Horizon 2020
TO DE-POLLUTE THE MEDITERRANEAN BY THE YEAR 2020

Training on mercury management and remediation of contaminated sites

Human Health Risk Assessment

Mercury contaminated sites

Almadén, Spain. 18-19 November 2015

UNEP

MAP

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Definition

A *Human health risk assessment* is the process to estimate the nature and probability of adverse health effects in humans who may be exposed to chemicals in contaminated environmental media, now or in the future (*EPA*)

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Main objectives

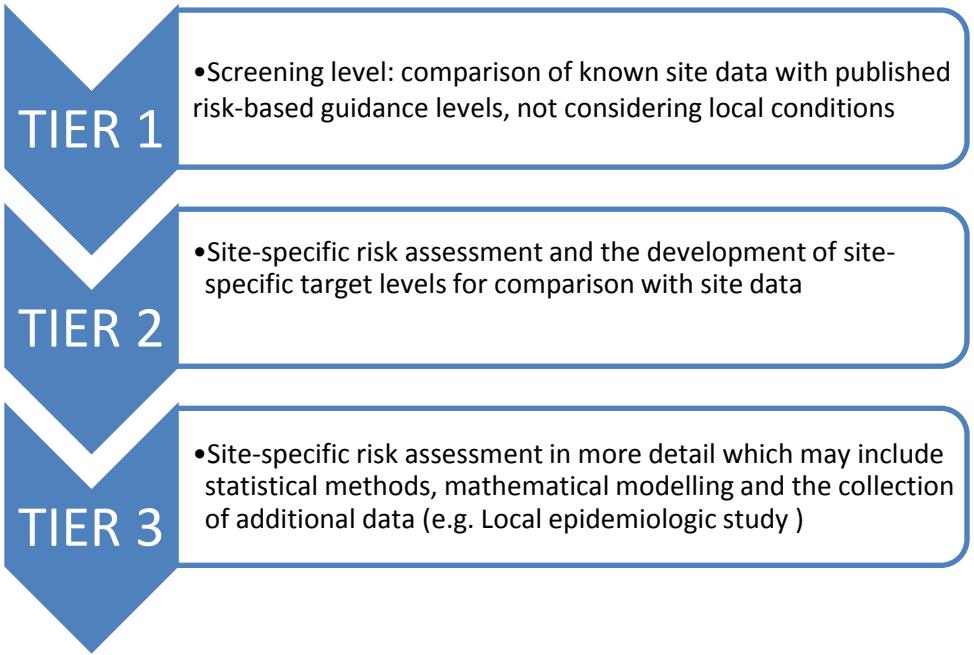
✓to determine tolerable levels of contaminants in soil and groundwater that are protective of public health and ecosystems: Site Specific Target Level (SSTL)

✓to provide a consistent methodology for appraising and recording public health risks at contaminated sites

✓to establish the baseline risks and determine whether site remediation is required (Decision-making)

✓to enable the comparison of potential health impacts of various remedial technologies.

Tiers of analysis



European soils policies

- ✓EU Thematic Strategy for Soil Protection, adopted in 2006
- ✓Some countries:
  - ✓National policies for the management of contaminated sites
  - ✓Specific legislation regulating investigation and clean-up of contaminated land

- ✓*Proposal for a Directive of the European Parliament and of the Council establishing a framework for the protection of soil and amending Directive 2004/35/EC (may of 2014)*

European soils policies

Overview of general practices for the identification and characterisation of contaminated sites in twenty three European countries (based on data from: Ferguson, 1999; CLARINET, 2002; CLARINET, Contaminated Land Approaches in 16 European Countries, Online on the internet http://www.clarinet.at/policy/, accessed: December 27, 2007)

Country	Most common approach for the classification of contaminated sites and definition of clean-up criteria	Specific contaminated land policy
Austria	Site-specific risk assessment	Yes
Belgium (Flanders)	Site-specific risk assessment (exposure assessment)	Yes
Bulgaria	Norms of maximum admissible contents of hazardous substances in the soil	No
Czech Republic	"ABC" limit values: A — background values; B — Possible possible adverse effects; C — Significant significant risk to human health and the environment. Risk assessment approach for state B criterion.	No
Denmark	Risk-based guideline values	Yes
Estonia	Target values and guidance values (based on risk for human health)	Preliminary
Finland	Risk-based guideline values	No
France	Site-specific risk assessment (tiered approach: preliminary site investigation; simplified risk assessment; detailed risk assessment)	No
Germany	Risk-based soil screening values (trigger values) and action values	Yes
Hungary	Limit values for soil and groundwater: A: background values; B: Threshold threshold values of contamination; C: Threshold threshold values of measures; D: target values. (based on Dutch, German, US EPA and Canadian guidelines)	Preliminary
Italy	Original 'limit value' approach has been included into a 'risk-based' multi-tier approach: Tier 1 — screening values or contamination threshold values; Tier 2 — site-specific target levels or risk threshold values	Yes
Latvia	Threshold values (Dutch threshold values used as reference)	No
Lithuania	Standards for contaminated soil and groundwater drafted (in line with Dutch threshold values). Site-specific simplified risk assessment.	No
Norway	Tiered approach: Tier 1 — generic target values ("TVs" based on existing Dutch and Danish guidelines); Tier 2 — site specific risk assessment (when TVs are exceeded); Tier 3 — Detailed detailed investigation	Part of "Pollution Control Act" and several specific Guidelines
Poland	Standards for environmental protection are generally based on fixed regulatory limits, but still no generic values for contaminated land. US EPA methods often used in site-specific risk assessments.	No
Portugal	Guideline values — Ontario (Canada) guideline values used as reference	No (under development)
Slovakia	Target values or permissible levels (former Dutch threshold values list was adapted in 1994)	Yes
Slovenia	Limit, warning and critical concentration values of dangerous substances in soil	Yes
Spain	Screening/guideline values and site-specific risk assessment	Yes
Sweden	Site-specific risk assessment (exposure assessment). The Swedish EPA defined guideline values for levels in polluted soils, for the most sensitive types of land-uses	No
Switzerland	Site-specific risk analysis. Intervention values for leachate and gaseous phase.	Yes
Netherlands	Risk-based norms (criteria): *target values* and *intervention values*	Yes
United Kingdom	Site-specific risk assessment based on Source–Pathway–Receptor approach and on the definition of "pollutant linkages". ". Soil Guideline Values have been derived using the Contaminated Land Exposure Assessment (CLEA) model for three land uses.	Yes

Environment International, 2009

Human health Risk Assessment

Spanish approach

- ✓Royal Decree 9/2005
  - ✓Risk-based Generic Values of Reference (GVRs) for 60 priority pollutants
  - ✓Site-specific risk assessment ⟹ Risk-based Corrective Action
- ✓Law 22/2011

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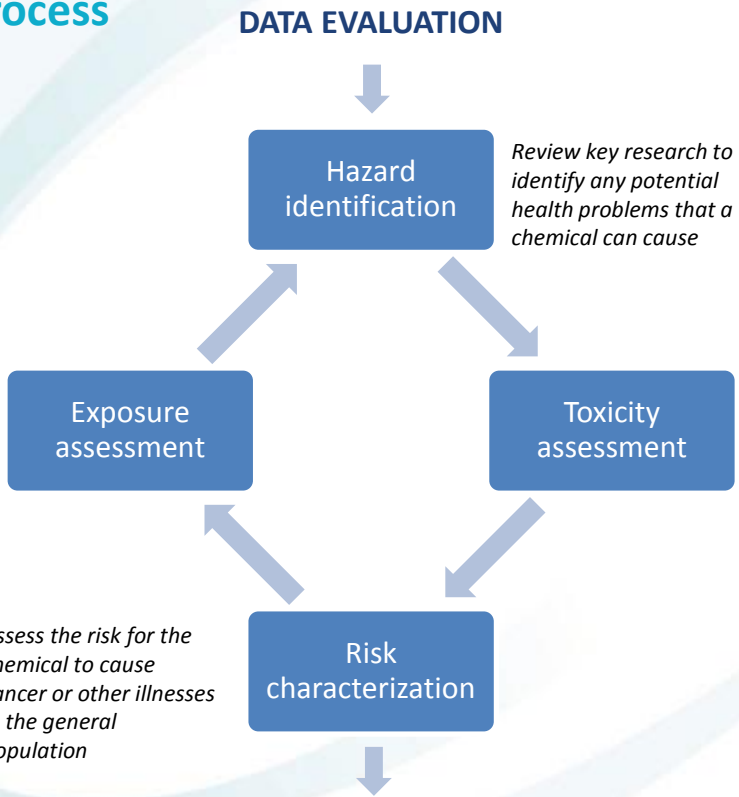
Human health Risk Assessment

Four-Step Process



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Step 0: Planning and Scoping Process and Data Evaluation

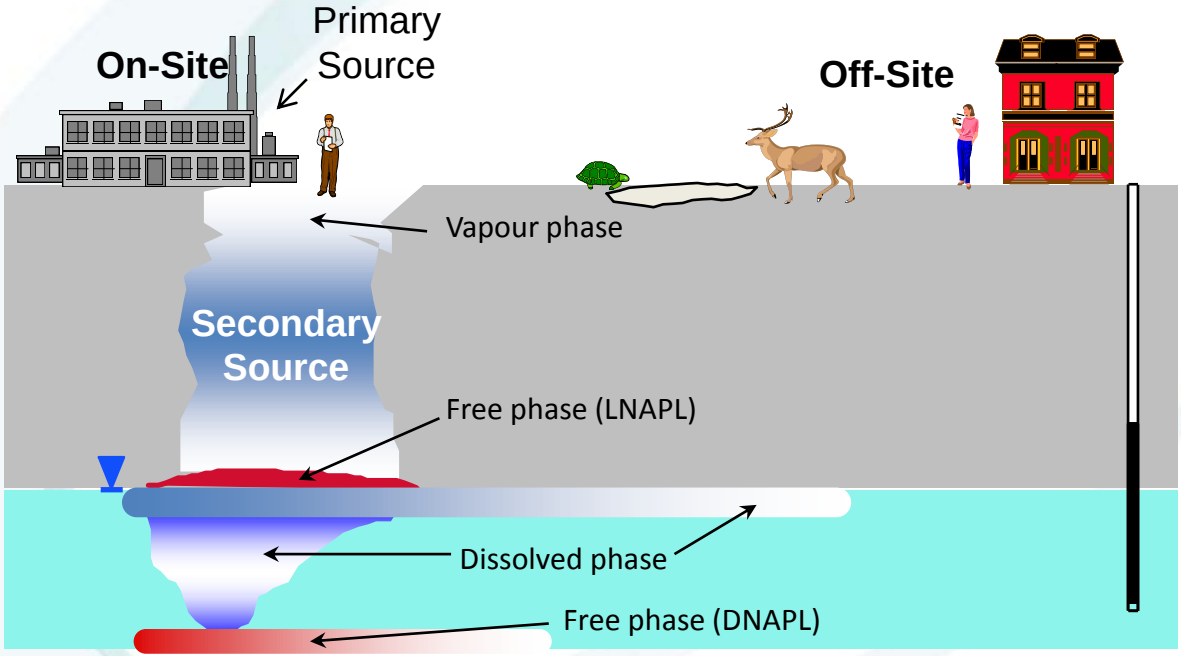
✓Planning and research

✓Developing a Conceptual Site Model (CSM): is a *representation of the physical, chemical and biological processes that control the transport, migration and actual/potential impacts of contamination (in soil, air, ground water, surface water and/or sediments) to human and/or ecological receptors*.

✓Factors to be considered:

- ✓the contaminants: concentration, distribution and media affected, on and off the site
- ✓ physical characteristics of the environment
- ✓ characteristics of the exposed population
- ✓means by which exposure could occur

CSM- Source



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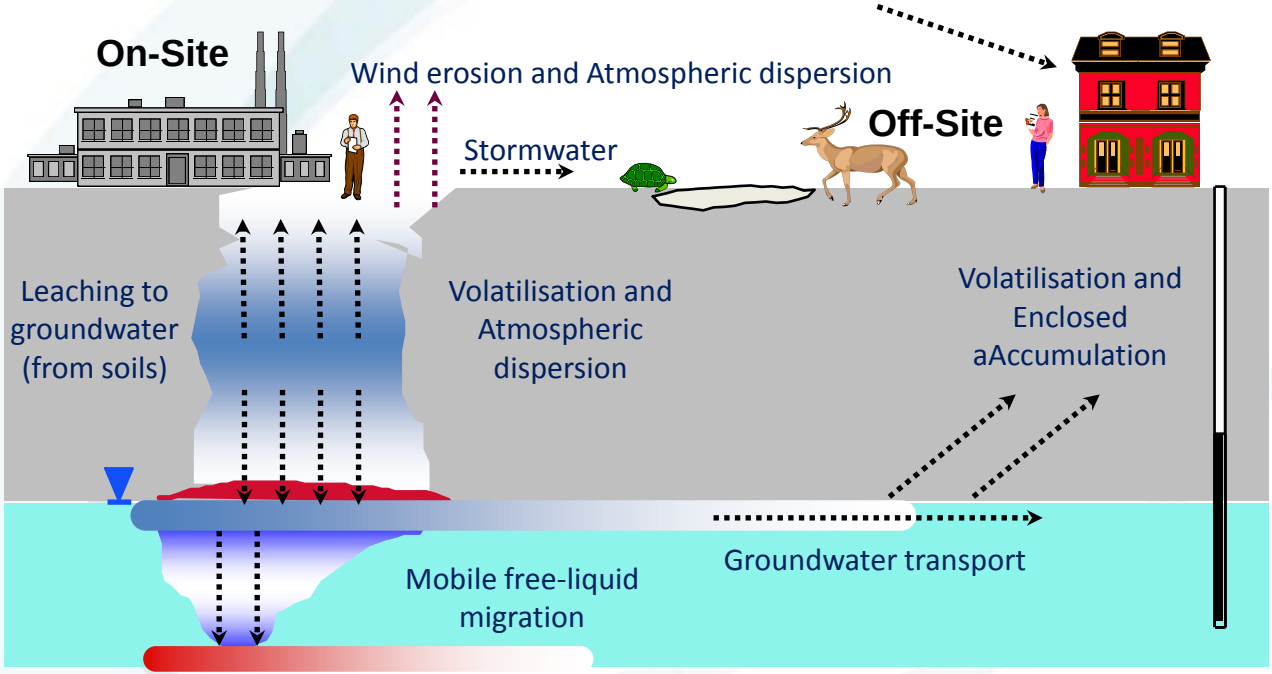
Human health Risk Assessment

SCM- Transport



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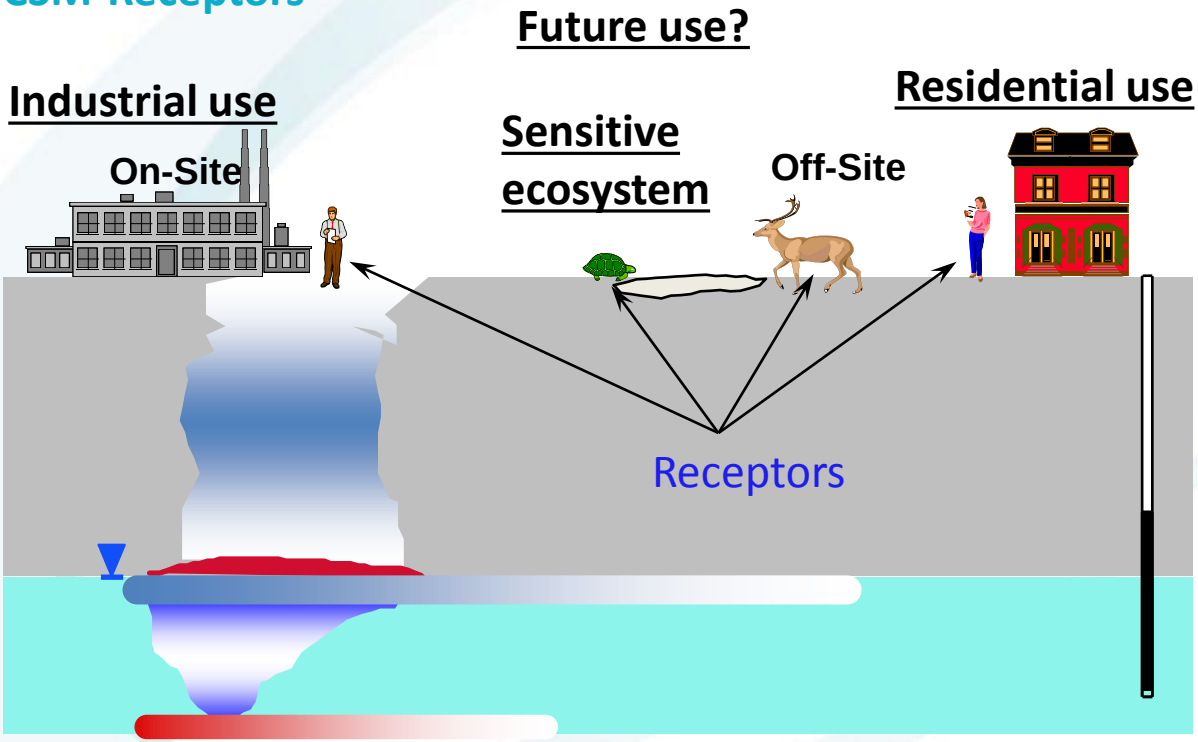
Human health Risk Assessment

CSM-Receptors



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Step 1: Hazard Identification

✓ Process of determining whether exposure to a stressor can cause an increase in the incidence of specific adverse health effects (e.g., cancer, birth defects). It is also whether the adverse health effect is likely to occur in humans.

✓Types of health effects:

- ✓Acute effects
- ✓Chronic threshold effects (all kinds of chronic toxicity other than cancer)
- ✓Chronic cancer effects

✓Source of data:

- ✓Statistically controlled clinical studies on humans and animals (more common)
- ✓Epidemiological studies

Step 2: Exposure Assessment

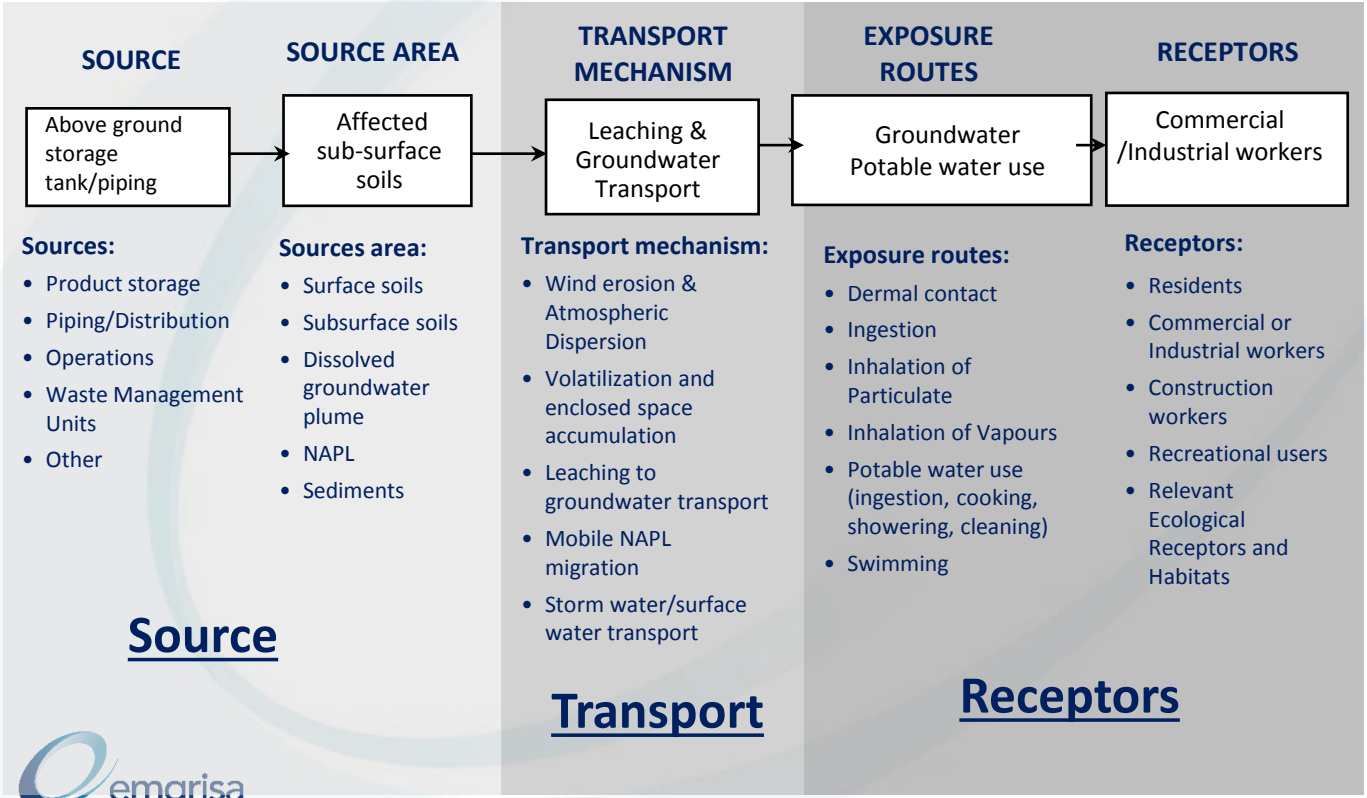
✓ Estimation of the magnitude, frequency, extent and duration of exposures to contaminants

✓The key elements of exposure assessment are:

- ✓ Analysis of contaminant releases (concentration)
- ✓ Identification of potential exposure pathways
- ✓ Estimation of exposure for each pathway
- ✓ Estimation of contaminant intake for each pathway
- ✓ Evaluate uncertainties

Human health Risk Assessment

Exposure Pathway Flowchart



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Step 3: Toxicity Assessment

✓Defines toxicity and dose-response relationship for each contaminant of concern

✓Literature-based research exercise.

✓Sources of toxicity information (among others):

- ✓ World Health Organization sources
- ✓IRIS (Integrated Risk Information Systems), USEPA
- ✓Risk Assessment Information System (RAIS)
- ✓International Agency for Research on Cancer (IARC) documents

Step 4 : Risk Characterization

✓ Information from the data collection, exposure and toxicity assessments is summarised and integrated.

✓Three steps:

- ✓Risk estimation
- ✓Risk evaluation
- ✓Sensitivity and uncertainty analysis

Step 4 : Risk Characterization

✓**Non-carcinogenic substances:**

Characterized by a threshold below which the body is able to cope with or recover from the exposure

HI (Hazard Index**)=∑HQ (**Hazard Quotient**) = Intake** non-carcinogenic**/ Reference Dose Factor**

HI >1 →UNSAFE

HI <1 →SAFE

✓**Carcinogenic substances:**

There is no threshold and the effect of episodic doses accumulate. There is no zero risk if there is exposure at all

IELCR = **Intake** carcinogenic **x Slope Factor** (SFo) of the Dose response curve

IELCR = Individual Excess Lifetime Cancer Risk

Acceptable threshold is 10^{-5} (in Spain)

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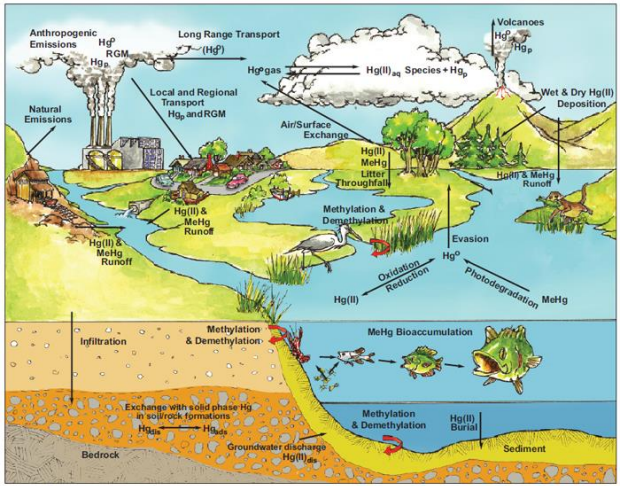
Mercury (Hg)

- ✓Mercury exists in several forms:
  - ✓methylmercury and other organic compounds,
  - ✓elemental (metallic) mercury and
  - ✓inorganic mercury compounds.



Source: Tetra Tech, Inc. 2010

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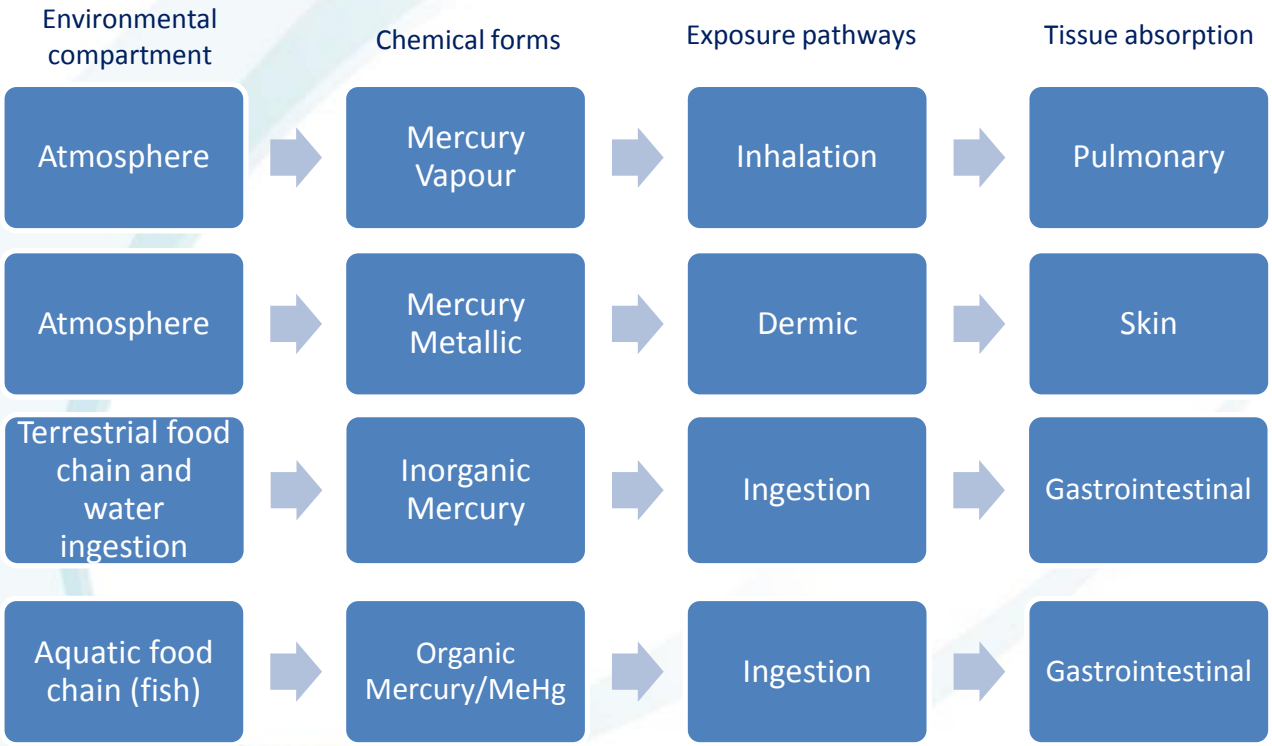
Mercury (Hg) toxicity

- ✓For exposed living organisms, the form of mercury affects:
  - ✓how available it is to cause effects within the body;
  - ✓how it moves around inside the body;
  - ✓how toxic it is;
  - ✓how it accumulates, is transformed and leaves the body;
  - ✓how it biomagnifies (builds up) along the food chain.

- ✓There are important qualitative and quantitative differences in the toxicity of different species of Mercury (e.g. methylmercury and Hg^{2+} ions).

- ✓e.g. Cancer Risk (EPA):
  - ✓Elemental mercury: Group D, not classifiable as to human carcinogenicity
  - ✓Inorganic mercury: mercuric chloride, as a Group C, possible human carcinogen
  - ✓Methylmercury: Group C, possible human carcinogen

Mercury (Hg) main exposure assessment



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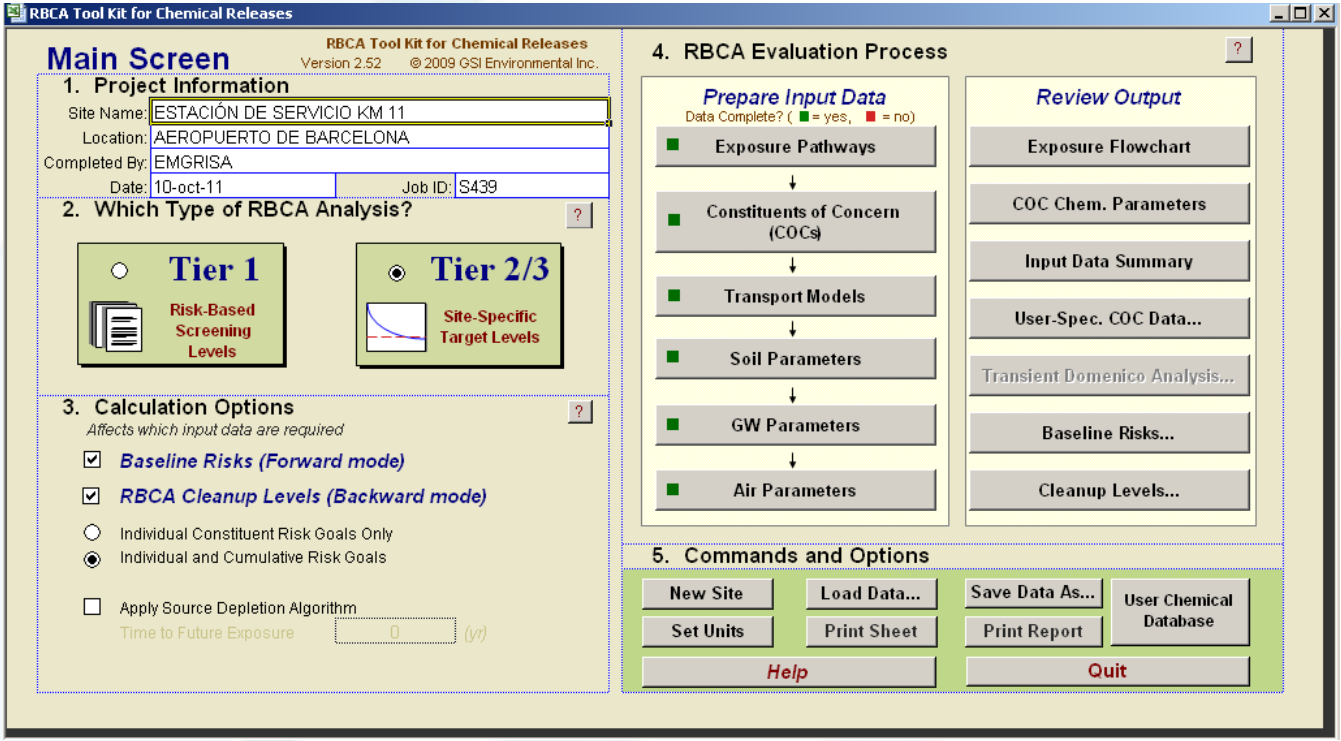
Software

- ✓ UMS System (Germany)
- ✓Vlier-Humaan (Belgium)
- ✓JAGG (Denmark)
- ✓Arrikugest (Spain)
- ✓ConSim (Great Britain)
- ✓P20—RTW (Great Britain)
- ✓CLEA (Great Britain)
- ✓Risc-Human (The Netherlands)
- ✓ROME (Italy)
- ✓RBCA Tool Kit for Chemical Releases (USA): http://www.gsi-net.com/en/software/rbca-tool-kit-for-chemical-releases-version-2-6e.html
- ✓RISC (USA): http://www.groundwatersoftware.com/risc.htm

RBCA Tool Kit for Chemical Releases



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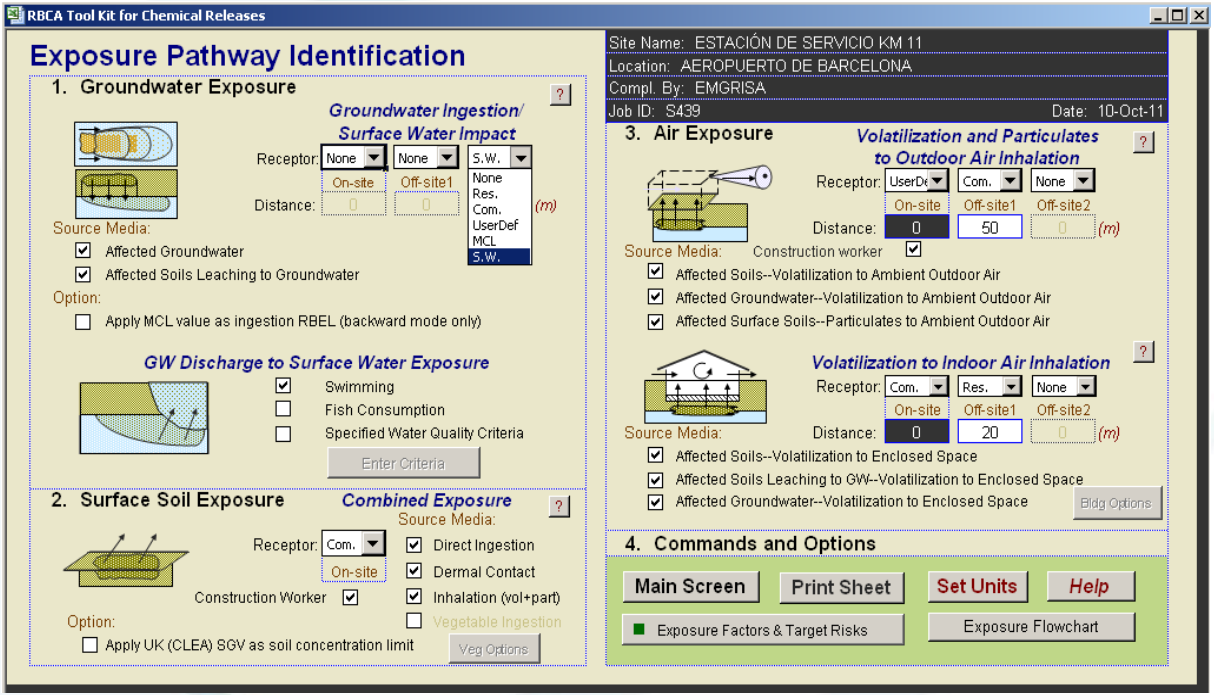
RBCA Tool Kit for Chemical Releases



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RBCA Tool Kit for Chemical Releases

RBCA Tool Kit for Chemical Releases

Exposure Factors and Target Risk Limits

Site Name: ESTACIÓN DE SERVICIO KM 11
Location: AEROPUERTO DE BARCELONA
Compl. By: EMGRISA
Job ID: S439 Date: 10-Oct-11

1. Exposure Parameters

	Residential Receptors			Commerical Receptors		User Defined
	Child	Adolescent	Adult	Adult	Construc.	
Averaging time, carcinogens (yr)	70					70
Averaging time, non-carcinogens (yr)	6	12	1	25	1	25
Body weight (kg)	15	35	70	70	70	70
Exposure duration (yr)	6	12	1	25	1	25
Averaging Time for Vapor Flux (yr)	30			30	30	30
Exposure frequency (d/yr)	350			230	180	28,75
Dermal exposure freq. (d/yr)	350			230	180	28,75
Seasonal-avg skin surface area (cm^2/d)	2023	2023	3160	3160	3160	3160
Soil dermal adherence factor (mg/cm^2)	0,5	0,5	0,5	0,5	0,5	0,5
Water ingestion rate (L/d)	1	1	2	1	1	1
Soil ingestion rate (mg/d)	200	200	100	50	100	50
Swimming exposure time (hr/event)	1	8	8			
Swimming event frequency (events/yr)	12	180	180			
Swimming water ingestion rate (L/hr)	0,5	0,001	0,001			
Skin surface area, swimming (cm^2)	3500	5900	5900			
Fish consumption rate (kg/d)	0,025	0,025	0,025			
Vegetable ingestion rate (kg/d)						
Above-ground vegetables	0,002	0,002	0,006			
Below-ground vegetables	0,001	0,001	0,002			
Contaminated fish fraction (-)	1					

2. Age Adjustment for Carcinogens

(residential receptor only)

	Adjustment Factor	
Seasonal skin surface area, soil contact	367,686	(cm^2-yr/kg)
Water ingestion	0,25714	(mg-yr/L-day)
Soil ingestion	124,286	(mg-yr/kg-day)
Swimming water ingestion	2,418	(L/kg)
Skin surface area, swimming	106200	(cm^2-yr/kg)
Fish consumption	0,0125	(kg-yr/kg-day)
Below-ground vegetable ingestion	0,09	(kg-yr/kg-day)
Above-ground vegetable ingestion	0,01	(kg-yr/kg-day)

3. Non-Carcinogenic Receptor

(residential receptor only)

Adult

4. Target Health Risk Limits

	Individual	Cumulative
Target Cancer Risk (Carcinogens)	1,0E-5	1,0E-5
Target Hazard Quotient/Index (non-Carc.)	1,0E+0	1,0E+0

5. Commands and Options

Return to Exposure Pathways

Use/Set Default Values

Print Sheet

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RBCA Tool Kit for Chemical Releases

RBCA Tool Kit for Chemical Releases

Site-Specific Soil Parameters

1. Soil Source Zone Characteristics

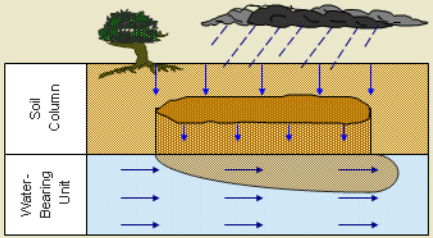
Hydrogeology

Depth to water-bearing unit	2,054	(m)
Capillary zone thickness	0,05	(m)
Soil column thickness	2,004	(m)

Affected Soil Zone

Depth to top of affected soils	0	(m)
Depth to base of affected soils	2,054	(m)
Length of affected soil parallel to assumed GW flow direction	50	(m)

	Res/Com	Construction	
Affected soil area	2025		(m^2)
Length of affected soil parallel to assumed wind direction	50	50	(m)



Site Name: ESTACIÓN DE SERVICIO KM 11 — Job ID: S439
Location: AEROPUERTO DE BARCELONA — Date: 10-Oct-11
Compl. By: EMGRISA

2. Surface Soil Column

Predominant USCS Soil Type

Calculate

SW/SP: Sand

ASTM Default
SW/SP: Sand
SM: Silty Sand
SC: Clayey Sand
ML: Sandy Silt
ML: Silt
MH: Clayey Silt
CL: Sandy Clay
CL: Silty Clay
CH: Clay
CLEA-UK: Sand
CLEA-UK: Loam
CLEA-UK: Clay

Volumetric water content
Volumetric air content
Total porosity
Dry bulk density (kg/L)
Vertical hydraulic conductivity (m/d)
Vapor permeability (m^2)
Capillary zone thickness (m)

Net Rainfall Infiltration

Net infiltration estimate	Calculate	73,728	(mm/yr)
or		↑ or	
Average annual precipitation		640	(mm/yr)

Partitioning Parameters

Fraction organic carbon - entire soil column	0,009	(-)
Fraction organic carbon - root zone	0,01	(-)
Soil/water pH	6,8	(-)

3. Commands and Options

Main Screen | Use/Set Default Values | Print Sheet
Set Units | | Help

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RBCA Tool Kit for Chemical Releases

Site-Specific Groundwater Parameters

Site Name: ESTACIÓN DE SERVICIO KM 11 — Job ID: S439
Location: AEROPUERTO DE BARCELONA — Date: 10-Oct-11
Compl. By: EMGRISA

1. Water-Bearing Unit

Hydrogeology

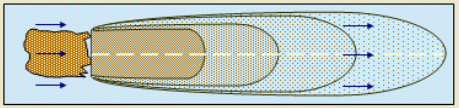
Groundwater Darcy velocity	6,0E-2	(m/d)
Groundwater seepage velocity	1,6E-1	(m/d)
or — Calculate	or	
Hydraulic conductivity	1,0E+2	(m/d)
Hydraulic gradient	0,0006	(-)
Effective porosity	0,38	(-)

Sorption

Fraction organic carbon--saturated zone	0,001	(-)
Groundwater pH	6,2	(-)

2. Groundwater Source Zone

Groundwater plume width at source	50	(m)
Plume (mixing zone) thickness at source	5,45877387	(m)
Calculate — or		
Saturated thickness	15	(m)
Length of source zone	50	(m)



3. Groundwater Dispersion

Model: ASTM Default

	GW Ingestion		GW to Indoor Air	
	Off-site 1	Off-site 2	Off-site 1	Off-site 2
Distance to GW receptors	0	0	0	0 (m)
Calculate				
Longitudinal dispersivity				(m)
Transverse dispersivity				(m)
Vertical dispersivity				(m)

4. Groundwater Discharge to Surface Water

	Off-site 2	
Distance to GW/SW disharge point	0	(m)
Plume width at GW/SW discharge	50	(m)
Plume thickness at GW/SW discharge	2	(m)
Surface water flowrate at GW/SW discharge	1E-99	(m^3/s)

5. Commands and Options

Main Screen | Use/Set Default Values | Print Sheet
Set Units | | Help

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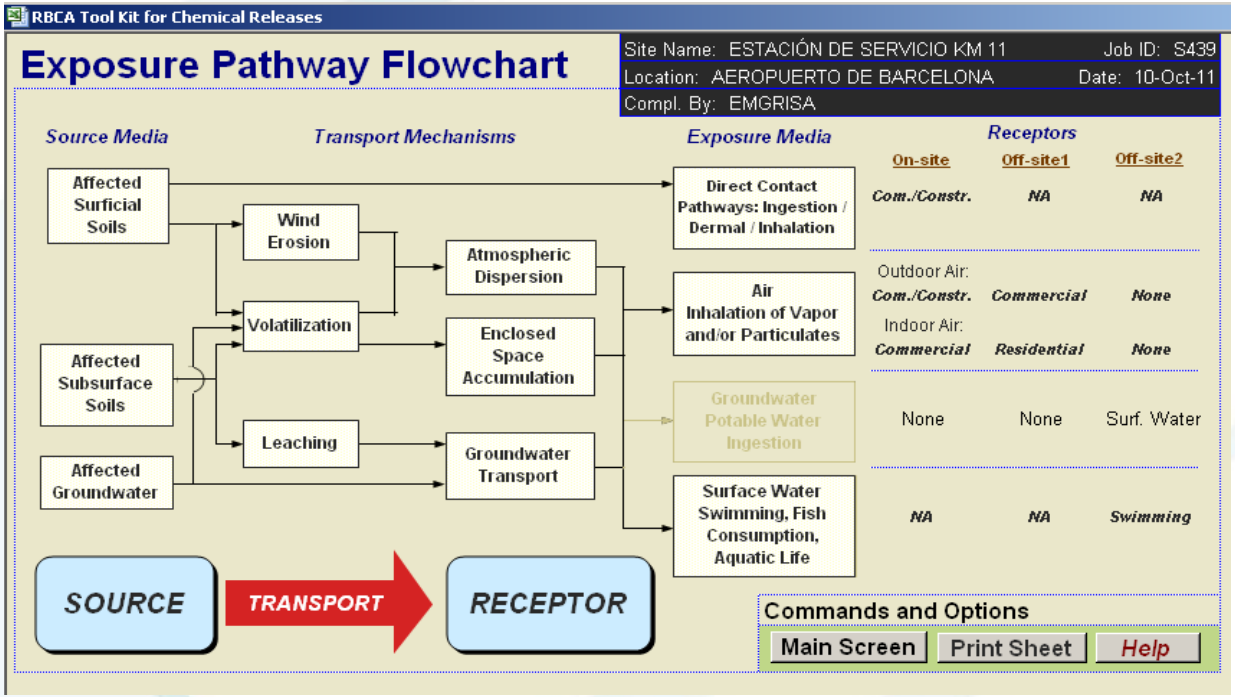

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Human health Risk Assessment

RBCA Tool Kit for Chemical Releases

RBCA SITE ASSESSMENT — **Input Parameter Summary**

Site Name: TALLER ADIF MIRANDA EBRO. Z. SUMINISTRC
Site Location: MIRANDA DE EBRO (BURGOS)

Completed By: EMGRISA
Date Completed: 22/04/2016

Exposure Parameters		Residential				Commercial/Industrial		User Defined
		Child	Adolescent	Adult*	Age Adjusted**	Adult	Construct.	
ATc	Averaging time for carcinogens (yr)	70	70	70	NA	70	70	70
ATn	Averaging time for non-carcinogens (yr)	6	12	30	NA	25	1	25
BW	Body weight (kg)	15	35	70	NA	70	70	70
ED	Exposure duration (yr)	6	12	30	NA	25	1	25
τ	Averaging time for vapor flux (yr)	30	30	30	NA	30	30	30
EF	Exposure frequency (days/yr)	350	350	350	NA	230	180	58
EFD	Exposure frequency for dermal exposure	350	350	350	NA	230	180	58
IRw	Ingestion rate of water (L/day)	1	1	2	NA	1	NA	1
IRs	Ingestion rate of soil (mg/day)	200	200	100	NA	50	100	50
SA	Skin surface area (dermal) (cm^2)	2023	2023	3160	NA	3160	3160	3160
M	Soil to skin adherence factor	0,5	0,5	0,5	NA	0,5	0,5	0,5
ETswim	Swimming exposure time (hr/event)	1	1	1	NA	NA	NA	NA
EVswim	Swimming event frequency (events/yr)	90	90	90	NA	NA	NA	NA
IRswim	Water ingestion while swimming (L/hr)	0,5	0,5	0,05	NA	NA	NA	NA
SAswim	Skin surface area for swimming (cm^2)	3500	8100	23000	NA	NA	NA	NA
IRfish	Ingestion rate of fish (kg/yr)	0,025	0,025	0,025	NA	NA	NA	NA
Fifish	Contaminated fish fraction (unitless)	1	1	1	NA	NA	NA	NA
IRbg	Below-ground vegetable ingestion	0,002	0,002	0,006	NA	NA	NA	NA
IRabg	Above-ground vegetable ingestion	0,001	0,001	0,002	NA	NA	NA	NA
VGabg	Above-ground Veg. Ingest. Correction Factor	0,01	0,01	0,01	NA	NA	NA	NA
VGabg	Below-ground Veg. Ingest. Correction Factor	0,01	0,01	0,01	NA	NA	NA	NA

* = Adult Receptor used for Non-Carcinogens
** = NC= Age Adjustment not selected for this parameter. Age-adjusted rate is effective value corresponding to adult exposure factors.

Complete Exposure Pathways and Receptors	On-site	Off-site 1	Off-site 2
Groundwater:			
Groundwater Ingestion	None	None	None
Soil Leaching to Groundwater Ingestion	None	None	None
Apply MCL Values	No	No	No
Applicable Surface Water Exposure Routes:			
Swimming	NA	NA	None
Fish Consumption	NA	NA	None
Aquatic Life Protection	NA	NA	None
Soil:			
Direct Contact: direct combined pathways	None	NA	NA
Apply CLEA- UK SGV levels		No	
Outdoor Air:			
Particulates from Surface Soils	User Defined	None	None
Volatilization from Soils	User Defined	None	None
Volatilization from Groundwater	User Defined	None	None
Indoor Air:			
Volatilization from Soils	User Defined	NA	NA
Volatilization from Groundwater	User Defined	None	None
Soil Leaching to Groundwater Volatilization	User Defined	None	None

Receptor Distance from Source Media	On-site	Off-site 1	Off-site 2	(Units)
Groundwater receptor	NA	NA	NA	(m)
Outdoor air inhalation receptor	0	NA	NA	(m)
Indoor air inhalation receptor	0	NA	NA	(m)

Target Health Risk Values		Individual	Cumulative
TR	Target Risk (Carcinogens)	1,0E-5	1,0E-5
THQ	Target Hazard Quotient (non-carcinogenic risk)	1,0E+0	1,0E+0

Modeling Options	
RBCA tier	Tier 2
Outdoor air volatilization model	Surface & Subsurface Models: ASTM Model
Indoor air volatilization model	Johnson & Ettinger model
Soil leaching model	ASTM leaching model
Use soil attenuation model (SAM) for leachate?	No
Use dual equilibrium desorption model?	No
Apply Mass Balance Limit for Soil Volatilization?	No
Apply UK (CLEA) SGV as soil concentration limit	No
Vegetable calculation options	NA
Air dilution factor	NA
Groundwater dilution-attenuation factor	NA

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THANK YOU FOR YOUR ATTENTION!!!

Silvia de la Rosa López

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