4.0 EXPOSURE ASSESSMENT

The goal of the exposure assessment for the HHRA is to determine the total daily exposure (or dose) of a contaminant (mg of contaminant per kg of body weight per day). Conceptual diagrams were used to determine which exposure pathways needed to be assessed for each of the human health receptor scenarios: landfill employee (adult) and local resident (adult and child).

Mathematical exposure equations provided in the POPs Toolkit (http://www.popstoolkit.com/riskassessment/eco.aspx) were used to complete the Exposure Assessment calculations (Figure 4.1).

Figure 4.1 Equations used in the Exposure Assessment.

Accidental Soil Ingestion Dose Calculation (hide)

$$Dose_{SoilIngestion} = \frac{(C_S \times IR_S \times AF_{GIT} \times D_{Hours} \times D_{Days} \times D_{Weeks} \times D_{Years})}{BW \times 16 \times 365 \times LE} =$$

C_S =		mg/kg	Concentration of contaminant in soils, usually 90th percentile or maximum.
IR_S =		kg/day	Accidental soil ingestion rate for adult (see Table: Receptor Characteristics)
AF_{GIT} =		(unitless)	Absorption Factor for the gastrointestinal tract. **Use a value of 1** for a preliminary risk assessment (as recommended by Health Canada, 2004)
D_{Hours} =		# of hours	Hours per-day with exposure (0 - 16) *(16 is the maximum assumed awake hours per day)*
D_{Days} =		# of days in a week	Days in a week with exposure (0 - 7)
D_{Weeks} =		# of weeks in a year	Weeks in a year with exposure (0 - 52)
D_{Years} =	N/A	years	Number of years of exposure (not used for non-carcinogens)
BW =		kg	Body Weight of Receptor (see Table: Receptor Characteristics)
LE =	N/A	years	Life expectancy. The number of year that the person is likely to live. Not used for non-carcinogens.

Food Ingestion Dose Calculation (hide)

$$Dose_{FoodIngestion} = \frac{(C_{food} \times IR_{food} \times AF_{GIT} \times D_{Days} \times D_{Years})}{BW \times 365 \times LE} =$$

C_{food} =		mg/kg	Concentration of contaminant in soils, usually 90th percentile or maximum.
IR_{food} =		kg/day	Food ingestion rate (see Table: Receptor Characteristics)
AF_{GIT} =		(unitless)	Absorption Factor for the gastrointestinal tract. **Use a value of 1 for a preliminary risk assessment** (as recommended by Health Canada, 2004)
D_{Days} =		# of days in a year food item is ingested	Number of days in a year food from the site is ingested (0 - 365)
D_{Years} =	N/A	years	Number of years of exposure (not used for non-carcinogens)
BW =		kg	Body Weight of Receptor (see Table: Receptor Characteristics)
LE =	N/A	years	Life expectancy. The number of year that the person is likely to live. Not used for non-carcinogens.

Inhalation of contaminated particles Dose Calculation (hide)

$$Dose_{ParticleInhalation} = \frac{(C_S \times P_{Air} \times IR_A \times AF_{Inh} \times D_{Hours} \times D_{Days} \times D_{Weeks} \times D_{Years})}{BW \times 365 \times LE \times 10e^{-9}} =$$

C_S =		mg/kg	Concentration of contaminant in soils, usually 90th percentile or maximum.
P_{Air} =		µg/m^3	Concentration of particles in the air. **Use 0.76µg/m^3** for typical conditions as per USEPA (1992)
IR_A =		m^3/hour	Inhalation rate (see Table: Receptor Characteristics)
AF_{Inh} =		(unitless)	Absorption Factor for the lungs. **Use a value of 1** for a preliminary risk assessment (as recommended by Health Canada, 2004)
D_{Hours} =		# of hours in a day	Hours of a day with exposure (0 - 24)
D_{Days} =		# of days in a week	Days in a week with exposure (0 - 7)
D_{Weeks} =		# of weeks in a year	Weeks in a year with exposure (0 - 52)
D_{Years} =	N/A	years	Number of years of exposure (not used for non-carcinogens)
BW =		kg	Body Weight of Receptor (see Table: Receptor Characteristics)
LE =	N/A	years	Life expectancy. The number of year that the person is likely to live. Not used for non-carcinogens.

Dermal contact with contaminated soil Dose Calculation (hide)

$$Dose_{DermalContact} = \frac{(C_S \times SA_H \times SL_H \times AF_{Skin} \times EF \times D_{Days} \times D_{Weeks} \times D_{Years})}{BW \times 365 \times LE} =$$

C_S =		mg/kg	Concentration of contaminant in soils, usually 90th percentile or maximum.
SA_H =		cm^2	Surface area of hands (assumes only hands are exposed, see Table: Receptor Characteristics)
SL_H =		kg/cm^2 - event	Soil loading to exposed skin (see Table: Receptor Characteristics). For a given area of skin, hands will be exposed to a greater mass of contaminated soil than skin on other parts of the body. Health Canada (2004) give hands a 10x greater loading (SLH) than other skin covered portions of the body.
AF_{Skin} =		(unitless)	Absorption Factor for the skin (see Table: Relative Dermal Absorption Factors)
EF =		events/day	number of dermal exposures per day
D_{Days} =		# of days in a week	Days in a week with exposure (0 - 7)
D_{Weeks} =		# of weeks in a year	Weeks in a year with exposure (0 - 52)
D_{Years} =	N/A	years	Number of years of exposure (not used for non-carcinogens)
BW =		kg	Body Weight of Receptor (see Table: Receptor Characteristics)
LE =	N/A	years	Life expectancy. The number of year that the person is likely to live. Not used for non-carcinogens.

4.1 IDENTIFICATION OF DATA FOR EXPOSURE MODELLING

The Exposure Assessment model required concentration data for soil and food items. For POPs chemicals, the absorption of contaminants from water was not assessed, because the concentration in water will generally be extremely low (due to low solubility and greater affinity to sequester into sediment); potential for dermal exposure as a major pathway is therefore reduced.

The maximum concentrations measured in each exposure scenario data grouping (i.e., on-site soils, near-field off-site soils, sediments and tissues) were used in the exposure model (Table 4.2) to provide a reasonable worst-case exposure estimate given the limited number of samples available. If the data set were larger, for instance more than 10 quantified measurements in each data grouping, it may be appropriate to use a less conservative estimate of exposure (i.e., the 90th percentile concentration or a 95% upper confidence limit of the mean).

As discussed in methods section (section 2.6.2), a sub-set of the samples assessed using CALUX analysis were re-assessed using HR-GCMS. The results of the CALUX (section 3.1, Appendix A2) and the HR-GCMS analysis (Table 4.2) were both considered for selecting model input concentrations. Consistent with the conservative approach adopted for screening level risk assessments, the higher of the CALUX or HR-GCMS results was adopted for the risk assessment calculations (Table 4.3).

Dioxin/furan and DL-PCB concentrations were added together before running the exposure model. The reason for doing this was as follows:

- Because PCDD/Fs and DL-PCBs are expressed in terms of 2,3,7,8 TCDD toxic equivalence, the concentrations can be added together; and
- By adding the PCDD/Fs and DL-PCBs together, the risk assessment provides a more conservative estimate of risk from similar acting contaminants.

Table 4.1 Contaminant concentration data needs for each exposure scenario.

	Landfill Employee	Local Residents	Aquatic Animal	Terrestrial Animal
Soil or Dust				
On-site Surface Soils	Yes			Yes
Near Field Off-site Soils	Yes	Yes		Yes
Sediments				
			Yes	
Tissue				
	Yes	Yes		Yes

Table 4.2 HR-GCMS analysis results for PCDD/F[2].

Soils or Sediments	Location	PCDDs/Fs - TEQs (TEQs, WHO 2005) pg TEQ/g HR-GCMS ND=0	PCDDs/Fs - TEQs (TEQs, WHO 2005) pg TEQ/g HR-GCMS ND=1/2DL	PCDD/Fs + DL-PCB (TEQs, WHO 2005) pg TEQ/g HR-GCMS ND=0	PCDD/Fs + DL-PCB (TEQs, WHO 2005) pg TEQ/g HR-GCMS ND=1/2DL	Total PCDDs/Fs pg/g HR-GCMS	Total PCBs pg/g HR-GCMS
08MAL009B	From treatment pond	14.2	14.2	15.18	16.58	NM	372,000
08MAL010B	Residential area south of entrance	0.342	0.368	0.342	0.378	NM	NM

"ND" indicates that the concentration was below the method detection limit

"NM" indicates that the parameter was not assessed

"TEQ" is toxic equivalence quotient

Table 4.3 Contaminant concentrations designated for the exposure model.

Laboratory	Hiyoshi	Axys	ALS Technichem
Units	**pg TEQ/g[1]**	**µg/kg[2]**	**µg/kg[3]**
On-site Soils (including sludge collected from the edges of the leachate treatment pond)			
PCB	2.83	372	-
PCDD/F	13.3	-	-
PCB + PCDD/F	16.1	-	-
Off-site Soils			
PCB	<DL	-	-
PCDD/F	0.63	-	-
PCB + PCDD/F	0.63	-	-
Fish Tissue Data			
PCB	-	-	<5,000[4]
PCDD/F	-	-	-
PCB + PCDD/F	-	-	

[1] Concentrations from CALUX analysis, Hiyoshi, Japan.

[2] Concentrations from HR-GCMS analysis, Axys Analytical, Canada.

[3] Concentration from low resolution GCMS analysis, ALS Technichem, Malaysia.

[4] Concentration in the fish tissue sample were below the method detection limit for PCBs. A value of ½ the diction limit will be used in the model (i.e., 2,500 µg/kg).

[2] Reference to the WHO 1998 and 2005 update can be found at: http://www.who.int/ipcs/assessment/tef_update/en/

4.2 INPUT TABLE

Once the exposure concentrations have been selected, the next step is to assemble a model input table (Table 4.4). This table provides all the variables required to run the exposure component of the risk assessment model. The principles are described in further detail in Health Canada's *Guidance on Preliminary Human Health Quantitative Risk Assessment* (2004) and the reader should refer to this documentation for additional insight. If possible, country-specific variables should be put into the table. However, where country-specific values do not exist, values can be extracted from a default table provided in the model. It should be understood; however, that the default values were intended for a Canadian population.

For the AHSL site, input variables consist of a mixture of default variables and site-specific variables derived in consultation with Malaysian team members during meetings held in December 2008 in Putrajaya. Additional refinement may be necessary. The rationale for the selection of each model input variable is briefly discussed in Appendix A4.

Table 4.4 Exposure model input table, AHSL site, Malaysia.

Total PCBs
TDI = 0.001 mg/kg-day (HC 2004)

Location		Landfill Employee Adult	Local Resident Adult	Local Resident Child
Accidental Soil Ingestion				
C_S	(mg/kg)	0.372	0.372	0.372
IR_S	kg/day	0.00002	0.00002	0.00002
AF_{GIT}	(no units)	1	1	1
D_{hours}	(hours/day)	16	16	16
D_{days}	(days/week)	7	7	7
D_{weeks}	(weeks/year)	48	52	52
D_{years}	(years)	-	-	-
BW	(kg)	69.3	69.3	32.2
LE	(years)	-	-	-
Food Ingestion				
C_{Food}	(mg/kg)	2.5	2.5	2.5
IR_{Food}	(kg/day)	0.11	0.11	0.09
AF_{GIT}	(no units)	1	1	1
D_{days}	(days/year)	24	24	24
D_{years}	(years)	-	-	-
BW	(kg)	69.3	69.3	32.2
LE	(years)	-	-	-
Inhalation of Contaminated Particles				
C_S	(mg/kg)	0.372	0.372	0.372
P_{AIR}	(ug/m3)	0.76	0.76	0.76
IR_A	(m3/day)	0.66	0.66	0.60
AF_{Inh}	(no units)	1	1	1
D_{hours}	(hours/day)	24	24	24
D_{days}	(days/week)	7	7	7
D_{weeks}[3]	(weeks/year)	26.4	28.6	28.6
D_{years}	(years)	-	-	-
BW	(kg)	69.3	69.3	32.2
LE	(years)	-	-	-
Dermal Contact with Contaminated Soil				
C_S	(mg/kg)	0.372	0.372	0.372
S_{AW}	(cm2)	800	800	400
SL_H	(kg/cm2-event)	0.0000001	0.0000001	1E-07
AF_{Skin}[2]	(no units)	0.14	0.14	0.14
EF	(events/day)	1	1	1
D_{days}	(days/week)	7	7	7
D_{weeks}	(weeks/year)	48	52	52
D_{years}	(years)	-	-	-
BW	(kg)	69.3	69.3	32.2
LE	(years)	-	-	-

PCDD/F + PCB TEQS
TDI = 2.0 x 10^{-9} mg/kg day (HC 200
SF = 130,000 (kg day)/mg (USEPA

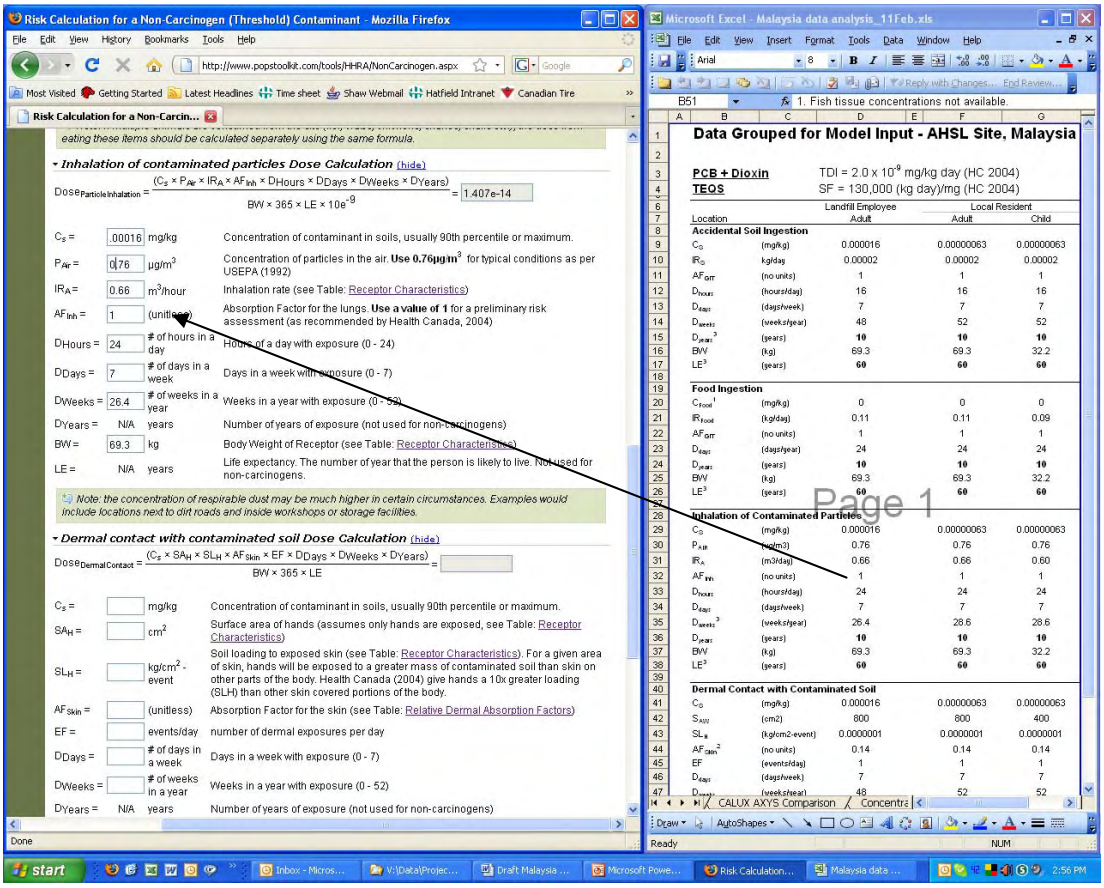
Location		Landfill Employee Adult	Local Resident Adult	Local Resident Child
Accidental Soil Ingestion				
C_S	(mg/kg)	0.000016	6.3E-07	6.3E-07
IR_S	kg/day	0.00002	0.00002	0.00002
AF_{GIT}	(no units)	1	1	1
D_{hours}	(hours/day)	16	16	16
D_{days}	(days/week)	7	7	7
D_{weeks}	(weeks/year)	48	52	52
D_{years}[3]	(years)	**10**	**10**	**10**
BW	(kg)	69.3	69.3	32.2
LE[3]	(years)	**60**	**60**	**60**
Food Ingestion				
C_{Food}[1]	(mg/kg)	0	0	0
IR_{Food}	(kg/day)	0.11	0.11	0.09
AF_{GIT}	(no units)	1	1	1
D_{days}	(days/year)	24	24	24
D_{years}	(years)	**10**	**10**	**10**
BW	(kg)	69.3	69.3	32.2
LE[3]	(years)	**60**	**60**	**60**
Inhalation of Contaminated Particles				
C_S	(mg/kg)	0.000016	6.3E-07	6.3E-07
P_{AIR}	(ug/m3)	0.76	0.76	0.76
IR_A	(m3/day)	0.66	0.66	0.60
AF_{Inh}	(no units)	1	1	1
D_{hours}	(hours/day)	24	24	24
D_{days}	(days/week)	7	7	7
D_{weeks}[3]	(weeks/year)	26.4	28.6	28.6
D_{years}	(years)	**10**	**10**	**10**
BW	(kg)	69.3	69.3	32.2
LE[3]	(years)	**60**	**60**	**60**
Dermal Contact with Contaminated Soil				
C_S	(mg/kg)	0.000016	6.3E-07	6.3E-07
S_{AW}	(cm2)	800	800	400
SL_H	(kg/cm2-event)	0.0000001	0.0000001	0.0000001
AF_{Skin}[2]	(no units)	0.14	0.14	0.14
EF	(events/day)	1	1	1
D_{days}	(days/week)	7	7	7
D_{weeks}	(weeks/year)	48	52	52
D_{years}[4]	(years)	**10**	**10**	**10**
BW	(kg)	69.3	69.3	32.2
LE[4]	(years)	**60**	**60**	**60**

1. Fish tissue concentrations not available.
2. AF_{skin} for PCBs =14% (Mayes et al., 2002).
3. D_{weeks} for inhalation pathway is multiplied by the proportion of days without precipitation for the area = 0.55.
4. Additional variables required for running carcinogen (non-threshold) model (shown as Bold).

4.3 VARIABLE ENTRY INTO MODEL

The variables provided in the data table were used to populate the risk assessment model (Figure 4.2). The figure shows the toolkit model and the pop-up window providing default values for many of the required variables. On the right hand side of the figure is an Excel window showing the data input table.

Figure 4.2 Screenshot – data entry into the Exposure Assessment component of the Risk Assessment tool.



As the input table is filled in, exposure doses are calculated automatically. Once all the required variables are put into the model, the calculated doses for all potential exposure routes are presented at the bottom of the window. According to this risk calculation model simulation, exposure via the diet from eating contaminated fish may contribute the greatest exposure of PCB + Dioxin/Furan TEQs, followed by dermal contact with contaminated soil (Table 5.1). The results are based on a non-quantified measurement of PCBs, i.e., an elevated method detection limit in the fish tissue samples. Therefore, the exposure concentration was taken to be 0.5 of the detection limit. While this is a common approach when dealing with non-detect able concentrations, the contribution of PCB via fish is not fully resolved and may warrant re-sampling and detailed analysis using high-resolution instrumentation.