3.0 PROBLEM FORMULATION

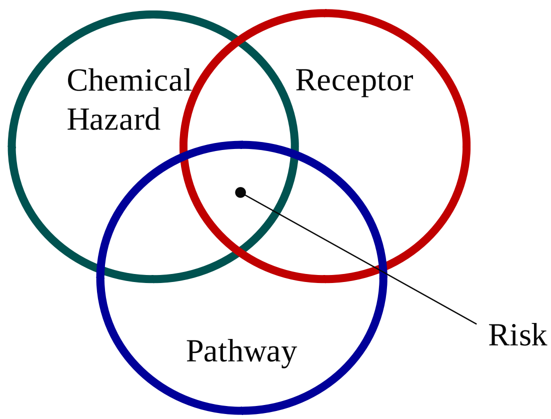
The problem formulation is the first step of a risk assessment it is essentially a *qualitative assessment* of potential risk.

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 Diagrams 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 AHSL 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 (Laos, 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. Exceedance factors greater than one identify a chemical as a hazard (CCME, 2008b).

Because the site is a landfill, a wide variety of POPs contaminants may be associated with the site. PCBs, PCDD/Fs (i.e., dioxins/furans) and chlorinated pesticides were targeted for screening. PCBs and dioxins were evaluated using both CALUX analysis on all environmental samples collected, and high resolution analyses on a subset of samples. Chlorinated pesticides were assessed using high resolution analyses on a subset of samples. Polybrominated diphenyl ethers (PBDEs) and polyfluorinated chemicals (PFCs) were analyzed, but not screened because of the absence of applicable guidelines. The data for these chemicals was included in Appendix 2, for use if more detailed risk assessments are conducted on the site in future.

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 AHSL site, other potential sources of contaminants are a sewage treatment plant discharge and urban surface water runoff. Both discharge to the same stream as the landfill.

In addition to the leachate treatment pond sludge sample (i.e., dried sludge exposed along the pond edge due to low water level), several other sediment samples were grouped with the soils data for screening. These sediments were collected from shallow water and therefore these sediments were liable to be accessible by people, and therefore can be considered soils (as well as sediments). All together, eight samples were considered for screening against soil guidelines and six 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 sediments 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:

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

Figure 3.1 Photographs of Treatment Pond, and sediment sample collection, AHSL site, Malaysia (note partially exposed sludge at pond edge).

PCDD/Fs and PCBs

For PCDD/Fs (i.e., dioxins/furans) and PCBs, both the CALUX TEQ concentrations and high resolution analysis results were used for screening of environmental samples. For both soils and sediment the maximum CALUX TEQ concentrations were 13 pg-TEQ/g for PCDD/Fs, and 2.8 pg-TEQ/g for dioxin-like PCBs. Maximum concentrations were derived from material collected from the treatment pond Table 3.1). The total PCB concentration for the same sample, analyzed using HRGCMS, was 372 µg/kg.

Maximum concentrations in soil were compared to the lowest applicable USEPA Risk Based Concentration (USEPA 2008A). CALUX TEQ concentrations were compared to the residential soil guideline, for protecting human health, for 2, 3, 7, 8-TCDD (4.5 pg-TEQ/g) and for 2, 3, 7, 8-TCDD in sediments (4.0 pg-TEQ/g)(AEA Technology. 1999). The 2,3,7,8-TCDD guidelines are appropriate considering that concentrations of PCDD/Fs, and dioxin-like PCBs are expressed in terms of 2,3,7,8-TCDD toxic equivalents (pg-TEQ/g). Maximum total PCB concentrations in soil were compared to the most conservative residential soil guideline, for protecting human health (i.e., 240 µg/kg; USEPA 2008a).

The guidelines for the protection of potable groundwater, which are more conservative, were not used because it is our understanding that excavated sludge has not, and will not be applied to any soils where potable groundwater may be impacted. However, handling and final destination of excavated treatment pond sludge should be confirmed by NRE and AHSL site management.

Screening the maximum CALUX TEQ concentrations for PCDD/F + dioxin-like PCBs based on sediment guidelines (AEA Technology 1999) resulted in exceedance factors of 3.3 and 0.7 respectively. Because the maximum exceedance factor for PCDD/Fs were greater than one, they were considered contaminants of potential concern and retained for risk further assessment.

PCBs were also included as contaminants of potential concern because the highest Total PCB concentration, 372 µg/kg, resulted in an exceedance factor of 1.55. Although it might be argued that such a marginal exceedance may at times not justify further risk assessment, Total PCBs were retained for illustrative purposes of the case study.

Table 3.1 Concentrations of PCDD/F and PCB TEQs in Soils and Sediment for Screening using CALUX Analysis, AHSL site, Malaysia.

Exceedance Factors →

Soil Samples from Case Study Site

(soils and those sediments easily accessed by humans)

			PCDDs/Fs (WHO-TEF2006, pg-TEQ(WHO2006)/g)	DL-PCBs (WHO-TEF2006, pg-TEQ(WHO2006)/g)		DXNs (WHO-TEF2006, pg-TEQ(WHO2006)/g)
08MAL001B	Near main entrance		0.49	<		0.49
08MAL008B	Bank btw WQ Stations 3 & 4		2.3	<		2.3
08MAL002B	Water quality (WQ) station 2	NDR	0.19	<	NDR	0.19
08MAL003B	WQ station 1		0.52	<		0.52
08MAL004B	WQ station 5		0.41	<		0.41
08MAL006B	WQ station 4	NDR	0.20	<	NDR	0.20
08MAL007B	WQ station 3	NDR	0.17	<	NDR	0.17
08MAL009B	Sludge collected from the edge of the leachate treatment pond		13	2.8		16
Average			**2.2**	**2.8**		**2.5**
Median			**0.45**	**2.8**		**0.45**
Max			**13**	**2.8**		**16**
90th percentile			**5.6**	**2.8**		**6.4**

Soil Exceedance Factors of PCB & PCDD/F TEQs

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

The residential soil guideline for protecting human health (the lowest applicable guideline).

	PCDDs/Fs (WHO-TEF2006, pg-TEQ(WHO2006)/g)	DL-PCBs (WHO-TEF2006, pg-TEQ(WHO2006)/g)	DXNs (WHO-TEF2006, pg-TEQ(WHO2006)/g)
08MAL001B			
08MAL008B			
08MAL002B			
08MAL003B			
08MAL004B			
08MAL006B			
08MAL007B			
08MAL009B	**2.9**		**3.6**
Average			
Median			
Max	**2.9**		**3.6**
90th percentile	**1.2**		**1.4**

Exceedance Factors →

Sediment Samples from Case Study Site

			PCDDs/Fs (WHO-TEF2006, pg-TEQ(WHO2006)/g)	DL-PCBs (WHO-TEF2006, pg-TEQ(WHO2006)/g)		DXNs (WHO-TEF2006, pg-TEQ(WHO2006)/g)
08MAL002B	Water quality (WQ) station 2	NDR	0.19	<	NDR	0.19
08MAL003B	WQ station 1		0.52	<		0.52
08MAL004B	WQ station 5		0.41	<		0.41
08MAL006B	WQ station 4	NDR	0.20	<	NDR	0.20
08MAL007B	WQ station 3	NDR	0.17	<	NDR	0.17
08MAL009B	Sludge collected from the edge of the leachate treatment pond		13	2.8		16
Average			**2.5**	**2.8**		**2.9**
Median			**0.30**	**2.8**		**0.30**
Max			**13**	**2.8**		**16**
90th percentile			**6.9**	**2.8**		**8.3**

Sediment Exceedance Factors of PCB & PCDD/F TEQs

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

	PCDDs/Fs (WHO-TEF2006, pg-TEQ(WHO2006)/g)	DL-PCBs (WHO-TEF2006, pg-TEQ(WHO2006)/g)	DXNs (WHO-TEF2006, pg-TEQ(WHO2006)/g)
08MAL002B			
08MAL003B			
08MAL004B			
08MAL006B			
08MAL007B			
08MAL009B	**3.3**		**4.0**
Average			
Median			
Max	**3.3**		**4.0**
90th percentile	**1.7**		**2.1**

"NDR" indicates that the contaminant was measured, but did not meet quantification criteria. Concentration presented has greater uncertainty associated with it.
"<" indicates that the contaminant was at a concentration below the minimum quantification threshold.

Chlorinated Pesticides

The chlorinated pesticide analysis results (n = 6) were also screened against the USEPA Risk Based Concentrations (Table 3.2). Similar to the dioxin/furan and PCB results, the maximum site concentrations were derived from the treatment pond. None of the assessed pesticides exceeded the lowest applicable USEPA (2008a) Region 3 guideline, the residential soil guideline for the protection of human health.

There was insufficient volume of sample collected from the edges of the leachate treatment pond to assess all the chlorinated pesticides. Consequently, heptachlor-epoxide, alpha-endosulphan, dieldrin, endrin, beta-endosulphan, endosulphan-sulphate, endrin-aldehyde, endrin-keton, and methoxychlor were not assessed. The concentration of these pesticides is unknown and therefore must be considered an uncertainty for the purposes of this risk assessment.

Table 3.2 Concentrations of Chlorinated Pesticides in Soil and Sediment Screened Against Soil Quality Guidelines, AHSL site, Malaysia (direct human exposure).

CLIENT ID	'08MAL003A	'08MAL004A	'08MAL008A	08MAL009A	'08MAL010A	'08MAL011A	Lowest RBC[1]	
Sample Size	21.7 g (dry)	12.7 g (dry)	12.0 g (dry)	6.86 g (dry)	12.4 g (dry)	11.5 g (dry)		
UNITS	ng/g (dry weight basis)	ng/g (dry weight basis)	ng/g (dry weight basis)	ng/g (dry weight basis)	ng/g (dry weight basis)	ng/g (dry weight basis)	ng/g dry	mg/kg dry
HCB	0.012	0.018	0.183	0.183	0.016	0.015	300	0.3
alpha-HCH	< 0.001	< 0.0013	< 0.001	0.083	< 0.0017	< 0.0019	77	0.077
beta-HCH	< 0.001	NDR 0.002	< 0.0016	0.087	< 0.0028	< 0.0031	270	0.27
gamma-HCH	NDR 0.001	0.003	0.013	0.919	< 0.002	< 0.0022	520	0.52
HEPTACHLOR	< 0.001	0.01	< 0.001	0.29	< 0.001	< 0.001	110	0.11
ALDRIN	NDR 0.001	< 0.001	< 0.001	0.59	NDR 0.002	< 0.001	29	0.029
OXYCHLORDANE	< 0.0011	< 0.0024	NDR 0.072	NDR 0.473	< 0.002	< 0.0027		
t-CHLORDANE	NDR 0.002	0.177	0.232	4.91	0.004	NDR 0.003		
c-CHLORDANE	NDR 0.003	0.165	0.241	4.12	NDR 0.004	NDR 0.003		
t-NONACHLOR	0.001	0.128	0.292	2.01	NDR 0.003	NDR 0.003		
c-NONACHLOR	< 0.001	0.034	0.152	1.59	< 0.001	NDR 0.006		
o,p-DDD	< 0.003	< 0.006	< 0.0061	0.549	< 0.0058	< 0.0082		
p,p-DDD	< 0.0035	0.015	< 0.0071	0.99	< 0.0067	< 0.0095		
o,p-DDE	< 0.0022	< 0.0034	< 0.0032	1.58	< 0.004	< 0.0055		
p,p-DDE	0.007	0.058	0.02	10.2	0.008	< 0.007	1400	1.4
o,p-DDT	< 0.0052	< 0.0097	< 0.0094	0.164	< 0.0089	< 0.0128		
p,p-DDT	< 0.0063	NDR 0.02	0.02	0.706	0.014	< 0.017		
MIREX	0.001	0.075	0.095	0.359	0.009	NDR 0.005	27	0.027
delta-HCH	< 0.001	NDR 0.002	< 0.0016	37.7	NDR 0.002	< 0.001		
Heptachlor-Epoxide	< 0.001	0.006	0.041		< 0.001	< 0.001	53	0.053
alpha-Endosulphan		NDR 0.039	NDR 0.017		NDR 0.024	NDR 0.027		
Dieldrin	0.004	0.03	0.044		0.009	NDR 0.003	30	0.03
Endrin	NDR 0.003	< 0.0012	NDR 0.004		NDR 0.002	< 0.0019	18000	18
beta-Endosulphan		NDR 0.008	NDR 0.049		NDR 0.033	NDR 0.041		
Endosulphan-Sulphate		NDR 0.03	NDR 0.021		NDR 0.017	NDR 0.011		
Endrin-Aldehyde	0.002	< 0.0022	< 0.0019		< 0.0026	NDR 0.002		
Endrin-Ketone	< 0.001	< 0.001	< 0.001		< 0.001	< 0.0011		
Methoxychlor	< 0.0029	< 0.003	< 0.0064		< 0.0023	< 0.0019	310000	310
Total Toxaphene			< 0.0597	< 1.2			440	0.44
% Moisture	51.5	19.6	14.2	37.7	13.1	12.2		
Chlordane	0.005	0.342	0.473		0.008	0.006	1600	1.6
Total DDD	0.0065	0.021	0.0132		0.0125	0.0177	2000	2
Total DDT	0.0115	0.0297	0.0294		0.0229	0.0298	1700	1.7
Endosulfan	0	0.047	0.066		0.057	0.068	370000	370

[1] Measured concentrations were measured against the lowest applicable USEPA region 3 risk based concentrations, the residential soil guideline for the protection of human health. Grey shading indicates a sum of individual analytes higher in the table.

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 (October 2008) and the site reconnaissance and sampling program (August 2008).

Table 3.3 Potential Human Receptors related to the AHSL site, Malaysia (within 1 km radius).

Air Hitam Sanitary Landfill, Selangor, Malaysia	Estimated numbers
Potentially exposed:	
▪ Residents of housing area (1km radius)	6,095
▪ Full time staff of the site	9
▪ Full time security	3
▪ Students & staff of nearby secondary school (pending)	1,000
▪ Shift workers and visitors	45
Total	7,253

Site workers and security persons working permanently at the site are primary potential receptors. A public health and socio-economic survey conducted by the National Consultant (Mazrura 2009) revealed that some of the nearby residents (2.7% of the total respondance) may be involved directly in activities that could increase their exposure to contaminants present at the site.

Near to the site there are approximately 1,500 housing units in 3 main residential areas covering an area of over 800 hectares. An estimated 6,253 people live within 1 km radius of the site (Figure 3.2).

Figure 3.2 Vulnerability Map, AHSL, Puchong, Selangor, Malaysia.

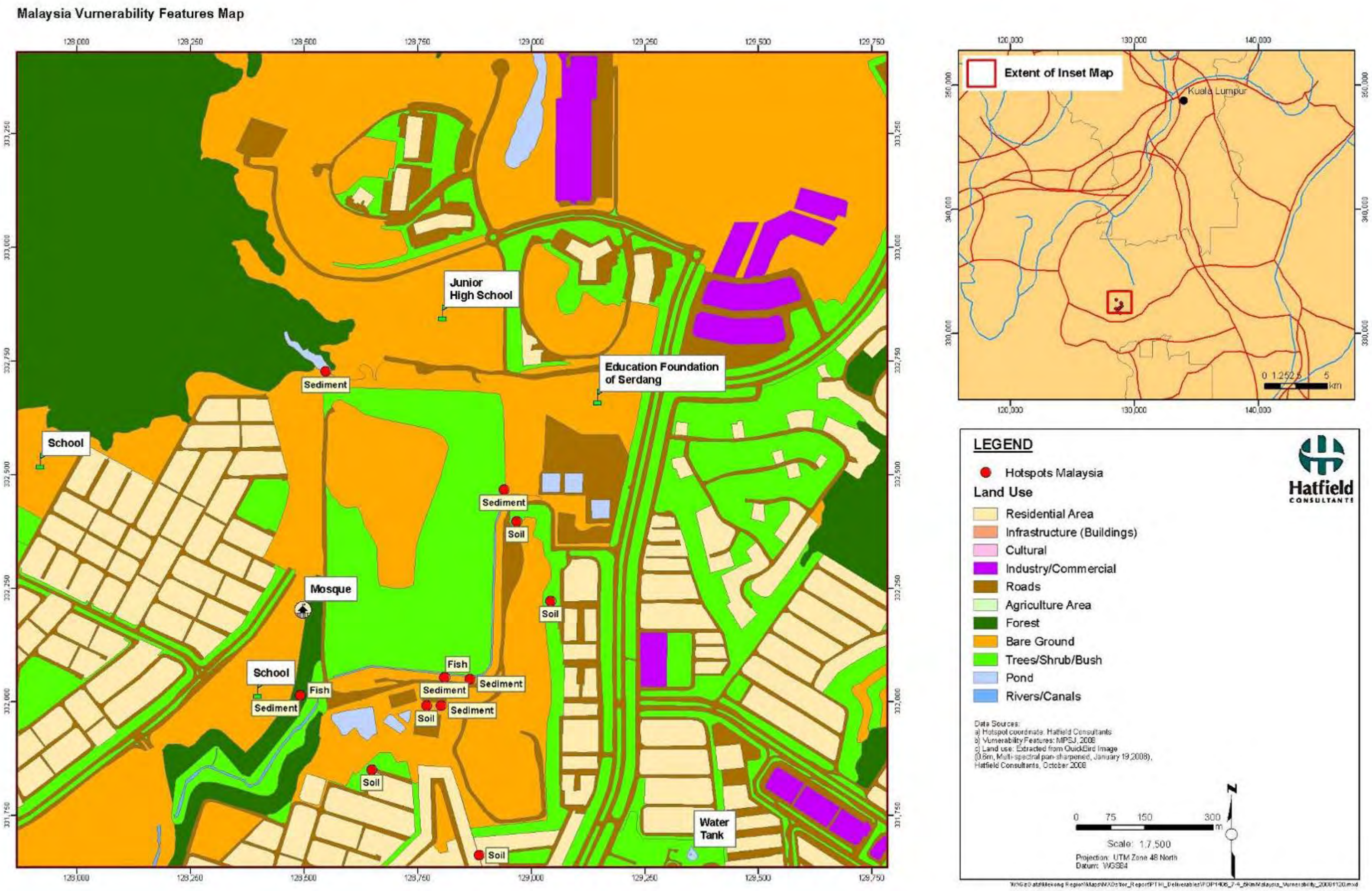


Figure 3.3 Potential receptors associated with the AHSL site, Malaysia.

Children living in housing adjacent to the site

.Fish living in the aquatic receiving environment.

Families living in housing adjacent to the site.

Natural receiving environment (ecological receptors)

Natural receiving environment (ecological receptors)

3.4 IDENTIFICATION OF PATHWAYS

An exposure pathway is the route a chemical ***hazard*** takes to reach (and potentially affect) a ***receptor.*** Exposure pathways generally fall in 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 (in other countries) people bringing PCB containing oils home to be burned in kitchen fires.

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

Potential exposure pathways at the AHSL site were identified using the results of the human exposure survey (October 2008, Mazrura 2009) and the site reconnaissance and sampling program (August 2008).

There are several potential exposure pathways at the site related to the treatment pond sediments:

- On-site: inhalation, accidental ingestion and dermal contact of treatment pond sediments;
- Off-Site: wind erosion/transportation to off-site water bodies with treated leachate waters, followed by 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 AHSL site four conceptual models were created to show these interrelationships (Figure 3.4 to Figure 3.7).

Figure 3.4 Conceptual Exposure Model for Landfill Employees, AHSL site, Malaysia.

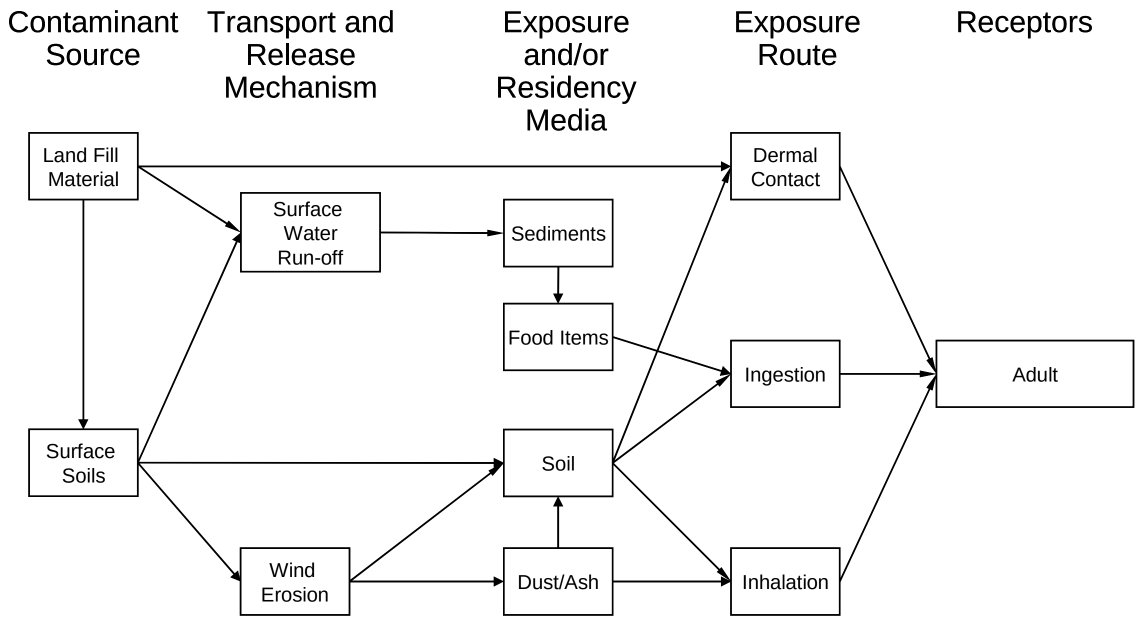


Figure 3.5 Conceptual Exposure Model for Local Residents, AHSL site, Malaysia.

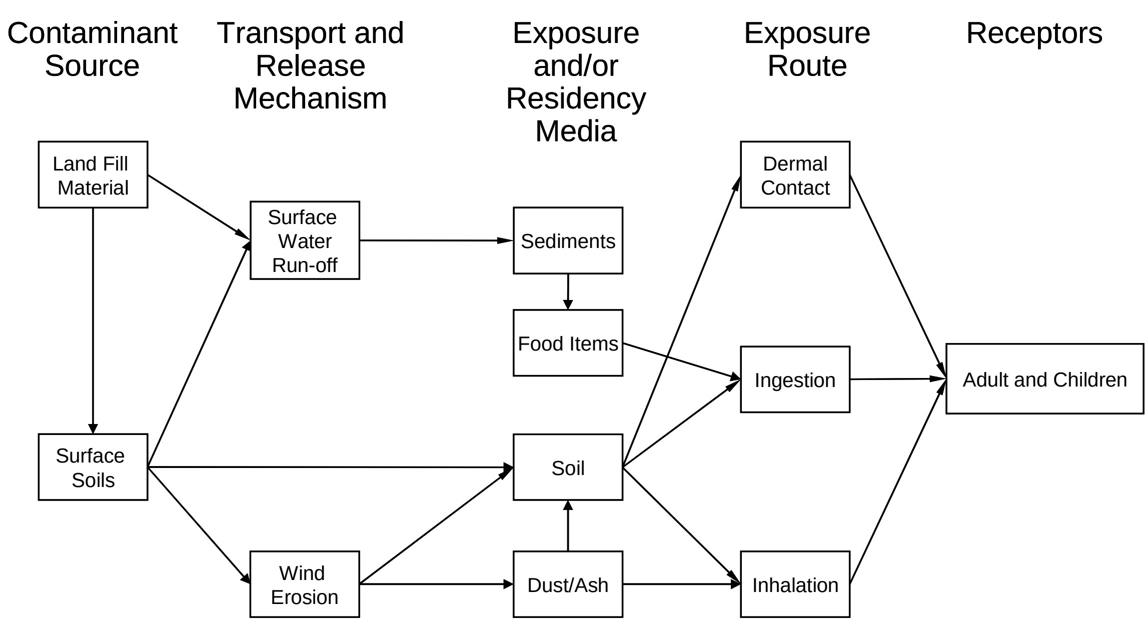


Figure 3.6 Conceptual Exposure Model for Aquatic Animals, AHSL site, Malaysia.

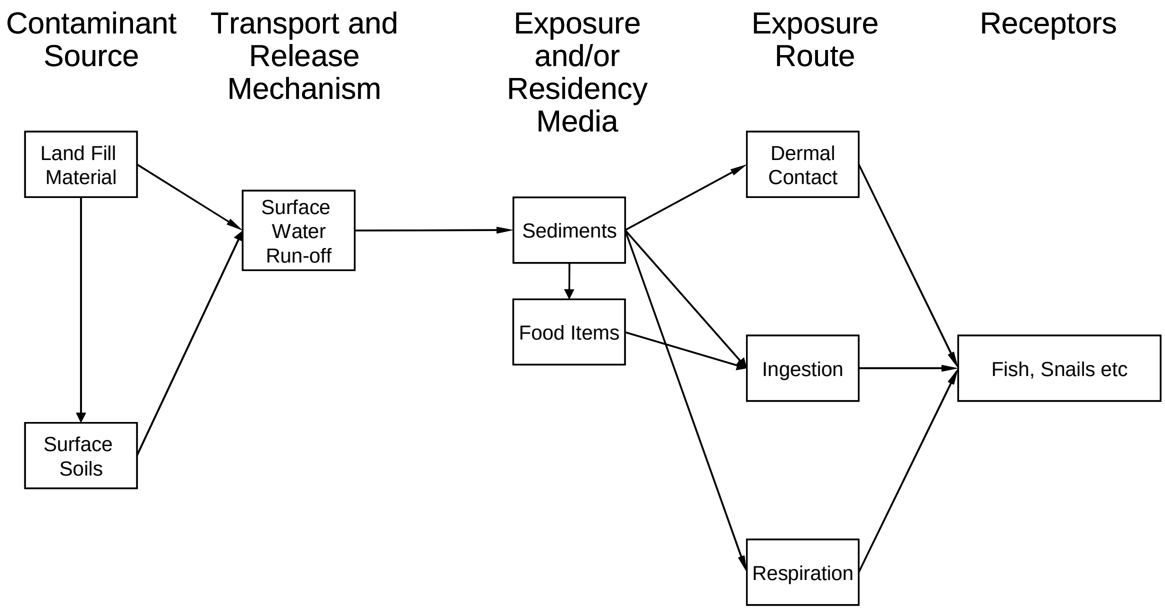


Figure 3.7 Conceptual Exposure Model for Terrestrial Animals, AHSL site, Malaysia.