Technical Appendix C

Derivation of Model Exposure Parameters

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1 Introduction

This appendix provides information on the data and methods used to derive subpopulation exposure parameters for use in the Indicators model. Three human exposure parameters (an inhalation rate, fish ingestion rate, and drinking water ingestion rate) and body weight are currently used in the RSEI model to generate sex-specific exposure factors for four age groups (ages #17, 18-44, 45-64, 65+). Earlier versions of the model used standard assumptions to represent intake for all individuals within the general population. However, because there are population-specific intake differences and because some populations may be more susceptible to certain chemicals than others, subpopulation intake and census data have been included in the model to estimate a more accurate surrogate dose.

2 Exposure Parameters

The most recent *Exposure Factors Handbook* (EPA, 2011) is the primary source of information used to generate exposure parameters for both inhalation and drinking water ingestion. Fish consumption data was obtained directly from EPA's Office of Water (EPA, 20002, based on an analysis of the 1994-1996 USDA Continuing Survey of Food Intake in Individuals (CSFII).

The exposure parameters were generated in such a way as to ensure as much consistency as possible among pathways, while basing the estimates on values recommended in the *Exposure Factors Handbook* (EPA, 2011), when available. The parameters generally reflect those recommended in EPA (2011), however, some estimates are derived from data in EPA (2011) that were not explicitly included in their summarized recommendations.

The exposure factors in EPA (2011) are available for a large number of discrete age groups, particularly for children. The RSEI age groups are generally broader than those in EPA (2011). To match the RSEI age groups, we calculate an average of exposure factors for all ages within the RSEI age group. The equation C-1 is shown below. Intake rates are then adjusted by body weight estimates from EPA (2011), when necessary. The sections below provide further detail on the calculation of pathway-specific exposure parameters.

Equation C-1:

$$\text{RSEI Exposure Factors} = \frac{\sum_i (IR_i \times n_i)}{N}$$

where:

IR is the intake rate for age group *i*,
n is the number of years in age group *i*, and
N is the total number of years in the RSEI model age group for all age groups *i* that fall within the RSEI age group.

2.1 Body Weights

EPA (2011) provides updated estimates of mean body weight for boys and girls, for small increments up to one year, one-year age increments from one year up to 19 years of age and for several adult age groups. Generally, these estimates are higher than those provided in the previous EFH version.

Sex-specific body weights were averaged across the range of each RSEI age group and are presented in Table C-1.

Table C-1. Body Weights for Each RSEI Age Group from EPA (2011)

Model Age Group	Body Weight (kg)	
	Male	Female
0-17	38.4	36.5
18-44	85.8	73.2
45-64	89.7	77.2
65+	81.5	69.3

Source: EPA (2011), Tables 8-4 and 8-5, pp. 8-13 and 8-1.4

2.2 Inhalation

EPA (2011) recommended new studies as the basis for inhalation rates for both adults and children. For adults, EPA based their inhalation rates on three recent studies: Brochu et al. (2006a, as cited in EPA 2011), Stifelman et al. (2007, as cited in EPA 2011), and EPA (2009, as cited in EPA 2011). Additionally, for children EPA based their suggested inhalation rates on Arcus-Arth and Blaisdell (2007, as cited in EPA 2011). Data from these four studies were combined, where appropriate. If the data were combined from multiple studies, they was averaged by sex and grouped according to the age groups selected for use in the *Exposure Factors Handbook*. If age groups in the original reference did not match the EPA groupings in the Handbook, statistics were averaged from all age groupings in the original reference that overlapped with EPA's age groupings by more than one year, weighted by the number of observations contributed from each age group. EPA's final inhalation rate estimates are presented in Table C-2 along with the reference(s) used to derive them.

Table C-2. Inhalation Rates Recommended by EPA (2011)

Age	Mean (m^3/day)	Reference
0 - <0.083 year (1 month)	3.6	1
0.083 - 0.25 year	3.5	2,3
0.25 - < 0.5 year	4.1	2,3
0.5 - <1 year	5.4	2,3
1 - <2 years	5.4	1,2,3,4
2 - <3 years	8.9	1,2,3,4
3 - <6 years	10.1	1,2,3,4
6 - <11 years	12	1,2,3,4
11 - <16 years	15.2	1,2,3,4
16 - <21 years	16.3	1,2,3,4
21 - <31 years	15.7	2,3,4
31 - <41 years	16	2,3,4
41 - <51 years	16	2,3,4
51 - <61 years	15.7	2,3,4
61 - <71 years	14.2	2,3,4
71 - <81 years	12.9	2.4
≥81 years	12.2	2,4

[1] Arcus-Arth and Blaisdell 2007 (as cited in EPA 2011)
[2] Brochu et al. 2006a (as cited in EPA 2011)
[3] EPA 2009 (as cited in EPA 2011)
[4] Stifelman 2007 (as cited in EPA 2011)
Source: Table 6-1, page 6-3 (incorrectly labeled 6-1) in EPA (2011)

The inhalation rates and body weights recommended by EPA (2011) were adjusted for the RSEI age groups using the weighted average approach explained in the previous section. Table C-2 below shows the adjusted inhalation rates. Male and female rates are the same because EPA (2011) only presented combined rates for both sexes.

Table C-3. Inhalation Rates, Based on EPA (2011), Adjusted for RSEI Age-Sex Groups

	Mean Inhalation Rate (m^3/day)	
Age	**Male**	**Female**
0-17 years	12.1	12.1
18-44 years	15.9	15.9
45-64 years	15.5	15.5
65+ years	12.9	12.9

Source: Calculated from EPA (2011)

For adults and children, the age and sex-specific inhalation values were adjusted by body weight using estimates recommended by EPA and presented in the previous section. The final inhalation exposure factors used in the model are given in Table C-4.

Table C-4. Inhalation Exposure Factors Used in RSEI

	Exposure Factor (m^3/kg-day)	
Age	**Male**	**Female**
0-17 years	0.315	0.332
18-44 years	0.185	0.217
45-64 years	0.173	0.201
65+ years	0.159	0.187

2.3 Drinking Water Ingestion

EPA recommended three recent studies for children and adult mean tap water intake: Kahn and Stralka (2008a, as cited in EPA 2011) and Kahn (2008, as cited in EPA 2011) for children <3 years of age, and EPA's 2010 analysis of NHANES data from 2003–2006 for individuals ≥3 years of age. These new values are summarized in Table C-5 below.

Table C-5. EPA (2011) Recommended Tap Water Intake Estimates

Age range	Mean	
	Tap water intake (ml/day)	**Tap water intake per kg of body weight (ml/kg-day)**
0 to <1 month	184	52
1 to <3 months	227	48
3 to <6 months	362	52

Age range	Mean	
	Tap water intake (ml/day)	Tap water intake per kg of body weight (ml/kg-day)
6 months to <1 year	360	41
1 to <2 years	271	23
2 to <3 years	317	23
3 to <6 years	327	18
6 to <11 years	414	14
11 to <16 years	520	10
16 to <18 years	573	9
18 to <21 years	681	9
≥21 years	1,043	13
≥65 years	1,046	14

Source: These values are the per capita intake values from Table 3-1, page 3-3 in EPA (2011).

The EPA 2010 NHANES analysis does not present tap water intake estimates for age categories that correspond with or can be weighted to match the RSEI categories for adults; they only present data for adults ≥21 and ≥65.

Even though EPA recommends new standard body weights in EPA (2011), they were not used to calculate the per-kilogram intake rates from the suggested studies. The body weights from the original studies were instead used to calculate these intake rates. Table C-6 shows a comparison of the body weights used in Kahn and Stralka (2008a), Kahn (2008) and the NHANES study to calculate the EFs presented in **Error! Reference source not found.** alongside the new body weight recommendations provided in the *Exposure Factors Handbook.* Although Kahn (2008) presents mean body weights in their paper, dividing the per person ml/day mean intake by the weights provided in the paper presented does not result in the ml/kg-day mean estimate presented in the Handbook due to issues with rounding. Additionally the *Exposure Factors Handbook* does not present the body weights EPA used in coming up with the drinking water intake rates for individuals > 3 years old. Therefore, Abt back-calculated the body weights they used to generate the mean intake rates given in *Exposure Factors Handbook* and presented it to one decimal place following EPA (2011). We used the formula:

$$\frac{I_D}{I_{BW}} = W$$

Where:

W = Weight [kg]

I_D = Intake per day $\left[\frac{\text{ml}}{\text{day}}\right]$

I_{BW} = Intake per body weight per day $\left[\frac{\text{ml}}{\text{kg}-\text{day}}\right]$

Table C-6. Body Weights Used to Determine the Suggested ml/kg-day Intake Rates Based on Primary Study and Presented by EPA (2011).

Age	Recommended Values for Drinking Water Ingestion Rates[1]		Body Weights used in EPA's recommended sources[2]	Standard Body Weights Presented in the Exposure Factors Handbook (2011)[3]		
	Mean (mL/day) [a]	Mean (mL/kg-day) [b]	Mean (kg) [c] = [a/b]	Mean	Male	Female
0 to <1 month	184	52	3.5	4.8	4.9	4.6
1 to <3 months	227	48	4.7	5.9	6.0	5.7
3 to <6 months	362	52	7.0	7.4	7.6	7.2
6 months to <1 year	360	41	8.8	9.2	9.4	9.0
1 to <2 years	271	23	11.8	11.4	11.6	11.1
2 to <3 years	317	23	13.8	13.8	14.1	13.5
3 to <6 years	327	18	18.2	18.6	18.8	18.3
6 to <11 years	414	14	29.6	31.8	31.9	31.7
11 to <16 years	520	10	52.0	56.8	57.6	55.9
16 to <21 years	627[4]	9[4]	69.7[4]	71.6	77.3	65.9
21 to <30 years				78.4	84.9	71.9
30 to <40 years				80.8	87.0	74.8
40 to <50 years				83.6	90.5	77.1
50 to <60 years				83.4	89.5	77.5
60 to <70 years				82.6	89.1	76.8
70 to <80 years				76.4	83.9	70.8
80+ years				68.5	76.1	64.1
21-65 years	1043	13	80.2	81.8[5]	88.1[5]	75.5[5]
>65 years	1046	14	74.7	75.4[5]	81.5[5]	69.3[5]

[1] From EPA (2011), Table 3-1, p. 3-3
[2] Based on Abt calculations
[3] From EPA (2011), Table 8-3, 8-4, 8-5 pp. 8-12, 8-13, 8-14
[4] The age ranges used in the calculation of exposure factors is 16 to <18 and 18 to <21. Therefore body weights were calculated for both of these age ranges and then averaged to compare to the 16 to <21 age range presented by EPA (2011).
These values were calculated as a weighted average of body weights.

Table C-6 demonstrates that the body weights used in the studies differ from the EPA (2011) recommended body weights depending on the age and sex of the individual. Table C-7 presents the exposure factors calculated using the study-specific body weights as well as factors calculated using the body weights currently recommended in EPA (2011) and presented in section 2.1.

Table C-7. Exposure Factors Calculated with EPA (2011) Suggested Body Weights and Study-Specific Body Weights

Age	Male		Female	
	EF using EPA (2011) body weights	**EF using study-specific body weights**	**EF using EPA (2011) body weights**	**EF using study-specific body weights**
0-17 years	0.0111	0.0158	0.0117	0.0158
18-44 years	0.0117	0.0124	0.0137	0.0124
45-64 years	0.0117	0.0130	0.0135	0.0130
65+ years	0.0128	0.0140	0.0151	0.0140

2.4 Fish Consumption

Data on fish consumption (g/day) by age group and gender were obtained directly from EPA's Office of Water (EPA, 2002). The data is based on the 1994-1996 USDA Continuing Survey of Food Intake by Individuals (CSFII). Data on freshwater/estuarine fish consumption was available for three broad age groups: 14 and younger, 15-44 years old, and 45 and older. To estimate exposure parameters for recreational consumers, the 90th percentile of intake was used, while for subsistence consumers, the 99th percentile was chosen. Table C-8 shows the consumption values for recreational and subsistence consumers.

Table C-8. Fish Consumption Intake Data, CSFII 94-96[1]

Age	Sex	Fish Consumption1 (g/day)	
		Recreational	**Subsistence**
<15	Male	0.00	79.03
	Female	0.00	58.83
15-44	Male	15.63	151.19
	Female	6.31	109.79
45+	Male	32.47	165.92
	Female	17.65	108.80

[1] Fish consumption data comes from EPA (2002, Section 5.1.1.1, Table 1, p. 5-3). Data is based on the 1994-96 USDA Continuing Survey of Food Intakes by Individuals (CSFII). The 90th percentile is used to represent recreational consumers and 99th percentile is used to represent subsistence consumers.

To estimate fish ingestion values for the RSEI age groups, average intake rates were calculated using Equation C-1. For example, in order to calculate fish ingestion rates for the RSEI #17 year old age group, the intake rate for <15 year olds is multiplied by 15 and the intake rate for 15-44 year olds is multiplied by 3. These products are then summed and divided by the total number of years in the RSEI age group, 18. The fish ingestion intakes and body weights for each of the

model age groups are presented in Table C-9. The corresponding fish ingestion exposure factors used in the RSEI model are shown in Table C-10.

Table C-9. Fish Ingestion Values and Body Weights for Each RSEI Age Group from EPA (2002) and EPA (2011)

Model Age Group	Recreational Fish Ingestion (g/day)[1]		Subsistence Fish Ingestion (g/day)[1]	
	Male	Female	Male	Female
0-17	2.61	1.05	91.1	67.3
18-44	15.6	6.31	151	110
45-64	32.5	17.7	166	109
65+	32.5	17.7	166	109

[1] See text for discussion of method used to calculate ingestion values.

Table C-10. Fish Ingestion Exposure Factors Used in RSEI Model

	Recreational (g/kg-day)[1]		Subsistence (g/kg-day)[1]	
Model Age Group	Male	Female	Male	Female
0-17	0.0756	0.0372	2.83	2.05
18-44	0.199	0.114	1.92	1.71
45-64	0.407	0.262	2.08	1.60
∃65	0.434	0.267	2.22	1.63

[1] Fish ingestion exposure factors are converted to kg/kg-day for the surrogate dose calculation in the RSEI model.

3 References

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