)			12.4 (18.7)				15.1 (23.5)						16.5 (27.6)	Section 5.1.3
For specific inhalation rates by activity or for short term exposures, see section 5.1 (Table 5.1.2)																			

See Footnote (a) to Table E1. For screening risk assessments and establishing guidelines the most sensitive receptor is assumed to be a 2–3 year old (see Table E5) or a 1–2 year old child (see Table E6).

Total surface area for 6 to <12 month old child (US EPA 2008, Table 7–1).

Inhalation rate for 6 to <12 month old child (US EPA 2008, Table 6–1).

Average body heights and weights for all age groups, except for 0-<1 and 1-<2 year olds, which are median values (i.e. 50th percentiles) from WHO (2009).

Table E3: Summary of intakes of environmental media and food by children and adolescents (male and female combined). Values are average or 95th percentile (in parenthesis)[a]

Parameter	Units	Age bracket (years)															Comment
		0–<1	1–<2	2–<3	3–<4	4 – < 5	5 – < 6	6 – < 7	7 – < 8	8 – < 9	9– <10	10 – <11	11 – <12	12 – <13	13 – <14	14– <15	15 – <16	16–<18	
Oral exposure parameters																			
Drinking water[b]	L/day	0.5[c] (1.1)[c]	0.3 (0.9)	0.4 (0.9)	0.4 (1.1)			0.5 (1.3)					0.7 (1.7)					0.8 (2.0)	Section 4.2.3.
Breast milk	mL/day	850 (less than 6 months of age). High end of range of average intake.																	Section 4.3.3.
Food intake; (excluding beverages except milk)	g/day	225 (810)[d]	720 (1700)[d]	1,100		1,100			1,300						14-≤16 : 1,400 17-≤18 : 1,500				For individual food groups, see Section 4.4.4 & tables 4.4.1c, 4.4.2 and 4.4.5).
				Upper estimates not available															
Soil intake	mg/day	30 (CT,OS) 60 (CT, OS+ID)	50 (CT,OS = central tendency, outside soil) **100** (reasonable maximum, outside soil) 100 (CT, OS+ ID = central tendency, outside soil +indoor dust)														For outside soil +indoor dust: **50** (ave) 60 (95th percentile)		Section 4.5.3 (Bolded values are those commonly used in Australia)
Incidental water ingestion while swimming	mL/hr	50 (approx average) 150 (approx upper estimate)															25 (~ ave) 120 (~ upper estimate)		Section 4.6.3

See Footnote (a) to Table E1. For screening risk assessments and establishing guidelines the most sensitive receptor is assumed to be a 2–3 year old (see Table E5) or a 1–2 year old child (see Table E6).

Values of tap water intake (i.e. community supply). Includes water used in food preparation. Excludes commercially purchased bottled water and water intrinsic to purchased food and beverages (i.e. milk) (Section 4.2.3).

Drinking water ingestion rate for 6 to <12 month old child, from US EPA 2008, Table 3–14.

Average and 95th percentile (rounded) per capita intakes for US children.

Table E4: Summary of activity factors for children and adolescents (male and female combined). Values are average or 95th percentile (in parenthesis)[a]

Parameter	Units	Age bracket (years)															Comment
		0–<1	1–<2	2–<3	3–<4	4–<5	5–<6	6–<7	7–<8	8–<9	9–<10	10–<11	11–<12	12–<13	13–<14	14–<15	15–<16	16–<18	
Activity patterns																			
Frequency of hand to mouth	contacts/hr (Indoors)	28 (65)[b] 19 (52)[c]	20 (63)	13 (37)	15 (54)			7 (21)					No data						Section 6.1.1.3
	contacts/hr (Outdoors)	15 (47)[c]	14 (42)		9 (36)			3 (12)					No data						
Mouthing duration	hr/d	Differs by object (i.e. pacifier, fingers, toys, or other objects) and age																	Section 6.1.1.3
Time indoors	hr/d (Total)	23.3[d]	22.6	21.9	21.3			20.7					21					20.8	Section 6.1.2.3
		Upper estimates not available																	
	hr/d (At home)	18.5 (24)	17.8 (24)	16 (21.6)	16 (22.6)			14.9 (21.3)					14.8 (21.9)					13.9 (21.5)	
Time outdoors	hr/d	0.4	1.4	2	1.8			2.2					1.7					1.7	Average values. Upper estimates not available (Section 6.1.2.3)
Time playing on sand/gravel	hr/d	0.3	0.7	0.9	1			1.1					1.1					1.4	

Parameter	Units	Age bracket (years)															Comment
		0–<1	1–<2	2–<3	3–<4	4–<5	5–<6	6–<7	7–<8	8–<9	9–<10	10–<11	11–<12	12–<13	13–<14	14–<15	15–<16	16–<18	
Activity patterns																			
Time playing on grass	hr/d	0.9	1.1	1	1.3			1.2					1.3					1	
Time playing on dirt	hr/d	0.6	0.9	0.8	1.1			1.1					0.8					0.5	
Time spent swimming	hr/yr	19	21	23	27	0.5 (hr/d, general population) 1.5 (hr/d, people who swim regularly)													Ave values. Section 6.2.4.3

See Footnote (a) to Table E1. For screening risk assessments and establishing guidelines the most sensitive receptor is assumed to be a 2–3 year old (Table E5) or a 1–2 year old (Table E6).
Mouthing frequency for 3-<6 month old children (US EPA 2008, Table 4–1).
Mouthing frequency for 6-<12 month old children (US EPA 2008, Table 4–1).
Time spent indoors (total) averaged for 0-<1, 1-<3, 3-<6, and 6-<12 month olds.

Table E5: Summary of suggested exposure factors for 2–3 year old child (male and female combined). Values are average or 95th percentile (in parenthesis)[a]

Parameter	Suggested default	Units	Comment and internal reference
Anatomical and physiological parameters			
Body weight	15 (17)	kg	Section 2.2.4
Body height	96 (106)	cm	Section 2.1.4
Dermal exposure parameters			
Total skin surface area	6,100 (7,000)	cm^2	Section 3.2.4. See Table 3.2.5 for specific body part data.
Exposed skin surface area	1,800 (2,100)	cm^2	Section 3.2.3, 3.2.4
Oral exposure parameters			
Drinking water intake	0.4 (1)	L	Tap water intake. Includes water used in food preparation. (Section 4.2.3).
Food intake (excludes beverages except for milk)	1,100	g/day	Upper estimate not available. For intakes of individual food groups, see section 4.4.4 and Table 4.4.2.
Soil ingestion	50, (100), [100]	mg/day	Central tendency for outside soil. (Reasonable maximum, outside soil), [Central tendency outside soil + indoor dust]. (Section 4.5.3)
Incidental water ingestion while swimming	50 (~ average) 150 (~ upper estimate)	mL/hr	Section 4.6.3
Inhalation exposure parameters			
Inhalation rate	9.5, (15.9)	m^3/day	Section 5.1.3. For specific inhalation rates by activity or for short term exposures, see Section 5.1; Table 5.1.2
Activity patterns			
Frequency of hand to mouth	13 (37) (Indoors)	contacts /hr	Section 6.1.1.3
	5 (20) (Outdoors)		
Mouthing duration	Varies	hr/d	Mean and maximum values differ by object mouthed (Section 6.1.1.3)
Time spent indoors	21.9 (Total)	hr/d	Upper estimate not available (Section 6.1.2.3)
	16 (21.6) (At home)	hr/d	Section 6.1.2.3
Time spent outdoors	2	hrs/d	Average. Upper estimates not available (Section 6.1.2.3)
Playing on	0.9	hrs/d	

Parameter	Suggested default	Units	Comment and internal reference
sand/gravel			
Playing on grass	1	hrs/d	
Playing on dirt	0.8	hrs/d	
Time spent swimming	23	hr/year	Average value. Upper estimate not available (Section 6.2.4.3)

See Footnote (a) to Table E1. For screening risk assessments and establishing guidelines the most sensitive receptor is assumed to be a 2–3 year old (Table E5) or a 1–2 year old (Table E6).

Table E6: Summary of suggested exposure factors for 1–2 year old child (male and female combined). Values are average or 95th percentile (in parenthesis)

Parameter	Suggested default	Units	Comment and internal reference
Anatomical and physiological parameters			
Body weight	11 (13)	kg	Section 2.2.4
Body height	81 (86)	cm	Section 2.1.4
Dermal exposure parameters			
Total skin surface area	5,300 (6,100)	cm^2	Section 3.2.4. See Table 3.2.5 for specific body part data.
Exposed skin surface area	1,600 (1,900)	cm^2	Section 3.2.3, 3.2.4
Oral exposure parameters			
Drinking water intake	0.3 (0.9)	L	Tap water intake. Includes water used in food preparation (Section 4.2.3).
Food intake (excludes beverages except for milk)	720 (1,700)	g/day	For intakes of individual food groups, see section 4.4.4.
Soil ingestion	50, (100), [100]	mg/day	Central tendency for outside soil. (Reasonable maximum, outside soil), [Central tendency outside soil + indoor dust]. (Section 4.5.3)
Incidental water ingestion while swimming	50 (~ average) 150 (~ upper estimate)	mL/hr	Section 4.6.3
Inhalation exposure parameters			
Inhalation rate	8.0 (12.8)	m^3/day	Section 5.1.3. For specific inhalation rates by activity or for short term exposures, see Section 5.1;Table 5.1.2

Parameter	Suggested default	Units	Comment and internal reference
Activity patterns			
Frequency of hand to mouth	20 (63) (Indoors)	contacts/ hr	Section 6.1.1.3
	14 (42) (Outdoors)		
Mouthing duration	Varies	hr/d	Mean and maximum values differ by object mouthed (section 6.1.1.3)
Time spent indoors	22.6 (Total)	hr/d	Upper estimate not available (Section 6.1.2.3)
	17.8 (24) (At home)	hr/d	Section 6.1.2.3
Time spent outdoors	1.4	hr/d	Average. Upper estimates not available (Section 6.1.2.3)
Playing on sand/gravel	0.7	hr/d	
Playing on grass	1.1	hr/d	
Playing on dirt	0.9	hr/d	
Time spent swimming	21	hr/year	Average value. Upper estimate not available (Section 6.2.4.3)

Table E7: Summary of non-age dependent exposure factors. Values are average or 95th percentile (in parenthesis)[a]

Parameter	Suggested value	Units	Comment
Anatomical and physiological parameters			
Life Expectancy	82 (*)	yrs	Male and female combined (Section 2.4.1)
	79		Male (Section 2.4)
	84		Female (Section 2.4)
* Upper estimate not publicly available. Many national and international agencies use 70 years as the assumed lifetime exposure to environmental agents.			
Dermal exposure parameters			
Soil adherence	0.5 (1.7)	mg soil/ cm^2 skin	Applicable for outdoor and indoor residential child and adult exposures (Section 3.3.1). For specific activities and body parts see Tables 3.3.3, 3.3.4, and 3.3.5.
Dermal Bioavailability	Organics: 1 Inorganics: 0.0001	Unitless	Chemical specific. These Table values are to be used *only* when other reasonable information is not available. Bioaccessibility of inorganics from soil or other media can be approximated with experimental tests (sections 3.4 and 4.1).
Dermal Bioaccessibility	Organics: 1 Inorganics: No default		
Shower and bath frequency	1 (2)	#/day	Central estimate (upper estimate) for adults and children (Section 3.5.5)
Shower duration	8 (16)	mins	Section 3.5.5
Shower volume	72	L	Volume and flow rate of non-water saving shower (Section 3.5.5). Upper estimates not available.
Shower flow rate	9	L/min	
Bath duration	21	mins	Bath duration for adults and children combined (Section 3.5.5). Upper estimate not available.
Bath volume	Insufficient data	L	Insufficient data (Section 3.5.4).
Oral exposure parameters			
Oral Bioavailability	Organics: 1 Inorganics: No default	Unitless	Chemical specific. These Table values are to be used *only* when other reasonable information is not available. Bioaccessibility of inorganics from soil or other media can be approximated with experimental tests (Sections 3.4 and 4.1).
Oral Bioaccessibility	Organics: 1 Inorganics: No default		

Parameter	Suggested value	Units	Comment
Inhalation exposure parameters			
Building air exchange rate	*Residential:* 0.6 *Commercial:* no recommendation	#/hr	The residential value is mid point of range for 'closed' Australian dwellings. Air changes will be higher with open doors/windows, ceiling fans and air conditioning. A single value is not suggested for commercial buildings. Upper estimates not available (Section 5.2.4).
Indoor particle deposition rate	No recommendation	#/hr	Markedly differs from house to house. No suggested value (Section 5.3.1).
Floor area of residential dwelling	*Houses:* 210 *Other:* 120 *All*: 180	m^2	Average values. There is a wide range of values for houses and other types of dwellings (Section 5.4.1). Upper estimates not available.
Air volume of residential dwellings	*Houses:* 500 *Other:* 280 *All*: 420	m^3	Average values. Assumed ceiling height is 2.4 m. There is a wide range of values for houses and other types of dwellings (Section 5.4.1). Upper estimates not available.
Uptake (product of retention and absorption) of inhaled contaminants	*Default 100%*	unitless	Chemical specific value should be used if available (Section 5.5).
Background particulate levels for urban ambient air	PM_{10};17 (39) $PM_{2.5}$; 7 (16) Ratio; [0.4]	µg/m^3 [unitless]	National average of all urban monitoring sites – 50th percentile, (95th percentile). Proportion of PM_{10} that is $PM_{2.5}$. (Section 5.6.2).
Fraction of indoor dust from outside soil	50 (100)	%	Average (maximum) (Section 5.7)
Activity patterns			
Time spent in transit	1	hr/day	Total time by all travel modes (Section 6.2.3.2). Upper estimate not available.
Frequency of swimming	52 (150)	d/yr	Approximate median (upper estimate). Actual frequency will depend on the Australian locality (Section 6.2.4.3).
Residence and population mobility parameters			
Duration of residence	10 (35)	yr	Section 7.1.3.

See Footnote (a) to Table E1. For screening risk assessments and establishing guidelines the most sensitive receptor is assumed to be a 2–3 year old.

1. Introduction

1.1 Using the exposure information

The information in this document is not intended to be a comprehensive compendium of exposure parameters. It has been produced to provide guidance. While a number of recommendations have been made regarding parameter values, risk assessors and others using the information should check to ensure the suggestions presented are suitable for the scenarios they are evaluating. Australian data should be used where it is available. In Australia it is generally assumed that the most sensitive individual is the 2–3 year old child (enHealth 2003, 2004; NEPC 1999). Data is provided throughout the document for a 2–3 year old child. However, in Table E6, information is also provided for a 1–2 year old child. The risk assessor should determine which age bracket most closely resembles the most sensitive individual for their exposure scenario.

Australian exposure factor information has been sought and juxtaposed with overseas data to allow an appreciation of the fact that not all overseas data reflects sectors of the current Australian population. If Australian information is not available, overseas data may be used but will require justification in the risk assessment why they are applicable in Australia.

It should also be appreciated that the information may not be current at the time the risks assessor consults this document; indeed, some values may be more than a decade old and Australian demographics and behaviour may have changed from the time the information was first gathered, and may be different for the geographic locality of the risk assessment. For example, there are currently many more people of Asian, Indian and African descent residing in Australia, people are more mobile and, due to water restrictions in most states, shower durations and garden irrigation are different than 10–20 years ago. These examples highlight the necessity to make certain exposure parameter values are contemporary and 'fit for purpose'. It is the risk assessor's responsibility to ensure this is so.

This guidance document provides a brief indication of the variability in each of the exposure factors discussed. Variability is addressed by presenting data on the exposure factors as tables with percentiles or ranges of values, and/or as estimated values, with a brief discussion of the uncertainty in the estimates. However information on variability is limited and the risk assessor should address variability, and uncertainty, issues to the extent warranted by the risk assessment being undertaken. If the assessor wishes to apply probabilistic techniques then Sections 13.1 and 13.2 in the enHealth document *Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazards* (enHealth 2011) should be consulted.

1.2 Arrangement of exposure information

The exposure factor information is basically arranged according to the primary routes of exposure (i.e. dermal, inhalation and ingestion) so calculations by exposure route are facilitated.

The first section contains general anatomical and physiological parameters; however, it does not contain all human anatomical information pertinent to exposure assessment. Anatomical data specific for a particular exposure route may be found under the exposure route in question (e.g. ventilation rates for various physical activities are in the section dealing with inhalation exposure).

Information on general behaviour activity patterns is at the end of this document, however behaviour patterns pertinent to a given exposure route is within the section dealing with the exposure route.

Within each section Australian data are first provided; this may or may not be supplemented with overseas data.

Suggestions for specific values for use in Australian screening (i.e. Tier 1) risk assessments are provided where appropriate. However, some sections while providing useful information (e.g. organ weight data) do not contain specific recommended values. If site-specifc data are unavailable, values for calculating exposure in Australian screening risk assessments have been suggested by bolding and shading in tables within the body of each chapter. In addition, where appropriate, these specific suggestions are reiterated in the "recommendation" sections within each chapter.

It is re-emphasised that the reader should enquire throughout to identify the factor information required; the suitability and currency of the data in this document should also be affirmed.

1.3 Literature search strategy

In the first instance, an attempt was made to source all reports and articles originally referenced in the first draft of the Exposure Factors Handbook (enHealth 2004). These were checked for currency.

To obtain updated information, literature searches using key identifying phrases for each subject matter of interest were undertaken. These searches were conducted on agency websites and the peer-reviewed scientific literature using a number of search engines. Articles of relevance were obtained; the bibliographic citations in these articles as well as the 'related articles' links were inspected for additional information.

Relevant information was sought from the following example sources:

- Australian Bureau of Statistics (ABS)
- Australian State and Federal Departments of Health websites
- South Australian Health Commission contaminated sites monographs
- National Health and Medical Research Council (NHMRC)
- Food Standards Australia New Zealand (FSANZ)
- United States Environmental Protection Agency (US EPA)
- Health Canada
- Rijksinstituut voor Volksgezondheid en Milieu (RIVM- Dutch National Institute for Public Health and the Environment)
- UK Environmental websites (DEFRA, British Council, Environment Agency)
- World Health Organization (WHO)
- United Nations International Children's Emergency Fund (UNICEF)
- European Commission (EC)
- International Commission on Radiological Protection (ICRP)
- International Atomic Energy Agency (IAEA)

References

enHealth (2011). *Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazards*. Environmental Health Committee (enHealth) of the Australian Health Protection Prinicpal Committee.

enHealth (2003). *Australian Exposure Assessment Handbook: Consultation Draft*. enHealth Council.

enHealth (2004). Environmental health risk assessment: guidelines for assessing human health risks from environmental hazards. Department of Health and Ageing and enHealth Council.

NEPC (1999). National Environment Protection (Assessment of Site Contamination) Measure 1999. National Environment Protection Council.

2. Anatomical and physiological parameters

2.1 Height

Although height information may not be used routinely in risk assessments, it has been included for completeness regarding physiological parameters.

2.1.1 Australian data

Aged two years to adult

Height measurements to the nearest 0.1 cm were collected from Australian populations (aged 2 years to ≥ 65 years) in the 1995 National Nutrition Survey (ABS 1995). These data were updated for 5–>65 year olds in the 2007–08 survey (ABS 2008; ABS 2011 customised report). The data are summarised in Table 2.1.1. The surveys included data for individuals residing in Australia but born in other regions of the world such as Asia, Africa, Europe and the (ABS 1995; ABS 2008).

The information is not available in a form that would allow separation into different racial groups (e.g. Caucasions, South-east Asians, Indians, etc)[1]. However, data by region of birth (e.g. Asia, Europe, Africa and the Middle East, etc) are summarised in Table 2.12.

Young children (aged under two years)

Australian height data for children below the age of two years were not located. See section 2.3 (growth charts) for more information

2.1.2 Overseas data

The International Commission on Radiological Protection (ICRP 2002, p. 1) indicates limited variability (5–10%) in average human height worldwide.

The International Atomic Energy Agency (IAEA 1998) collected body height data from individuals in China, Japan, the Republic of Korea and Pakistan (group 1), as well as Bangladesh, India, the Philippines and Vietnam (group 2). They found differences in body height for the populations of these countries (e.g. average body height of males from group 1 countries was 5 cm higher than that of group 2 countries; 20–50 year olds were 168.6 cm vs. 163.6 cm). Body height measurements for these populations are given in Table 2.1.3.

The average height of Asian adult males (aged 20–50 years) in Table 2.1.3 (approximately 166 cm) is 11 cm less than the Australian adult male (aged 19–64 years) mean body height presented in Table 2.1.1. Average adult Australian female heights (approximately 163 cm in Table 2.1.1) are also higher than their Asian counterparts in Table 2.1.3 (151–158 cm).

Table 2.1.1: Australian population measured height by age

Males – Age group (years)										
Height (cm)	**2–3**	**4–7**	**8–11**	**12–15**	**16–18**	**19–24**	**25–44**	**45–64**	**≥65**	**≥18**
Mean	**96.1**[a]	**120.2**[c]	**141.6**[c]	**163.9**[c]	**176.7**[c]	178.5	177.5	175.4	171.3	**176.0**[b]
95th percentile	**105.2**[a]	**131**[c]	**159**[c]	**180**[c]	**189**[c]	189	189	187	182.5	**188**[b]

[1] Personal communication with ABS (phone call on 26th July, 2011).

Females – Age group (years)										
Height (cm)	**2–3**	**4–7**	**8–11**	**12–15**	**16–18**	**19–24**	**25–44**	**45–64**	**≥65**	**≥18**
Mean	**95.8** [a]	**119.0**[c]	**139.4**[c]	**160.7**[c]	**164.6**[c]	163.9	163.8	161.4	158.3	**162.1**[b]
95th percentile	**105.8**[a]	**132**[c]	**156**[c]	**174**[c]	**175**[c]	175	176	172	170.5	**174**[b]

Data for 2–3 year olds from ABS (1995); Data for 4–7 year olds is based on 5–7 year old data from ABS (2008), provided in ABS (2011, customised report); all other data also from ABS (2008), provided in ABS (2011, customised report).

The average of mean and 95th percentile male (96.1, 105.2 cm) and female (95.8, 105.8 cm) heights for a 2–3 year old child (96, 105.5 cm) have been rounded to 96 and 106 cm and brought forward as suggested values for use in screening risk assessment (Section 2.1.4).

Mean male (176 cm) and female (162.1 cm) heights for adults > 18 years of age were rounded and brought forward as suggested values for use in risk assessment (Average male height = 176 cm; female = 162 cm; male and female combined = 169 cm). 95th percentile male (188 cm) and female (174 cm) heights were also rounded and brought forward as suggested values for use in Australian screening risk assessments (Section 2.1.4).

The average of male and female mean and 95th percentile heights for children of other age groups were calculated and rounded; these were then brought forward as suggested values for use in screening risk assessments (Section 2.1.4 and Table E2).

Table 2.1.2: Australian population measured body height by age and region of birth

Age (years)	Oceania & Antarctica	Europe	Asia	Africa & Middle East	Americas	Overall
Average height (cm)						
Males						
5–11	131.7	132.8	131.0	na	na	131.8
12–17	168.3	172.3	168.5	na	na	168.3
18–54	178.0	176.4	171.8	177.4	177.2	177.3
55+	174.0	172.5	167.0	171.0	174.9	173.2
Females						
5–11	131.1	126.6	130.2	na	na	130.9
12–17	162.0	164.3	157.3	na	na	161.9
18–54	164.2	163.3	158.1	161.1	164.0	163.4
55+	160.1	158.6	155.1	156.3	157.7	159.4
95th percentile height (cm)						
Males						
5–11	156	147	153	na	na	na

Age (years)	Oceania & Antarctica	Europe	Asia	Africa & Middle East	Americas	Overall
Average height (cm)						
12–17	185	181	182	na	na	na
18–54	189	187	183	188	192	na
55+	185	184	175	182	184	na
Females						
5–11	153	147	157	na	na	na
12–17	175	173	169	na	na	na
18–54	175	176	171	175	173	na
55+	171	170	165	170	167	na

Data from ABS (2008; 2011 customised report)

np = not available or not applicable

Table 2.1.3: Overseas heights (cm ± SD) by country and age

Males – Age (years)						
Country	**Newborn**	**1**	**5**	**10**	**15**	**20–50**
Pakistan	48.8 ± 7.0	–	116.8 ± 6.9	143.0 ± 9.4	165.1 ± 8.5	170.6 ± 6.4
China	50.2 ± 1.2	72.9 ± 4.2	104.6 ± 4.1	135.5 ± 6.2	162.3 ± 7.5	169.2 ± 5.8
Japan	49.7 ± 1.8	75.3 ± 2.3	110.5 ± 4.6	137.4 ± 5.7	167.2 ± 5.9	167.8 ± 5.7
Rep. of Korea	–	–	–	135.8 ± 5.7	164.2 ± 6.2	166.8 ± 5.5
Bangladesh	47.3 ± 3.0	71.3 ± 5.3	106.4 ± 8.3	133.9 ± 7.8	162.8 ± 7.7	163.9 ± 12.8
Vietnam	48.7 ± 1.2	74.6 ± 4.2	98.9 ± 4.3	122.2 ± 4.7	156.0 ± 6.1	163.8 ± 5.2
Philippines	–	75.7 ± 4.7	102.9 ± 6.4	126.8 ± 6.2	155.1 ± 8.2	163.4 ± 13.8
India	49.0 ± 2.0	74.4 ± 5.0	102.7 ± 6.0	128.1 ± 7.0	154.2 ± 8.5	163.4 ± 7.5

Females – Age (years)						
Country	**Newborn**	**1**	**5**	**10**	**15**	**20–50**
Pakistan	48.5 ± 4.2	–	113.5 ± 10.3	120.4 ± 10.2	154.2 ± 6.6	157.5 ± 6.7
China	49.6 ± 1.1	71.3 ± 4.2	103.6 ± 3.6	133.8 ± 7.0	155.4 ± 5.4	158.2 ± 5.4
Japan	49.3 ± 1.8	74.0 ± 2.5	109.6 ± 4.6	138.4 ± 6.6	156.7 ± 5.0	155.0 ± 5.2
Rep. of Korea	–	–	–	136.7 ± 6.2	155.4 ± 4.9	154.9 ± 4.9
Bangladesh	47.7 ± 2.5	70.1 ± 3.7	109.7 ± 4.2	135.4 ± 5.0	154.1 ± 5.3	154.9 ± 5.6
Vietnam	48.7 ± 1.2	71.5 ± 4.2	101.3 ± 4.4	124.7 ± 4.9	152.1 ± 5.9	154.0 ± 4.5
Philippines	–	75.0 ± 4.9	102.6 ± 5.9	128.9 ± 7.9	149.8 ± 5.9	151.3 ± 5.4
India	48.0 ± 2.0	72.4 ± 5.5	100.8 ± 9.0	128.5 ± 7.0	148.8 ± 6.0	151.0 ± 6.5

Data from IAEA (1998)

2.1.3 Reference man and woman

Because 'Western European and North American populations have been well studied with respect to anatomy, body composition, and physiology', body height reference values generated by the International Commission on Radiological Protection (ICRP 2002) are based on central estimates of European and North American populations. Table 2.1.4 shows the ICRP (2002) default (average) values for a reference man and woman.

Table 2.1.4: Reference man and woman values for height

Age (years)	Height (cm)[a]	
	Males	**Females**
Newborn	51	51
1	76	76
5	109	109
10	138	138
15	167	161
Adult	176	163

Data from ICRP (2002)
Average estimates based on European and North American populations.

2.1.4 Discussion on height data and recommendations

Australian adult average body height

From Table 2.1.1, the mean height of adult Australian men and women aged 18 years and over is respectively 176 cm and 162.1 cm. The average adult height of males and females combined is 169.1 cm. These values can be rounded to give average body heights of 176 cm for adult males, 162 cm for adult females, and 169 cm for adult males and females combined. 95th percentile values (rounded) for adult height are 188, 174, and 181 cm for males, females and males and females combined, respectively.

Child average body height

Australian data (Table 2.1.1) indicate average body height of a 2–3 year old (male and female combined) child in Australia is 96 cm. This value could be used in screening risk assessments. The 95th percentile from Australian data is not much different (106 cm). Both are close to the 50th and 95th percentiles for a 3 year old child provided by the WHO (2009) (Table 2.3.1). For children of other age groups, the measured Australian data in Table 2.1.1 may be used. For 0–1 and 1–2 year olds, for which Australian data are unavailable, data from WHO (2009) may be used (Table 2.3.1).

Using body height in risk assessments

Although height information may not be used routinely in risk assessments, if it is required, risk assessors should use body height data that match the exposure scenarios they are evaluating. The data suggest that for risk assessments specific for adult males in Australia (e.g. construction workers) a body height of approximately 176 cm would be appropriate and for females 162 cm; for a population of adult males and females a value of 169 cm could be used.

2.2 Weight

2.2.1 Australian data

Aged two years to adult

Weight data for Australians are available (for 2–>65 year olds) from the 1995 National Nutrition Survey (ABS 1995). Weight was measured to the nearest 0.1 kg using digital scales with maximum capacity of 140 kg. These data were updated for 5 to >65 year olds in the 2007–08 survey (ABS 2008; ABS 2011, customised report). The data are summarised in Table 2.2.1.

The 2007–08 National Health Survey (NHS) provides information on the self-reported weights of Australians aged 18 and over (ABS 2008; ABS 2011, customised report); the data are in Table 2.2.2. It should be noted that people tend to underestimate their own weight (ABS 1995).

In the NHS, overweight and obesity are assessed using body mass index calculated from self-reported height and weight information. In 2007–08 more than half (56%) of all adults aged 18 years and over, were either overweight or obese, an increase from 44% in 1995, 50% in 2001, and 54% in 2004–05 (ABS 2008). Rates of overweight and obesity vary with age and with gender. A summary of the percentage of people in different body mass index groups can be found in Table 2.2.3.

The information is not available in a form to allow separation into different racial groups (e.g. Caucasions, South-east Asians, Indians, etc)[2]. However, by region of birth (e.g. Asia, Europe, Africa and the Middle East, etc) is summarised in Table 2.2.4.

Young children

Australian weight data for children below the age of two years were not located. Section 2.3 (growth charts) contains more information.

[2] Personal communication with ABS (phone call on 26th July, 2011).

Table 2.2.1: Australian population measured weight by age

Males – Age group (years)										
Weight (kg)	**2–3**	**4–7**	**8–11**	**12–15**	**16–18**	**19–24**	**25–44**	**45–64**	**≥65**	**≥18**
Mean	**15.5**[a]	**24.2**[c]	**37.6**[c]	**57.5**[c]	**75.0**[c]	80.0	86.1	87.6	82.2	**85.2**[b]
95th percentile	na	**33**[c]	**62**[c]	**88**[c]	**112**[c]	110	117	115	106.5	**114**[b]

Females – Age group (years)										
Weight (kg)	**2–3**	**4–7**	**8–11**	**12–15**	**16–18**	**19–24**	**25–44**	**45–64**	**≥65**	**≥18**
Mean	**15.3**[a]	**23.6**[c]	**35.4**[c]	**54.8**[c]	**61.9**[c]	66.6	70.7	72.3	68.1	**70.1**[b]
95th percentile	na	**33**[c]	**54**[c]	**78**[c]	**82**[c]	97	103	101	94	**100**[b]

Data for 2–3 year olds from ABS (1995). All other data is from ABS (2008) provided in ABS (2011, customised report).

na = not available

The average of mean male (15.5 kg) and female (15.3 kg) weights for a 2–3 year old child (15.4 kg) has been rounded to 15 kg and brought forward as the suggested value for use in risk assessment (Section 2.1.4).

Mean male (85.2 kg) and female (70.1 kg) weights for adults > 18 years of age were rounded and brought forward as suggested values for use in risk assessments (Average male weight = 85 kg; female = 70 kg; male and female combined = 78 kg). The 95th percentile male (114 kg) and female (100 kg) weights were also rounded and brought forward as suggested values for use in Australian screening risk assessments (Section 2.1.4).

The average of male and female mean and 95th percentile weights for children of other age groups have been calculated and rounded; these were then brought forward as suggested values for use in screening risk assessments (Section 2.1.4 and Table E2).

Table 2.2.2: Self reported weights of adults by age group

Males – Age group (years)								
Weight (kg)	**18–24**	**25–34**	**35–44**	**45–54**	**55–64**	**65–74**	**≥75**	**≥18**
Mean	78.7	84.5	86.8	87.8	86.2	84.2	77.8	84.6
95th percentile	110	115	119	120	113	108	102	115

Females – Age group (years)								
Weight (kg)	**18–24**	**25–34**	**35–44**	**45–54**	**55–64**	**65–74**	**≥75**	**≥18**
Mean	63.8	68.3	71.0	69.7	72.1	70.2	64.9	69.0
95th percentile	95	100	106	96	98	96	93	100

Data from ABS (2008; 2011, customised report)

Table 2.2.3: Body mass index of Australian adults 2007–08

Males (proportion of persons, %) – Age group (years)								
Body mass index	**18–24**	**25–34**	**35–44**	**45–54**	**55–64**	**65–74**	**≥75**	**Overall**
Underweight	3.6	2.2*	0.8**	0.4**	np	np	1.0**	1.2
Normal weight	56.6	35.9	28.5	22.8	np	np	24.7	31.1
Overweight	28.0	42.5	44.2	47.0	40.0	44.9	52.8	42.2
Obese	11.9	19.5	26.6	29.7	34.9	34.0	21.5	25.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Females (proportion of persons, %) – Age group (years)								
Body mass index	**18–24**	**25–34**	**35–44**	**45–54**	**55–64**	**65–74**	**≥75**	**Overall**
Underweight	7.2	3.4	1.9*	1.7*	na	na	2.5*	2.7
Normal weight	58.0	52.2	43.0	39.6	na	na	40.6	42.6
Overweight	20.7	26.4	32.4	32.5	34.7	42.0	32.6	31.0
Obese	14.2	18.0	22.7	26.3	33.2	29.4	24.3	23.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Data from ABS (2008)

* Estimate has a relative standard error of 25 - 50 % and should be used with caution.

** Estimate has a relative standard error greater than 50 % and is considered unreliable for general use.

na = not available.

Table 2.2.4: Australian population measured body weights by age and region of birth

Age (years)	Oceania & Antarctica	Europe	Asia	Africa & Middle East	Americas	Overall
Average weight (kg) – Males						
5–11	31.6	29.0	28.7	np	np	31.6
12–17	64.2	60.1	58.4	np	np	63.7
18–54	86.8	84.6	73.2	82.8	87.2	85.3
55+	85.9	86.5	71.5	83.4	88.4	85.0
Average weight (kg) – Females						
5–11	30.6	27.1	30.5	np	np	30.4
12–17	57.5	66.0	49.1	np	np	57.4
18–54	71.6	69.5	58.6	67.9	72.4	69.8
55+	72.1	68.9	60.9	70.3	71.8	70.8
95th percentile weight (kg) – Males						
5–11	55	40	41	np	np	–
12–17	96	79	81	np	np	–
18–54	120	109	100	110	117	–
55+	112	110	94	101	136	–
95th percentile weight (kg) – Females						
5–11	50	37	55	np	np	–
12–17	79	90	61	np	np	–
18–54	105	96	79	93	97	–
55+	100	94	80	90	87	–

Data from ABS (2008; 2011, customised report)

np =not available for publication

– = not applicable

2.2.2 Overseas data

The IAEA (1998) collected body weight data from individuals in China, Japan, the Republic of Korea, Pakistan, Bangladesh, India, the Philippines, and Vietnam. Body weight varied according to country; within country it varied by ethnic background, religion and income. The body weight data in the different countries in provided in Table 2.2.5.

The adult average weight of males and females aged 20–50 years in Bangladesh, Vietnam, the Philippines and India (Table 2.2.5) is respectively 54.4 kg and 47.5 kg. For males it is 30 kg (approximately 35%) less than the mean body weight for Australian adult males (19-64 years; 84.6 kg Table 2.2.1). The adult female body weight for these countries is approximately 22 kg (31%) less than Australian females (69.9 kg Table 2.2.1).

2.2.3 Reference man and woman

Because Western Europeans and North Americans have been well studied with respect to anatomy, body composition and physiology, the International Commission on Radiological Protection (ICRP 2002) based their body weight reference values on these populations; Table 2.2.6 shows the ICRP (2002) values (averages) for a reference man and woman.

Table 2.2.5: Overseas body weights (kg ± SD) by country and age

Males – Age (years)						
Country	**Newborn**	**1**	**5**	**10**	**15**	**20–50**
Pakistan	3.2 ± 0.6	–	20.3 ± 3.0	34.2 ± 7.0	51.6 ± 8.8	63.9 ± 8.1
China	3.2 ± 0.3	9.1 ± 1.0	16.3 ± 1.4	27.0 ± 3.9	48.6 ± 7.0	58.3 ± 6.4
Japan	3.2 ± 0.4	9.6 ± 1.0	19.0 ± 1.7	32.5 ± 6.2	57.2 ± 9.2	63.6 ± 8.8
Rep. of Korea	–	–	–	30.7 ± 4.5	53.2 ± 7.0	63.8 ± 7.7
Bangladesh	2.4 ± 0.7	8.1 ± 1.4	16.4 ± 2.6	27.2 ± 6.5	43.9 ± 6.3	57.8 ± 9.0
Vietnam	3.0 ± 0.3	7.6 ± 2.0	14.8 ± 2.5	23.5 ± 2.6	40.9 ± 4.8	51.8 ± 5.4
Philippines	–	9.3 ± 1.4	15.2 ± 1.7	24.3 ± 3.8	43.1 ± 7.6	56.6 ± 8.3
India	2.9 ± 0.3	8.5 ± 1.5	14.6 ± 2.0	22.9 ± 3.5	38.2 ± 6.5	51.5 ± 8.5

Females – Age (years)						
Country	**Newborn**	**1**	**5**	**10**	**15**	**20–50**
Pakistan	3.3 ± 0.5	–	15.7 ± 2.5	19.1 ± 5.1	46.9 ± 7.2	52.6 ± 8.5
China	3.1 ± 0.2	8.5 ± 1.0	15.8 ± 1.4	27.1 ± 4.2	46.3 ± 5.5	51.1 ± 6.4
Japan	3.2 ± 0.4	9.1 ± 0.9	18.6 ± 2.6	32.8 ± 6.3	51.6 ± 7.1	52.3 ± 7.4
Rep. of Korea	–	–	–	30.6 ± 5.1	49.3 ± 5.8	54.5 ± 6.5
Bangladesh	2.5 ± 0.7	7.0 ± 1.0	16.4 ± 2.5	26.7 ± 4.3	42.5 ± 6.0	49.9 ± 7.9

Females – Age (years)						
Vietnam	2.9 ± 0.4	7.8 ± 2.3	14.5 ± 2.6	22.0 ± 2.7	40.5 ± 4.6	46.8 ± 5.3
Philippines	–	9.0 ± 1.7	15.2 ± 1.7	25.7 ± 5.0	43.3 ± 6.2	49.2 ± 8.7
India	2.8 ± 0.3	8.1 ± 1.5	14.2 ± 2.0	22.9 ± 3.4	38.7 ± 6.0	44.2 ± 8.0

Data from IAEA (1998)

Table 2.2.6: Reference man and woman values for weight (kg)

Age	Weight (kg)	
	Males	Females
Newborn	3.5	3.5
1 year	10	10
5 years	19	19
10 years	32	32
15 years	56	53
Adult	73	60

Data from ICRP (2002)

2.2.4 Discussion on weight data and recommendation

The Australian National Health and Medical Research Council (NHMRC) and many other agencies use a standard default body weight of adults of 70 kg. The World Health Organization (WHO) has used 60 kg as the standard body weight for an adult in its calculations of acceptable daily intakes and water quality guidelines (WHO 2008; 1999). The United States Environmental Protection Agency (US EPA) Integrated Risk Information System (IRIS) uses a 70 kg body weight assumption in the derivation of cancer slope factors and unit risk (US EPA 1997). Both these body weights are used for risk assessments and guideline setting where chemical exposure is presumed to be over the lifetime of an individual.

Lifetime average body weight of Australians

Using the data in Table 2.2.1 the lifetime average body weight (rounded) of Australians from Table 2.2.1 is calculated to be 77 kg for males and 64 kg for females[3]. The average lifetime body weight for males and females combined is approximately 70 kg (rounded down[4] from 70.5 kg).

[3] These lifetime averages were calculated from the data in Table 2.2.1. The the mean body weight for each age group was multiplied by the age interval, these were summed then averaged over the average life expectancy of males or females (Section 2.4) (minus two years, as weight data in Table 2.2.1 starts at age 2). For example, for males lifetime time-weighted average body weight was calculated as follows:

[(15.5 kg x 2 yrs) + (24.2 kg x 4 yrs) + (37.6 kg x 4 yrs) + (57.5 kg x 4 yrs) + (75 kg x 3 yrs) + (80 kg x 6yrs) + (86.1 kg x 20 yrs) + (87.6 kg x 20 yrs) + (82.2 kg x 14 yrs)] ÷ 77 yrs (life expectancy of Australian males minus two years) = 76.9 kg, rounded to 77 kg.

[4] Although it is mathematically correct to round 70.5 kg to 71 kg, in this instance the calculation was rounded down for consistency with the current Australian practice of using 70 kg as the average lifetime body weight of Australian adults.

Australian adult average body weight

From Table 2.2.1 the measured mean weight of adult Australian men, women, and men and women combined aged 18 years and over is respectively 85, 70, and 78 kg. These values are suggested for use in screening risk assessments. The 95th percentile values (rounded) for adult weight are 114, 100, and 107 kg for males, females and males and females combined, respectively.

Child (2–3year old) body weight

Australian data (Table 2.2.1) indicate the average body weight of a 2–3 year old (male and female combined) child in Australia is approximately 15 kg (rounded down from 15.4 kg). This is close to the 99th percentile value for 2 year olds derived by the WHO in Table 2.3.2.

The 95th percentile Australian body weight data for 2–3 year olds were not available. Consequently, the average of the 95th percentile body weights for 36 month-old girls and boys (17 kg, rounded down from 17.4 kg) calculated from WHO (2009) data in Table 2.3.2 is suggested for use in Australian screening risk assessments.

For children of other age groups, the Australian data in Table 2.2.1 may be used.

However, for 0–1 and 1–2 year olds, for which Australian data are unavailable, data from WHO (2009) may be used (Table 2.3.2).

Using body weight in risk assessments

Risk assessors should use body weight data that match the exposure scenarios they are evaluating. The data suggest that for risk assessments specific for adult males in Australia (e.g. construction workers) a body weight of 85 kg would be appropriate and for females 70 kg; for a population of adult males and females a value of 78 kg could be used (this is the rounded average weight of adult males and females combined). If exposures are calculated to be over a lifetime, then use of lifetime average body weight for males and females (70 kg) should be considered.

2.3 Growth data

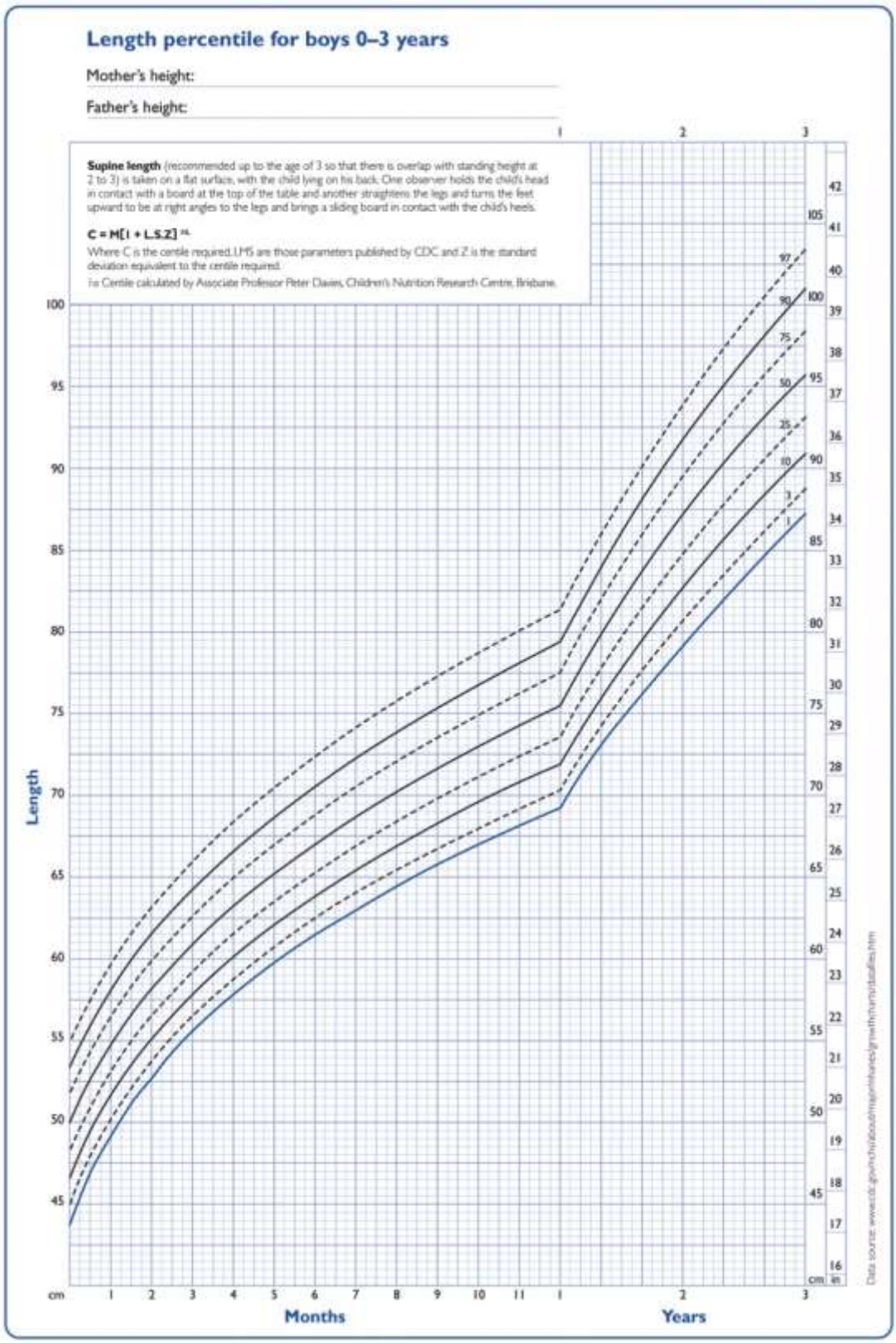
2.3.1 United States

The Australian Paediatric Endocrine Group (APEG 2008) recommends the US Centers for Disease Control and Prevention (CDC 2000) growth charts for use in Australia and New Zealand. These charts are based on data collected over a 31 year period between 1963 and 1994 as part of the US National Health and Nutrition Examination Survey (NHANES) program. The data were derived from a mix of infants who were either exclusively breast-fed or formula-fed. However, it was noted that babies exclusively breastfed may grow more rapidly in the first four months, and then grow at a slower rate between 4–6 months of age than those that are formula-fed.

Figures 2.3.1 and 2.3.2 shows the CDC (2000) height (length percentile) growth charts respectively for boys and girls aged 0–3 years.

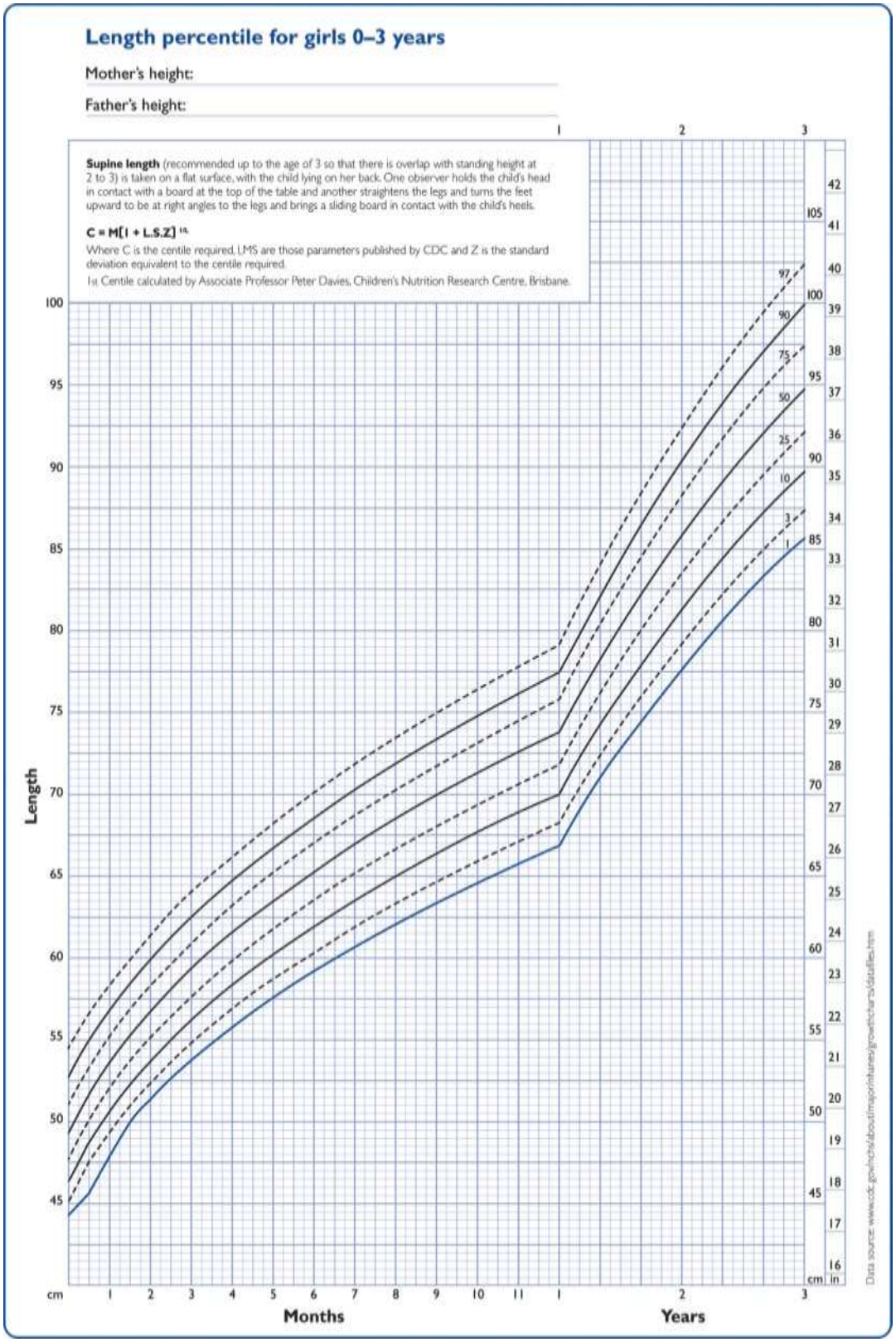
Figures 2.3.3 and 2.3.4 shows the CDC (2000) weight growth charts respectively for boys and girls aged 0–3 years.

Figure 2.3.1: Growth in height (length percentile in centimetres) for boys aged 0–3 years



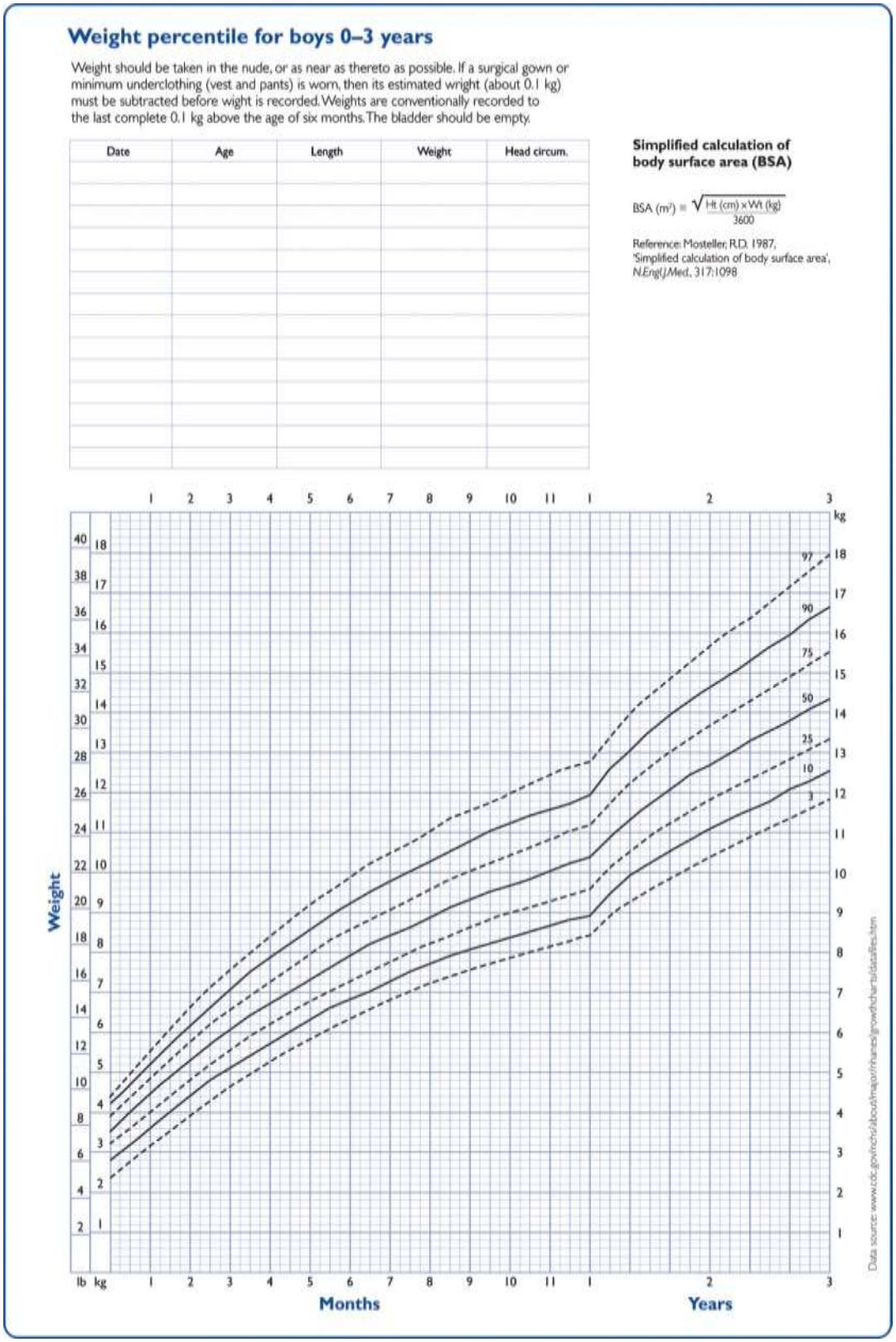
Source: APEG 2008

Figure 2.3.2: Growth in height (length percentile in centimetres) for girls aged 0–3 years



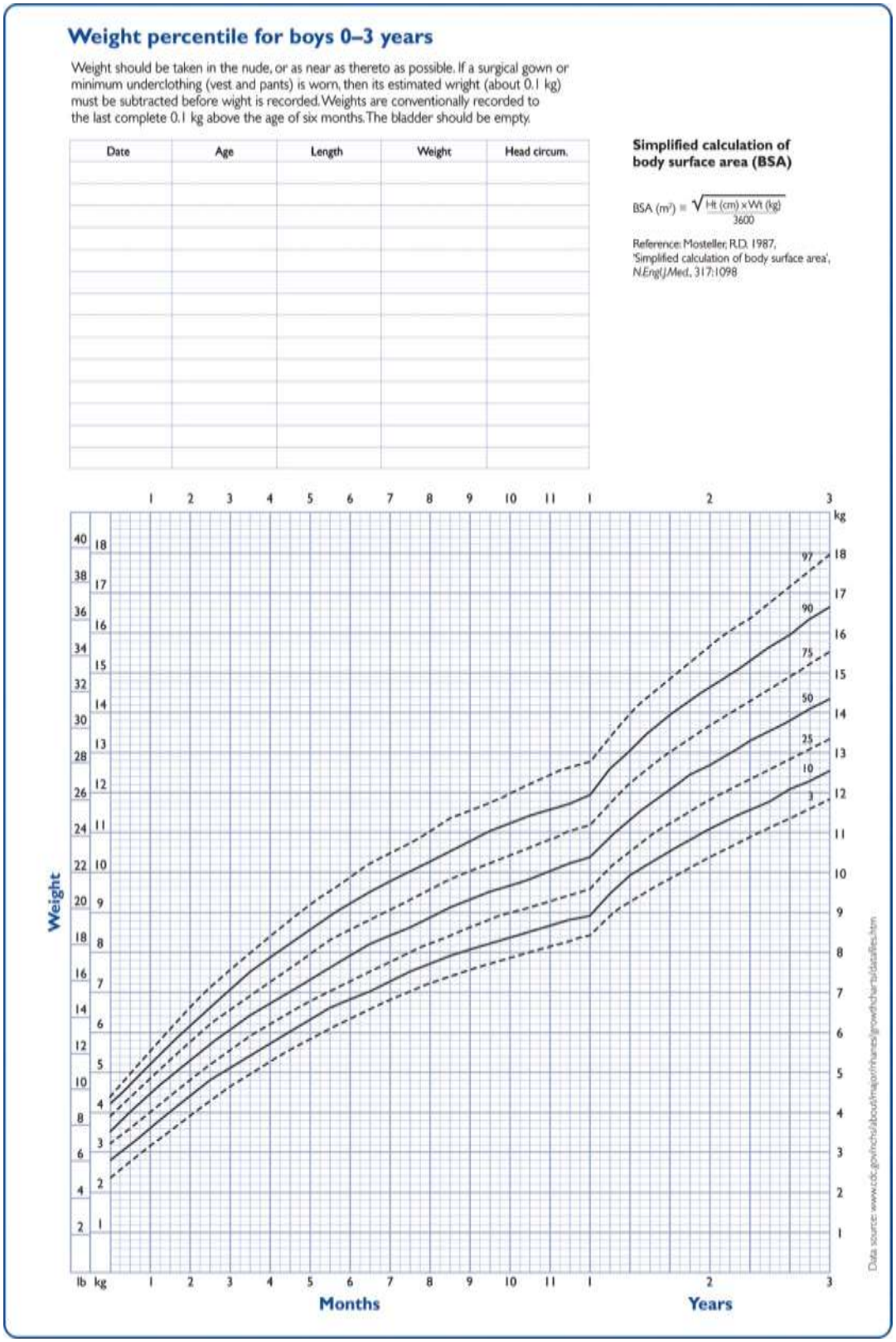
Source: APEG 2008

Figure 2.3.3: Weight (kg) growth chart for boys 0–3 years



Source: APEG 2008

Figure 2.3.4: Weight (kg) growth chart for girls 0–3 years



Source: APEG 2008

2.3.2 World Health Organization

In 2006 WHO released new growth curves for infants and children aged from birth to five years (WHO 2009). This information is the result of the WHO Multicentre Growth Reference Study (MGRS) undertaken between 1997 and 2003. Data were collected from approximately 8,500 children around the world from widely different ethnic backgrounds and cultural settings (Brazil, Ghana, India, Norway, Oman and the US).

WHO (2009) describe the data as representing a single international reference for the best description of growth for children from birth to age five and establish breastfed children as the normative model for growth and development (WHO 2009). The study measured a variety of data including length/height for age, weight for age, weight for length, weight for height, body mass index for age, head circumference for age, triceps skin fold for age and subscapular skin fold for age. Selected percentile values for length and weight by age, respectively, for girls and boys aged from birth to five years are presented in Tables 2.3.1 and 2.3.2. For growth charts and more extensive data, WHO (2009) should be consulted.

Table 2.3.1: Length (cm) by age for girls and boys

Girls – Percentiles			
Age (Month)	**50th**	**95th**	**99th**
0	**49.1[a]**	**52.2[a]**	53.5
4	**62.1[a]**	**65.7[a]**	67.1
6	**65.7[a]**	**69.5[a]**	71.0
12	**74.0[a]**	**78.3[a]**	80.0
18	**80.7[a]**	**85.5[a]**	87.5
24	**86.4[a]**	**91.7[a]**	93.9
36	95.1	101.3	103.9
48	102.7	109.8	112.8
60	109.4	117.2	120.5

Boys – Percentiles			
Age (Month)	**50th**	**95th**	**99th**
0	**49.9[a]**	**53.0[a]**	54.3
4	**63.9[a]**	**67.3[a]**	68.7
6	**67.6[a]**	**71.1[a]**	72.6
12	**75.7[a]**	**79.7[a]**	81.3
18	**82.3[a]**	**86.7[a]**	88.5
24	**87.8[a]**	**92.8[a]**	94.9
36	96.1	102.2	104.7
48	103.3	110.2	113.1
60	110.0	117.6	120.7

Data from WHO (2009)

50th percentile (i.e. median) and 95th percentile height data for 0, 4, 6, and 12 month-old children were averaged and rounded (64, 67 cm respectively); these values are suggested for use in screening risk assessments for the 0–1 year old age group (M & F combined) . Similarly, the mean and 95th percentile data for 12, 18, and 24 month-old children were averaged and rounded (81, 86 cm) and brought forward as the suggested values for the 1–2 year old age group (Section 2.2.4).

Table 2.3.2: Weights (kg) by age for girls and boys

Girls – Percentiles			
Age (Month)	**50th**	**95th**	**99th**
0	**3.2[a]**	**4.0[a]**	4.4
4	**6.4[a]**	**7.9[a]**	8.6
6	**7.3[a]**	**8.9[a]**	9.7
12	**8.9[a]**	**11.0[a]**	12.0
18	**10.2[a]**	**12.6[a]**	13.8
24	**11.5[a]**	**14.2[a]**	15.5
36	13.9	**17.3[a]**	19.0
48	16.1	20.4	22.6
60	18.2	23.5	26.3

Boys – Percentiles			
Age (Month)	**50th**	**95th**	**99th**
0	**3.3[a]**	**4.2[a]**	4.6
4	**7.0[a]**	**8.4[a]**	9.1
6	**7.9[a]**	**9.5[a]**	10.2
12	**9.6[a]**	**11.5[a]**	12.4
18	**10.9[a]**	**13.1[a]**	14.2
24	**12.2[a]**	**14.7[a]**	15.9
36	14.3	**17.5[a]**	19.1
48	16.3	20.2	22.1
60	18.3	23.0	25.3

Data from WHO (2009)

50th percentile (i.e. median) and 95th percentile weight data for 0, 4, 6, and 12 month-old children were averaged and rounded (7, 8 kg respectively); these values are suggested for use in screening risk assessments for the 0–1 year old age group.
Similarly, the mean and 95th percentile data for 12, 18, and 24 month-old children were averaged and rounded (11, 13 kg) and brought forward as the suggested values for the 1–2 year old age group (Section 2.2.4).
The 95th percentile data for 36 month-old girls and boys were averaged, rounded, and brought forward as the suggested value for the 2–3 year old age group (Section 2.2.4).

2.4 Life expectancy

Life expectancy data may be useful for estimating the duration of chronic exposure. Overall, females have longer life expectancy than males. In 2007–09, life expectancy at birth for Australia was 79 years (rounded down from 79.3 years) for males and 84 years (rounded up from 83.9 years) for females (ABS 2010). Average life expectancy for males and females combined is 82 years (rounded up from 81.6 years). Upper estimates were not publicly available.

2.4.1 Recommendation

The above data indicate a life expectancy of 82 years for the Australian population (male and female combined).

For some time the national and international default for assumed lifetime exposure to environmental agents has been 70 years; it is recognised some agencies within Australia may continue to use this value. The risk assessor may wish to explore the use of both 70 and 82 years to facilitate comparison with the procedures of particular agencies or with guideline values found in the literature.

2.5 Miscellaneous data

2.5.1 Organ weights

The data in Tables 2.5.1 and 2.5.2 may be useful in calculating the dose of chemical delivered to specific organs if appropriate toxicokinetic information on the chemical is known. According to ICRP (2002), the worldwide variability in the mass of a particular organ is limited to 5–10%. However, as shown in Table 2.5.1, there are potentially much larger differences between the ICRP reference values and those observed in certain populations. The data herein are not typically required for screening risk assessments. Thus no specific recommendations for anatomical values are made.

Information on physiological and anatomical parameters for laboratory animals may also be useful when extrapolating animal toxicity data to humans. This information is available from several international sources (e.g. ECB 2003, Derelanko and Hollinger 1995, US EPA 1988).

Table 2.5.1: Weights of organs and tissues for reference human male

Organ/tissue	Weight (g)			
	ICRP reference[a]	Chinese[b]	Japanese[b]	Indian[b]
Brain	1,450	1,400	1,400	1,200
Heart	330	300	400	240
Kidneys (2)	310	280	320	220
Liver	1,800	1,400	1,600	1,140
Lungs	1,000	1,100	1,200	840
Pancreas	140	110	140	100
Spleen	150	170	130	140
Adrenals	14	14	14	–
Thyroid	20	27	19	19
Thymus	25	36	33	–
Pituitary	0.6	0.8	0.6	–
Testes	35	56	37	35
Total body[c]	73,000	60,000	60,000	–

Data from ICRP (1975; 2002).

Data from IAEA (1998

Total body includes more organs/tissues than shown in the table.

Table 2.5.2: Tissue volumes/size[a] for reference human male

Body part	Reference value
Alveoli surface area	140 m^2
Blood volume (total)	5,300
Arterial system	1,110
Venous system	3,150
Pulmonary system	560
Heart cavity (average value)	480
Blood volume:	
Red blood cell volume	2,300
Plasma volume	3,000
Body water (total)	600 ml/kg
Extracellular	260 ml/kg

Units are ml unless otherwise specified. Data from ICRP (1975; 2002)

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3. Estimating intake from dermal exposure

3.1 Introduction

Although dermal exposure to chemicals via environmental media frequently occurs, the skin is a relatively good barrier to their absorption into the systemic circulation. To estimate dermal exposure and subsequent absorption of chemicals from environmental media the following parameters are required:

- the assessment scenario specific chemical concentration in the media (e.g. soil/dust, water, air)
- the area of actual or potentially exposed skin (Section 3.2)
- amount of media in contact with skin (Section 3.3)
- amount of chemical available for absorption (bioaccessibility) and the amount absorbed (bioavailability) through the skin (Section 3.4)
- activity patterns, behavioural patterns and body weights of the exposed population (Sections 3.5 and Chapters 2 and 6).

3.2 Skin surface area

3.2.1 Australian data

Australian data for skin surface area were not located. However these are not expected to be markedly different from overseas data.

3.2.2 Overseas data

A number of studies (Table 3.2.1) have generated algorithms relating total skin area to more easily measured body characteristics such as height and weight (Boyd 1935; Current 1998; Du Bois and Du Bois 1916; Gehan and George 1970; Haycock et al. 1978; Mosteller 1987; US EPA 1985) (Table 3.2.1).

Table 3.2.1: Algorithms for calculating body surface area (BSA)

Reference	BSA formula (m^2)	Comments
Boyd (1935) (cited in Current 1998)	$W^{0.7285-0.0188\log W} * H^{0.3} * 0.000327$	Equation based on 231 Caucasian subjects (a subset of 1,114 persons who were measured or estimated), including children, infants and foetuses using triangulation, surface integration and coating methods.
Current (1998)	1321 + 0.3433 * W	Linear equation based on data from Boyd (1935) for children with weights ranging from 3 to 30 kg; intended for use in medical applications where a quick calculation is needed; in more critical applications, Current recommends use of Boyd's formula.
Gehan and George (1970)	$W^{0.51456} * H^{0.42246} * 0.02350$	Based on 401 measurements from the total Boyd (1935) dataset. Estimates and prenatal subjects were excluded but measurements for Japanese and Chinese were included.[a] This formula was used by ICRP (2002) to create their BSA reference values.
Mosteller (1987)	$(H * W/3600)^{1/2}$	Modification of Gehan and George formula, but easier to use.
Du Bois and Du Bois (1916)	$W^{0.425} * H^{0.725} * 0.007184$	Based on nine individuals (predominantly males of European origin), one of whom was a 'sickly' child. Used a technique of coating and wrapping subjects with 'gummed paper'. Tends to underestimate BSA, especially in small individuals.

Reference	BSA formula (m^2)	Comments
US EPA (1985)	$W^{0.517} * H^{0.417} * 0.0239$	Based on data used in the Gehan and George's equation, but re-evaluated using the least squared procedure.
Haycock et al. (1978)	$W^{0.5378} * H^{0.3964} * 0.024265$	Based on 81 individuals including newborn infants, infants, children and adult members of medical and secretarial staff in two hospitals in the US (black, Hispanic and white ethnic groups were included).

W = weight (kg), H = height (cm)
Dataset consisted of 9.5% Chinese individuals, 20% Japanese individuals, 55% Caucasian and 15% whose ethnicity was recorded as 'unknown.'

Wang et al. (1992) evaluated formulae from Boyd (1935), Current (1998), Gehan and George (1970), Mosteller (1987) and Du Bois and Du Bois (1916) and found they had a root mean squared error of less than 1%, making them substantially equivalent. Although only based on nine subjects, the Du Bois and Du Bois (1916) equation is commonly used for body surface area (BSA) calculations in medicine (Bonate 2005, p. 276; Livingston and Lee 2001).

Boyd (1935) estimated skin surface area associated with various portions of the body using a number of different techniques (triangulation, surface integration and coating methods). The original Boyd (1935) reference consisted of 1,114 measurements from 231 subjects (more than half were from children). The Gehan and George (1970) algorithm is based on a subset (401 measurements) of the total data within Boyd (1935).

The US EPA (1985) considered the surface area data selected by Gehan and George (1970) to be the best for establishing an algorithm; the US EPA used the data to generate the equation reported in the US EPA publication *Development of statistical distributions or ranges of standard factors used in exposure assessments* (1985). This equation was used to estimate BSA in the US EPA (1997) exposure factor handbook from the 1976 -1980 data set of the US National Health and Nutrition Examination Surveys (NHANES), and in US EPA (2009) exposure factor handbook 2005–06 NHANES data.

The US EPA 2009 *Exposure factors handbook* notes:

- 50^{th} percentile of 2.07 m^2, a mean of 2.06 m^2 and 95^{th} percentile of 2.52 m^2 for adult men.
- 50^{th} percentile of 1.82 m^2, a mean of 1.85 m^2 and 95^{th} percentile of 2.33 m^2 for adult women.

Banerjee and Sen (1955) measured the BSA of 15 Indian males (aged 18–44 years) in India using several methods, and compared their results with calculated BSAs using the Du Bois and Du Bois (1916) formula. The mean measured BSA was 1.58 m^2 (standard deviation: 0.15 m^2; 95^{th} percentile: 1.65 m^2). The measured BSA was slightly greater than the calculated value in all cases (variation 1.9–5.8%). It should be borne in mind that Indians living in Australia may have different eating habits, which may contribute to differences in body sizes when compared with Indians living in India particularly for second and later generations.

The ICRP (2002) used the Gehan and George (1970) formula to calculate reference values for total BSA and surface area of body portions for males and females in six separate age groups (Table 3.2.2). These values are similar to the direct measurements summarised by the US EPA (2008, Table 7–6) for children aged under 18 years (n = 21).

US EPA (2009) also provides mean and 95^{th} percentile values for surface areas (m^2) by body part for adults (Table 3.2.3). They separate the body parts further than ICRP, which is useful for some risk assessments.

The algorithms developed by the US EPA (1985) have recently been applied (US EPA 2008) to the US NHANES 1999–2006 data for children and adolescents up to the age of 21 years to determine child total BSA, and surface area of body parts important in risk assessment (Tables 3.2.4 and 3.2.5).

Table 3.2.2: ICRP body surface area (BSA) for males and females by age

Age	BSA (m^2)		Percentage (%) of total surface area of body[a]			
	Males	Females	Head	Trunk	Upper extremities	Lower extremities
Newborn	0.24	0.24	20.8	31.9	16.8	30.5
1 year	0.48	0.48	17.2	34.4	17.8	30.6
5 years	0.78	0.78	13.1	33.0	19.6	34.3
10 years	1.12	1.12	10.9	33.6	19.4	36.2
15 years	1.62	1.55	8.8	31.9	21.4	37.9
Adult	1.90	1.66	7.5	34.6	19.4	38.5

Data from ICRP (2002, pp. 64–65)
Same for male and female.

Table 3.2.3: US EPA (2009) surface area by body part for adults (m^2)

Body part	Male		Female	
	Mean	95th percentile	Mean	95th percentile
Head	0.14	0.15	0.11	0.12
Trunk (incl. neck)	0.83	1.10	0.65	0.85
Upper extremities	0.39	0.47	0.30	0.35
Arms	0.31	0.40	0.24	0.27
Upper arms	0.17	0.22	– [a]	– [a]
Forearms	0.15	0.20	– [a]	– [a]
Hands	0.11	0.13	0.09	0.11
Lower extremities	0.80	0.97	0.71	0.88
Legs	0.68	0.85	0.60	0.76
Thighs	0.41	0.52	0.36	0.48
Lower legs	0.27	0.32	0.23	0.29
Feet	0.14	0.16	0.12	0.15

Body part	Male		Female	
	Mean	95th percentile	Mean	95th percentile
Total BSA	**2.06**[b]	**2.52**[b]	**1.85**[b]	**2.33**[b]
Suggested surface area for adult **male and female combined**	**Mean estimate 2 m^2** [b] **95th percentile 2.4 m^2** [b]			

Source: US EPA 2009

Rounded data from US EPA (2009, Tables 7–11 and 7–12)
Data for upper arms and forearms for women were not reported in US EPA (2009)

Mean and 95th percentile rounded total BSAs for males (2.1, 2.5 m^2), females (1.9, 2.3 m^2), and males and females combined (2, 2.4 m^2) have been brought forward (Table E1) as suggested values in Australian screening risk assessments (Section 3.2.4).

Table 3.2.4: US EPA (2008) total surface area for children and adolescents (m^2)

Age	Surface area (m^2)	
	Mean	95th percentile
Birth–<1 month	0.29	0.34
1–<3 months	0.33	0.38
3–<6 months	0.38	0.44
6–<12 months	**0.45**[a]	**0.51**[a]
1–<2 years	**0.53**[a]	**0.61**[a]
2–<3 years	**0.61**[a]	**0.70**[a]
3–<6 years	**0.76**[a]	**0.95**[a]
6–<11 years	**1.08**[a]	**1.48**[a]
11–<16 years	**1.59**[a]	**2.06**[a]
16–<21 years	**1.84**[a]	**2.33**[a]

Data from US EPA (2008, Table 7–1)

Mean and 95th percentile total BSAs for children of different age groups have been brought forward as suggested values for use in Australian screening risk assessments (Section 3.2.4, Tables E2 and E5).

Table 3.2.5: US EPA (2008) values for surface area of body parts for children and adolescents

Age	Mean percent of total surface area					
	Head	Trunk	Arms	Hands	Legs	Feet
Birth–<1 mo	18.2	35.7	13.7	5.3	20.6	6.5
1–<3 mo	18.2	35.7	13.7	5.3	20.6	6.5
3–<6 mo	18.2	35.7	13.7	5.3	20.6	6.5
6–<12 mo	18.2	35.7	13.7	5.3	20.6	6.5
1–<2 yrs	16.5	35.5	13.0	5.7	23.1	6.3
2–<3 yrs	14.2	38.5	11.8	5.3	23.2	7.1
3–<6 yrs	13.7	31.7	14.2	5.9	27.3	7.3
6–<11 yrs	12.6	34.7	12.7	5.0	27.9	7.2
11–<16 yrs	9.4	33.7	12.9	5.3	31.3	7.5
16–<21 yr	7.8	32.2	15.3	5.4	32.2	7.1

Age	Mean (95th percentile) surface area by body part (m^2)					
	Head	Trunk	Arms	Hands	Legs	Feet
Birth–<1 mo	0.05 (0.06)	0.10 (0.12)	0.04 (0.05)	0.02 (0.02)	0.06 (0.07)	0.02 (0.02)
1–<3 mo	0.06 (0.07)	0.12 (0.14)	0.05 (0.05)	0.02 (0.02)	0.07 (0.08)	0.02 (0.03)
3–<6 mo	0.07 (0.08)	0.14 (0.16)	0.05 (0.06)	0.02 (0.02)	0.08 (0.09)	0.03 (0.03)
6–<12 mo	0.08 (0.09)	0.16 (0.18)	0.06 (0.07)	0.02 (0.03)	0.09 (0.11)	0.03 (0.03)
1–<2 yrs	0.09 (0.1)	0.19 (0.22)	0.07 (0.08)	0.03 (0.04)	0.12 (0.14)	0.03 (0.04)
2–<3 yrs	0.09 (0.1)	0.24 (0.27)	0.07 (0.08)	0.03 (0.04)	0.14 (0.16)	0.04 (0.05)
3–<6 yrs	0.10 (0.13)	0.24 (0.3)	0.11 (0.14)	0.05 (0.06)	0.21 (0.26)	0.06 (0.07)
6–<11 yrs	0.14 (0.19)	0.38 (0.51)	0.14 (0.19)	0.05 (0.07)	0.30 (0.41)	0.08 (0.11)
11–<16 yrs	0.15 (0.19)	0.54 (0.69)	0.21 (0.27)	0.08 (0.11)	0.50 (0.65)	0.12 (0.16)
16–<21 yr	0.14 (0.18)	0.59 (0.75)	0.28 (0.36)	0.10 (0.13)	0.59 (0.75)	0.13 (0.17)

Rounded data from US EPA (2008, Table 7–2)

3.2.3 Exposed skin surface area

Wong et al. (2000) reported on two surveys that gathered information on activity patterns related to dermal contact with soil. The surveys recorded the clothing worn during 'gardening and yard work' and 'outdoor play activities' but this information is not provided in the published paper by Wong et al (2000). Instead, for children (<5 years) and children/adolescents (5–17 years) estimated average percentages of skin likely to be exposed was calculated. The clothing information was used to assign the percentage of total skin potentially exposed using clothing coverage information from Anderson et al. (1985). According to the US EPA (2008), the results of the surveys summarised by Wong et al. (2000) indicate most children wore short pants, a dress or skirt, short sleeve shirts, no socks, and leather or canvas shoes during outdoor play activities. Wong et al. (2000) estimated for children under five years the percentage of skin exposed was 38% and for 5–17 year olds 33.8%.

From this information, the body parts likely to be exposed during outdoor activities are the hands, lower legs, forearms, and feet. For a 2–3 year old child, this equates to a potentially exposed mean skin surface area[5] of 0.18 m^2 (95^{th} percentile = 0.21 m^2).

Assuming the exposed skin of adults is forearms, lower legs, hands and feet (Table 3.2.3) the mean exposed surface areas are 0.67 m^2 (males), 0.59 m^2 (females) [6], and 0.63 m^2 (male and female combined). Outdoor maintenance workers can reasonably be expected to wear long trousers and closed shoes. Long sleeve shirts may not always be worn.

3.2.4 Recommendations

Several competent authorities have derived estimates for total skin surface area and various body parts for adults and children (ICRP 2002; US EPA 1997; 2008; 2009). The estimated values for adults are similar between authorities, for example, average reference values for adult men are 1.90 m^2 and 2.06 m^2 from ICRP (2002) and US EPA (2009) respectively.

The ICRP (2002) and US EPA (2008) have also developed estimates specific for children (Tables 3.2.2, 3.2.4 and 3.2.5).

For Australia, the mean and 95^{th} percentile values for skin surface area from the US EPA (2008; 2009) are suggested for use because they offer the greatest flexibility for individual body parts for adults and children (Table 3.2.3 for adults, Tables 3.2.4 and 3.2.5 for children).

For adults:

- Rounded mean values of 2.1, 1.9, and 2 m^2 and 95^{th} percentile values of 2.5, 2.3, and 2.4 m^2 are suggested as the total BSAs for adult males, females, and males and females combined, respectively (Table 3.2.3).
- The estimates of surface areas for various body parts of adults, the mean and 95^{th} percentile values in Table 3.2.3 may be used.
- For potentially exposed skin the sum of the exposed individual body parts should be used as dictated by the exposure scenario in the risk assessment As a generic default mean values of 0.67, 0.59, and 0.63 m^2 and 95^{th} percentiles of 0.81, 0.75, and 0.79 m^2 for potentially exposed skin in males, females, and males and females combined, respectively are suggested for use in screening risk assessments.

For children:

- Age/weight-specific BSA should be used for risk assessments involving children.
- For screening risk assessments involving 2–3 year old children, mean and 95^{th} percentile values of 0.61 and 0.7 m^2 are suggested for total skin surface area.
- For other age groups, the mean and 95^{th} percentile total BSAs in Table 3.2.4 are suggested for use.
- For estimates of surface areas for various body parts of children, the mean and 95^{th} percentile values in Table 3.2.5 may be used.
- For potentially exposed skin the sum of the exposed individual body parts should be used as indicated by the exposure scenario. As a generic default a mean value of 0.18 m^2 and a 95^{th} percentile of 0.21 m^2 is suggested for a 2–3 year old child. This assumes 50% of the arms and legs (i.e. approximately the forearms and lower legs) are exposed, together with the feet and hands. The suggested values for other age groups are provided in Table E2.

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[5] Surface area data for forearms and lower legs of children and adolescents are not available. Assuming the area of forearms and lower legs are approximately 50% of that for arms and legs and using information from Table 3.2.5, the exposed skin surface area is calculated for a 2–3 year old child as: [0.5 x 0.07 (arms)] + [0.5 x 0.14 (legs)] + 0.03 (hands) + 0.04 (feet) = 0.18m^2.

[6] Surface area of female forearms was assumed to be the same as for males, as female data was not available.

3.3 Soil adherence

Important factors influencing the amount of soil adhering to skin include (US EPA 1997; Ferguson et al. 2007):

- activity patterns such as occupation (farming, gardening, excavation), recreational activities (time spent outdoors, sport) – high soil adherence levels are associated with activities involving wet soils
- skin properties – soil adherence varies considerably across different parts of the body; the highest occurs on common contact points such as hands, knees and elbows and the lowest on the face (Kissel et al. 1996a, b)
- properties of the soil (i.e. adherence increases with increasing moisture content and decreases with increasing particle size (US EPA 2008).

Choate et al. (2006) determined adhered fractions of dry or moderately moist soils to the palm generally consisted of particles with a diameter less than 63 µm; moisture content became a factor only for very moist soils (> 9%) and organic carbon content did not influence adherence over the range 0.62–1.14 mg soil/cm^2 skin. A number of studies are quoted by Choate et al. (2006) to support the view that adhering soil is mostly composed of particles less than 125 µm.

Kissel et al. (1996a) consider 150 µm could be a practical upper limit on the size of soil and dust particles to be investigated as potential sources of human exposure to environmental agents. These authors found that larger particles may be important if soil moisture is greater than 10%. Soil adherence (range for five different soils) to the palm was respectively 0.22–0.54, 0.39–3.09, and 1.64–14.8 mg/cm^2 for less than 0.1 to 9%, 10 to 19%, and 21 to 27% moisture.

Studies on soil adherence are summarised in Table 3.3.2. Soil to skin adherence has been estimated from staged (e.g. orchestrated hand presses) and un-staged (e.g. removing adhering mass from hands after normal activities) experiments. The data indicate a three order of magnitude difference (0.01–10 mg soil/cm^2 skin) for various studies and body parts (Driver et al. 1989; Holmes et al. 1999; Kissel et al. 1996a; 1996b; Lepow et al. 1975; Que Hee et al. 1985). Comparison across studies is difficult due to the variability in experimental techniques and exposure scenarios (e.g. different soil types, activities and locations and varying measurement methodology) (Ferguson et al. 2007).

A number of authorities have suggested various default soil adherence factors for residential settings (Langley and Sabordo 1996; UK Environment Agency 2009; US EPA 2004) (Table 3.3.1). However, given that soil adherence is highly dependent upon activity patterns the ‘default’ recommendations may not reflect many activity scenarios (e.g. garden maintenance worker, playing sport etc). Table 3.3.2 summarises some of the literature information.

The US EPA recommends activity-specific soil adherence factors:

- In *Risk assessment guidance for superfund, volume I* (US EPA 2004) soil adherence factors for all exposed skin are provided according to activity (Table 3.3.4).
- In the draft US *Exposure factors handbook* (US EPA 2009, Table 7–4) the adherence factors are provided for specific body areas as well as by activity (Table 3.3.5).

3.3.1 Recommendations

The average soil skin adherence of studies applicable to residential situations (summarised in Table 3.3.2) is 0.5 mg/cm^2, with an approximate 95th percentile of 1.7 mg/cm^2. It is suggested for outdoor or indoor residential scenarios these soil adherence factors be adopted for screening risk assessments for children and adults.

However, given the large variability observed across studies it is also recommended that exposure assessors use soil adherence data that match as close as possible the exposure scenario being evaluated; considerations should be given to factors such as soil type, the particular exposed body parts and activities. Assessors should refer to the study descriptions in the original references for the data contained in Tables 3.3.2 to 3.3.5 to select soil adherence values that best represent their specific exposure scenarios.

It should also be noted that the soil adherence data are skewed, with the arithmetic mean distorted by high end values. The geometric mean or median (where available) may be a better representation of the central tendency (Table 3.3.5). For example, the weighted geometric average of soil loading to children’s hands indoors is 0.01 mg/m^2 (Table 3.3.3) whereas the suggested default average for all skin and activities is 0.5 mg/m^2 (Table E7). It is for these types of variabilities (and uncertainties) that risk assessors are recommended to use specific values that best match their exposure scenarios.

Table 3.3.1: Default soil adherence factors for residential scenarios from various authorities

Agency	Soil adherence factor (mg soil/cm^2)	Comment
Child 1–5 years		
Australia (Langley and Sabordo 1996, p. 157)	0.5	In deriving Australian health-based investigation levels a soil adherence factor of 11 mg of soil per 21.5 cm^2 of skin based on the work of Hawley (1985) was used by Langley and Sabordo (1996). Consequently, it was proposed a value of 0.5 mg of soil per cm^2 skin be used in Australian risk assessments.
UK (UK Environment Agency 2009, p. 112)	1 (outdoor) 0.06 (indoor)	Indoor value is the 95th percentile in experimental studies and is consistent with the US EPA (2004). Outdoor value was chosen because it is between the US EPA (2004) 95th percentile adherence for dry and wet soil (0.4 and 3.3 mg/cm2) respectively.
USA (US EPA 2004, pp. 3–14)	0.2	Based on the 95th percentile weighted adherence factor for children playing at a day care centre and 50th percentile weighted adherence factor for children playing with wet soil.
Adult		
Australia (Langley and Sabordo 1996, p. 157)	0.5	Based on Hawley (1985) using 11 mg per 21.5 cm^2 (i.e. 1,074 mg of soil on the exposed skin).
UK (UK Environment Agency 2009)	0.3 (outdoor) 0.06 (indoor)	The value of 0.3 was based on US EPA (2004) estimate of the 95th percentile weighted adherence factor for gardeners. The UK EA (2009) assumes gardening is a typical activity.
USA (US EPA 2004, pp. 3–15)	0.07 residential adult 0.2 (adult worker)	Based on the 50th percentile weighted adherence factor for gardeners (an activity selected to represent high end soil contact). Based on 50th percentile weighted adherence factor for utility workers.

Table 3.3.2: Summary of key literature on soil adherence factors applicable to residential situations

Citation	Soil adherence factor (mg soil/cm^2)	Brief description
Hawley (1985) relied primarily upon Lepow et al. (1974; 1975) and Roels et al. (1980)	**0.5** (calculated from the mean weight of hand dirt on a 21.5 cm2 adhesive label attached to a child's hand was 11 mg).	Hawley used an estimate of soil adherence by Lepow et al. (1975) who measured the amount of soil that accumulated on adhesive tape placed on the palms of 16 male and female children (aged 2–6 years) during routine outdoor play.
Finley et al. (1994): A review of primary papers. Adults: Hartung (1977), Que Hee et al. (1985), Driver et al. (1989) Children: Roels et al. (1980), Charney et al. (1980), Gallacher et al.	Central tendency Adult: 0.49 Child: 0.63 95th percentile Adult: 1.6 Child: 2.4 For all age groups: **0.52** (arithmetic mean)	The review collated reliable data on soil adherence for children and adults in order to define a probability density function. The review concluded soil adherence is minimally influenced by age, gender, soil type and particle size. The authors concluded a standard soil adherence factor of 0.52 mg/cm^2 for all ages was applicable.

Citation	Soil adherence factor (mg soil/cm^2)	Brief description
(1984)	0.25 (50th percentile) 1.7 (95th percentile)	
Kissel et al. (1996a, Table 3)	Average of 5 soils 150–250 µm particle size: **0.34** (<2% moisture). 2.96 (12–18% moisture).	Hand-press technique onto five different soils. Particle size and moisture content varied for each soil.
Choate et al. (2006)	Mean: **0.7**. Range: 0.51–1.04.	Two soils in which particle size, moisture and carbon content were varied. Open end of container of soil placed on palm and inverted 10 times. Loose soil gently tapped off and adhered soil quantitated after removal by tape or water washing. Adult volunteers aged 18–30 years.
Ferguson et al. (2009)	Mean soil adherence to skin after transfer from: Carpet: **0.37** Aluminium: **0.42**	Computer-controlled mechanical chamber designed to control contact pressure and time of adult cadaver skin to nylon carpet or aluminium sheet that had been loaded with soil. The experimental design approximates transfer of soil/dust from a rough and smooth indoor surface to skin. Skin was obtained from chin, ankle, forehead, cheek, neck, arms, chest abdomen and thighs but data were pooled for all skin.
Average (rounded) of bolded mean values	**0.5**[a]	
95th percentile (from Finley et al. 1994)	**1.7**[b]	

This average of mean values from several studies has been brought forward as a suggestion for use in screening risk assessments, and is applicable for assessing outdoor and indoor residential child and adult exposure. However, it is also recommended that exposure assessors use soil adherence data derived from testing that matches as close as possible the exposure scenario being evaluated. For soil adherence factors for specific activities see Tables 3.3.3, 3.3.4, and 3.3.5.

95th percentile soil adherence values were only available from the review conducted by Finley et al. (1994). The 95th percentile for all age groups (1.7 mg soil/cm^2) was brought forward as a suggested 95th percentile value for assessing outdoor and indoor residential child and adult exposure in Australian screening risk assessments.

Table 3.3.3: Activity specific soil adherence factors (mg/cm^2) to children's skin by body part

Activity	Face	Arms	Hands	Legs	Feet	Comment/assumptions
Residential indoors	–	0.0041	0.011	0.0035	0.010	Weighted average of geometric mean soil loadings for children (*n* = 10, 2 groups) 3–13 yrs. Holmes et al. (1999)
Daycare (indoor + outdoor)	–	0.024	0.099	0.020	0.071	Weighted average of geometric mean soil loadings for children (*n* = 10, 4 groups) 1–6.5 yrs playing both indoors and outdoors. Holmes et al. (1999)
Outdoor sports	0.012	0.011	0.11	0.031	–	Geometric mean soil loadings of 8 children (13–15 yrs) playing soccer. Kissel et al. (1996b).
Indoor sports	–	0.0019	0.0063	0.0020	0.0022	Geometric mean soil loadings for six children ≥8 yrs and 1 adult engaged in tae kwon do. Kissel et al (1996b).
Activities with soil	0.054	0.046	0.17	0.051	0.20	Geometric mean soil loadings for gardeners and archeologists (16–35 yrs). Holmes et al. (1999)
Playing in mud	–	11	47	23	15	Geometric mean soil loading of 9–14 yrs children (*n* = 12, 2 groups) playing in mud. Kissel et al. (1996b)

Data from US EPA (2008 Table 7-4, pp. 7–8)

Table 3.3.4: Activity specific, surface area weighted soil adherence factors (AF)

		Weighted soil adherence factor (mg/cm^2)	
Exposure scenario	**Age (years)**	**50th percentile**	**95th percentile**
Children[a]			
Indoor children	1–13	0.01	0.06
Day care children (playing indoors and outdoors)	1–6.5	0.04	0.3
Children playing (dry soil)	8–12	0.04	0.4
Children playing (wet soil)	8–12	0.2	3.3
Children in mud[e]	9–14	21	231
Residential adults[b]			
Groundskeepers	>18	0.01	0.06

Exposure scenario	Age (years)	Weighted soil adherence factor (mg/cm^2)	
		50th percentile	95th percentile
Landscape/rockery	>18	0.04	0.2
Gardeners	>16	0.07	0.3
Commercial/industrial adults[c]			
Groundskeepers	>18	0.02	0.1
Landscape/rockery	>18	0.04	0.2
Staged activity: pipe layers (dry soil)	>15	0.07	0.2
Irrigation installers	>18	0.08	0.3
Gardeners	>16	0.1	0.5
Construction workers	>18	0.1	0.3
Heavy equipment operators	>18	0.2	0.7
Utility workers	>18	0.2	0.9
Staged activity: pipe layers (wet soil)	>15	0.6	13
Miscellaneous Activities [d]			
Soccer players #1 (teens, moist conditions)	13–15	0.04	0.3
Soccer Players #2 (adults)	>18	0.01	0.08
Farmers	>20	0.1	0.4
Rugby players	>21	0.1	0.6
Archaeologists	>19	0.3	0.5
Reed gatherers	>22	0.3	27

Data from US EPA (2004 Exhibit 3-3, p. 3–15 adapted from–Table IV).
Weighted AF for face, forearms, hands, lower legs and feet.
Weighted AF for face, forearms, hands and lower legs.
Weighted AF for face, forearms and hands.
Weighted AF based on all exposed body parts for which data were available.

Information on soil adherence values for the children-in-mud scenario is provided to illustrate the range of values for this type of activity and the US EPA do not recommended the 95th percentile AF values be used in a quantitative dermal risk assessment.

Table 3.3.5: US EPA recommended values for mean soil adherence to skin (mg/cm^2)

	Soil adherence by body part (mg/cm^2)[a]				
	Face	**Arms**	**Hands**	**Legs**	**Feet**
Children					
Residential (indoors)	–	0.004	0.01	0.004	0.01
Daycare (indoors and outdoors)	–	0.02	0.10	0.02	0.07
Outdoor sports	0.01	0.01	0.1	0.03	–
Indoor sports	–	0.002	0.006	0.002	0.002
Activities with soil	0.05	0.05	0.2	0.05	0.2
Playing in mud	–	11	47	23	15
Playing in sediment	0.04	0.2	0.5	0.7	21
Adults					
Outdoor sports	0.03	0.09	0.1	0.1	–
Activities with soil	0.02	0.04	0.2	0.02	0.1
Construction activities	0.10	0.2	0.3	0.07	–

Rounded data from US EPA (2009, Table 7–4)

Data are primarily geometric mean or weighted average of geometric mean, soil loading for various age groups. For sample numbers and individual age groups, consult the footnotes in US EPA (2009, Table 7–4).

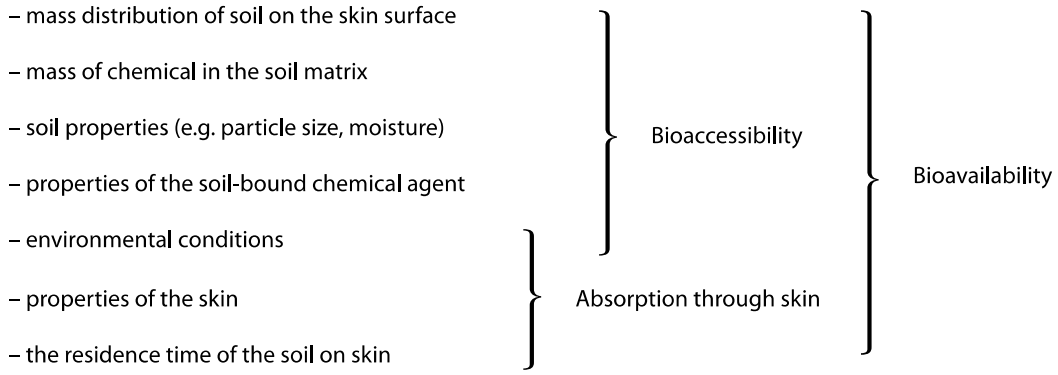
3.4 Dermal bioavailability

See also section 4.1 on oral bioavailability.

Bioavailability is the fraction of a chemical dose absorbed by an organism that reaches the circulatory system (Ruby et al. 1999). The intake of a chemical via skin is dependent on its bioaccessibility (i.e. what proportion of the chemical in the soil is available for uptake) and how easily the free chemical is absorbed through the skin. Together, the bioaccessibility and absorption determine the overall bioavailability. In some jurisdictions this is called the dermal absortion factor when dermal exposure calculations are undertaken. The overall extent of chemical intake through skin is approximately proportional to the soil concentration in the mono-layer adhered to skin (Paustenbach 2000; US EPA 1992a).

Thus, bioavailability = bioaccessibility x absorption

Note that after oral ingestion, clearance of chemicals by the liver also determines bioavailability. Although this section discusses bioavailability from soil, the principles pertain to any environmental medium containing chemicals. Some factors that influence bioavailability are listed below.



For inorganic compounds it is particularly important to consider the form of the compound present in soil when calculating bioavailability because different forms can have starkly different absorption. Substances in weathered soil may be sequestered differently compared with freshly spiked soil (e.g. Juhasz et al. 2008; Lowney et al. 2007; Smith et al. 2008; White et al. 1997).

The overall dermal bioavailability from soil should be chosen on a chemical-specific basis following a review of the scientific literature by the risk assessor. The US EPA has published default dermal bioavailability factors for 23 chemicals (US EPA 2004). These values are presented in Table 3.4.1, the relatively few values reflect a paucity of scientific literature on the subject. Table 3.4.1 also includes default absorption values from soil recommended by regulatory authorities.

The US EPA (2004) uses a default dermal absorption fraction of 10% for semi-volatile organic compounds in soil. The UK Environment Agency (UK EA) uses 10% as a default for all organic compounds (UK EA 2009). The European Chemicals Bureau *Technical Guidance Document on Risk Assessment* (ECB 2003, pg. 269) also provides a default of 10% dermal absorption for all organic chemicals.

Default bioavailability values for inorganic compounds are not provided by US EPA (2004) due to insufficient data and dependence on speciation. The UK and Netherlands on the other hand use a default bioavailability factor of 0% for inorganic compounds in soil. (It is noted that scientific justification is not provided, see UK EA 2009, p. 113 and RIVM 2007, p. 19.)

Tables 3.4.1 and 3.4.2 provide snapshots of some literature values available for dermal absorption (i.e. bioavailability) from soil.

Table 3.4.3 lists the assumptions used for dermal bioavailability when soil health investigation levels (HILs) have been set for inorganics in Australia. It is apparent that dermal uptake of metals from soil has been historically regarded as being very low, approaching 0%. However, this supposition has usually not been based on empirical data.

Table 3.4.1: Some dermal bioavailability values from soil

Compound	Bioavailability	Reference
Arsenic	0.03[a]	Wester et al. (1993a)
Cadmium	0.001[a]	Wester et al. (1992a), US EPA (1992a)
Chlordane	0.04	Wester et al. (1992b)
2,4–Dichlorophenoxyacetic acid	0.05	Wester et al. (1996)
DDT	0.03	Wester et al. (1990)
TCDD and other dioxins – where soil organic content is >10%	0.03 0.001	US EPA (1992b)
Lindane	0.04	Duff and Kissel (1996)
Benzo(a)pyrene and other PAHs	0.13	Wester et al. (1990)
Aroclors 1254/1242 and other PCBs	0.14	Wester et al. (1993b)
Pentachlorophenol	0.25	Wester et al. (1993c)
Semi-volatile organic compounds without experimental data for bioavailability from soil.	0.1	US EPA default (US EPA 2004)[b]
Organic compounds without experimental data for bioavailability from soil.	0.1	UK Environment Agency default (UK EA 2009)
Inorganic compounds	0	Default used by UK Environment Agency default (UK EA 2009) and Dutch National Institute for Public Health and Environment (RIVM 2007)

Data from US EPA (2004, Exhibit 3–4, pp. 3–16).

Soluble forms freshly mixed with soil.

For inorganic compounds, US EPA (2004) state a reasonable default value cannot be provided because speciation state is critical to the bioavailability of inorganics and there are too little data on dermal bioavailability of inorganics from soil.

Table 3.4.2: Some literature values and experimental information[a] for dermal bioavailability of substances from soil

Chemical	Soil type and load[b]	Experimental details	Fraction absorbed from soil (%)	Citation
Ni^{63}	Commercial garden soil, 63% om, 90–70µm, 5 mg/cm^2	*In vitro* human breast, tissue at 32oC for 24 hours at 6 µg Ni/gm soil.	1	Moody et al. (2009)
Hg^{203}			47	
Ni^{63}	Sandy soil, 2% om, 50–250µm, 47 mg/cm^2	*In vitro* pig abdomen tissue, 32°C for 16 hours at 4 µg Ni/gm soil.	12	Turkall et al. (2008)
Hg^{203}			38	
Hg^{203}	Loam soil, 2%om, size NS, 42 mg/cm^2.	*In vitro* human abdomen, tissue at 32°C for 72 hours at 0.002 to 0.032 ng Hg/gm soil.	11	Sartorelli et al. (2003)
Mercury [c]	Soil from Yolo County CA, 1% om, <180µm, ca 40 mg/cm^2	*In vitro* human cadaver skin (anatomical site not specified) for 24 hours.	8	Wester and Maibach (2005)
PCBs (^{14}C–Aroclor 1260)	Sandy silt 20% sand (80–2000 µm), 54% silt (5–80 µm), and 20% clay (<5 µm) with total oc 5–6%.	*In vivo*: Four groups of four female rhesus monkeys exposed for 12 or 24 hours to PCBs aged in soil, or 24-hour exposure to soil freshly spiked with PCBs. Organic content typical for US soil.	4[d]	Mayes et al. (2002)
PCBs (^{14}C–Aroclor 1260)		*In vivo*	14[d]	Wester et al. (1993b)
As	Residential soil, Denver Colarado[e] 1230 mg As/kg dry and wet soil.	*In vivo*: female rhesus monkeys, approximately 20 years old (*n* = 3 or 4). Dose applied to 100cm2 of abdominal skin and occluded for 8 hours. Arsenic absorption calculated on urinary excretion of total arsenic.	0.24 (dry) 0.5 (wet)	Lowney et al. (2007)
As	New York Pesticide facility[f] 1400 mg As/kg dry and wet soil.		0.18 (dry) 0.39 (wet)	

This Table is only intended to provide a guide to variability and type of key experimental details to be considered; it is not a comprehensive literature review of dermal absorption from soil for any individual compound.

Includes percentage organic matter (om), particle size range (µm), and soil load (mg/cm^2), organic carbon (oc).

Mercury form not specified.

Mayes et al. 2002 postulated the difference between Wester et al's 1993b estimate of 14% and their estimate of 4% was due to removal of the silt and clay fraction from soil by Wester et al. (1993b) eliminating organic binding sites usually occupied by PCBs; this increases the fraction of unbound PCBs available for percutaneous absorption.

Soil collected from an area with historical application of arsenic trioxide (25%) and lead arsenate (8%) containing pesticide.

Soil collected from top 15 cm at site that had formerly produced inorganic arsenical pesticides.

Table 3.4.3: Assumed dermal bioavailability of inorganic metals historically used to set soil health investigation levels in Australia

Inorganic compound	Assumed bioavailability	Comment	Source
Lead	None provided.	States primary sites of absorption are lungs and intestinal tract. Does not discuss dermal absorption.	Maynard (1991)
Arsenic	1%	Assumed absorption through skin from soil will be 1% in 24 hours.	Langley (1991a)
Cadmium	0.1%	Assumed absorption of cadmium in soil through skin based on a study using soluble Cd compounds showing an absorption of 1.8% in 5 hours in guinea pigs, 0.4–0.6% in 3 weeks for rabbits, and 0.2–0.8% in 1 week for mice.	Langley (1991b)
Beryllium	0	Stated transdermal absorption of beryllium is unlikely. Dermal pathway not included in HIL derivation.	Di Marco and Buckett (1996).
Manganese	0	Stated absorption through skin is not considered to occur to any great extent. The HIL derivation does not include dermal uptake.	Lindon and Sabordo (1996).
Mercury	1% (elemental)	Dermal uptake from soil was not considered in the calculation of a HIL. Hg^{++} dermal absorption considered insignificant.	Imray and Neville (1996a)
Nickel	0%	Dermal absorption considered negligible.	Turczynowicz and Sabordo (1996)
Zinc	0%	Stated direct dermal absorption of zinc from soil would be very low. Not included in HIL derivation.	Imray and Neville (1996b)
Cobalt and cobalt compounds	0%	In the absence of specific information the dermal absorption of cobalt was assumed to be zero in the calculation of the HIL.	Buckett and DiMarco (1998)
Boron and boron compounds	1%	Dermal absorption across abraded skin in an oil based vehicle. Authors note that dermal absorption across intact skin is assumed to be very low.	Mangas (1998)

3.4.1 Bioaccessibility

For a chemical to be absorbed into the systemic circulation it must be in a form available for uptake. For absorption to take place a degree of desorption or dissociation from the medium in which it is present is required, the degree that this can occur is termed the substance's bioaccessibility from the medium (UK EA 2003). For soil, therefore, the bioaccessible fraction represents the amount of contaminant partitioned from the soil that is available for absorption (i.e. not tightly bound).

Inorganic substances (i.e. metals) occur in soil as a complex mixture of solid phase compounds of varying particle size and morphology. These compounds may include discrete mineral phases, co-precipitated and sorbed species associated with soil minerals or organic matter, and dissolved species that may be complexed by a variety of organic and inorganic ligands (Juhasz et al. 2008; Ruby et al. 1999). A substance's dissolution properties (and, hence, its bioavailability) is therefore largely dependent on the nature of associations within/between these phases. The bioaccessible fraction of a given compound can vary considerably between different soils and chemicals.

A default bioaccessibility factor (called a matrix factor) of 0.15 is used by the Dutch National Institute for Public Health and the Environment (RIVM) to calculate dermal intake of chemicals from soil (RIVM 2007, p. 30). The factor is based on a description of a study (Poiger and Schlatter 1980) by Hawley (1985, p. 293). The study investigated the influence of solvents and inert matrices on dermal and gastrointestinal absorption of TCDD by rats. When TCDD was applied to skin in a methanol vehicle 14.8% of the dose was found in the liver (the initial organ of sequestration). The highest proportion found in liver following application to skin of a soil–water paste containing various amounts of TCDD was 2.2%. The effect of the soil matrix was therefore to reduce absorption to 15% of that which occurred in the absence of soil (2.2 ÷ 14.8). Hawley (1985) and RIVM (2007) use this proportion (0.15) as a default bioaccessibility factor when calculating dermal intake of any chemical from soil or dust, even though it is acknowledged the value is likely to vary from substance to substance.

Leachate tests are often performed on contaminated soils. Knowledge of the mass of soil used in the test, the substance concentration in soil, together with the volume of leachate and concentration of substance in the leachate allows calculation of the proportion of substance removed from the soil during the test. This may be used as a crude estimate of bioaccessibility in screening risk assessments. There is an Australian standard for conducting leachate tests (AS 4439.3-1997). The information is, however, more relevant if the leaching solute is representative of the biological medium: sweat for dermal bioaccessibility and gastrointestinal fluids for oral bioaccessibility (discussed further in section 4.0).

3.4.2 Dermal absorption

There have been many studies that have investigated dermal absorption of neat chemicals (or chemicals dissolved in solvent) through skin (Buist et al. 2009; Kezic and Nielsen 2009; Sample 2004). Absorption data specific for the substances being investigated, or structurally similar compounds, should be sought.

Adopting an absorption (bioavailability) factor from reported experiments requires careful consideration of the experimental conditions under which the data were obtained. Important factors to consider include (European Food Safety Authority 2004; Moody et al. 2009; UK EA 2009, p. 113):

- Form of the chemical tested.
- Contact times.
- Test species. Inter-species skin differences are well documented (Bartek et al. 1972; Bronaugh and Maibach 1987; Bronaugh et al. 1990; Feldman and Maibach 1970; Maibach and Wester 1989). According to Brandau and Lippol (1982) skin permeability across the species is in the following order: rabbit > rat > guinea pig > mini-pig > rhesus monkey > man.
- Skin location. The extent of chemical absorption through skin differs with the location of the skin (McDermott 2004; Wester et al. 1984). Human skin for *in vitro* experiments is usually abdomen, breast or foreskin, while skin from animals is commonly from the flank and back (rat), or flank and ear (pig).
- *In vitro* or *in vivo*. In *in vitro* experiments the blood vessels and nerve fibres in the excised skin are not functional. Three types of skin membranes can be prepared for *in vitro* experiments: epidermal membranes (thickness of approximately 0.1 mm, prepared by heat, chemical or enzymatic separation), split-thickness skin (0.2–0.5 mm thick prepared with a dermatome) and full-thickness skin (0.5–1.0 mm). Since the main barrier function of the skin is located in the stratum corneum, all three skin preparations have been used for absorption studies. It should be noted that with full-thickness skin, lipophilic compounds may be retained in the dermis instead of entering into the receptor fluid. On the other hand, the thinner epidermal membranes are more fragile and sometimes overestimate human *in vivo* skin absorption (Van de Sandt et al. 2000).

The OECD have published a standard *in vitro* method for dermal absorption of neat chemicals (OECD 2004); however, standardised *in vivo* or *in vitro* methods for bioaccessibility and/or overall bioavailability of chemicals from soil are not available.

Care should be exercised when using *in vitro* data. Particular attention needs to be given to the analytical methods used for estimating the parent compound in excreta and tissues (radiolabel methods may be measuring metabolites as well as parent compound). Mass balance calculations should be done to determine how much of the applied dose can be accounted for in the analyses. Compound that is sequestered in skin is often assumed by regulatory agencies to be absorbed material contributing to bioavailability calculations, even though it has not entered the systemic circulation. This is because it is envisaged to represent a depot of material that may eventually be systemically absorbed.

Because full-term newborns have a well-developed stratum corneum, it is generally regarded that the dermal permeability of full-term newborns and older children is not materially different from adults (Ginsberg et al. 2004; US EPA 1992a, pp. 2–19; European Union Scientific Committee on Cosmetic Products and Non-Food Products Intended for Consumers – EU SCCNFP 2002). According to Ginsberg et al. (2004) this has been shown with *in vitro* test systems for trichlocarban (Wester et al. 1985), phenobarbital (Bonina et al. 1993), lidocaine (Barrett and Rutter 1994) and phenylephrine (Harpin and Rutter 1983).

3.4.3 Recommendations

The risk assessor is expected to seek information that will allow meaningful consideration of bioaccessibility/bioavailability when quantitating the amount of substance in environmental media that may be absorbed through the skin. Documentation of efforts to obtain such data should be included in the risk assessment.

Assessment-specific tests that incorporate both bioaccessibility and absorption phases of bioavailability (e.g. dosing animals with soil containing the chemical and determining the amount absorbed into the systemic circulation) are encouraged. Published bioavailability data for the substance from the generic environmental medium (soil, dust, food) may be used if justification is provided by the risk assessor.

A generic default bioaccessibility factor to account for absorption retardation of chemicals by soil or other environmental media is not recommended as it depends on factors that are risk assessment specific. However, it is suggested for soil that appropriate leachate tests conducted with solute representing the biological fluid of interest may be used in screening risk assessments as a surrogate estimate of bioaccessibility. For organic compounds, if a bioaccessibility factor cannot be justified, then the conservative[7] default is to assume 100% of the substance in the environmental media is bioaccessible.

Dermal absorption factors of neat or dissolved organic substances through skin (for use with bioaccessibility factors when calculating overall absorption from environmental media) are substance specific. Data for structurally similar compounds may be used if robustly justified. If an absolute absorption factor cannot be justified, then the conservative default is to assume 100% of the substance in the environmental media is absorbed.

Therefore, for **organic chemicals** the defaults of 1.0 for both bioaccessibility and neat substance absorption translate into a **default of 100% (1.0) for dermal bioavailability** from the environmental media.

For inorganic substances in soil a default dermal bioavailability factor of 0.01% (0.0001) is suggested when substance specific data are not available and a different value cannot be justified. This is based on the rationale, commonly used to set existing Australian soil HILs for inorganic substances, that inorganic compounds have negligible absorption through intact skin. This is consistent with the default bioavailability of zero per cent for inorganic substances from soil used by the UK Environment Agency (UK EA 2009, p. 113) and the Dutch National Institute for Public Health and Environment (RIVM 2007, p. 19). For practical purposes the value of 0.01% is considered negligible.

The default value for bioaccessibility is not recommended since this can be readily approximated from a suitable leachate test.

[7] In this context, conservative is intended to imply a cautious approach to evaluating and managing the uncertainties inherent in a risk assessment, that reduces the probability of harm occurring.

3.5 Dermal exposure during bathing and showering

Bathroom water uses dominate personal exposure to waterborne contaminants of individuals in the home. Therefore an understanding of population water-use behaviour for bathroom activities is important to inform exposure estimates. Water use is a function of (Wilkes et al. 2005):

- shower and bath frequency
- shower and bath duration
- shower volume and flow rate
- bath volume.

3.5.1 Shower and bath frequency

3.5.1.1 Australian data

Australian studies on shower and bath frequencies were not located. However, not withstanding a higher propensity for water saving and installation of showers heads in Australia to achieve this, the Australian distribution for shower/bath frequency is likely to be approximately similar to that in the US.

3.5.1.2 Overseas data

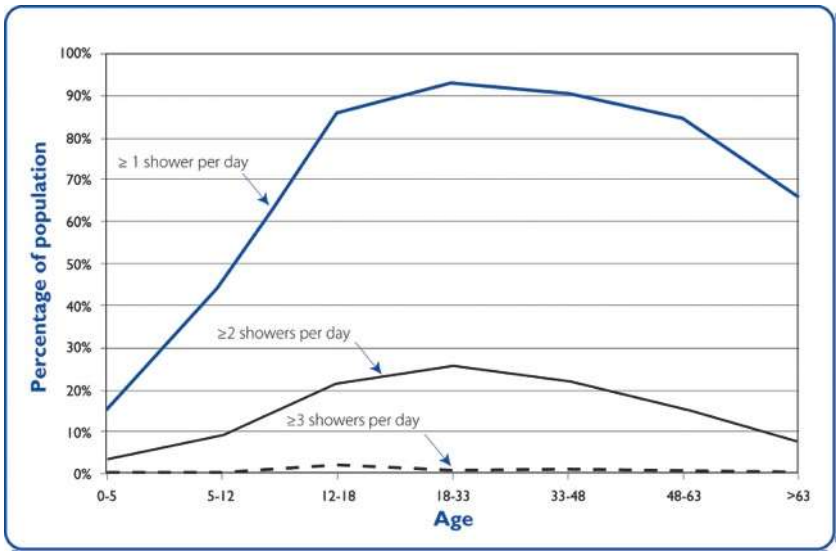
Wilkes et al. (2005) reviewed available US studies on shower and bath frequency and state the most reliable study for this parameter, the US National Human Activities Pattern Survey (NHAPS), estimates 78% of the population took at least one shower in a given day. From Figure 3.5.1(a) it appears about 90% of people aged 12–63 years have at least one shower per day.

Bathing frequency depends on age and is inverse to that for showering. According to the NHAPS data summarised in Wilkes et al. (2005), approximately 90% of newborns have at least one bath per day while less than 20% of adolescents (aged over 12) and adults have one or more baths per day (Figure 3.5.1b).

The US EPA (1997 Table 15–176; 2009 Table 16–27) recommend a value of **one shower per day** based on the same dataset described by Wilkes et al. (2005).

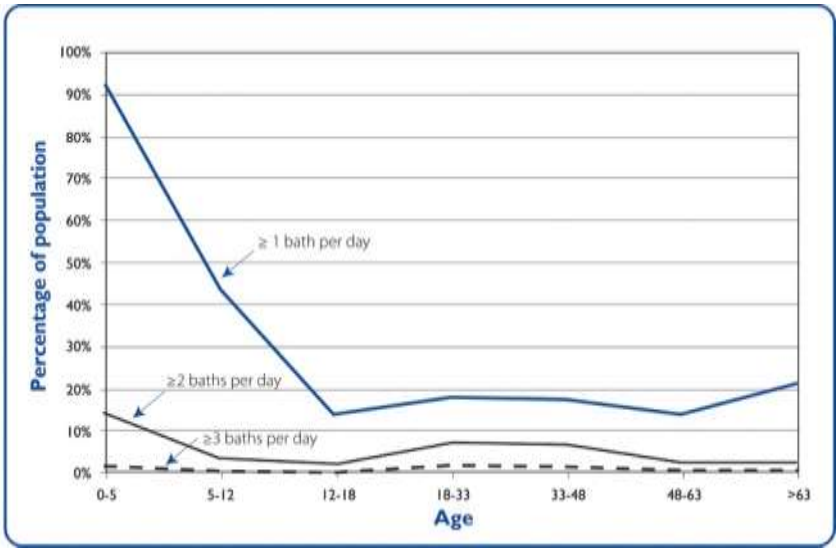
A value of one shower or bath per day has been brought forward as the suggested value (central estimate) for use in Australian screening risk assessments (Section 3.5.5). From Figures 3.5.1(a) and 3.5.1(b), about 5–25% and 5–15% of the population (depending on age group) take 2 showers or baths per day, respectively. A reasonable upper estimate is therefore **two showers or baths per day**.

Figure 3.5.1a: Mean showering frequency as a function of age, NHAPS



Source: Wilkes et al. 2005. Reproduced with permission from John Wiley and sons

Figure 3.5.1b: Bathing frequency (self-taken or given to another) as a function of age, NHAPS



Source: Wilkes et al. 2005. Reproduced with permission from John Wiley and sons

3.5.2 Shower and bath duration

3.5.2.1 Australian data

A study of domestic water use in Perth during the year 1981 to June 1982 by the WA Water Authority[8] included a study of water usage for each in-house activity including showers (but not baths). The Western Australian Domestic Water Use Study (WA Water Corp. 2003) estimated an average shower duration of 7 minutes (Table 3.5.3).

US EPA (1997, Table 15–4) cite James and Knuiman (1987), also a Western Australian study, and provide numerical data, not available in the original publication. The median, average and 95th percentile shower durations were approximately 7, 8 and 16 minutes respectively. Table 3.5.1 and Figure 3.5.2 summarise the findings of the study.

The Australian median and average (7 and 8 minutes) for shower duration are consistent with the US REUWS (Residential End Uses of Water Study) dataset values of 6.8 and 7.6 respectively (Wilkes et al. 2005).

Average and 95th percentile values for shower duration of 8 and 16 minutes, respectively, have been brought forward as the suggested values for use in Australian screening risk assessments (Section 3.5.5).

[8] The study has been updated (WA Water Corp. 2003) however the frequency/duration of showering component does not appear to have been repeated.

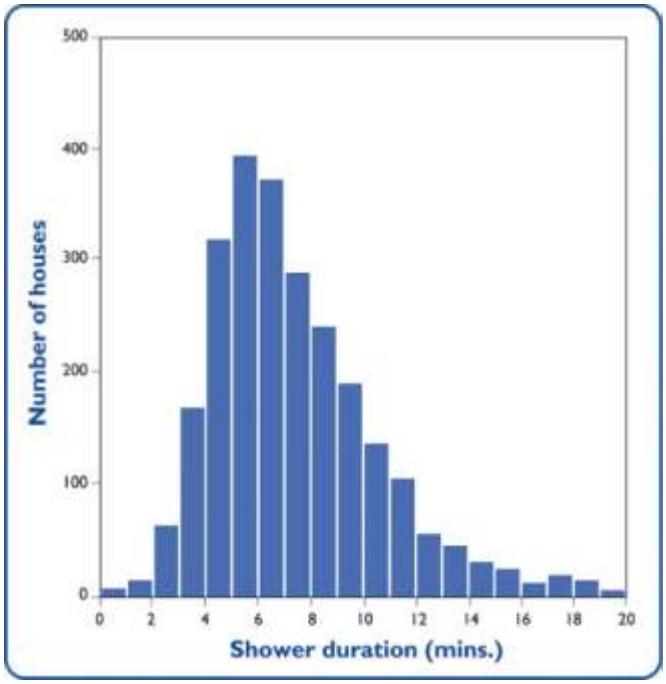
Table 3.5.1: Cumulative shower frequency distribution of average shower duration for 2,550 households

Shower duration (minutes)	Cumulative frequency (%)
1	0.2
2	0.8
3	3.1
4	9.6
5	22.1
6	37.5
7	51.6
8[a]	62.5
9	72.0
10	79.4
11	84.5
12	88.4
13	90.6
14	92.3
15	93.7
16[a]	94.9
17	95.7
18	96.7
19	97.6
20	98.0
<20	100.0

Information from US EPA (1997, Table 15-4) describing Australian data from James and Knuiman (1987) not available in the original publication.

These are the approximate average (8 mins, see text) and 95th percentile (16 mins) shower durations and have been brought forward as suggested values for use in Australian screening risk assessments (Section 3.5.5).

Figure 3.5.2: Distribution of adjusted average shower duration for 2,500 households



Source: James and Knuiman 1987. Reprinted with permission from the Journal of the American Statistical Association. Copyright 1987 by the American Statistical Association. All rights reserved.

3.5.2.2 Overseas data

The US EPA (1997, Table 15–176) recommended an activity factor of 10 minutes per day for showering duration based on an evaluation of the National Human Activities Pattern Survey (NHAPS) database. Since then the REUWS database has been produced and assessed by Wilkes et al. (2005). For shower duration, the REUWS database was recommended by these authors because it was based on actual water usage as measured by household water meters. The Australian median and average (7 and 8 minutes) for shower duration (Section 3.5.2.1) are consistent with the US REUWS dataset values of 6.8 and 7.6 minutes respectively (Wilkes et al. 2005).

The REUWS database is compiled from information gathered by modified residential water meters, which provided data on the time it took to fill a bathtub, but not on how the long a person bathed, nor any time lag between drawing bath water and bathing. Therefore, Wilkes et al. (2005) were unable to deduce bath duration from the REUWS database. Instead they summarise the most recent self-reported US NHAPS data on bath duration and, using a log-normal distribution, estimate an overall geometric mean of 17.6 minutes (geometric standard deviation 0.634 minutes) and an arithmetic mean of 21 minutes (a standard deviation for the arithmetic mean was not provided) (Table 3.5.2). Upper estimates were not provided.

Table 3.5.2: Summary of bathing duration in the United States

Age group	Geometric mean (minutes)	Geometric SD	Arithmetic mean (minutes)
0–18 years	19.5	0.58	22.5
18–48 years	17.5	0.65	21.1
>48 years	15.0	0.66	18.3
Overall	17.6	0.63	**20.9**[a]

Rounded data from Wilkes et al. (2005, Table VI)

Average bath duration for all age groups (20.9 min) was rounded to 21 min and brought forward as the suggested value for use in Australian screening risk assessments (section 3.5.5).

3.5.3 Shower volume and flow rate

3.5.3.1 Australian data

Table 3.5.3 provides average estimates of shower volume (per shower and per day), shower duration and flow rate for Western Australians. The data are presented for two types of showers: conventional normal flow and water-efficient shower roses, and by type of residence (WAWC 2003, Table 5.2, p. 22). Upper estimates were not available.

The data presented by WAWC (2003) are consistent with the average shower flow rate distribution developed by James and Knuiman (1987, Figure 3.5.3).

3.5.4 Bath volume

No quantitative survey information was available for bath volume (James and Knuiman 1987; US EPA 1997, 2009; WAWC 2003; Wilkes et al. 2005).

3.5.5 Recommendations

Dermal surface area while showering, bathing and swimming:

The mean and 95th percentile total surface areas (m^2) suggested for use in Section 3.2.4 may be used for the purposes of whole-body immersion bathing assessments.

Suggested default values for showering and bathing:

Table 3.5.4 summarises the suggested default values for use in bathing scenarios.

Values for shower and bath frequency as well as bath duration are based on US data from the analysis of Wilkes et al. (2005) (Sections 3.5.1 and 3.5.2). The available Australian data (James and Knuiman 1987) described by US EPA (1997) and WA Water Corporation (WAWC 2003) indicate shower durations are 7–8 minutes long. Assuming a water flow rate of 9 L/min (WAWC 2003) the average amount of water used per shower event is 63–72L (these are higher than reported by WAWC 2003). The upper end of these mean values (72 L) is suggested for use in Australian screening risk assessments. For shower duration a 95th percentile value of 16 minutes is suggested from Australian data described by US EPA (1997) (Sections 3.5.2 and 3.5.3). Upper estimates for shower volume, flow rate and bath duration were not available.

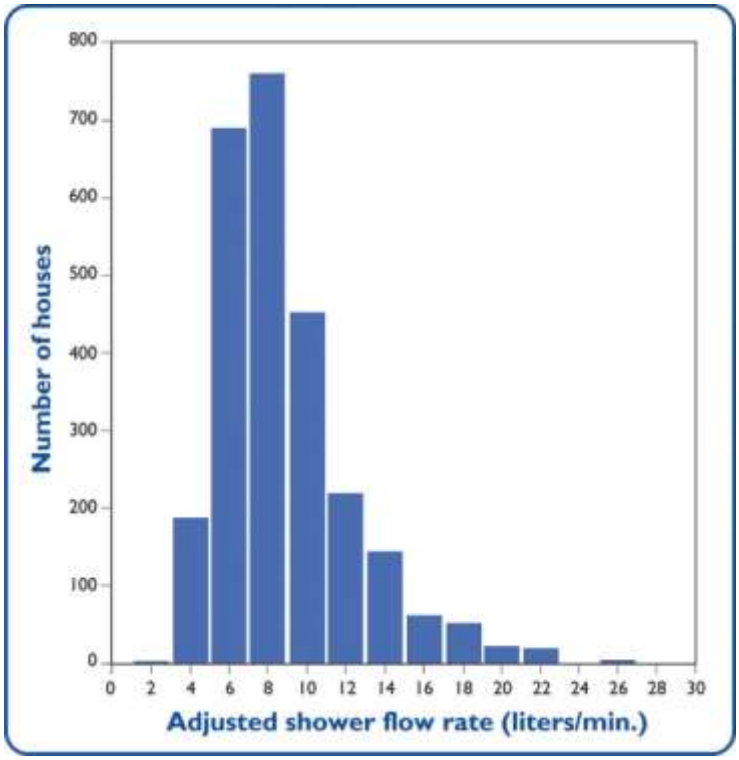
Table 3.5.3: Shower water usage by people in Western Australia

Type of residence	Shower type	L/day	L/shower	Min/ shower	L/min
Single residential	Normal flow	152	60	7	**9**[a]
	Water efficient	135	48	7	7
Multi-residential	Normal flow	113	64	7	**9**[a]
	Water efficient	110	58	7	8

WAWC (2003, Table 5.2 p. 22). Reproduced with permission from Water Corporation WA.

Average shower flow rate of 9L/min recorded in this study was brought forward as the suggested value for use in Australian screening risk assessments (Section 3.5.5).

Figure 3.5.3: Shower flow rate



Source: James and Knuiman 1987. Reprinted with permission from the Journal of the American Statistical Association. Copyright 1987 by the American Statistical Association. All rights reserved.

Table 3.5.4: Suggested values for showering and bathing

Parameter	Value	Internal reference
Shower and bath frequency per day	1 (central estimate) 2 (upper estimate)	Section 3.5.1
Shower duration (mins)	8 (average) 16 (95th percentile)	Section 3.5.2
Shower volume (L)	72	Section 3.5.3
Flow rate (L/min)	9	
Bath duration (mins)	21	Section 3.5.2
Bath volume (L)	Insufficient data	Section 3.5.4

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4. Estimating intake from ingestion

4.1 Oral bioavailability

In the absence of specific data it has been common practice[9] to conservatively assume the oral bioavailability of a chemical from environmental media will be at least the same as the bioavailability of the chemical in the human or animal studies underlying the derivation of the guideline value (UK EA 2009a; US EPA 2007b).

Oral bioavailability (absolute bioavailability) is defined as the fraction of an orally administered dose of chemical that reaches the systemic circulation (RIVM 2009; CRC CARE 2010).

The term relative bioavailability refers to a comparison of absolute bioavailabilities. This is the ratio of the bioavailability of a substance in one exposure context (e.g. the chemical in environmental media) to that in another exposure context (commonly the chemical administered in a convenient dosing vehicle in an experimental study).

Many substances are able to tightly bind to environmental matrices such as soil or sediment. The bioavailability of the substance from the media consists of two major processes:

- *Bioaccessibility:* This is the amount of contaminant released from the media (e.g. during digestion in the gastrointestinal tract) that is available to be absorbed (i.e. the unbound fraction). Given the fact that bioaccessibility is one of the principal factors limiting the bioavailable fraction, quantifying it can be important for health-based risk assessment. The solubility of the substance in gastrointestinal media markedly influences its bioaccessibility.
- *Absorption:* Usually only part of the bioaccessible fraction is transported across the intestinal epithelium and to reach the systemic circulation. This is the absorbed fraction.

Estimates of bioaccessibility and overall bioavailability (i.e. bioaccessibility plus absorption) can be determined from experimental studies: *in vitro* systems mimicking biological conditions for bioaccessibility and *in vivo* (whole animal) models for bioavailability.

The processes of bioaccessibility and absorption affect the bioavailability of all chemicals from environmental media but are of special importance for metals. This is because metals can exist in a variety of chemical and physical forms, and not all forms of a given metal are absorbed to the same extent. For example, a metal in contaminated soil may be absorbed to a greater or lesser extent (but generally somewhat lesser) than when ingested in drinking water (US EPA 2007b).

This section provides a brief overview of currently available test systems for relative oral bioavailability and their validation (Table 4.1.1, Figures 4.1.1–4.1.2).

The US EPA (1989) and UK EA (2009a) allow deviation of the general default of 100% relative bioavailability on a case-by-case basis when data from whole animal bioavailability or *in vitro* bioaccessibility studies are available (US EPA 2007b; 2009b; UK EA 2009a).

Historically, bioavailability has been estimated based on either:

- experimental animal models,
- validated toxicokinetic models, or
- human studies.

Methods for assessing *in vivo* bioavailability are generally complex, slow and expensive (NRC 2003; Ruby et al. 1999: US EPA 2007b). This limits situation specific derivation of *in vivo* bioavailability in many Australian risk assessments. *In vitro* bioaccessibility testing on the other hand can be simple, rapid and relatively inexpensive.

Juvenile swine are arguably the most applicable animal model for *in vivo* bioavailability testing because of their physiological similarity to the human gastrointestinal tract (Bruce et al. 2007; NRC 2003; Ruby et al. 1999; US EPA 2007a; CRC CARE 2010).

[9] The derivation of Australian soil health investigation levels (HILs) for many compounds including lead (Pb), arsenic (As), mercury (Hg), zinc (Zn), boron (B) and polycyclic aromatic hydrocarbons have, in the past, assumed 100 per cent bioavailability (Imray and Neville 1996a,b; Langley 1991a, b; Mangas 1998; Maynard 1991). With the exception of arsenic and lead, the latest draft update of the HILs (NEPC 2010) assumes bioavailability of all contaminants is 100%. For lead and arsenic oral bioavailability is conservatively assumed to be 50 and 70%, respectively, from soil/dust.

Guidance on possible validation strategies for *in vitro* bioaccessibility studies is available from the US EPA (2007a), the NIEHS (1997) and the NRC (2003). In general, validation can be achieved by demonstrating that a method is reliable and relevant for its proposed use. Underlying the validation process is establishing a dependable correlation between *in vivo* bioavailability testing and the *in vitro* test system and/or assessment of the reproducibility and variability of the test system between samples and between different laboratories.

Recently, the US EPA published a standard operating procedure for an *in vitro* bioaccessibility assay (IVBA) for lead (Pb) that can be used for site-specific risk assessment of Pb in soil (US EPA 2007a, b; 2008b). The method measures the extent of lead solubilisation in an extraction solvent that resembles gastric fluid. However, this test does not include a phase mimicking the milieu of the small intestine and so is not reflective of the physiological conditions affecting the location where absorption actually occurs. In the test, and others like it, samples are extracted in simulated gastric juice by rotating in a modified TCLP extractor. The fraction of lead that solubilises is referred to as *in vitro* bioaccessibility (IVBA), which may then be used as an indicator of *in vivo* relative bioavailability (RBA). Based on *in vitro – in vivo* comparisons for 19 soil samples the IVBA test was shown to be a reliable predictor of *in vivo* RBA for Pb (US EPA 2007a, p. ES4; 2008b, p. 6). The soils used included samples from eight different mining and smelting sites in the United States. In addition, two prepared materials were analysed, plus a galena-enriched soil and a National Institute of Standards and Technology (NIST) paint standard. A strong statistically significant positive correlation was shown to exist between the *in vivo* and the *in vitro* results across many different samples (Figure 4.1.1) (US EPA 2007a). The correlation equations are used to estimate *in vitro* bioavailability from the *in vitro* data.

The method has undergone formal validation and regulatory acceptance using ICCVAM guidelines (NIEHS 1997) and was found to satisfy the validation (and regulatory acceptance) criteria (US EPA 2007a; 2009b).

However, the validation did not include non-mine impacted soils that may contain lead in highly soluble forms (Juhasz et al. 2009; Marschner et al. 2006). Recent work in Australia by Juhasz et al. (2009) found the correlation between the IVBA test and soluble forms of lead (e.g. Pb acetate) was relatively poor because the extract test will solubilise approximately 100% of the Pb and ignores the subsequent precipitation and decrease in absorption that is expected to occur in the higher pH environment of the small intestine. However, for highly soluble forms of lead the *in vitro* bioaccessibility correlated well with *in vivo* bioavailabilty results when an intestinal digestion extract was included.

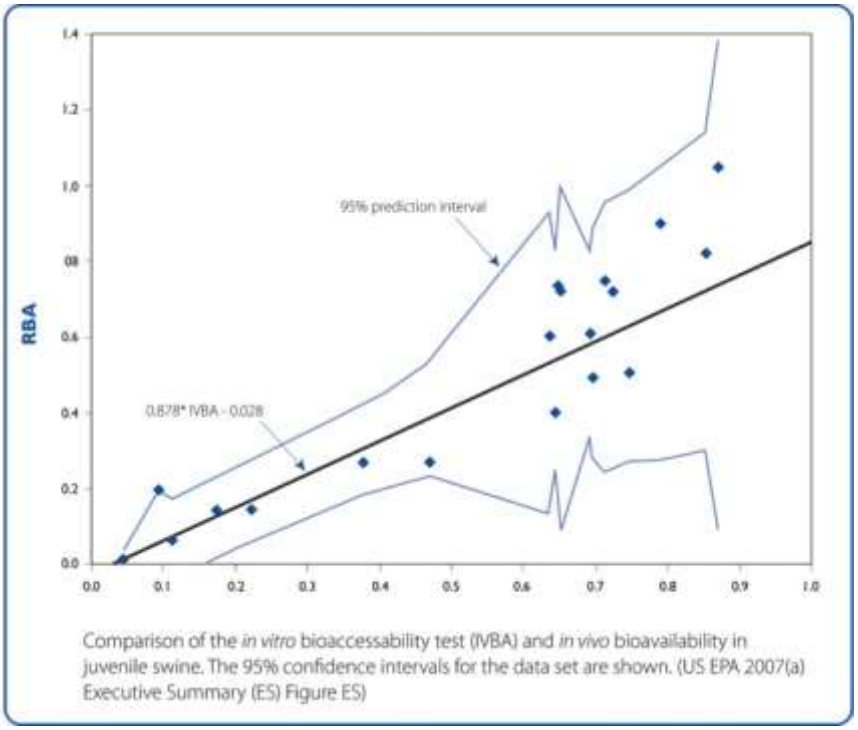
Juhasz et al. (2007a) used the same protocol to the IVBA (i.e. extraction using a solvent that resembles gastric fluid) to assess the bioaccessibility of arsenic in Australian soils. Soils tested were from a variety of locations around Australia with known elevated concentrations of arsenic in different forms (railway corridor, cattle dip site, former gold mines and from highly mineralised locations with geologic arsenic sources). The same soils were also tested *in vivo* using juvenile swine assay. A strong correlation between the *in vivo* RBA *in vitro* test was observed ($R^2 = 0.92$) (Figure 4.1.2). Practically all results are within a 95th percentile prediction interval indicating a strong correlation similar to the *in vivo – in vitro* work conducted by the US EPA for lead.

The clear correlations observed for lead and arsenic (Juhasz et al. 2007a; US EPA 2007a) are consistent with findings from other *in vitro* digestion tests mimicking the phases of the gastrointestinal tract (e.g. Bruce et al. 2007; Ruby et al. 1996), suggesting the bioavailability of lead and arsenic are limited by the dissolution kinetics that occur from the environmental matrix (i.e. the bioaccessibility) (Bruce et al. 2007).

There are a number of test protocols for bioaccessibility using *in vitro* digestion models that are intended to simulate conditions in various compartments of the gastrointestinal tract (saliva, stomach, small intestine). The RIVM (2009), UK Environment Agency (2002; 2005), Ruby et al. 1996 and Van de Wiele et al. (2007) describe protocols for many of these test systems. A brief summary is provided in Table 4.1.1.

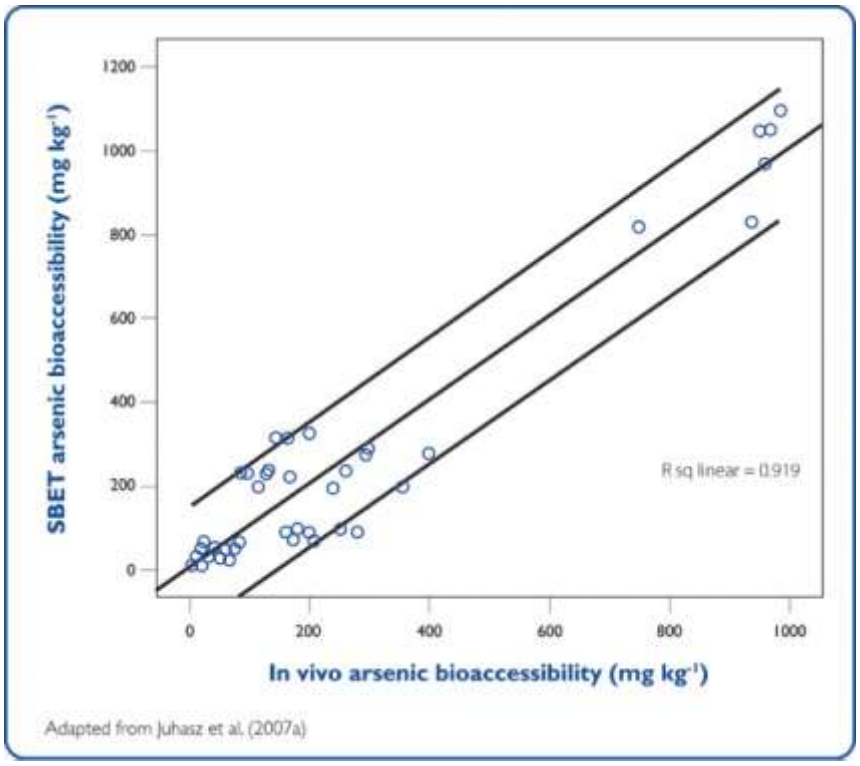
Ruby et al. (1996) described the physiologically based extraction test (PBET), a two-stage digestion system simulating the leaching of a solid matrix in the fed and fasted human stomach and small intestine. Validation has been undertaken for lead and arsenic using oral bioavailability studies in rats, rabbits and monkeys. Bruce et al. (2007) have used the PBET model for assessing the bioavailability of lead and arsenic in mine waste from a Queensland mining operation.

Figure 4.1.1: Comparison of the in vitro bioaccessibility test (IVBA) and the in vivo bioavailability in juvenile swine



Comparison of the *in vitro* bioaccessability test (IVBA) and *in vivo* bioavailability in juvenile swine. The 95% confidence intervals for the data set are shown. (US EPA 2007(a) Executive Summary (ES) Figure ES)

Figure 4.1.2: Correlation of the in vitro bioaccessibility and in vivo bioavailability for arsenic in Australian soils



Adapted from Juhasz et al. (2007a)

Source: Reprinted from Juhasz et al. (2007a) with permission from Elsevier

The RIVM *in vitro* digestion (IVD) model can simulate both fasted and fed conditions of the human gastrointestinal tract. The differences in physiology between fasted and fed state changes the bioaccessibility of contaminants, as pH, salt and enzyme concentrations are different (RIVM 2009, p. 55). According to RIVM the *in vitro* bioaccessibility of lead from soil for both fasted and fed conditions was in agreement with the oral bioavailability of lead from soil as determined in a human study.

As part of a project to develop a standard bioaccessibility for Europe a comparison of five *in vitro* digestion test systems was conducted using a lead contaminated standard soil sample (Bunker Hill soil) (Van de Wiele et al. 2007). The results were compared with a previously conducted *in vivo* study on the same soil (Maddaloni et al. 1998[10]). The test systems included were PBET (UK), Method E DIN 19738 (Germany), RIVM (Dutch), SHIME (Belgium) and TIM (Dutch). Under fed conditions all *in vitro* models returned higher bioaccessibility than the *in vivo* bioavailability. The PBET system, although conservative appeared to perform best.

Table 4.1.1: Comparison[a] of in vitro digestion methods for bioaccessibility

	Validated ✓ = yes × = no	Segments of GI T included	Addition of food	Brief summary of test conditions
IVBA (US EPA 2008b; US EPA 2009b)	✓ (Pb)	Stomach	None	Dry soil particle size < 250 µm. Extracted into 0.4 M Glycine at pH 1.5 with a sample to solute ratio 1:100, end-over-end at 30±2 rpm for 1 hour at 37°C.
SBET Juhasz et al. (2007)	✓ (As)	Stomach	None	Gastric as for IVBA (sample to solute ratio 1:100, 40 rpm, 37°C) Intestinal: Following gastric phase dissolution, gastric solution modified to intestinal phase by adjusting the pH to 7.5 with NaOH and then addition of bovine bile (1750 mg L^{-1}) and porcine pancreatin (500 mg L^{-1}).
Juhasz et al. (2007)	(Pb)	Stomach and intestine		
PBET (UK) Ruby et al. (1996); Bruce et al. 2007)	✓ (Pb) × (As)	Stomach and intestine	None	Dry soil particle size < 250 µm. Sample to solute ratio 1:150. Gastric solute = 1.25 g pepsin, 0.50 g sodium malate, 0.5 g sodium citrate, 420µL lactate and 500 µL acetate per litre of water, pH 2.5. 2 hours at 37°C. Test vessel then adjusted to intestinal conditions (pH to 7, addition bile salts and pancreatin, for 4 hours at 37°C).
Method E DIN 19738 (Germany) Van de Wiele et al. (2007).	×	Static test Stomach and intestine, saliva optional	Optional	Soil to solute ratio 1:50, solute = dilute HCl (pH 2.0) for 2 hours. Addition of intestinal juice adjust pH to 7.5 (phosphate buffer) for 6 hours. Agitate at 37°C and 200 rpm.
IVD Netherlands RIVM (2009)	×	Static test Saliva, stomach and intestine.	Optional	Saliva (pH 6.5) mixed with 0.06 g of soil (dw). Rotated 5 min., 55 rpm. Then 13.5 ml of gastric juice (pH 1.1) is added, rotated for 2 h. Mixture of saliva and gastric juice usually has a pH of about 1.2, Finally, 27 ml of duodenal juice (pH 7.8) and 9 ml bile juice (pH 8.0) added simultaneously. The pH of final mix = 6.0 and is rotated for 2 h. Entire test is done at 37°C.
TIM Netherlands RIVM (2009)	×	Dynamic test Entire GIT	Included	Complex set of *in vitro* systems electronically controlled and combined within a panel.

Comparison is intended only as a simple overview of the test systems and to highlight main features and some differences in experimental conditions. For a detailed appraisal see original studies. Matched samples tested both *in vitro* and *in vivo* for validation.

[10] The Maddaloni et al. (1998) study determined the bioavailability of soilborne lead (Pb) in human adult volunteers (via sTable isotope dilution). Soil (<250 µm) was taken from a residential yard at a mining-impacted site with negligible amounts of other priority pollutants. The soil contained a mean Pb concentration of 2924±36 mg/kg. Six adults with 206Pb/207Pb ratios of > 1.190 were admitted to the clinical research centre and fasted overnight prior to dosing with 250 pg Pb/70 kg bw (i.e., 85.5 mg soil/70 kg) in a gelatin capsule. Blood for Pb and 206Pb/207Pb ratios was obtained at 14 time points within 30 hours. Results of the isotopic analyses from these subjects indicate that on average 26.2% ±8.1 of the administered dose was absorbed. Six additional subjects were subsequently studied but ingested soil immediately after a standardised breakfast. Bioavailability in this group was only 2.52% ± 1.7.

4.1.1 Recommendations

Bioavailability of inorganic substances from environmental media is compound and media specific. Consequently recommendations for suggested values for use as defaults in screening risk assessments are not made. Information should be obtained from the scientific literature and/or experimental investigations. Any value used in the risk assessment should be justified.

In vitro bioaccessibility studies are relatively easy to perform and can be used as conservative surrogates for bioavailability since this assumes 100% of the bioaccessible substance will be absorbed into the systemic circulation.

Risk assessors need to understand the bioavailability of the compound on which toxicity reference value is based. It can be assumed bioavailability from environmental media will be at least the same as that in those studies.

Thus a value of 100% for relative bioavailability is commonly applied to organic chemicals in the absence of:

- a regulatory value for relative bioavailability in a particular environmental medium
- an appropriate test result for bioavailability or bioaccessibility from environmental media of interest, or
- a detailed reasoned, scientific justification of a relative bioavailability.

An assumption of 100% bioavailability for inorganic substances from environmental media will likely over estimate the true absorbed dose.

NEPC (2010), in the draft National Environmental Protection Measure, has reviewed the oral bioavailability of lead and arsenic, and has suggested conservative defaults of 50 and 70% from soil/dust for use in derivation of health investigation levels (HILs).

4.2 Drinking water consumption

4.2.1 Australian data

There are few studies measuring drinking water intake specifically for Australians.

At the time of compiling these data the 1995 *National Nutrition Survey* (ABS 1995) was the only Australian National survey publicly available that reports mean intake data (g/d, i.e. mL/d) (by age group) for non-alcoholic beverages. Mean intakes of fluids are separated into tea, coffee and coffee substitutes, fruit and vegetable juices, soft drinks, and mineral waters and water. The category 'mineral waters and water' includes tap water, bottled water, and 'plain mineral water' (not further described). Upper percentile values from this data for adult intakes were provided in the NHMRC (2003) *Dietary Guidelines for Australian Adults*. Upper estimates for intakes by children were not publicly available. The data for adults are provided in Table 4.2.1 (converted to L/d). Rounded mean (95^{th} percentile) total non-alcoholic beverage intakes for adults ≥ 19 years of age were 2.1 (4.3), for males, 1.9 (3.5) for females and 2 (3.9) L/day for males and females combined, respectively. This includes tap water for drinking, beverages prepared with tap water (e.g. tea, coffee), bottled water, and commercially available soft drinks and juices (excludes milk). The estimates do not include water used to prepare foods.

The South Australian Department of Health (SADH 2006) summarised self-reported water consumption among 16,500 South Australians aged 16 years and over; 44.5% of respondents consumed an average of 600 ml to 1 L of water per day, with 22.8% consuming 1.2 to 1.8 L/day, and 18.7% consuming 2 L or more per day.

Table 4.2.1: Daily non-alcoholic beverage intakes for Australian population

Males – Age group (years)										
Beverage intake (L/d)	**2–3**	**4–7**	**8–11**	**12–15**	**16–18**	**19–24**	**25–44**	**45–64**	**≥65**	**≥19**
Mean (95^{th} percentile)[a]										
Tea	0.01	0.01	0.02	0.02	0.02	0.1	0.24	0.47	0.63	0.34 (1.47)
Coffee and coffee substitutes	–	0.006	0.003	0.02	0.13	0.23	0.55	0.56	0.31	0.47 (1.78)

Males – Age group (years)										
Fruit & vegetable juices	0.32	0.3	0.27	0.33	0.32	0.26	0.15	0.1	0.08	0.14 (0.74)
Soft drinks[b]	0.07	0.13	0.19	0.31	0.52	0.53	0.28	0.12	0.06	0.24 (1.16)
Mineral waters and water[c]	0.45	0.54	0.73	0.84	1.0	1.1	0.95	0.75	0.56	0.85 (2.8)
Total[d]	0.86	0.99	1.21	1.53	2.0	2.22	2.16	2.01	1.64	2.05 (4.25)

Females – Age group (years)										
Beverage intake (L/d)	**2–3**	**4–7**	**8–11**	**12–15**	**16–18**	**19–24**	**25–44**	**45–64**	**≥65**	**≥19**
Mean (95th percentile)[a]										
Tea	0.006	0.01	0.03	0.05	0.07	0.21	0.39	0.55	0.61	0.45 (1.52)
Coffee and coffee substitutes	–	–	0.006	0.02	0.09	0.20	0.44	0.44	0.27	0.38 (1.27)
Fruit & vegetable juices	0.25	0.33	0.28	0.26	0.24	0.18	0.12	0.09	0.07	0.11 (0.53)
Soft drinks[b]	0.05	0.09	0.16	0.21	0.30	0.27	0.15	0.09	0.04	0.13 (0.75)
Mineral waters and water[c]	0.45	0.53	0.65	0.86	0.91	0.94	0.91	0.80	0.72	0.85 (2.25)
Total[d]	0.76	0.96	1.12	1.39	1.62	1.81	2.0	1.96	1.71	1.92 (3.54)

Rounded mean values adapted from ABS (1995, Table 1); rounded 95th percentiles adapted from NHMRC (2003).
95th percentile data were only publically available for the ≥ age group.
Includes soft drinks, flavoured mineral water and electrolyte drinks.
Tapwater, bottled water or plain mineral water.
Total was rounded from the total reported in ABS (1995) and NHMRC (2003).

In developing guidelines for drinking water in Australia the NHMRC assume an adult weighing 70 kg drinks 2 L of water per day (NHMRC 2004, Ch. 6; NHMRC 2009).

4.2.2 Overseas data

In developing drinking water quality guidelines for potentially hazardous chemicals WHO assumed daily consumption of 2 L for a 60 kg person (WHO 2006a, p. 152; WHO 2008, pg. 90). Data from temperate countries typically report daily water consumption less than 2 L but, with data lacking from hotter climates, 2 L was assumed. Where it was judged a population segment was at particularly high risk, the drinking water guideline values were derived using the children as

the at risk population; 1 L water consumption was assumed for a 10 kg child, or 0.75 L for a 5 kg bottle-fed baby (WHO 2006a, p. 152). WHO (2008) recognises water intake can vary significantly in different parts of the world, particularly where consumers are involved in manual labour in hot climates. In such cases, local adjustments of the guidelines may be required.

For its risk assessments the US EPA assumes 2L of fluid intake per day for adults (70 kg) and 1L for infants (<10 kg). This is inclusive of all liquid intake (e.g. coffee and juices). It was noted there were limited data on sensitive sub-populations such as people performing heavy manual work. A summary of water ingestion rates from several studies reviewed by the US EPA showing the median, range and 90th percentile is presented as Table 4.2.2; the 95th percentile data were not available from most of these sources. The average adult mean tap water intake from these data is 1.2L/d.

The International Commission on Radiological Protection (ICRP) summarised the range of fluid intakes under a variety of conditions (ICRP 1975, p. 358) but have not updated this information in their 2002 publication. Details are in Tables 4.2.2 and 4.2.3.

McKone and Daniels (1991) state the amount of fluid ingested daily is 0.03 L/kg body weight (bw) for an adult and 0.05 L/kg bw for a child.

Table 4.2.2: Summary of water ingestion rates

	Mean (L/day)	Range (L/day)	90th percentile (L/day)	Basis Comments
US EPA (2008)	See Tables 4.2.5			Children specific
ICRP (1975)	See Table 4.2.3			Combined data from 14 studies. Adults under various conditions and children.
Ershow and Cantor (1989)	2.07 (total[a]) 1.19 (tap water[a])	–	– 2.09 (tap water)	NFCS data (26,446 US individuals) for adults and children but excluding pregnant and lactating women. Concluded tap water intake is 55% of total fluid intake.
	0.3		0.65	Tap water intake for children age < 1
	0.74	–	1.29	Tap water intake for children aged 1–10
US EPA (2004)	1.23 (all sources)		2.34 (all sources)	Data for children and adults from combined 1994, 1995, 1996, and 1998 Continuing Survey of Food Intakes by Individuals (CSFII) conducted by US Department of Agriculture (USDA).
US National Academy of Sciences (NAS 1977)	1.63	–	–	Review of 9 studies (1941–1975), study populations not always adequately defined. Adopted 2 L/day to 'represent majority of consumers'.
US National Cancer Institute (Cantor et al. 1987)	1.3	–	~2.4	Questionnaire of 8,000 adults (exclusively Caucasian).
Gillies and Paulin (1983)	1.25 (tap water) (Median 1.26)	0.26-2.8	1.9	Survey of 109 NZ adults (16–80 yr). Values for tap water.
Pennington (1983)	1.15 (tap water)	–	–	Adult tap water intake from US Food and Drug Administration Total Diet Study (1983).
US EPA (1984)	Adults: 1.04–1.47 (tap water) Children: 0.19–0.9 (tap water)	– –	– –	US Department of Agriculture Nationwide Food Consumption Study (1977–78).
Forssén et al. (2008)	1.7 (tap water)	–	3.8	Telephone interviews on tap water intake by pregnant women.

Most data in the Table are from US EPA (1997, Ch. 3). See other tables in this section for additional detailed information.

Total tap water intake is defined as water consumed directly from the tap as a beverage or used in the preparation of foods and beverages. Total fluid intake is defined as consumption of all types of fluids including tap water, milk, soft drinks, alcoholic beverages, and water intrinsic to purchased foods.

Table 4.2.3: Measured fluid intakes (L/day) reported by ICRP

Subject	Total fluids[a]	Milk	Tap water	Water-based drinks
Adults ('normal' conditions)	1.0–2.4	0.12–0.45	0.045–0.73	0.32–1.45
Adults (temperature to 32°C)	2.84–3.41 (3.26 ± 0.9)			
Adults (moderately active)	3.7			
Children (5–14 yr)	1.0–1.67	0.33–0.65	~ 0.2	~ 0.38
			0.54–0.79[b]	

Data from ICRP (1975, p. 358). Reproduced with permission from ICRP. Combined data from 14 studies.

Includes tea, coffee, soft drinks, beer, cider, wine, etc.

range of estimates for combined tap water and water-based drinks

The US EPA (1997, 2009a) summarised its recommended drinking water (tap water) intake rates for adults based on information from several key studies (Table 4.2.4). Given the assumption that bottled water, and purchased foods and beverages that contain water are widely distributed and less likely to contain source-specific water, the use of total water ingestion rates in risk assessments may overestimate the potential exposure to substances present only in local water supplies; therefore, values for tap water ingestion rates from a community water supply, rather than total water ingestion, are recommended for risk assessment use by the US EPA.

Kahn and Stralka (2008a) analysed community drinking water[11] ingestion by age range for the US population based on data collected in the US Department of Agriculture's (USDA) 1994–96 and 1998 Continuing Survey of Food Intakes by Individuals (CSFII); the results are published in the US EPA child-specific exposure factors handbook (US EPA 2008) and the draft US EPA (2009a) exposure factors handbook. Ingestion rates for direct and indirect ingestion of water are reported[12] based on data collected from more than 20,000 respondents for water and food consumption over two non-consecutive days.

The US EPA (2008) recommended consumer-only[13] estimates of community water ingestion rates (L/day and L/kg bw/day) for adults (Table 4.2.4) and children and adolescents (Table 4.2.5). It is apparent from the different studies upon which US EPA (1997; 2009a) recommendations are based that there has been little change in water consumption habits over the past 10–20 years. According to the US EPA, there is however anecdotal evidence (not presented) that consumption of bottled water has increased since the 1980s (US EPA 1997, Ch.3). It is likely that contemporary water intakes by Australians will be similar to the recent US data.

[11] For the purposes of exposure assessments involving site-specific contaminated drinking water, ingestion rates based on the community supply are most appropriate (US EPA 2008). Community supply includes tap water from a community or municipal water supply, wells, springs and cisterns. Given the assumption that bottled water, and purchased foods and beverages that contain water are widely distributed and less likely to contain source-specific water, the use of total water ingestion rates may overestimate the potential exposure to toxic substances present only in local water supplies; therefore, tap water ingestion of community water, rather than total water ingestion, from the Kahn and Stralka (2008) study make up the recommended values for water intake for children.

[12] Direct ingestion is defined as direct consumption of water as a beverage, while indirect ingestion includes water added during food preparation at home or by local food service establishments such as school cafeterias and restaurants, but not water that is naturally contained in purchased foods (i.e. commercial water added by manufacturer, such as water contained in soda and beer, and intrinsic water in foods and liquids (i.e. milk and undiluted juice) are not included).

[13] The consumer-only estimates exclude individuals who did not ingest community water during the survey period.

Table 4.2.4: Recommended values for drinking water intake rates for adults by the US EPA (L/day)

Age group/population	Mean	90th percentile	95th percentile	Reference
US EPA 1997[a]				
Adults	1.4	2.3	–	Ershow and Cantor (1989)
Pregnant women	1.2	2.2	2.4	Ershow et al. (1991)
Lactating women	1.3	1.9	2.2	
Adults in high activity/ hot climate conditions	0.21–0.65 L/hour depending on ambient temperature and activity level			McNall and Schlegal (1968)
Active soldiers[b]	6 (temperate climate)[c] 11 (hot)[c]			US Army (1983; 1999) See also Table 4.2.6
US EPA 2009a[d]				
Adults[e]	**1.2[g]**	**2.3[g]**	**2.8[g]**	Data from Kahn and Stralka (2008a)
Pregnant women[f]	0.9	1.8	2.6	
Lactating women[f]	1.7	3.0	3.6	

Information adapted from US EPA (1997, Table 3–30).

Universal unit level water requirement (L/soldier/d).

Temperate = climate with annual mean daily temperature 0–26.7°C. Hot = annual mean daily temperature > 26.7°C.

Information from Kahn and Stralka (2008a; 2008b) adapted from US EPA (2009a, Tables 3–1, 3–3 and 3–7). Note that the US EPA (2009a) makes no official recommendations for drinking water intakes for adults in high temperatures and/or activity levels. Instead, data from McNall and Schlegal (1968) and estimates from the US Army (1983) are presented in Tables 3–72 and 3–73 respectively.

These values are for combined direct and indirect water (water used as a beverage and food preparation; excludes intrinsic water in commercially purchased beverages and foods) from community water supply for consumers only (excludes data for people that reported zero intake of water).

These values are for combined direct and indirect water (water used as beverage and food preparation; excludes intrinsic water in commercially purchased beverages and foods) from community water supply for consumers only (excludes data for people that reported zero intake of water). Note that the sample sizes do not meet the minimum reporting requirements as described in the *Third report on nutrition monitoring in the United States* (LSRO 1995, as cited in US EPA 2009a).

These values for adults have been brought forward as suggested values for evaluation of short or medium (i.e. not lifetime) exposures for use in Australian screening risk assessments. Note these value could change appreciably during hot climates, intensive exercise or while performing heavy work. For example, based on information in Tables 4.2.3, 4.2.4 and 4.2.6, reasonable water intakes in temperate and tropical climates when undertaking moderate activity would be 5 and 10 L/d, respectively (Section 4.2.3).

Table 4.2.5: Recommended values for drinking water ingestion rates from community water supply for children[a]

Age	Mean		90th percentile		95th percentile	
	L/day	L/kg-day	L/day	L/kg-day	L/day	L/kg-day
Birth–<1 month	0.470*	0.153*	0.849*	0.269*	0.858*	0.273*
1–<3 months	0.552	0.116	0.943*	0.216*	1.053*	0.291*
3–<6 months	0.556	0.090	1.021	0.161	1.171*	0.195*
6–<12 months	**0.467[d]**	0.063	0.971	0.120	**1.147[d]**	0.152
1–<2 years	**0.308[d]**	0.031	0.674	0.064	**0.893[d]**	0.086
2–<3 years	**0.356[d]**	0.031	0.700	0.059	**0.912[d]**	0.073
3–<6 years	**0.417[d]**	0.029	0.867	0.056	**1.099[d]**	0.070
6–<11 years	**0.480[d]**	0.021	0.994	0.039	**1.251[d]**	0.050
11–<16 years	**0.652[d]**	0.016	1.432	0.031	**1.744[d]**	0.039
16–<18 years	**0.792[d]**	0.015	1.647	0.029	**2.002*[d]**	0.037*
18–<21 years	0.895	0.016	1.860	0.032	2.565*	0.041*

Information from Kahn and Stralka (2008a), presented in US EPA (2008, Tables 3–14 and 3–23).

* The sample size does not meet minimum requirements.

These estimates are for 'consumers' only (some individuals reported zero consumption of community water in the survey period (two non-consecutive days).The ingestion rates are based on estimates of combined direct and indirect water ingestion. Direct water is defined as water ingested directly as a beverage; indirect water is defined as water added in the preparation of food (including by local restaurants) and beverages but excludes water naturally contained in purchased foods and commercially available beverages. Water originating from the community supply includes tap water from a community or municipal water supply.

Bolded/shaded values for drinking water intake for children were rounded to the nearest decimal place and brought forward as suggested values for use in Australian screening risk assessments (section 4.2.3). Estimates for the <1 year age group were based on data for 6-<12 month-olds.

The US Army (1999) provides estimates of drinking water requirements for soldiers performing light, moderate or heavy work in temperate and hot environments (Table 4.2.6).

Others have also reported high water intake when working in hot climates. For example, Karim (2000) reported the normal daily consumption of water was 5–6 L/d for adults in a Bangladeshi village involved in manual crop production work.

Mean and upper percentile (90th) water ingestion rates for adults and children have been published by the US EPA (2004); the same dataset is used in the *Child-specific exposure factors handbook* (US EPA 2008). The data show bottled water contributes approximately 13–36% of the total per capita water intake estimate. This may be important and should be considered in risk assessments. However, because this study was conducted in the US, bottled water intake may vary in the Australian population.

The US EPA (2004) study also showed that lactating women may ingest greater amounts of water than other women. Lactating women ingested an average of 1.4 L of community water per day, with 90th and 95th percentiles of 2.9 and 3.4 L/day, respectively. This is greater than the daily mean, 90th, and 95th percentile community water ingestion rates for non-pregnant and non-lactating women of 0.9, 2.0 and 2.6 L/day, respectively, from the same study.

Table 4.2.6: Potable water requirements[a] for soldiers performing light, moderate and heavy work in temperate and hot environments

Level of work[b]	Water requirements (L/day)
Hot[c]	
Light	7.6
Moderate	**10.4f**
Heavy (sustainable)	13.2
Heavy (maximum)	18.9
Temperate[d]	
Light	2.8
Moderate	**4.7f**
Heavy (sustainable)	7.7
Heavy (maximum)	13.2
Universal unit level water requirement (L/soldier/d)[e]	
Temperate	6
Hot	11

Data from US Army (1999), converted to L/day.

Defined as all fluids made from potable water consumed by an individual (including soups, hot and cold drinks, as well as plain water).

Light work includes deskwork, vehicle driving, light bench work; moderate work includes route marching, working with moderate lifting or pushing; heavy work includes forced marching, stevedoring, entrenching, route marching with heavy loads or wearing NBC (nuclear, biological or chemical) protective clothing.

Hot climate = annual mean daily temperature > 26.7°C.

Temperate = annual mean daily temperature of 0–26.7°C.

Universal unit level water requirement based on a mixture of 15 per cent light work, 65 per cent medium work, and 20 per cent heavy work (US Army 1999). It should be noted these intake rates are based on assumptions about water loss from urination, exhalation and perspiration, and are not based on survey data or actual measurements.

These values were rounded and brought forward as suggested values for use in Australian risk assessments (section 4.2.3). They are comparable to recommended drinking water intakes for soldiers in temperate and tropical climates from the US EPA (1997) (Table 4.2.4).

The information for lactating women however, was based on a sample size which did not meet the minimum reporting requirements according to the US EPA (*n* = 40 lactating women). Conversly, data from Ershow et al. (1991) indicate lactating women may ingest about the same amount of water as pregnant and non-gravid women (Table 4.2.7), albeit the study is somewhat older.

Ethnic and socioeconomic differences may also have an impact on daily water ingestion. Forssén et al. (2007) investigated a large sample of pregnant women (interviewed before 16 weeks gestation) in the southern United States (*n* = 2,297, mean age 27). The use and self-reported consumption of water was investigated in relation to demography, health (e.g. body mass index) and behavioural characteristics (e.g. recreational exercise, smoking). Water ingestion was separated into filtered and unfiltered tap water (including beverages made from tap water), as well as bottled water. The overall mean for ingested tap water was 1.7 L/day (90th percentile: 3.8 L/day) and for bottled water 0.6 L/day (90th percentile: 1.8 L/day) (Forssén et al. 2007). A lower amount of tap water was ingested by young (17–25 years), less

educated women, whereas intakes were higher for older (≧ 36 years), more educated, married, unemployed women. Healthier behaviour (e.g. exercise) was associated with higher tap water ingestion rates, a higher proportion of which was filtered water. The Forssén et al. (2007) study, when compared directly with the US EPA (2009a) recommended water intakes for adults (Table 4.2.4), suggests tap intakes may be higher in pregnant women.

Although women experience increased thirst and fluid intake during pregnancy, the intake is only transient according to Davison et al. (1988, cited in ICRP 2002, p. 236), being significant only around the 5th to 10th week of gestation, when recalibration of the osmoregulatory set point is complete. After these changes occur, pregnant women in general do not have elevated water intake or excess urine production (ICRP 2002, p. 236).

Table 4.2.7: Tap water[a] intake by women 15–49 years old (L/day)

		Percentile	
Reproductive status	**Mean**	**90th**	**95th**
Control	1.2	2.0	2.3
Pregnant	1.2	2.2	2.4
Lactating	1.3	1.9	2.2

Data from Ershow et al. (1991). Based on data from a Nationwide Food Consumption Survey (NFCS) conducted in 48 states in the US over a period of 7 days. Women aged 15–49 were grouped into three categories: control, i.e. non-pregnant and non-lactating (*n* = 6,201), pregnant (*n* = 188) and lactating (*n* = 77).

Tap water intake includes water used as a beverage as well as water added in final preparation of foods (and tap-water based beverages). It excludes water contained in commercially available foods.

4.2.3 Recommendations

Australian survey data from 1995 (ABS 1995) on non-alcoholic beverage consumption provide intake estimates for tea, coffee and coffee substitutes, fruit and vegetable juices, soft drinks, and mineral waters and water (Table 4.2.1). The category ‘mineral waters and water’ includes tap water, bottled water, and ‘plain mineral water’. The estimates do not include water used to prepare foods.

Given the assumption that bottled water, and purchased foods and beverages that contain water are widely distributed and less likely to contain source-specific water, the use of total water ingestion rates in risk assessments may overestimate the potential exposure to substances present only in local water supplies; therefore, values for tap water ingestion rates of community water, rather than total water ingestion, are suggested for use in Australian screening risk assessments. The Australian data (ABS 1995) do not separate out tap water and commercially-available bottled water intakes, and do not include intakes for water used in food preparation. Thus the US EPA (2008, 2009a) data were considered more conducive for use in Australian screening risk assessments.

Most surveys on water intake have been conducted overseas. These report a 90th percentile tap water (or community water) intake of between 1.9 and 2.4 L/day for adults (Gillies and Paulin 1983; Ershow and Cantor 1989; Cantor et al. 1987; US EPA 1997; 2009a) and 0.7–1 and 1.6 L/day for children (≤ 2yrs) and adolescents (16–18 years), respectively (US EPA 2008) (Tables 4.2.2 and 4.2.5).

It is apparent from comparison of large size surveys in the US (US EPA 1997; 2009a) that water consumption of tap water (i.e. community water) has not changed appreciably over the past 10–20 years; the mean tap water consumption by US adults (≥ 21 years) has decreased slightly from 1.4L/d to 1.2 L/d but the 90th percentile consumption has not changed (2.3L/d) (Table 4.2.4). It is considered likely that water intake by contemporary Australians not actively undertaking moderate or high levels of activity will be similar to that of the overall US population; that is, the amount drunk by the average adult will be about 1.2 L/d and that by the 95th percentile individual about 2.8 L/d (US EPA 2009a). This is consistent with the 2006 South Australian survey that reported approx 45 per cent of adults (≥ 16 years) drank 0.6–1 L/d and 18.7 per cent consumed 2 L or more per day (i.e. close to an 80th percentile) (SADH 2006).

Adult male & female combined:

A reasonable value for use in screening risk assessments or guideline setting that represents *long-term* tap water (i.e. community water) intake by most Australian adults spanning a range of climates and short term activities would be 2 L per day. This is consistent with the NHMRC default for development of drinking water guidelines and 'high end' intakes for adults determined in overseas studies (1.9–2.4 L) (Table 4.2.2).

Suggested values for mean, 90th and 95th percentile drinking water intake for *short or medium periods* (not lifetime) by Australian adults are 1.2 L/d, 2.3 L/d and 2.8 L/d respectively. These values may change appreciably in hot climates and/or with short term periods of high activity (e.g. intenstive exercise among athletes). For example, based on information in Tables 4.2.3, 4.2.4 and 4.2.6, reasonable water intakes in temperate and tropical climates when undertaking moderate activity would be 5 and 10 L/d respectively.

Pregnant and lactating women:

The available data for tap water intake by pregnant women are inconsistent, relative to non-pregnant women some studies show an increase (Forssen et al. 2007) while others suggest a decrease (Kahn and Stralka 2008a,b) or no change (Erschow et al. 1991). However all studies consistently show increased consumption during lactation. These increases are 8% (Erschow et al. 1991), 42% (Kahn and Stralka 2008a,b)[14] and 56% (US EPA 2004).

For Australian screening risk assessments it is suggested that for pregnant women the same water intake exposure estimates as for the general population may be used. However it is suggested that for lactating women the short term water intake be increased by 50%; i.e. from 1.2 L to 1.8 L, as a mean value. The suggested 90th and 95th percentile intakes for lactating women are 3.5 L and 4.2 L respectively.

Children:

For a 2–3 year old child water intakes (i.e. tap water) of 0.4 L/d and 1 L/d are rounded mean and 95th percentile values respectively (Table 4.2.5). For other age groups, the tap water (i.e. community water) ingestion rates in Table 4.2.5 recommended for use by the US EPA (2008) are suggested for use in Australian screening risk assessments (Table E3).

Values should be adjusted to suit the conditions of the risk assessment, such as specific exposure in tropical conditions and/or performance of manual labour. Suggestions for drinking water intakes for use in screening risk assessments are summarised in Table 4.2.8.

[14] The Kahn and Stralka (2008a,b) information may be a reanalysis of the the same data set used by US EPA (2004).

Table 4.2.8: Suggested values for drinking water intake (L/day)

Group			(L/day) [c]
Adult (M & F combined, pregnant women)	Lifetime average daily intake		2
	Short/medium term exposure[a]		
		Mean	1.2
		90th percentile	2.3
		95th percentile	2.8
	Temperate climate	Moderate work	5
	Tropical climate	Moderate work	10
Lactating women		Mean	1.8
		90th percentile	3.5
		95th percentile	4.2
Child[b] (2 year old)	Mean		0.4
	90th percentile		0.7
	95th percentile		0.9

From Tables 4.2.4 and 4.2.6
Table 4.2.5
Values in Table are rounded

4.3 Breast milk

The amount of contaminants in breast milk is influenced by their solubility in fat or water, their concentration in maternal plasma, the degree of ionisation, and the mechanism by which they are transported to the mammary glands. Lipophilic compounds (e.g. organochlorine pesticides) will tend to concentrate in breast milk because human milk contains a higher concentration of lipids than human plasma (WHO 1985). The influence of lipophilic contaminants in breast milk should be considered for breastfeeding infants.

4.3.1 Australian data

Incidence of breastfeeding

Records from 739 primiparous Victorian women who gave birth between 1 May 1984 and 30 April 1985 showed that smoking, greater maternal age and excess weight were independent risk factors for early cessation of breastfeeding in mothers who breastfed for at least 14 days; an incidental finding from this study was that 8% of mothers breastfeeding at discharge from hospital ceased within 14 days (Rutishauser and Carlin 1992).

The NHMRC has set breastfeeding targets for Australia. It recommends a 90% initiation rate and 80% of infants to be breastfed until at least six months of age, and breastfeeding with appropriate complementary foods is encouraged up to at least 12 months of age (Binns 2003). A survey conducted by the Australian Institute of Family Studies (AIFS 2008) showed that 92% of children were breastfed at birth, with this number decreasing with age.

Table 4.3.1: Incidence of exclusive breastfeeding in Australia by age

Infants[a]	% breastfed
At hospital discharge	92
Age 1 month	71
Age 3 months	56
Age 5 months	28
Age 6 months	14
Age 12 months	0

Data from AIFS 2008, pg. 15

Study included data from a first wave study of 4,606 infants aged 0–1 year from all states across Australia; information was collected via interviews with parents, self-complete questionnaires and time-use diaries; 3.9% of children were of Aboriginal or Torres Strait Islander ethnicity and 13.4% came from families where the mother speaks a language other than English at home. 61.9% of children selected lived in capital cities, as opposed to 38.1% in other parts of the state.

The results of the study are shown in Table 4.3.1. This is similar to findings in a recent study on incidence and duration of breastfeeding in 587 women who gave birth in Perth hospitals (Scott et al. 2006), where only 12% of children were being fully breastfed at six months of age. Breastfeeding duration was negatively associated with breastfeeding difficulties in the first four weeks, maternal smoking, introduction of a pacifier, and early return to work.

In 1985 the Working Party on Implementation of the WHO International Code of Marketing of Breast-milk Substitutes noted that the incidence of breastfeeding observed among Australian women was ranked among the highest in the Western world and exceeded those reported from less developed countries (NHMRC 1985, cited in enHealth 2004). WHO is currently working to update its global database on breastfeeding. Although updated information from WHO could not be located, UNICEF (2009) has published infant and young child-feeding data for developing countries around the world ranging in date from 2000 to 2007. This does not include Australian data, but breastfeeding rates from these less developed countries are lower than the incidence recorded in Australia from the 2008 AIFS study (AIFS 2008).

The 2001 National Health Survey (ABS 2001) indicated that the proportion of children receiving breast milk was higher among older mothers. By age six months, 38% of children were being breastfed by mothers aged 18–29 years compared with 54% of children with mothers aged 30 years and over.

Apart from the National Health Survey (ABS 2001) and the survey conducted by the AIFS (2008)[15], national data on prevalence and duration of breastfeeding were collected in Australia only in 1983, when 85% of mothers were breastfeeding at discharge and 54–55% three months later.

Table 4.3.2 gives a summary of breastfeeding rates in different states of Australia.

Table 4.3.2: Summary of Australian state incidence (%) of breastfeeding for fully breastfeeding mothers

				Western Australia[e]	
Duration	**Victoria[b]**	**Tasmania[c]**	**South Australia[d]**	**Urban**	**Rural**
Initial[a]	85.8	77	78	n/a	99
3 months	60.5	51	46	71	99
6 months	38.7	39	32	66	99
12 months	n/a	12	n/a	61	96

Most data from Lester 1994

n/a : not available
at first visit to baby centre or clinic (normally about 1 week after discharge).
Data from 1991–92, Victorian Department of Community Services and Health and.Amir et al. (2010)
1984 , Hobart Department of Health Services.
1986, CAFHS, 1987.
1983, Aboriginal data, WHO/NUT Breastfeeding databank.

Composition of breast milk

Gibson and Kneebone (1981) have compared fatty acid composition in samples of breast milk from Australian mothers both early (day 3 to 5, colostrum; *n* = 80) and later (day 40 to 45, mature; *n* = 60) in lactation. Table 4.3.3 shows the comparison of saturated and unsaturated fatty acid composition in the colostrum and mature breast milk.

Saturated fatty acids constituted 46% of the total acids in the lipids of mature breast milk and 44% of the fatty acids of colostrum. Palmitic acid (16:0) accounts for 56% of the saturated fatty acids of colostrum and 49% of mature milk. Unsaturated fatty acids accounted for 54% of the total fatty acids of mature breast milk and 56% of colostrum fatty acids. Most of the unsaturated fatty acids were monounsaturated (41–44% of total fatty acids in mature milk and colostrum respectively). The largest differences were found in levels of oleic acid (18:1), which is greater than 85% of the monounsaturates in both colostrum and mature milk.

Culture and maternal diet influences the composition of breast milk. Connon (1985) has reviewed studies of breast milk fatty acid composition, which revealed marked differences between milk from Indian, Chinese, Malay and Australian mothers (Table 4.3.4).

Cultural/ethnic differences can also have an impact on the initiation and duration of breastfeeding, which may be important in a largely multicultural population such as Australia. For example:

- Diong et al. (2000) showed that 72.2% of a test population (*n* = 101) of Chinese migrant mothers to Australia initiated breastfeeding after birth of their child, with a 50% reduction in breastfeeding three months after birth.
- Even though the tendency to stop breastfeeding with age after birth is comparable to the results of an Australian survey (refer to Table 4.3.1), the initiation of breastfeeding was lower for the Chinese women in this study.

[15] This survey included the *National Health Survey* data collected in 2004–05.

Table 4.3.3: Composition (weight percentage) of some breast milk saturated and unsaturated fatty acids in early (colostrum) and late (mature) lactation in Australian mothers

Fatty acid[a]	Composition (mean weight % ± SD) Colostrum (day 3–5)	Mature (day 40–45)
Saturated fatty acids		
14:0	5.09 ± 1.10	5.63 ± 1.45
16:0	24.47 ± 1.70	22.44 ± 1.82
18:0	8.24 ± 1.27	9.20 ± 1.43
Unsaturated fatty acids		
18:1	37.18 ± 2.47	35.00 ± 2.31
18:2	7.82 ± 2.01	10.75 ± 4.22
20:2	0.65 ± 0.24	0.24 ± 0.11
20:4	0.71 ± 0.18	0.40 ± 0.10
22:6	0.64 ± 0.27	0.32 ± 0.17

Data from Gibson and Kneebone 1981
Only information for some fatty acids is given here. For more information, consult original reference.

Table 4.3.4: Breast milk fatty acid analysis

Fatty acid chain lengths	Australian	Chinese	Indian	Malay
14:0	5.4	6.5	8.9	10.1
18:0	9.2	5.2	5.0	4.1
18:2	10.7	17.0	10.7	8.8
20:2	0.2	0.7	0.4	0.3
20:4	0.4	0.6	0.6	0.5
22:6	0.3	0.7	0.9	0.9

Data from Connon 1985, cited in enHealth 2004

Homer et al. (2002) compared initiation of breastfeeding, as well as percentage of women still breastfeeding at eight weeks for Chinese, English and Arabic-speaking women (*n* = 986) at an urban hospital in Sydney representative of the cultural diversity in Australia. The study showed that:

- Arabic-speaking women had high initiation rates (95%) and significant longer duration rates than the other two groups; 79% of Arabic-speaking women were still breastfeeding their child eight weeks after the birth.
- English-speaking women also had high initiation rates (91%), but only 57% were still breastfeeding after eight weeks.
- Chinese-speaking women had the lowest initiation rates (79%), but tended to continue to breastfeed (60%).
- FSANZ uses an estimated daily intake of 800 mL(g)/day of formula for 3-month old infants in their dietary intake assessments of chemicals (FSANZ 2008a). This is calculated from the estimated energy requirement (343 kJ/kg bw/day) multiplied by the infant's body weight (6.4 kg), and then divided by the energy content of cow's milk based infant formula (274 kJ/100 g)[16]. Using the suggested body weight for 0–1 year old infants from FSANZ (2008a, Table 2.3.2) of 7 kg, this would equate to approximately 880 mL(g) of formula/day. This is similar to the international figure for average daily intake of breast milk (850 mL/day) (section 4.3.2).

4.3.2 Overseas data

The figure for average daily intake of breast milk by infants usually used in calculations of the dietary requirements of lactating women and infants below six months of age is 850 mL/day (WHO 1985). This figure is similar to the value used by FSANZ (800 mL/day) in Australian dietary assessments (FSANZ 2008a).

Other investigators have reported the average daily intake of breast milk by infants in developed countries is in the range of 600–800 mL/day (Thompson and Black 1975; Whitehead 1982). The volume of milk infants ingest is less than the mother's supply (WHO 1985). Bonyata (2006) performed a literature search on the average infant milk intake per day and summarised the data. Average milk intake was highest between one and six months of age (approximately 700-900 mL/day). These data are presented in Table 4.3.5.

Breast milk contains proteins including antibodies, such as immunoglobulin A and lactoferrin (Hambraeus et al. 1978), lactose, fat, glucose, urea, vitamins and trace elements, the observed concentrations of which are given in Table 4.3.6.

Table 4.3.5: Summary of research data on infant average intake of breast milk per day

Age (months)	Avg milk intake/day (ml)	Reference
5 days	483	Neville et al. 1988
1	706	Salazar et al. 2000
1	673	Dewey and Lönnerdal 1983
1	687	Cox et al. 1996
1–6	880	Kent et al. 1999
3	793	Dewey et al. 1991
3–5	730	Neville et al. 1988
6	896	Dewey and Lönnerdal 1983
6	720	Cox et al. 1996
7	875 (93% of total energy intake)	Dewey et al. 1984

[16] i.e. 343 KJ/kg bw/day x 6.4 kg = 2195 kJ/day ÷ 274 kJ/100 g formula = 800 g infant formula/day

Age (months)	Avg milk intake/day (ml)	Reference
11–16	550 (50% of total energy intake)	Dewey et al. 1984
12–17	546	Brown et al. 1982
12–23	532	Persson et al. 1998
15	404	Kent et al. 1999
18–23	486	Brown et al. 1982
>24	357	Brown et al. 1982w
24–36	303	Persson et al. 1998

Data from Bonyata 2006

Table 4.3.6: Range of trace element concentrations in breast milk observed under usual ('normal')[a] conditions

Element	Range (units are µg/L unless stated otherwise)
Antimony	1–4
Arsenic	0.2–0.6
Cadmium	< 1
Calcium	220–300 mg/L
Chlorine	320–410 mg/L
Cobalt	0.15–0.35
Chromium	0.8–1.5
Copper	180 – 310
Fluorine	7–17
Iodine	55–65
Iron	350–720
Lead	2–5
Magnesium	29–38 mg/L
Manganese	3–4
Mercury	1.4–1.7

Element	Range (units are µg/L unless stated otherwise)
Molybdenum	0.3–3.0
Nickel	11–16
Phosphorus	135–155 mg/L
Potassium	410–550
Selenium	13–24
Sodium	90–130 mg/L
Tin	~1
Vanadium	0.1–0.3
Zinc	0.7–2.0 mg/L

Data from WHO 1989, Table 33. Reproduced with permission from WHO
These data exclude study areas where exceptionally low or high values were observed.

4.3.3 Recommendations

No Australian data were located for the average infant's daily intake of breast milk. However, FSANZ (2008a) regularly uses an estimated daily intake of 800 mL/day for formula in their dietary exposure assessments. This is based on a calculation of energy requirements which includes body weight. Using the body weight of a 0-1 year old infant suggested for screening risk assessment in this report (7 kg) (section 2.2.4), and the FSANZ calculation, this would equate to approximately 880mL of formula/day.

The WHO (1985) indicate the average infant's daily intake of breast milk (less than six months of age) is similar at 850 mL/day; this intake appears consistent with a recent literature review of available studies (Bonyata 2006). For 3–7 month old infants who presumably derive most if not all of their energy intake from breast milk the range of average intakes reported was 730–896 mL/day (Bonyata 2006).

A value of 850 mL/day is towards the high end of the measured average intakes from the literature and close to the estimated required intake calculated from energy requirements and body weight information. This value is suggested for use in Australian screening risk assessments. Upper estimates were not available.

4.4 Dietary intake

There are various different methodologies for collection of food consumption data; however, the most commonly used method is the 24 hour recall survey where participants are interviewed on the contents of meals consumed over the previous 24 hours (FSANZ 2009). This method relies on participants remembering what they consumed and estimating the amount of foods consumed. The methodology is used in Australian national nutrition surveys as well as overseas (FSANZ 2009).

4.4.1 Australian studies

Australia currently does not have a comprehensive food and nutrition monitoring and surveillance system. Available studies identifying dietary intake trends in the Australian population include a range of surveys with differing methodologies. The most comprehensive studies are those of the national nutrition surveys (ASSDA 2009a, ASSDA 2009b, ABS 1997, CSIRO 2007b) as these studies collect food consumption data from individuals from all sectors of the Australian population. However, it is rarely possible to obtain a sample of respondents that is truly representative of the overall population. Some population groups such as people who live in remote areas, indigenous peoples, poorly educated people and people for whom English is not their first language may be poorly represented in the surveys, or conversely there may be a deliberate oversampling of such populations (FSANZ 2009).

Information pertaining to minority groups can be gleaned from surveys for individual States and Territories (Baghurst and Record 1984 cited in enHealth 2004, CAPANS 2003, NSW Health 2004), or for specific population sectors. For example, age groups (e.g. the aged, Baghurst, 1991), professions (e.g. fishermen, WGMF 1980) and minority populations such as migrants (e.g. Webb & Manderson 1990, Kouris-Blazos et al 1996, Renzaho and Burns 2006), Aboriginal Australians and Torres Straight Islanders (Longstreet et al. 2008). However, the available information for such sectors is sparse and in some cases opportunistic so may not always present an accurate representation of the minority group being examined (e.g. Longstreet et al 2008).

National nutrition surveys

Australian national nutrition surveys form the basis for dietary exposure assessments conducted by Food Standards Australia New Zealand (FSANZ) for Australian food regulatory purposes (FSANZ 2009).

Available national nutrition surveys include:

- National Dietary Survey of Adults: 1983 1. Foods Consumed (ASSDA 2009a).
- National Dietary Survey of School Children (aged 10-15 years): 1985 1. Foods Consumed (ASSDA 2009b).
- National Nutrition Survey Selected Highlights. Australia: 1995 (ABS 1997) and National Nutrition Survey Foods Eaten Australia. 1995 (ABS 1999).
- Australian National Children's Nutrition and Physical: 2007 (CSIRO 2007b).

The first national nutrition surveys in Australia were conducted in 1983 on adults aged 25–64 years (ASSDA 2009a) and 1985 on schoolchildren aged 10–15 years (ASSDA 2009b). However, data provided in these surveys are now outdated by the 1995 national nutrition survey.

The 1995 National Nutrition Survey Australia (ABS 1997, 1999) provides the most comprehensive and up to date dataset on the dietary habits of the Australian population aged above 16 years (FSANZ 2009)[17]. Data from this survey are used by Food Standards Australia New Zealand (FSANZ) as the basis for most dietary exposure assessments for Australians (FSANZ 2009)[18].

In ascertaining temporal trends in Australian national dietary intake, Cook et al. (2001) provides an evaluation of the appropriateness of comparing published results from the 1995 National Nutrition Survey and that of the 1983 and 1985 National Nutrition Surveys. More recently, Cook et al. (2007) provide estimates of temporal changes in the diets of adults between 1983 and 1995, and that of children between 1985 and 1995 based on results of these surveys.

For the Australian population aged 2 to 16 years the most up to date information is from the 2007 Australian National Children's Nutrition and Physical Activity Survey (2007 children's survey) (CSIRO 2007b). This survey has been used by FSANZ since 2009, however, the 1995 National Nutrition Survey remains the most frequently used survey by FSANZ for dietary exposure assessments (FSANZ 2009).

National Nutrition Survey, Australia: 1995 (adults and children aged >2 years)

The 1995 National Nutrition Survey was designed and undertaken as a component of the 1995 National Health Survey conducted by the Australian Bureau of Statistics (ABS) in collaboration with the Commonwealth Department of Health and Aged Care (formerly the Department of Health and Family Services).

Publications released by the ABS relating to the 1995 National Nutrition Survey include a Users' Guide (ABS 1998a), a summary of selected highlights (ABS 1997), a summary of food consumption data (ABS 1999) and a summary of nutrient intakes and physical measurements (ABS 1998b). Information contained in these publications provides the most up to date and comprehensive data set on the dietary habits of the Australian population aged above 16 years (FSANZ 2009).

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[17] Data for a 2011/2012 National Nutrition Survey is currently being collected and is expected to be available from 2013 for the general population and from 2014 for Aboriginal and Torres Straight Islanders.

[18] For this purpose FSANZ use individual confidential records rather than the aggregated population statistics which are reported in the national nutrition summary publications noted above (FSANZ 2009) and in this document.

The 1995 National Nutrition Survey was conducted over a one year period from February 1995 to March 1996. Data were collated from 13,858 people (response rate of 61.4%) aged two years or over from both urban and rural areas from across each state and territory within Australia. The survey collected information on food and beverage intake, usual frequency of intake, food-related habits and attitudes, and physical measurements. Dietary consumption data were collected using a 24-hour recall method for all respondents, with 10% of respondents also completing a second 24-hour recall on a second, non-consecutive day. These additional data enabled an estimate of the within-person variation in nutrient intake to be obtained and used to adjust the one-day intakes from the survey to provide a more accurate approximation of the 'usual' intake for the whole population. In addition to the 24-hour recall, food frequency data were collected from a subset of the national sample (respondents aged 12 years and above) where respondents provided information on the usual frequency of intake of selected food and supplements.

The response rate of 61.4% is considerably lower than the ABS household-based survey standard and well below the number (76.8 %) of National Health Survey respondents who agreed to participate in the nutrition survey (Cook et al. 2007). While adjustments were made for non-response bias, it was acknowledged by authors of the survey that it may be subject to higher errors than normally expected in household surveys.[19]

Consumed foods were classified into one of 17 broadly defined food groups (major food groups) including:

(1) cereal and cereal based products
(2) fruit products and dishes
(3) vegetables products and dishes
(4) legumes and pulse products and dishes
(4) milk products and dishes
(5) meat, poultry and game products and dishes
(6) fish and seafood products and dishes
(7) egg products and dishes;
(8) snack foods
(9) sugar products and dishes
(10) confectionary
(11) seed and nut products and dishes
(12) fats and oils
(13) soup
(14) savoury sauces and condiments
(15) non-alcoholic beverages
(16) alcoholic beverages, and
(17) miscellaneous.

These food groups represent an aggregation of data from more specific food groups (so called sub major food groups). Information pertaining to the various food encapsulated in each food group is available in the ABS summary of food consumption data (ABS 1999).

Food consumption data are presented as mean daily intakes for males, females, and all persons; median food intake for those who consumed foods during the survey and the percentage of persons who consumed each food group. These data are presented by age group and sex. No upper estimates are publicly available.

For adults (>19 years) additional data are presented for a range of characteristics including, day of the week, season of intake, state and territory of residence, geographic region, region of birth and an area index of relative socio-economic disadvantage (ABS 1999).

Data relating to total energy intake, nutrient intake, self reported diets (e.g. no special diet, vegetarian, weight reducing, diabetic, fat modified or other), place of consumption and source of food (e.g. home or away from home) and eating patterns are available in the ABS summary of selected highlights (ABS 1997) and the ABS summary of nutrient intakes and physical measurements (ABS 1998b).

Mean daily intakes for all males, females and persons (males and females combined) as presented in the ABS summary of food consumption data (ABS 1999) are provided in Tables 4.4.1a to 4.4.1c. It should be noted that in order to present the data in this guidance document in a more condensed format, the aggregated food groups used to classify consumption data as presented in the ABS summary of food consumed data (ABS 1999) differ slightly from that presented in the ABS summary of selected highlights (ABS 1997).

[19] Age and income were major factors in non-response: people with high income (income not given) or age greater than 59 were more likely to decline. Marital status, age and employment status were major factors in non-response for those who actually participated in the survey: generally unmarried people were less likely to participate and unmarried people who were unemployed were least likely to participate; for those aged 20 years and older who agreed to participate, non-responsiveness declined with age and was higher for unmarried people than for married people.

Table 4.4.1a: Average daily intake of major and sub-major food groups, males

	Age group (years)									
	2–3	4–7	8–11	12–15	16–18	19–24	25–44	45-64	≥65	≥19
	Males (average grams per person)									
Cereals and cereal products (total)	**136.1**	**168.1**	**208.1**	**250.0**	**269.9**	**272.7**	**262.5**	**240.8**	**212.3**	**250.2**
Regular breads, and rolls	58.2	78.0	99.1	105.4	108.9	117.8	109.7	110.2	96.1	109.0
Breakfast cereals, plain, single source	10.7	14.2	14.5	20.3	19.1	12.7	12.5	13.5	14.9	13.2
Fancy breads, flat breads, English-style muffins and crumpets	*2.5	5.7	8.9	11.1	8.4	16.4	14.0	8.7	6.7	11.7
Pasta and pasta products	*25.1	28.7	27.7	31.3	61.6	41.3	41.2	30.9	14.8	34.4
Rice and rice products	*12.3	23.4	31.0	39.8	*40.7	58.5	56.1	40.2	19.7	46.5
Breakfast cereals, mixed source	9.1	10.1	21.6	25.8	26.1	18.7	16.5	13.1	13.2	15.3
Breakfast cereal, hot porridge source	*18.1	*7.2	*5.4	*16.2	*4.8	7.3	11.9	23.1	46.0	19.5
Cereal-based products and dishes (total)	**68.1**	**111.3**	**154.5**	**159.2**	**199.8**	**229.9**	**173.2**	**127.4**	**81.7**	**154.1**
Sweet biscuits	7.8	12.4	13.3	13.8	7.7	9.1	10.3	10.5	11.4	10.4
Savoury biscuits	*6.6	6.5	6.2	7.1	2.4	3.3	4.5	4.0	3.5	4.1
Cakes, buns, muffins, scones, cake-type desserts	9.5	16.9	32.6	25.4	19.8	20.7	25.6	26.1	21.2	24.5
Pastries	15.1	20.0	22.4	39.3	67.8	48.1	43.9	35.6	24.9	39.3
Mixed dishes where cereal is the major ingredient	23.8	46.2	72.7	68.0	96.3	143.1	83.2	47.0	18.0	71.2
Batter-based products	**5.3	*9.2	*7.3	*5.5	*5.9	*5.5	5.6	4.2	*2.7	4.8
Fruit products and dishes (total)	**153.8**	**146.1**	**131.4**	**122.0**	**97.1**	**88.7**	**126.8**	**168.2**	**178.8**	**141.3**
Pome fuit	62.9	60.3	63.1	60.1	39.3	23.2	42.8	51.2	47.1	43.2
Berry fruit	**2.6	*2.2	*3.0	*1.0	*0.5	*0.8	1.3	2.1	*2.4	1.7

	Age group (years)									
	2–3	4–7	8–11	12–15	16–18	19–24	25–44	45-64	≥65	≥19
Citrus fruit	*15.5	18.1	20.1	16.4	24.3	14.2	18.1	26.5	23.6	20.9
Stone fruit	*18.6	*9.1	*8.9	*5.8	*4.3	5.9	12.7	19.5	30.7	16.3
Tropical fruit	29.4	22.7	21.2	14.9	14.0	20.4	26.8	32.3	40.1	29.5
Other fruit	*13.0	*27.6	*11.5	*19.7	*8.4	19.8	14.6	25.7	20.2	19.3
Mixtures of two or more groups of fruit	**6.7	*3.2	*1.8	–	*4.9	*2.2	6.8	6.6	*8.4	6.3
Dried fruit, preserved fruit	*4.4	*2.5	*0.9	*2.5	*0.6	*0.5	2.5	3.1	*4.8	2.8
Vegetable products and dishes	**92.6**	**102.2**	**157.5**	**219.9**	**282.6**	**272.1**	**275.3**	**301.4**	**281.7**	**283.4**
Potatoes	44.8	53.1	81.4	116.1	146.4	120.7	102.0	107.5	102.9	106.2
Cabbage, cauliflower and similar brassica vegetables	6.2	7.3	8.8	11.8	21.1	19.7	18.9	25.7	29.4	22.5
Carrot and similar root vegetables	10.0	11.0	13.5	15.7	16.8	18.4	22.9	26.0	25.1	23.5
Leaf and stalk vegetables	1.6	3.8	7.4	7.2	11.9	13.8	16.4	19.1	14.8	16.6
Peas and beans	7.4	6.3	11.3	21.2	18.4	17.5	19.4	23.2	25.5	21.2
Tomato and tomato products	6.7	5.9	10.3	16.2	18.8	27.1	35.6	40.1	32.1	35.3
Other fruiting vegetables	8.4	6.8	9.8	15.7	27.8	23.5	25.9	31.6	30.1	27.8
Other vegetables and vegetable combinations	5.5	6.3	13.7	15.2	20.8	29.0	28.5	26.5	18.0	26.4
Dishes where vegetable is the major component	**2.0	*1.5	*1.3	–	**0.8	*2.5	5.7	*1.8	*3.7	3.8
Legume and pulse products and dishes (total)	***7.1**	***8.9**	***5.3**	***13.6**	***16.2**	***12.0**	**11.2**	**15.2**	**9.2**	**12.2**
Mature legumes and pulses	–	**0.6	**0.6	**2.0	**1.7	*1.7	*1.7	*3.3	*1.3	2.1
Mature legumes and pulse products and dishes	*7.1	*8.3	*4.7	*11.6	*14.5	*10.3	9.5	11.9	*7.8	10.0
Milk products and dished (total)	**507.8**	**417.6**	**427.1**	**501.5**	**549.9**	**396.9**	**330.9**	**290.7**	**288.6**	**321.9**
Dairy milk	405.9	308.7	311.1	349.9	403.5	256.0	222.7	213.2	215.1	223.3

	Age group (years)									
	2–3	4–7	8–11	12–15	16–18	19–24	25–44	45-64	≥65	≥19
Yoghurt	*18.1	13.0	11.5	10.2	*16.9	7.3	11.8	11.4	11.2	11.0
Cream	*0.2	*0.1	*0.7	*1.7	*0.9	3.5	3.3	3.0	3.4	3.2
Cheese	10.9	12.2	12.2	16.9	20.4	17.9	19.0	14.5	10.2	16.2
Frozen milk products	17.8	36.7	51.6	68.4	57.0	30.8	23.7	20.5	15.3	22.5
Other dishes where milk or a milk products is the major component	*25.8	*23.2	*11.7	*13.9	*11.7	8.5	9.9	12.2	25.0	12.6
Milk substitutes	**19.7	*4.2	*4.8	–	–	*4.2	4.9	*4.2	*5.4	4.7
Flavoured milks	*9.3	*19.5	*23.3	*38.0	*38.3	*68.8	35.6	11.7	3.1	28.3
Meat, poultry and game products and dishes (total)	**62.2**	**81.2**	**116.7**	**145.0**	**191.8**	**225.4**	**212.7**	**196.1**	**146.0**	**199.9**
Muscle meat	11.3	19.2	26.8	48.4	51.5	73.1	66.7	62.6	45.4	63.3
Poultry and other feathered game	9.0	9.0	12.1	17.7	37.8	29.2	29.6	24.5	17.6	26.3
Organ meat and offal, products and dishes	–	**0.1	**0.1	**0.6	–	**0.4	*0.9	*1.1	*3.3	1.2
Sausages, frankfurts, and saveloys	*8.3	8.6	16.4	15.1	*8.5	14.4	15.3	15.6	10.1	14.5
Processed meat	*6.8	*2.9	*6.2	*4.7	*6.9	6.2	7.5	8.2	7.6	7.6
Mixed dishes where beef or veal is the major component	*17.3	20.9	23.4	35.0	55.2	52.5	52.0	59.1	35.6	51.8
Mixed dishes where lamb or pork, bacon, ham is the major component	–	*3.4	*13.6	*5.5	*4.0	*13.5	10.0	8.2	*8.8	9.8
Mixed dishes where poultry or game is the major ingredient	*8.9	17.3	17.9	17.6	*27.7	36.0	30.3	16.7	17.7	25.2
Fish and seafood products and dishes (total)	***6.9**	**10.6**	**14.5**	**19.5**	**13.8**	**27.4**	**27.8**	**32.8**	**25.6**	**28.9**
Fin fish (excluding canned)	*0.3	*1.1	*3.7	*4.8	*1.6	*5.2	7.6	8.5	*8.3	7.7
Crustacea and molluscs (excluding canned)	–	**0.4	**1.7	–	–	*3.6	2.6	*3.9	*1.5	3.0

	Age group (years)									
	2–3	4–7	8–11	12–15	16–18	19–24	25–44	45-64	≥65	≥19
Packed (canned and bottled) fish and seafood	*1.1	*0.6	*0.8	*1.6	*3.3	*2.6	3.5	3.5	*4.0	3.4
Fish and seafood products	*2.1	*2.8	*2.8	*11.2	*5.8	10.5	9.3	8.0	6.9	8.7
Mixed dishes with fish or seafood as the major component	–	*5.6	*5.6	*1.7	**2.3	*5.6	4.8	*8.9	*5.0	6.1
Egg products and dishes (total)	***5.9**	**7.1**	**9.9**	**11.4**	**14.9**	**17.5**	**15.8**	**17.9**	**13.7**	**16.3**
Eggs	*3.3	4.7	6.0	7.9	13.1	9.5	10.1	10.5	9.0	10.0
Dishes where egg is the major ingredient	**2.6	*2.3	*3.9	*3.5	–	*8.1	5.7	7.4	*4.6	6.3
Snack foods (total)	***6.8**	**11.0**	**11.4**	**12.6**	***14.0**	**9.8**	**4.4**	**1.7**	**0.8**	**3.8**
Potato snacks	*3.5	*6.4	*5.0	*8.0	*7.4	5.3	2.7	1.2	0.5	2.3
Corn snacks	**0.8	*2.1	*3.4	*2.7	**3.4	*3.1	0.9	*0.4	–	0.9
Extruded snacks	**2.5	*2.5	*2.8	*1.7	**2.0	*1.3	*0.7	*0.1	–	0.5
Sugar products and dishes (total)	**18.6**	**30.9**	**33.9**	**22.4**	**25.5**	**18.5**	**21.6**	**25.4**	**28.4**	**23.3**
Sugar, honey and syrups	4.1	7.0	7.4	9.6	15.0	13.7	16.1	18.5	18.4	16.8
Jam and lemon spreads, chocolate spreads	*3.2	3.6	4.2	3.4	1.1	1.5	2.9	4.1	6.8	3.6
Dishes and products other than confectionary where sugar is the main component	**11.3	*20.3	*22.3	*9.5	*9.4	*3.3	2.7	2.8	*3.2	2.9
Confectionary (total)	**14.4**	**19.4**	**22.1**	**23.8**	**27.1**	**15.0**	**10.6**	**6.6**	**4.0**	**9.1**
Chocolate and chocolate-based confectionary	*6.4	7.9	7.8	12.2	18.1	9.2	7.5	4.1	2.5	6.0
Cereal-, fruit-, nut-, and seed-bars	*5.1	*6.2	*6.4	*4.7	*2.5	*2.6	1.4	0.8	*0.1	1.2
Other confectionary	*2.9	*5.2	*7.8	*6.9	*6.4	3.2	1.7	1.8	1.4	1.9
Seed and nut products and dishes (total)	***1.9**	***3.3**	***2.9**	***3.1**	***1.4**	**3.9**	**6.8**	**4.3**	**2.8**	**5.1**

	Age group (years)									
	2–3	4–7	8–11	12–15	16–18	19–24	25–44	45-64	≥65	≥19
Nuts and nut products	*1.9	*3.3	*2.9	*3.0	*1.3	3.9	6.7	4.2	2.7	5.0
Fats and oils (total)	**6.6**	**8.9**	**11.1**	**12.3**	**12.2**	**14.4**	**13.9**	**15.1**	**16.9**	**14.8**
Dairy fats	1.1	1.6	1.6	1.8	2.5	2.8	3.8	4.3	5.1	4.0
Margarine	5.2	6.8	9.4	10.4	9.0	10.2	9.0	9.7	11.2	9.7
Vegetable oil	**0.2	*0.2	*0.1	*0.1	**0.5	*0.7	0.4	*0.5	*0.3	0.5
Unspecified fats	*0.1	*0.3	*0.1	*0.1	*0.2	*0.6	0.7	0.5	0.3	0.6
Soup (total)	***12.2**	**18.4**	**31.4**	**26.1**	**21.4**	**39.4**	**40.3**	**61.0**	**76.9**	**51.5**
Soup	*12.2	18.4	31.4	25.6	21.4	39.2	40.1	60.2	75.9	51.0
Savoury sauces and condiments (total)	**10.1**	**14.8**	**21.3**	**28.8**	**41.0**	**34.5**	**37.4**	**29.7**	**25.2**	**33.0**
Gravies and savoury sauces	9.3	12.9	18.8	24.4	36.1	30.0	30.9	22.5	19.3	26.7
Pickles, chutneys and relishes	*0.3	*0.3	*1.2	*1.6	*1.2	1.4	3.1	3.6	2.8	3.0
Salad dressings	*0.2	1.4	1.3	2.7	3.7	2.9	3.0	3.3	3.1	3.1
Non-alcoholic beverages (total)	**858.1**	**991.7**	**1213.1**	**1525.9**	**2004.6**	**2223.7**	**2161.9**	**2014.6**	**1643.9**	**2052.3**
Tea	13.5	12.1	19.1	21.1	24.4	102.3	238.1	471.1	630.5	344.8
Coffee and coffee substitutes	-	5.9	3.6	16.0	131.7	229.3	546.3	561.5	311.3	474.6
Fruit and vegetable juices and drinks	319.2	296.6	274.7	338.2	317.6	257.8	146.6	104.5	80.0	139.5
Soft drinks, flavoured mineral waters and electrolyte drinks	69.3	128.9	188.3	314.4	525.4	528.2	280.8	124.3	61.4	236.3
Mineral waters and water[a]	455.1	547.7	726.1	835.7	1003.0	1105.7	945.5	753.1	560.2	854.9
Alcoholic beverages (total)[b]	**–**	**–**	**–**	**–**	**175.1**	**333.5**	**453.2**	**436.5**	**299.4**	**410.1**
Beers	–	–	–	–	140.1	289.0	395.4	350.4	236.6	345.1
Wines	–	–	–	–	18.9	20.5	45.6	79.4	56.0	53.6
Spirits	–	–	–	–	*5.7	*5.8	3.7	4.5	*6.4	4.6
Other alcoholic beverages	–	–	–	–	**10.5	*18.1	*8.5	*2.1	*0.4	6.7

	Age group (years)									
	2–3	**4–7**	**8–11**	**12–15**	**16–18**	**19–24**	**25–44**	**45-64**	**≥65**	**≥19**
Miscellaneous (total)	**2.3**	**2.6**	**3.5**	**3.7**	**2.9**	**2.4**	**2.1**	**1.3**	**1.3**	**1.8**
Beverage flavourings	*1.5	*1.2	*1.8	*1.6	*1.8	0.9	0.6	0.4	0.4	0.6
Yeast; yeast, vegetable and meat extracts	*0.8	1.4	1.7	1.9	1.1	1.5	1.2	0.7	0.7	1.0
Artificial sweetening agents	–	–	–	–	–	–	–	0.1	*0.1	–
Herbs, spices, seasonings and stock cubes	–	–	–	–	–	*0.1	*0.2	*0.1	*0.1	*0.2
Total[c]	**1978.0**	**2154.1**	**2575.7**	**3101.5**	**3963.1[d]**	**4238.3**	**4189.5**	**3987.1**	**3337.2**	**4013.7[d]**

Data from ABS (1999).

– no data

* Estimate has a relative standard error of 25% to 50% and should be used with caution.

** Estimate has a relative standard error greater than 50% and is considered too unreliable for general use.
Includes plain drinking water

Includes all alcoholic beverages containing alcohol (e.g. whisky, low-alcohol beer) and does not indicate amount of pure alcohol consumed

Few people reported consuming foods from a small number of food groups, resulting in estimates considered unreliable for most uses. Estimates for these food groups have therefore not been reported separately, but have been included in the major food group totals and the total for all foods at the end of the table. Food groups which have not been published include: water with other additions as a beverage, flours and other cereal grains and starches, other fats, mixed dishes where fruit is the major component, egg substitutes and dishes, game and other carcass meat, dry doup mix, canned condensed soup, seeds and seed products, stuffings, pretzels and snack crackers, special dietary foods, formula dietary foods, enteral formulae, essences, chemical raising agents and cooking ingredients, infant formulae and foods, infant formulae and human breast milk, infant cereal products, infant foods, and infant drinks.

Alcoholic and non-alcoholic beverage intakes were subtracted from total daily intakes for >16-18 (3963.1 – 2179.7= 1783.4 g/day) and ≧19 year olds (4013.7-2462.4=1551.3 g/d). Results were rounded and brought forward as suggested food intakes for use in Australian screening risk assessments (Section 4.4.4, Tables E1 and E3).

Table 4.4.1b:Average daily intake of major and sub-major food groups (females)

	Age group (years)									
	2–3	4–7	8–11	12–15	16–18	19–24	25–44	45-64	≥65	≥19
	Females (average grams per person)									
Cereals and cereal products (total)	**132.0**	**140.4**	**175.7**	**175.7**	**194.6**	**195.7**	**192.3**	**171.9**	**159.7**	**181.2**
Regular breads, and rolls	58.0	69.6	78.1	75.6	95.3	62.1	74.8	77.1	76.7	74.2
Breakfast cereals, plain, single source	10.3	11.4	10.8	8.3	4.5	6.3	6.8	9.3	11.1	8.2
Fancy breads, flat breads, English-style muffins and crumpets	*2.0	4.6	6.7	7.1	7.3	12.8	11.2	7.2	5.0	9.2
Pasta and pasta products	*23.8	21.0	35.5	38.9	*30.9	45.9	32.5	19.2	9.6	26.3
Rice and rice products	*17.6	14.0	28.7	25.1	*40.7	46.7	43.7	28.6	13.9	34.5
Breakfast cereals, mixed source	8.4	9.1	11.1	13.0	11.3	12.5	11.3	11.3	9.1	11.2
Breakfast cereal, hot porridge source	*11.7	*10.3	*4.9	*7.6	*4.7	*8.8	11.3	18.4	31.3	16.6
Cereal-based products and dishes (total)	**67.7**	**83.4**	**116.2**	**120.7**	**134.9**	**115.7**	**116.3**	**88.1**	**70.7**	**100.1**
Sweet biscuits	8.1	12.2	9.6	9.0	5.3	5.5	7.3	7.9	9.5	7.6
Savoury biscuits	*2.2	5.7	5.7	3.9	4.3	3.2	4.3	3.9	4.1	4.0
Cakes, buns, muffins, scones, cake-type desserts	14.1	19.7	20.1	21.5	21.1	26.3	23.7	23.2	22.2	23.6
Pastries	8.5	17.7	35.3	24.8	38.4	26.3	27.1	24.1	21.1	25.1
Mixed dishes where cereal is the major ingredient	31.3	21.7	37.5	55.5	64.6	51.8	50.1	26.7	11.3	36.8
Batter-based products	**3.5	*6.4	*8.0	*6.1	*1.2	*2.5	3.8	2.3	*2.5	3.0
Fruit products and dishes (total)	**137.0**	**141.3**	**115.5**	**130.6**	**118.0**	**92.3**	**132.2**	**169.8**	**176.2**	**145.7**
Pome fuit	49.9	61.2	52.6	66.3	47.3	31.3	40.8	49.0	48.5	43.3
Berry fruit	**1.4	*1.9	*1.1	*1.6	-	*2.0	2.5	2.8	*2.2	2.5

	Age group (years)									
	2–3	4–7	8–11	12–15	16–18	19–24	25–44	45-64	≥65	≥19
Citrus fruit	*21.8	23.1	16.1	17.7	9.7	10.3	16.7	23.0	26.0	19.3
Stone fruit	*11.0	*8.5	*9.3	*8.6	*23.0	4.7	14.9	24.1	24.0	17.8
Tropical fruit	23.8	24.1	19.8	9.8	11.6	24.6	27.2	35.2	39.8	31.4
Other fruit	*14.5	*12.2	*13.0	*21.9	*22.1	14.7	22.5	27.1	23.9	23.1
Mixtures of two or more groups of fruit	**10.9	*7.7	*2.5	*2.5	*2.6	*3.4	4.8	3.9	*7.4	4.9
Dried fruit, preserved fruit	*3.1	*2.7	*1.0	*2.0	*0.3	*0.9	1.8	3.8	3.9	2.6
Vegetable products and dishes	**88.8**	**114.2**	**156.7**	**185.7**	**192.8**	**224.2**	**220.2**	**256.1**	**243.6**	**234.9**
Potatoes	42.3	54.4	69.7	89.0	66.2	75.4	68.7	75.6	76.3	72.8
Cabbage, cauliflower and similar brassica vegetables	4.1	4.8	8.8	11.4	14.2	18.6	18.4	24.7	23.6	21.1
Carrot and similar root vegetables	8.0	11.9	15.0	15.7	16.4	17.2	17.6	23.0	23.1	20.0
Leaf and stalk vegetables	3.7	4.0	8.7	10.2	9.7	16.4	16.8	17.9	16.0	16.9
Peas and beans	4.1	9.4	12.4	12.7	11.8	14.9	13.9	18.5	19.4	16.3
Tomato and tomato products	7.9	10.7	10.4	14.0	24.1	23.8	30.0	36.7	32.8	31.6
Other fruiting vegetables	8.7	6.9	19.3	15.6	23.0	26.9	27.0	32.9	34.1	29.9
Other vegetables and vegetable combinations	9.1	7.7	8.4	14.7	23.7	23.8	22.6	21.9	16.8	21.5
Dishes where vegetable is the major component	**0.9	*4.5	*3.9	*2.4	**3.7	*7.2	5.2	*4.8	*1.6	4.7
Legume and pulse products and dishes (total)	***6.7**	***5.6**	***2.8**	***6.7**	***9.0**	**9.1**	**8.4**	**8.0**	**3.6**	**7.5**
Mature legumes and pulses	–	–	–	**2.4	**1.9	*0.7	*1.3	*2.0	*1.0	1.4
Mature legumes and pulse products and dishes	*6.5	*5.5	*2.8	*4.3	*7.2	*8.4	7.1	6.0	2.6	6.1
Milk products and dished (total)	**467.1**	**343.1**	**359.4**	**336.6**	**277.7**	**264.4**	**257.4**	**259.1**	**251.7**	**257.7**
Dairy milk	369.1	245.0	254.0	233.4	167.8	184.2	181.0	189.7	184.4	184.4

	Age group (years)									
	2–3	4–7	8–11	12–15	16–18	19–24	25–44	45-64	≥65	≥19
Yoghurt	*19.0	15.4	12.3	*20.5	*19.2	12.0	16.7	18.1	16.6	16.5
Cream	*0.9	*0.8	*1.2	*0.9	*3.4	1.9	2.7	2.5	2.6	2.6
Cheese	10.7	9.8	12.7	11.9	17.0	13.9	13.8	13.7	9.7	13.0
Frozen milk products	*15.9	27.7	44.2	48.6	26.4	15.9	14.2	11.3	10.1	12.9
Other dishes where milk or a milk products is the major component	*23.3	*21.6	*15.7	*8.9	*4.1	11.8	9.0	10.7	18.9	11.6
Milk substitutes	**13.0	*3.1	*3.8	*0.4	–	*4.5	4.5	*6.0	*7.0	5.4
Flavoured milks	*15.2	*19.7	15.6	*12.1	*39.6	*20.2	15.4	7.2	2.4	11.3
Meat, poultry and game products and dishes (total)	**53.3**	**80.1**	**98.4**	**116.0**	**128.5**	**133.0**	**120.9**	**115.1**	**94.9**	**116.1**
Muscle meat	8.8	12.5	23.6	29.4	32.3	33.7	31.5	34.2	29.7	32.2
Poultry and other feathered game	6.8	12.2	9.6	18.6	23.8	18.9	18.8	16.9	15.3	17.6
Organ meat and offal, products and dishes	–	–	–	–	–	**0.3	*0.7	*1.6	**1.8	*1.1
Sausages, frankfurts, and saveloys	*8.1	10.5	8.8	10.4	*8.2	6.6	6.8	5.7	5.8	6.3
Processed meat	*3.5	*3.7	*2.3	*2.3	*3.2	2.6	2.6	4.3	3.9	3.3
Mixed dishes where beef or veal is the major component	*21.0	29.8	24.4	31.5	37.8	41.4	32.9	28.6	22.8	31.0
Mixed dishes where lamb or pork, bacon, ham is the major component	–	*2.8	*7.5	–	*5.3	*6.0	7.2	6.6	*6.1	6.7
Mixed dishes where poultry or game is the major ingredient	*6.9	8.5	21.8	16.5	*17.9	23.5	20.3	17.1	9.5	17.8
Fish and seafood products and dishes (total)	***6.5**	**13.6**	**12.8**	**16.4**	**17.8**	**25.5**	**20.0**	**27.0**	**20.0**	**22.6**
Fin fish (excluding canned)	*1.0	*1.7	*0.4	*1.8	*4.7	*2.8	3.9	8.0	5.5	5.2
Crustacea and molluscs (excluding canned)	**0.3	**0.7	**0.5	**0.1	**2.5	*2.0	2.3	*3.1	*1.5	2.4

	Age group (years)									
	2–3	4–7	8–11	12–15	16–18	19–24	25–44	45-64	≥65	≥19
Packed (canned and bottled) fish and seafood	*0.4	*2.3	*2.0	*1.0	*4.9	*1.1	3.2	4.0	3.7	3.2
Fish and seafood products	*3.4	*5.0	*5.5	*5.4	*4.0	5.5	5.4	5.9	4.2	5.3
Mixed dishes with fish or seafood as the major component	**1.4	*4.0	*4.3	*8.1	–	*14.1	5.2	6.1	*5.1	6.5
Egg products and dishes (total)	***7.4**	**7.9**	**9.0**	**6.4**	**8.4**	**9.2**	**11.9**	**11.6**	**10.3**	**11.2**
Eggs	*5.0	5.8	3.8	3.9	3.4	4.7	5.9	7.1	5.2	6.0
Dishes where egg is the major ingredient	**2.4	*2.1	*5.3	*2.5	*5.0	*4.5	6.0	4.5	*5.1	5.2
Snack foods (total)	***5.9**	**10.3**	**12.3**	**12.5**	***8.8**	**8.5**	**4.4**	**1.1**	**0.4**	**3.2**
Potato snacks	*3.8	*5.3	*7.0	*7.8	*3.4	3.6	2.5	0.6	0.3	1.7
Corn snacks	**0.5	*1.9	*2.0	*1.6	**2.6	*2.6	1.0	*0.3	–	0.8
Extruded snacks	**1.6	**2.8	**3.1	**3.0	**2.4	*2.4	*0.6	*0.1	–	0.6
Sugar products and dishes (total)	**14.7**	**17.2**	**24.4**	**25.3**	**24.1**	**13.2**	**13.9**	**16.4**	**17.1**	**15.1**
Sugar, honey and syrups	3.7	5.6	7.8	7.1	9.1	9.2	9.4	8.7	8.7	9.1
Jam and lemon spreads, chocolate spreads	*1.1	2.2	2.9	2.1	2.2	0.9	1.8	3.0	3.9	2.4
Dishes and products other than confectionary where sugar is the main component	**9.9	*9.4	*13.7	*16.1	*12.8	*3.1	2.7	4.6	*4.5	3.6
Confectionary (total)	**12.6**	**18.4**	**23.5**	**22.2**	**18.3**	**13.6**	**10.1**	**6.6**	**4.1**	**8.5**
Chocolate and chocolate-based confectionary	*6.1	7.5	11.9	12.0	15.2	9.2	6.9	4.4	2.8	5.8
Cereal-, fruit-, nut-, and seed-bars	**2.8	*5.7	*5.3	*3.4	*1.3	*1.5	1.1	0.8	0.2	0.9
Other confectionary	*3.7	*5.2	*6.3	*6.8	*1.9	2.8	2.1	1.4	1.2	1.8
Seed and nut products and dishes (total)	***2.8**	***3.5**	***3.9**	***2.3**	***3.8**	**4.7**	**4.1**	**3.6**	**1.7**	**3.6**

	Age group (years)									
	2–3	4–7	8–11	12–15	16–18	19–24	25–44	45-64	≥65	≥19
Nuts and nut products	*2.8	*3.5	*3.9	*2.3	*3.8	3.8	4.0	3.4	1.6	3.4
Fats and oils (total)	**6.5**	**7.5**	**9.7**	**8.8**	**7.1**	**8.2**	**8.8**	**10.0**	**12.2**	**9.7**
Dairy fats	1.3	1.4	1.7	1.6	2.0	2.1	2.8	2.9	3.9	2.9
Margarine	5.0	5.9	7.6	6.7	4.3	5.5	5.2	6.0	7.6	5.9
Vegetable oil	–	*0.1	*0.1	*0.3	**0.5	*0.3	0.5	*0.7	*0.2	0.5
Unspecified fats	–	*0.2	*0.3	*0.2	*0.3	*0.3	0.4	0.4	0.4	0.4
Soup (total)	***14.6**	**20.5**	**13.3**	**20.9**	***20.0**	**46.6**	**52.7**	**63.7**	**69.1**	**57.9**
Soup	*14.6	20.5	13.3	20.9	*20.0	46.2	52.6	63.4	68.8	57.7
Savoury sauces and condiments (total)	**9.5**	**11.5**	**15.9**	**25.9**	**27.8**	**29.1**	**27.4**	**25.0**	**19.7**	**25.5**
Gravies and savoury sauces	8.4	9.7	14.1	22.1	24.5	24.1	21.8	19.3	14.8	20.1
Pickles, chutneys and relishes	*0.4	*0.7	*0.6	*1.5	*0.7	1.6	2.0	2.0	2.0	2.0
Salad dressings	*0.7	1.0	1.3	2.3	2.5	3.3	3.2	3.7	2.8	3.3
Non-alcoholic beverages (total)	**756.3**	**961.3**	**1122.2**	**1386.0**	**1620.3**	**1813.4**	**2004.1**	**1964.5**	**1714.3**	**1916.7**
Tea	6.0	11.6	26.4	46.2	72.8	211.5	391.1	545.2	611.2	451.5
Coffee and coffee substitutes	–	–	6.0	16.7	93.9	200.3	437.7	443.5	268.2	378.9
Fruit and vegetable juices and drinks	250.6	329.8	281.5	256.7	236.1	181.7	119.2	85.2	74.6	109.4
Soft drinks, flavoured mineral waters and electrolyte drinks	46.6	86.7	160.5	210.8	303.5	268.7	148.5	86.1	37.8	126.0
Mineral waters and water[a]	452.4	533.0	647.9	855.1	913.9	944.3	906.0	803.9	722.3	849.0
Alcoholic beverages (total)[b]	**–**	**–**	**–**	**–**	**52.4**	**123.8**	**114.4**	**105.2**	**55.3**	**102.2**
Beers	–	–	–	–	23.7	57.0	40.7	34.8	19.5	37.2
Wines	–	–	–	–	*10.0	20.5	60.2	64.3	32.1	51.3
Spirits	–	–	–	–	*1.3	*1.7	2.5	2.4	*3.0	2.5

	Age group (years)									
	2–3	4–7	8–11	12–15	16–18	19–24	25–44	45-64	≥65	≥19
Other alcoholic beverages	–	–	–	–	**17.4	*44.6	*10.9	*3.7	*0.7	11.2
Miscellaneous (total)	**2.5**	**2.2**	**2.6**	**3.2**	**1.8**	**2.2**	**1.4**	**1.2**	**1.1**	**1.4**
Beverage flavourings	*1.5	*1.2	*1.4	*1.9	*0.7	0.7	0.5	0.4	0.4	0.5
Yeast; yeast, vegetable and meat extracts	*1.0	0.9	1.2	1.3	1.0	1.4	0.7	0.6	0.6	0.7
Artificial sweetening agents	–	–	–	–	–	–	–	0.1	*0.1	0.1
Herbs, spices, seasonings and stock cubes	–	–	–	–	**0.1	*0.1	*0.2	*0.1	*0.1	*0.1
Total[c]	**1796.5**	**1984.3**	**2274.4**	**2617.8**	**2866.1[d]**	**3133.1**	**3321.1**	**3304.3**	**2925.9**	**3221.1[d]**

Data from ABS (1999).

– no data

* Estimate has a relative standard error of 25% to 50% and should be used with caution.

** Estimate has a relative standard error greater than 50% and is considered too unreliable for general use.

Includes plain drinking water

Includes all alcoholic beverages containing alcohol (e.g. whisky, low-alcohol beer) and does not indicate amount of pure alcohol consumed

Few people reported consuming foods from a small number of food groups, resulting in estimates considered unreliable for most uses. Estimates for these food groups have therefore not been reported separately, but have been included in the major food group totals and the total for all foods at the end of the table. Food groups which have not been published include: water with other additions as a beverage, flours and other cereal grains and starches, other fats, mixed dishes where fruit is the major component, egg substitutes and dishes, game and other carcass meat, dry doup mix, canned condensed soup, seeds and seed products, stuffings, pretzels and snack crackers, special dietary foods, formula dietary foods, enteral formulae, essences, chemical raising agents and cooking ingredients, infant formulae and foods, infant formulae and human breast milk, infant cereal products, infant foods, and infant drinks.

Alcoholic and non-alcoholic beverage intakes were subtracted from total daily intakes for >16-18 (2866.1 – 1672.7= 1193.4 g/day) and ≥19 year olds (3221.1-2018.9=1202.2 g/d). Results were rounded and brought forward as suggested food intakes for use in Australian screening risk assessments (Section 4.4.4, Tables E1 and E3).

Table 4.4.1c: Average daily intake of major and sub-major food groups (persons)

	Age group (years)									
	2–3	4–7	8–11	12–15	16–18	19–24	25–44	45-64	≥65	≥19
	Male and female combined (average grams per person)									
Cereals and cereal products (total)	**134.1**	**154.6**	**192.3**	**213.9**	**233.3**	**235.0**	**227.4**	**206.8**	**182.5**	**215.2**
Regular breads, and rolls	58.1	73.9	88.8	90.9	102.3	90.5	92.2	93.9	85.1	91.3
Breakfast cereals, plain, single source	10.5	12.8	12.7	14.4	12.0	9.5	9.6	11.4	12.8	10.6
Fancy breads, flat breads, English-style muffins and crumpets	2.2	5.2	7.8	9.2	7.9	14.6	12.6	8.0	5.8	10.4
Pasta and pasta products	24.5	25.0	31.5	35.0	46.7	43.6	36.8	25.1	11.9	30.3
Rice and rice products	14.9	18.8	29.9	32.7	40.6	52.7	49.9	34.5	16.5	40.4
Breakfast cereals, mixed source	8.8	9.7	16.5	19.6	18.9	15.7	13.9	12.2	11.3	13.2
Breakfast cereal, hot porridge source	*15.0	8.7	5.2	12.0	*4.7	8.0	11.6	20.8	37.7	18.0
Cereal-based products and dishes (total)	**67.9**	**97.7**	**135.8**	**140.5**	**168.2**	**173.9**	**144.7**	**108.0**	**75.5**	**126.7**
Sweet biscuits	8.0	12.3	11.5	11.5	6.5	7.3	8.8	9.2	10.3	9.0
Savoury biscuits	4.5	6.1	5.9	5.6	3.3	3.3	4.4	4.0	3.8	4.0
Cakes, buns, muffins, scones, cake-type desserts	11.8	18.3	26.5	23.5	20.4	23.5	24.7	24.7	21.8	24.0
Pastries	11.9	18.9	28.7	32.2	53.5	37.4	35.5	29.9	22.8	32.1
Mixed dishes where cereal is the major ingredient	27.4	34.3	55.5	61.9	80.9	98.4	66.7	37.0	14.2	53.7
Batter-based products	*4.4	*7.8	*7.6	*5.8	*3.6	4.0	4.7	3.3	2.6	3.9
Fruit products and dishes (total)	**145.6**	**143.7**	**123.7**	**126.2**	**107.3**	**90.5**	**129.5**	**169.0**	**177.3**	**143.5**
Pome fuit	56.6	60.7	58.0	63.1	43.2	27.1	41.8	50.1	47.9	43.3
Berry fruit	*2.0	*2.1	*2.0	*1.3	*0.7	1.4	1.9	2.5	2.3	2.1

	Age group (years)									
	2–3	4–7	8–11	12–15	16–18	19–24	25–44	45-64	≥65	≥19
Citrus fruit	18.6	20.5	18.1	17.0	17.2	12.3	17.4	24.8	25.0	20.1
Stone fruit	*14.9	8.8	9.1	7.2	13.4	5.3	13.8	21.7	26.9	17.1
Tropical fruit	26.7	23.4	20.5	12.4	12.8	22.5	27.0	33.7	40.0	30.4
Other fruit	*13.7	20.1	12.3	20.7	15.0	17.3	18.6	26.4	22.3	21.2
Mixtures of two or more groups of fruit	*8.7	*5.4	*2.1	*1.8	*3.8	2.8	5.8	5.3	7.8	5.6
Dried fruit, preserved fruit	*3.8	*2.6	*0.9	*2.3	*0.4	0.7	2.1	3.4	4.3	2.7
Vegetable products and dishes	**90.8**	**108.0**	**157.1**	**203.2**	**238.9**	**248.6**	**247.7**	**279.0**	**260.2**	**258.8**
Potatoes	43.6	53.8	75.7	103.0	107.4	98.5	85.3	91.8	87.9	89.3
Cabbage, cauliflower and similar brassica vegetables	5.2	6.1	8.8	11.6	17.8	19.2	18.7	25.2	26.1	21.8
Carrot and similar root vegetables	9.1	11.5	14.3	15.7	16.6	17.8	20.3	24.5	23.9	21.8
Leaf and stalk vegetables	2.6	3.9	8.0	8.6	10.8	15.1	16.6	18.5	15.5	16.8
Peas and beans	5.8	7.8	11.8	17.1	15.1	16.2	16.7	20.9	22.0	18.7
Tomato and tomato products	7.3	8.2	10.4	15.1	21.3	25.5	32.8	38.4	32.5	33.4
Other fruiting vegetables	8.5	6.9	14.5	15.6	25.4	25.2	26.4	32.2	32.4	28.9
Other vegetables and vegetable combinations	7.2	7.0	11.1	15.0	22.2	26.4	25.5	24.2	17.3	23.9
Dishes where vegetable is the major component	*1.5	*3.0	*2.5	*1.6	*2.2	*4.8	5.4	3.3	*2.6	4.3
Legume and pulse products and dishes (total)	***6.9**	**7.3**	**4.1**	**10.3**	***12.7**	**10.6**	**9.8**	**11.6**	**6.0**	**9.8**
Mature legumes and pulses	–	*0.4	*0.3	*2.2	*1.8	*1.2	1.5	*2.6	*1.1	1.7
Mature legumes and pulse products and dishes	*6.8	6.9	3.8	8.0	*10.9	9.4	8.3	9.0	4.9	8.1
Milk products and dished (total)	**487.9**	**381.3**	**394.1**	**421.4**	**417.5**	**332.0**	**294.2**	**275.1**	**267.8**	**289.3**
Dairy milk	388.0	277.7	283.3	293.3	288.9	220.8	201.8	201.6	197.7	203.5

	Age group (years)									
	2–3	4–7	8–11	12–15	16–18	19–24	25–44	45-64	≥65	≥19
Yoghurt	18.5	14.2	11.9	15.2	18.1	9.6	14.3	14.7	14.3	13.8
Cream	*0.5	0.4	1.0	1.3	2.1	2.7	3.0	2.7	3.0	2.9
Cheese	10.8	11.0	12.5	14.5	18.8	16.0	16.4	14.1	9.9	14.6
Frozen milk products	16.9	32.3	48.0	58.8	42.1	23.5	19.0	16.0	12.3	17.6
Other dishes where milk or a milk products is the major component	*24.6	22.4	13.7	11.5	8.0	10.1	9.5	11.4	21.6	12.1
Milk substitutes	*16.5	*3.7	*4.3	*1.5	–	*4.3	4.7	5.1	6.3	5.0
Flavoured milks	*12.2	19.6	19.5	25.4	*38.9	45.0	25.5	9.5	2.7	19.7
Meat, poultry and game products and dishes (total)	**58.9**	**80.6**	**107.7**	**130.9**	**161.0**	**180.1**	**166.8**	**156.1**	**117.1**	**157.4**
Muscle meat	10.1	15.9	25.2	39.1	42.1	53.8	49.1	48.6	36.5	47.5
Poultry and other feathered game	7.9	10.6	10.9	18.1	31.0	24.1	24.2	20.7	16.3	21.9
Organ meat and offal, products and dishes	–	–	**0.2	**0.7	–	**0.4	*0.8	*1.3	*2.4	*1.2
Sausages, frankfurts, and saveloys	8.2	9.5	12.7	12.8	8.4	10.5	11.1	10.7	7.7	10.3
Processed meat	*5.2	3.3	4.3	3.5	5.1	4.5	5.1	6.3	5.5	5.4
Mixed dishes where beef or veal is the major component	19.1	25.2	23.9	33.3	46.7	47.1	42.5	44.1	28.4	41.2
Mixed dishes where lamb or pork, bacon, ham is the major component	*0.5	*3.1	*10.6	*6.0	*4.6	9.9	8.6	7.4	7.3	8.2
Mixed dishes where poultry or game is the major ingredient	7.9	13.0	19.8	17.1	23.0	29.9	25.3	16.9	13.1	21.5
Fish and seafood products and dishes (total)	**6.7**	**12.1**	**13.7**	**18.0**	**15.7**	**26.5**	**23.9**	**30.0**	**22.5**	**25.7**
Fin fish (excluding canned)	*0.6	*1.4	*2.1	*3.4	*3.1	4.0	5.8	8.3	6.7	6.4
Crustacea and molluscs (excluding canned)	**0.2	*0.6	*1.1	–	*1.6	*2.8	2.5	3.5	*1.5	2.7

	Age group (years)									
	2–3	4–7	8–11	12–15	16–18	19–24	25–44	45-64	≥65	≥19
Packed (canned and bottled) fish and seafood	*0.7	*1.4	*1.4	*1.3	*4.1	1.8	3.3	3.7	3.8	3.3
Fish and seafood products	*2.7	3.9	4.1	8.4	*5.0	8.1	7.3	7.0	5.4	7.0
Mixed dishes with fish or seafood as the major component	*2.4	*4.8	*5.0	*4.8	*2.0	*9.7	5.0	7.5	5.1	6.3
Egg products and dishes (total)	**6.7**	**7.5**	**9.5**	**9.0**	**11.7**	**13.4**	**13.8**	**14.8**	**11.8**	**13.7**
Eggs	4.2	5.3	4.9	5.9	8.4	7.1	8.0	8.8	6.9	7.9
Dishes where egg is the major ingredient	*2.5	*2.2	*4.6	*3.0	*3.3	6.3	5.8	6.0	4.9	5.8
Snack foods (total)	**6.4**	**10.6**	**11.9**	**12.5**	**11.5**	**9.2**	**4.4**	**1.4**	**0.6**	**3.5**
Potato snacks	*3.7	5.8	6.0	7.9	*5.5	4.5	2.6	0.9	0.4	2.0
Corn snacks	*0.6	*2.0	*2.7	*2.2	*3.0	*2.8	1.0	0.3	–	0.9
Extruded snacks	*2.1	*2.6	*2.9	*2.4	*2.2	*1.8	0.6	0.1	–	0.5
Sugar products and dishes (total)	**16.7**	**24.2**	**29.2**	**23.8**	**24.8**	**15.9**	**17.8**	**21.0**	**22.0**	**19.1**
Sugar, honey and syrups	3.9	6.3	7.6	8.4	12.2	11.5	12.8	13.7	12.9	12.9
Jam and lemon spreads, chocolate spreads	2.2	2.9	3.5	2.7	1.6	1.2	2.3	3.6	5.1	3.0
Dishes and products other than confectionary where sugar is the main component	*10.6	*15.0	*18.1	*12.7	*11.0	3.2	2.7	3.7	3.9	3.2
Confectionary (total)	**13.5**	**18.9**	**22.8**	**23.0**	**22.8**	**14.3**	**10.4**	**6.6**	**4.1**	**8.8**
Chocolate and chocolate-based confectionary	6.3	7.7	9.8	12.1	16.7	9.2	7.2	4.3	2.7	5.9
Cereal-, fruit-, nut-, and seed-bars	*3.9	*6.0	*5.8	*4.1	*1.9	2.1	1.2	0.8	0.2	1.0
Other confectionary	*3.3	5.2	7.1	6.9	4.2	3.0	1.9	1.6	1.3	1.8
Seed and nut products and dishes (total)	***2.4**	**3.4**	**3.4**	**2.7**	**2.5**	**4.3**	**5.5**	**4.0**	**2.2**	**4.3**

	Age group (years)									
	2–3	4–7	8–11	12–15	16–18	19–24	25–44	45-64	≥65	≥19
Nuts and nut products	*2.4	3.4	3.4	2.7	2.5	3.8	5.3	3.8	2.1	4.2
Fats and oils (total)	**6.6**	**8.3**	**10.4**	**10.6**	**9.7**	**11.4**	**11.4**	**12.6**	**14.2**	**12.2**
Dairy fats	1.2	1.5	1.6	1.7	2.3	2.5	3.3	3.6	4.4	3.5
Margarine	5.4	6.3	8.5	8.6	6.7	7.9	7.1	7.9	9.2	7.8
Vegetable oil	*0.1	*0.2	*0.1	*0.2	*0.5	*0.5	0.4	0.6	0.2	0.5
Unspecified fats	*0.1	0.2	0.2	0.2	*0.3	0.5	0.5	0.5	0.3	0.5
Soup (total)	**13.3**	**19.4**	**22.6**	**23.6**	**20.7**	**42.9**	**46.5**	**62.3**	**72.5**	**54.8**
Soup	13.3	19.4	22.6	23.3	20.7	42.6	46.3	61.8	71.9	54.4
Savoury sauces and condiments (total)	**9.8**	**13.2**	**18.7**	**27.4**	**34.6**	**31.8**	**32.4**	**27.4**	**22.1**	**29.2**
Gravies and savoury sauces	8.9	11.4	16.5	23.3	30.4	27.1	26.4	20.9	16.7	23.3
Pickles, chutneys and relishes	*0.3	0.5	0.9	1.6	1.0	1.5	2.6	2.8	2.3	2.5
Salad dressings	0.5	1.2	1.3	2.5	3.1	3.1	3.1	3.5	2.9	3.2
Non-alcoholic beverages (total)	**808.5**	**976.9**	**1168.8**	**1457.9**	**1817.8**	**2022.7**	**2083.0**	**1989.9**	**1683.7**	**1983.4**
Tea	9.9	11.8	22.7	33.3	48.0	155.8	314.7	507.7	619.6	399.0
Coffee and coffee substitutes	–	3.0	4.8	16.4	113.3	215.1	492.0	503.3	287.0	426.0
Fruit and vegetable juices and drinks	285.8	312.8	278.0	298.6	278.0	220.5	132.9	95.0	76.9	124.2
Soft drinks, flavoured mineral waters and electrolyte drinks	58.3	108.4	174.7	264.1	417.5	401.0	214.6	105.5	48.0	180.3
Mineral waters and water[a]	453.8	540.6	687.9	845.2	959.7	1026.6	925.7	778.2	651.8	851.9
Alcoholic beverages (total)[b]	**–**	**–**	**–**	**–**	**115.5**	**230.7**	**283.7**	**273.0**	**161.4**	**253.8**
Beers	–	–	–	–	83.5	175.3	218.0	194.6	113.9	188.8
Wines	–	–	–	–	14.6	20.5	52.9	72.0	42.5	52.5
Spirits	–	–	–	–	*3.5	3.8	3.1	3.5	4.5	3.5

	Age group (years)									
	2–3	4–7	8–11	12–15	16–18	19–24	25–44	45-64	≥65	≥19
Other alcoholic beverages	–	–	–	–	**13.9	*31.1	9.7	*2.9	*0.5	9.0
Miscellaneous (total)	**2.4**	**2.4**	**3.0**	**3.5**	**2.4**	**2.3**	**1.8**	**1.3**	**1.2**	**1.6**
Beverage flavourings	*1.5	1.2	1.6	1.7	1.3	0.8	0.6	0.4	0.4	0.5
Yeast; yeast, vegetable and meat extracts	0.9	1.2	1.4	1.6	1.0	1.4	1.0	0.6	0.6	0.9
Artificial sweetening agents	–	–	–	–	–	–	–	0.1	0.1	-
Herbs, spices, seasonings and stock cubes	–	–	–	*0.1	**0.1	*0.1	*0.2	*0.1	*0.1	0.1
Total[c]	**1889.6**	**2071.4**	**2428.8**	**2866.4**	**3429.8[d]**	**3696.8**	**3755.1**	**3650.1**	**3104.7**	**3611.3[d]**

Data from ABS (1999).

– no data

* Estimate has a relative standard error of 25% to 50% and should be used with caution.

** Estimate has a relative standard error greater than 50% and is considered too unreliable for general use.
Includes plain drinking water
Includes all alcoholic beverages containing alcohol (e.g. whisky, low-alcohol beer) and does not indicate amount of pure alcohol consumed

Few people reported consuming foods from a small number of food groups, resulting in estimates considered unreliable for most uses. Estimates for these food groups have therefore not been reported separately, but have been included in the major food group totals and the total for all foods at the end of the table. Food groups which have not been published include: water with other additions as a beverage, flours and other cereal grains and starches, other fats, mixed dishes where fruit is the major component, egg substitutes and dishes, game and other carcass meat, dry doup mix, canned condensed soup, seeds and seed products, stuffings, pretzels and snack crackers, special dietary foods, formula dietary foods, enteral formulae, essences, chemical raising agents and cooking ingredients, infant formulae and foods, infant formulae and human breast milk, infant cereal products, infant foods, and infant drinks.

Alcoholic and non-alcoholic beverage intakes were subtracted from total daily intakes for >16-18 (3429.8 – 1933.3= 1496.5 g/day) and ≥19 year olds (3611.3-2237.2=1374.1 g/d). Results were rounded and brought forward as suggested food intakes for use in Australian screening risk assessments (Section 4.4.4, Tables E1 and E3).

2007 Australian National Children's Nutrition and Physical Activity Survey (children aged 2–<16 years)

The 2007 Australian National Children's Nutrition and Physical Activity Survey (2007 children's survey) was conducted by the Commonwealth Scientific and Industrial Research Organisation and the University of South Australia on behalf of the Commonwealth Department of Health and Ageing, the Department of Agriculture, Fisheries and Forestry, and the Australian Food and Grocery Council. The 2007 children's survey is the first national survey to measure food and activity patterns in the same sample.

Publications released by the Department of Health and Ageing relating to the 2007 children's survey include a user's guide (CSIRO 2007a) and a summary of the main findings (CSIRO 2007b).

This children's survey was conducted over a 7 month period from February to August 2007. Data were collated from 4,487 children (or their caregivers) aged between 2 and 16 years from urban and rural regions in each state and territory within Australia. The survey collected information on food and beverage intake, exercise and physical activity-related habits and attitudes, and physical measurements. Dietary consumption data were collected using two non-consecutive 24-hour recalls (conducted 7 to 21 days apart and where feasible on different days of the week e.g. weekend or week day).

The survey excluded children living in very remote areas and those of Indigenous origin. Eligible households with children aged 2–16 years were identified and asked to participate in the survey. One child from each selected household was the designated "study child". There was an agreed quota of 1,000 children (50% boys and 50% girls) for each age group in the survey (age groups included: 2–3 years, 4–8 years, 9–13 years and 14–16 years). The South Australian Department of Health contributed towards a booster sample (n=400) for South Australian children, to allow for more detailed estimates for that particular State. Pre-determined quotas and selective sampling resulted in a study population that is disproportionate to the actual proportion each population group comprises of the national population and results in inherent bias in the survey design, the details of which are discussed in the 2007 children survey's user's guide (CSIRO 2007a). To account for this bias weighting was applied to each individual's response to more closely reflect the whole Australian child population.

Consumed foods were classified into one of 22 broadly defined food groups (major food groups) including: (1) cereal and cereal products (2); cereal-based products and dishes (3) fruit products and dishes (4); vegetables products and dishes; (5) legumes and pulse products and dishes; (6) milk products and dishes; (7) dairy substitutes (8) meat, poultry and game products and dishes; (9) fish and seafood products and dishes; (10) egg products and dishes; (11) snack foods; (12) sugar products and dishes; (13) confectionary and cereal bars; (14) seed and nut products and dishes; (15) fats and oils; (16) soup; (17) savoury sauces and condiments; (18) non-alcoholic beverages; (19) alcoholic beverages; (20) special dietary foods; (21) infant formulae and foods; and (22) miscellaneous. Food consumption data are presented as mean daily intakes for all male and female children surveyed in Table 4.4.2 (weighted data are presented), seperated by age group and sex. No upper estimates are publicly available.

Information relating to child and caregiver demographics, and household characteristics, total energy intake, nutrient intake, physical activity and attainment of dietary guidelines is available in the 2007 children's survey summary of the main findings (CSIRO 2007b).

Table 4.4.2: Mean daily consumption (g/day) of major food groups in Australian children

	Age group (years)			
Major food group	**2–3**	**4–8**	**9–13**	**14–16**
Males				
Non-alcoholic beverages	700.7	998.4	1443.5	1665.8
Cereals and cereal products	152.8	190.0	243.5	268.2
Cereal-based products and dishes	62.6	96.1	139.3	199.5
Fats and oils	7.1	7.6	6.7	7.8
Fish and seafood products and dishes	10.6	13.2	17.0	13.2

Major food group	Age group (years) 2–3	4–8	9–13	14–16
Fruit products and dishes	185.8	174.7	156.5	133.4
Egg products and dishes	5.2	9.7	7.4	9.4
Meat, poultry and game products and dishes	60.8	92.8	129.4	182.4
Milk products and dishes	434.4	362.5	411.9	445.9
Dairy substitutes	21.4	7.0	7.5	10.7
Soup	15.0	15.6	23.8	31.6
Seed and nut products and dishes	2.0	2.8	2.9	4.5
Savoury sauces and condiments	12.0	15.8	31.8	35.1
Vegetable products and dishes	95.0	109.5	161.0	202.8
Legume and pulse products and dishes	5.9	7.7	8.7	11.7
Snack foods	4.4	11.7	15.2	15.9
Sugar products and dishes	14.1	19.7	20.4	20.2
Confectionary and cereal bars	10.9	19.2	27.4	28.2
Alcoholic beverages	0.3	0.1	0.1	4.5
Special dietary foods	1.2	1.9	2.1	6.9
Miscellaneous	5.1	2.8	5.9	3.6
Infant formulae and foods	10.2	0.2	0.1	0.2
Total (males)	**1,817.5[a]**	**2,159[a]**	**2,862.1[a]**	**3,301.5[a]**
Females				
Non-alcoholic beverages	686.9	876.9	1234.6	1448.8
Cereals and cereal products	145.5	168.2	181.7	193.9
Cereal-based products and dishes	58.6	94.8	134.4	131.4
Fats and oils	6.7	7.4	6.6	7.1
Fish and seafood products and dishes	11.9	12.1	13.5	14.6

Major food group	Age group (years) 2–3	4–8	9–13	14–16
Fruit products and dishes	170.6	171.6	157.9	135.0
Egg products and dishes	6.8	7.6	6.7	9.4
Meat, poultry and game products and dishes	63.0	73.4	108.3	101.4
Milk products and dishes	416.3	319.7	312.2	287.3
Dairy substitutes	16.9	11.0	4.2	6.7
Soup	13.3	25.2	37.4	34.6
Seed and nut products and dishes	2.7	2.1	3.5	4.3
Savoury sauces and condiments	10.5	15.0	26.0	30.6
Vegetable products and dishes	95.5	113.0	151.0	178.9
Legume and pulse products and dishes	7.0	6.6	4.1	8.2
Snack foods	5.3	9.2	12.2	12.0
Sugar products and dishes	10.5	18.0	24.7	15.6
Confectionary and cereal bars	10.8	18.7	22.6	25.1
Alcoholic beverages	0.2	0.1	0.3	22.0
Special dietary foods	0.4	3.1	0.4	1.7
Miscellaneous	5.2	4.7	3.3	4.7
Infant formulae and foods	9.2	0.2	0.7	0.0
Total (females)	**1,753.8[a]**	**1,958.6[a]**	**2,446.3[a]**	**2,673.3[a]**

Data from CSIRO (2007b, Table 4); total were calculated from the data provided.

Alcoholic and non-alcoholic beverage intakes were subtracted from total daily total intakes for male and female children by age group; results were averaged for males and females, rounded and brought forward as suggested intakes for use in Australian screening risk assessments (Section 4.4.4, Table E3).

Children under the age of two years

Available Australian national nutrition surveys do not provide dietary intake information for children under the age of two years.

For dietary assessments of this age group FSANZ uses recommended energy intakes as defined by the WHO (WHO 2006b, FAO 2004) to construct model dietary exposure estimates for three month old infants (100% of energy intake sourced from breast milk or formula), nine month old infants (50% of energy intake sourced from breast milk or formula and 50% from other solid foods and beverages including non milk beverages) and for one year old children (35% of energy intake sourced from breast milk or formula and 65% from other solid foods and beverages including non milk beverages). WHO recommended energy intakes are typically taken for boys at the 50th percentile weight as they have higher energy needs per kg body weight than girls of the same age. The patterns of solid food consumption used to determine the solid food component of energy intakes are those of two year old children as presented in the 1995 Australian National Nutrition Survey (ABS 1997, 1999). Solid food intakes are scaled down in proportion to energy requirements and certain foods such as nuts, alcohol and coffee are removed from the diet (FSANZ 2009).

Home grown produce

Dietary intake statistics differentiating between consumption of home grown produce and market supplied produce are important when considering dietary exposure assessments relating to contaminated sites or in the fall out zone of industrial emissions. This is not something which is captured in available national nutrition surveys. There is limited information available on the percentage of Australian households producing their own foodstuffs or the proportion of home grown produce consumed in relation to that which has been purchased from market. Available information as presented here has been gleaned from studies reported by the Australian Bureau of Statistics (ABS 1994) and Langley et al. (1998).

In April 1992 the Australian Bureau of Statistics undertook a survey of the home production of foodstuffs for the Australian population (ABS 1994). A single occupant from each of approximately 34,000 households across Australia was interviewed. The survey collected data on the total production of selected food stuffs for each household over the 12 month period ending April 1992. Selected food items were broadly classified as fruits, vegetables, eggs, nuts, poultry, seafood (recreational fishing), beer and fortified wine. The ABS (1994) compared results of the survey with commercial production levels drawn from varying sources, the details of which are provided in the publication. Results indicate that home grown produce comprises a small percentage of total food production by the general Australian population. For example, the ABS (1994) report that annual home grown fruit (110,000 tonnes) and vegetable (153,000 tonnes) crops comprised 4.3 % and 5.6 % respectively of total national production of fruit (2,554,000 tonnes) and vegetables (2,725,000 tonnes) as reported in the ABS Agricultural Census for the year ending April 1992.

The ABS (1994) report provides information relating to the total number and percentage of households producing home grown food stuffs according to capital city, State and Territory, ethnic background of respondents and age of respondents. However, the report does not provide data on the consumption of home grown produce.

Details relating to the consumption of home grown vegetables and eggs can be found in the survey data compiled by Langley et al. (1998) and reported in 1996 *Australian exposure factors* (Langley et al. 1998, pp. 259–289). The data in Langley et al (1998) represent the most recent account of consumption patterns for home-grown produce in Australia. Data contained within this report are for South Australian's consumption of home-grown produce, however, in the absence of national data, and although they are old these data are expected to brioadly reflect those of the wider Australian population. This assumption is supported by the results of the ABS home production of food stuffs survey in which the total production of fruits, vegetables, eggs, nuts, poultry, seafood, beer and fortified wine for South Australia appear to lie within the mid range of that reported for all other States and Territories in Australia (ABS 1994).

The survey examined home-grown produce and consumption patterns for vegetables and eggs by means of a random telephone survey conducted in 1996. All households in South Australia (Adelaide and rural South Australia) with a telephone connected were eligible, with those persons selected to participate in the survey being the oldest household member (aged 18 years or over). Respondents were requested to provide information relating to their personal consumption of home grown produce and that of the youngest household child between the age of 2 and 5 years – with questions relating to when the child was 2 years of age. The response rate was 76.1% (3,020 households) with 11.3% of respondents providing information pertaining to the diets of children (339 children). Results indicate that 38% of respondents (> 18 years) consumed home-grown vegetables as part of their diet and of those persons who consumed eggs (2,702 persons or 89.4% of respondents), 23.6% consumed home-produced eggs. Consumption of home grown vegetables was similar between males (38.5% of male respondents) and females (37.3% of female respondents).

For children aged 2 years, approximately 31% consumed home-grown vegetables, and of those children who consumed eggs (266 children or 77.3% of respondents) 24% consumed home-grown eggs. The primary results of the study are presented below in Tables 4.4.3 and Table 4.4.4.

Table 4.4.3 identifies the various home grown vegetables consumed by respondents (>18 years), and the percentage of respondents who consumed them.

Table 4.4.4 provides the percentage of respondents (>18 years and 2 year old children) fitting into one of seven broad categories describing the proportion of their diets comprising of home grown vegetables (all vegetables) and eggs.

Data relating to the consumption of recreationally caught seafood are available from a study and health surveys conducted in 1977 (PA Consulting Group 1977, cited in enHealth 2004, p. 82). Average weekly consumption of seafood by leisure anglers (adults) was 513 g while that of persons who did not participate in leisure angling was 610 g. However, results from this study are at variance to seafood consumption statistics presented in the 1983 National Dietary Survey of adults (ASSDA 2009a) which indicate that daily consumption of fish by adults in 1983 was 11g for males and 9 g for females.

Table 4.4.3: Main vegetables grown by people who have home-grown vegetables in their diet

Vegetable grown	n	% of people with home-grown vegetables in their diet
Tomatoes	782	68.6
Carrots	316	27.7
Beans (all types)	283	24.8
Spinach/silverbeet	269	23.6
Capsicum	267	23.4
Herbs (e.g. parsley, chives, rosemary, chilli)	232	20.3
Potatoes	221	19.4
Pumpkin/squash (all types)	208	18.3
Lettuce (all types e.g. endive)	200	17.6
Cucumber	168	14.7
Onion (all types)	161	14.1
Broccoli	149	13.1
Peas (including snowpeas)	147	12.9
Zucchini	143	12.5
Cabbage	130	11.4
Cauliflower	102	8.9
Sweetcorn	93	8.1
Eggplant	29	2.5
Turnips (all types)	23	2.0

Vegetable grown	n	% of people with home-grown vegetables in their diet
Beetroot	20	1.7
Brussel sprouts	9	0.8
Celery	9	0.8
Garlic	5	0.5
Artichoke	4	0.4
Asparagus	4	0.4
Rhubarb	3	0.2
Other	8	0.7
Don't grow any	101	8.9
No particular vegetable	3	0.3

Data from Langley et al. (1998, p. 268)

Multiple responses allowed (i.e. it is possible that more than one home-grown vegetable be specified)

n = number of responses

Table 4.4.4: Proportion of vegetables and eggs in the diet of adults (>18 years) and children (2 years old) that are home grown

Proportion of produce that is home grown	Vegetables		Eggs	
	Adults (>18 years)	Children (2 years)	Adults (>18 years)	Children (2 years)
None	62 % (n = 1869)	67.3% (n=228)	76.2% (n=2059)	69.1% (n=184)
Less than a quarter of all the produce	23.5 % (n=709)	17.7% (n=60)	1.5% (n=41)	1.3% (n=4)
Between a quarter and a half	7.1% (n=213)	7.7% (n=26)	1.1% (n=31)	0.4% (n=1)
Between half and three quarters	4.1% (n = 123)	2.7% (n=9)	1.4 % (n=37)	1.2% (n=3)
More than three quarters but not all	2.3% (n= 70)	2.0% (n=7)	1.5% (n=40)	1.3% (n=3)
All of the produce	0.9 % (n=27)	1.3% (n=4)	18.1% (n=489)	25.6% (n=68)
Don't know (or in the case of children, didn't consume eggs or vegetables)	0.1 % (n=3)	1.4% (n=5)	0.2% (n=5)	% (n=3)

Other Data

The Australian Food Consumption program run by FSANZ publishes the data sets NUTTAB (Nutrition Tables) and AUSNUT (Australian Food and Nutrient Database) which compile Australian food composition data. NUTTAB is a national reference database series that contains primarily analytical data on the nutrient content for a range of foods that are staple to the Australian diet, or are commonly used as ingredients in other foods. The latest NUTTAB was released by FSANZ in 2010 (FSANZ 2010).

AUSNUT is a survey database that contains only data that are directly relevant to the particular national nutrition survey for which it was developed. The foods contained in AUSNUT depend on which foods were identified as being consumed during the national nutrition survey of interest. AUSNUT databases have been developed and released for the 1995 National Nutrition Survey (FSANZ 1999) and the 2007 children's survey (CSIRO 2007b). AUSNUT and NUTTAB databases are available from FSANZ. Sobelewski et al. (2010) provide a discussion paper on the similarities and differences between the two databases to aid in determining which is more suitable for user needs.

Information relating to the chemical composition of Australian foods is presented in the Australian Total Diet Study (ATDS previously called the "market basket study"). The ATDS is Australia's most comprehensive assessment of consumers' dietary intake of a range of food chemicals including food additives, nutrients, pesticide residues, contaminants and other substances. The studies have been conducted in Australia approximately every two years since 1970. Dietary intake is estimated by determining the level of the nutrient in foods (prepared to a 'table-ready' state before analysis) and then combining this with the amount of food consumed as determined by national nutrition surveys. The ATDS assesses the dietary intake of nutrients against their respective reference health standard for Australian population groups. In conducting ATDS FSANZ calculates the mean daily consumption of individual foods (e.g. apples, avocados, almonds etc) from data provided in the 1995 National Nutrition Survey. Mean daily intakes for individual foods for males and females (age group include 1–3, 4–8, 9–13, 14–18, 19–29, 30–49, 50–69, >69 years) are available in the appendices of ATDS reports; for example, Appendix 8 in the 22nd Australian Total Diet Study (FSANZ 2008b), contains estimated intakes for children and adolescents (2–18 years) as well as adults (>18 years) for each of food consumed in the ATDS.

4.4.2 Overseas studies

Dietary habits and food consumption data may vary significantly between countries, even those with similar economies and cultural backgrounds. Moreover, food composition data may differ due to methods of analyses or presentation formats or because the foods themselves differ (Cunningham et al. 2010). Consequently caution is needed before adopting overseas data for local dietary assessments. For this reason, where local alternatives are available, overseas data are not presented in this report.

Children under the age of two years

The US EPA *Child-specific Exposure Factors Handbook* (2008) reports dietary intakes (in g/kg body weight/day) for children under two years of age for consumers only[20] and per-capita[21]. The information comes from a US EPA analysis of data collected in the 1994–96 and 1998 Continuing Survey of Food Intake among Individuals (CSFII); recommended values for major food groups for the 0–1 and 1–<2 year old child are summarised in Table 4.4.5. For individual sub-group intakes, the original publication should be consulted. The values are provided as daily intakes by body weight (g/kg body weight/day). The US EPA rounded recommended body weights for 0–1 and 1–2 year olds are the same as the values suggested in this report (7 and 11 kg, respectively; refer to Table E2).

Recreational fishing

The US EPA draft update to the *Exposure Factors Handbook* (US EPA 2009) provides mean and 95th percentile marine recreational fish consumption data (in g/day) for the US population; these data are summarised in Table 4.4.6. The values are based on the surveys of the National Marine Fisheries Service (NMFS 1993), which were assumed to represent per capita intake of recreational marine fish among adult recreational fishers. Age-specific values were not available from this source, but have been estimated based on the age-specific ratios of general population children's marine fish intake to general population adult marine fish intake.

Information was not available for children under the age of three. US national estimates were not provided for recreational freshwater fish intake because the available data were limited to certain geographic areas and could not be readily generalised to the US population of freshwater recreational anglers as a whole.

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[20] Consumer-only intakes are defined as the quantity of a particular food consumed by children during the survey period, generated by averaging intake across only those children in the survey who consumed these food items.

[21] Per-capita intake rates represent an average across the entire population (including those that did not eat a particular food during the survey period); this may underestimate consumption for a subset of the population that consumed the food in question.

4.4.3 Dietary exposure models

Dietary exposure assessment seeks to provide an estimate of the magnitude, frequency and duration of exposure to risk factors found in the diet. Dietary exposure modelling combines food consumption data with food contaminant concentration data to estimate dietary exposure to food contaminants or intake of nutrients (FSANZ 2009).

Table 4.4.5: US data for dietary intakes for children under two years of age

	Per capita intake (g/kg/d)[a]		Consumers only (g/kg/d) =[b]	
	Mean	95th percentile	Mean	95th percentile
0–1 years				
Total fruits	5.7	21	10	26
Total vegetables	4.5	15	6.2	16
Total meats	1.2	6.7	3.0	9.2
Total dairy products	13	49	16	58
Total fats	5.2	16	7.8	16
Total grains	2.5	8.6	3.6	9.2
1–<2 years				
Total fruits	6.2	19	6.9	19
Total vegetables	6.9	17	6.9	17
Total meats	4.1	9.8	4.2	9.8
Total dairy products	37	88	37	88
Total fats	4.5	11	6.0	12
Total grains	6.4	12	6.4	12

Data from US EPA (2008, Tables 9–1, 11–1, and 12–1)

Per-capita intake rates represent an average across the entire population (including those that did not eat a particular food during the survey period); this may underestimate consumption for a subset of the population that consumed the food in question.

Consumer-only intake rates are defined as the quantity of a particular food consumed by children during the survey period (one day), generated by averaging intake across only those children in the survey who consumed these food items.

Table 4.4.6: US estimates for recreational marine fish intake

Age group (years)	Per capita recreational marine fish intake (g/day)[a]	
	Mean	95th percentile
3–<6[b]	2.5	8.2
6–<11[b]	2.5	9.1
11–<16[b]	3.4	14.1
16–<18[b]	2.8	13.5
>18	5.6	18.0

Data from US EPA (2009, Table 10–3)

Represents per capita values for recreational fishing population only. Data from US EPA analysis of NMFS (1993) assumed to represent adults >18 years. Per capita values represent both survey individuals who ate recreational fish during the survey period and those that did not.

Values for children estimated based on proportion of children's intake of adult intake for general population marine fish intake, applied to >18 years marine recreational fish intake rates.

DIetAry Modelling of Nutritional Data (DIAMOND)

Dietary exposure assessments are part of the FSANZ scientific risk assessment process and are used as a tool for decision-making as they provide a guide to the possible impact of different exposure scenarios concerning food chemicals (FSANZ 2009). FSANZ uses an 'inhouse' software system called DIAMOND (DIetAry Modelling of Nutritional Data) to undertake dietary modelling. Data inputs relating to dietary consumption are primarily obtained from the 1995 National Nutrition Survey (ABS 1997, 1999), data pertaining to chemical concentrations in foods are gleaned from a variety of sources which may include publicly available information such as FSANZ food standards relating to maximum levels of contaminants, maximum residue limits and maximum permitted levels of food additives, as well as the data contained in the Total Diet Study, NUTTAB and AUSNUT (FSANZ 2009). DIAMOND is not publicly available.

4.4.4 Recommendations

For adolescents and adults (>16 years) average daily intakes for major food groups as derived from the 1995 National Nutrition Survey are presented in Tables 4.4.1a to 4.4.1c. For children (2 to ≤16 years) average daily intakes for major food groups as derived from the 2007 Australian National Children's Nutrition and Physical Activity Survey are presented in Table 4.4.2. These values represent the latest and most comprehensive survey information available for the Australian population, and are suggested for use in Australian screening risk assessments.

For average intakes of sub-groups of foods (e.g. specific vegetables), the intakes in Tables 4.4.1a to 4.4.1c may be used for *adults and children* since the more recent survey (CSIRO 2007b) on children's intakes only provided information for major food groups, and not for sub-groups. In the absence of Australian data for children *under the age of two*, the US data for per capita intakes of major food groups in Table 4.4.5 may be used for risk assessments (the per capita intake data are likely to be more comparable to the available Australian data than the consumer-only values). A summary of these suggested values for intakes of the major food groups by age is shown in Table 4.4.7.

Table 4.4.7: Summary of suggested (average) values for food intakes (males and females combined) (grams/day)

	Age (years)							
Major food groups	**0–1[a]**	**1–2[a]**	**2–3[d]**	**4–8[d]**	**9–13[d]**	**14–16[d]**	**17–18[h]**	**≥ 19[h]**
Total cereal intake	20[b] (60)[j]	70 [b] (130)[j]	210[e]	275[e]	350[e]	400[e]	400	340
Total fruit intake	40 (150)[j]	70 (210)[j]	180	170	160	130	110	140
Total vegetables and legumes	30 (105)[j]	80 (190)[j]	100	120	160	200	250	260
Total dairy	90 (340)[j]	400 (970)[j]	445[f]	350[f]	370[f]	375	420	290
Total meat intake	8 (50)[j]	45 (110)[j]	60	80	120	140	160	160
Fish and seafood	–	–	11	13	15	14	16	26
Total egg intake	–	–	6	7	7	9	12	14
Total	**225[c] (810)[j]**	**720[c] (1,700)[j]**	**1,100[g]**	**1,100[g]**	**1,300[g]**	**1,400[g]**	**1,500[i]**	**1,400[i]**

Food intakes exclude all beverages, except for milk.

– no data

Average (rounded) per capita intakes from Table 4.4.5 were converted to intake rates by multiplying by the average body weight for each age group (7 kg for 0–1 year olds; 11 kg for 1–2 year olds).

Total grains from Table 4.4.5 were assumed to represent total cereal intake

Sum of all intakes (rounded) in Table 4.4.5 multiplied by average body weight (7 or 11 kg).

Intakes (rounded) from Table 4.4.2 were averaged for males and female children.

Sum of “cereals and cereal products” and “cereal-based products and dishes” from Table 4.4.2, rounded.

Sum of “milk products and dishes” and “dairy substitutes” from Table 4.4.2, rounded.

Average (rounded) of “total” male and female intakes minus alcoholic and non-alcoholic beverages, except for milk in Table 4.4.2.

Total intakes minus intake of alcoholic and non-alcoholic beverages (rounded) for 16–18 and ≧ 19 year olds from Table 4.3.1c (males and females combined).

Includes all food intakes in Table 4.4.1c; excludes alcoholic and non-alcohlic beverages, rounded.
Values in brackets are 95th percentile intakes calculated from Table 4.4.5 (also see footnotes a, b, and c).

Upper estimates of food intake information is not publicly available. Examination of food frequency and other food consumption surveys conducted in the US shows consumption at the 90th percentile is approximately two times the mean and at the 95th percentile is approximately four times the mean (US FDA 2006). FSANZ use this relationship for estimation of 90th percentile model dietary intakes for Australian children under the age of 2 years (for which there is no information) (FSANZ 2009).

4.5 Soil ingestion

The inadvertent ingestion of soil is a common and important human exposure pathway. Young children are particularly prone to ingest soil as they have greater contact with soil during play and have not developed avoidance strategies of older children and adults.

Pica is defined as repeatedly ingesting non-food substances such as soil (referred to as soil-pica). People with soil-pica behaviour may ingest large quantities of soil on a regular basis that have, in some cases, been associated with physical disorders (e.g. anaemia) (Taylor 1991).

Data on the prevalence of soil-pica in the Australian population could not be located. Taylor (1991, p. 72) comments that the behaviour of soil-pica occurs only quite rarely in the general population of Australia. Susceptible sub-populations may include institutionalised children and children with developmental delays, autism or celiac disease (US EPA 2008, p. 5–1).

Soil-pica and geophagy[22] may be associated with cultural practices, the need to alleviate nutritional deficiencies or other medical disorders, and other physiological influences (US EPA 2008). For instance, some Aborigines eat clay for relief of stomach discomfort and diarrhoea (Taylor 1991). 'Geophagy' is not considered a common practice in Australia but it may be an important risk assessment consideration for Aboriginal communities and certain migrant populations. For example, the mean daily soil intake for pregnant women from the coast of Kenya, Sierra Leone or Ghana is estimated to be 40–80 grams (see Luoba et al. 2004 who also cites Hunter 1984 and Vermeer 1971). School children from Yimbo, western Kenya were reported to consume an average of 28 g of earth in a day with a range of 8–108 g (Geissler et al. 1998). The US EPA (2008, Table 5–1) assumes a default of 1 g/day for children with soil-pica behaviour and 50 g/day for geophagic children. These values could be used in Australian risk assessment where specific consideration of pica or geophagic behaviour is warranted.

House dust is largely composed of finer particles than soil (Paustenbach et al. 1997) and originates from a number of sources including: cooking and heating; residues from building components; hair; fibres; moulds; soil tracked-in or resuspended from outdoors; clothing; atmospheric deposition of particulates; pollens; and so on. In addition to being more mobile, fine particles adhere to skin more effectively, thus increasing the potential of exposure (Finley et al. 1994; Kissel et al. 1996). For this reason risk assessments need to carefully consider outside soil contribution to house dust as a potential exposure pathway when estimating soil ingestion at a residence.

A significant proportion of indoor settled dust (i.e. house dust) can be attributable to soil particles that have been tracked into the indoor environment from outdoors (UK EA 2009b). For instance an appreciable percentage of the source of lead (Pb) found in homes originates from outside sources tracked on shoes and feet of family pets (Hunt et al. 2006; Laidlaw et al. 2008; Paustenbach et al. 1997). The US EPA IEUBK model for predicting blood–lead concentrations in children assumes 45% of total dust intake by children is outdoor soil (US EPA 1994; 2002). Paustenbach et al. (1997) concluded that approximately 50% of house dust originates from exterior soil and noted that the confidence in this estimate was low requiring additional data. In section 5.7 it is suggested a value of 50% outside soil contribution to indoor dust be used in screening risk assessments.

Soil ingestion has been documented in several studies using 'tracer element' methodology. This quantifies amounts of soil ingested by analysing samples of soil[23] from residences, and the resident's (either children or adult) excreta (faeces and sometimes also urine). The soil, faecal and urine samples are analysed for the presence and quantity of tracer elements – typically, aluminium (Al), silicon (Si), titanium (Ti), and yttrium (Y). These elements are natural compounds occurring in soil and because they are not metabolised into other substances by the body, their presence in faeces and urine can be used to estimate the quantity of soil ingested. Calabrese et al. (1997a) found the most reliable tracers to be Al and Si.

The concentration of tracer elements in dust has been reported to be lower than in soil. Van Wijnen et al. (1990) report Ti, Al, and AIR (acid insoluble residue) levels in dust were on average 52, 21, and 17% of the mean soil values respectively. Calabrese et al. (1997a) report that Al and Si content in dust (two of the best tracers) were on average 44 and 43% of the mean soil values respectively. However, in a latter study Calabrese et al. (1989) reported that soil and dust samples did not significantly differ in their levels of tracer elements.

It is important to recognise that because subjects are not confined to a particular location (outdoors or indoors), the tracer element studies do not differentiate between the sources of element in the excreta, it may come from either outside soil/dust or indoor dust. In reporting ingestion of soil or house dust investigators may have assumed all the tracer element was derived from either soil or indoor dust (i.e. the other sources were not accounted for), or they may have apportioned the concentration of tracer in excreta according to relative outdoor and indoor activity patterns.

[22] Geophagy: the deliberate ingestion of soil or dirt; pica is also a term used to indicate the ingestion of dirt, but in risk assessment, the context is usually associated mainly with children.

[23] Generally a composite surface sample is taken from outdoor areas commonly associated with soil contact (play or gardening).

4.5.1 Children

4.5.1.1 Australian data

Australian soil ingestion studies are not available. A previous Australian review (Taylor 1991) indicated a best estimate for average child soil ingestion per day would be of the order of 12.5 to 21 mg/day; however, given the limited number of studies the author concluded that a 'provisional' value of 100 mg/day should be used pending 'further developments in knowledge'.

4.5.1.2 Overseas data

Detailed reviews of available studies on soil ingestion by children have been recently conducted by the US EPA (2008) and Belgium/Dutch authorities (Van Holderbeke et al. 2007) (see Table 4.5.2).

Despite their drawbacks, it is generally agreed the most useful estimates are from tracer element studies. Some (Calabrese et al. 1989; 1997a; Davis et al. 1990; Davis and Mirick 2006) but not all (e.g. Binder et al. 1986; Van Wijnen et al. 1990, Clausing et al. 1987)[24] use measurements of tracer elements in food and other non-soil sources to take account of this intake. This is a limitation because it assumes all faecal tracer quantities are from ingested soil or house dust and therefore overestimate the true value. Some of the studies also have very small sample sizes (Davis and Mirick 2006). To date most studies have investigated children because they are more likely to ingest soil and house dust (e.g. Binder et al. 1986; Clausing et al. 1987; Davis et al. 1990; LaGoy 1987). Many of these studies were performed for reasons unrelated to estimating soil ingestion. The age groups covered in these studies range from newborns to seven year olds.

Based on a re-evaluation of Calabrese et al. (1997), Stanek and Calabrese (2000) estimated a mean and median outside soil ingestion of 31 and 17 mg/day. Extrapolating their results over longer time periods than the study duration (i.e. seven days) they estimated 95th percentile soil ingestion rates for 7, 30, 90 and 365 days as 133, 112, 108 and 106 mg/day respectively. A further re-analysis of the dataset (Stanek et al. 2001) using 'bootstrapping' estimated the median soil ingestion as 24 mg/d, with the 95th percentile soil ingestion as 91 mg/d.

Van Holderbecke et al. (2007), as part of a project for the Dutch Government on harmonisation of human health risk assessment methodology, integrated separate reviews and assessments on soil and dust ingestion by children. They concluded different techniques for estimating soil and dust ingestion by children resulted in values of the same order of magnitude, but some techniques (e.g. tracer studies) are considered more reliable than others (e.g. biomonitoring) because they are able to separate the contribution of soil and dust. The estimates of soil and/or dust ingestion from different techniques were:

- 30 (median) to 60 (mean) mg/day (soil only) using tracer studies
- 7 to 60 mg/day (means) based on different hand loading scenarios and assumptions
- 50 to 100 mg/day (means) from modelled biomonitoring data (soil and probably dust)
- 20 to 70 mg/day (means) from empirical relations.

Overall, Van Holderbecke et al. (2007) concluded the data from studies using different techniques for estimating soil ingestion by children suggested average soil/indoor dust ingestion by children was not higher than 100 mg/day but may well be lower, probably between 40 and 80 mg/day.

In investigating outdoor soil (only) ingestion estimates, van Holderbecke et al. (2007) conducted a quantitative bootstrapping statistical analysis assuming a lognormal distribution to analyse data from selected tracer element studies which had been corrected for background intakes in food and other sources (i.e. sources other than soil ingestion); if results had been re-analysed by authors, the most recent results were used (Calabrese et al. 1997a; Clausing et al. 1987; Davis et al. 1990; Davis and Mirick 2006; Stanek and Calabrese 2000; van Wijnen et al. 1990)[25]. The analysis produced a central tendency distribution of arithmetic means for outdoor soil (only) ingestion with an overall calculated mean for the distribution of all studies included in the analysis of 63 mg/day and a 95th percentile of 81 mg/day.

[24] Binder et al. (1986) did not account for trace elements from non-soil sources, whereas van Wijnen et al. (1990) and Clausing et al. (1987) used trace element measurements in excreta of "non-exposed" groups of hospitalised children to serve as controls instead of measuring the trace element contents in food and medicines for "exposed" children.

[25] The studies listed here were those include in the analysis; other were either not background corrected or reflected the same data as a more recent re-analysis of the same study. In addition, not all values provided in each of the listed studies were included in the analysis. For example, only the mean but not the median values given by van Wijnen et al. (1990) and Clausing et al. (1987) were included in the analysis, as the median values were not background corrected.

The following is summarised from the US EPA *Child-specific exposure factors handbook* (US EPA 2008):

Ingestion of soil only:

For non-pica or non-geophagy children the recomndations are central tendency values for soil only of 30, 50, and 50 mg soil/day for newborns (6–<12 months), 1–5 year olds and 6–20 year olds respectively. These are recommended for use when the risk assessment is not considering children's ingestion of indoor dust.

Ingestion of indoor dust:

A central tendency value of 30 mg/day for newborns (6-<12 months) and 60 mg/day for children aged 1 to under 21 years for indoor dust only is recomended. Such circumstances may include an indoor-only, or inside a transportation vehicle scenario.

Ingestion of soil plus indoor dust:

Soil plus indoor dust intake estimates were not available for 6–20 year old subjects so the US EPA (2008) extended the data obtained for 1–5 year olds (100 mg/d) to those aged under 21 years. Consequently, for risk assessments that consider ingestion of outside soil plus indoor dust, the US EPA recommends central tendency intakes of 100 mg/d for those aged 1 to under 21 years (US EPA 2008), but 60 mg/d for newborns (6–<12 months). This value tacitly assumes approximately 50% of indoor dust is outside soil (see also section 5.7). It is anticipated that most risk assessments for residential contaminated soil should include house dust.

After reviewing a number of studies, Cornelis and Swartjes (2007) report estimates of the contribution of soil to house dust range from 8 to 80%, depending on a wide variety of site-specific factors and methodological approaches. These authors recommend the use of 50% exterior soil in interior dust for residential quarters. In situations without a garden Cornelis and Swartjes (2007) propose a value of 25% exterior soil in interior dust.

All of the above soil and dust ingestion values are intended for children who are not expected to exhibit soil-pica or geophagic behaviour.

4.5.2 Adults

4.5.2.1 Australian data

No Australian studies for adult soil ingestion were located.

4.5.2.2 Overseas data

Three studies (Calabrese et al. 1990; Davis and Mirick 2006; Stanek et al. 1997) have investigated soil/dust ingestion by adults and all have small sample sizes (6, 10, and 33 respectively) and were conducted over a limited time frame (1–3 weeks). The authors also noted a high degree of variability between subjects. Thus interpretation of the statistical representations of the findings for the general population is highly uncertain. The results of these studies are summarised in Table 4.5.1. The arithmetic mean and median values of these studies respectively range between 10–92 and 1–30 mg/day. As expected most estimates are lower than those for children.

The US EPA (1997, Table 4–23; 2009a, Table ES-1), UK Environment Agency (2009b, section 6.1.4) and Van Holderbeke et al. (2007, p. 39) recommended a default adult soil ingestion value of 50 mg/day for adults. Based on "bootstrapping" analysis of three tracer element studies which accounted for background intakes[26] (Calabrese et al. 1990; Davis and Mirick 2006; Stanek et al. 1997), Van Holderbeke et al. (2007) concluded average soil/dust ingestion values for adults probably range from 25 (median) to 45 (mean) mg/day (95th percentile 60 mg/day). Taylor (1991) and Health Canada (2004) recommended a default adult soil ingestion value of 25 and 20 mg/day respectively.

Table 4.5.2 is a summary of three soil/dust ingestion scenario (daily residential outdoor soil, indoor dust, or outdoor soil plus indoor dust ingestion) values suggested by overseas competent authorities for use in risk assessments. These defaults are used for unintentional ingestion of soil which is not normalised to body weight. Thus to calculate the dose of compound from soil the exposure assessor will need to quantitatively consider the average weight of the exposed population during the time when the exposure actually occurs (US EPA 2008, pp. 1–13).

[26] All three studies accounted for background intakes in food but only Davis and Mirick (2006) accounted for background intake in dust.

Table 4.5.1: Adult soil, or soil plus dust, ingestion from key studies

Study citation[a]	Ingestion medium	No. of adults	Geographic location	Mean (mg/d)	Median (mg/d)	Method/ comments
Davis and Mirick (2006)	Soil [c]	33	Three cities in SW Washington state during summer–autumn 1987	Mother: 92 (Al), 23 (Si) Father: 68 (Al), 26 (Si) Average (Al & Si combined): 52	Mother: 0 (Al), 5 (Si) Father: 23 (Al), 0.2 (Si)	Soil tracer (Al, Si)[b]
Calabrese et al. (1990)	Soil + dust?[d]	6	Anaconda Montana during autumn (Sept–Oct)	39	30	Tracer (4 best tracers Al, Si Y, Zr)
Stanek et al. (1997)	Soil + dust?[d]	10	Anaconda Montana during autumn (Sept–Oct)	10	1	Limited tracer method (Al, Si and Y)
Range of values				10–92	1–30	

Key studies are defined as tracer element studies considered important by recent regulatory agency reviews (US EPA 2008) for estimating soil ingestion rates. Table entries for each study are based on the original citation as well as descriptions provided in Van Holderbeke et al. (2007) and US EPA (2008).

The mean and median are for the two tracers Al and Si. These two were selected for consistency with other studies and because they are ranked as the best two tracers by Davis and Mirick (2006), Calabrese et al. (1997a, Table 12, Table 13).

[c] Accounted for background intakes in food and indoor (i.e. house) dust.

[d] Accounted for background intakes in food but not indoor dust.

Table 4.5.2: Summary of soil ingestion recommendations from national and international agencies (mg/day)

Approx age groups[a]	Australia (Taylor 1991, enHealth 2004)	Canada (Health Canada 2004)	van Holdebecke et al. 2007 (Flanders/ Dutch)	The Netherlands (RIVM 2007)	UK (UK EA 2009b)	USA (US EPA 1997, 2008[b], 2009a[b])
0–<1	Negligible	20 (0–6 mo)	60 (based on mean values of range 40–80) (for studies of children aged 1–7 yrs)	Not specified	100 (young children – not further defined)	**30**[d] **60**[d] (soil plus indoor dust)
1–<6	100 (1–5 yrs)	80 (7mo–4yrs)		100[c]		Central tendency[b] **100**[d] (soil plus indoor dust) **50**[d] (outside soil) 60 (all indoor dust)
6–<21	50 (5–15 yrs)	20 (5–19 yrs)		Not specified		
Adults	25	20 (>20 yrs)	25 (median) -**45** (mean)[e]	50[c]	50 (soil + dust)	50 (>21yrs) (outside soil)

Approx age groups[a]	Australia (Taylor 1991, enHealth 2004)	Canada (Health Canada 2004)	van Holdebecke et al. 2007 (Flanders/ Dutch)	The Netherlands (RIVM 2007)	UK (UK EA 2009b)	USA (US EPA 1997, 2008[b], 2009a[b])
Critical study(s)	Binder et al. 1986; Clausing et al. 1987; Calabrese et al. 1989; van Wijnen et al. 1990, Davis et al. 1990	Primary source not provided	Statistical integration of data from several studies, accounting for background intake.	Hawley 1985, van Wijnen et al. 1990, Calabrese et al. 1989, 1990, 1997a and Stanek et al. 1997	Not specified	Calabrese et al. 1989; van Wijnen et al. 1990, Davis et al. 1990, Davis and Mirick 2006, Stanek et al. 1998.
Type of study	Tracer	Tracer	Tracer	Tracer	Not specified	Tracer

Different jurisdictions use different age group categories. Those used in the Table are consistent with those recommended by Taylor (1991).

Central tendency. For individual children who may exhibit soil-pica behaviour, a value of 1,000 mg/day is recommended. Soil ingestion is for outdoor soil, dust ingestion includes indoor settled dust form all sources (outside soil tracked or blown inside plus dust from indoor sources). Values were rounded by US EPA (2008) from 110 to 100 mg/day. See also Section 5.7.

Default parameters for the Dutch CSOIL model used within the standard scenario called 'Residential with garden'. Child is defined within CSOIL to have a body weight of 15 kg (i.e. also 2 year old child refer to Section 2.2.4). For a house with no garden CSOIL does not include the soil ingestion route of exposure, therefore the default values are apparently intended for soil only.

These central tendency values for child ingestion of outside soil (30 mg/d for 0–<1 year olds; 50 mg/d for 1–15 year olds) and outside soil plus indoor dust (60 mg/d for 0–<1 year olds; 100 mg/d for 1–15 year olds) were brought forward as suggested values for use in Australian screening risk assessments. The analysis by van Holderbecke et al. (2007) showed data from studies using different techniques for estimating soil ingestion by children suggested average outdoor soil ingestion by children was not higher than 100 mg/day. Thus a reasonable maximum value of 100 mg/d for outside soil ingestion by children aged 1–15 years is also suggested for use in Australian residential screening assessments (Table 4.5.3). This reasonable maximum is similar to the 95th percentile outdoor soil ingestion estimates calculated by Van Holderbecke et al. (2007), Stanek et al. (2001), and Stanek and Calabrese (2000) of 81, 91, and 106–133 mg/day, respectively.

This average soil/dust ingestion value for adults (45 mg/d), based on "bootstrapping" statistical analysis of mean values from three tracer studies, was rounded up to 50 mg/d and brought forward as the suggested value for soil plus indoor dust ingestion for use in Australian screening risk assessments. This value is consistent with the value recommended by the Netherlands (RIVM 2007), UK (UK EA 2009b), and the US EPA (2009a).

4.5.3 Recommendations

The suggested exposure factors for soil ingestion are summarised in Table 4.5.3. The suggested values for outdoor soil and outdoor soil plus indoor dust ingestion for a 0–1 year old are 30 and 60mg/day, respectively (US EPA 2008); however, these values are based on very limited data from tracer studies for young infants.

1 to 5 year old children:

The age group that generally ingests the highest amount of soil are 1–5 year old children due to their intimate contact with soil during play. The US EPA (2008) recommended "central tendency" for outdoor soil ingestion and outdoor soil plus indoor dust ingestion of 50 and 100 mg/d respectively are suggested for use in Australian risk assessments (for 1–15 year old children). The "central tendency" for outdoor soil ingestion is similar to the overall calculated mean of 63 mg/day for the distribution of all tracer studies included in a Dutch analysis (van Holderbecke et al. 2007). The analysis by van Holderbecke et al. (2007) also showed data from studies using different techniques for estimating soil ingestion by children suggested average outdoor soil ingestion by children was not higher than 100 mg/day. Thus a reasonable maximum value of 100 mg/d for outside soil ingestion by children aged 1–15 years is also suggested for use in Australian residential screening assessments (Table 4.5.3). This reasonable maximum is similar to the 95th percentile outdoor soil ingestion estimates calculated by Van Holderbecke et al. (2007), Stanek et al. (2001), and Stanek and Calabrese (2000) of 81, 91, and 106–133 mg/day, respectively.

Adults:

The average and median values for soil/dust ingestion by adults from experimental studies ranged between 10–92 and 1–30 mg/d respectively. Based on "bootstrapping" statistical analysis of mean values from three tracer studies, Van Holderbeke et al. (2007) concluded average outdoor soil/indoor dust ingestion values for adults probably range from 25 (median) to 45 (mean) mg/day (95th percentile 60 mg/day). The mean value of 45 mg/day was rounded up to 50 mg/d and brought forward as the suggested value for outdoor soil plus indoor dust ingestion for use in Australian screening risk assessments, together with a 95th percentile of 60 mg/day. The mean value is consistent with the value of 50 mg/day recommended by the Netherlands (RIVM 2007) for outdoor soil, UK (UK EA 2009b) for outdoor soil plus indoor dust, and the US EPA (2009a) for outdoor soil.

Table 4.5.3: Suggested soil ingestion values for non-pica and non-geophagy (mg/day)

Age (years)	Soil ingestion (mg/day)
0–1	30 (Central tendency, outside soil) 60 (Central tendency, outside soil plus indoor dust)
1–15[a]	50 (Central tendency, outside soil) 100 (Reasonable maximum, outside soil) 100 (Central tendency, outside soil plus indoor dust; 50% of indoor dust is assumed to be derived from outdoor sources – see section 5.7).
≥ 15	50 (Rounded average, outside soil plus indoor dust) 60 (95th percentile, outside soil plus indoor dust)

The experimental data for children are for ages up to about 7 years, the soil or soil plus indoor dust ingestion is recommended for up to 15 years to be consistent with van Holdebecke et al. (2007), UK EA (2009b) and US EPA (2008) (see Table 4.5.2).

For residences with a garden it can be assumed that approximately 50% of indoor dust is outdoor soil (Section 5.7).

These suggested values should not be used in cases where soil-pica or geophagia are suspected. Such scenarios should be considered on a case-by-case basis. The US EPA defaults of 1,000 mg/day for individuals (1–<21 years) displaying soil-pica behaviour and 50,000 mg/day (age 1–adult) for geophagia may be used in the absence of specific information (US EPA 1997; 2009a).

For specialised site-specific risk assessments that require a distinction between source of the contaminant (soil only or house dust only), the standard residential default of 100 mg/day for a child may not be appropriate. The risk assessor is encouraged to refer to the discussion within the text and tables above as well as the original literature in such cases; the recommendations of the US EPA (2008) may be appropriate.

4.6 Incidental ingestion during swimming

During swimming the whole body or the face and trunk are frequently immersed, or the face is frequently wetted by spray, and thus it is likely that some water will be incidentally swallowed. The skill of the participant in water recreation will be important in determining the extent of involuntary water ingestion.

Actual data on the quantities of water ingested while swimming are difficult to obtain.

4.6.1 Australian data

No Australian data for incidental ingestion of water while swimming were located. The NHMRC (2008, p. 155) *Guidelines for Managing Risks in Recreational Water* state that when applying drinking water quality guidelines to recreational water, consumption of 100-200 mL per day should be taken into consideration, but provide no references for this range.

4.6.2 Overseas data

Three studies were found that quantified incidental ingestion while swimming (Dufour et al. 2006; Schets et al. 2011; Dorevitch et al. 2011).

Dufour et al. (2006) investigated outdoor pool water intake from 53 swimmers (12 adults, 41 children aged 6–15 years). The amount of water ingested in a swimming session lasting 45 minutes was estimated using cyanuric acid in urine as an indicator of pool water ingestion exposure. Cyanuric acid is a breakdown product of chloroisocyanurates, which are commonly used in disinfectant stabilisers in recreational water treatment and is not metabolised therefore the amount ingested can be estimated from the concentration in pool water and urine.

The range of water volume ingested by children was 0–154 mL; 97% swallowed 90 mL or less. Adults swallowed between 0–53 mL of water. No upper estimates were provided. The study results are summarised in Table 4.6.1 as average water ingestion rate per 45 minute event and per hour.

Schets et al. (2011) collected questionnaire data on self-reported volume of water swallowed during swimming and frequency and duration of swimming events in swimming pools, fresh water and seawater from Dutch adults during the 2007 and 2009 swimming season. Questionnaires were answered by adults (≧ 15 years) on behalf of themselves and their eldest child in the household. A total of 8000 adults (>15 years) and 1,924 children (<15 years) participated in the survey.

Respondents were asked to describe water ingestion in terms of “none or only a few drops”, “one to two mouthfuls”, “three to five mouthfuls”, or “six to eight mouthfuls”. For reference, participants were told one or two mouthfuls was equivalent to a shot glass, three to five was equivalent to a coffee cup, etc. These estimates were subsequently translated to millilitre volumes by collecting data on the actual volumes of mouthfuls experimentally from a panel of 119 males and females of various ages, and using this information to construct a distribution using Monte Carlo. It was assumed that “none or a few drops” was a continuous uniform gamma distribution from 0 to 5 mL.

Table 4.6.1: Pool water incidental ingestion

Age	No of subjects	Average water ingestion rate (mL)[a]	Average water ingestion rate (mL/hour)[b]
Children < 16 years old			
Male plus female	41	37	**49**[c]
Males	20	45	60
Females	21	30	43
Adults (>18 years)			
Male plus female	12	16	21
Men	4	22	29
Women	8	12	16

Data from Dufour et al. 2006 as reported in US EPA (2008, Table 3–34).

Per 45 minute event.

Converted from mL/45 minute interval to mL/hr.

This value was rounded (50 mL/hr) and brought forward as the suggested average incidental ingestion rate for children (≦ 15 yrs) for Australian screening risk assessments (Tables 4.6.3 and E3).

Adults swallowed an average of 18–34 mL per swimming event, and children an average of 31–51 mL per event for swimming pools, fresh water and sea water. Swimming events lasted on average 41–68 minutes for adults and 65–81 minutes for children. The data from Schets et al. (2011) for swimming pools are presented in Table 4.6.2.

Dorevitch et al. (2011) used a combination of experimental and survey methods. They collected self-reported estimates of water ingestion during recreational water sport activities (canoeing, kayaking and fishing) for 2705 people, as well as for 662 people engaged in various recreational activities in and around swimming pools. They used the cyanuric acid tracer method from Dufour et al. (2006) to quantitatively measure incidental water ingestion in the latter group. There was no constraint on duration of outdoor recreational activities, but duration of all swimming pool activities (with the exception of head immersion) was 60 minutes. Results of water ingestion were not presented by age group, but by activity. Average ingestion rate for the "swimming" activity was 10 mL/hr, the median was 6 mL/hr, and the upper confidence limit was 34.8 mL/hr (95 adults aged >18 years, 19 children aged <18 years).

Table 4.6.2: Water ingestion during recreational swimming in swimming pools

	Volume of water swallowed per event (mL)		Average duration of event (mins)	Average water ingestion rate (mL/hr)[a]	Calculated upper estimate water ingestion rate(mL/hr) [b]
	Average	95th % CI			
Adults (>15 yrs)					
Men	34	0.022–170	68	**30**[c]	**150**[d]
Women	23	0.033–110	67	**21**[c]	**98**[d]
Children (<15 yrs)					
	51	0.062–200	81	38	**150**[d]

CI = confidence interval

Data from Schets et al. (2011)

Calculated from average volume of water swallowed (mL) and average duration of event (mins).

Calculated from upper 95th percentile confidence limit for volume of water swallowed (mL) and average duration of event (mins).

The average incidental water ingestion rate for males and female adults (>15 yrs) combined (25.5 mL/hr) was rounded down (25 mL/hr) and brought forward as the suggested value for use in Australian screening risk assessments.

The average male and female adult (>15 yrs) calculated upper estimate incidental water ingestion rate (124 mL/hr) was rounded down and brought forward as the suggested upper estimate value for Australian screening risk assessments. Similarly the upper estimate value (150 mL/hr) for children (≦15 yrs) was also brought forward (Table 4.6.3).

4.6.3 Recommendations

Mance et al. (1984, cited in WHO 1998) considers ingestion of bathing water should only make a relatively minor contribution to overall water water intake. WHO (2003, p. 170) states:

They assumed a contribution for bathing of an equivalent of 10 per cent of drinking water consumption. Since most authorities assume 2 L consumption of drinking water per day, an intake of 200 mL per day from recreational contact with water seems reasonably conservative. Since most authorities (including WHO) assume consumption of 2 litres of drinking-water per day, this would result in an intake of 200 ml per day from recreational contact with water.

(WHO 2003, p. 170)

A similar assumption has been made by the NHMRC in the recreational water quality guidelines document (NHMRC 2008). However, this is simply a rule of thumb and does not consider the circumstances of exposure nor empirical data. It is logical to assume ingestion of bathing waters will be proportional to the time spent swimming.

Children:

The US EPA (1989) recommend an ingestion rate of 50 mL/hour (adults and children) for swimming in a pool, and the US EPA's Science Advisory Panel use this value to estimate pesticide intake by children after application to swimming pools (US EPA 1997b). This US EPA (1989) value is the same as the experimental data (Dufour et al. 2006) for the average amount (49 mL/hr) ingested for male and female children combined (Table 4.6.1), but slightly greater than the average ingestion rate (38 mL/hr) for children (<15 years) in the Schets et al. (2011) study (Table 4.6.2). The higher of the two estimates was rounded (50 mL/hr) and brought forward as the suggested approximate average value for use in Australian screening risk assessments for children (≤15 years).

Adults:

The empirical data for average ingestion while swimming by adults (males and females combined) are 21 and 25.5 mL/hr from Dufour et al. (2006) and Schets et al. (2011), respectively (Tables 4.6.1 and 4.6.2). Thus for adults (>15 years) an approximate average ingestion rate of 25 mL/hr (rounded down from 25.5 mL/hr) is the suggested value for use in Australian risk assessments.

Upper estimates children and adults:

Upper percentile confidence limits are only provided by the Schets et al. (2011) study (Table 4.6.2). For male and female adults (>15 yrs) combined the suggested estimate of upper ingestion rate is 125 mL/hr (rounded up from 124 mL/hr); for children (≤15 yrs), the suggested estimate is 150 mL/hr.

The suggested values for Australian risk assessments are summarised in Table 4.6.3. Time spent swimming is discussed in section 6.2.4.

Table 4.6.3: Suggested values for incidental water ingestion rates while swimming

		Suggested incidental water ingestion rate (mL/hr**)**
Adults (>15 yrs)	Approximate average	25
	Approximate upper estimate	125
Children (≤ 15 yrs)	Approximate average	50
	Approximate upper estimate	150

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5. Estimating intake via inhalation

Exposure to contaminants in air is most commonly characterised by direct measurement or modelled estimation of substance concentration (e.g. as µg/m^3) in the general area or immediate vicinity of individuals exposed or assumed to be exposed. When judging the impact of long-term exposure to airborne pollutants, average concentrations and average daily inhalation rates over the exposure period are appropriate. For short-term exposures, substance concentrations and inhalation rates that match the particular scenario should be used.

In some multiple-intake pathway assessments estimating an intake (absorbed dose expressed in mg/kg bw/day) is usually required (US EPA 1989). Estimating the absorbed dose via inhalation depends on exposure factors such as: inhalation rate; airborne chemical concentration; bioavailability; body weight; exposure time and duration. For particles, aerodynamic size, shape and solubility are important determinants for deposition and fate within the lung. The selection of inhalation rates to be used for exposure assessments depends on the age of the exposed population and the specific activity levels expected in the exposure scenarios.

5.1 Inhalation rates

5.1.1 Australian data

Australian data for inhalation rates were not located.

5.1.2 Overseas data

Health Canada (2004) recommends air intakes of 2.1, 9.3, 14.5, 15.8 and 15.8 m^3/d for those aged 0–6 months, 7 months to 4 years, 5–11 years, 12–19 years and over 20 years respectively. These are based a number of sources, some of which are Canada specific.

The US EPA Integrated Risk Information System (IRIS) apply an inhalation rate of 20 m^3/day when developing inhalation cancer potency factors and reference concentrations (RfCs) for non-cancer endpoints (IRIS 1995, 2002, 2003, 2009).

Some WHO documents also use 20 m^3/d (e.g. WHO CICAD 2006).

Inhalation rate recommendations in the US EPA (1997) *Exposure factors handbook* were made on a number of key studies in which ventilation rates were calculated from regression equations relating heart rate to ventilation rate under various levels of exertion (Adams 1993; Linn et al. 1992; 1993; Spier et al. 1992). In these investigations children, adolescents and adults were initially calibrated in laboratory conditions where both heart and ventilation rates were measured in order to establish the regression equations. Subjects subsequently undertook 'real life' activities (e.g. resting, sitting, slow/fast walking, jogging, car driving, car maintenance, spontaneous play) during which heart rates were measured; this enabled time-weighted ventilation rates for the various activities to be calculated. An update of US EPA (1997) is available in draft format (US EPA 2009a), see below for discussion.

Layton (1993) calculated breathing rates based on weighted average oxygen uptake associated with variable energy expenditures for short (hours) and long (weeks and months) periods of time using a general physiological equation relating energy expenditure to ventilation rates. Energy expenditure was estimated from basal metabolic rates (BMR) determined from daily food energy intakes from US nationwide food surveys, or from energy regression equations to predict BMR from body weights of various age/gender cohorts. The US EPA (1997) presented ventilation rate estimations for children, adults and outdoor workers for five levels of activity (rest, sedentary, light, moderate and heavy activities). The long-term mean inhalation rates for adults recommended by the US EPA (1997) were 11.3 m^3/d and 15.2 m^3/d for females and males respectively.

The US EPA has subsequently published new recommended inhalation rates for children in their *Child-specific exposure factors handbook* (US EPA 2008), which have been incorporated, together with updated data for adults, into a draft update of the US EPA 1997 *Exposure factors handbook* (US EPA 2009a). The Layton (1993) methodology using energy utilisation and associated oxygen consumption at different activity levels has been improved and applied to current food consumption data and the US EPA's Consolidated Human Activity Database (CHAD) to produce recommended values for short-term inhalation rates by age group and activity level (Arcus-Arth and Blaisdell 2007, US EPA 2009b) (Table 5.1.2).

Information on inhalation rates has also been supplemented by studies using doubly labelled water (DLW) (Brochu et al. 2006, Stifleman 2007). The DLW method administers two forms of sTable isotopically labelled water: deuterium-labelled (^2H_2O) and 18-oxygen labelled ($H_2{}^{18}O$). The difference in disappearance rates between the two isotopes represents the energy expended over a period of one to three half-lives of the labelled water. The actual observation period is thus one to three weeks depending on the size and activity level. DLW data have been compiled by the Institute of Medicine (IOM) Panel on Macronutrients and the Food and Agriculture Organization of the United Nations (FAO) and contains multinational information portraying diversity in ethnicity, age, activity, body type and fitness level. Stifelman (2007) used Layton's (1993) equation to convert the recommended energy levels of IOM to their equivalent inhalation rates.

Table 5.1.1 summarises the inhalation rates for 'long-term' exposure recomended by the US EPA (2008; 2009b). These have been incorporated into their 2009 draft *Exposure factors handbook* (US EPA 2009a) with a note there is medium overall confidence in the information. Long-term exposure refers to repeated exposure for more than 30 days, up to approximately 10% of the life span in humans; the data are presented as daily rates (m^3/day). Table 5.1.1 also includes inhalation rates (m^3/hr) for outdoor workers from the US EPA (1997). It also contains upper percentile values; however, the US EPA (2009a) advises these represent unusually high inhalation rates for long-term exposures, even for the upper end of the distribution.

The US EPA (2009a) draft *Exposure factors handbook* also provides recommended inhalation rates for *short-term* exposure (repeated exposure for more than 24 hours and up to 30 days) for adults and children performing various activities originally published by US EPA (2009b). The recommended short-term inhalation rates are presented in Table 5.1.2.

Table 5.1.1: Inhalation rates for 'long-term' exposure (more than 30 days) (m^3/d or m^3/hr) recommended by the US EPA for males and females combined

Population		Inhalation rate (m^3/day)	
		Mean	95th percentile[c]
Children (US EPA 2008, wTable 6–1)	0–<1 month	3.6	7.1
	1–<3 months	–	–
	3–<6 months	4.1	6.1
	6–<12 months	**5.4**[d]	**8.1**[d]
	1–<2 yrs	**8.0**[d]	**12.8**[d]
	2–<3 yrs	**9.5**[d]	**15.9**[d]
	3–<6 yrs	**10.9**[d]	**16.2**[d]
	6–<11 yrs	**12.4**[d]	**18.7**[d]
	11–<16 yrs	**15.1**[d]	**23.5**[d]
	16–<21 yrs	**16.5**[d]	**27.6**[d]
Adults (US EPA 2009b, Table 6–1)	21–<31 yrs	**15.7**[e]	**21.3**[e]
	31–<41 yrs	**16.0**[e]	**21.4**[e]
	41–<51 yrs	**16.0**[e]	**21.2**[e]
	51–<61 yrs	**15.7**[e]	**21.3**[e]

Population		Inhalation rate (m^3/day) Mean	95th percentile[c]
	61–<71 yrs	**14.2**[e]	**18.1**[e]
	71–<81 yrs	**12.9**[e]	**16.6**[e]
	81 yrs and older	12.2	15.7

Population	Activity[a]	Mean (m^3/hr)	Upper percentile (m^3/hr)
Outdoor[b] Workers (US EPA 1997, Table 5–23)	Hourly average	1.3	3.3
	Light activities	1.1	–
	Moderate activities	1.5	–
	Heavy activities	2.5	–

– No data for this group

Light is defined as walking at a speed level of 2.4–4.8 km/hr; moderate is fast walking (5.3–6.4 km/hr) or slow running (5.6–6.4 km/h); heavy is fast running (7.2–9.6 km/hr).

From US EPA (1997). Recommendations are based on data from Linn et al. (1992; 1993). The upper percentile average hourly inhalation rate is calculated as the weighted mean of the 99th percentile values from the studies. Outdoor workers from Linn et al. (1993) included general construction workers/labourers (*n* = 5), iron workers (*n* = *3*) and carpenters (*n* = 11), and those from Linn et al. (1992) included 20 healthy outdoor workers (jobs not specified) and construction workers (*n* = 7). Inhalation rates were measured during exercise tests, which included slow walking, fast walking, jogging, lifting and carrying. The US EPA (1997) states that inhalation rates for outdoor workers may be higher than in the Table because the level of work or activities performed may be higher in some cases than in the studies by Linn et al. (1992, 1993).

The US EPA (2009a) states some 95th percentile values may be unrealistically high and not representative of the average person.

These mean (i.e. average) and 95th percentile inhalation rates for children (by age group) were brought forward as suggested values for use in Australian screening risk assessments (Section 5.1.3).

The mean and 95th percentile inhalation rates for adults of different age groups ranging from 21 to <81 years were averaged to give 'average' mean and 'average' 95th percentile inhalation rates of 15 and 20 m^3/d. These values were brought forward as suggested values for Australian screening risk assessments.

Table 5.1.2: Inhalation rates for short-term exposure (less than 30 days) recommended by the US EPA for males and females combined

Activity level [a]	Age group	Inhalation rate (m^3/min) Mean	Inhalation rate (m^3/min) 95th percentile
Sleep or nap	Birth–<1 yr	0.003	0.0046
	1–<2 yrs	0.0045	0.0064
	2–<3 yrs	0.0046	0.0064
	3–<6 yrs	0.0043	0.0058
	6–<11 yrs	0.0045	0.0063
	11–<16 yrs	0.005	0.0074
	16–<21 yrs	0.0049	0.0071
	21–<31 yrs	0.0043	0.0065
	31–<41 yrs	0.0046	0.0066
	41–<51 yrs	0.005	0.0071
	51–<61 yrs	0.0052	0.0075
	61–<71 yrs	0.0052	0.0072
	71–<81 yrs	0.0053	0.0072
	81 yrs and older	0.0052	0.007
Sedentary/ passive	Birth–<1 yr	0.0031	0.0047
	1–<2 yrs	0.0047	0.0065
	2–<3 yrs	0.0048	0.0065
	3–<6 yrs	0.0045	0.0058
	6–<11 yrs	0.0048	0.0064
	11–<16 yrs	0.0054	0.0075
	16–<21 yrs	0.0053	0.0072
	21–<31 yrs	0.0042	0.0065
	31–<41 yrs	0.0043	0.0066
	41–<51 yrs	0.0048	0.007
	51–<61 yrs	0.005	0.0073
	61–<71 yrs	0.0049	0.0073
	71–<81 yrs	0.005	0.0072
	81 yrs and older	0.0049	0.007
Light intensity	Birth–<1 yr	0.0076	0.011
	1–<2 yrs	0.012	0.016

Activity level [a]	Age group	Inhalation rate (m^3/min)	
		Mean	95th percentile
	2–<3 yrs	0.012	0.016
	3–<6 yrs	0.011	0.014
	6–<11 yrs	0.011	0.015
	11–<16 yrs	0.013	0.017
	16–<21 yrs	0.012	0.016
	21–<31 yrs	0.011	0.016
	31–<41 yrs	0.011	0.016
	41–<51 yrs	0.012	0.016
	51–<61 yrs	0.012	0.017
	61–<71 yrs	0.011	0.016
	71–<81 yrs	0.011	0.015
	81 yrs and older	0.012	0.015
Moderate intensity	Birth–<1 yr	0.014	0.022
	1–<2 yrs	0.021	0.029
	2–<3 yrs	0.021	0.029
	3–<6 yrs	0.021	0.027
	6–<11 yrs	0.022	0.029
	11–<16 yrs	0.025	0.034
	16–<21 yrs	0.026	0.037
	21–<31 yrs	0.026	0.038
	31–<41 yrs	0.027	0.037
	41–<51 yrs	0.028	0.039
	51–<61 yrs	0.029	0.04
	61–<71 yrs	0.026	0.034
	71–<81 yrs	0.025	0.032
	81 yrs and older	0.025	0.031
High intensity	Birth–<1 yr	0.026	0.041
	1–<2 yrs	0.038	0.052
	2–<3 yrs	0.039	0.053
	3–<6 yrs	0.037	0.048
	6–<11 yrs	0.042	0.059

Activity level [a]	Age group	Inhalation rate (m^3/min)	
		Mean	95th percentile
	11–<16 yrs	0.049	0.07
	16–<21 yrs	0.049	0.073
	21–<31 yrs	0.05	0.076
	31–<41 yrs	0.049	0.072
	41–<51 yrs	0.052	0.076
	51–<61 yrs	0.053	0.078
	61–<71 yrs	0.047	0.066
	71–<81 yrs	0.047	0.065
	81 yrs and older	0.048	0.068

Data from US EPA (2009b).

The Consolidated Human Activity Database (CHAD) contains information from 12 pre-existing human activity studies conducted within the US. The database includes information on each activity undertaken by a given study subject during a monitoring period of at least 24 hours. The activity-specific information includes an estimate of the metabolic cost of performing the activity. Metabolic cost is given in units of METS or 'metabolic equivalents of work.' The CHAD assigns a METS value to an activity, but does not always assign the same single point METS value to each occurrence of the same activity within the database. Instead, CHAD assigns a statistical distribution to each activity code representing the distribution of possible METS values associated with that activity. The US EPA (2009b) grouped activity patterns according to their METS value: sedentary/passive (METS < 1.5), light intensity (1.5 < METS < 3.0), moderate intensity (3.0 < METS < 3.0), and high intensity (METS > 6.0) (US EPA 2009b).

From US EPA (1997, Table 5A-6), the following representative activities are associated with different minute inhalation rates in male adults:

Inhalation rate (m^3/min)	Representative activities
0.013	Level walking at 3.2 km per hour; washing clothes
0.019	Level walking at 4.8 km per hour; bowling; scrubbing floors
0.025	Dancing; pushing wheelbarrow with 15-kg load; simple construction; stacking firewood
0.03	Easy cycling; pushing wheelbarrow with 75-kg load; using sledgehammer
0.035	Climbing stairs; playing tennis; digging with spade
0.04	Cycling at 20.9 km per hour; walking on snow; digging trenches
0.055	Cross-country skiing; rock climbing; stair climbing with load; playing squash or handball; chopping with axe
0.063	
0.072	
0.085	Level running at 16.1 km per hour; competitive cycling
≥0.1	Competitive long distance running; cross-coutry skiing

Reference men, women and children

The ICRP (1975 p. 346; 2002, p. 26) estimated daily inhalation rates for reference adult males, females, children (10 years old), infants (1 year) and newborns (three months of age) using a time-activity ventilation approach. ICRP assumed:

- a newborn's (three months) day consisted of 17 hours of sleep and seven hours of light exercise.
- that an infant's day consisted of 14 hours of sleep, 3.3 hours of sitting and 6.7 hours of light exercise
- the daily activities of a reference adult woman and man consisted of 8–8.5 hours of sleep, 5.4–6 hours of sitting, 9.8–9.9 hours of light exercise, and 0.19–0.25 hours of heavy exercise.

Hourly ventilation rates were calculated using average lung tidal volume and respiration frequency, with daily ventilation rates derived from hourly activities in a day. Reference values from ICRP are given in Table 5.1.3. The ICRP recommendation for the average inhalation rate for adults (male and female combined) in the general population is 20 m^3/day. This is close to the 95th percentile values from the US EPA in Table 5.1.1.

Table 5.1.3: ICRP average reference values for daily ventilation rates

Life stage	Ventilation rate (m^3/day)
Children	
3 months	2.8
1 year	5.1
5 years	8.8
10 years	15.2
15 year old females	15.8
15 year old males	20.1
Adults	
Female	18.2
Male	22.2

Data from ICRP 2002, p. 26

Workers

The ICRP (2002, p. 27) also provide reference ventilation rates for workers according to the level of work performed. Table 5.1.4 provides the ICRP reference values for sedentary male and female workers, and males conducting heavy work like firemen, construction workers and farm workers. Information for female workers performing heavy duties was not available.

5.1.3 Recommendations

The ICRP (1975, 2002) recommendation for the average inhalation rate for adults (male and female combined) in the general population is 20 m^3/day (from Table 5.1.3). The US EPA IRIS (1995; 2002; 2003; 2009) also uses a default inhalation rate of 20 m^3/day for its calculations. The WHO also applies the 20 m^3/day inhalation rate in some of its assessments (e.g. WHO CICAD 2006).

In 1994 Health Canada (CEPA 1994) recommended an average value of 23m^3/d for use in risk assessments for priority substances (for adults). However, for federal contaminated site risk assessment, the Canadian 2004 guidance on preliminary quantitative risk assessment indicates an average of 15.8 m^3/d is appropriate (Health Canada 2004). It is noted these different recommendations are supported by different source documents; the higher inhalation rate was taken from a survey of Canadians undertaken in 1992, the lower value is supported by a probabilistic assessment of a large number of studies cited in Allan and Richardson (1998) and is likely to be more representative of the overall Canadian adult population. The lower value is similar to the average inhalation rate for adults (average for 16–<81 years old is 15 m^3/d) recommended by the US EPA (2009b, Table 5.1.1), the US EPA recommendation is supported by a diferent set of studies to the Canadian recommendation.

Table 5.1.4: ICRP reference ventilation rates (m^3/day) for adult workers

Activity	Ventilation rate (m^3/day)		
	Sedentary worker		Heavy worker (Male)
	Male	Female	
Sleeping (8 h)	3.6	2.6	3.6
Occupational (8 h)	9.6[a]	7.9 [a]	13.5[b]
Non-occupational (8 h)[c]	9.7	8.0	9.7
Total air breathed	22.9	18.5	26.8

Data from ICRP 2002, p. 27

Assumed to consist of 1/3 sitting and 2/3 light exercise.

Assumed to consist of 7/8 light exercise and 1/8 heavy exercise.

Assumed to consist of 4/8 sitting, 3/8 light exercise and 1/8 heavy exercise.

Adults:

An inhalation rate of 15 m^3/day as an average would be suitable for adults (male and female combined) in Australian screening risk assessments involving long-term exposures to airborne substances; a value of 20 m^3/d, according to the US EPA (2009 a, b), is approximately a 95th percentile value (Table 5.1.1).

Children:

Inhalation rates for children vary markedly according to age and activity. For a 2 year old, an average inhalation rate of 9.5 m^3/d would be suitable in screening risk assessments (Table 5.1.1). A value of 15.9 m^3/d represents a 95th percentile. Suggested values (averages and 95th percentiles) for long term exposures of children in other age groups are also provided in Table 5.1.1.

For both adults and children some of the upper values represent unrealistically high inhalation rates for the average population (US EPA 2009b).

Sub-populations:

Exposure calculations for sensitive or specific sub-populations (such as outdoor workers) and for short-term exposures should utilise inhalation rates that correspond to the population and activity of interest (some of these values are provided in Tables 5.1.1; 5.1.2, and 5.1.4).

5.2 Building air exchange rates

Air exchange rates are generally expressed in terms of the number of air changes per hour (AC/hr) or as the mass of airflow per hour (m^3/h).

Air exchange is the balance of air flow into and out of a building, and is influenced by three processes:

(1) Infiltration – air leakage through building openings.

(2) Natural ventilation -airflows through open windows, doors etc.

(3) Forced or mechanical ventilation, such as controlled air movement driven by fans (US EPA 1997).

The US EPA (1997) note that although the following model by Dietz et al. (1986) has not been extensively validated it can be used in estimating air change due to infiltration as follows:

$$A = L \left[0.006\ \Delta T + \frac{0.03}{C} U^{1.5}\right]$$

A = average air changes (AC) per hour of infiltration rate, AC/hr

L = generalised house leakiness factor (1<L<5)

C = terrain sheltering factor (1<C<10)

ΔT = indoor-outdoor temperature difference (C°)

U = wind speed (ms^{-1})

The value of L is greater as house leakiness increases and the value of C is greater as terrain sheltering (shielding by nearby wind barriers) increases. Meteorological data (including wind speed and temperature) are available from the Bureau of Meteorology for many airports and geographic locations around Australia. The calculation for air exchanges due to infiltration by the above equation is applicable if exterior doors and windows are closed. It does not include contributions from mechanical systems. Occupant behaviour, such as window opening, can overwhelm the idealised effects of temperature and wind speed in the equation (US EPA 1997, Section 17.3.3).

5.2.1 Residential buildings

5.2.1.1 Australian data

Air exchange levels in residential buildings are difficult to objectively determine as they require an understanding of lifestyle factors such as times when windows and doors are open. He et al. (2005), resident's descriptions of their normal practice, estimated the 'normal' rate of air changes in 13 houses in Brisbane in a suburb with reasonably flat topography to be 0.61 ± 0.45 AC/hr with doors/windows closed, and 3 ± 1.23 AC/hr with doors/windows open. Infiltration rates (minimum air changes via infiltration of air through cracks, spaces and ventilators in the building envelope) were experimentally determined using tracer gas techniques.

Infiltration rates for houses have also been measured in Melbourne, Perth and Sydney (Biggs et al.1987; Harrison 1985; Ferrari 1991, all cited in Brown 1997) and are presented in Table 5.2.1.

Biggs et al. (1986, cited in Brown 1997) measured the pressurised infiltration rates of a variety of Australian house designs, ranging from those more than 30 years old to contemporary ones. Older style houses with fixed wall vents had the highest AC/hr. Biggs et al. (1986) report that air change rates for houses typical of the building stock in the populous south-eastern part of Australia are relatively high by international standards, being approximately double the values quoted for houses in the UK, the Netherlands and New Zealand, and about six times those reported for houses in Sweden and Canada (Biggs et al. 1986, cited in Brown 1997).

Intuitively open doors and windows, ceiling fans and air conditioning will increase the rate of air changes in residential buildings; this is supported by the limited data in Table 5.2.1.

5.2.1.2 Overseas data

The US EPA (1997, section 17.6; 2009a, p. 19-2) recommends a default value of 0.45 AC/hr for residential buildings based on data from Koontz and Rector (1995). This value is the median for all regions in the United States. Murray and Burmaster (1995) categorised essentially the same data according to climate and season as shown in Table 5.2.2. The median values for the 'warmer' and 'warmest' climates varied between 0.39 and 1.1 AC/hr; it is noted the range of mean values for Australian residences that were 'closed up' are about the same (0.33–0.9 AC/hr, Table 5.2.1).

Table 5.2.1: Measured building air exchange rates (ACH) in Australia from several sources

Mean value (AC/hr)	Location	Notes	Reference
0.61 or 3	Brisbane	Mix of 13 houses, new and old, brick and timber, high and low set, flat topography. All doors and windows closed, or doors/windows normally open stayed open during measurements.	He et al. (2005)
0.33[b]	Melbourne	7 unoccupied houses; single-storey, suburban that varied widely in age and construction material (included examples of the more significant types of houses to be found in the building stock in SE Australia at the time). All houses had floor coverings and were painted; pressurised infiltration was measured (all windows and external doors shut and all internal doors except toilet open). Increases with increasing wind speed.	Biggs et al.(1987)[a]
0.05–0.41	Perth	9 new houses; brick veneer, tile roof, concrete slab floor, single storey, no fixed wall vents; used tracer gas technique.	Harrison (1985)[a]
0.9	Sydney	43 dwellings (no description given), measured on winter evenings (heating unflued gas heaters, windows and doors closed – simulated winter conditions).	Ferrari (1991)[a]
0.33	Sydney	Dwellings < 5 years old (no description given), measured on winter evenings (heating unflued gas heaters, windows and doors closed – simulated winter conditions).	Ferrari (1991)[a]
0.6[c]	**Mid-point of range of measured air exchange rates in residential dwellings of Australia (0.3-0.9 AC/hr)**		
7.92	Queensland	Classroom (9.6 x 7.25 x 2.7m) in small village surrounded by local residences; windows open, air conditioning and ceiling fans on.	Guo et al. (2008)

Cited in Brown 1997

Background infiltration (no wind). The authors used empirical equations and wind data to estimate the natural infiltration rate for the test houses in major Australian cities. Their results were 0.44 AC/hr in Canberra, 0.55 in Sydney and Hobart and 0.57 AC/hr in Melbourne.

Mid-point of range (0.3–0.9 AC/hr) of measured air exchange rates in residential dwellings of Australia, 0.6 AC/hr, was brought forward as a suggested value for use in Australian screening risk assessments. Upper estimates were not available. No specific recommendation is made for commercial buildings (Section 5.2.4).

Table 5.2.2: Residential US Air exchange data by climatic region and season

Climate	Season	Sample size	Air changes per hour (AC/hr)	
			Median	90th percentile
Coldest: Most samples from New York	Winter	161	0.27	0.71
	Spring	254	0.36	0.80
	Summer	5	0.57	2.01
	Autumn	47	0.22	0.42
Colder: Most samples NY and WA	Winter	428	0.42	1.18
	Spring	43	0.24	0.83
	Summer	2	–	–
	Autumn	23	0.33	0.59
Warmer: Most samples from Oregon (OR)	Winter	96	0.39	0.78
	Spring	165	0.48	1.11
	Summer	34	0.51	1.30
	Autumn	37	0.44	0.82
Warmest: Most samples from California	Winter	454	0.48	1.13
	Spring	589	0.63	1.42
	Summer	488	1.10	3.28
	Autumn	18	0.42	0.74

Data from Murray and Burmaster (1995)

Nazaroff (2004) provides probability distribution figures for air exchange rates measured in US buildings (residences and offices) based on information in Persily (1989) and Murray and Burmaster (1995). From these figures approximately 50% of US residences have an air exchange rate of less than 0.6/hr.

RIVM (2006) also recommends a default value of 0.6 air exchange rates per hour for residential homes based on Dutch data.

5.2.2 Non-residential

5.2.2.1 Australian data

Australian data for non-residential air exchange rates were not located.

Australian standards for ventilation and air conditioning in residential and non-residential buildings for indoor air contaminant control give a prescriptive procedure for calculating minimum airflow rates according to the number of occupants (L/s per occupant) (Standards Australia 2002). Standard minimum airflow rates are dependant on temperature as well as the use of enclosures within the building (i.e. level of activity of occupants).

The *Australian building code* states that natural ventilation is accepable as long as opened windows in each room have an area of 5% or more of the floor area of the room.

5.2.2.2 Overseas data

Johnson (2002b) has summarised data for US non-residential air exchange rates and generated frequency distributions using data primarily from two studies:

- Turk et al. (1989), in which air exchange in schools (7), offices (25), libraries (3) and multipurpose buildings (5) were measured.
- California Energy Commission (Lagus Applied Technology Inc. 1995), which measured schools (15), offices (22) and retail stores (13).

All non-school data were combined into a single dataset of 68 values, which were reported to have a log-normal distribution with geometric mean and standard deviation of 1.24 ± 1.93AC/hr (Johnson 2002b).

5.2.3 Car parks

Section 7 of the Australian Standard AS1668.2 (2002) provides ventilation guidance for all enclosures in which vehicles powered by combustion engines are parked, serviced or operated. It includes guidance for naturally ventilated and mechanically ventilated enclosures. The amount of ventilation depends on the type and quantity of vehicles using the enclosures, the time engines operate and the time the occupant spends in the enclosure. Higher ventilation rates are needed where the occupant is present for extended duration (i.e. occupational exposure of a car park attendant). Minimum airflow rate calculation methods are described in AS1668.2 (2002).

In risk assessment scenarios involving car parks, particularly those in basements, the air exchange rate should be based on site-specific considerations.

5.2.4 Recommendations

Residential:

Studies on air exchange rates in Australian homes have been conducted over a wide time scale and with different methods (Table 5.2.1). The data suggest resdiential air exchange rates in Australia are generally higher than those in the US (Table 5.2.2). The US EPA (1997) default (0.45 per hour) is based on the median value for all US regions (including many that are not representative of the Australian climate) and it is likely that most of the homes tested had windows closed for the duration of the test.

Given the more temperate climate in Australia, and in the absence of specific building information, a value of 0.6 air exchanges per hour is recommended. This is the mid point of the measured range (0.3–0.9 AC/hr) for Australian dwellings with doors and windows closed. This range is consistent with data from warm regions of North America (0.39–1.1 AC/hr). The value of 0.6AC/hr is considered conservative for vapour intrusion assessments because air exchange within the dwelling will increase with open doors and windows, and the use of fans and air conditioners. Upper estimates were not available.

Non-residential:

Data for Australian non-residential buildings could not be located. However, it is expected that for many non-residential buildings that are mechanically ventilated a building-specific air exchange rate can be provided. A default sometimes used in the US is 0.83 air exchanges per hour (e.g. Galbraith 2004); however, US studies of non-residential buildings (excluding schools) have derived a geometric mean of 1.24 air exchanges per hour.

The lack of Australian data, coupled with the almost infinite range of types of non-residential buildings, does not enable recommendation of air exchange rates for non-residential buildings. The risk assessor should use building-specific information; if this cannot be obtained then the value used in the risk assessment for air changes in non-residential buildings should be justified (e.g. by calculation according to the relevant Australian ventilation standard(s) for buildings).

5.3 Indoor particle deposition rates

Knowledge of particle deposition rates onto indoor surfaces and the factors governing these rates is important in assessing exposures to individuals to indoor dust. Nazaroff (2004) gives a practical overview of issues related to indoor particulate matter. The major factors governing indoor particle concentrations include direct emissions from indoor sources, ventilation supply from outdoor air, infiltration, deposition onto indoor surfaces, and removal from indoor air by means of ventilation.

Deposition rate (hr^{-1}) is a function of the deposition velocity (m/hr), also dependent on particle size and mass, and the surface to volume ratio (m^2/m^3) of the building or room interior (US EPA 1997, Section 17.3.4.1).

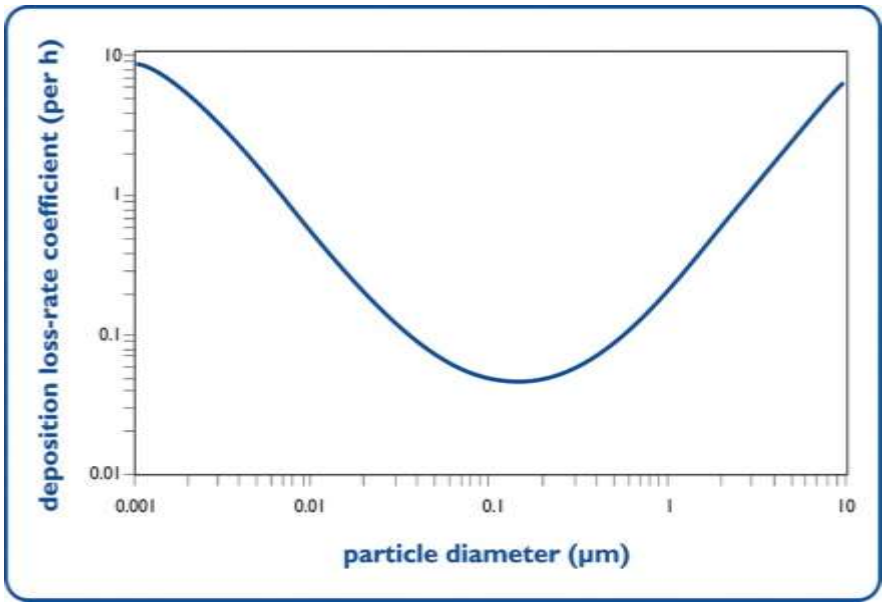
Studies quantifying size-dependent particle loss rates from air within residences, plus or minus ventilation, due to deposition have been reviewed by Lai (2002), Howard-Reed et al. (2003), Wallace et al. (2004) and He et al. (2005). These reviews summarise at least 25 studies of particle deposition. Thirteen of these were performed in experimental chambers, four were conducted in controlled test houses and the remainder in occupied or unoccupied houses.

In general:

- The studies were undertaken to address a variety of research objectives and have consequently employed different methods and estimation techniques to derive deposition rates. Some have used occupied residences with or without mechanical ventilation.
- All studies agree on the general relationship of particle size on deposition rate (U-shaped curve). Figure 5.3.1 is sourced from Nazaroff (2004) and represents a synthesis of model and measurement results as described by Riley et al. (2002).According to Nazaroff (2004) the figure represents the single-best estimate of size-dependent particle deposition loss rate for typical indoor environments. Not reflected is the large variability observed among different experiments in deposition rates for particles of any given size (Lai 2002).
- There is agreement that increased surface area of furnishings and increased air speeds are associated with higher deposition rates, although the effect of both these parameters is not large compared with the effect of particle size (Howard-Reed et al. 2003).

The US EPA (1997, section 17.3.4.1) cites a major review of indoor particles undertaken by Wallace (1996) who reported overall particle deposition rates (Table 5.3.1) for PM_{10} , $PM_{2.5}$, and $PM_{2.5–10}$ particulate size fractions from measurements taken in nearly 200 residences.

Figure 5.3.1: Particle size/diameter versus deposition rate



Source: Nazaroff (2004). Reproduced with permission from John Wiley and Sons (note deposition loss rate coefficient is equivalent to deposition rate)

Table 5.3.1: Deposition rates for indoor particles

Size fraction	Deposition rate (h^{-1})[a]
$PM_{2.5}$	0.39
PM_{10}	0.65
Coarse ($PM_{2.5\text{-}10}$)	1.0

Information from US EPA (1997, Table 17–12), which was adapted from Wallace (1996).

5.3.1 Recommendations

It is not possible to suggest a single-particle deposition rate suitable for all risk assessments since they markedly vary from house to house. It is important to consider factors contributing to this variation before selecting values to be used in risk assessments. For situations where estimates are required and specific data are not available, Figure 5.3.1 provides a guide for indoor deposition of different size particulates.

5.4 Volume and area of residential properties

Volume of an indoor air space (single-story house or commercial building) can be an important input parameter to estimating indoor air concentrations. For example, screening models for estimating vapour intrusion from contaminated soil or groundwater beneath a building treat the entire building as a single chamber with instantaneous and homogeneous vapour dispersion. One of the inputs to these models is the volume of the house or commercial building (i.e. surface area x ceiling height).

Table 5.4.1 provides a summary of common values used as an estimate of residential building volume and Table 5.4.2 summarises the average floor area of new residential buildings in Australia (ABS 2005, 2010).

The minimum ceiling height for a 'habitable room' stipulated by *Building code of Australia* is 2.4 metres (BCA 2009). However, a common default value for room height used for vapour intrusion modelling is 3 metres (e.g. Hers et al. 2002). Table 5.4.3 provides estimates of volume using the average floor area for each dwelling type assuming a 2.4-metre ceiling height and a 3-metre ceiling height.

Table 5.4.1: Summary of values used in vapour intrusion models for residential house volume

Source	Volume (m^3)	Basis
Turczynowicz (2003)	342.9	Not described
Johnson (2002a)	450–675 m^3 (225 m^2 surface area x 2–3 m height)	Typical values, basis not described
US EPA (1997, p. 55)	Default 451 m^3 Range of values 147–672 m^3	Based on a US Department of Energy survey of US housing characteristics

Table 5.4.2: Summary of new residential buildings floor areas (m^2) in Australia

Type of dwelling	1984–85 (m^2)	1993–94 (m^2)	2002–03 (m^2)	2008–09 (m^2)	Average (m^2)
New houses	162.2	188.7	227.6	245.3	**206.0**[a]
New other residential buildings	99.2	115.9	134.0	**–**	**116.4**[a]
All new residential buildings	149.7	171.1	205.7	**–**	**175.5**[a]

Data from ABS (2005, 2010)

Average floor areas for residential dwellings were rounded and brought forward as suggested values for use in Australian screening risk assessments (Section 5.4.1).

Table 5.4.3: Residential volume (m^3) assuming ceiling height of 2.4 or 3 metres by dwelling type

Type of dwelling[a]	Volume (m^3)									
	Ceiling height = 2.4 m					Ceiling height = 3 m				
	1984–85	1993–94	2002–03	2008–09	Avg '84–'09	1984–85	1993–94	2002–03	2008–09	Avg '84–'09
New houses	390	450	550	590	**500**[b]	490	560	680	740	620
New other residential buildings	240	280	320	**–**	**280**[b]	300	350	400	**–**	350
All new residential buildings	360	410	490	**–**	**420**[b]	450	510	620	**–**	530

Volume values have been rounded

The average floor area of new residential buildings from Table 5.4.2 has been used to calculate the building volume assuming the two different ceiling heights.

Average residential dwelling volumes assuming a ceiling height of 2.4 m were brought forward as suggested values for use in Australian screening risk assessments (Section 5.4.1).

5.4.1 Recommendations

If site-specific data are available, that information should be used.

In the absence of site-specific information, the values for the average residence (built between 1984 and 2009) with a ceiling height of 2.4 metres are suggested for use in Australian screening risk assessments (Table 5.4.4). Upper estimates are not available.

5.5 Deposition and absorption of inhaled contaminants

Airborne contaminants that can be inhaled directly into the lungs can be classified on the basis of their physical properties: gases, vapours, aerosols or particulate matter. This is a large subject area and the information presented here is not comprehensive, the risk assessor is encouraged to become familiar with the subject by consulting appropriate text books and reviews.

Table 5.4.4: Suggested values for residential dwellings

Type of dwelling	Average floor area (m^2)	Average residential volume[a] (m^3)
Houses	210	500
Other residential buildings	120	280
All residential buildings	180	420

Volume of enclosed area of a single story. (average area (1984–2009) x ceiling height (2.4 m)

Absorption of inhaled gas and vapour into the blood is determined by the partitioning of the compound between the gas phase and blood as determined by its water/fat solubility and tissue reactivity. It is commonly assumed all inhaled gas or vapour is available for absorption (i.e. default bioavailability = 100%). However, large amounts of water-soluble gases may be efficiently removed by the upper airways before reaching the alveolar region, particularly during nose only breathing. Similarly not all substances that are tissue reactive will reach the lower parts of the lung where most absorption into blood occurs.

Uptake of aerosols and particulates depend on particle size and solubility. Inhalation estimates can be made using the concentration of particulate in air, the fraction of the particulate that is 'respirable' (i.e. particles ≤ 10μm) and the concentration of the chemical in the respirable fraction.

Table 5.5.1: Proportion respirability of dust by particle size (μm)[a]

Particle equivalent aerodynamic diameter (μm)	Respirability (percent)
0	100
1	98
2	92
3	82
4	68
5	50
6	28
7	0

Adapted from Standards Australia AS 2985–2004 Table 1

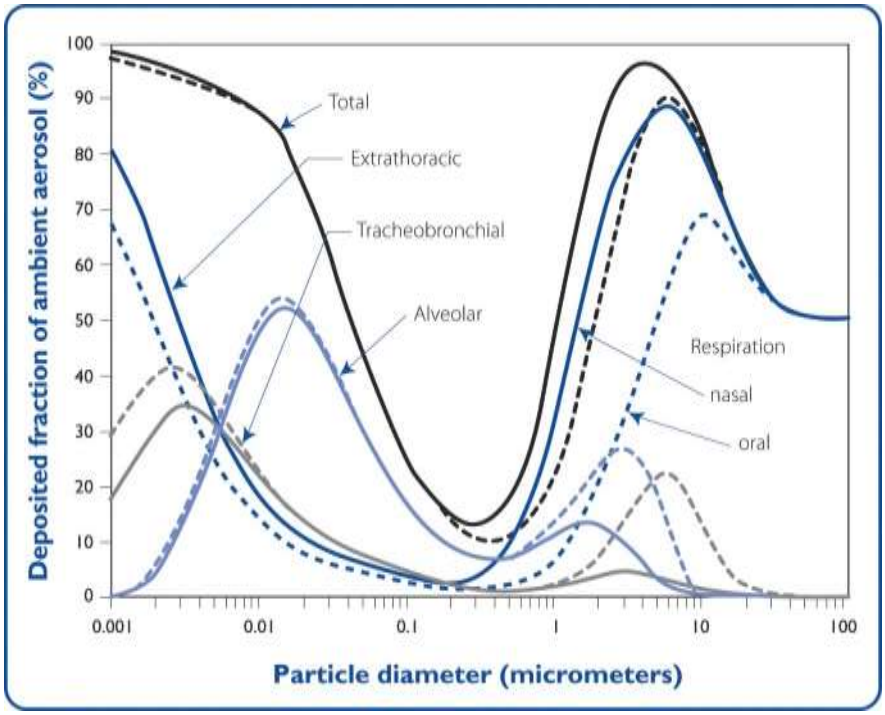
It is usually assumed that if particles enter the lower respiratory tract, they will eventually be absorbed unless the chemical is highly insoluble and biopersistent.

The fraction of inhaled particles that deposit to the alveolar region of the lung varies considerably according to the particle characteristics (size, shape) and their behaviour in air. Understanding the regional deposition of particles in the lung is important for human health risk assessment and dose conversions. Mathematical models have been developed to predict deposition of inhaled particles (ultrafine dusts) in the lungs of humans and animals. These are largely based on experimental data for ultrafine dusts.

There are many deposition models available including Price et al. (2002) (Dutch RIVM), Witschger and Fabries (2005) (French INRS), US EPA (2004) and Nordic Council (2007). These models consistently show fractional deposition in the alveolar region of the respiratory tract for healthy individuals with peaks for particles of approximately 20 nm as shown in Figure 5.5.1. The existing mechanistic models may need to be refined for nanosize materials as there are nanoparticle-specific mechanisms of transport and deposition that can alter the deposition efficiency. Asgharian and Price (2007) modelled fractional deposition including nanoparticle-specific considerations and report that fractional deposition in the alveolar region may increase up to 10% depending on particle size.

For absorption of inhaled contaminants a value of 100% is suggested for use in screening risk assessments unless chemical-specific data are available. Deposition in the respiratory tract is dependent on particle size (Table 5.5.1).

Figure 5.5.1: Modelled total and regional deposits of particles in the airway



Modelled by Institut National de Recherche Scientifique (reproduced in Ostinguy et al. 2006, p. 2). Reproduced here with permission from the Institut National de Recherche Scientifique

5.6 Ambient dust exposures

Particulates represent a broad class of chemically and physically diverse substances that exist as discrete particles in the condensed (liquid or solid) phase. Particles can be characterised by size, formation mechanism, origin, chemical composition and atmospheric behaviour (US EPA 2005).

Particle properties and their associated health and welfare effects differ by particle size and chemical properties. The diameters of atmospheric particles span five orders of magnitude, ranging from 0.001 micrometers to 100 micrometers (µm). The size and associated composition of particles are important factors for estimating their fate and transport in the environment and their behaviour in the respiratory system (see Figure 5.5.1).

5.6.1 Australian data

Size distributions of ambient particles

Based on examinations of particle size distributions collected over a period of three years for a range of ambient aerosol types in several locations around Brisbane, Morawska et al. (1999) found that particles display a consistent multi-modal distribution. These modes are apparent in Figures 5.6.1a,b,c which show average ambient distributions of particle number, and volume by particle size as influenced by different sources. Figures 5.6.1a,b,c illustrate the largest number of ambient particles in a typical distribution are very small (< 0.1 µm), while most of the particle volume, and therefore most of the mass, is found in particles with diameters greater than 0.1 µm and less than 10 µm. The pattern of particle size distribution is markedly affected by the dominant particulate source.

Information from other regions of Australia, particularly dry climates in the south, was not located. Thus there is uncertainty regarding the variability in particle size of ambient particulates across Australia.

Dust concentrations

Dust is commonly characterised as:

- total suspended particulates (refers to all particulate sizes in air, those ~50 µm or less are referred to as inspirable dust)
- PM_{10} (particulate matter < 10 µm, thoracic and respirable) and/or
- $PM_{2.5}$ (particulate matter < 2.5 µm respirable fraction thought to be related to health effects associated with exposure to urban air pollution).

Dust that is inspirable but not respirable will not reach the alveoli but be deposited in other parts of the respiratory tract and be gradually removed on the mucus raft lining the upper and thoracic respiratory tract. It will be removed from the body by either nose blowing (if deposited in the nasal area) or by ingestion. Therefore the inspirable minus the respirable dust fraction may need to be taken into account in ingestion exposure assessments.

Australian data for PM_{10} and $PM_{2.5}$ for each state and territory are readily available because the Ambient Air Quality National Environment Protection Measure (NEPC 1998) requires an air monitoring program to be developed and approved for each region. Each state or territory also collects air-monitoring data for different purposes. Annual reporting for PM_{10} and $PM_{2.5}$ includes 24-hour averages for the following percentiles: 99^{th}, 98^{th}, 95^{th}, 90^{th}, 75^{th} and 50^{th} (NEPC 2011). Tables 5.6.1 and 5.6.2 summarises PM_{10} and $PM_{2.5}$ data for 2009 in Australian states and territories.

PM_{10} (24-hour average):

- 50^{th} percentile range: 11.4–22.8 µg/m^3, average 16.8 µg/m^3
- 95^{th} percentile range 24.5–67.8 µg/m^3, average 39.2 µg/m^3

$PM_{2.5}$ (24 hour average):

- 50^{th} percentile range: 4.0–11.9 µg/m^3, average 6.6 µg/m^3
- 95^{th} percentile range 11.4–26.1 µg/m^3, average 15.7 µg/m^3

It should be noted, however, that the dataset for $PM_{2.5}$ measurements is not extensive so there is uncertainty regarding the averages for the percentiles for $PM_{2.5}$.

Figures 5.6.1b and 5.6.1c illustrate the frequency distribution and inverse cumulative frequency distribution (percentage of days above each concentration level) of composite daily 24-hour $PM_{2.5}$ concentrations in Sydney, Melbourne, Brisbane and Perth for combined 3 year periods (1998–2000 for Melbourne, 1999–2001 all other cities) (NEPC 2002, Figure E5b). Bushfire-affected data (Sydney, 25–31 December 2001; Brisbane, 7–13 October 2001) have been excluded. The distributions show that a representative value for $PM_{2.5}$, central tendency is approximately 6–8 µg/m^3.

Total suspended particulate monitoring is not required by the NEPM and so data for total suspended particulates (TSP) are not as readily available. The Victorian EPA noted when TSP and PM_{10} sampling was conducted at three sites in the Melbourne particle monitoring network, that approximately 90% of the TSP lead was contained in the PM_{10} fraction (VIC EPA 2002).

5.6.2 Recommendation

Site and/or region-specific data should be used for background concentrations of airborne $PM_{2.5}$ and PM_{10}.

Tables 5.6.1 and 5.6.2 summarise the PM_{10} and $PM_{2.5}$ concentrations measured in 2009 at a range of locations around Australia (all available data are for urban areas)[27]. In the absence of specific data for the region to be assessed, it is suggested the national averages (rounded) of the 50th or 95th percentile values for all urban sites may be used as estimates of background airborne PM in screening risk assessments. That is, for PM_{10}, 17 and 39 µg/m^3 for 50th and 95th percentiles, and for $PM_{2.5}$ 7 and 16 µg/m^3, respectively. Australian data for rural sites (i.e. population <1000 people) are not readily available but the use of the urban national averages (for the 50th and 95th percentiles) is considered conservative for rural sites. It is noteworthy that PM levels and sizes are likely to differ by locality and activity performed near the locality (e.g. quarries, rock grinding, etc).

The ratio of $PM_{2.5}/PM_{10}$ for the above average values of the 50th and 95th percentile measurements is approximately 40%. It is suggested that this ratio could be applied in situations where background PM_{10} has been measured but no data are available for $PM_{2.5}$.

Table 5.6.1: Summary of Australian PM_{10} measurements reported in 2009

	PM_{10} daily average concentration (µg/m^3)						
Location	**Max**	**99th**	**98th**	**95th**	**90th**	**75th**	**50th**
New South Wales							
Sydney							
Bringelly	1683.9	114.8	47.4	37.1	31.9	22.8	17.0
Chullora	1474.7	120.9	58.4	38.0	32.8	25.1	20.0
Liverpool	1579.8	114.8	59.5	38.8	31.7	25.1	18.4
Macarthur	1146.3	111.4	56.2	35.5	29.6	21.2	15.5
Oakdale	1528.3	130.2	48.4	30.6	25.5	19.5	12.7
Prospect	1680.3	135.3	60.7	38.9	32.3	24.1	18.2
Richmond	1637.3	121.7	46.1	32.9	28.0	19.4	13.4
Rozelle	1562.8	128.5	55.8	36.1	31.0	24.3	17.8
Illawarra							
Albion Park South	1359.6	73.0	50.7	38.0	31.6	22.8	15.4
Kembla Grange	1174.0	134.4	67.0	42.5	34.3	25.5	18.1
Wollongong	1145.4	107.0	49.5	40.3	34.7	24.5	18.8
Lower Hunter							
Beresfield	1999.0	174.3	70.6	47.7	35.3	26.2	18.4
Newcastle	2426.8	119.5	71.2	44.9	37.0	28.1	22.3
Regional							
Albury	249.7	144.0	102.0	39.0	28.5	19.3	14.0
Bathurst	2114.4	122.4	69.8	36.9	26.8	20.3	13.8

[27] An urban area is classified as an area with a population of ≥ 1000 people (ABS 2011). A rural area is defined as an area with a population <1000 people. Suburbs of major cities (e.g. Sydney) that have populations <1000 people but are still part of a large city are classified as urban.

Location	PM_{10} daily average concentration ($\mu g/m^3$)						
	Max	99th	98th	95th	90th	75th	50th
Tamworth	1791.4	235.9	120.7	47.0	33.8	22.8	15.7
Wagga Wagga	297.4	214.4	112.3	55.9	46.2	30.6	19.8
Australian Capital Territory[a]							
	210.0	116.0	62.4	50.5	37.7	25.5	15.2
Northern Territory[a]							
	101.6	86.5	78.4	38.9	30.7	22.7	16.2
Queensland							
South-east Queensland							
Mountain Creek	863.8	116.2	63.0	35.6	24.7	19.2	14.5
Rocklea	1033.4	124.7	75.9	40.8	35.2	24.7	17.7
Springwood	960.0	120.0	68.3	32.2	28.2	18.5	14.8
Flinders View	1001.8	111.3	72.4	32.3	27.9	18.9	15.1
Toowoomba							
North Toowoomba	1131.0	127.8	87.8	41.7	32.2	22.3	15.2
Gladstone							
South Gladstone	252.3	114.5	69.0	38.8	30.8	24.8	20.3
Mackay							
West Mackay	514.8	202.6	89.8	50.9	40.8	29.5	22.8
Townsville							
Pimlico	460.4	302.2	121.5	33.9	23.6	17.7	14.4
Mount Isa							
The Gap	508.5	283.6	135.6	67.8	45.8	29.1	18.3
South Australia							
Adelaide							
Elizabeth Downs	197.5	61.2	53.4	46.8	34.9	24.4	15.6
Kensington Gardens	68.1	41.0	38.3	32.0	27.3	19.6	12.8
Netley	108.7	58.2	45.7	39.6	30.3	22.8	16.8
Christie Downs	83.9	45.8	42.8	35.9	28.7	21.1	15.9
Spencer							
Whyalla Schulz Park	283.8	70.9	52.7	41.2	35.2	26.0	16.3
Pt Pirie Oliver St	183.0	97.4	57.2	46.0	34.8	24.3	14.6

Location	PM_{10} daily average concentration (µg/m^3)						
	Max	99th	98th	95th	90th	75th	50th
Tasmania							
New Town Hobart	43.2	36.1	33.4	26.4	23.3	17.3	11.4
Ti Tree Bend Launceston	44.1	42.3	38.1	29.8	22.1	16.4	12.2
Victoria							
Port Phillip							
Alphington	140.8	58.9	49.6	39.8	31.5	25.3	18.5
Brighton	132.4	57.1	48.5	35.7	29.1	22.8	17.1
Dandenong	199.7	63.7	54.8	43.3	36.8	26.0	18.7
Footscray	166.5	67.9	58.5	43.5	34.8	27.0	18.7
Geelong South	154.6	65.4	57.3	46.2	36.6	27.8	20.1
Mooroolbark	214.1	82.3	67.5	50.7	41.6	28.6	20.7
Richmond	121.2	55.2	50.3	36.7	30.0	23.5	17.8
Latrobe Valley							
Moe	169.6	55.2	51.8	37.6	30.0	21.6	16.3
Traralgon	125.7	51.0	40.4	35.3	29.2	23.5	17.9
Western Australia[a]							
Perth Region							
Caversham Nth East Metro	45.7	37.2	32.4	29.0	25.8	20.5	16.2
Duncraig Nth Metro	45.5	36.2	30.0	24.5	22.6	18.4	15.0
South Lake Sth East Metro	49.0	38.7	34.3	30.8	27.5	20.6	16.2
Southwest Region							
Albany	35.5	30.3	28.6	26.5	23.3	18.8	14.5
Bunbury	53.8	40.3	36.0	29.5	25.4	20.8	17.1
Midwest Region							
Geraldton	128.9	69.2	58.6	48.5	40.3	30.8	21.0
National range (all urban monitoring sites in Australia)	35.5–2426.8	30.3–302.2	28.6–135.6	24.5–67.8	22.1–46.2	16.4–30.8	11.4–22.8
National average (all urban monitoring sites in Australia)	680.1	103.3	61.4	**39.2[b]**	31.6	23.2	**16.8[b]**

Data from NEPM Reporting 2009: ACT Gov (2010), NSW DEC (2009), NT Gov (2010), Qld DERM (2010), SA EPA (2009), Vic EPA (2008), Tas Gov (2010), WA DEC (2010).

Percentiles correspond to daily peak PM10 concentrations.

National average 50th (16.8 µg/m^3) and 95th (39.2 µg/m^3) percentile urban PM_{10} concentrations were rounded to 16 and 39 µg/m^3 and brought forward as suggested values for use in Australian screening risk assessments. These values are only to be used if site-specific data are unavailable.

Table 5.6.2: Summary of Australian $PM_{2.5}$ measurements reported in 2009

Location	$PM_{2.5}$ daily average concentration ($\mu g/m^3$)[a]						
	Maximum Conc	99th	98th	95th	90th	75th	50th
New South Wales							
Sydney							
Chullora	183.2	18.9	17.2	14.0	11.1	8.5	5.9
Earlwood	186.7	22.5	18.9	13.9	11.3	8.2	5.2
Liverpool	268.2	25.2	19.9	15.0	12.9	9.7	6.7
Richmond	192.3	23.0	16.9	11.5	9.8	6.7	4.4
Illawarra							
Wollongong	241.0	23.0	19.3	15.0	12.0	8.3	5.6
Lower Hunter							
Beresfield	230.9	34.4	21.5	16.3	13.6	9.6	6.6
Wallsend	415.6	38.4	20.3	14.3	12.5	8.1	5.4
Australian Capital Territory[b]							
	53.3	42.5	31.7	26.1	24.2	17.3	11.9
Northern Territory[c]							
	28.9	25.9	23.1	19.5	16.4	11.9	7.2
Queensland							
South-east Queensland							
Rocklea	19.1	19.1	13.8	12.3	10.4	8.2	6.5
Springwood	150.6	25.3	18.0	11.4	9.0	6.2	4.0
Gladstone							
South Gladstone	50.8	29.8	26.9	12.7	13.8	10.5	8.2
South Australia							
Adelaide Netley	26.8	17.9	15.2	13.5	11.9	9.6	7.6
Tasmania							
New Town Hobart	28.4	26.1	24.1	19.1	15.2	8.5	5.6
Ti Tree Bend Launceston	36.3	32.9	29.8	22	14.8	8.9	5.4
Victoria							
Port Phillip							
Alphington	27.0	26.4	24.1	21.2	15.0	9.1	6.6
Footscray	26.9	24.1	19.4	15.7	12.7	9.4	5.6

Location	$PM_{2.5}$ daily average concentration ($\mu g/m^3$)[a]						
	Maximum Conc	99th	98th	95th	90th	75th	50th
Western Australia[c]							
Perth Region							
Caversham Nth East Metro	25.5	19.4	17.3	12.9	11.0	8.6	7.2
Duncraig Nth Metro	32.7	22.1	17.5	13.2	11.5	9.3	7.5
Quinns Rocks Outer Nth Coast	31.3	20.7	15.2	12.7	11.3	8.8	7.1
South Lake (Sth East Metro)	32.0	22.8	19.1	14.1	11.7	9.4	7.4
Southwest Region							
Bunbury	40.0	26.6	22.3	16.9	12.6	9.2	7.5
Busselton	69.0	45.0	31.6	17.7	14.0	9.5	7.2
National range (all urban monitoring sites in Australia)	19.1–415.6	17.9–45.0	13.8–31.7	11.4–26.1	9.0–24.2	6.2–17.3	4.0–11.9
National average (all urban monitoring sites in Australia)	104.2	26.6	21.0	**15.7[d]**	13.0	9.3	**6.6[d]**

Data from NEPM Reporting 2009:ACT Gov (2010), NSW DEC (2009), NT Gov (2010), Qld DERM (2010), SA EPA (2009), Vic EPA (2008), Tas Gov (2010), WA D

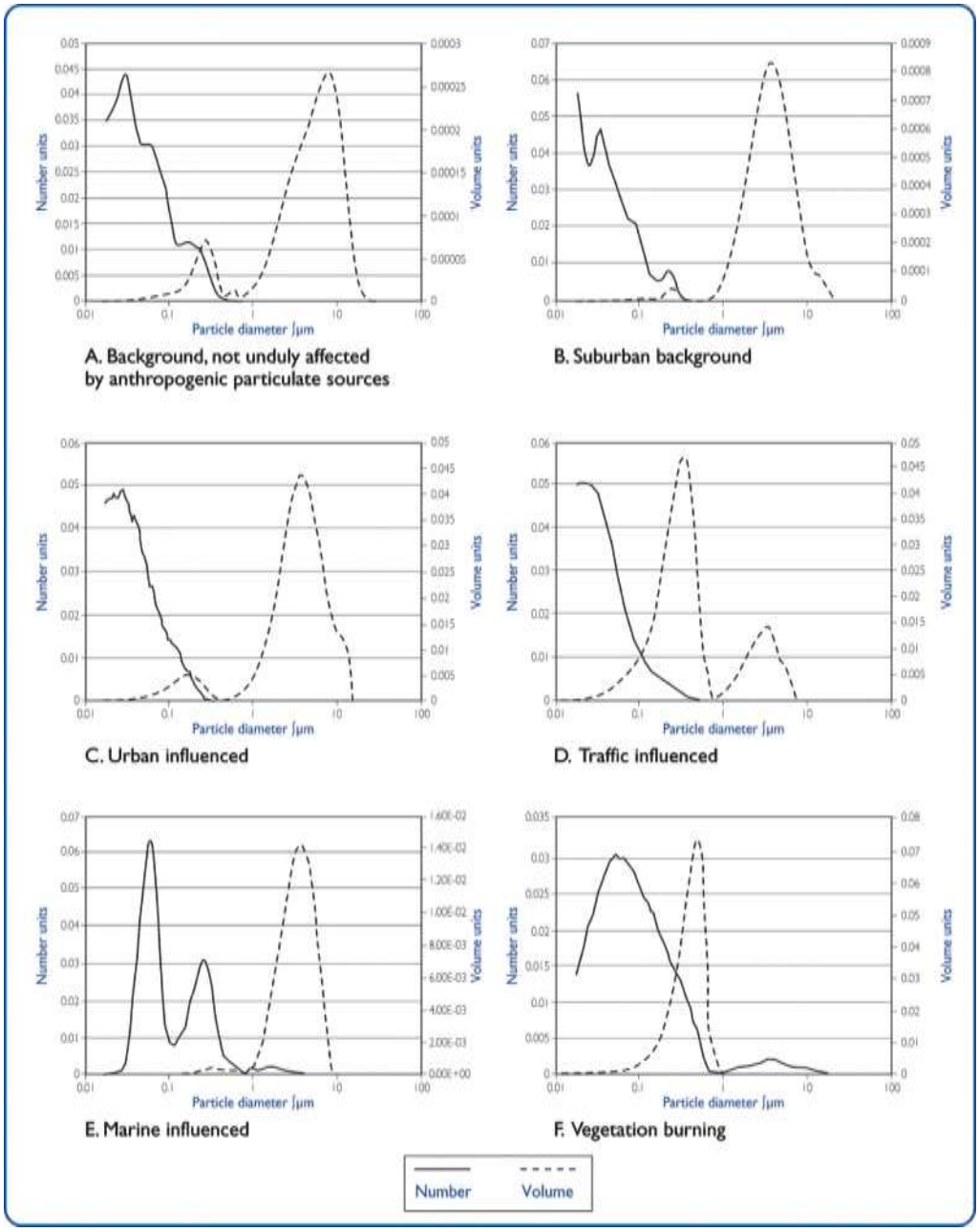
Values obtained using the TEOM method for PM2.5 (NEPC 2002).

Percentiles correspond to daily peak PM2.5 concentrations in 2008. Data were not available for the year 2009.

Percentiles correspond to daily peak concentrations of PM2.5.

National average 50th (6.6 µg/m3) and 95th (15.7 µg/m3) percentile urban PM2.5 concentrations were rounded to 7 and 16 µg/m3 and brought forward as suggested values for use in Australian screening risk assessments. These values are only to be used if site-specific data are unavailable.

Figure 5.6.1a: Normalised aerosol number and volume size distributions



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A = Brisbane Forest Park, 15 km west of Brisbane CBD, away from urban/traffic influences.

B = Scarborough bayside suburb approx. 25 km north of t he Brisbane CBD

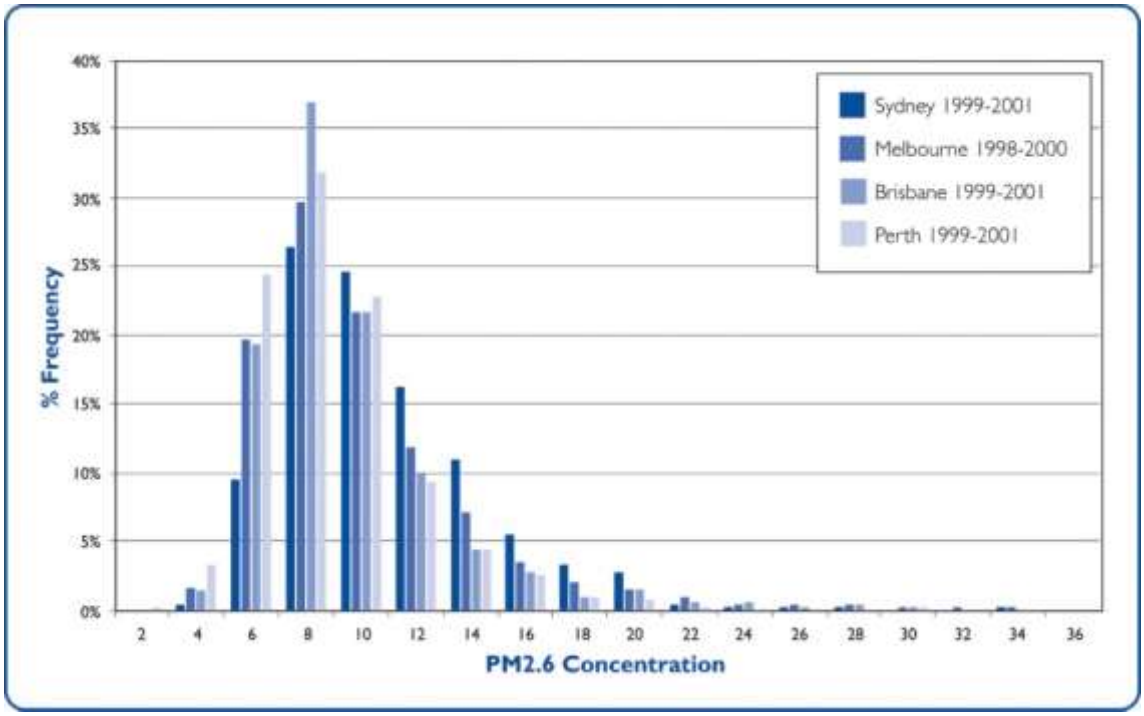
C = QUT, within the Brisbane CBD at a distance of 210 m from the South-East Freeway

D = Adjacent (15 m) to major arterial routes during peak hour

E = Moreton Island 15 km east of Brisbane and only accessible by water transport (car free)

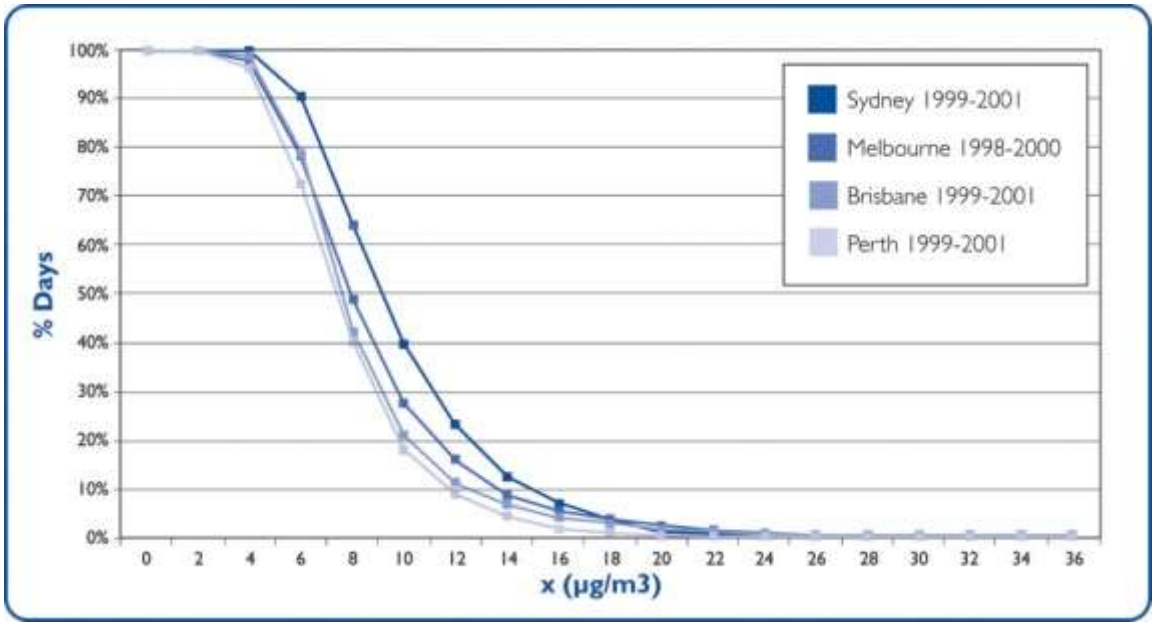
F = Hazard reduction burning in forest/farming land to the west Brisbane

Figure 5.6.1b: Frequency distribution of composite daily 24-hour $PM_{2.5}$



Concentrations **in Sydney, Melbourne, Brisbane and Perth** for each combined three year period (1998–2000 for Melbourne, 1999–2001 all other cities) adapted from NEPC (2002, Figure E5a). The concentrations for the frequency distribution on the *X*-axis denote concentration bins of *X*-2 to *X* µg/m3. Bushfire-affected data (Sydney, 25–31 December 2001; Brisbane, 7–13 October 2001) have been excluded.

Figure 5.6.1c: Inverse cumulative frequency distribution



(Percentage of days above each concentration level) of composite daily 24-hour $PM_{2.5}$ concentrations in Sydney, Melbourne, Brisbane and Perth for each combined three year period (1998–2000 for Melbourne, 1999–2001 all other cities) adopted from NEPC (2002, Figure E5b). Bushfire-affected data (Sydney, 25–31 December 2001; Brisbane, 7–13 October 2001) have been excluded.

5.7 Percentage indoor dust from outdoor sources

Indoor dust (i.e. house dust) is derived from indoor activities, particularly cooking and heating, indoor furnishings, pot plants, insects and human/pet detritus, plus dust blown in from outside. A significant proportion of indoor dust may also be due to outside soil tracked inside on shoes and clothes. Ingestion of house dust can therefore be an important consideration for exposure assessment in indoor environments (UK EA 2009). House dust is largely composed of finer particles than soil (Paustenbach et al. 1997). In addition to being more mobile, fine particles adhere to skin more effectively, thus increasing the potential of exposure (Finley et al. 1994; Kissel et al. 1996). Therefore, risk assessments including house dust as a potential exposure route need to carefully consider the contribution from outside soil.

5.7.1 Australian data

No Australian data for percentage of indoor dust attributed to outside sources were located.

5.7.2 Overseas data

Overseas studies show a large percentage of lead found in homes originates from outside sources: wind-blown resuspension and tracked inside on shoes and the feet of family pets (Hunt et al. 2006; Laidlaw and Filippelli 2008; Paustenbach et al. 1997). The US EPA's Integrated Exposure Uptake Biokinetic (IEUBK) model for predicting blood–lead concentrations in children assumes 45% of total dust intake by children is derived from outdoor soil (US EPA 1994; 2002).

Paustenbach et al. (1997) reviewed five studies (Calabrese and Stanek 1992; Camann and Harding 1989; Fergusson and Kim 1991; Hawley 1985; Thornton et al. 1985) that examined the contribution of exterior soil to indoor dust (Table 5.7.1). Based on element concentration ratios, Paustenbach et al. (1997) suggested approximately 50% of house dust originates from exterior soil. However, if the ratio was based on considerations of relative proportion of time spent outdoors and indoors this could be as high as 90%.

After reviewing a number of studies, Cornelis and Swartjes (2007) report estimates of the contribution of soil to house dust range from 8 to more than 80%, depending on a wide variety of site-specific factors and methodological approaches. These authors recommend using 50% exterior soil in interior dust for residential quarters. This proportion is consistent with the recommendations of the US EPA (2008; 2009a) where ingestion of outside soil by children is 50 mg/d and that for outside soil plus all indoor dust is 100 mg/d. In situations without a garden Cornelis and Swartjes (2007) propose a value of 25% exterior soil in interior dust.

A recent study (Zota et al. 2011) estimated the median percent contribution of outdoor soil to indoor dust concentrations of various metals (Pb, Zn, Cd, and As) at a mining Superfund site in the US to range from 20–60%.

5.7.3 Recommendations

Studies investigating the percentage of indoor dust originating from outdoor sources report a wide range (20–98%); however, most of the data appear to tend towards an average of about 50% (Table 5.7.1). In the absence of Australian data it is suggested for screening risk assessments that an average of 50% (and a maximum of 100%) of indoor dust may originate from outside soil in the immediate area of the dwelling. The average value is consistent with US EPA (2008) recommendations that children ingest 50 mg/d of outside soil and 100 mg/d of outside soil plus indoor dust.

Table 5.7.1: Estimates of the relative contribution of exterior soil to indoor dust

% indoor dust from soil	Reference
20-60	Zota et al. (2011)
20–78 (49.2 ± 29.2)	Calabrese and Stanek (1992)[a]
20	Thornton et al. (1985)[a]
30–50	Fergusson and Kim (1991)[a]
50	Camann and Harding (1989)[a]
80	Hawley (1985)[a]
20 – 98 (45 ± 17)[b]	Trowbridge and Burmaster (1997)

[a] An assumption not based on cited data.

[b] This is the arithmetic mean ± standard deviation reported by Trowbridge and Burmaster (1997) for the log-normal distribution of transfer coefficients derived from measurements of element concentrations in indoor dust and outdoor soil reported in five studies (Bowen 1979; Davis et al. 1990; Calabrese et al. 1989; Fergusson et al. 1986; Fergusson and Kim 1991). The transfer coefficient is defined as the ratio of the concentration of the tracer element in indoor dust to the concentration of the tracer element in outdoor soil.

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6. Activity patterns

Time–activity patterns can vary considerably within and between communities depending on the climate, residential setting (i.e. rural vs urban), personal traits (e.g. health status) and personal habits. Also, some activity factor statistics are average values for the general population and thus may underestimate time associated with activities in a particular region and location in Australia.

Thus assessors should always consider whether time–activity factors would be better addressed on an assessment-specific basis.

6.1 Children

6.1.1 Mouthing behaviour

Compared with adults, young children mouth objects or their fingers as they explore their environment, potentially increasing exposure to environmental contaminants. Mouthing behaviour includes all activities in which objects and fingers are touched by the mouth or put into the mouth except when eating or drinking; it includes licking, sucking, chewing and biting (US EPA 2008).

6.1.1.1 Australian data

Australian data on mouthing behaviour are limited. As part of six studies completed over a 2 year period to investigate activity patterns of children aged 1–59 months, mouthing behaviours of children were included by Brinkman et al. (1999) using parent and video observations. Parent observations were qualitative in nature (e.g. questions such as: *Do 1–31 month old children suck their fingers or thumbs?* Yes or no). Video-taped observations were used to estimate frequency and duration of mouthing activity; however, this method has been found to be of limited utility due to the intrusive and distractive nature of videotaping (Brinkman et al. 1999; US EPA 2008, pp. 4–5; UK DTI 2002, p. 34).

6.1.1.2 Overseas data

The US EPA (2008) has reviewed available studies and has made recommendations for frequency (expressed as contacts per hour) and duration of mouthing (Table 6.1.1). Studies considered key to the recommendations were Zartarian et al.(1997a; 1997b; 1998), Xue et al. (2007), Black et al. (2005), Tulve et al. (2002), Freeman et al. (2001), Reed et al. (1999), AuYeung et al. (2004), Juberg et al. (2001) and Greene (2002). The US EPA rate the overall confidence in the data as low due to small sample sizes of the studies relative to the overall US population.

Table 6.1.1: US EPA recommended values for mouthing frequency and duration

		Age					
Parameter	**Statistic**	**3–<6m**	**6–<12m**	**1–<2y**	**2–<3y**	**3–<6y**	**6–<11y**
Hand to mouth – indoor[a]							
Contacts/hour	Mean	**28[j]**	**19[j]**	**20[j]**	**13[j]**	**15[j]**	**7[j]**
	95th percentile	**65[j]**	**52[j]**	**63[j]**	**37[j]**	**54[j]**	**21[j]**
Hand to mouth – outdoor[a]							
Contacts/hr	Mean	–	**15[j]**	**14[j]**	**5[j]**	**9[j]**	**3[j]**
	95th percentile	–	**47[j]**	**42[j]**	**20[j]**	**36[j]**	**12[j]**

Parameter	Statistic	Age					
		3–<6m	6–<12m	1–<2y	2–<3y	3–<6y	6–<11y
Object to mouth							
Contacts/hr	Mean	–	20[b]	20[c]	10[d]	10[d]	1[e]
	95th percentile	–	–	–	–	–	–
Duration							
min/hr	Mean	11[f]	11[f]	8	13[h]	–	–
	95th percentile	26[g]	26[g]	22	16[i]	–	–

Data from US EPA (2008, Table 4– 1).

Based on Xue et al. (2007). Authors performed meta-analysis of hand-to-mouth frequency data from nine studies representing 429 subjects and more than 2000 hours of behaviour observation. The frequency data are expressed in contacts per hour, between either any part of the hand (including fingers and thumbs) and the mouth, or between an object or surface and the mouth.

Mean; calculated from Black et al. (2005) for 7–12 month olds.

Mean; calculated from Tulve et al.(2002) (24 months), AuYeung et al. (2004) (24 months) and Black et al. (2005) (1–2 years).

Mean; calculated from Reed et al.(1999) (2–6 years), Freeman et al.(2001) (3–4 years and 5–6 years), AuYeung et al. (2004) (2–6 years) and Black et al.(2005) (37–53 months).

Mean; calculated from Freeman et al.(2001) (7–8 years and 10–12 years).

Mean; calculated from Juberg et al. (2001) (0–18 months) and Greene (2002) (3–12 months).

Calculated 95th percentile from Greene (2002) (3–12 months).

Mean; calculated from Juberg et al. (2001) (19–36 months) and Greene (2002) (24–36 months).

Calculated 95th percentile from Greene (2002) (24–36 months)

Mean and 95th percentile values for frequency of hand to mouth activity (contacts/hr) indoors and outdoors by age group have been brought forward as suggested values for use in Australian screening risk assessments (Section 6.1.1.3).

To investigate the extent of exposure to consumer products, the United Kingdom Department of Trade and Industry (UK DTI) conducted a mouthing behaviour study in children aged one month to five years (UK DTI 2002). The overall aim of the project was to estimate the total time children within this age range are expected to mouth items per day. Observations were carried out by parents in the child's home for a total of five hours, split into 20 15-minute observation sessions; there were 236 children enrolled in the study. Table 6.1.2 provides the mean and maximum estimated daily mouthing data for male and female children combined. The maximum values are the highest estimated daily mouthing times of any child in each age category for each item.

NICNAS (2010) has reviewed several overseas studies (including the UK DTI 2002 study) on mouthing behaviour in children, and found considerable variability in mouthing times among children aged 3–36 months. NICNAS concluded mouthing times were highest for children aged 6–12 months, with a maximum value of approximately three hours per day. Table 6.1.3 provides the mean and maximum estimated daily mouthing time for male and female children combined, as summarised by NICNAS (2010).

Table 6.1.2: Estimated mean and max daily mouthing time by item mouthed (hours:minutes:seconds) per day

	Dummy/soother[a]		Fingers[a]		Toys[a]		Other objects[a]		Not recorded[a]	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
1–3 mths	0:47:13	2:54:50	0:18:22	0:50:31	0:00:14	0:00:59	0:05:14	0:28:11	0:00:45	0:06:42
3–6 mths	0:27:45	2:32:48	0:49:03	1:36:02	0:28:20	2:34:45	0:12:29	0:36:39	0:00:24	0:03:07
6–9 mths	0:14:36	1:40:02	0:16:54	1:17:13	0:39:10	3:46:46	0:24:30	1:10:23	–	–
9–12 mths	0:41:39	5:23:45	0:14:07	1:38:42	0:23:04	1:04:49	0:16:25	1:31:00	0:00:01	0:00:09
12–15 mths	1:00:15	3:32:15	0:08:24	0:35:53	0:15:18	0:44:01	0:12:02	1:03:03	0:00:02	0:00:26
15–18 mths	0:25:22	3:40:21	0:10:07	0:39:21	0:16:34	0:58:28	0:23:01	1:38:02	0:00:08	0:01:55
18–21 mths	1:09:02	5:17:35	0:18:40	1:20:29	0:11:07	0:32:49	0:19:49	1:06:21	0:00:11	0:02:05
21–24 mths	0:25:12	1:54:37	0:35:34	1:53:10	0:15:46	1:42:04	0:12:53	0:40:20	0:14:13	2:50:37
2–3 yrs	0:32:55	3:37:00	0:29:43	2:27:48	0:12:23	2:05:48	0:21:46	2:57:58	0:02:40	1:35:15
3–4 yrs	0:48:42	5:04:03	0:34:42	3:18:33	0:11:37	1:34:36	0:15:16	1:25:29	0:00:01	0:00:37
4–5 yrs	0:16:40	5:21:39	0:19:26	2:51:01	0:03:11	0:20:46	0:10:44	1:16:40	0:00:05	0:02:24
5–6 yrs	0:00:20	0:08:08	0:44:06	9:02:45	0:01:53	0:11:20	0:10:00	0:52:47	0:02:58	1:05:08

Data from UK DTI (2002, Table 3, 4 p. 14)

Mean and maximum duration of mouthing by item (dummy, i.e. pacifier), fingers, toys, and other objects (includes “not recorded”), by age group were brought forward as suggested value for use in Australian screening risk assessments (Table 6.1.4). Values for 3–6, 6–9, and 9–12 months were averaged for the 3–12 month age group. Similarly values for 12–15, 15–18, 18–21, and 21–24 months were averaged for the 1–2 year old age group.

Table 6.1.3: Estimated mean and maximum daily mouthing time from overseas studies

Age (mths)	Object Mouthed	Daily mouthing time (mins)		Reference
		Mean	Maximum	
3–6	Toys, non-toys & fingers (excludes pacifiers)	36.9	67.0	Groot et al. 1998
6–12		44.0	171.5	
12–18		16.4	53.2	
18–36		9.3	30.9	
3–12	Teethers and other mouthing products (excluding pacifiers)	120	180	Health Canada 1998
0–18	Plastic toys	17	–	Juberg et al. 2000
	Teethers	6	–	
	Other objects (excludes pacifiers & fingers)	9	–	
19–36	Plastic toys	2	–	
	Teethers	0	–	
	Other objects (excludes pacifiers & fingers)	2	–	
3–18	All objects, excluding pacifiers	36	–	
3–12	All objects, excluding pacifiers	70	–	Kiss (2001)
12–24		48	–	
24–36		37	–	
1–3	Toys, other objects (excluding pacifiers and fingers)	5	29	UK DTI (2002)
3–6		40	231	
6–9		63	297	
9–12		39	155	

Data from NICNAS (2010, pg. 83).

6.1.1.3 Recommendation

For frequency of hand-to-mouth behaviour, the mean and 95th percentile estimates of contacts per hour in Table 6.1.1 may be used for the purpose of screening risk assessments. These data represent contacts per hour between either any part of the hand (including fingers and thumbs) and the mouth, or between an object or surface and the mouth.

Duration estimates of mouthing behaviour are highly variable and depend on age group and the type of objects included in the estimates (i.e. whether or not pacifier or finger sucking is included). Approximate mean and maximum values for duration (min/day) of mouthing by age group (for toys, pacifiers, fingers and other objects) suggested for use in screening risk assessments are summarised in Table 6.1.4.

6.1.2 Time spent inside, outside, away from home

6.1.2.1 Australian data

Brinkman et al. (1999) conducted a longitudinal behaviour observation study between 1995 and 1997 for activity patterns and associated household and environmental characteristics of children in Port Pirie, South Australia. Diary information was aggregated and analysed for children aged 7–31 months. Table 6.1.5 summarises the percentage of time spent inside, outside and away from home during a child's 'waking hours' or 'daytime hours' (times ranged from 7.30 am to 9.30 pm .i.e. 14 hours). Average time spent inside decreased with increasing age and, correspondingly, the amount of time spent outdoors and away from home increased between the first and second year for young children.

Table 6.1.6 provides age stratified data for the average percentage of time spent in different areas around the home and away from home.

Table 6.1.4: Suggested values for mouthing duration

	Mouthing duration (hr/d)[a]							
	Pacifier		Fingers		Toys		Other objects	
Age	Mean	Max	Mean	Max	Mean	Max	Mean	Max
1–3 mths	0.8	2.9	0.3	0.8	0.003	0.02	0.1	0.6
3–12 mths	0.5	3.2	0.4	1.5	0.5	2.5	0.3	1.1
1–2 yrs	0.7	3.6	0.3	1.1	0.2	1.0	0.3	1.8
2–3 yrs	0.5	3.6	0.5	2.5	0.2	2.1	0.4	4.5
3–4 yrs	0.8	5.1	0.6	3.3	0.2	1.6	0.3	1.4
4–5 yrs	0.3	5.4	0.3	2.9	0.05	0.3	0.2	1.3
5–6 yrs	0.005	0.1	0.7	9.0	0.03	0.2	0.2	0.9
>6 yrs	No data							

Suggested values (rounded) by age group from Table 6.1.2 for "dummy/soother", "fingers", "toys", and "other objects" (includes "not recorded"). Values for 3–6, 6–9, and 9–12 months were averaged for the 3–12 month age group in this table. Similarly values for 12–15, 15–18, 18–21, and 21–24 months were averaged for the 1–2 year old age group.

Table 6.1.5: Percentage of waking or day time (14 hours) Australian children spent indoors, outdoors (at home) or away from home

Age group (months)	Average time inside at home (%)		Average time outside at home (%)		Average time away from home (%)		Number of diaries
	Mean	Std dev	Mean	Std dev	Mean	Std dev	
1–7[a]	92	13	**2[b]**	3	7	12	19
7–9	84	10	**4[b]**	9	12	9	13
10–12	79	14	**3[b]**	4	18	14	64
13–15	77	10	**7[b]**	6	16	10	73
16–18	76	12	**10[b]**	8	14	11	85
19–21	67	11	**11[b]**	7	22	14	39
22–24	67	10	**12[b]**	9	21	10	32
25–27	62	8	**15[b]**	9	23	9	16
28–31	64	14	**13[b]**	8	23	15	29
Total	73	13	9	8	18	12	351

Data from Brinkman et al. (1999, Tables 1 and 3).

[a] Data for this age group are based on a 24-hour diary as opposed to a 14-hour 'daylight hour' diary for other age groups.

[b] Percentage time (of 14 hours, with the exception of 1–7 month olds for which it is 24 hours) spent outside at home was converted to time spent outside at home (hr/d) for each age group. The average time spent outside at home was then calculated and rounded for age groups <1, 1–2 and 2–3 years of age. For example, for 2–3 year olds 14% (the average of 25–27 month and 28–31 month old Australian children) of 14 hours = 2 hours. The values for each age group (0.4, 1.4 and 2 hrs/d for <1, 1–2 and 2–3 year olds, respectively) were brought forward as suggested values for use in Australian screening risk assessments (section 6.1.2.3).

Table 6.1.6: Percentage of waking or day time (14 hours) spent in each home area for Australian children

	Age (months)								
	7–9	10–12	13–15	16–18	19–21	22–24	25–27	28–31	All
Inside locations									
Own bedroom	22	30	31	28	22	24	16	21	27
Family/lounge/dining	32	21	19	20	23	21	26	20	21
Kitchen	12	12	12	10	10	9	8	8	11
Hallway	2	1	<1	1	<1	1	<1	<1	<1
Bathroom	3	3	3	3	3	3	2	4	3
All over the house	6	10	10	13	7	6	8	9	10
Other area inside	10	2	<1	1	2	2	3	2	2
Outside locations									
Backyard	2	3	5	6	9	10	11	8	6
Frontyard	1	<1	1	2	1	<1	1	2	1
Shed	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cubby house	0	<1	3	<1	<1	<1	1	1	<1
Verandah	<1	<1	<1	<1	<1	1	1	1	<1
Other area outside	0	0	<1	<1	0	0	<1	<1	<1
On floor/ground	23	27	27	27	22	24	19	18	25
On blanket/mat	5	4	<1	1	1	2	1	1	2
On furniture	4	3	5	8	10	8	15	11	7
In bed/cot	31	31	30	28	22	24	17	22	27
Table/highchair	1	3	6	6	8	7	9	10	6
In play pen	<1	1	<1	<1	<1	<1	0	0	<1
In walker	5	1	<1	2	<1	<1	0	0	<1
Other	11	6	5		1	<1	<1	<1	3

	Age (months)								
	7–9	10–12	13–15	16–18	19–21	22–24	25–27	28–31	All
Paved area	1		2		4		3		3
Grassed area	1		3		4		5		4
Dirt/sand area	<1		2		2		4		2
Gravelled area	<1		<1		1		1		1
On blanket/mat	<1		<1		0		<1		<1
In play pen	<1		<1		0		0		<1
Other	1		<1		<1		<1		<1

Data from Brinkman et al. 1999, Tables 1 and 3

6.1.2.2 Overseas data

The US EPA default recommendations (central estimates) for time activities are provided in Table 6.1.7 and the upper estimates (95th percentile) in Table 6.1.8.

Tables 6.1.7 and 6.1.8 are US EPA (2008) recommended values for important activities routinely evaluated in risk assessments involving residential exposures. These recommendations were developed by the US EPA following a review of available studies for each activity factor. The footnotes to the Tables 6.1.7 and 6.1.8 provide a link to the key original study and location of summary tables within US EPA (2008).

Table 6.1.7: US EPA recommended mean values for activity factors (min/d)

Age group	Total indoors	Indoors at residence	Total outdoors	Shower	Bath	Swimming[a]	Playing on sand/gravel	Playing on grass	Playing on dirt
0–<1 month	**1,440[b]**	**1,108[b]**	0	15	19	96	**18[b]**	**52[b]**	**33[b]**
1–<3	**1,432[b]**		8		23				
3–<6	**1,414[b]**		26		23				
6–<12	**1,301[b]**		139		24				
1–< 2 year	**1,353[b]**	**1,065[b]**	36	20	24	105	**43[b]**	**68[b]**	**56[b]**
2–< 3	**1,316[b]**	**979[b]**	76	22	25	116	**53[b]**	**62[b]**	**47[b]**
3–<6	**1,278[b]**	**957[b]**	**107[b]**	17	33	137	**60[b]**	**79[b]**	**63[b]**
6–<11	**1,244[b]**	**893[b]**	**132[b]**	18	19	151	**67[b]**	**73[b]**	**63[b]**
11–<16	**1,260[b]**	**889[b]**	**100[b]**	18	23	139	**67[b]**	**75[b]**	**49[b]**

Age group	Total indoors	Indoors at residence	Total outdoors	Shower	Bath	Swimming[a]	Playing on sand/gravel	Playing on grass	Playing on dirt
16–<21	**1,248[b]**	**833[b]**	**102[b]**	20	23	145	**83[b]**	**60[b]**	**30[b]**

Information from US EPA (2008, Table 16–1). See also footnotes at bottom of Table 6.1.6

Swimming in minutes/month

Shaded values for average time spent for activity factors were brought forward as suggested values for use in Australian risk assessments (Section 6.1.2.3). Australian data from Brinkman et al. (1999) were suggested for time spent outdoors by <1, 1–2, and 2–3 years olds instead of the US EPA (2008) data (Tables 6.1.5 and 6.1.9).

Table 6.1.8: US EPA recommended 95th percentile values for activity factors (min/d)[i]

Age group [a, b]	Total indoors	Indoor at residence[c, d]	Total outdoors[a, b]	Shower[c, e]	Bath[a, c, e]	Swimming[a, c, f, h]	Playing on sand/gravel[a, c, g]	Playing on grass[a, c, g]	Playing on dirt[a, c, g]
0–<1 mth	–	**1,440[j]**	–	–	30	–	–	–	–
1–<3									
3–<6									
6–<12									
1–< 2 yrs	–	**1,440**	–	–	32	–	**121[j]**	**121[j]**	**121[j]**
2–< 3	–	**1,296[j]**	–	44	45	181	**121[j]**	**121[j]**	**121[j]**
3–<6	–	**1,355[j]**	–	34	60	181	**121[j]**	**121[j]**	**121[j]**
6–<11	–	**1,275[j]**	–	41	46	181	**121[j]**	**121[j]**	**121[j]**
11–<16	–	**1,315[j]**	–	40	43	181	**121[j]**	**121[j]**	**120[j]**
16–<21	–	**1,288[j]**	–	45	60	181	–	–	–

Information from US EPA (2008, Table 16–1)

– Percentiles were not calculated for sample sizes less than 10.

Average for boys and girls

Based on US EPA analysis of source data, in particular Wiley et al. (1991) for age groups birth to <12 months and US EPA (1996) for age groups 1–<21 years. Refer to US EPA (2008, Tables 16–10 and 16–14).

Based on US EPA reanalysis of source data for respondents only (i.e. not an average for the general population).

Refer also to US EPA (2008, Table 16–11).

Refer also to US EPA (2008, Table 16–18).

Refer also to US EPA (2008, Table 16–21).

Refer also to US EPA (2008, Table 16–22).

Swimming in minutes/month

There are 1,440 minutes in a day. Time spent indoors and outdoors may not add up o 1,440 minutes due to activities that could not be classified as either indoors or outdoors.

Shaded values for 95th percentile time spent for activity factors were brought forward as suggested values for use in Australian screening risk assessments (Section 6.1.2.3).

6.1.2.3 Recommendation

Table 6.1.9 summarises the recommended default parameters for time spent indoors (total and at residence) and outdoors by children from various overseas agencies. Upper estimates are only available from the US EPA for time spent indoors (at residence).

The US EPA (2008) average values for time spent indoors (total), averages and 95th percentiles for time spent indoors (at residence), and averages for time spent outdoors (total) are suggested for use in Australian screening risk

assessments, with the exception of time spent outdoors for <1, 1–2, and 2–3 year olds. For these age groups, Australian data from Brinkman et al. (1999) are suggested (average values of 0.4, 1.4 and 2 hrs/d, respectively – see Table 6.1.5). The Brinkman et al. (1999) indoor data have not been used to replace the US EPA (2008) recommended values for time during a 24-hour day spent indoors since it would require assumptions regarding the amount of time different age groups slept and time spent away from home for the eight hours (9:30 p.m. – 7:30 a.m.) where survey data were not collected.

For time spent playing on sand/gravel, grass or dirt, the US EPA (2008) averages and 95th percentile values in Tables 6.1.7 and 6.1.8 may be used.

Table 6.1.9: Summary of default parameters for time spent indoors and outdoors (hrs/d) by children from various overseas agencies

Country	Age	Indoor [total] Average	Indoor (at residence)	Outdoor (total)	
Canada (Health Canada 1994, pg 17).	Entire population	20	–	4 (2 outdoors, 2 in transit)	
UK UK EA (2009)	1–4 year old	23	–	1	
	5–6 year old	19		5	
United States					
US EPA (2008) Table 16–1[a]	0–<1 month	**24**[b]	**18.5 (24)**[b]	0	**0.4**[b, c]
	1–<3 months	**23.9**[b]		0.1	
	3–<6 months	**23.6**[b]		0.4	
	6–<12 months	**21.7**[b]		2.3	
	1–<2 years	**22.6**[b]	**17.8 (24)**[b]	0.6	**1.4**[b, c]
	2–<3 years	**21.9**[b]	**16.3 (21.6)**[b]	1.3	**2.0**[b, c]
	3–<6 years	**21.3**[b]	**16 (22.6)**[b]	**1.8**[b]	
	6–< 11 years	**20.7**[b]	**14.9 (21.3)**[b]	**2.2**[b]	
	11–<16 years	**21**[b]	**14.8 (21.9)**[b]	**1.7**[b]	
	16–<21 years	**20.8**[b]	**13.9 (21.5)**[b]	**1.7**[b]	
US EPA (1997) Table 15–176	Children aged 3–11	19 (w/days) 17 (w/ends)	16.4	5 (w/days) 7 (w/ends)	

– No default (i.e. recommended) parameter available; w/days = weekdays; w/end = weekends

Times have been converted from min/d (Table 6.1.7) to hrs/d; resulting values were rounded to one decimal place.

Bolded values in shaded cells are the suggested values for use in Australian screening risk assessments (see text).

These values are not from the US EPA (2008); they have been calculated for each age group from the Brinkman et al. (1999) data in Table 6.1.5.

6.2 Adults

6.2.1 Time spent outdoors

6.2.1.1 Australian data

Time-use surveys have been conducted on three occasions (1992; 1997; 2006a) by the Australian Bureau of Statistics (ABS). The survey data are derived from a representative national sample collected in four separate periods over a calendar year; the information is collected by interviewing a responsible adult in each household. All participants are asked to complete a diary, describing their activities for two days. Unfortunately the published tables and reports do not

provide the time spent indoors and outdoors (ABS 1994; 1998; 2006a). An analysis of the time spent outdoors (at residence) was provided by the ABS[28] to enHealth based on the 1992 Time Use Survey (ABS 1994) and is summarised in Figures 6.2.1–6.2.3. The raw data underpinning these figures were not available.

From Figure 6.2.1, it would seem approximately 22% of women and 12% of men aged at least 15 years spend less than 30 minutes outdoors (at private residences) each day and approximately 4% of women and 12% of men spend more than three hours outdoors each day at private residences. However, it is noted the percentage of women and men in the figure do not add up to 100%; in fact, on visual inspection this is closer to 60% and 45% for women and men, respectively. The same problem exists for the data in Figures 6.2.2 and 6.2.3. This limits the usefulness of these data for the general population.

Time spent by adults indoors and outdoors is unlikely to have changed significantly between 1992 and 2006 as the data between these three surveys do not indicate significant change in other aspects of behaviour. Importantly the time spent on grounds and animal care (subcategorised as housework) for each of the three surveys in 1992, 1997 and 2006 is 26, 25 and 22 minutes respectively as shown in Table 6.2.1. Average time spent on 'ground and animal care' was approximately 1.3, 1, and 1.1 hrs/d for males, females, and males and females combined who participated in these activities.

Australian data for time spent just on residential gardening could not be located.

Figure 6.2.1: Time spent outdoors at private residences, men and women all age groups

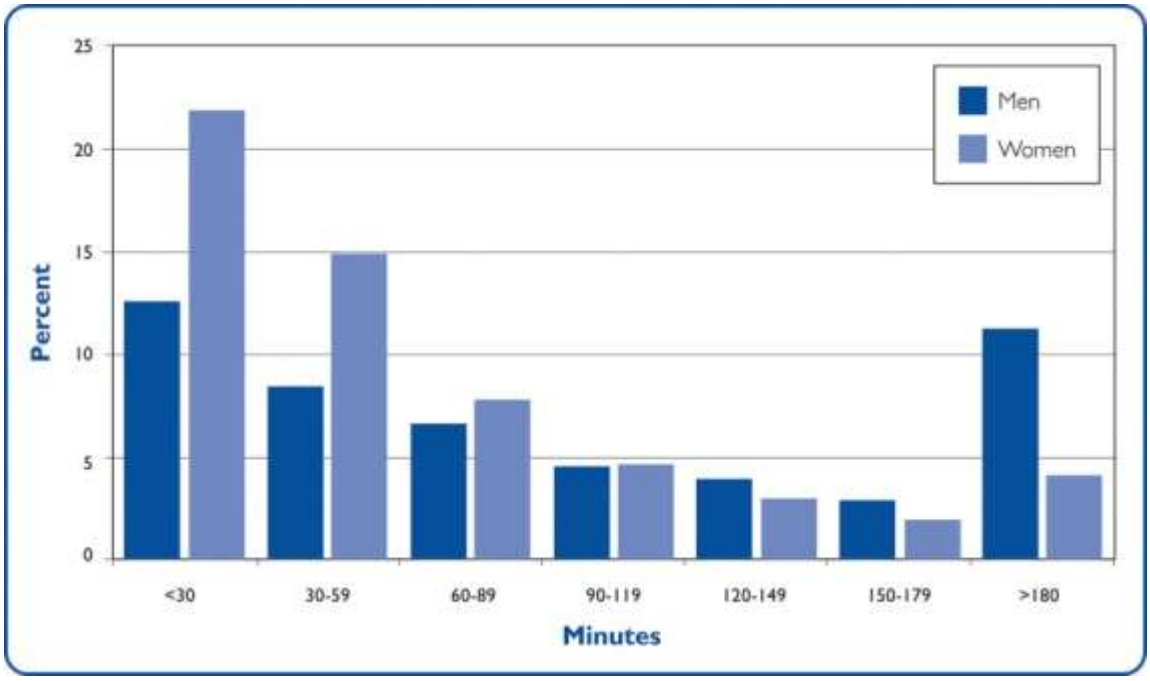


Figure is from enHealth (2004) and reflects data collected for ABS (1994)

[28] As reported in enHealth (2004) consultation draft of the *Australian exposure assessment handbook*.

Figure 6.2.2: Time spent by men outdoors at private residences

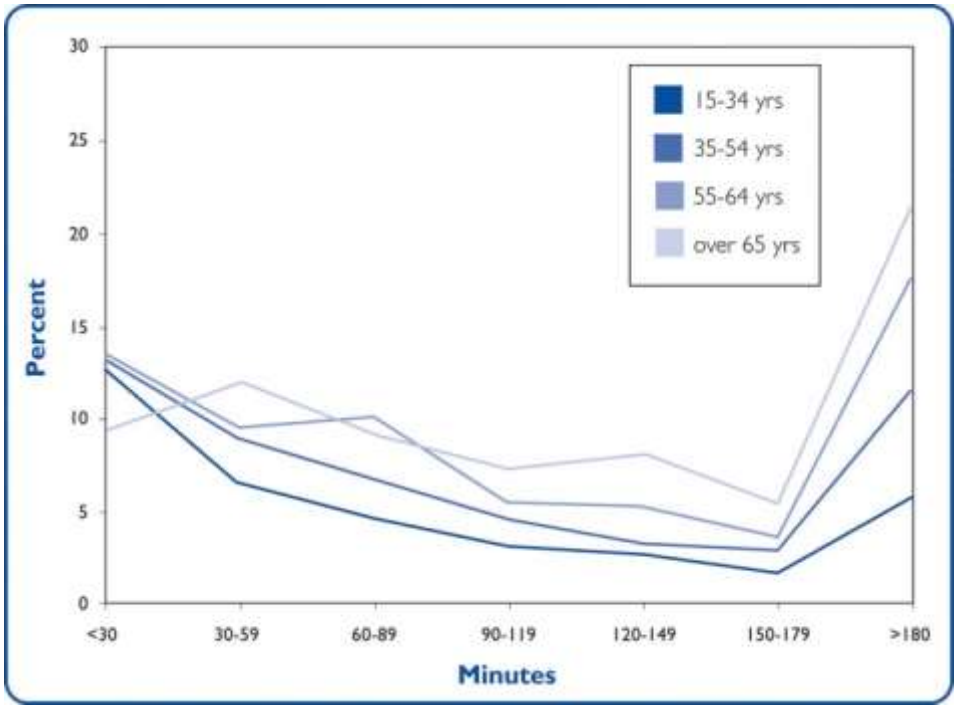


Figure is from enHealth (2004) and reflects data collected for ABS (1994)

Figure 6.2.3: Time spent by women outdoors at private residences

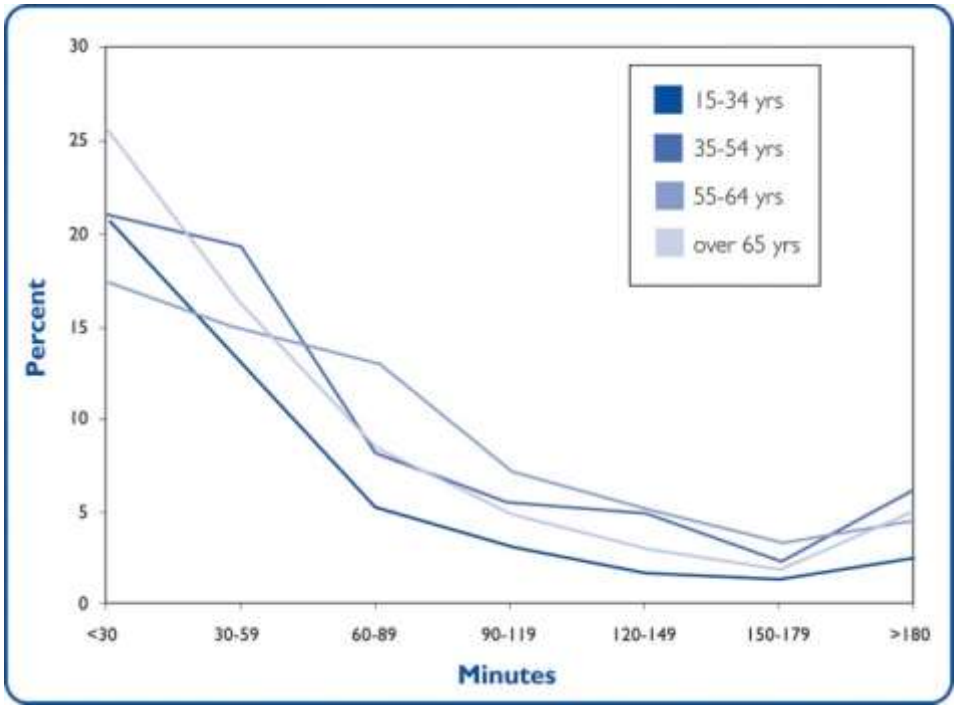


Figure is from enHealth (2004) and reflects data collected for ABS (1994)

Table 6.2.1: Average time spent on ground and animal care at private residences as reported in Time Use Surveys 1992, 1997, 2006

	1992 survey			1997 survey			2006 survey		
	Hours and minutes per day								
	Males	Females	Persons	Males	Females	Persons	Males	Females	Persons
All persons	0:30	0:22	0:26	0:27	0:23	0:25	0:23	0:21	0:22
Participants[a]	–	–	–	–	–	–	1:17	0:57	**1:06**[b]

Data from ABS (2006a, Table 1).

– information not available

Participation rates in ground and animal care for 2006 were reported as 29, 37 and 33% for males, females, and males and females combined.

Average time spent by participants (i.e. males and females combined who participated in ground and animal care) on ground and animal care (1.1 hrs/d) was added to average time spent by participants in sport and outdoor activity (1.5 hrs/d from Table 6.2.2). The resulting value of 2.6 hrs/d was rounded up to 3 hrs/d and brought forward as the suggested value for time spent outdoors by adults for Australian screening risk assessments (Section 6.2.3.2).

The Australian Time Use Survey (ABS 2006a) also considers the average time participants spent on 'sports and outdoor activities' (not further defined). The data are averaged across four seasons. Average time spent on 'sport and outdoor activities' was approximately 1.7, 1.2 and 1.5 hrs/d for adult Australian males, females, and males and females combined who participated in these activities.

6.2.1.2 Overseas data

The US EPA (1997) recommended a default of two hours per day as the total time spent outdoors (all time spent outdoors not just time spent outdoors at private residences) based on a review of 1987–88 Californian and 1985 national survey data conducted by Robinson and Thomas (1991) for people aged 12 years and older. The key data used to derive the two-hour default are described in Table 6.2.3.

In their draft update of the US *Exposure Factors Handbook* (2009), the US EPA recommend an average of 4.7 and 5.0 hours/day for adults aged 18–<65 and $\geq$ 65 years for total time spent outdoors based on data from Tsang and Klepeis (1996). These authors analysed 24-hour diary data collected by the US National Human Activity Patterns Survey (NHAPS) in 1992–1994 and provided estimates for duration and frequency for a range of selected activities and time spent in selected microenvironments.

Tsang and Klepeis (1996) estimated the time spent in the garden or other circumstances working with soil for US persons aged 18–64 years (Table 6.2.4) for the 90th, 95th and 99th percentile to be 16, 40 and 200 hours/month respectively.

Table 6.2.2: Average time spent on sport and outdoor activities by Australians

	All persons average time (hours and minutes per day)			Participants[a] average time (hours and minutes per day)		
	Males	Females	Persons	Males	Females	Persons
Sport and outdoor activity	0:26	0:18	0:22	1:43	1:13	**1:28**[b]

Data from ABS (2006a, Table 4)

Participation rates in sport and outdoor activity were reported as 25% of the survey respondents for both males and females.

Average time spent by participants (i.e. males and females combined who participated in ground and animal care) on sport and outdoor activity (1.5 hrs/d) was added to average time spent by participants on ground and animal care (1.1 hrs/d from Table 6.2.1). The resulting value of 2.6 hrs/d was rounded up to 3 hrs/d and brought forward as the suggested value for time spent outdoors by adults for Australian screening risk assessments (Section 6.2.3.2).

Table 6.2.3: US data on total[a] time spent outdoors

Study	Description	Minutes per day	
Robinson and Thomas (1991) US EPA	Physical activities outdoors	19[b]	123[c]

Study	Description	Minutes per day	
(1997, Table 15–9)	Other activities outdoors	65[b]	120[c]

Data from US EPA (1997)
All time spent outdoors (not just at residences)
Average for the US population.
Data for respondents ('Doers') who reported participating in each activity.

Table 6.2.4: Number of hours spent (US data[a]) working with soil in a garden or other working circumstance (hours/month)

Category	90th percentile	95th percentile	99th percentile
Overall	15	40	160
Male	20	50	230
Female	12	30	90
1–4 years of age	7	20	120
5–11 years of age	10	20	60
12–17 years of age	5	10	60
18–64 years of age	16	40	200
> 64 years of age	25	60	164

Tsang and Klepeis (1996) reports the US National Human Activity Pattern Survey (NHAPS). This survey was conducted by the US EPA and is one of the largest current human activity pattern surveys available (US EPA 1997, 2009). Data for 9,386 respondents in the 48 contiguous US states were collected via minute-by-minute 24-hour diaries between October 1992 and September 1994. Detailed data were collected for a maximum of 82 different possible locations, and a maximum of 91 different activities.

6.2.2 Time spent indoors

6.2.2.1 Australian data

An analysis of the time spent indoors (at private residences) was provided[29] to enHealth based on the 1992 Time Use Survey (ABS 1994) (Figures 6.2.4–6.2.6). These data have not been published as part of the ABS (1994) document.

Table 6.2.5 is a summary of time spent for an average Australian on a range of indoor and outdoor activities. The data are taken from the 2006 Time Use Survey (ABS 2006a) (survey described above in section 6.2.1.1). An average is available for the entire Australian population and also for participants only (i.e. only those actually doing each activity); the participation rate of respondents for each activity is also provided in the table. Upper estimates are not available.

From Figures 6.2.4–6.2.6 time spent indoors (at private residences) increases with age. They indicate approximately 18%of men and 5% of women (>15 years of age) spend less than 12 hours indoors at private residences and approximately 21% of men and 42% of women spend more than 20 hours indoors (at private residences) (Figure 6.2.4). Thus an estimate of 20 hours for time spent indoors (at residence) is a central estimate for women but an approximate upper estimate for men.

[29] As reported in enHealth (2004) consultation draft of the *Australian exposure assessment handbook.*

Table 6.2.5: Time spent indoors and outdoors by Australians by activity based on the 2006 Time Use Survey

	All persons avg time			Participation rate			Participants avg time		
	M	F	All	M	F	All	M	F	All
Purpose of activities	**Hours and minutes /day**			**%**	**%**	**%**	**Hours and minutes /day**		
Personal care	**11:01**	**11:23**	**11:12**	**100**	**100**	**100**	**11:01**	**11:23**	**11:12**
Sleeping	8:30	8:32	8:31	100	100	100	8:31	8:32	8:32
Personal hygiene	0:45	0:56	0:50	94	96	95	0:48	0:58	0:53
Eating and drinking	1:38	1:45	1:41	98	99	98	1:40	1:46	1:43
Employment related	**4:34**	**2:22**	**3:27**	**53**	**34**	**43**	**8:39**	**7:03**	**8:01**
Main job	3:59	2:02	3:00	50	31	41	7:56	6:31	7:23
Other job	0:02	0:01	0:01	1	1	1	4:05	3:08	3:38
Job search	0:01	0:01	0:01	1	1	1	1:39	1:29	1:34
Associated travel	0:27	0:14	0:21	47	28	37	0:58	0:51	0:55
Education	**0:31**	**0:30**	**0:31**	**9**	**11**	**10**	**5:45**	**4:51**	**5:15**
Attendance at educational courses (excluding job related training)	0:14	0:13	0:14	5	5	5	5:02	4:36	4:49
Homework/study/research	0:11	0:12	0:12	6	7	7	3:09	2:51	2:59
Domestic activities	**1:37**	**2:53**	**2:15**	**77**	**92**	**85**	**2:05**	**3:08**	**2:39**
Total housework	*0:44*	*2:12*	*1:28*	*66*	*89*	*78*	*1:06*	*2:28*	*1:54*
Food and drink preparation/cleanup	0:28	1:08	0:48	60	84	72	0:47	1:21	1:07
Laundry and clothes care	0:05	0:30	0:18	14	51	33	0:38	0:58	0:54
Other housework	0:10	0:34	0:22	22	59	41	0:46	0:58	0:55
Total other household work	*0:45*	*0:35*	*0:40*	*47*	*56*	*52*	*1:35*	*1:02*	*1:17*
Grounds and animal care	0:22	0:21	0:22	29	37	33	1:17	0:57	1:06
Home maintenance	0:14	0:03	0:09	15	6	10	1:37	0:52	1:24
Household management	0:08	0:11	0:09	22	34	28	0:35	0:32	0:33

	All persons avg time			Participation rate			Participants avg time		
	M	F	All	M	F	All	M	F	All
Purpose of activities	**Hours and minutes /day**			**%**	**%**	**%**	**Hours and minutes /day**		
Child care	**1:06**	**2:39**	**1:53**	**24**	**34**	**29**	**4:32**	**7:49**	**6:28**
Purchasing goods and services	**0:38**	**0:58**	**0:48**	**48**	**60**	**54**	**1:20**	**1:36**	**1:29**
Voluntary work and care	**0:20**	**0:31**	**0:25**	**17**	**26**	**22**	**1:57**	**1:58**	**1:58**
Social and community interaction	**0:52**	**0:58**	**0:55**	**45**	**56**	**51**	**1:55**	**1:43**	**1:48**
Recreation and leisure	**7:57**	**7:47**	**7:52**	**99**	**99**	**99**	**8:04**	**7:51**	**7:58**
Sport and outdoor activity	0:26	0:18	0:22	25	25	25	1:43	1:13	1:28
Games, hobbies, arts, crafts	0:17	0:17	0:17	16	19	17	1:48	1:33	1:40
Audio/visual media	4:34	4:08	4:21	95	95	95	4:48	4:20	4:34
Talking (including phone) or writing/reading own correspondence	1:29	1:57	1:43	63	76	70	2:22	2:33	2:28

Avg = average, M = males, F= females, All average of male and female value.

Data from ABS 2006a, Table 4

Figure 6.2.4: Time spent indoors at private residences, men and women all age groups

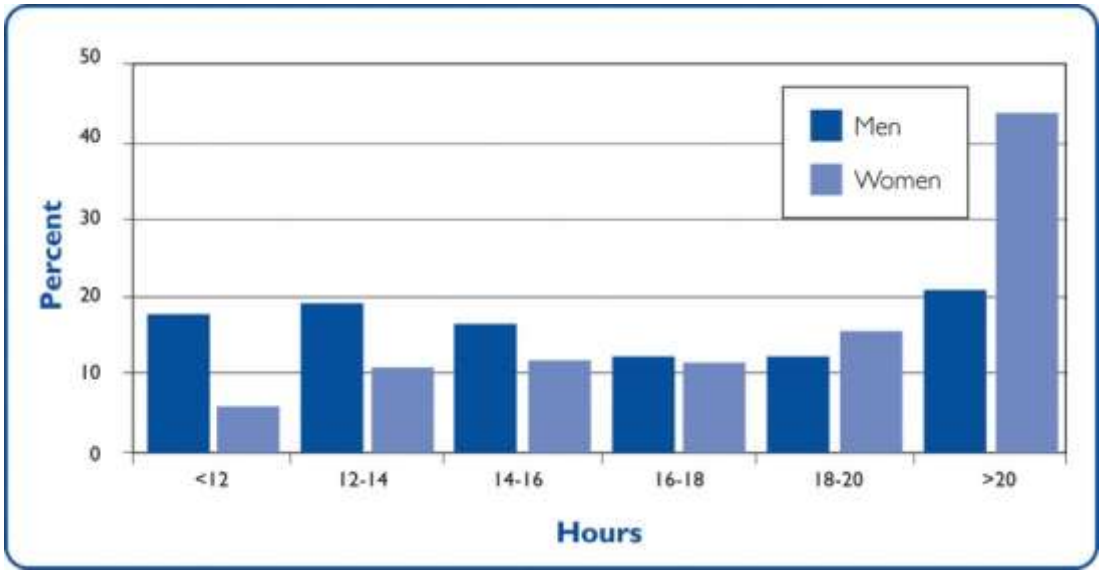


Figure is from enHealth (2004) and reflects data reported in ABS (1994)

Figure 6.2.5: Time spent by men indoors at private residence

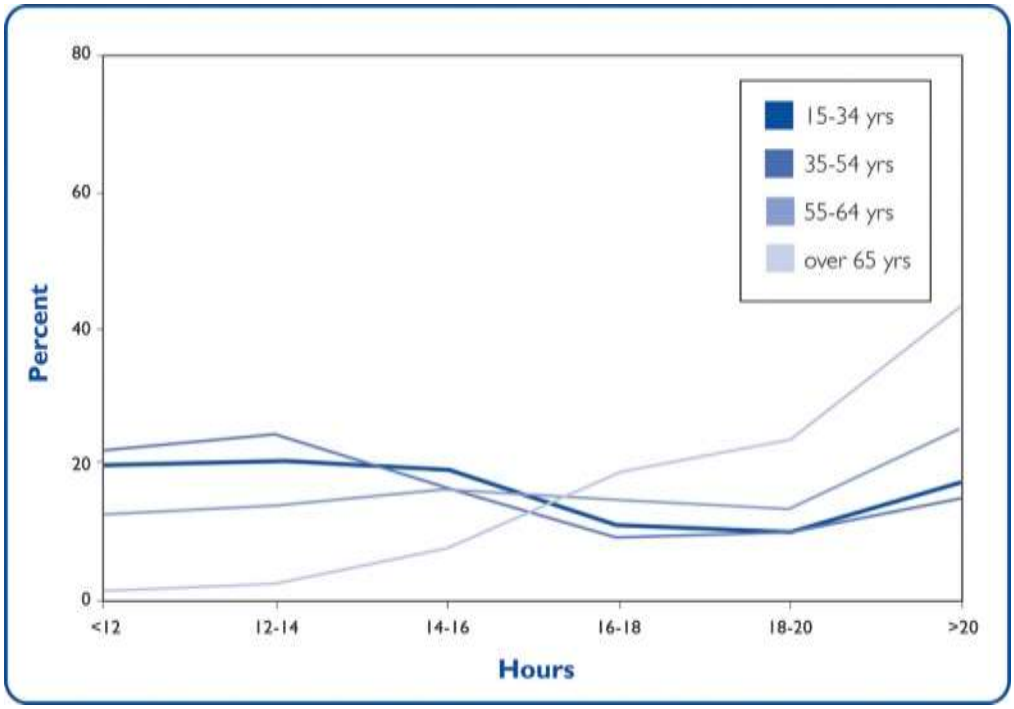


Figure is from enHealth (2004) and reflects data reported in ABS (1994)

Figure 6.2.6: Time spent by women indoors at private residences

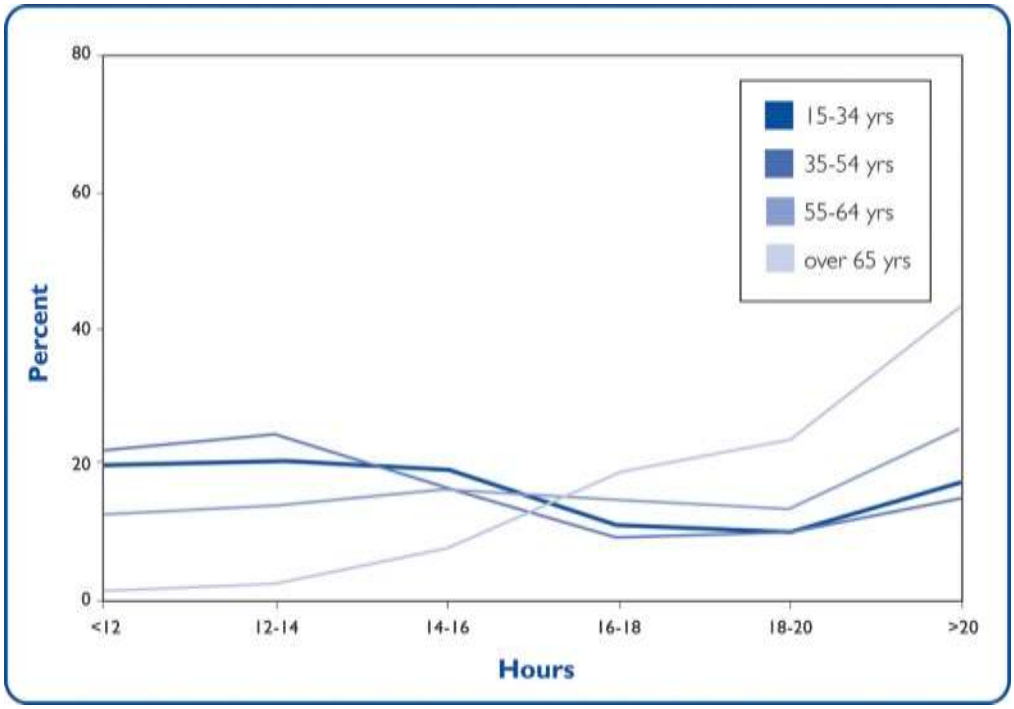


Figure is from enHealth (2004) and reflects data reported in ABS (1994)

Table 6.2.6: Time spent indoors and outdoors at Californian homes by level of physical exertion and life-stage

	Adults	Adolescents	Children (6–11)
Activity group[a]	Mean (min/day) ± (standard deviation)		
Low	702 ± (214)	789 ± (230)	823 ± (153)
Moderate	257 ± (183)	197 ± (131)	241 ± (136)
High	9 ± (38)	1 ± (11)	3 ± (17)
High ('doers')	92 ± (83)	43 ± (72)	58 ± (47)

Data from Funk et al. (1998). Reproduced with permission from John Wiley and sons

Low-level activities included resting activities requiring little physical exertion, such as sleep, TV use, reading and paperwork. Moderate-level activities included those requiring moderate physical exertion, food preparation, plant, pet and child care, outdoor playing, washing, hobbies and computer use. High-level activities were classified as those requiring more substantial physical exertion, such as outdoor cleaning (adults and adolescents only).

Time spent indoors on activities

Given that Australians spend most of their time at home it is useful to consider the time spent on various activities and how these may influence exposure estimates. One of the key exposure intake parameters is inhalation rate, thus linking time spent on activities indoors by the level of ventilation rate (low medium and high) can be useful in understanding the variability in substance intake due to inhalation.

Using a combination of Californian studies on time spent on activities (indoors and outdoors) at various locations, and estimates of inhalation rates for each activity, Funk et al. (1998) have grouped each activity based on degree of physical exertion (i.e. low, moderate or high). Ambiguous activities were included in the moderate exertion group. Table 6.2.6 summarises the aggregate time spent at home by activity groups for Californian adults, adolescents and children.

6.2.3 Time spent in transit (car, public transport)

6.2.3.1 Australian data

The Australian Time Use Survey taken in 1992, 1997 and 2006 (ABS 1994; 1998; 2006a) provides data on time spent travelling related to particular activities including employment, education, child care, domestic, commercial, social and recreational activities (for persons aged 15 and over). Table 6.2.7 summarises average time spent on travel by activity per person. An analysis of the values for respondents only (i.e. doers) or by geographical location, or transport mode is not presented within ABS 1994, 1998 or 2006.

Table 6.2.7: Average travel time (hours:minutes per day) by activity

	1992[a]			1997[b]			2006[c]		
Travel activity	Males	Females	Persons	Males	Females	Persons	Males	Females	Persons
	All values are in hours: minutes per day								
Employment associated	0:24	0:11	0:18	0:26	0:14	0:20	0:27	0:14	0:21
Education associated	0:04	0:03	0:03	0:03	0:03	0:03	0:04	0:04	0:04
Domestic activities associated	0:04	0:02	0:03	0:03	0:02	0:03	0:04	0:03	0:04

Travel activity	1992[a]			1997[b]			2006[c]		
	Males	Females	Persons	Males	Females	Persons	Males	Females	Persons
Child care associated	0:02	0:06	0:04	0:02	0:07	0:05	0:03	0:09	0:06
Purchasing goods and services associated	0:13	0:18	0:15	0:13	0:18	0:16	0:16	0:21	0:19
Voluntary work and care associated	0:06	0:06	0:06	0:04	0:04	0:04	0:02	0:03	0:03
Social and community interaction associated	0:16	0:17	0:16	0:12	0:13	0:13	0:11	0:13	0:12
Recreation and leisure associated	0:06	0:04	0:05	0:11	0:07	0:09	0:06	0:05	0:05
Sum total (mins)	75	67	70	74	68	73	73	72	**74[d]**

ABS (1994)

ABS (1998)

ABS (2006a)

This value (1.2 hrs/day) is similar to the average travel time for all persons in 2006 (i.e. 1.1 hrs/day) from a survey conducted in Melbourne (Ironmonger 2008, Table 6.2.8). The values were rounded down to 1 hr/day and brought forward as the suggested value for average travel time for use in Australian screening risk assessments (section 6.2.3.2).

A recent study of transit time in the city of Melbourne appears to be the only systematic survey of its kind available for Australia (Ironmonger 2008). The study integrates and utilises 12 disparate datasets, some very large. The integrated approach is called the 'Melbourne Time Accounts.' The datasets include the VicRoads Traffic Statistics Database (VRTSD), which has large amounts of travel time data including the strategic traffic monitoring program. This is a sampling program of traffic counts repeated every year at about 90 sites on arterial roads and freeways. Other data systems cover only particular years such as the Time Use Survey (ABS 1994; 1998; 2006a) and others, such as Automated Ticketing System (public transport data) (Ironmonger 2008).

Table 6.2.8 provides summaries of average hours per week spent on travel by individuals (including children, i.e. <15 years of age) for different modes of travel (car, public transport and other motorised travel, walking and cycling). It should be noted that significant differences in travel time are expected between city and rural centres as well as between city centres in Australia.

Both surveys summarised in Tables 6.2.7 and 6.2.8 indicate the average travel time per day for Melburnians correlates well with the Time Use Survey data for Australia, showing an average travel time per day of 1.0–1.1 hours and 1.1–1.3 hours respectively.

Table 6.2.8: Average hours per week travel time in Melbourne

	1991	1996	2001	2006
	hours per week			
Total travel time				
Women	6.6	7.4	8.0	8.6
Men	8.3	8.6	8.7	8.7
Adults	7.5	8.0	8.7	8.7
Children	5.2	5.2	5.2	5.2
All persons	7.0	7.4	8.0	**8.0**[a]
Car travel time				
Women	5.1	5.4	5.7	6.1
Men	6.4	6.5	6.5	6.6
Adults	5.7	5.9	6.1	6.3
Children	3.7	3.9	4.1	4.3
All persons	5.3	5.5	5.7	5.9
Public transport travel time				
Women	0.69	0.75	0.80	0.85
Men	0.78	0.75	0.73	0.71
Adults	0.73	0.75	0.77	0.78
Children	0.38	0.38	0.38	0.38
All persons	0.66	0.68	0.69	0.71
Other motorised travel time				
Women	0.11	0.10	0.08	0.07
Men	0.31	0.31	0.31	0.31
Adults	0.21	0.20	0.19	0.19
Children	0.06	0.06	0.05	0.05
All persons	0.18	0.17	0.17	0.16
Walking travel time				
Women	1.14	1.14	1.14	1.14
Men	1.02	1.02	1.02	1.02
Adults	1.08	1.08	1.08	1.08
Children	0.77	0.77	0.77	0.77
All persons	1.019	1.019	1.019	1.019

	1991	1996	2001	2006
	hours per week			
Cycling travel time				
Women	0.06	0.06	0.05	0.05
Men	0.16	0.17	0.17	0.18
Adults	0.11	0.11	0.11	0.11
Children	0.09	0.11	0.13	0.15
All persons	0.10	0.11	0.11	0.12

Data from Ironmonger (2008)

This value (1.1 hrs/day) is similar to the average travel time for all persons in 2006 (i.e. 1.2 hrs/day) from a national survey (ABS 2006a, Table 6.2.7). The values were rounded down to 1 hr/day and brought forward as the suggested value for average travel time for use in Australian screening risk assessments (Section 6.2.3.2).

6.2.3.2 Recommendations

Table 6.2.9 summarises the recommended default parameters for time spent indoors (total and at residence) and outdoors by adults from overseas agencies. Upper estimates are only available from the US EPA for time spent indoors (at home). Australian data for total time spent indoors (at home and away from home) are not available. It is suggested 20 hrs/d may be used as an average value for total time spent indoors by adults (at home and away from home), with a reasonable maximum of 24 hrs/d (this is simply total number of hours in a day). This is consistent with average values of 19–21 hours for total time spent indoors from overseas agencies (Table 6.2.9). Australian data indicate approximately 42% of adult women and 22% of adult men spend 20 hours or more per day indoors (at home). Thus it is suggested the average total time spent indoors of 20 hrs/d may also be applied for time spent indoors at home, with a reasonable maximum of 24 hrs/d.

For time spent outdoors by adults, Australian data (for participants) from the 2006 Time Use Activity survey (ABS 2006a) indicate an average of 2.6 hrs/d is spent in total on ‘ground and animal care’ and ‘sport and outdoor activity’ by males and females combined. In the absence of more information, this value was rounded up to 3 hrs/d and suggested as an approximate average for time spent outdoors by adults for use in Australian screening risk assessments (Tables 6.2.1 and 6.2.2). Upper estimates are not available.

A central estimate (i.e. average) of 1 hr/d spent in transit is recommended as a suggested value for use in Australian screening risk assessments based on the time activity surveys produced by Ironmonger (2008) and the ABS (ABS 2006a) (Tables 6.2.7 and 6.2.8). Upper estimates are not available.

Table 6.2.9: Summary of default parameters for time spent indoors and outdoors (hrs/d) by adults from various overseas agencies

Country	Age	Indoor (total) hr/d	Indoor (at home)	Outdoor (total)
Canada (Health Canada 1994, pg 17).	Entire population	**20**[a]	–	4 hours (2 outdoors, 2 in transit)
United States				
US EPA (2009, Table 16–1)	18-<65 years	**19.3**[a]	15.8 (23.8)	4.7
	>65 years	**19.0**[a]	19.6 (24)	5.0
US EPA (1997, Table 15–176)	Adults	**21**[a]	16.4	2

The average total time spent indoors for US and Canadian adults is approximately 20 hrs/d. This value was brought forward as the suggested value for adults in Australian screening risk assessments.

6.2.4 Swimming

In Australia, a swimming pool is defined under the *Building Act (1975*) as being any excavation or structure:

- capable of being filled with water to a depth of 300 mm or more
- capable of being used for swimming, wading, paddling or bathing, or some other human aquatic activity
- solely or principally used, or designed, manufactured or adapted, to be solely or principally used for the purposes mentioned above despite its current use.

According to the Standard Building Regulation of Australia (1993), a porTable wading pool is a pool that:

- can be filled with water to a depth of no more than 450 mm
- has a volume of no more than 2,000 L
- has no filtration system.

6.2.4.1 Australian data

Participation in swimming activities

Only very limited information is available relating to the time that various Australian age groups spend swimming. Mean frequency of children (5–14 years of age) participating in 'organised sport' (meaning of sport was left to the participant to decide) was 75.5 times in a year (ABS 2006b, Table 13 p. 30). Of the participants who indicated they participated in swimming, only 18.7% indicated they did so 53 times or more in a year. In 2008, this was 14.2% (ABS 2009, Table 13 p. 29). Approximately half of all children who participated in swimming (50.9% in 2006 and 52.5% in 2008) indicated they did so 27–52[30] times in a year (ABS 2006b, Table 16 p. 33; ABS 2009, Table 13 p. 29).

The 2001 South East Queensland Outdoor Recreation Demand Study (DNR 2001 – summary only available) investigated the nature and extent of participation in outdoor recreation activities by the residents of South Eastern Queensland. The report states that 56% of residents aged over 15 years participate in water activities, with a median frequency of 12 times per year (i.e. only once per month). This is assumed by DNR (2001) to be representative of the general population in South East Queensland. Intuitively, however, this seems to be a low frequency for the area of Queensland in question.

Because only a summary of the study was available the value is regarded as being of low reliability.

Australian time use surveys characterising the time spent swimming per event are not available. However experience suggests the time spent at the beach or pool during summer can be considerable in most parts of Australia for a large cross section of the population.

The Australian Time Use Survey (ABS 2006a) does consider the average time participants spent on 'sports and outdoor activities'. The data are not available by season and is averaged across four seasons. As shown in Table 6.2.10 assuming an individual spends all of this time swimming it would result in an estimate of between 1.5 and 2 hours for active participants. Upper estimates are not available.

According to the ABS (2008):

- A total of about 1.4 million people aged 15 and over (out of about 15.5 million survey participants; i.e. around 9%) participate in swimming activities.
- Around 0.6 million of these participants were men, and around 0.8 million were women. Data on time spent swimming were not part of the survey.

Based on a similar survey conducted in 2006 (ABS 2006a) for children aged 5–14 years who provided information on their participation in organised sporting activities:

- Swimming was the most popular sport for children with a participation rate of 17% (462,500 out of a total of approximately 2.6 million children involved in the survey).
- Individual time spent swimming was not part of the survey, but it was recorded that an average of six hours per fortnight (i.e. ~25 min/d) were spent participating in all organised sports.

[30] An approximate median of 52 days/year was brought forward as the suggested value for use in Australian screening risk assessments for frequency of swimming.

Table 6.2.10: Average time spent on sport and outdoor activities by Australians

	All persons' average time (hours and minutes per day)			Participants'[a] average time (hours and minutes per day)		
	Males	Females	Persons	Males	Females	Persons
Sport and outdoor activity	0:26	0:18	**0:22**[b]	1:43	1:13	**1:28**[c]

Data from ABS (2006a, Table 4)

Participation rates in sport and outdoor activity were reported as 25% of the survey respondents for both males and females.

Value for the general population (22 minutes, i.e. 0.4 hrs/d) is the same as the estimate for time spent on organised sport by children aged 5–14 years (6 hrs/fortnight, i.e. ~0.4 hrs/d) (ABS 2006a). A conservative assumption is made that all sport/outdoor activity is swimming, reflecting the lack of data for the parameter. This value was rounded up (0.5 hrs/d) and brought forward as the suggested average time spent swimming for the general population for use in Australian screening risk assessments (Section 6.2.4.3).

Value for participants in Table (1.47 hrs/d) was rounded up (1.5 hrs/d) and brought forward as the suggested average time spent swimming by active participants for use in Australian screening risk assessments (Section 6.2.4.3).

The data from this survey may have limited usefulness for risk assessment, because data on frequency of recreational swimming (such as swimming or wading in a backyard pool) were not produced.

No Australian data for participation in swimming activities for children under the age of five could be located.

Frequency of swimming

According to the ABS (2008):

- Australians aged 15 years and over spend an average of 19 minutes (7.5%) of their free time each day on sport and outdoor activity. Males spend more time on sport and outdoor activity than females (23 minutes compared with 16 minutes).
- On average, 25% of Australians aged 15 years and over participated in sport and outdoor activity each day. Those who participated spent an average of one hour and 28 minutes (18.4%) of their free time each day.

No Australian data on frequency of swimming for children under 5 years old could be located.

Number and size of swimming pools

The proportion of households in Australia with swimming pools increased slightly to 11.7% in 2007, up from 11.3% in 2004 and 10.0% in 2001 (Figure 6.2.7). The states and territories covering Australia's north had the highest proportion of households with swimming pools:

Northern Territory 28.9%

Queensland 17.9%

Western Australia.....15.4%

Tasmania 3.8%

Victoria 7.0%

New South Wales.....13.3%

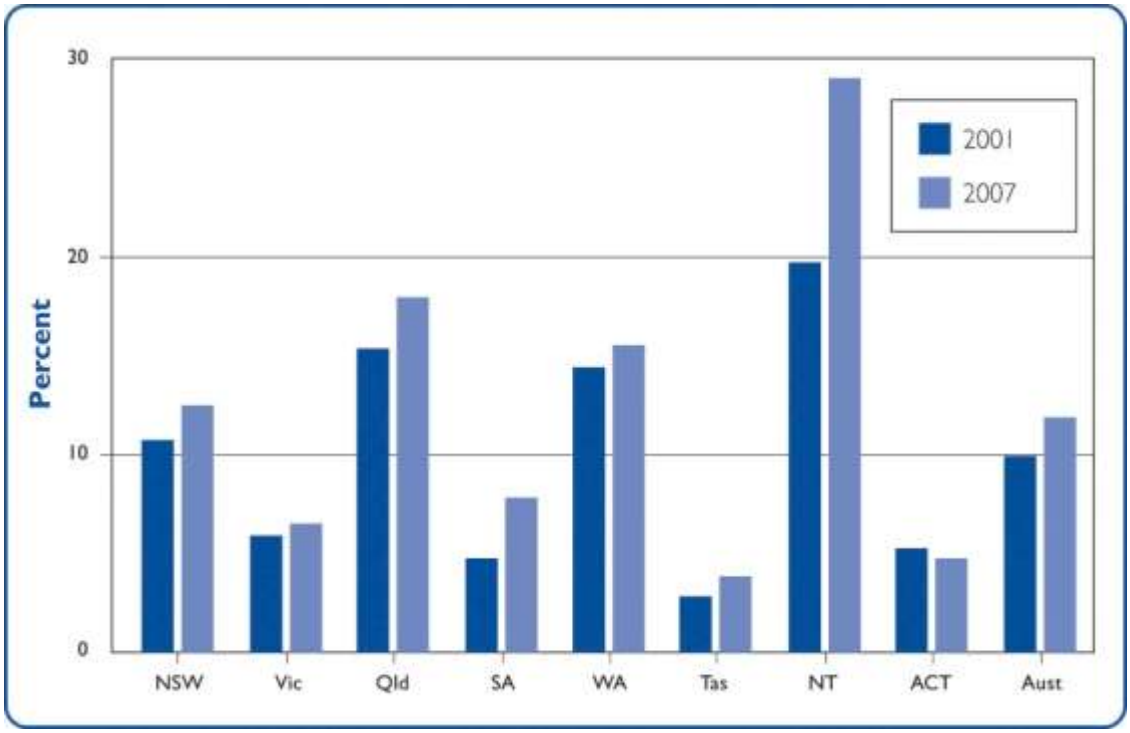
South Australia.....8.5%

Australian Capital Territory.....5.2%

In-ground pools made up the majority of Australian pools, with 9.8% of households having an in-ground pool and 2.0% of households having an above-ground swimming pool (ABS 2007).

Data on the average volume and dimensions of a domestic swimming pool were not found. The New South Wales Swimming Pool and Spa Association (SPASA) claim that the average swimming pool holds between 22,000 and 66,000 litres of water (SPASA 2008). Typical pool sizes of some swimming pools in Australia are shown in Table 6.2.11.

Figure 6.2.7: Households with swimming pool at dwelling, 2001 and 2007



Source: ABS 2007, Figure 5.3, p. 64

Table 6.2.11: Typical sizes of Australian domestic swimming pools

Pool length (m)	Pool width (m)	Average depth (m)	Water capacity (l)
8.0	4.0	1.3	41,600
9.2	4.5	1.3	53,820
10.0	5.0	1.3	65,000

Courtesy of Daisy Pool Covers (undated)

6.2.4.2 Overseas data

The US EPA analysed the US National Human Activity Patterns Survey (NHAPS) for the frequency of swimming per month and number of minutes spent swimming in a freshwater swimming pool per month from a representative cross-section of the US population. The number of times respondents swam per month ranged from 1 to 60 with the greatest number of respondents (147, i.e. 23%) reporting they swam one time a month. The utility of these statistics for the Australian population is limited; site-specific climate and behaviour should be carefully considered. The US EPA recommended event time, event frequency and exposure duration is summarised in Table 6.2.12 and the distribution of time spent in the water by swimmers (US EPA 1997, Table 15–67) is summarised in Table 6.2.13.

Table 6.2.12: US (1997) suggested default values for dermal exposure while swimming[a]

Parameter	Central estimate	Upper estimate
Event time	0.5/event	1.0hr/event
Events per day	1 event/day	1 event/day
Events per year	5 days/year	**150 days/year[a]**

Data from US EPA 1997, Table 15–18

This value was brought forward as the suggested upper estimate for frequency of swimming for use in Australian screening risk assessments (Section 6.2.4.3).

Table 6.2.13: Number of minutes spent swimming in a month in the US (freshwater swimming pools)

		Percentiles								
Category	N	1	2	5	10	25	50	75	90	95–100
Total	640	2	3	10	15	30	60	90	180	181
Male	295	3	4	8	10	30	45	90	180	181
Female	345	2	3	10	15	30	60	90	180	181
Age 1–4	60	3	3	7.5	15	20	42.5	120	180	181
Age 5–11	95	2	3	20	30	45	60	120	180	181
Age 12–17	83	4	5	15	20	40	60	120	180	181
Age 18–64	357	2	3	5	10	20	45	60	120	181
Age > 64	38	5	5	8	10	30	40	60	120	181

Data from US EPA 1997, Table 15–67; US EPA 2009, Table 16–37

In the updated draft US EPA *Exposure Factors Handbook* (2009), mean and 95th percentiles for time spent swimming are provided in minutes per month by age group. A value of 181 minutes signifies more than 180 minutes were spent swimming. The data are summarised in Table 6.2.14.

Table 6.2.14: US suggested values for time spent swimming (2009)

	Time spent swimming (minutes/month)	
Age (years)	Mean	95th percentile
<1	**96[b]**	–
1-<2	**105[b]**	–
2-<3	**116[b]**	181
3-<6	**137[b]**	181

Age (years)	Time spent swimming (minutes/month)	
	Mean	95th percentile
6-<11	151	181
11-<16	139	181
16-<21	145	181
18-<65	45[a]	181
≥ 65	40[a]	181

Data from US EPA 2009, Table 16–1

Median value, mean not available

Australian data for time spent swimming for children under five years of age were not available. Therefore, US EPA (2009) data in this Table for the children under five were converted to average time spent swimming per year, rounded, and brought forward as suggested values for use in Australian screening risk assessments.

Schets et al. (2011) collected questionnaire data on self-reported frequency and duration of swimming events in swimming pools, fresh water and seawater from Dutch adults during the 2007 and 2009 swimming season. Questionnaires were answered by adults (≥ 15 years) on behalf of themselves and their eldest child in the household. A total of 8000 adults (>15 years) and 1,924 children (<15 years) participated in the survey.

Swimming frequency (in swimming pools, freshwater and seawater) was on average 6–24 times/year. Swimming events lasted on average 41–68 minutes (0.7–1.1 hrs) for adults and 65–81 minutes (1.1–1.4 hrs) for children.

6.2.4.3 Recommendation

Insufficient survey data exist to provide a robust estimate for frequency and time spent by Australians swimming in either swimming pools or natural water bodies (e.g. beaches, lakes, creeks and rivers). However, it is common sense that swimming activity will likely be dependent on the location in Australia; higher in tropical and sub-tropical regions compared with temperate or colder areas.

The suggested values for time spent swimming for persons aged five years or older in Table 6.2.15 are based on the average time spent on sport and outdoor activities (by adults > 15 years of age) and organised sport (by children 5–14 years of age) reported in the Australian Time Use Survey (ABS 2006a). For the purpose of suggesting values for use in screening risk assessments it is conservatively assumed all sport and outdoor activity will be swimming. This assumption reflects the lack of specific data for the parameter.

Good Australian data for the frequency (number of days per year) that a person may swim were not located for this report. The approximate median (i.e. 50th percentile) frequency of children (aged 5–14 years) who participate in swimming is 27–52 times in a year (ABS 2006b, Table 16, p. 33; ABS 2009, Table 13 p. 29). This represents an average for all participants surveyed (i.e. national population average). Thus a median frequency of 52 d/year is suggested for use in Australian risk assessments (≥ 5 years of age). It is however conceivable that in warm/hot regions of Australia the frequency of swimming could be higher. In the absence of Australian upper estimated data, the US EPA (1997, Table 15–18) upper estimate of 150 d/yr for a person who swims regularly for exercise or competition is suggested for use in Australian screening risk assessments. This may, however, be a generous 'high end' estimate for many risk assessment scenarios since ABS (2006, Table 16 p. 33) indicated only 18.7% of the general Australian population participated in swimming more than 53 times in a year.

Table 6.2.15: Suggested values for swimming (swimming pools only)[a]

Age (years)	Parameter	Value	Description
> 5	Event time (hr/d)	0.5[b]	General population[a]
		1.5[c]	People who swim regularly[a]
	Frequency (d/yr)	52 (150)	Approximate median (upper estimate) (Section 6.2.4.1 and Table 6.2.12).
<1	Time per year (hrs/yr)	19	Mean (i.e. average) time spent swimming by US children[d].
1-<2		21	
2-<3		23	
3-<5		27	

Values for the general population in the Table reflect the rounded-up average time spent on sport/outdoor activity by Australian adults (≥ 15 years) (22 minutes, i.e. 0.4 hrs/d) and organised sport by children aged 5–14 years (6 hrs/fortnight, i.e. ~0.4 hrs/d) (ABS 2006a). The value for people who swim corresponds to the time spent on sport/outdoor activity by those survey respondents (≥ 15 years) who indicated they participated in sport/outdoor activities (Table 6.2.10, Australian Time Use Survey Table 4 (ABS 2006a). A conservative assumption is made that all sport/outdoor activity is swimming, reflecting the lack of data for the parameter.

Rounded up from 22 min/day (i.e. 0.4 hrs/d) for male and female adults combined and 6 hrs/fortnight (i.e. 0.4 hrs/d) for children (Table 6.2.10).

Rounded up from 1.47 hrs/day for males and females combined (Table 6.2.10).

Average times spent swimming (min/month) from Table 6.2.14 for <1, 1–<2, 2–<3, and 3–<6 year olds was converted to hrs/year for the age groups listed in this table.

No Australian data were available for children under the age of five. Therefore, US EPA (2009) data for average time spent swimming (minutes/month) for children under the age of five are suggested for use in Australian screening risk assessments. The upper percentile data are not recommended as they were truncated by the US EPA at 181 minutes for statistical analysis.

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7. Residence and population mobility

7.1 Duration of residence

7.1.1 Australian data

The default duration of residence recommended by regulatory authorities in Australia was previously 70 years (enHealth 2004). This default was used because Australian census data do not sufficiently investigate the frequency of movement to allow estimation of the number of years that an individual spends in a single dwelling (Bell and Hugo 2000, p. 165). However, a recent Australian statistical survey has been initiated that provides a robust statistical basis for determining duration of residence in Australia (HILDA 2007).

The HILDA survey (household, income and labour dynamics in Australia) is a large-scale, representative household-based panel (i.e. longitudinal) survey designed to collect large amounts of information about Australian households and their members. It is intended to be a dynamic dataset that addresses information deficiencies (Watson 2009). The survey is funded by the Australian Government through the Department of Families, Housing, Community Services and Indigenous Affairs.

In line with studies conducted in other countries, the sampling unit is the household, and members of those households are intended to be traced over their lifetime. The HILDA survey involves annual interviews with a representative national sample of about 15,000 individuals in 6,900 households (Watson 2009). The survey includes a question on 'Years at current address' (i.e. a direct question on duration of residence). The frequency and cumulative frequency distribution of responses (2001–2005) to this question (HILDA 2007, survey release 5.1), are presented in Figures 7.1a and 7.1b.

Figure 7.1: Statistical representations of Australian duration of residence

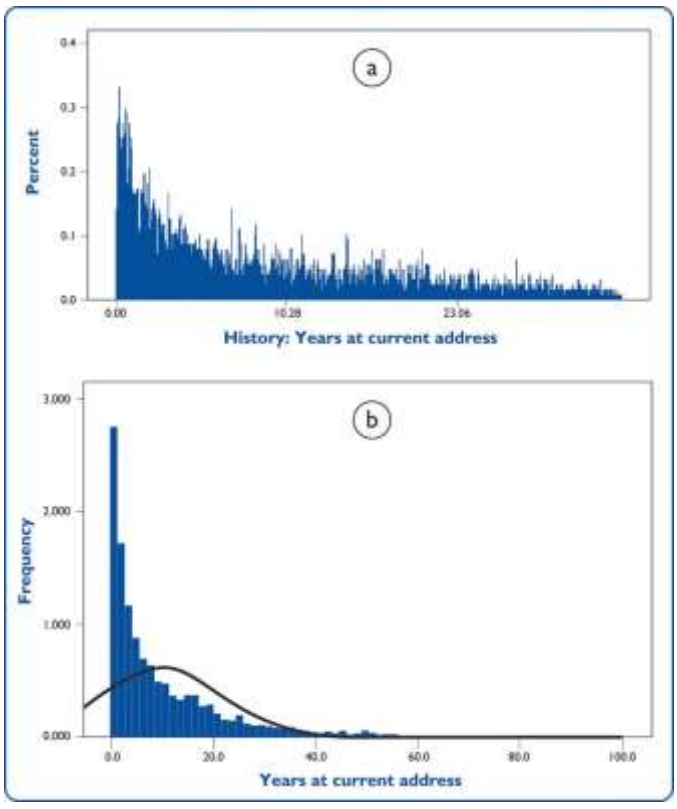


Figure 7.1a is a frequency distribution of the number of years a respondent has resided at their current address. Figure 7.1b is a cumulative frequency distribution of the same dataset (HILDA 2007, release 5.1). The distribution is based on HILDA wave five history variable ('HSYRCAD History: Years at current address'). The solid line in Figure 7.1b fits the data to a Beta distribution based on a preliminary evaluation of the best fit.

Source: Frangos and Arunachalam 2008, an analysis of data in HILDA 2007

Table 7.1.1 shows the median duration of residence was approximately 5 years, with a mean of 10 and a 95th percentile of 35 years.

Table 7.1.2 provides data for duration of residence by age group and sex for each year the survey has been undertaken (2001–2006) (Wilkins et al. 2009, p. 140). The average duration of residence for males and females combined for all survey years was approximately 10 years (rounded down from 10.3 years).

Other important findings include:

- There is very little difference in duration of residence between males and females (Table 7.1.2).
- Average duration of residence changes with age, 25–34 year olds and 55–64 year olds have an average duration of residence of approximately 4 and 15 years respectively (Table 7.1.2).

Table 7.1.1: Summary statistics on Australian duration of residence

Statistic	Value[a]
No. of samples	12,667
Mean	**10 years[b]**
Standard error of mean	0.1
Median	5 years
Standard deviation	11.7
Skewness	2.0
Kurtosis	4.6
Maximum	85 years
90th percentile	25 years
95th percentile	**35 years[b]**
99th percentile	52 years

Values rounded

Mean (i.e. average) and 95th percentile duration of residence (10 and 35 years, respectively) were brought forward as suggested values for use in Australian screening risk assessments (Section 7.1.3)

From Frangos and Arunachalam (2008), an analysis of data in HILDA (2007).

- Families where the youngest child is 0–4 years of age have the highest frequency (20 % of moves from their house in the previous year compared with families with older children or no children (ca. 13%) (Wilkins et al. 2009, p. 141).
- There is a large difference in the duration of residence between those who own or are paying off their home (approximately 12–14 years) versus those renting (approximately four years for private renters and nine years for those in public housing). Refer to Table 7.1.3 (adapted from Wilkins et al. 2009, Table 28.4).

Table 7.1.2: Mean number of years living in current residence, by sex and age[a]

Age group (years)	2001	2002	2003	2004	2005	2006
Males						
15–19	8.3	7.9	8.2	8.3	8.6	8.6
20–24	6.5	6.3	6.5	6.2	6.4	6.9
25–34	4.4	4.3	4.4	4.3	4.4	4.1
35–44	6.1	6.2	6.2	6.7	6.8	7
45–54	10.7	10.5	10.6	10.3	10.2	10.6
55–64	15.5	15.4	15.2	15.4	15.1	15.4
65+	20.1	19.9	20.6	21.2	20.9	21.2
Total	9.9	9.8	10	10.2	10.3	10.4
Females						
15–19	7.4	8.2	8	8.2	8.4	8.7
20–24	4.7	4.9	4.6	4.7	4.4	4.7
25–34	4	4.2	4.3	4.6	4.2	3.9
35–44	6.4	6.4	6.4	6.4	6.7	7.1
45–54	11.6	11.1	11.2	11.1	11.2	10.7
55–64	15.1	15.6	16.1	16	15.8	16.2
65+	20.4	20.7	20.8	21.3	21.5	21.5
Total	10	10.3	10.4	10.6	10.7	10.8

Wilkins et al. 2009, Table 28.1 p. 140, population weighted results

Table 7.1.3: Mean duration of residence by type of housing tenure[a]

Housing tenure	2001	2002	2003	2004	2005	2006
Own home outright	13	13	13.2	13.9	14	14.5
Currently paying off mortgage	12.3	12.2	12.3	12.4	12.5	12.4
Rent or pay board private rental	2.4	2.8	3.1	3.1	3.2	3.3
Rent or pay board government housing	7.9	8.4	9.1	9.6	10	11.1
Live rent free or life tenure	8.2	8.2	7.5	8.4	7.7	8.5
Involved in a rent-buy scheme[b]	n/a	5.6[c]	6.3[c]	3.8[c]	5.3[c]	7.4[c]
Total	10	10	10.2	10.4	10.5	10.6

Adapted from Wilkins et al. (2009, Table 28.4, pg 141).
In 2001 this group was included in the rent or pay board category.
Estimate not reliable due to large standard error.

7.1.2 Overseas data

Table 7.1.4 shows that the Australian distribution for duration of residence is similar to US distributions from studies with similar statistical survey design (longitudinal). Using these studies the US EPA recommends default duration of residence of 30 years as a 95th percentile (US EPA 1997, Table 15–176). The similarity between the Australian and US distributions has been previously noted in a comparison of mobility data (Bell and Hugo 2000).

Table 7.1.4: Comparison of Australian and overseas distributions on duration of residence (years)

	US population			Australia
Percentile	Israeli and Nelson (1992)	US Census Bureau (1993)	Johnson and Capel (1992)	HILDA (2007)
25th	0.5	4	4	2
50th	1.4	9	9	5
75th	4	18	16	14
90th	13	32	26	25
95th	23	40	33	35

7.1.3 Recommendation

The average and 95th percentile duration of residence in Australia from the 2001–2006 HILDA survey data are approximately 10 and 35 years, respectively (Table 7.1.1). These values are suggested for use in Australian screening risk assessments.

7.2 Mobility characteristics of the population

The data herein are provided to provide information for the sake of completeness, and are not typically required for screening risk assessments. Thus no specific recommendations are made.

7.2.1 Australian data

Wilkins et al. (2009) summarises the distance people move according to the reasons for the move. As shown in Table 7.2.1 most Australians that changed residences (60%) moved by less than 10 kilometres. There are a variety of reasons for the move, but the most cited were to improve housing or neighbourhood.

Table 7.2.2 summarises the residential mobility characteristics of Australians. Historically the primary information on population movements in Australia has been drawn from the census held every five years and provides the population proportion that changed residence at least once within the survey period. The proportion of the population that changed their place of usual residence in the surveys of 1976 and 2001 was 41% and 42% respectively, indicating residential turnover is relatively sTable (ABS 2001; Bell 1996; Bell and Hugo 2000; Maher and Whitelaw 1995). Australians move house on average approximately 12 times during their lives (Bell and Hugo 2000).

Table 7.2.2 is based on census data. The data do not allow a detailed analysis of the number of years spent by an individual in a dwelling (Bell and Hugo 2000). The census only provides data down to a statistical local area (SLA).[31] The census collects information on movers on census night every five years; however, mobility may have occurred at any time in the past five years, thus the characteristics attributed to the SLA on census night may or may not correspond to individual characteristics at the time of the move.

Table 7.2.1: Distance moved and reason for moving[a, b]

		Reason for move (%)			
Distance moved (km)	**% respondents who moved**	**Personal or family**	**Housing**	**Work or education**	**Better area**
0–9	60.2	53.7	76.7	22.8	54.3
10–19	12.1	12.5	13.1	11.5	8.6
20–49	7.5	8.9	5.5	11.1	12
50–99	2.8	3.6	1.7	5.8	5.1
100–499	7.6	8.0	2.5	22.7	14.8
500+	10	13.4	0.85	26.3	5.3
Total	100	100	100	100	100

Adapted from Wilkins et al. 2009, Table 28.7 p. 143

Respondents who moved house in the 12 months prior to their 2006 interview.

[31] A statistical local area is the basic spatial unit used to collect and describe population characteristics by the Australian Bureau of Statistics. Statistical local areas are continuous, non-overlapping areas that cover the whole of Australia. They are roughly designed to align with Australian administrative and economic boundary definitions.

Table 7.2.2: Housing mobility statistics, expressed as a percentage of the Australian population[a]

Type of move[b]	1971–76	1976–81	1981–86	1986–91	1991–96	1996–2001
Did not move	63.5	59.2	58.9	59.6	56.9	57.6
Total moved	36.5	40.8	41.1	40.4	43.1	42.4
Moved same SLA	10.9	12.1	12.1	12.1	14.1	13.7
Moved another SLA same state	20.9	23.3	23.7	22.8	23.4	22.9
Moved interstate	4.6	5.3	5.3	5.5	5.2	4.8

a ABS 1976, 1981, 1986, 1991, 1996 Census unpublished data, as presented by Bell and Hugo (2000, Table 2.2, p. 23) and ABS 2001 (Table 3.1).

b SLA = statistical local area.

7.2.2 Overseas data

Using similar data from different countries, Bell and Hugo (2000) compared migration in Australia, New Zealand and the US in 1995–96 and found a remarkable consistency between countries (Table 7.2.3). The US has a lifetime mobility of 11.7 moves and 44% of that population changed address in the last 5 year inter-censual period (US Census Bureau 2000) and in Canada the rate was 43%.

Table 7.2.3: Mobility rates in selected countries

Country	Mobility rate (%) (five year)
Australia	45.3 (circa 1996)
Canada	43.3 (circa 1996)
Great Britain	N/A
New Zealand	52.0 (circa 1996)
United States	44.1 (US Census Bureau 2000 Table 1)

Information from Bell and Hugo (2000)

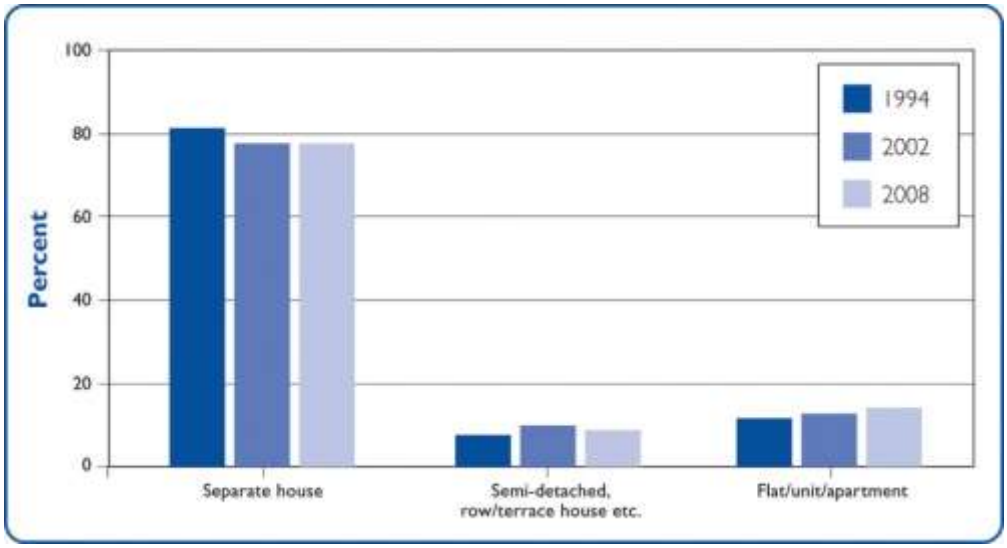
7.3 Type of residence

The data herein are provided to provide information for the sake of completeness, and are not typically required for screening risk assessments. Thus no specific recommendations are made.

7.3.1 Australian data

As part of a recent survey on energy use and conservation (ABS 2008) data were collected on dwelling type and size. The survey found that the majority of households (77%) were separate houses of which 37% had four or more bedrooms. Separate houses were more common outside of capital cities (85%) than within capital cities (73%). Of the states and territories, Tasmania had the highest proportion of separate dwellings (86%), whereas New South Wales and the Northern Territory had the highest proportion of flats or units (19%) (Figure 7.3.1, Table 7.3.1).

Figure 7.3.1: Dwelling types in Australia



Source: ABS 2008, Figure 2.1, p. 9

Table 7.3.1: Type of dwelling by Australian state/territory

Type of dwelling	NSW	Vic.	Qld	SA	WA	Tas.	NTa	ACTa	Aust
	Capital city (proportion)								
Separate house	63.3	73.9	82.7	78.8	78.4	80.5	70.3	80.5	73
Semi-detached, row/terrace house	11.8	9.8	5.9	8.4	13.2	3.8	10.5	6.6	10
Flat/unit/apartment	24.8						18.7	12.9	16.9
Other types	0.1[b]		0.1[b]	0.1[b]			0.5		0.1[b]

Type of dwelling	NSW	Vic.	Qld	SA	WA	Tas.	NTa	ACTa	Aust
	Balance of state/territory (proportion)								
Separate house	84.3	89.7	79.5	89.4	89.9	90.4			77.4
Semi-detached, row/terrace house	5.9	4.0	8.6	6.0	7.4	2.8			8.6
Flat/unit/apartment	9.8	5.8	11.8	4.6	2.1	6.8			13.9
Other types		0.4 [b]	0.1 [b]		0.6 [b]				0.1 [b]

Values are for the entire state not just for capital city.
Estimate has a relative standard error of > 50% and should be used with caution.

Data from ABS 2008, Table 2.6, p. 14

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Glossary

This glossary has been reproduced from the Guidance document for Environmental Health Risk Assessment (2011).

Term	Description
Absorbed dose	The amount of chemical that, after contact with the exchange boundary (skin, lungs, gut), actually penetrates the exchange boundary and enters the circulatory system. The amount may be the same or less than the applied dose. (See also Table Table other types of doses used in health risk assessment.)
Accuracy	The degree to which a measurement represents the true value of the variable that is being measured (NHMRC 2000); or the degree of agreement between the average predictions of a model or the average of measurements and the true value of the quantity being predicted or measured (WHO 2003).
Accepable daily intake (ADI)	The daily intake of a chemical that, during a lifetime, appears to be without appreciable risk on the basis of all the facts known at the time. It is expressed in milligrams per kilogram of body weight per day (mg/kg/day). For this purpose, 'without appreciable risk' is taken to mean that adverse effects will not result even after a lifetime of exposure. Furthermore, for a pesticide residue, the ADI is intended to give a guide to the maximum amount that can be taken daily in the food without appreciable risk to the consumer. Accordingly, the figure is derived as far as possible from feeding studies in animals. (See also 'tolerable daily intake' and 'reference dose'.)
Acceptable risk	This is a risk management term. The acceptability of risk depends on scientific data, social, economic and political factors, and the perceived benefits arising from exposure to an agent. (See also 'target risk'.)
Acute exposure	A contact between an agent and a target occurring over a short time, generally less than 14 days, with a single or repeated dose. (Other terms, such as 'short-term exposure' and 'single-dose' are also used.)
Adduct	A chemical moiety that is covalently bound to a large molecule such as DNA or protein.
Adverse effect	The change in the morphology, physiology, growth, development, reproduction or life span of an organism, system or (sub)population that results in an impairment of functional capacity, an impairment of the capacity to compensate for additional stress or an increase in susceptibility to other influences. Some adaptive changes are not generally considered to be adverse (e.g. some changes in enzyme levels).
Agent	Any chemical, physical or biological substance or factor (including social factor) being assessed in the context of an environmental health risk assessment.
Aggregate/cumulative risk	Terminology derived from US legislation. The term 'aggregate risk' in this context, implies consideration of all sources of exposure to determine a total (or aggregated) exposure estimate. The term 'cumulative' risk implies that the risk associated with substances sharing a common mode of action or toxicity outcome, are aggregated across the exposure estimates for all such substances.
Air pollution	The presence of contaminants (air pollutants) in high enough concentrations in the air that could interfere with human health or welfare, or produce other harmful environmental effects.
Ambient air	Any unconfined portion of the atmosphere; also open air or surrounding air (see also indoor air).
Applied dose	Amount of an agent presented to an absorption barrier and available for absorption. The amount may be the same or more than the absorbed dose. (See also Table Table other types of doses used in health risk assessment.)
Background level (or concentration)	The amount (or concentration) of agent in a medium (e.g. water or soil) that is not attributed to the sources(s) under investigation in an exposure assessment. Background level(s) can be naturally occurring or the result of human activities.
Benchmark dose (BMD)	The dose associated with a given incidence (the benchmark risk e.g. 1%, 5% or 10% incidence) of effect, based on the best-fitting dose–response curve.
Benchmark risk (BMR)	A predetermined incidence of adverse response that determines the benchmark dose.
Bias	A process resulting in a tendency to produce results that differ in a systematic value from the true values. Also known as systematic error.

Term	Description
Bioaccessibility	The fraction of a contaminant in an exposure medium that is soluble in the relevant physiological milieu (usually the gastrointestinal tract) and available for absorption. Generically, it is the ability for a chemical to come into contact with the absorbing surfaces in an organism. It is related to solubility and dissolution, since absorption usually can only occur from a liquid or gaseous phase and not from a solid phase.
Bioavailability	A generic term defined as the fraction of a contaminant that is absorbed into the body following dermal contact, ingestion or inhalation. It is expressed as the ratio (or percentage) of the absorbed dose (systemic dose) to the administered dose. (See also Table Table other measures of bioavailability.)
Biological monitoring	Measurement of a contaminant or metabolite in body tissue, fluid, blood or expired air.
Biomarker	Any measurement reflecting an interaction between a biological system and an environmental agent that may be chemical, physical or biological (WHO 1993). Often used to describe measurements used in biological monitoring.
Cancer or carcinogenesis	A disease of heritable, somatic mutations affecting cell growth and differentiation. That is, genetic alterations incurred in the first damaged cells are acquired in subsequent cells after cell division within the same individual. It encompasses the origin, causation and development of tumours and applies to all forms of tumours (e.g. benign and malignant).
Cancer slope factor (CSF)	The plausible upper-bound estimate of the probability of a response per unit of intake of an agent over a lifetime.
Carcinogen	Chemical, biological or physical cancer-causing agent. A distinction may be made based on the presumed mode of action (MoA) – see genotoxic and non-genotoxic carcinogen.
Carcinogenicity	A property of an agent that enables it to produce tumours, whether benign or malignant.
Causality	The relating of causes to the effects they produce. Most of epidemiology concerns causality, and several types of causes can be distinguished. However, epidemiological evidence by itself is insufficient to establish causality, although it can provide powerful circumstantial evidence.
Chronic exposure	A contact between an agent and a target occurring over a continuous or repeated basis for a duration of three months or greater. (See also ‘sub-chronic exposure’ and ‘lifetime’ exposure.)
Chronic toxicity	An adverse effect that is generally induced by prolonged exposure to a chemical. It may also include an ability to produce an adverse effect that persists over a long period of time, whether or not it occurs immediately upon exposure to a chemical or is delayed.
Chemical of potential concern (COPC)	An agent that is potentially associated with the site or exposure medium under consideration and whose data is of sufficient quality to be judged as potentially causing an adverse health effect.
Cluster	A greater that expected number of cases that occur within a group of people in a geographic area over a period of time (Queensland Health, 2009).
Cluster assessment	A scientific process to determine if there is an increased number of cases of a specific disease or condition and to determine if there is a biologically plausible causal agent/s for the disease (Queensland Health, 2009).
Community	Those individuals and/or groups residing in a locality where a site assessment is to be conducted and who may be affected by the assessment and/or possible site contamination physically (e.g. through risks to health or the environment, loss of amenity) or non-physically such as via concern about possible contamination). The term ‘wider community’ may be applied to individuals and/or groups not necessarily residing in the locality of the site assessment who may have an interest in the assessment (NEPC 2010).
Conceptual site model	A description of a site including the environmental setting, geological, hydrogeological and soil characteristics together with nature and distribution of contaminants. Potentially exposed populations and exposure pathways are identified. Presentation is usually graphical or tabular with accompanying explanatory text.
Confidence	Weight assigned by the evaluator to the quality of the information available (high, medium or low confidence) to indicate that a chemical possesses certain toxicological properties.

Term	Description
Confidence limit	A range of values determined by the degree of presumed random variability in a set of data, within which the value of a parameter (e.g. the mean) lies with a specified level of confidence or probability (e.g. 95%). The upper and lower confidence limits refer to the values at opposite ends of the specified range.
Confounding factor	A factor that distorts the apparent effect or magnitude of the effect of a study factor or risk. Confounding factors must be controlled for in order to obtain an undistorted estimate of the effect under study.
Conservatism (conservative)	A cautious approach to evaluating and managing the uncertainties inherent in a risk assessment, that reduces the probability of harm occurring.
Contaminant	Any chemical existing in the environment above background levels and representing, or potentially representing, an adverse health or environmental risk (may be synonymous with a pollutant).
Contamination	The condition of land, water or food where any chemical substance or waste has been added or detected at above background level and represents, or potentially represents, an adverse health or environmental impact (NEPC 2010).
Critical effect	The adverse effect judged to be the most important for setting an accepTable Table intake or exposure. It is usually the most sensitive adverse effect, that is, that with the lowest effect level, or sometimes a more severe effect, not necessarily having the lowest effect level.
Data quality objectives (DQOs)	The establishment of the amount, nature and quality of data required to complete a specific risk assessment.
Default value	A pragmatic, fixed or standard value used in the absence of relevant data.
Deterministic/probabilistic	A deterministic approach uses single values or point estimates as input values in an exposure or risk estimation model. These are intended to be 'best estimates' of the value of the input variables. A probabilistic approach uses frequency distributions of parameters from which input data are randomly selected for repeated calculations to generate a frequency distribution of the output (exposure or risk).
Disability-adjusted life years (DALYs)	For a given health condition, the sum of the years of life lost due to premature mortality in the population and the years lost due to disability for incident cases. It is a term used more commonly in quantitative microbiological risk assessment (QMRA) rather than in HRA for chemicals.
Dose	A stated quantity or concentration of a substance to which an organism, system or (sub)population is exposed over a continuous or intermittent duration of exposure. It is generally the total amount of a chemical administered, but there may be other expressions relating to the amounts actually absorbed or taken up (see Table Table other types of doses used in health risk assessment). Dose is most commonly expressed as the amount of test substance per unit weight of test animal (e.g. mg/kg body weight).
Dosage	A general term comprising the dose, its frequency and the duration of dosing. Dosage is properly applied to any rate or ratio involving a dose. Dosages often involve the dimension of time (e.g. mg/kg/day), but the meaning is not restricted to this relationship.
Dose–response	Relationship between the amount of chemical administered to, taken up by, or absorbed by an organism, system or (sub)population and the change developed in that organism, system or (sub)population in reaction to the agent. It is the correlative association existing between the dose administered and the response (effect) or spectrum of responses that is obtained. The concept expressed by this term is indispensable to the identification, evaluation and interpretation of most pharmacological and toxicological responses to chemicals. The basic assumptions that underlie and support the concept are: (a) the observed response is a function of the concentration at a site; (b) the concentration at a site is a function of the dose; and (c) response and dose are causally related (Eaton & Klaassen 1996). The existence of a dose–response relationship for a particular biological or toxicological response (effect) provides a defensible conclusion that the response is a result of exposure to a known substance.
Dose–response curve	Graphical representation of a dose–response relationship that is essential to any quantitative estimation of risk for a given exposure.
Endpoint	An observable or measurable biological event used as an indicator of the effect of a chemical on a biological system (cell, organism, organ etc.). It may also be expressed as a 'toxicological endpoint'.

Term	Description
Environmental health	Those aspects of human health determined by physical, chemical, biological and social factors in the environment. Environmental health practice covers the assessment, correction, control and prevention of environmental factors that can adversely affect health, as well as the enhancement of those aspects of the environment that can improve human health.
Environmental monitoring	The monitoring of the concentration of substances in the physical environment of air, water, soil and food.
Epidemiology	The study of the distribution and determinants of health-related states or events in specified populations, and the application of the study to the control of health problems.
Expert	An expert has (1) training and experience in the subject area resulting in superior knowledge in the field (2) access to relevant information, (3) an ability to process and effectively use the information, and (4) is recognised by his or her peers or those conducting the study as qualified to provide judgements about assumptions, models and model parameters at the level of detail required (NCRP 1996).
Expert/professional judgement	Opinion of an authoritative person on a particular subject.
Exposure	Concentration or amount of a particular chemical that reaches a target organism, system or (sub)population in a specific frequency for a defined duration. Exposure is usually quantified as the concentration of the agent in the medium integrated over the time duration of contact.
Exposure assessment	The estimation (qualitative or quantitative) of the magnitude, frequency, duration, route and extent (e.g. number of organisms) of exposure to one or more contaminated media for the general population, for different subgroups of the population, or for individuals.
Exposure concentration	The exposure mass divided by the contact volume or the exposure mass divided by the mass of contact volume, depending on the medium.
Exposure duration	The length of time over which continuous or intermittent contacts occur between a chemical and the exposed population.
Exposure event	The occurrence of continuous contact between chemical and exposed population.
Exposure frequency	The number of exposure events within an exposure duration.
Exposure route or pathway	The way a chemical enters an organism after contact (e.g. by ingestion, inhalation or dermal absorption). The pathway usually describes the course a chemical or physical agent takes from a source to an exposed organism. An exposure pathway describes a unique mechanism by which an individual or population is exposed to chemicals or physical agents at or originating from a site. Each exposure pathway includes a source or release from a source, an exposure point and an exposure route. If the exposure point differs from the source, a transport/exposure medium (e.g. air) or media (in cases of inter-media transfer) is also indicated.
Exposure scenario	A set of conditions or assumptions about sources, exposure pathways, concentration of contaminants involved and exposed population (i.e., numbers, characteristics, habits) used in the evaluation and quantification of exposure(s) in a given situation. The exposure scenario may be expressed in terms of a model, that is, a conceptual or mathematical representation of the exposure process.
Exposed population	The people who may be exposed to the contaminant. Synonymous with ‘receptors’.
Extrapolation	For dose–response curves, an estimate of the response at a point outside the range of the experimental data most commonly extrapolated to low dose. Also refers to the estimation of a response in different species or by different routes than that used in the experimental study of interest.
Factor	A single factor or product of several single factors used to derive an accepTable Table . These factors account for adequacy of the study, interspecies extrapolation, inter-individual variability in humans, adequacy of the overall database, nature and extent of toxicity, public health regulatory concern and scientific uncertainty. The terms safety factor (SF), uncertainty factor (UF) and modifying factor (MF) are examples of the terminology used in different jurisdictions to imply essentially the same process.
False negative	A result that is erroneously negative leading to a determination that the factor under study is not present. In statistical inference this is a Type 2 error.

Term	Description
False positive	A result that is erroneously positive leading to a determination that the factor under study is present when it is not. In statistical inference this is a Type 1 error.
Genotoxicity	A broad term describing the ability to produce damage to the genetic material (DNA) of cells or organisms.
Genotoxic chemical	A chemical for which there is adequate evidence of the potential to interact with, and/or modify the function of genetic material.
Genotoxic carcinogen	A chemical for which there is adequate evidence that the ability to induce tumours is via a mechanism involving direct damage to DNA.
Geophagy	The deliberate ingestion of soil or dirt; pica is also a term used to indicate the ingestion of dirt, but in risk assessment, the context is usually associated mainly with children.
Guideline values (GVs)	Values such as concentrations in air or water that are derived after appropriate allocation of tolerable intake (TI) among the possible different media of exposure. Combined exposure from all media at the guidance values over a lifetime would be expected to be without appreciable health risk. The aim of a guidance value is to provide quantitative information from risk assessment for risk managers to enable them to make decisions concerning the protection of human health. (WHO 1994a, p. 16).
Hazard	Inherent property of a contaminant or situation having the potential to cause adverse effects when a population may be exposed to that contaminant. It is also described as the disposition of a thing, a condition or a situation to produce an adverse health or environmental effect; or an event, sequence of events or combination of circumstances that could potentially have adverse consequences (adapted from ACDP 1996). Note the definition of risk to distinguish hazard from risk.
Hazard identification	The identification of the type and nature of adverse effects that a contaminant has an inherent capacity to cause harm to an exposed population.
Hazard indices/index (HI)	The sum(s) of at least two hazard quotients.
Hazard quotient (HQ)	The ratio of the mean daily intake to the reference dose or tolerable daily intake for threshold exposure.
Health	Health is a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity (WHO 1946).
Health investigation levels (HILs)	Screening criteria based on health risk, presented in schedule B(7) of the contaminated sites NEPM. May also be called health screening levels (HSLs) to emphasise the fact that they represent an outcome of a Tier 1-type screening level risk assessment, and may require a more refined Tier 2–3 level process to better define the risk.
Health risk assessment (HRA)	The process of estimating the potential impact of a chemical, biological, physical or social agent on a specified human population system under a specific set of conditions and for a certain timeframe. May also be described as a process intended to calculate or estimate the risk to a given target organism, system or (sub)population, including the identification of attendant uncertainties following exposure to a particular contaminant, taking into account the inherent characteristics of the agent of concern as well as the characteristics of the specific target system.
Heuristics	A psychological term used to describe the process whereby people frame their perceptions of risk, based on ‘rules of thumb’ and other emotional (affective) factors by which we make judgements about everyday occurrences.
Hormesis	Demonstrated beneficial effects of an agent at low (but not homeopathic) doses but with toxicity occurring at higher doses. Also used to describe ‘hockey-stick’ or other J-shaped non-monotonic dose–response relationships where biological effects may appear to become greater as the dose decreases.
Immunotoxicity	The ability to produce an adverse effect on the functioning of organs and cells involved in immune competence (IEH 1999b).
In vitro / in silico	Describes tests undertaken in test tubes, culture dishes or other systems where a non-living organism is exposed to a test agent. In silico techniques refer to modern genomic methodologies where genes or DNA arrays on microchips are the responsive agents.

Term	Description
Integrated Risk Information System (IRIS)	The computerised database of the US EPA that provides the agency's adopted hazard and dose–response assessment for chemical and radiological agents. Used as guidance and to provide consistency in the agency's regulatory decisions designed to reduce risk related to environmental exposures.
LD50	The quantity of a chemical compound that, when applied directly to test organisms via inhalation, oral or dermal exposure, is estimated to be fatal to 50% of those organisms under the stated conditions of the test.
Lowest observed effect level (LOEL)	The lowest concentration or amount of a substance found by experiment or observation that causes alterations of morphology, functional capacity, growth, development or life span of target organisms. WHO (1990) define it as the lowest dose of a substance that causes changes distinguishable from those observed in normal (control) animals.
Lowest observed adverse effect level (LOAEL)	The lowest concentration or amount of a substance found by experiment or observation that causes adverse alterations of morphology, functional capacity, growth, development or life span of target organisms.
Level of detection (LOD)	The minimum concentration or mass of analyte that can be detected at a known confidence level.
Level (limit) of reporting (LOR)	The value calculated from the instrumentation detection limits and with appropriate scale-up factors applied. The scale-up factors are affected by the procedures, methods and the size of the sample.
Lifestyle factors	Behaviours or habits that are a matter of individual choice and that may impinge in the outcomes of a risk assessment. Examples include smoking, poor diet and alcohol intake.
Lifetime	A figure used in exposure assessment and risk characterisation representing the average life span of an organism. Seventy years has been conventionally used for humans, but newer demographic data suggests that human life spans are expanding.
Metabolite	A substance that is the product of biochemical alteration of the parent compound in an organism.
Mode of action (MoA)	A description of observable key events or processes from interaction of an agent with a cell or tissue through operational and anatomical changes to the disease state (EPA 2005).
Model	A mathematical representation of a biological system intended to mimic the behaviour of the real system, allowing description about empirical data and predictions about untested states of the system.
Mutagenicity	The ability to produce a permanent, heriTable Table in the amount or structure of genetic material of cells or organisms (IEH 1999b) (see also, genotoxicity).
National Environment Protection Measure (NEPM)	National guidance on assessment and management of environmental pollution, established under the National Environment Protection Act. NEPMs are broad framework-setting statutory instruments defined in the NEPC Act. They outline agreed national objectives for protecting or managing particular aspects of the environment. Establishment, maintenance and review of NEPMs is the responsibility of the Environment Protection and Heritage Council (EPHC), which incorporates the National Environment Protection Council (NEPC), a statutory body under the NEPC Acts of the Commonwealth, the states and the territories. The EPHC addresses broad national policy issues relating to environmental protection, particularly in regard to air, water and waste matters.
Neurotoxicity	The ability to produce an adverse effect in the central or peripheral nervous system (IEH 1999b).
No observed adverse effect level (NOAEL)	The highest concentration or amount of a substance, found by experiment or observation, that causes no observable alterations of morphology, functional capacity, growth, development or life span of target organisms. The NOAEL is the next dose below the LOAEL in the series of doses tested in a study, where no toxic (i.e. adverse) effects are observed. It may also be worded in more detail thus: The NOAEL is defined as the highest exposure at which there is no statistically or biologically significant increase in the frequency of an adverse effect when compared with a control group (National Academy of Sciences, National Research Council 1994). The definition of NOEL is equivalent, but with the removal of the term, 'adverse'. Often, the difficult issue in the use of the terms NOEL or NOAEL is in deciding whether a compound-related effect noted in a particular study is necessarily an 'adverse' effect. Alterations of morphology, functional capacity, growth, development or life span of the target organism may be detected, which are judged not to be adverse.

Term	Description
No observed effect level (NOEL)	The 'highest dose of a substance administered to a group of experimental animals at which there is an absence of observable effects on morphology, functional capacity, growth, development or life span that are observed or measured at higher dose levels used in the study. Thus, dosing animals at the NOEL should not produce any biologically significant differences between the group of chemically exposed animals and an unexposed control group of animals maintained under identical conditions. The NOEL is expressed in milligrams of chemical per kilogram of body weight per day (mg/kg bw/day) or, in a feeding study, in ppm in food (converted to mg/kg bw of compound intake by measured or estimated food intake over the period of the study). The NOEL has been simply defined as the highest dose of a substance that causes no changes distinguishable from those observed in normal (control) animals (WHO 1990).
Non-genotoxic carcinogen	An agent that induces tumours via a mechanism that does not involve direct damage to genetic material (DNA) sometimes referred to as epigenetic.
Physiologically based pharmacokinetic (PBPK) model	Modelling the dose or degree of exposure to a chemical at a target tissue, cell or receptor by integration of pharmacokinetic data with anatomical, physiological and biochemical data (IEH 1999b).
Particulate matter (PM10, PM2.5)	The fraction of particles passing an inlet with a 50% cut-off efficiency at an aerodynamic diameter of 10 µm (PM10) or 2.5 µm (PM2.5). May also be referred to as ultrafine particulate matter.
Pica	A behaviour exhibited occasionally by young children characterised by the deliberate ingestion of non-nutritive substances, such as soil.
Point of departure (POD)	A point on a dose–response curve that is defined by the available data and close to the range of observed data points, from which extrapolation techniques (e.g. linearised extrapolation and / or application of safety/uncertainty factors) are used to estimate a toxicity reference value.
Provisional tolerable weekly intake (PTWI)	The tolerable intake of a chemical expressed as a weekly amount. The term was established by WHO (1972) for several heavy metals which 'are able to accumulate within the body at a rate and to an extent determined by the level of intake and by the chemical form of the heavy metal present in food' (WHO 1989).
Public health	The science and art of preventing disease, prolonging life and promoting health through the organised efforts of society.
REACH program	The **R**egistration, **E**valuation, **A**uthorisation and Restriction of **Ch**emical substances program (REACH), established in 2006 as a new European Community program for regulating chemicals and their safe use.
Read across	An extrapolation technique that may be applied when information on the toxicological properties of a substance is missing or incomplete. It relies on extrapolating from the toxicological profile of a known, and related, substance to the substance under consideration.
Reproductive toxicity	The ability to produce an adverse effect on any aspect of reproductive capacity, function or outcome. It includes effects on the embryo, fetus, neonate and prepubertal organism and on adult reproductive and neuroendocrine systems (IEH 1999b).
Reference dose (RfD)	An estimate (with uncertainty factors spanning perhaps an order of magnitude) of the daily exposure (mg/kg/day) to the general human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime of exposure. It is derived from the NOAEL or the LOAEL by application of uncertainty factors that reflect various types of data used to estimate RfD and an additional modifying factor, which is based on professional judgement of the entire database of the chemical (IRIS 1996). The RfD is equivalent in meaning to tolerable daily intake (TDI) and accepTable Table intake (ADI). Usually doses less than the RfD are not likely to be associated with adverse health risks, and are therefore less likely to be of regulatory concern. As the frequency and/or magnitude of the exposures exceeding the RfD increase, the probability of adverse effects in a human population increases. However, all doses below the RfD are not assumed to be 'acceptable' (or risk-free) and nor are all doses that exceed the RfD necessarily 'unacceptable' (i.e. likely to result in adverse effects) (US EPA). The term acute reference dose (ARfD) is used to designate a level of exposure (using the same types of uncertainty and other qualifiers) that is likely to be without an appreciable risk or deleterious effect after a single dose or short period of exposure.

Term	Description
Risk	The probability that, in a certain timeframe, an adverse outcome will occur in a person, group of people, plants, animals and/or the ecology of a specified area that is exposed to a particular dose or concentration of a hazardous agent, that is, it depends on both the intrinsic toxicity of the agent and the level of exposure. Risk differs from hazard primarily because risk considers probability.
Risk characterisation	The qualitative and, wherever possible, quantitative determination, including attendant uncertainties, of the probability of occurrence of known and potential adverse effects of an agent in a given organism, system or (sub)population under defined exposure conditions.
Risk communication	An interactive two-way process involving the exchange among individuals, groups and institutions of information and expert opinion about the nature, severity and acceptability of risks and the decisions taken to combat them. It usually involves an interactive exchange of information about health and environmental risks among risk assessors, managers, news media, interested groups and the general public (see also 'stakeholders').
Risk management	The process of evaluating alternative actions, selecting options and implementing them in response to risk assessments. The decision making will incorporate scientific, technological, social, economic and political information. The process requires value judgements (e.g. on the tolerability and reasonableness of costs).
Safety	Practical certainty that adverse effects will not result from exposure to an agent under defined circumstances. It is the reciprocal of risk. Safety does not demand zero risk and would be a meaningless term if it did.
Safety factor (SF)	See 'factor'. Composite (reductive) factor by which an observed or estimated no observed adverse effect level (NOAEL) is divided to arrive at a criterion or standard that is considered safe or without appreciable risk.
Sensitive groups:	Refers to populations with both susceptibility and vulnerability factors (see 'susceptibility' and 'vulnerability').
Sensitivity analysis	The process of changing one variable while leaving the others constant and determining the effect on the output. The procedure commonly involves fixing each uncertain quantity, one at a time, at its credible lower-bound and then its upper bound (holding all other at their medians), and then computing the outcomes for each combination of values (USEPA 1992). It can be used to test the effects of both uncertainty and variability in input values.
Skin irritancy	A local inflammatory reaction affecting the skin.
Stakeholder	One who has an interest in a project or who may be affected by it.
Stochastic	A random probabilistic phenomenon.
Structure–activity relationship (SAR)	The relationship between the biological activity of a chemical or series of chemicals and their molecular structure. The relationships can be described qualitatively and quantitatively.
Sub-chronic exposure	A contact between an agent and a target of intermediate duration between acute and chronic. Different bodies vary on their definitions of the duration of 'sub-chronic' exposure, since it varies with species. US EPA uses up to 10% of an organism's lifetime; however, between three and six months is often used when discussing sub-chronic exposure to people (see also 'chronic exposure').
Susceptibility	Refers to intrinsic biological factors that can increase the health risk of an individual at a given exposure level; examples of susceptibility factors include – genetic factors; late-age and early-life; and prior or existing disease.
Teratogenicity	The ability to produce a structural malformation or defect in an embryo or fetus (IEH 1999b).
Threshold	The lowest dose or exposure level that will produce a toxic effect and below which no toxicity is observed (IEH 1999b). A non-threshold dose–response relationship implies that the response incidence is only zero at zero exposure, and that a finite level of risk may be determined (using extrapolation methodology) at any exposure level above zero. Linear extrapolation typically refers to extrapolation to the zero exposure or zero effect origin of a dose-response curve.
Tolerable intake (TI)	An estimate of the intake of a substance that over a lifetime is without appreciable health risk (WHO 1994a). Examples are the ADI, TDI and reference dose.

Term	Description
Tolerable daily intake (TDI)	An estimate of the daily intake of a substance that can occur over a lifetime without appreciable health risk. It may have different units depending on the route of administration (WHO 1994a). The term 'accepTable Table intake' is used for chemicals such as pesticides (herbicides, insecticides and antifungals) that are deliberately used on food crops or food-producing animals and for which some level of residues may be expected to occur in food. The term 'tolerable daily intake' is used when the chemical is a potential food or environmental contaminant. While exposure should not occur, a TDI is an established health limit below which lifetime exposure should not have any adverse health effects. (See also 'accepTable Table intake' and 'reference dose'.)
Tolerable weekly (monthly) intake (TWI/TMI)	The TI expressed as a weekly or monthly amount.
Toxicity	Inherent property of a chemical to cause an adverse biological effect.
Toxicity equivalence (TEQ)	A method of expressing the combined (assumed additive) toxicity of a group of like chemicals that share a common mode of action. The TEQ is based on summing exposure estimates for individual components of a mixture multiplied by an estimate of their toxic potency (toxicity equivalence factor – TEF) relative to a reference substance. An alternative US terminology for the TEF is relative potency factor (RPF).
Toxicity reference value (TRV)	Measures of tolerable intake or accepTable Table such as reference doses and cancer slope factors.
Tumour	A mass of abnormal, disorganised cells arising from pre-existing tissue that is characterised by excessive and uncoordinated cell proliferation or growth and by abnormal differentiation (specialisation). There are two types of tumours: benign and malignant. Benign tumours morphologically resemble their tissue of origin, grow slowly (may also stop growing) and form encapsulated masses; they do not infiltrate other tissues, they do not metastasise and are rarely fatal unless they cause physical disruption of a critical body function (e.g. a brain tumour). Malignant tumours (also called carcinomas) resemble their parent tissue less closely and are composed of increasingly abnormal cells genetically, morphologically and functionally. Most grow rapidly, spread progressively through adjacent tissues and metastasise to distant tissues.
Tumour initiation	The first step in carcinogenesis whereby a small number of cells (or one cell) are irreversibly changed due to genetic damage.
Tumour progression	The stage in carcinogenesis when tumours acquire the features of malignant growth.
Tumour promotion	The process by which initiated cells undergo clonal expansion (reproduction of a genetically damaged cell) to form overt tumours.
Uncertainty	Lack or incompleteness of information or knowledge about toxicological profile of a substance or the correct value to be input in to a risk assessment, such as a specific exposure measure or estimate.
Uncertainty factor	See 'factor': A numerical factor applied to the no-observed-adverse-effect level (NOAEL) to derive an exposure level considered to be without appreciable risk to health (the NOAEL is divided by the uncertainty factor). The magnitude of the uncertainty factor depends on the nature of the toxicity observed, the quality of the toxicological data available, and whether the effects were observed in humans or animals (IEH 1999b).
Unit risk factor (URF)	An expression of the incremental risk associated with increase in exposure by a single unit of exposure measure. It may also be expressed as the plausible upper bound estimate of the probability of a response from a chemical over a lifetime. It is derived from the slope of the linearised dose–response relationship and usually expressed in units of concentration for a specified medium (e.g. incremental risk per $\mu g/m^3$ in air).
Variability	True differences in attributes or values due to diversity or heterogeneity. This may include measurable factors that differ (e.g. height is variable across populations). The major types of variability are temporal, spatial and inter-individual. They may be discrete (e.g. albinism) or continuous (e.g. body weight). It may be readily identifiable (e.g. presence of albinism) or difficult to identify (e.g. ability to detoxify a particular chemical metabolite).
Vulnerability	Refers to human populations at higher risk due to environmental factors; examples of vulnerability factors include poverty, malnutrition, poor sanitation, climate change and stress associated with mental health diseases.

Term	Description
Weight of evidence (WoE)	Considerations in assessing the interpretation of published information about toxicity, quality of testing methods, size and power of study design, consistency of results across studies, and biological plausibility of exposure–response relationships and statistical associations.

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