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 models were used to determine which exposure pathways needed to be assessed for each of the human health receptor scenarios: SEDCW site employee (adult), people living in the EDC dormitory (adult and child), and local residents (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 NEEDS

The Exposure Assessment model required concentration data for soil and food items. For PCBs and dioxins/furans, 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 via water 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 4.1) 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 20 quantified measurements in each data grouping, it may be appropriate to use a less conservative estimate of worst-case averaged 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, expressed as pg TEQ/g, were added together before running the exposure model. The reason for doing this was as follows:

- Dioxin/furans and DL-PCBs are likely from the same source (Johnson et al., 2008), and therefore their exposure is coincident;
- Because dioxins/furans 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 dioxins/furans 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.

	Workshop Employee	Students in Dormitory	Local Residents	Aquatic Animal	Terrestrial Animal
Soil or Dust					
Warehouse Dust	Yes				
On-site Surface Soils	Yes	Yes			Yes
Near Field Off-site Soils			Yes		Yes
Sediments					
				Yes	
Tissue					
	Yes	Yes	Yes		
Oil					
	Yes				

Table 4.2 HR-GCMS analysis results for PCBs and PCDD/F.

		PCDDs/Fs - TEQs (TEQs, WHO 2005)		DL-PCBs (TEQs, WHO 2005)		Total PCDDs/Fs	Total PCBs
		pg TEQ/g		pg TEQ/g		pg/g	pg/g
Soils or Dust[1]		ND=0	ND=1/2DL	ND=0	ND=1/2DL		
08CAM010B Near-field Off-site Soils	Soil, dust off entrance road	NM	NM	0.163	0.168	NM	476
08CAM021B Warehouse	Inside floor sweeping	NM	NM	8.95	9.39	NM	NM
08CAM022B On-site Soils	Soil, oil stained	5	5	6.74	9.02	509.9	2380000
Fish Tissue Data[2]							
08CAM029B	Crab tissue	0.207	0.243	0.015	0.0404	1.84	2020

"NM" indicates that the parameter was not assessed

"TEQ" is toxic equivalence quotient

[1] Concentration was based on dry weight of soil.

[2] Concentration was based on wet weight of tissue.

4.2 INPUT TABLE

Once the exposure concentrations have been selected, the next step is to assemble a model input Table 4.3. 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. The default values were intended for a Canadian population and therefore may have to be modified to suit a South East Asian perspective.

For the SEDCW site, input variables consist of a mixture of default variables and site-specific variables derived in consultation with Cambodian team members during meetings held in December 2008 in Vientiane. Additional refinement may be necessary.

Table 4.3 Exposure model input table*, SEDCW site, Cambodia.

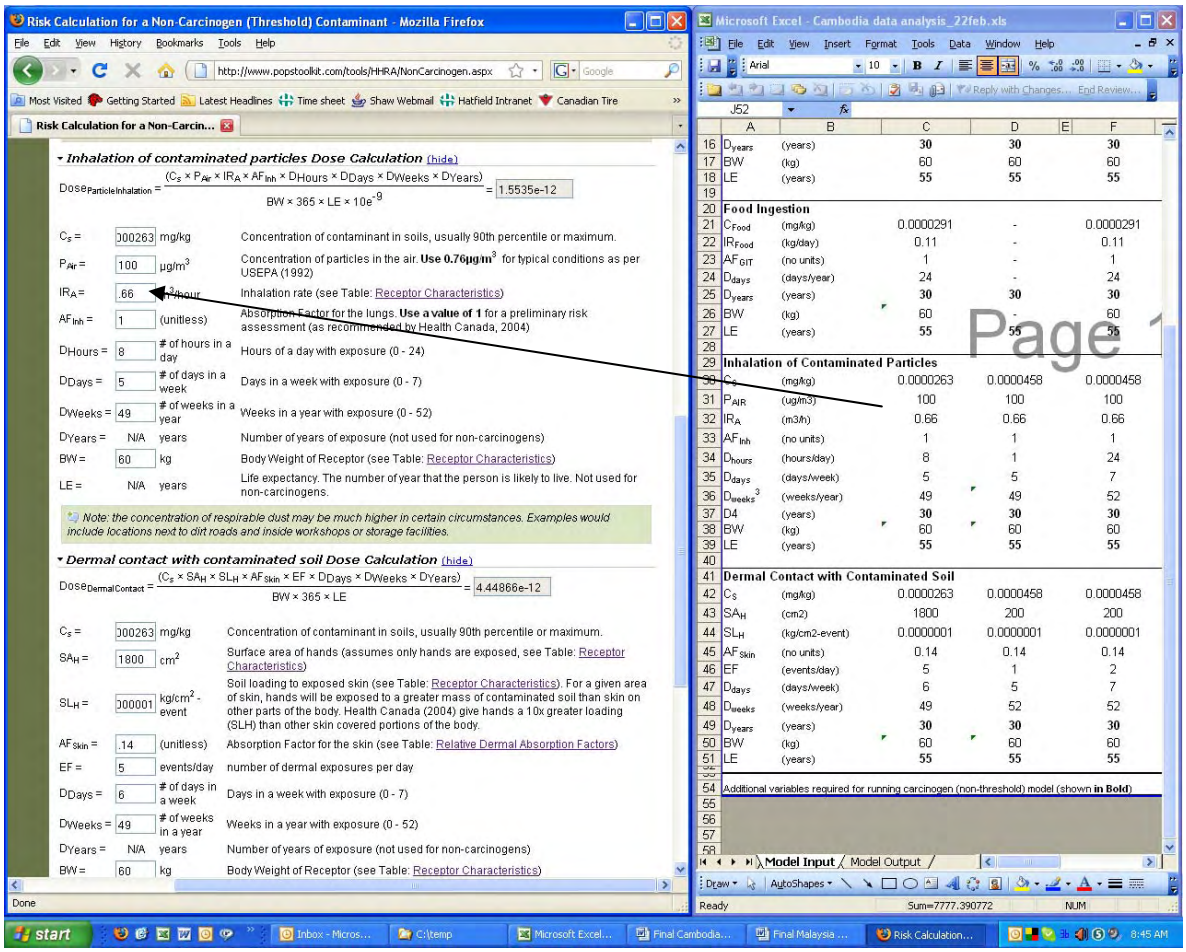
Location		Warehouse Employee		Resident of Dormatory		Local Resident	
		Adult		Adult	Child	Adult	Child
		Warehouse	SEDCW outside	Home	Home	Home	Home
Accidental Soil Ingestion							
C_S	(mg/kg)	0.0000263	0.0000458	0.0000458	0.0000458	0.00000254	0.00000254
IR_S	kg/day	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002
AF_{GIT}	(no units)	1	1	1	1	1	1
D_{hours}	(hours/day)	8	1	16	16	16	16
D_{days}	(days/week)	5	5	7	7	7	7
D_{weeks}	(weeks/year)	49	49	52	52	52	52
D_{years}	(years)	**30**	**30**	**30**	**30**	**30**	**30**
BW	(kg)	60	60	60	32.9	60	32.9
LE	(years)	**55**	**55**	**55**	**55**	**55**	**55**
Food Ingestion							
C_{Food}	(mg/kg)	0.0000291	-	0.0000291	0.0000291	0.0000291	0.0000291
IR_{Food}	(kg/day)	0.11	-	0.11	0.09	0.11	0.09
AF_{GIT}	(no units)	1	-	1	1	1	1
D_{days}	(days/year)	24	-	24	24	24	24
D_{years}	(years)	**30**	**30**	**30**	**30**	**30**	**30**
BW	(kg)	60	-	60	32.9	60	32.9
LE	(years)	**55**	**55**	**55**	**55**	**55**	**55**
Inhalation of Contaminated Particles							
C_S	(mg/kg)	0.0000263	0.0000458	0.0000458	0.0000458	0.00000254	0.00000254
P_{AIR}	(ug/m3)	100	100	100	100	100	100
IR_A	(m3/h)	0.66	0.66	0.66	0.6	0.66	0.6
AF_{Inh}	(no units)	1	1	1	1	1	1
D_{hours}	(hours/day)	8	1	24	24	24	24
D_{days}	(days/week)	5	5	7	7	7	7
D_{weeks}^3	(weeks/year)	49	49	52	52	52	52
D4	(years)	**30**	**30**	**30**	**30**	**30**	**30**
BW	(kg)	60	60	60	32.9	60	32.9
LE	(years)	**55**	**55**	**55**	**55**	**55**	**55**
Dermal Contact with Contaminated Soil							
C_S	(mg/kg)	0.0000263	0.0000458	0.0000458	0.0000458	0.00000254	0.00000254
SA_H	(cm2)	1800	200	200	100	200	100
SL_H	(kg/cm2-event)	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
AF_{Skin}	(no units)	0.14	0.14	0.14	0.14	0.14	0.14
EF	(events/day)	5	1	2	1	2	1
D_{days}	(days/week)	5	5	7	7	7	7
D_{weeks}	(weeks/year)	49	49	52	52	52	52
D_{years}	(years)	**30**	**30**	**30**	**30**	**30**	**30**
BW	(kg)	60	60	60	32.9	60	32.9
LE	(years)	**55**	**55**	**55**	**55**	**55**	**55**

* The results were presented and used by the Cambodian participants and Hatfield Project Team for the Risk Assessment exercise during the POPs toolkit review in MOE in December 2009 and at the National Training Workshop in Siem Reap from 19-21 January 2009.

4.3 VARIABLE ENTRY INTO MODELING

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 model simulation, exposure via the diet from eating contaminated fish/crabs as well as dermal contact with contaminated oil/soils contributes the greatest exposure of PCB + Dioxin/Furan TEQs.

Note that a SEDCW employee has two potential exposure scenarios which collectively compose the total SEDCW PCB and dioxins/furans exposure: (1) inside the warehouse buildings; and (2) exposures to soil outside, but within the SEDCW site. The estimated daily dose from both exposure scenarios must be added together to get the total daily dose of a warehouse worker.