Technical Appendix C

Derivation of Model Exposure Parameters

Table of Contents

1 Introduction

This technical appendix provides information on the data and methods used to derive subpopulation exposure parameters for use in the RSEI model. Three human exposure parameters (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 0-–17, 18-44, 45-64, and 65 and older). 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 U.S. 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, hereafter denoted as EFH) is the primary source of information[1] used to generate exposure parameters for both inhalation and drinking water ingestion. Fish consumption data were obtained directly from EPA's Office of Water (EPA, 2002), based on an analysis of the 1994-1996 U.S. Department of Agriculture (USDA) Continuing Survey of Food Intake by 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 EFH when available. The parameters generally reflect those recommended in the EFH, however, some estimates were derived from data that were not explicitly included in their summarized recommendations.

The exposure factors in the EFH are available for a large number of discrete age groups, particularly for children. The RSEI age groups are generally broader than those in the EFH. To match the RSEI age groups, a weighted average of EFH exposure factors for all ages within the RSEI age group was calculated using Equation C-1 shown below. Intake rates are then adjusted by body weight estimates from the EFH, when necessary. The sections below provide further detail on the calculation of pathway-specific exposure parameters.

Equation C-1:

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

[1] The latest edition of the *Exposure Factors Handbook* was released in 2011, but since October 2017, EPA has begun to release chapter updates individually. See https://www.epa.gov/expobox/about-exposure-factors-handbook for more information.

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

The EFH 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

The EFH 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 were averaged by sex and grouped according to the age groups selected for use in the EFH. If age groups in the original reference did not match the EPA groupings in the EFH, 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 the EFH were adjusted for the RSEI age groups using the weighted average approach explained in the previous section. Table C-3 below shows the adjusted inhalation rates. Male and female rates are the same because the EFH 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

In the February 2019 update to Chapter 3 of the EFH, EPA's recommended values are taken from the Agency's own analysis of 2005-2010 National Health and Nutrition Examination Survey (NHANES) data. These values are summarized in Table C-5 below.

Table C-5. EPA (2019) 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	42
1 to <3 months	145	25
3 to <6 months	187	27

Age range	Mean	
	Tap water intake (mL/day)	Tap water intake per kg of body weight (mL/kg-day)
6 months to <1 year	269	30
1 to <2 years	146	13
2 to <3 years	205	15
3 to <6 years	208	11
6 to <11 years	294	10
11 to <16 years	315	6
16 to <21 years	436	6
21 to <30 years	781	10
30 to <40 years	902	11
40 to <50 years	880	11
50 to <60 years	956	12
60 to <70 years	941	12
70 to <80 years	772	10
80+	784	11
21 to <50 years	858	11
50+ years	902	11
All ages	711	11

Source: These values are the per capita intake values from Table 3-1, page 3-3 in EPA (2019).

To convert these drinking water intake rates into exposure factors to fit the RSEI model they need to be grouped according to the age categories used in RSEI. As mentioned previously, RSEI's exposure factors are split into the 4 age categories (0-17, 18-44, 45-64, and 65 and older) and for this exposure pathway, will be in units of L/kg-day. To derive proper units, mL/kg-day estimates were first converted to L/kg-day for each age group. Then, to match the RSEI age groups, a weighted average of exposure factors for all ages within the RSEI age group was calculated using the following equation:

Equation C-2:

$$EF = \frac{\sum(IR_i \times n_i)}{N}$$

where:

EF= the exposure factor in L/kg-day

IR = the intake rate for age group i (L/kg-day)

n = the number of years in age group i

N = the total number of years in the RSEI model age group for all age groups i that fall within the RSEI age group.

The final drinking water ingestion rates used in the model are shown below in Table C-6.

Table C-6. EPA (2019) Recommended Tap Water Intake Estimates

Model Age Group	Exposure Factors (Male)	Exposure Factors (Female)
	(L/kg-day)	
0-17	0.0101	0.0101
18-44	0.0099	0.0099
45-64	0.0117	0.0117
>65	0.0108	0.0108

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 were available for three broad age groups: 14 years old 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-7 shows the consumption values for recreational and subsistence consumers.

Table C-7. Fish Consumption Intake Data, CSFII 94-96[1]

Age	Sex	Fish Consumption[1] (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 are 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 0-17 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-8. The corresponding fish ingestion exposure factors used in the RSEI model are shown in Table C-9.

Table C-8. 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-9. 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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