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: SPL 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} =		$\mu g/m^3$	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 MODELING

The Exposure Assessment model required concentration data for soil and food items. For PCBs, the absorption of contaminants from water was not assessed, because the concentration in water will generally be low compared to other pathways (due to low solubility and greater affinity to sequester into sediment); potential for ingestion and dermal exposure via water contact 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. The maximum concentration was used, as it provided a reasonable worst-case exposure estimate for a small amount of data available. If the data set were larger, for instance more than 20 quantified measurements in each data grouping, then 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	Employee Families	Local Residents	School Children	Aquatic Animal	Terrestrial Animal
Soil or Dust						
Workshop Soil/Oils	Yes	Yes				
On-site Surface Soils	Yes					Yes
Near Field Off-site Soils			Yes	Yes		Yes
Soil/Ash at Employee Homes	Yes	Yes				
Sediments						
					Yes	
Tissue						
	Yes	Yes	Yes			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
1. Soils or Dust	**Location**	ND=0	ND=1/2DL	ND=0	ND=1/2DL		
08Lao010	On site soil/sediment (dry drainage ditch)	NM	NM	65.2	73	NM	NM
08Lao016	Soil/ash (workers house)	0.0991	0.253	0.607	0.615	11.54	3660
08Lao032	Inside workshop from beams	NM	NM	10.6	19	NM	NM
2. Fish Tissue Data							
08Lao029	Fish eggs	0.142	0.202	5.64	6.58	3.06	649000

"NM" indicates that the parameter was not assessed

"TEQ" is 2,3,7,8 TCDD toxic equivalence

Table 4.3 Contaminant concentrations to be used in the exposure model.

Contaminant Of Potential Concern	pg TEQ/g (WHO 2005)
Workshop Soils[1]	
PCB	65.88
Dioxin/Furans	252.84
PCB + Dioxin/Furans	318.72
Workshop Oils[2]	
PCB + Dioxin/Furans	31,800
On-site Soils[1]	
PCB	71.97
Dioxin/Furans	24.56
PCB + Dioxin/Furans	96.53
Off-site Soils[1]	
PCB	1.45
Dioxin/Furans	9.87
PCB + Dioxin/Furans	11.32
Soil/Ash at Employee Homes[1]	
PCB	16.52
Dioxin/Furans	24.36
PCB + Dioxin/Furans	40.88
Sediments[1]	
PCB	10.40
Dioxin/Furans	14.37
PCB + Dioxin/Furans	24.77
Fish Tissue Data[3]	
PCB	6.58
Dioxin/Furans	0.202
PCB + Dioxin/Furans	6.78

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

[2] Estimated concentration, based on workshop soils concentration, see appendix A4 for more detail.

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

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* (2004a) 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 SPL site, input variables consist of a mixture of default variables and site-specific variables derived in consultation with Laotian team members during meetings held in December 2008 in Vientiane. Additional refinement may be possible.

Dermal exposure was divided into exposures to soil and exposures to contaminated oil. It was assumed that exposures to contaminated oil only occurred in the workshop, and in worker's homes during cooking. Because the concentration in oil was not measured, an estimate was made by assuming that contaminated oil would have a concentration 100 times greater than the highest workshop soil concentration (Appendix A4). It was also assumed that only 10% of the oil handled would contain high concentrations of PCBs. Other input variables were modified to address differences between dermal uptake of PCBs from soil and oils, these are discussed in Appendix A4.

Table 4.4 Exposure model input table, SPL site, Laos PDR.

Location		Workshop Employee			Employee Family		Local Resident		School Children
		Adult			Adult	Child	Adult	Child	Child
		Workshop	EDL outside	Home	Home	Home	Home	Home	School
Accidental Soil Ingestion									
C_S	(mg/kg)	0.000318	0.0000965	0.0000409	0.0000409	0.0000409	0.00001132	0.00001132	0.00001132
IR_S	kg/day	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002
AF_{GIT}	(no units)	1	1	1	1	1	1	1	1
D_{hours}	(hours/day)	8	1	9.57	16	16	16	16	9
D_{days}	(days/week)	5	5	7	7	7	7	7	5
D_{weeks}	(weeks/year)	49	49	52	52	52	52	52	40
D_{years}	(years)	**13**	**13**	**13**	**13**	**13**	**13**	**13**	**13**
BW	(kg)	60	60	60	60	32.9	60	32.9	32.9
LE	(years)	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**
Food Ingestion									
C_{food} [1]	(mg/kg)	0.0000067	0.0000067	0.0000067	0.0000067	0.0000067	0.0000067	0.0000067	0.0000067
IR_{Food}	(kg/day)	0.11	-	-	0.11	0.09	0.11	0.09	0.09
AF_{GIT}	(no units)	1	-	-	1	1	1	1	1
D_{days}	(days/year)	24	-	-	24	24	24	24	0
D_{years}	(years)	**13**	**13**	**13**	**13**	**13**	**13**	**13**	**13**
BW	(kg)	60	60	60	60	32.9	60	32.9	32.9
LE	(years)	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**
Inhalation of Contaminated Particles									
C_S	(mg/kg)	0.000318	0.0000965	0.0000409	0.0000409	0.0000409	0.00001132	0.00001132	0.00001132
P_{AIR}	(ug/m3)	300	100	100	100	100	100	100	100
IR_A	(m3/h)	0.66	0.66	0.66	0.66	0.6	0.66	0.6	0.6
AF_{Inh}	(no units)	1	1	1	1	1	1	1	1
D_{hours}	(hours/day)	8	1	17.6	24	24	24	24	9
D_{days}	(days/week)	5	5	7	7	7	7	7	5
D_{weeks} [3]	(weeks/year)	49	49	52	52	52	52	52	40
D4	(years)	**13**	**13**	**13**	**13**	**13**	**13**	**13**	**13**
BW	(kg)	60	60	60	60	32.9	60	32.9	32.9
LE	(years)	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**
Dermal Contact with Contaminated Soil									
C_S [2]	(mg/kg)	0.000318	0.0000965	0.0000409	0.0000409	0.0000409	0.00001132	0.00001132	0.00001132
S_{AH}	(cm2)	890	890	890	890	590	890	590	590
SL_H	(kg/cm2-event)	0.0000001	0.0000001	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	0.14	0.14
EF	(events/day)	1	1	1	1	1	1	1	1
D_{days}	(days/week)	5	5	7	7	7	7	7	5
D_{weeks}	(weeks/year)	49	49	52	52	52	52	52	40
D_{years}	(years)	**13**	**13**	**13**	**13**	**13**	**13**	**13**	**13**
BW	(kg)	60	60	60	60	32.9	60	32.9	32.9
LE	(years)	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**
Dermal Contact with Contaminated Oil									
C_{Oil}	(mg/kg)	0.0318		0.0318	0.0318				
S_{AH}	(cm2)	3390		890	890				
SL_H	(kg/cm2-event)	0.0000009		0.0000009	0.0000009				
AF_{Skin}	(no units)	0.5		0.5	0.5				
EF	(events/day)	0.1		0.1	0.1				
D_{days}	(days/week)	5		7	7				
D_{weeks}	(weeks/year)	49		52	52				
D_{years}	(years)	**13**		**13**	**13**				
BW	(kg)	60		60	60				
LE	(years)	**60**		**60**	**60**				

Additional variables required for running carcinogen (non-threshold) model (shown as Bold)

[1] Fish tissue (eggs) were only measured using high res analysis

Concentrations represent TCDD/F TEQs + PCB TEQs for WHO2005, MD=1/2DL.

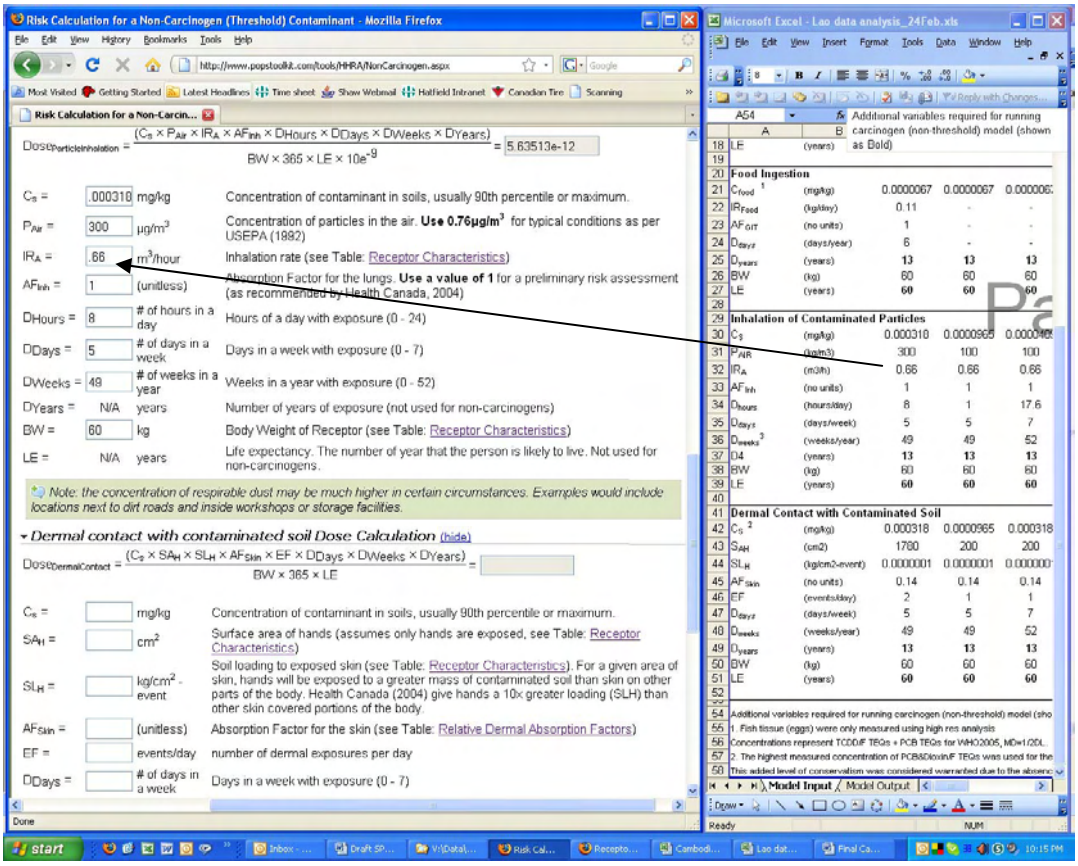
[2] The highest measured concentration of PCB&Dioxin/F TEQs was used for the dermal exposure for worker at home and adult family member.

This added level of conservatism was considered warranted due to the absence of an oil-to-skin exposure scenario.

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 model simulation, exposure via dermal contact with contaminated oil contributed the greatest exposure of PCB + Dioxin/Furan TEQs, followed by dietary exposure form eating contaminated fish.

An SPL workshop employee has three potential exposure scenarios which collectively compose total SPL-related PCB exposure: (1) inside the workshop; (2) exposures to soil within the SPL compound; and, (3) exposure to oil and soil at home (related to bringing contaminated oil home to start cooking fires). The estimated daily dose from each of these three exposure scenarios must be added together to get the total daily dose of a workshop worker.