3.0 PROBLEM FORMULATION

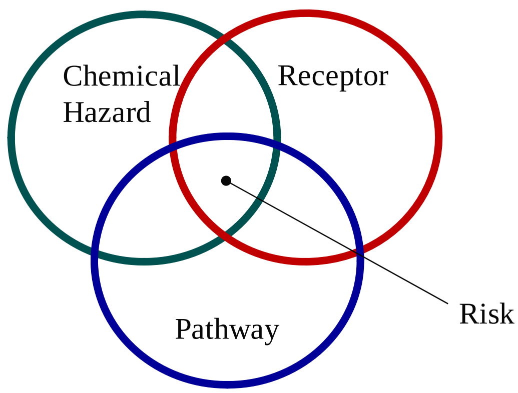
The problem formulation is the first step of a risk assessment it is essentially a *qualitative assessment* of potential risk.

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, and this limitation should be considered before final risk management decisions are made respecting the SEDCW site.

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;
- Bio-accumulative: 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 (Laos, 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
- Exceedances 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 were assessed in all environmental samples, while chlorinated pesticides were assessed in a single tissue sample (crab) only. The crab tissue sample was chosen because it had the greatest likelihood of having elevated concentrations of POPs, given their high potential to bio-accumulate and given that the crab tissue had the highest concentrations of PCBs and dioxins of all the tissue samples analyzed.

PCBs and dioxins were on all samples collected, and high resolution analyses on a subset of samples.

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 SEDCW site. However, dioxins/furans could be associated with burning of garbage by local residents and chlorinated pesticides could have been applied to the adjacent rice fields.

In total, 14 samples evaluated by using both CALUX were used for screening against soil guidelines, one sample was screened against sediment guidelines, and one fish sample was screened against the tissue guidelines.

Due to the limited number of samples available for screening (<20), the maximum concentrations in each of the soil, sediment and tissue 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 11.8 pg-TEQ/g for PCDD/Fs, and 43.9 pg-TEQ/g for dioxin-like PCBs. Maximum concentrations of PCDD/Fs were measured in dust collected from the floor of the southernmost warehouse, while maximum concentrations of dioxin-like PCBs were measured in soils collected within a area of stained soils adjacent to the old transformer storage area (Table 3.1).

Table 3.1 Concentrations of PCDD/F & PCB TEQs in Soils and Sediment using CALUX, SEDCW site, Cambodia.

Soil Samples from Case Study Site

(soils and those sediments easily accessed by humans)

		WHO-TEF1998 PCDDs/Fs	WHO-TEF1998 DL-PCBs	WHO-TEF1998 DXNs	WHO-TEF2006 PCDDs/Fs	WHO-TEF2006 DL-PCBs	WHO-TEF2006 DXNs
		pg-TEQ(WHO1998)/g			pg-TEQ(WHO2006)/g		
08CAM001B	soil, SE corner	0.30	0.00	0.30	0.28	0.00	0.28
08CAM002B	soil, S wall	0.35	0.00	0.35	0.32	0.00	0.32
08CAM003B	soil, SW corner	0.23	0.00	0.23	0.22	0.00	0.22
08CAM004B	soil, W wall	0.00	0.00	0.00	0.00	0.00	0.00
08CAM005B	soil, NW corner	NDR 0.20	0.00	0.20	NDR 0.18	0.00	0.18
08CAM006B	soil, N wall	0.43	0.00	0.43	0.40	0.00	0.40
08CAM007B	soil, NE corner	0.00	0.00	0.00	0.00	0.00	0.00
08CAM008B	soil, planted area, just outside gate	0.28	0.00	0.28	0.26	0.00	0.26
08CAM009B	soil, grass north of access road	0.26	NDR 1.40	1.66	0.24	NDR 1.50	1.74
08CAM010B	soil, dust off entrance road	0.48	NDR 2.00	2.48	0.44	NDR 2.10	2.54
08CAM019B	soil, near chicken coop	10.20	NDR 1.90	12.10	9.45	NDR 2.00	11.45
08CAM021B	Inside floor sweeping	12.76	13.91	26.67	11.82	14.46	26.28
08CAM022B	soil, oil stained	2.11	42.20	44.31	1.96	43.87	45.82
08CAM023B	soil, oil stained	1.30	15.19	16.49	1.20	15.79	16.99
Average		**2.06**	**5.47**	**7.54**	**1.91**	**5.69**	**7.61**
Median		**0.32**	**0.00**	**0.39**	**0.30**	**0.00**	**0.36**
Max		**12.76**	**42.20**	**44.31**	**11.82**	**43.87**	**45.82**
90th percentile		**7.77**	**14.81**	**23.62**	**7.20**	**15.39**	**23.50**

Exceedance Fators →

Soil Exceedance Factors of PCB & PCDD/F TEQs

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

	WHO-TEF1998 PCDDs/Fs	WHO-TEF1998 DL-PCBs	WHO-TEF1998 DXNs	WHO-TEF2006 PCDDs/Fs	WHO-TEF2006 DL-PCBs	WHO-TEF2006 DXNs
	pg-TEQ(WHO1998)/g			pg-TEQ(WHO2006)/g		
08CAM001B						
08CAM002B						
08CAM003B						
08CAM004B						
08CAM005B						
08CAM006B						
08CAM007B						
08CAM008B						
08CAM009B						
08CAM010B						
08CAM019B	**2.3**		**2.7**	**2.1**		**2.5**
08CAM021B	**2.8**	**3.1**	**5.9**	**2.6**	**3.2**	**5.8**
08CAM022B		**9.4**	**9.8**		**9.7**	**10.2**
08CAM023B		**3.4**	**3.7**		**3.5**	**3.8**
Average		**1.2**	**1.7**		**1.3**	**1.7**
Median						
Max	**2.8**	**9.4**	**9.8**	**2.6**	**9.7**	**10.2**
90th percentile	**1.7**	**3.3**	**5.2**	**1.6**	**3.4**	**5.2**

Sediment Samples from Case Study Site

		WHO-TEF1998 PCDDs/Fs	WHO-TEF1998 DL-PCBs	WHO-TEF1998 DXNs	WHO-TEF2006 PCDDs/Fs	WHO-TEF2006 DL-PCBs	WHO-TEF2006 DXNs
		pg-TEQ(WHO1998)/g			pg-TEQ(WHO2006)/g		
08CAM011B	sediment, pond at front of compound - E	0.49	0.00	0.49	0.46	0.00	0.46

Exceedance Factors →

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 PCDDs/Fs	WHO-TEF1998 DL-PCBs	WHO-TEF1998 DXNs	WHO-TEF2006 PCDDs/Fs	WHO-TEF2006 DL-PCBs	WHO-TEF2006 DXNs
	pg-TEQ(WHO1998)/g			pg-TEQ(WHO2006)/g		
08CAM011B						

Tissue Concentrations pg TEQ/g lipid

		WHO-TEF1998 PCDDs/Fs	WHO-TEF1998 DL-PCBs	WHO-TEF1998 DXNs	WHO-TEF2006 PCDDs/Fs	WHO-TEF2006 DL-PCBs	WHO-TEF2006 DXNs
		pg-TEQ(WHO1998)/g			pg-TEQ(WHO2006)/g		
08CAM027B	fish muscle (tilapia)	0.00	0.00	0.00	0.00	0.00	0.00

Exceedance Factors →

Tissue Exceedance Factors of PCB & PCDD/F TEQs

Used USEPA RBC standard for 2,3,7,8-TCDD 0.0243 pg TEQ/g

	WHO-TEF1998 PCDDs/Fs	WHO-TEF1998 DL-PCBs	WHO-TEF1998 DXNs	WHO-TEF2006 PCDDs/Fs	WHO-TEF2006 DL-PCBs	WHO-TEF2006 DXNs
	pg-TEQ(WHO1998)/g			pg-TEQ(WHO2006)/g		
08CAM027B						

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 concentrations for PCDD/Fs and dioxin-like PCBs resulted in exceedance factors of 2.6 and 10.2, 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.

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 using the results of the human exposure survey, and the site reconnaissance and sampling program (Hatfield, 2008b), (Figure 3.2).

Table 3.2 Potential Human receptors related to the SEDCW site (within 1 km radius) may include.

Sambour Site, Phnom Penh, Cambodia	
Types of potentially exposed	**Estimated numbers**
Sambour village residents Within 1 km radius	1,286
Full time staff of warehouse	22
Full time policemen	3
Full time EDC training center staff	25
Full time security staff of Center	7
Students (short-term training courses)	65-110
Shift workers and visitors	25
Total	1,438

(Source: Sith, 2008)

The full-time workers and guards at the SEDCW site are considered to have the greatest potential of exposure. Staff and students in the EDC training complex may also be potentially exposed, as well as regular visitors and shift workers. Members of the community, students of the nearby Training Center, and frequent visitors to the site are likely susceptible to exposure to environmental pollutants. Based on Hatfield’s reconnaissance and interviews with local people, over 1,286 people are living in 168 households (over 7.6 persons per household) within 1km radius of the site; 787 are female (63%). The average monthly household income is approximately US$ 100.

The students and staff of the secondary school across the road from the site and Training Center, as well as the occupants of the newly built condos and apartment complex, are also a potentially exposed population.

Furthermore, the expectant mothers as well as children (population age group 0-14 years old make up nearly 37% of the total population) can be highly sensitive to exposure and thus elicit disproportionate effects (Table 3.3).

Table 3.3 Key Demographic Characteristics of Cambodia and Sambour Village.

Key parameter	Key Indicators	Reference
Population within 1 km radius	1,286	1
Growth rate in urban	4%/annually	1
Density at site/km^2	1,286	1
Average family size (person)	7.6	1
Mean household income	US$ 100/month	1
Male (% of total)	37%	2
Female (%of total)	63%	2
Age 0 -14 (% of total)	36.7%	2
Age14 - 60 (% of total)	60.1%	2
Age 60 - 100 (% of total)	3.2%	2

[1] Roath 2008

[2] NIS 2000

3.3.1 ID 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.

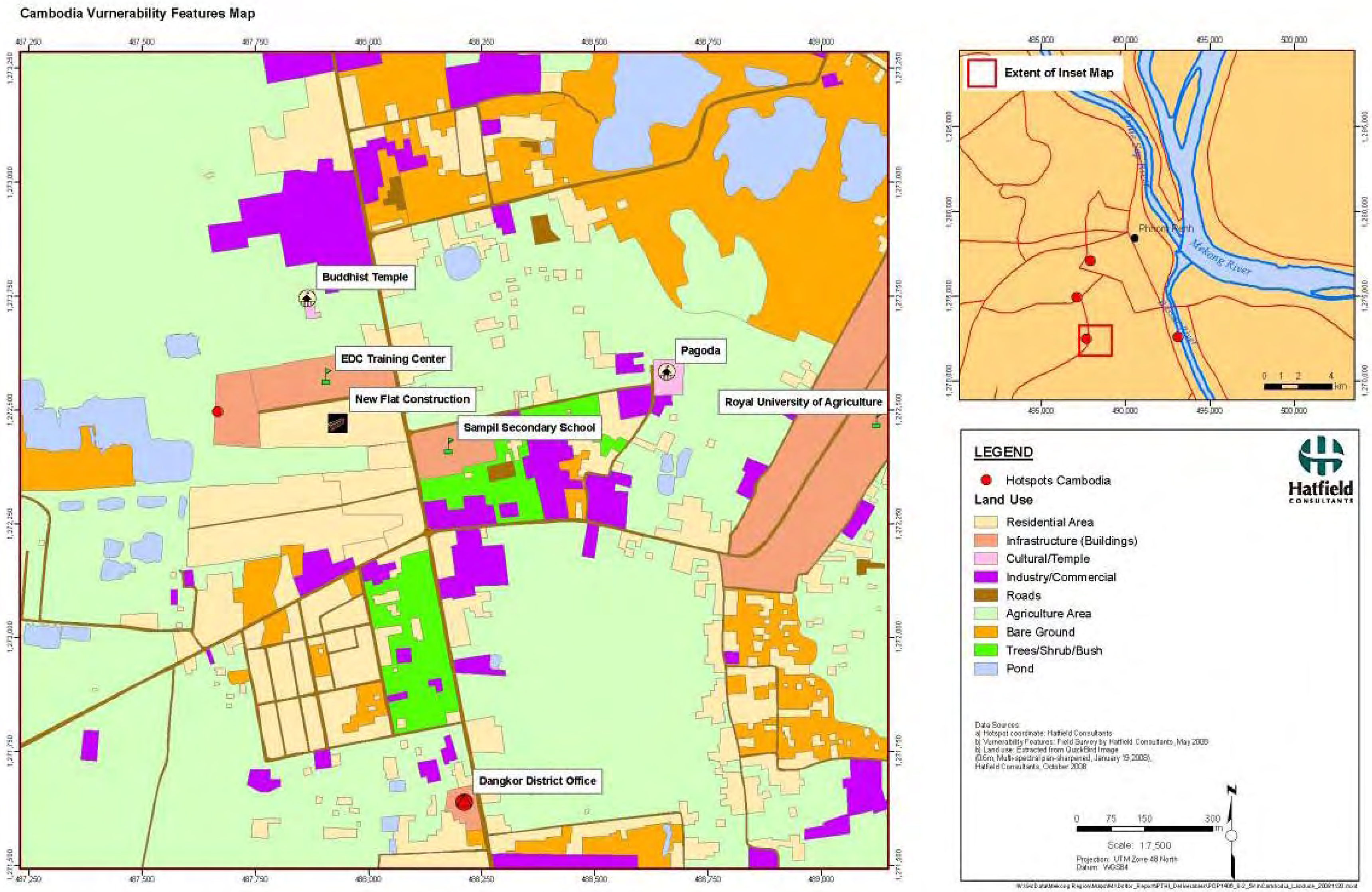
Human Behavior – for example, contaminated material can be moved by people from one location to another; contaminated soil on a truck's tires or people bringing PCB containing oils home to be burned in kitchen fires.

Biological Mechanisms of Chemical 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 SEDCW site:

- On-site: inhalation, accidental ingestion and dermal contact of soils/dust inside the warehouse buildings and outside on the SEDCW site;

Figure 3.1 Vulnerability map illustrating key buildings for human receptors in the area of SEDCW, Sambour, Phnom Penh.



- Off-Site: wind erosion and surface water transport of exposed soils followed by : inhalation, accidental ingestion and dermal contact;
- Transportation of 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).

Figure 3.2 Potential receptors associated with the SEDCW site, Phnom Penh, Cambodia.

Crab collected from rice field outside SEDCW site.

Local resident collecting snails outside SEDCW site.

Chickens foraging on the SEDCW site.

New housing complex adjacent to the SEDCW site. Warehouse is at the end of the driveway.

Figure 3.3 Local resident fishing from a pond behind the SEDCW site, Phnom Penh, Cambodia.

3.4 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 SEDCW site four conceptual models were created to show these interrelationships (Figure 3.4 to Figure 3.6). These form the basis for subsequent quantitative models used within the POPs Toolkit website (see next section).

Figure 3.4 Conceptual exposure model for warehouse employees, SEDCW site, Cambodia.

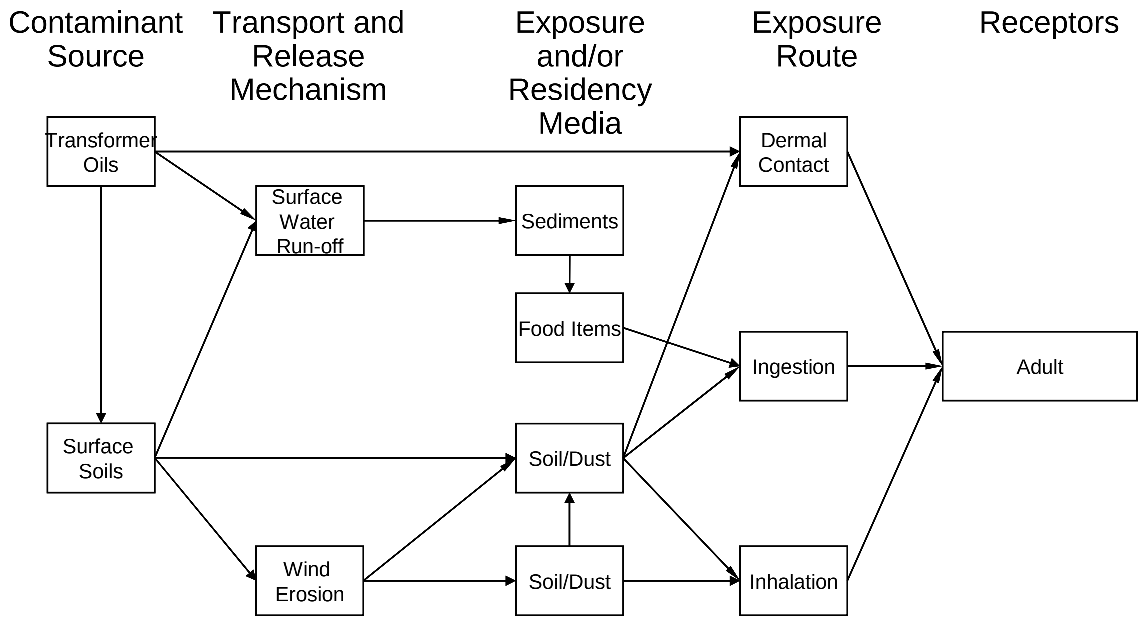


Figure 3.5 Conceptual exposure model for both Local Residents and Staff, trainees and residents of Training Center Dormitory, SEDCW site, Cambodia.

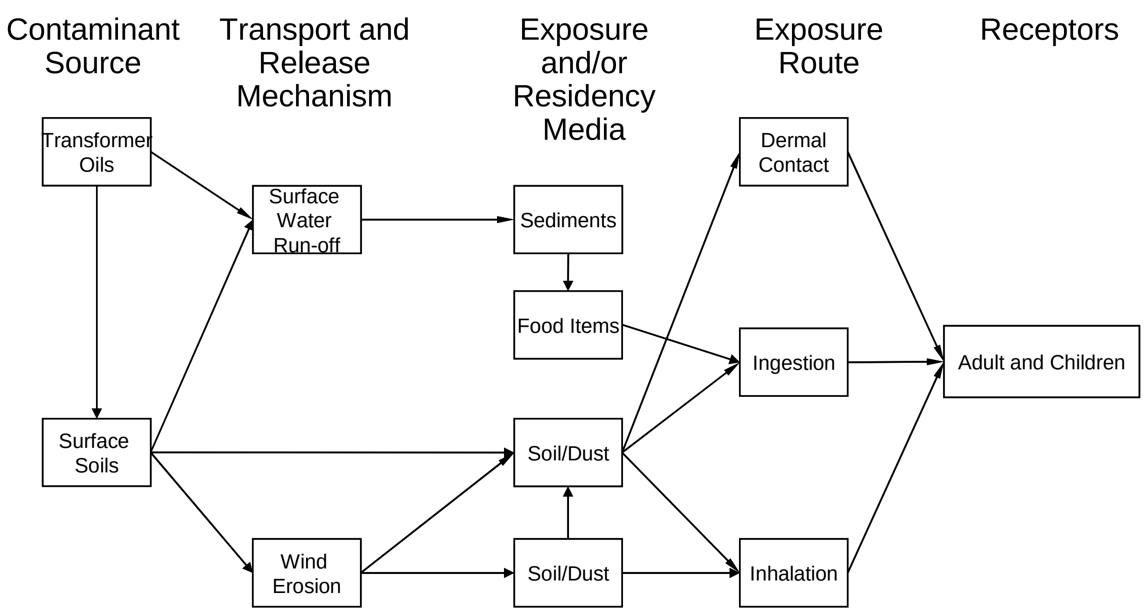


Figure 3.6 Conceptual exposure model for Aquatic Receptor, SEDCW site, Cambodia.