3.0 PROBLEM FORMULATION

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

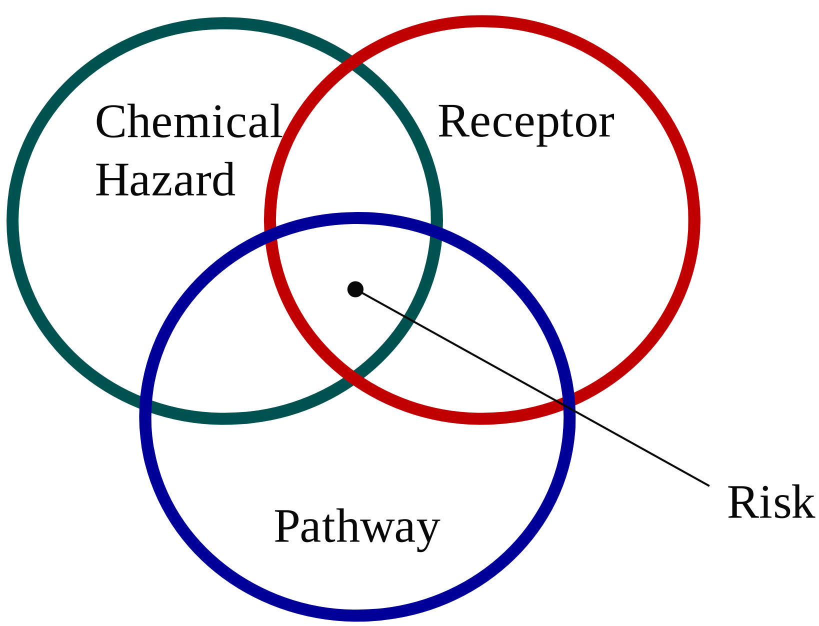
3.1 COMPONENTS OF A PROBLEM FORMULATION

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 (Figure 3.1):

- 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.

Figure 3.1 Three components required for risk.



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 MEA 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;
- 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 levels 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:

1. On-site concentration data were first summarized by calculating the mean, 90th percentile and maximum potential concentration;

2. Summary statistics were then compared to the environmental quality guidelines (USEPA 2008a). The ratio of summary statistics to the guidelines yielded an exceedance factor; and

3. Exceedances factors greater than one identify a chemical as a potential hazard, and therefore a contaminant of potential concern (CCME, 2008b).

Due to the known historical and ongoing activities at the site, PCBs and PCDD/PCDFs were targeted as chemicals to be screened. PCBs and PCDD/PCDFs were assessed using both CALUX analysis on all samples collected and high resolution analysis on a subset of samples. Chlorinated pesticides were assessed using high resolution analysis 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. For the MEA facility, off-site samples (i.e., river or water ways) may have been contaminated by contaminants transported in Chao Phraya River sediments. The MEA facility is often flooded by the Chao Phraya River.

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, 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, for PCBs and PCDD/PCDFs, 9 samples were considered for screening against soil guidelines. Due to the small 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 (Table 3.1). The maximum concentrations provide an estimate of worst-case exposure concentrations.

If the ratio of the 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/PCDFs and Dioxin-like PCBs

For PCDD/PCDF 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. (Table 3.1).

Table 3.1 Concentrations of PCDDs/PCDFs & PCBs in soil and sediments using CALUX, MEA Facility, Samut Prakan, Thailand (based on WHO-TEF2005* and NATO I-TEF).

		WHO-TEF2005			I-TEF
		PCDDs/PCDFs	DL-PCBs	DXNs	PCDDs/PCDFs
Sample ID	**Site Description**	**pg-TEQ(WHO2005)/g**			**pg-TEQ (I-TEF)/g**
08THA004B	Drainage ditch close to the site.	1.8	8.2	10.0	2.5
08THA005B	Storage area (concrete floor).	13.8	216.9	230.7	14
08THA008B	Storage oil (oil soaked).	14.0	125.8	139.7	14
08THA009B	Perimeter of the site (drainage).	3.5	57.5	61.0	3.5
08THA010B	Ditch near the storage area.	8.8	171.3	180.1	8.7
08THA011B	Ditch on the storage area edge	13.1	109.3	122.3	13
08THA012B	Field closer to river bank.	2.3	25.6	27.9	2.2
08THA014B	Field (middle of property).	1.2	5.0	6.2	1.2
08THA015B	Field in front of MEA meeting room.	3.1	2.6	5.7	4.3
Average		**6.8**	**80.2**	**87.1**	**7.04**
Median		**3.5**	**57.5**	**61.0**	
Max		**14.0**	**216.9**	**230.7**	**14**
90th percentile		**13.8**	**180.4**	**190.2**	

* PCDD/PCDF and Dioxin-like PCB concentrations expressed as World Health Organization (2005) 2,3,7,8-TCDD toxic equivalence concentrations (Van der Berg 2006).

Because of the small number of samples available for screening purposes, the maximum concentrations, 14.0 pg-TEQ/g for PCDDs/PCDFs, and 180.4 pg-TEQ/g for dioxin –like PCBs were selected for screening.

The maximum concentrations were compared to the USEPA Risk Based Criteria (USEPAa, 2008) for 2,3,7,8-TCDD (4.5 pg-TEQ/g). This guideline is appropriate considering that concentrations of PCDDs/PCDFs, and dioxin-like PCBs are expressed in terms of 2,3,7,8-TCDD toxic equivalents (pg-TEQ/g). PCBs and PCDDs/PCDFs consist of a mixture of many individual similar related chemicals, called congeners. Each congener has an individual toxic potency. By standardizing all concentrations to 2,3,7,8-TCDD toxic equivalence, it is possible to compare the relative toxicity of different PCB and PCDD/PCDF mixtures.

Screening the maximum concentrations for PCDDs/PCDFs and dioxin-like PCBs resulted in Exceedance Factors of 3.1 and 48.2 respectively. Because these

Exceedance Factors are both greater than one, both PCDD/PCDFs and dioxin-like PCBs are considered contaminants of potential concern.

Organo-chlorine Pesticides

A single fish tissue sample was assessed for organo-chlorine pesticides. This sample had exceedance factors for mirex and dieldrin exceeding the USEPA Risk Based Criteria (RBCs) by 3.7 and 8.7, respectively.

A sediment sample collected from the Chao Phraya River was also assessed for organo-chlorine pesticides. This sample had exceedance factors for dieldrin of 2.3. Similar to the fish tissue sample, this exposure factor indicates a possible chemical hazard.

Table 3.2 Concentrations of organo-chlorine pesticides in soil and sediments using HR-GCMS, MEA Facility, Samut Prakan, Thailand.

	River Sediment (ng/g dry)			Fish Tissue (ng/g wet)		
Contaminant Types		**08THA019A**	**Guideline (USEPA RBC's)[2]**		**'08THA040A**	**Guideline (USEPA RBC's)[3]**
HCB		0.039	300		0.072	1.97
alpha-HCH		0.017	0.074	<	0.0049	0.501
beta-HCH		0.012	0.26	<	0.0061	1.75
gamma-HCH		0.005	0.43	<	0.0061	2.87
HEPTACHLOR		0.002	1.6	<	0.0049	0.701
ALDRIN		0.07	0.84	<	0.0049	0.186
OXYCHLORDANE	NDR	0.005		NDR	0.087	
t-CHLORDANE		0.055			0.021	
c-CHLORDANE		0.111			0.118	
t-NONACHLOR		0.031			0.167	--
c-NONACHLOR		0.084			0.083	--
o,p-DDD		0.089		<	0.0122	
p,p-DDD		0.376			0.609	
o,p-DDE		0.068		<	0.0077	
p,p-DDE		1.36	60		1.38	9.28
o,p-DDT		0.048		<	0.0249	
p,p-DDT		0.101			0.131	
MIREX		0.01	3.5		**0.646**	0.175
delta-HCH		0.009		NDR	0.002	NA
Heptachlor-Epoxide	NDR	0.005	0.079		0.049	0.347
alpha-Endosulphan		0.346		NDR	0.02	
Dieldrin		**0.211**	0.09		**1.72**	0.197
Endrin	<	0.0148	43	NDR	0.007	406
beta-Endosulphan		0.213		NDR	0.052	
Endosulphan-Sulphate	NDR	0.11		NDR	0.212	NA
Endrin-Aldehyde	NDR	0.036		<	0.0023	NA
Endrin-Ketone		0.006		NDR	0.002	NA
Methoxychlor	<	0.129	3400	<	0.0015	6760
Total Toxaphene	<	0.101	12	<	0.0254	2.87

% Moisture	58.5			0.34	
Chlordane	0.166	33		0.139	9.01
Total DDD	0.465	86	<	0.62	13.1
Total DDT	0.149	87	<	0.15	9.28
Endosulfan	0.559	9700	NDR	0.072	8110

[1] Measured concentrations greater than the guideline shown in Bold.
[2] Lowest (most conservative) appliciable RBC was chosen for screening purposes. Usually this was the soil guideline for the protection of groundwater (Risk Based SSL - Groundwater).
[3] Lowest (most conservative) RBC for the protection of human consumers of fish.

However, neither the fish tissue sample, nor the sediment samples were included in the risk assessment, because:

1. The samples were collected from a pond adjacent to, but off the MEA Facility. It is likely that other sources of organo-chlorine pesticides could have contaminated the samples; and

2. It is unlikely that there were any application of organo-chlorine pesticides to the case-study site resulting in contamination of either the fish tissue or sediment sample.

3.3 IDENTIFICATION OF RECEPTORS

The receptors are the living organisms (humans, animals and plants) that may be affected by exposure to a chemical hazard. They are unique for a given contaminated site and exposure scenario. It is the receptor that experiences the risk that is being assessed. Potential receptors for the MEA Facility case-study site were identified using the results of the human exposure survey, and the site reconnaissance and sampling program (July 2008). In addition to human receptors (Table 3.3, Figure 3.2, Figure 3.3), aquatic wildlife (e.g., fish, snails, crabs) may also be impacted (Figure 3.3).

Table 3.3 Potential Human receptors related to the MEA Facility Case Study site (within 1km radius).

Types of Potentially Exposed Persons	Estimated numbers
Residents of nearby village	400
Full time staff of the site	5
Full time security	3
Students and staff of nearby school	300
Shift workers and visitors	25
Total	**733**

(Source: Jarupong BL, 2008, Data Gathering/analysis and Identification of Hot Spot Report).

The full-time staff/workers at the workshop are considered to have the greatest potential of exposure. The staff, workers and security guards in the MEA Facility, may also be potentially exposed. Members of 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. Children may be especially sensitive to exposure. According to Thai national statistics (Table 3.4), the population age group 0 - 14 years old makes up nearly 40% of the total population).

Table 3.4 Key Demographic Characteristics of Thailand

Parameters	Key Statistics
Growth rate in urban	4.7
Life Expectancy at birth	77
Density at site/km^2	1282
Average family size (person)	3.9
Male (% of total)	49
Female (%of total)	51
Age 0 -14 (% of total)	21.4
Age14 - 60 (% of total)	70.6
Age 60 - 100 (% of total)	8.0

(Source: National Statistical Office, the Key Statistics of Thailand 2007)

Figure 3.2 Vulnerability Map of the MEA Facility, Samut Prakan, Thailand.

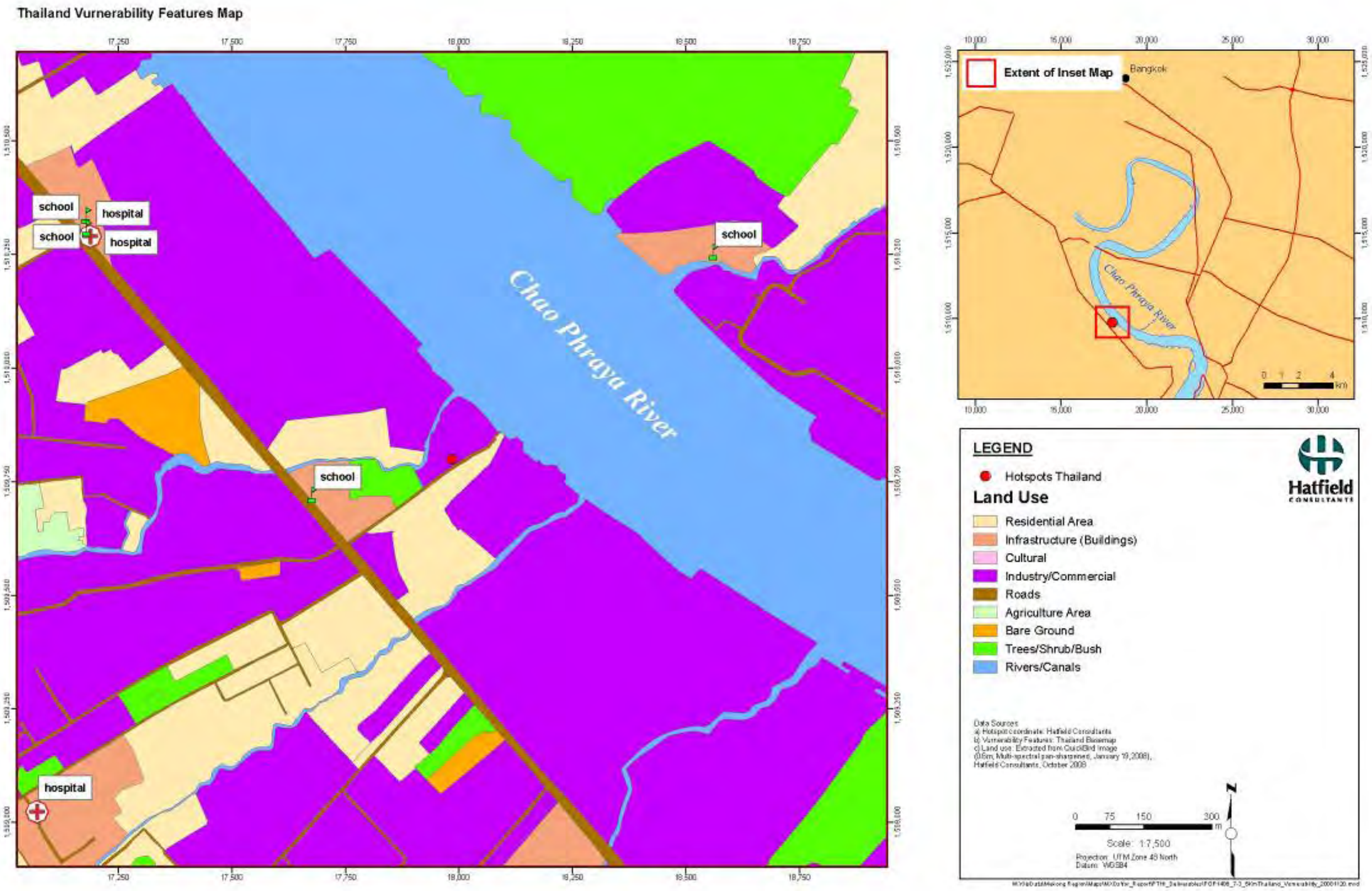


Figure 3.3 Potential receptors associated with the MEA Facility, Samut Prakan, Thailand.

Houses adjacent to the MEA Facility.

Canal located adjacent to the MEA Facility

Grass lands adjacent to the MEA Facility.

Foreshore of the MEA Facility on the Chao Phraya River.

Snails collected from the Chao Phraya River

Snake Head fish collected from aquaculture pond adjacent to the MEA Facility.

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. Surface water run-off and wind erosion of soils can also carry contaminated soils off site, exposing people living or working nearby;

- *Human Behavior* – for example, contaminated material can be moved by people from one location to another. Examples include contaminated soil on a truck's tires or (in other countries) people bringing PCBs containing oils home to be burned in cooking fires; and

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

A human exposure survey was conducted in August 2008. The results from the survey are very helpful to assess potential exposure pathways. There are several potential exposure pathways specifically related to the MEA Facility:

- On-site inhalation, accidental ingestion and dermal contact of contaminated soils;

- Wind erosion or surface water erosion of site soils off site, followed by exposure via inhalation, accidental ingestion and dermal contact;

- Transportation of contaminated soils off site on truck tires and subsequent inhalation, accidental ingestion and dermal contact; and

- Ingestion of potentially contaminated fish and wildlife.

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

Figure 3.4 Conceptual Exposure Model for Storage Facility Employees

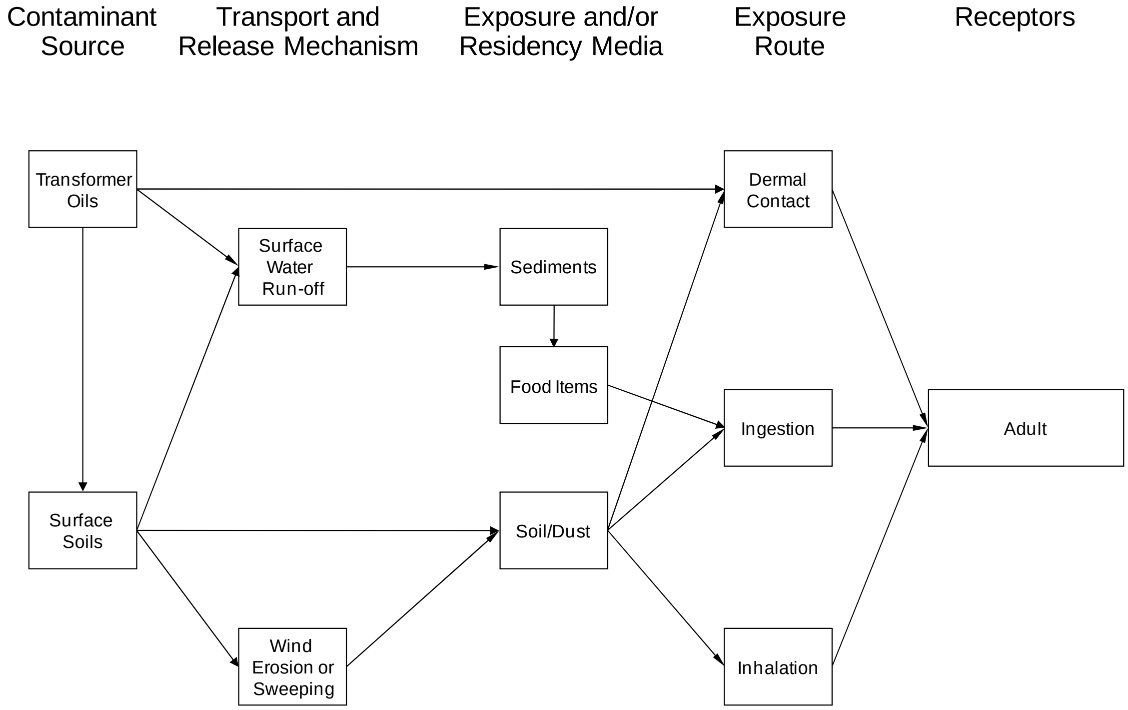


Figure 3.5 Conceptual Exposure Model for Local residents.

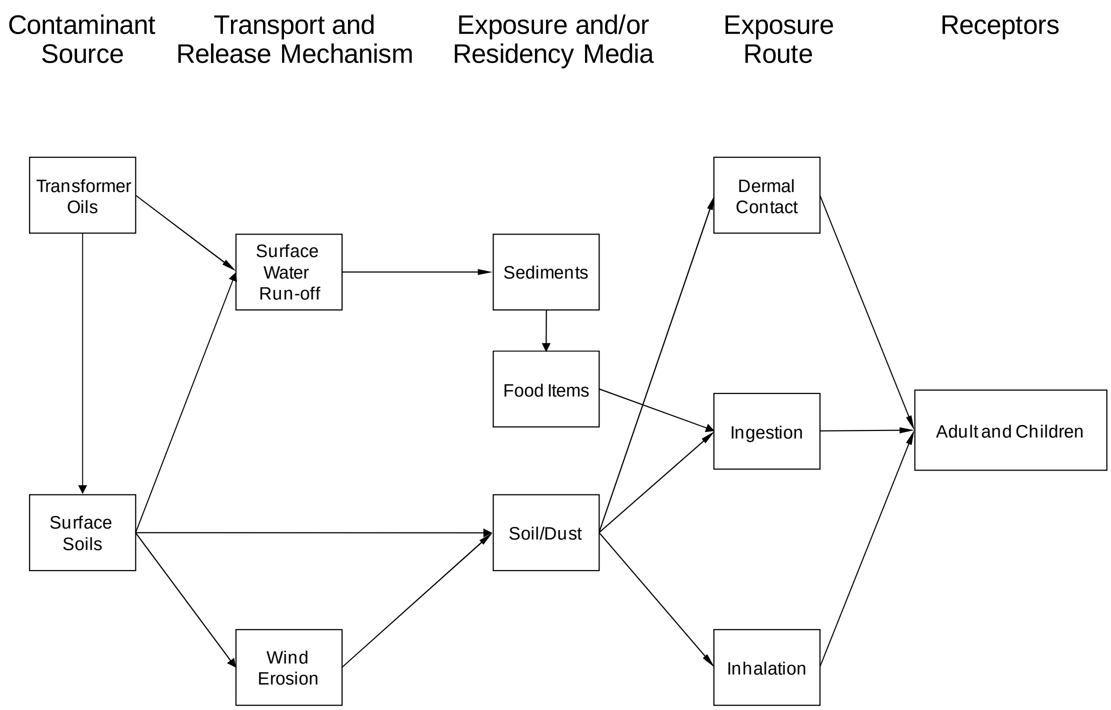


Figure 3.6 Conceptual Exposure Model for Aquatic Receptors.