3.0 PROBLEM FORMULATION

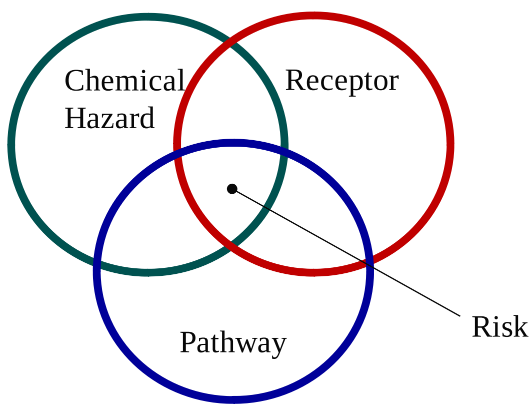
The problem formulation is the first step of a risk assessment it is essentially a *qualitative assessment* of potential risk.

3.1 PURPOSE OF A PROBLEM FORMULATION

The purpose of the Problem Formulation is to: (1) qualitatively assess whether a human health or ecological risks may be present; and, (2) to provide a framework for the subsequent risk assessment.

For risks to be present, a contaminated site must have three components:

- Chemical Hazard – one or more chemical contaminants at concentrations capable of causing human health or ecological impacts;
- Receptors – humans, animals or plants at the site; and
- Pathway – a way for chemical contaminants to reach the receptors.



The problem formulation must determine if each of these three components is present at the site. In the following sections, each of the three components is individually qualitatively assessed.

- Identification of Chemical Hazard;
- Identification of Receptor; and
- Identification of Pathway.

Once each of the three components is identified, a series of Conceptual Exposure Models is created to summarize the scenarios to be assessed in the subsequent (quantitative) portions of the risk assessment.

3.2 IDENTIFICATION OF CHEMICAL HAZARD

This risk assessment document only addresses potential chemical hazards posed by POPs. Other chemical hazards may exist at the site, but are not addressed in this report.

3.2.1 Characteristics of POPs

The following physical chemical properties are common to all POPs:

- Persistent: POPs persist in the environment for months and even decades because they are not-reactive and are resistant to degradation;
- Lipophilic: POPs are not very soluble in water, but are readily soluble in fats (lipids) or oils;
- Bioaccumulative: POPs can accumulate in living tissues at levels higher than those in the surrounding environment; and
- Potential for long range transport: Although in general POPs do not easily evaporate, especially those with more chlorine atoms, POPs evaporation does occur, and can account for significant amounts of POPs transport.

3.2.2 Screening Contaminant Concentrations Against Guidelines

To determine if a chemical is present at potentially hazardous concentrations, site chemical data were screened (i.e., compared) against environmental quality guidelines. For the purposes of this risk assessment, the USEPA Risk Based Concentration (RBCs; USEPA 2008a) were chosen because they are relatively complete, covering a large number of potential chemical contaminants. In addition, by using a single guideline source, readers of the risk assessments will be able to compare results of each of the four participating countries (Lao PDR, Cambodia, Thailand and Malaysia).

The steps followed were:

- On-site concentration data were first summarized by calculating the mean, 90th percentile and maximum potential concentration;
- Summary statistics were then compared to the environmental quality guidelines (USEPA 2008). The ratio of summary statistics to the guidelines yielded an exceedance factor; and
- Exceedance factors greater than one identify a chemical as a potential hazard, and therefore a contaminant of potential concern (CCME, 2008b).

Because contamination of the site is related to the storage and repair of electrical equipment, it is unlikely that POPs, other than PCBs and dioxins/furans are present. Therefore, PCBs and dioxins/furans concentrations were analyzed in all environmental samples, while chlorinated pesticides were analyzed in a single fish tissue sample. Fish tissue was chosen for the chlorinated pesticide analysis because it had the greatest likelihood of having elevated concentrations of POPs, given their high potential to bioaccumulate.

For screening purposes, only samples collected within a site's boundaries are usually considered. In many cases, off-site samples (i.e., waterways) can be contaminated by other sources of pollution. There are really no other obvious sources of PCBs within a square km of the SPL site. However, dioxins/furans may also be associated with backyard burning and chlorinated pesticides may have been stored or used in local residences or used in adjacent rice fields.

Some of the samples originally identified as sediments were grouped with the soil samples for screening purposes. These were samples collected from surface water drainage channels, and which were dry at the time of sample collection. As these "sediments" will likely be dry for much of the year, there can be direct human contact with them and consequently they can be considered soils, as well as sediments.

In total, 18 samples were considered for screening against soil guidelines and two samples were considered for screening against sediment guidelines.

Due to the limited number of samples available for screening, the maximum concentrations in each of the soils and sediment categories were actually used for screening against the respective soil and sediment quality guidelines. The maximum concentrations provide an estimate of worst-case exposure concentrations.

If the ratio of Maximum Concentration-to-Guideline is greater than one for a particular contaminant, then that contaminant is considered a potential chemical hazard. The ratio is called an Exceedance Factor, where:

$$Exceedance\ Factor\ (EF) = \frac{Maximum\ Measured\ Concentration}{Environmental\ Quality\ Guideline}$$

PCDD/Fs and Dioxin-like PCBs

For dioxins/furans and dioxin-like PCBs, only the CALUX TEQ concentrations were used for screening of environmental samples. The high resolution analyses were only conducted on a subset of environmental samples, and these were reserved for exposure assessment modeling. For both soils and sediments, the maximum concentrations were 72.0 pg-TEQ/g for PCDD/Fs, and 253 pg-TEQ/g for dioxin-like PCBs. Maximum concentrations were from soils collected within the drainage ditch immediately outside the workshop and dust collected from beams inside the workshop, respectively (Table 3.1).

Maximum concentrations were compared to the USEPA Risk Based Criteria (USEPA 2008) for 2, 3, 7, 8-TCDD in soils (4.5 pg-TEQ/g) and for 2,3,7,8-TCDD in sediments (4.0 pg-TEQ/g). The 2,3,7,8-TCDD guidelines are appropriate considering that concentrations of PCDD/F, and dioxin-like PCBs are expressed in terms of 2,3,7,8-TCDD toxic equivalents (pg-TEQ/g).

Screening the maximum TEQ concentrations for PCDD/Fs and dioxin-like PCBs resulted in exceedance factors of 16.0 and 56.2, respectively (based on WHO 2005 toxicity equivalence factors, Van den Berg 2006). Because these exceedance factors are both greater than one, both PCDD/Fs and dioxin-like PCBs were considered contaminants of potential concern

Table 3.1 Concentrations of PCDD/F & PCB TEQs in soils and sediments using CALUX, SPL site, Lao PDR.

Exceedance Factors →

Soil Samples from Case Study Site

(soils and those sediments easily accessed by humans)

		WHO-TEF1998			WHO-TEF2006		
		PCDDs/Fs	DL-PCBs	DXNs	PCDDs/Fs	DL-PCBs	DXNs
		pg-TEQ(WHO1998)/g			pg-TEQ(WHO2006)/g		
08Lao001A	Soil	1.07	0.00	1.07	1.00	0.00	1.00
08Lao002A	Soil	0.80	5.09	5.89	0.74	5.29	6.03
08Lao003A	Soil/Sediment	8.73	11.89	20.62	8.09	12.36	20.44
08Lao004A	Sediment from drain	1.12	4.45	5.58	1.04	4.63	5.67
08Lao005A	Soil (drainage off of field)	1.40	12.91	14.31	1.30	13.42	14.72
08Lao006A	Soil	0.52	NDR 2.50	3.02	0.48	NDR 2.60	3.08
08Lao008A	Soil	1.82	0.00	1.82	1.68	0.00	1.68
08Lao009A	Soil	3.00	34.53	37.54	2.78	35.90	38.68
08Lao010A	Soil/Sediment (dry drainage ditch)	77.69	23.62	101.31	71.97	24.56	96.53
08Lao011A	Soil (next to parking lot)	5.18	12.92	18.09	4.79	13.43	18.22
08Lao014A	Soil/Sediment (inside building where generators were)	19.20	152.02	171.22	17.79	158.03	175.82
08Lao015A	Floor dust (workshop)	9.13	35.15	44.28	8.46	36.54	44.99
08Lao019A	Grass near class rooms	0.75	0.00	0.75	0.69	0.00	0.69
08Lao020A	Garden (at EDL)	5.04	NDR 3.80	8.84	4.67	NDR 3.90	8.57
08Lao021A	Grass to south	0.95	8.50	9.45	0.88	8.84	9.72
08Lao028A	Road dust	1.56	9.50	11.06	1.45	9.87	11.32
08Lao032A	Inside workshop from beams	71.12	243.23	314.34	65.88	252.84	318.72
08Lao033A	Gravel driveway in front workshop	2.33	38.83	41.16	2.16	40.37	42.53
Average		**11.75**	**33.27**	**45.02**	**10.88**	**34.59**	**45.47**
Median		**2.07**	**10.69**	**12.68**	**1.92**	**11.12**	**13.02**
Max		**77.69**	**243.23**	**314.34**	**71.97**	**252.84**	**318.72**
90th percentile		**34.78**	**72.79**	**122.28**	**32.22**	**75.67**	**120.31**

Soil Exceedance Factors of PCB & PCDD/F TEQs

Used USEPA RBC standard for 2,3,7,8-TCDD 4.5 pg/g

	WHO-TEF1998			WHO-TEF2006		
	PCDDs/Fs	DL-PCBs	DXNs	PCDDs/Fs	DL-PCBs	DXNs
	pg-TEQ(WHO1998)/g			pg-TEQ(WHO2006)/g		
08Lao001A						
08Lao002A		**1.1**	**1.3**		**1.2**	**1.3**
08Lao003A	**1.9**	**2.6**	**4.6**	**1.8**	**2.7**	**4.5**
08Lao004A			**1.2**		**1.0**	**1.3**
08Lao005A		**2.9**	**3.2**		**3.0**	**3.3**
08Lao006A						
08Lao008A						
08Lao009A		**7.7**	**8.3**		**8.0**	**8.6**
08Lao010A	**17.3**	**5.2**	**22.5**	**16.0**	**5.5**	**21.5**
08Lao011A	**1.2**	**2.9**	**4.0**	**1.1**	**3.0**	**4.0**
08Lao014A	**4.3**	**33.8**	**38.0**	**4.0**	**35.1**	**39.1**
08Lao015A	**2.0**	**7.8**	**9.8**	**1.9**	**8.1**	**10.0**
08Lao019A						
08Lao020A	**1.1**		**2.0**	**1.0**		**1.9**
08Lao021A		**1.9**	**2.1**		**2.0**	**2.2**
08Lao028A		**2.1**	**2.5**		**2.2**	**2.5**
08Lao032A	**15.8**	**54.1**	**69.9**	**14.6**	**56.2**	**70.8**
08Lao033A		**8.6**	**9.1**		**9.0**	**9.5**
Average	**2.6**	**7.4**	**10.0**	**2.4**	**7.7**	**10.1**
Median		**2.4**	**2.8**		**2.5**	**2.9**
Max	**17.3**	**54.1**	**69.9**	**16.0**	**56.2**	**70.8**
90th percentile	**7.7**	**16.2**	**27.2**	**7.2**	**16.8**	**26.7**

Exceedance Factors →

Sediment Samples from Case Study Site

		WHO-TEF1998			WHO-TEF2006		
		PCDDs/Fs	DL-PCBs	DXNs	PCDDs/Fs	DL-PCBs	DXNs
		pg-TEQ(WHO1998)/g			pg-TEQ(WHO2006)/g		
08Lao007A	Sediment (pond where fish were captured)	2.19	3.66	5.85	2.36	2.33	4.69
08Lao013A	Sediment (pond at main entrance)	9.85	17.82	27.67	10.40	14.37	24.77

Sediment Exceedance Factors of PCB & PCDD/F TEQs

Used USEPA region 10 standard for 2,3,7,8-TCDD 4 pg TEQ/g

	WHO-TEF1998			WHO-TEF2006		
	PCDDs/Fs	DL-PCBs	DXNs	PCDDs/Fs	DL-PCBs	DXNs
	pg-TEQ(WHO1998)/g			pg-TEQ(WHO2006)/g		
08Lao007A			**1.5**			**1.2**
08Lao013A	**2.5**	**4.5**	**6.9**	**2.6**	**3.6**	**6.2**

Chlorinated Pesticides

The chlorinated pesticide analysis results for the single fish tissue sample were also screened against the USEPA Risk Based Criteria (Table 3.2). Dieldrin exceeded the RBC (exceedance factor of 2.6). Despite exceeding the RBC, dieldrin was not considered a contaminant of potential concern for the site. There is no record of its use or storage at the SPL case study site. Dieldrin was only assessed in a single fish caught in a pond down-gradient from the workshop. The pond also receives surface run-off water from neighboring properties, therefore it is possible that it originated from a separate location.

Table 3.2 Concentrations of Chlorinated Pesticides in fish tissue for screening, SPL site, Laos.

Measured Tissue Concentrations

UNITS	'08LAO029A ng/g (wet weight basis)	Guideline ng/g wet
HCB	0.502	1.97
alpha-HCH	< 0.0061	0.501
beta-HCH	< 0.0049	1.75
gamma-HCH	< 0.0049	2.87
HEPTACHLOR	< 0.0049	0.701
ALDRIN	< 0.0049	0.186
OXYCHLORDANE	NDR 0.078	
t-CHLORDANE	0.03	
c-CHLORDANE	0.245	
t-NONACHLOR	0.337	--
c-NONACHLOR	0.231	--
o,p-DDD	< 0.0097	
p,p-DDD	1.14	
o,p-DDE	< 0.0071	
p,p-DDE	5.14	9.28
o,p-DDT	< 0.0174	
p,p-DDT	0.383	
MIREX	0.01	0.175
delta-HCH	NDR 0.001	NA
Heptachlor-Epoxide	NDR 0.006	0.347
alpha-Endosulphan	NDR 0.023	
Dieldrin	0.509	0.197
Endrin	NDR 0.002	406
beta-Endosulphan	NDR 0.07	
Endosulphan-Sulphate	NDR 0.05	NA
Endrin-Aldehyde	< 0.004	NA
Endrin-Ketone	NDR 0.001	NA
Methoxychlor	< 0.002	6760
Total Toxaphene	< 0.0268	2.87
% Lipid	1.34	
Chlordane	0.275	9.01
Total DDD	< 1.15	13.1
Total DDT	< 0.39	9.28
Endosulfan	NDR 0.093	8110

Exceedance Factor

		'08LAO029A
HCB		
alpha-HCH	<	
beta-HCH	<	
gamma-HCH	<	
HEPTACHLOR	<	
ALDRIN	<	
OXYCHLORDANE	NDR	
t-CHLORDANE		
c-CHLORDANE		
t-NONACHLOR		
c-NONACHLOR		
o,p-DDD	<	
p,p-DDD		
o,p-DDE	<	
p,p-DDE		
o,p-DDT	<	
p,p-DDT		
MIREX		
delta-HCH	NDR	
Heptachlor-Epoxide	NDR	
alpha-Endosulphan	NDR	
Dieldrin		**2.6**
Endrin	NDR	
beta-Endosulphan	NDR	
Endosulphan-Sulphate	NDR	
Endrin-Aldehyde	<	
Endrin-Ketone	NDR	
Methoxychlor	<	
Total Toxaphene	<	
% Lipid		
Chlordane		0.0
Total DDD	<	0.1
Total DDT	<	0.0
Endosulfan	NDR	0.0

< indicates a concentration below the method detection limit, and therefore could not be quantified.

NDR indicates a measured concentration that did not meet all quantification criteria and therefore must be interpreted with some caution.

3.3 IDENTIFICATION OF RECEPTORS

Receptors are the living organisms (humans, animals and plants) that may be affected by exposure to a chemical hazard. Receptors are unique for a given contaminated site and exposure scenario. It is the receptor which experiences the risk that is being assessed. Potential receptors were identified (Table 3.3, Figure 3.1) using the results of the human exposure survey, and the site reconnaissance and sampling program (May 2008).

Table 3.3 Potential Human receptors related to the SPL site (within 1km radius) may include:

Sok Pa Loung Site, Vientiane, Lao PDR	
Types of Potentially exposed	**Estimated numbers**
Sok Pa Loung village residents within 1 km radius	450
Full time staff of workshop	12
Full time security	4
Full time SPL compound staff	100
Students and staff of National University of Laos	2000
Students and staff of international school	200
Shift workers and visitors	60
Total	2,826

(Source: May and August 2008 field works and estimates from average population density of Vientiane Capital)

The full-time staff/workers at the workshop are considered to have the greatest potential of exposure. The staff and workers in the entire SPL site may also be potentially exposed. Members of the community, students of the nearby educational institutions and training centers, and frequent visitors and shift workers to the site are likely susceptible to exposure to environmental pollutants. Based on Hatfield's reconnaissance and interviews of local people, approximately 100 families use the recycled transformer oil in Vientiane Capital (different villages/suburbs). Children may be especially sensitive to exposure. According to national statistics, the population age group 0 to 14 years old makes up nearly 40% of the total population) (Table 3.4).

Table 3.4 Key Demographic Characteristics of Lao PDR.

	Key Statistics
Growth rate in urban areas	5.5%
Life Expectancy at birth	61 years
Density at site/km^2	450
Average family size (person)	5.9
Male (% of total)	50.2%
Female (% of total)	49.8%
Age 0 –14 (% of total)	38.9%
Age14 – 60 (% of total)	57.5%
Age 60 – 100 (% of total)	3.5%

(Source: Laos Census, 2005 at www.nsc.gov.la/PopulationCensus2005.htm)

Figure 3.1 Vulnerability Map illustrating key buildings for human receptors in the area of SPL Site, Vientiane, Lao PDR.

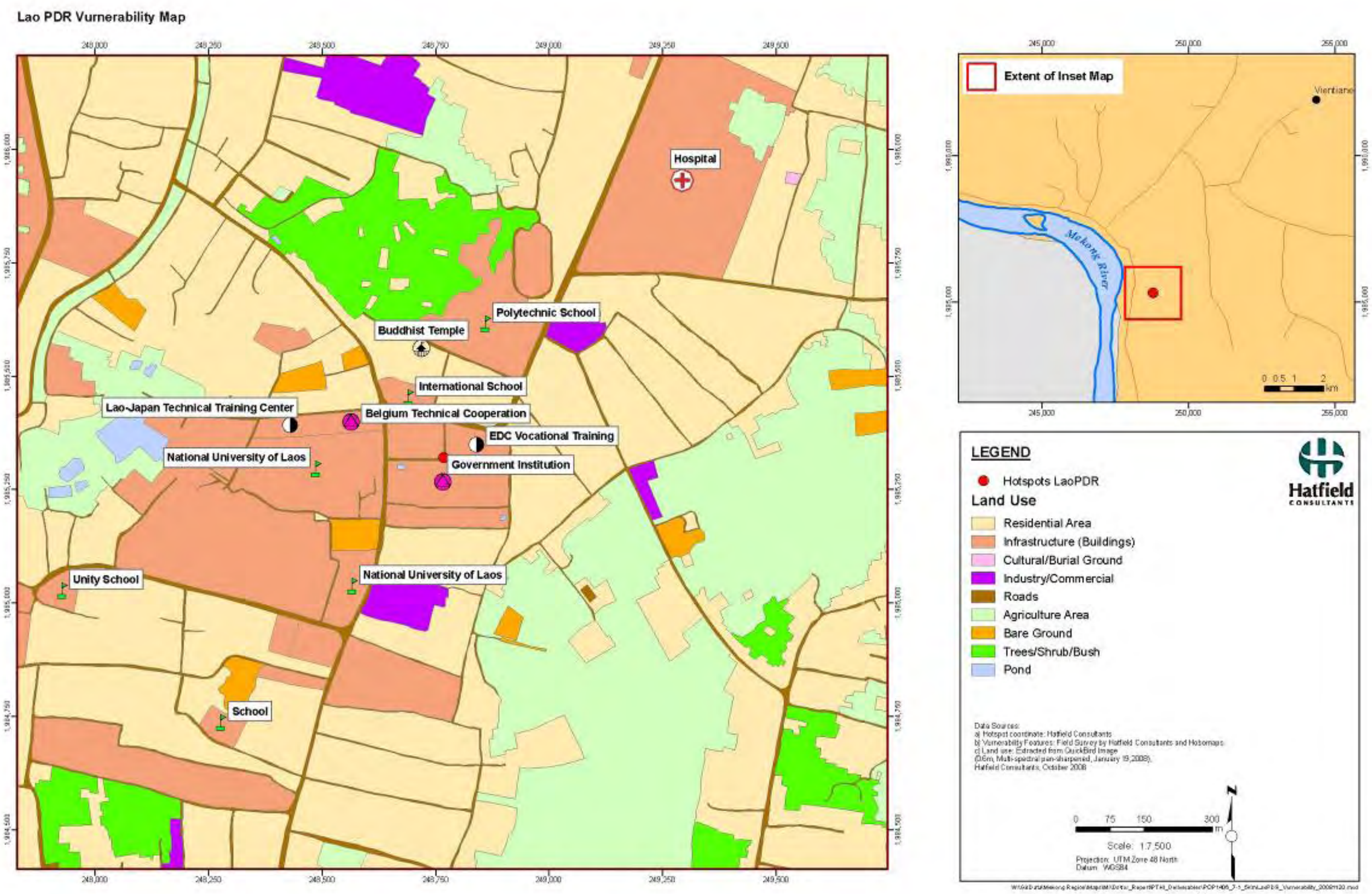


Figure 3.2 Potential receptors associated with the SPL site, Vientiane, Lao PDR.

Crabs living in rice field down-gradient of the SPL site.

Lane immediately behind SPL site showing ditch which carries surface water from the SPL site.

Homes immediately behind the SPL site

Pond down-gradient of the SPL site.

Rice field down-gradient of the SPL site.

3.4 IDENTIFICATION OF PATHWAYS

An exposure pathway is the route a chemical ***hazard*** follows to reach (and potentially affect) a ***receptor.*** Exposure pathways generally fall into the following broad categories:

Physical Mechanisms – for example, contaminated soil being washed into a nearby creek and potentially affecting sediment dwelling organisms.

Human Behavior – for example, contaminated material can be moved by people from one location to another; contaminated soil on a truck's tires or people bringing PCB-containing oils home as cooking fuel.

Biological Mechanisms of Chemcical Intake – dermal and/or eye contact with contaminated soil, ingestion of contaminated food and/or soils, and inhalation of dust.

There are several potential exposure pathways specifically related to the SPL site (see also Figure 3.3 for additional perspective:

- On-site: inhalation, accidental ingestion and dermal contact of soils/dust /oil in the workshop and outside on SPL compound;
- Off-Site: wind erosion and surface water transport of exposed soils followed by inhalation, accidental ingestion and dermal contact;
- Transportation of soils/sediments off site either on tires of trucks and subsequent inhalation, accidental ingestion and dermal contact;
- Transportation of transformer oils off site for use as cooking fuel (oil impregnated coconut husks are used to start cooking fires) and subsequent inhalation, accidental ingestion and dermal contact; and
- Ingestion of potentially contaminated fish and wildlife.

Figure 3.3 Photographs of selected potential exposure pathways associated with the SPL site, Vientiane, Lao PDR.

Oil impregnated coconut husks. To be used to light coal used for cooking fires.

Fish caught in pond down-gradient of the SPL site.

Dirty EDL truck tires, indicating possibility of off-site transfer of contaminated soils.

3.5 CONCEPTUAL EXPOSURE MODEL

A conceptual site exposure model illustrates how contaminant sources, exposure pathways, and receptors are linked together to form the potential for health risk. The conceptual exposure model provides the basis for developing the mathematical exposure model and estimation of health risks.

For the SPL site four conceptual models were created to show these interrelationships (Figure 3.4). These form the basis for subsequent quantitative models used within the POPS Toolkit website (see next section).

Figure 3.4 Conceptual exposure model for workshop employees, SPL site, Lao PDR.

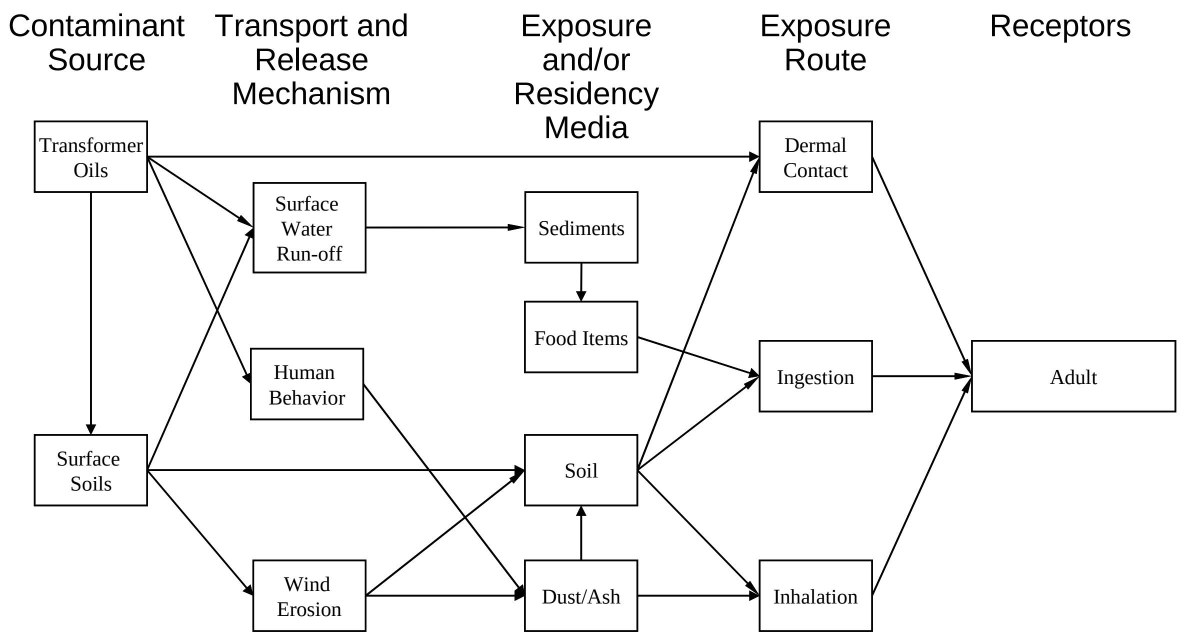


Figure 3.5 Conceptual exposure model for employees' family, SPL site, Lao PDR.

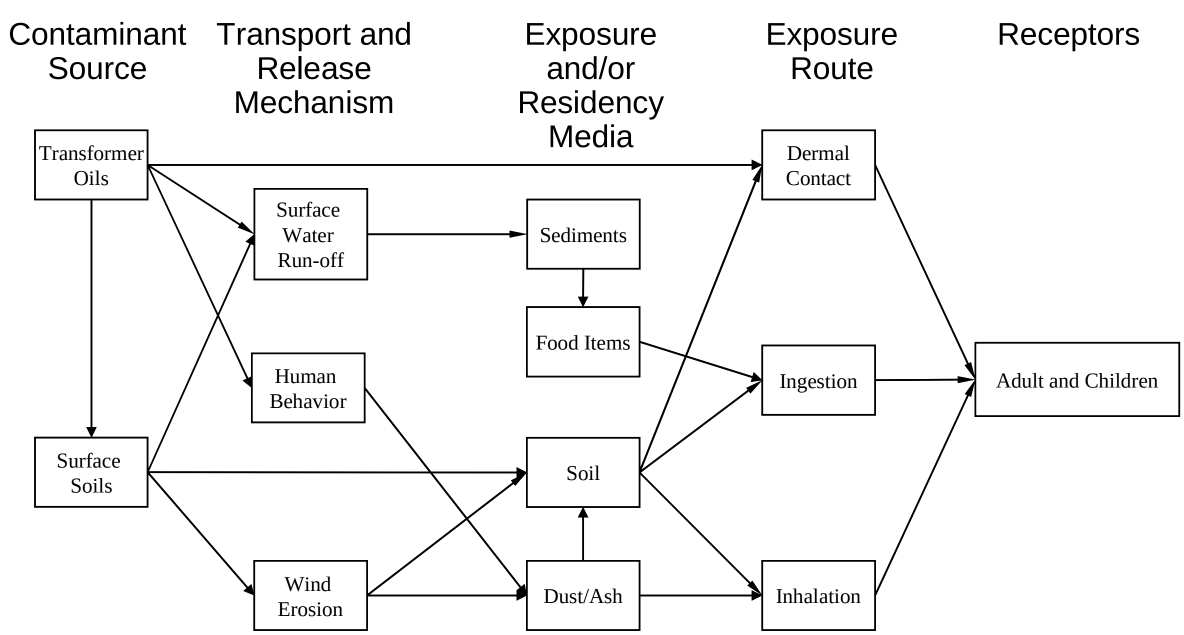


Figure 3.6 Conceptual exposure model for local residents, SPL site, Lao PDR.

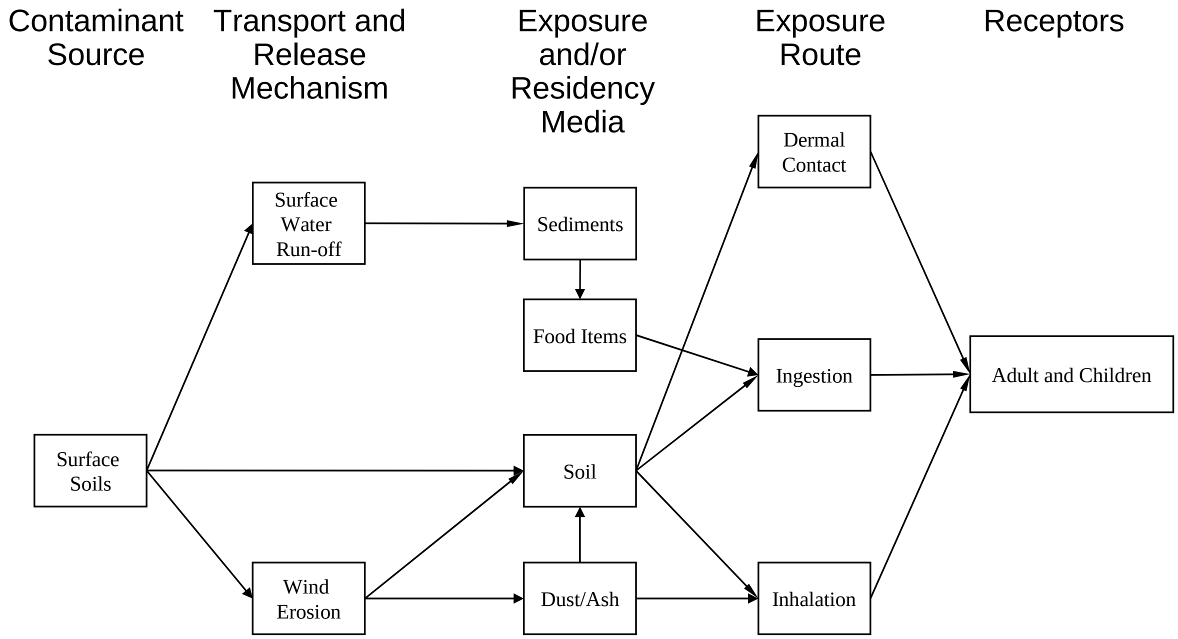


Figure 3.7 Conceptual exposure model for child attending local school, SPL site, Lao PDR.

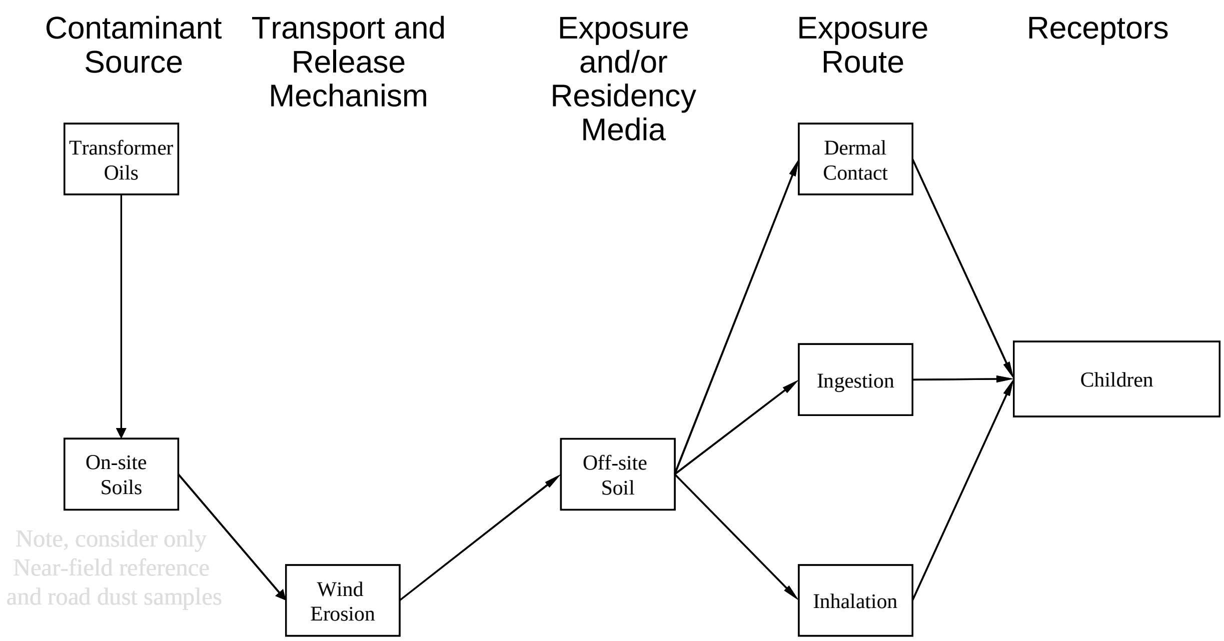


Figure 3.8 Conceptual exposure model for aquatic receptors, SPL site, Lao PDR.