Ecological Risk Assessment of Contaminated Sites

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The major types of risk assessment and their focus

Risk Assessment

- **Safety risks**
  low probability, high consequence, accidental, acute
  (human safety focus)
- **Health risks**
  high probability, low consequence, ongoing, chronic
  (human health focus)
- **Ecological/environmental risks**
  subtle changes, complex interactions, long latency, macro-impacts (habitat/ecosystem focus)
- **Public welfare/goodwill risks**
  perceptions, property value concerns, aesthetics
  (value focus)
- **Financial risks**
  business viability, liability, insurance, investment returns (economic focus)

Concepts and Definitions

- Ecological/Environmental risks
  - Subtle effects, myriad interactions among populations, communities, and ecosystems (including food chains) at micro and macro levels; great uncertainty in cause and effects.
  - Focus is on habitat and ecosystem impacts that may be manifest far away from the sources of concern.

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Introduction

- Ecological risk assessments are conducted to transfer scientific information about the risk of human activities to the environment. Their purpose is to enable risk managers to make informed environmental decision.

- Ecological risk assessment evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors.

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Introduction

- Ecological risk assessment is a flexible process for organizing and analyzing data, information, assumptions, and uncertainties to evaluate the likelihood of adverse ecological effects.

- Ecological risk assessment provides a critical element for environmental decision-making by giving risk managers an approach for considering available scientific information along with the other factors they need to consider (e.g., social, legal, political, or economic) in selecting a course of action.

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Introduction

- An assessment may involve chemical, physical, or biological stressors, and one stressor or many stressors may be considered.

- Ecological risk assessments are developed within a risk management context to evaluate human-induced changes that are considered undesirable.

- The acceptability of adverse effects is determined by risk managers.

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Introduction

- Although intended to evaluate adverse effects, the ecological risk management process can be adapted to predict beneficial changes or risk from natural events.

- Description of the likelihood of adverse effects may range from qualitative judgments to quantitative probabilities.

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Introduction

- Ecological risk assessments can be used to predict the likelihood of future adverse effects (prospective) or evaluate the likelihood that effects are caused by past exposure to stressors (retrospective).

- Combined retrospective and prospective risk assessments are typical in situations where ecosystems have a history of previous impacts and the potential for future effects from multiple chemical, physical, or biological stressors.

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Introduction

- Ecological risk assessment uses methods of systems analysis to integrate aspects of ecology, environmental chemistry, environmental toxicology, hydrology, and other earth sciences to estimate conditional probabilities of the occurrence of undesired ecological events.

- An ecological risk is the conditional probability of a specified ecological event occurring, coupling with some statement of its ecological consequences (e.g., reduced biodiversity, loss of commercially valuable resources, or ecosystem instability)

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Introduction

- In theory, ecological risk assessment applies to both natural and human impacts on ecological resources

- In practice, nearly all of the assessments address ecological impacts resulting from human activities

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The ecological risk assessment process

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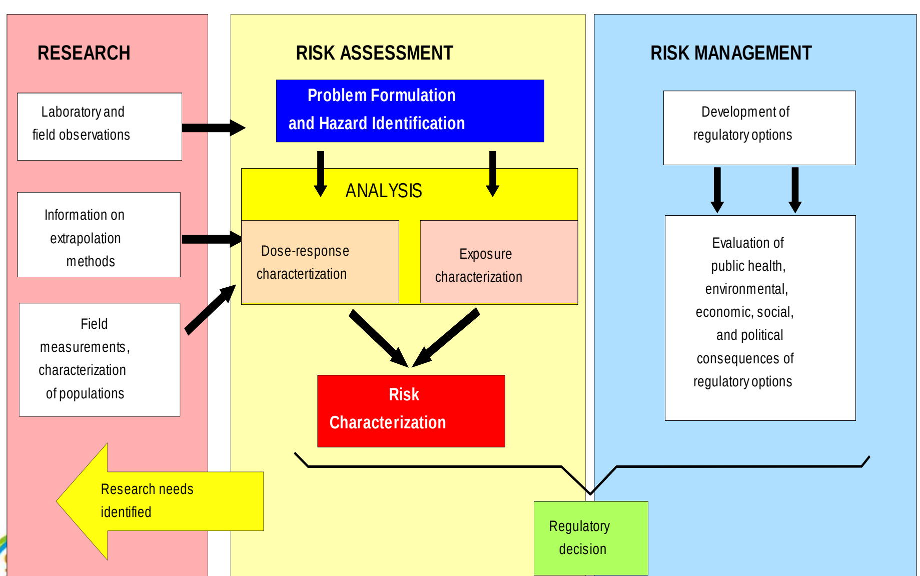
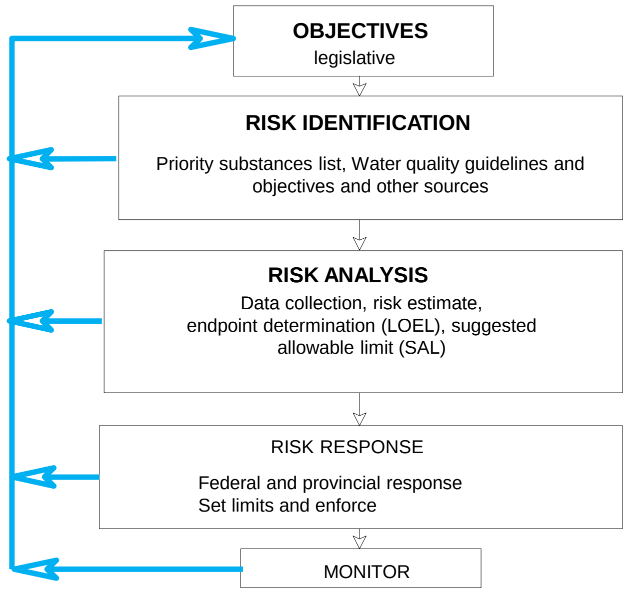
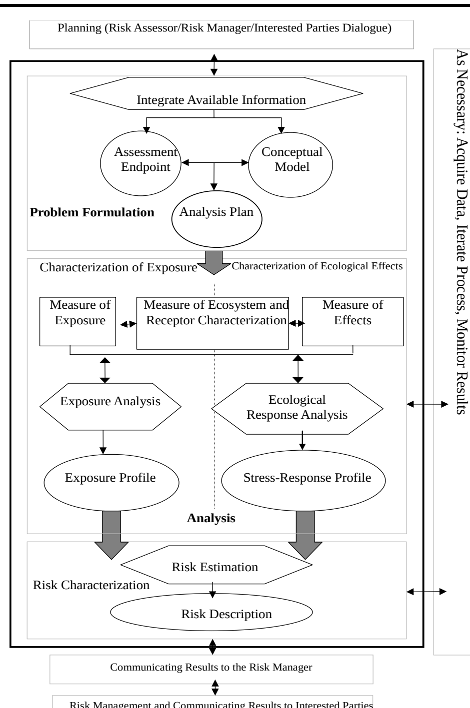
USEPA Risk Assessment Paradigm



Canadian Risk Assessment Paradigm

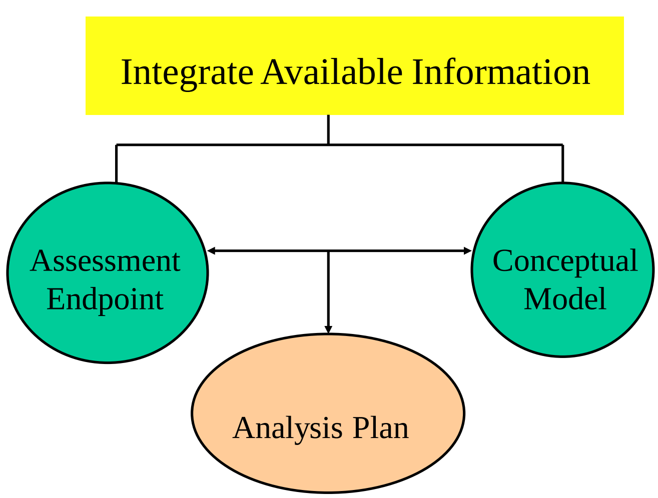




The ecological risk assessment framework

Problem Formulation

- Stressor characteristics
- Ecosystem at risk
- Assessment endpoints
- Ecological effects
- Conceptual model



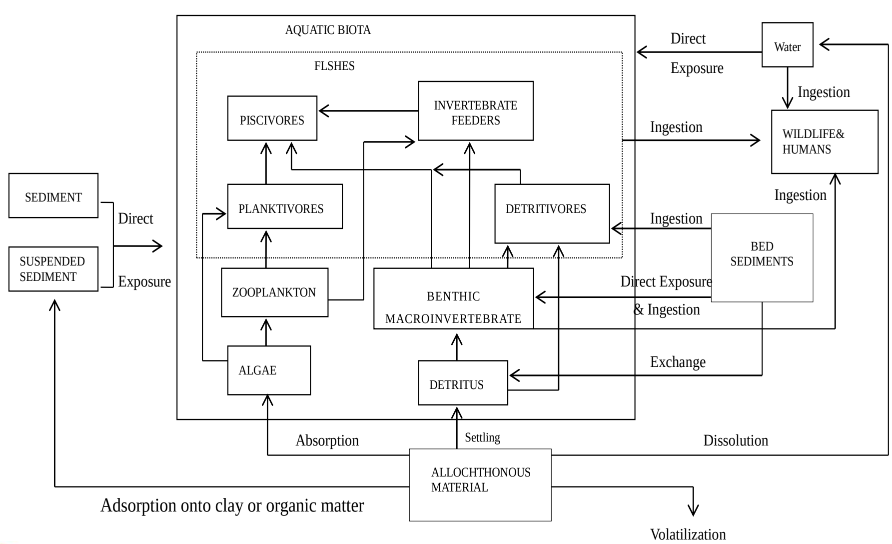
Problem Formulation

Problem formulation

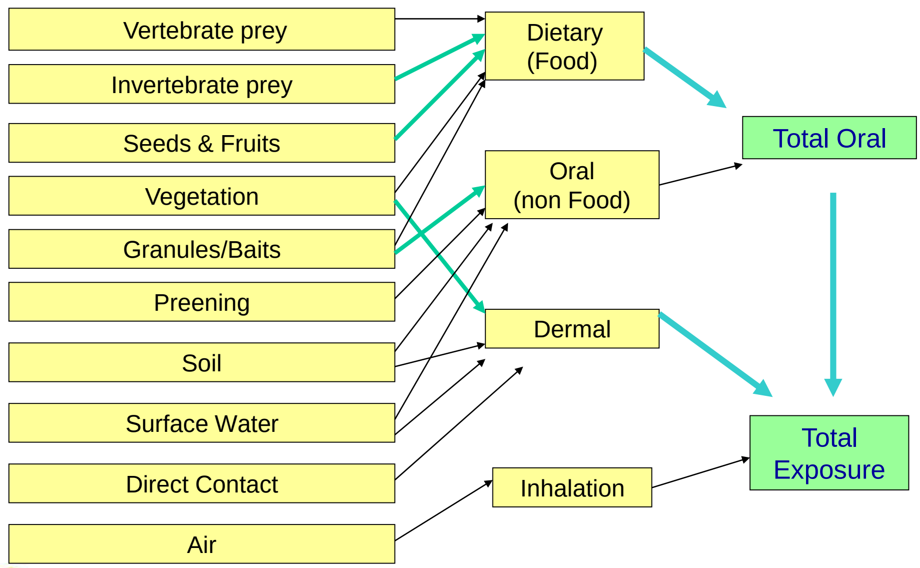
- The purpose for the assessment is articulated
- The problem is defined
- A plan for analyzing and characterizing risk is determined
- Initial work of problem formulation includes the integration of available information on sources, stressors, effects, and ecosystem and receptor characteristics
- From this information two products are generated:

1. Assessment endpoints
2. Conceptual models

Conceptual Model-Aquatic Ecosystem



Conceptual Model-Terrestrial Ecosystem



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Analysis

- ❑ Characterization of exposure
- ❑ Characterization of ecological effects

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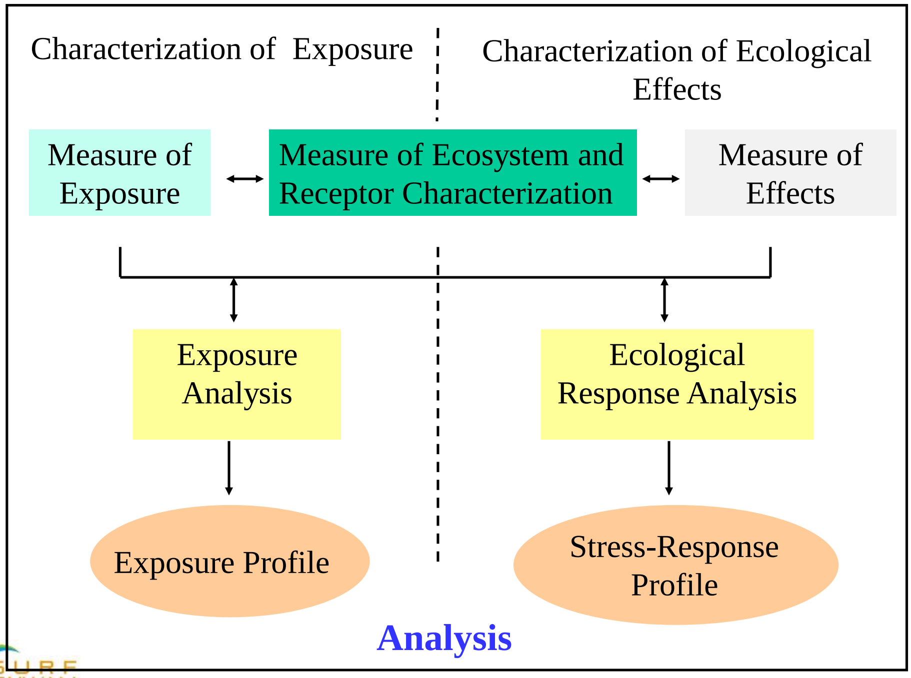


Analysis

- During the analysis phase, data are evaluated to determine how exposure to stressors is likely to occur (characterization of exposure) and the potential and type of ecological effects that can be expected (characterization of ecological effects)

- The steps in analysis is to

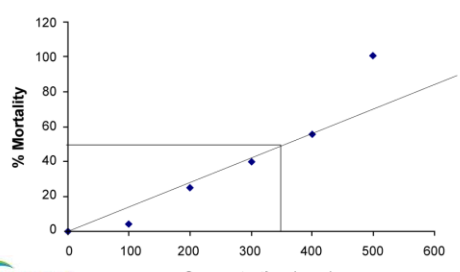
1. Determine the strengths and limitations of data on exposure, effects, and ecosystem and receptor characteristics
2. Data are then analyzed to characterize the nature of potential or actual exposure and the ecological responses under the circumstances defined in the conceptual models

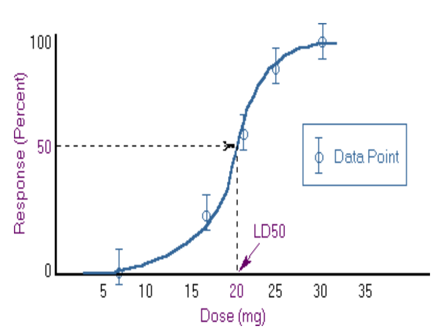
- Two products are generated:

1. Exposure profile
2. Stressor-response profile

What is an Exposure Profile?

- Range of concentrations/doses associated with the stressor in time and place
- Magnitude in uncertainty due to sampling and/or measurements error
- Identify the variability in concentrations and their causes





Types of Data used in Developing Exposure & Toxicity Profiles

- Laboratory data
- Field Observations
- Model output
- QSARs (Quantitative structure–activity relationship models)

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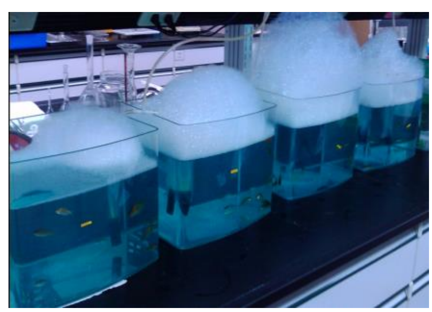
Aquatic Toxicity Test Species

Neocaridina shrimp (*Neocaridina denticulate)*



Carp (*Cyprinus Carpio*)

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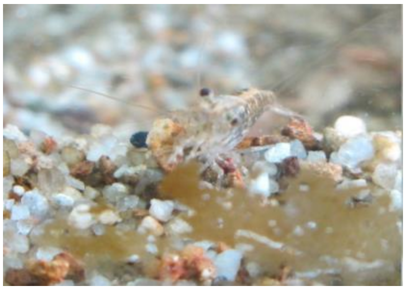
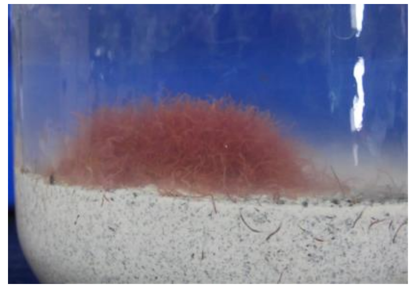
Sediment Toxicity Test Species



neocaridina shrimp (*Neocaridina denticulate)*

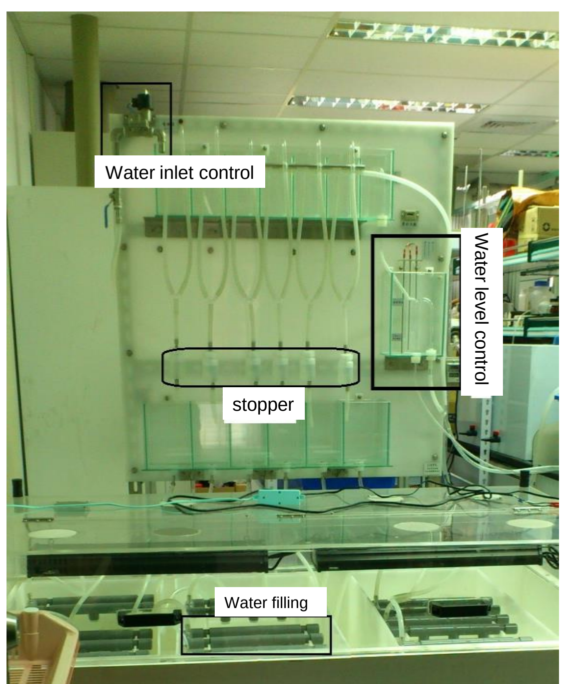


sewage worm (*Tubifex hattai*)

SURF TAIWAN *Hyalella Azteca* (amphipoda)

Sediment Toxicity test

Automated overlying water renewal system



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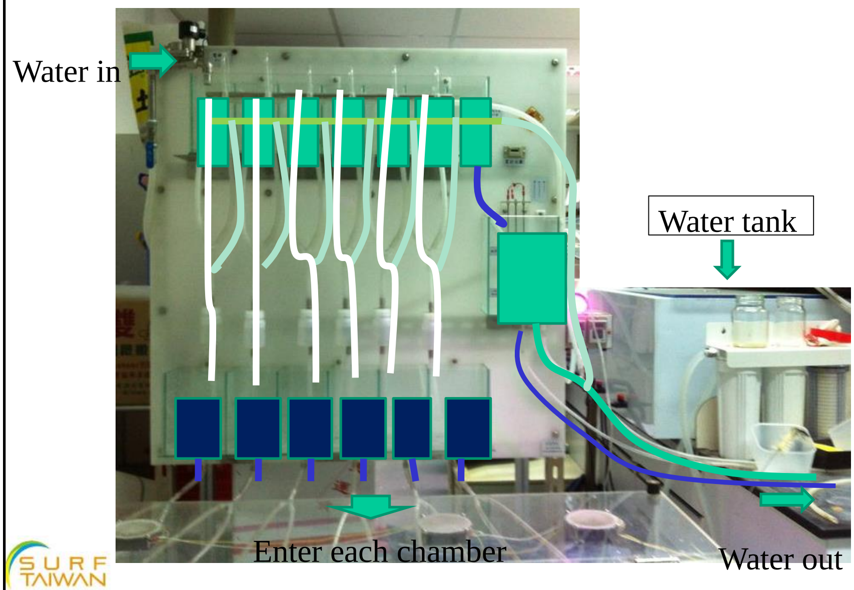
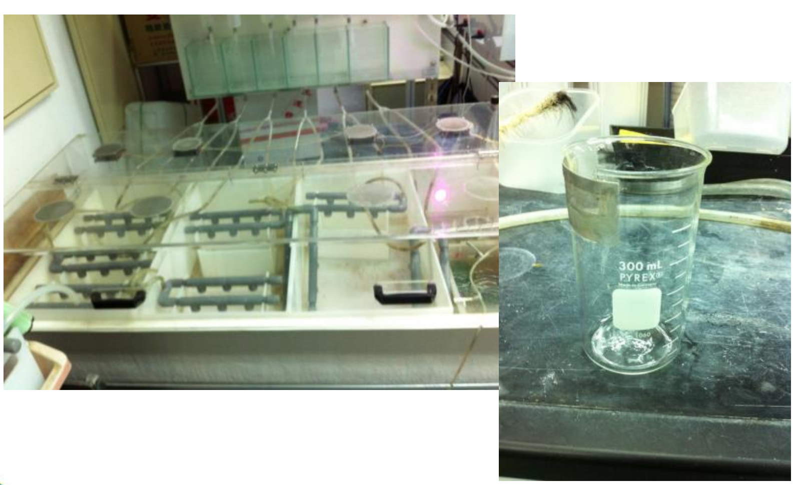
Sediment toxicity testing intermittent renewal system (STIR)



The chamber of the STIR system



Terrestrial Toxicity Test Species

Eisenia fetida

Metaphire posthuma

Perionyx excavatu

Terrestrial Toxicity Test Species

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Ecological Effects Profile

- Relationship between stressor level and ecological effect (Dose-Response Relationship) as a function of time and space
- Ecological effects can include: single species, populations, multiple species, general trophic levels, communities, ecosystems, landscapes

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Ecological Effects Profile : Single Species

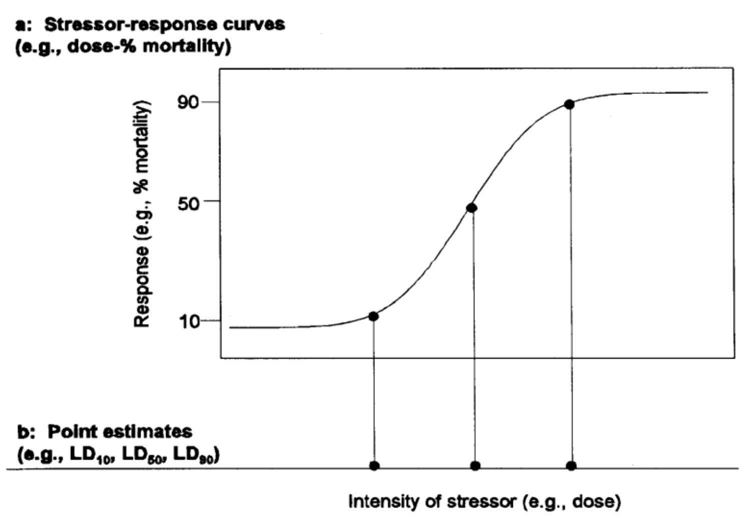

Figure 4-2. A simple example of a stressor-response relationship. Substantially more complex relationships are typical of many ecological risk assessments, given the range of stressors, endpoints, and environmental situations often encountered.

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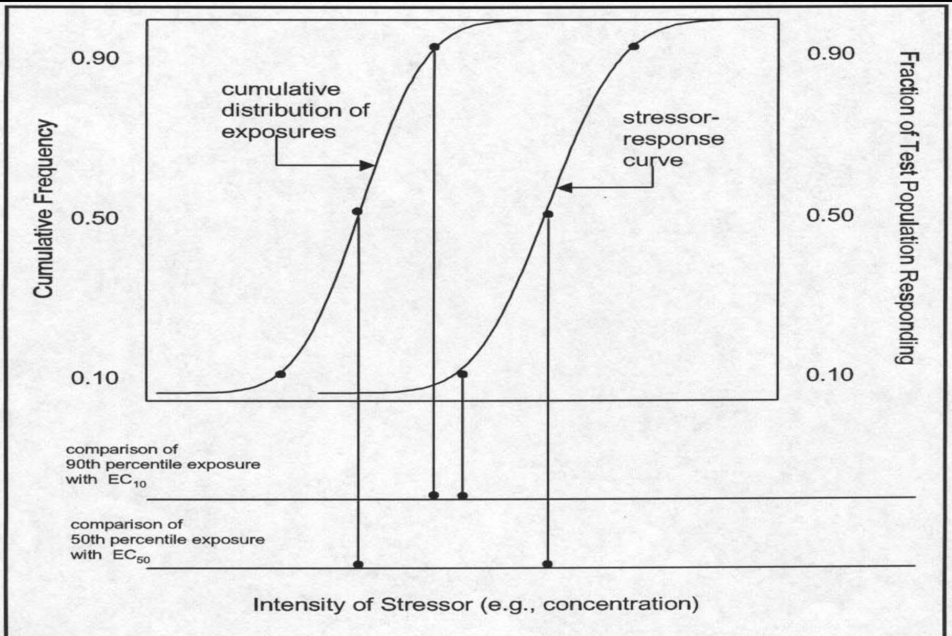

Figure 5-4. Risk estimation techniques: stressor-response curve versus a cumulative distribution of exposures.

Ecological Effects Profile : Multiple Species

Species	EC50 (ug/L)	Rank	Rank Order
Stonefly	5.9	1	14%
amphipods	11	2	29%
trout	12	3	43%
fathead minnow	40	4	57%
sunfish	65	5	71%
midge	100	6	86%

100 x n / (N + 1)

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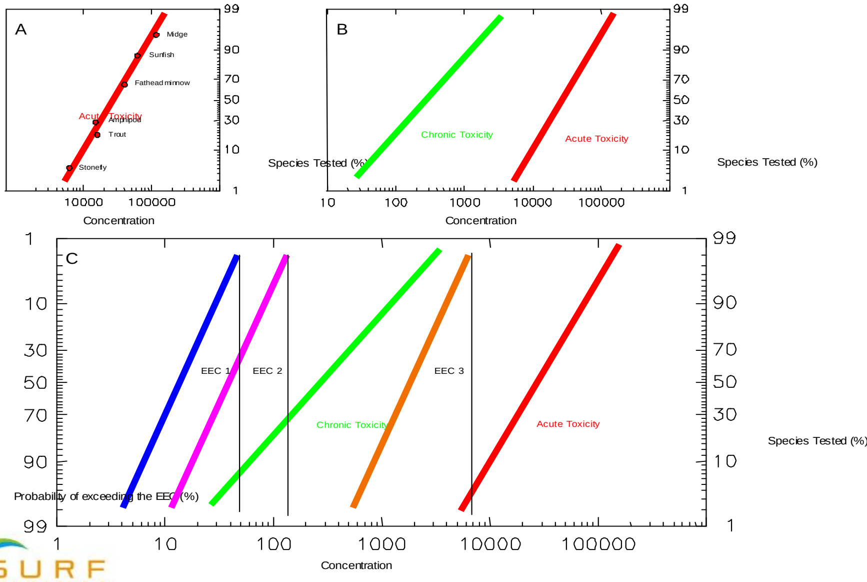
Ecological Effects Profile : Multiple Species



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Risk Characterization

- ❑ Screening-level calculation
- ❑ Risk quantification with models

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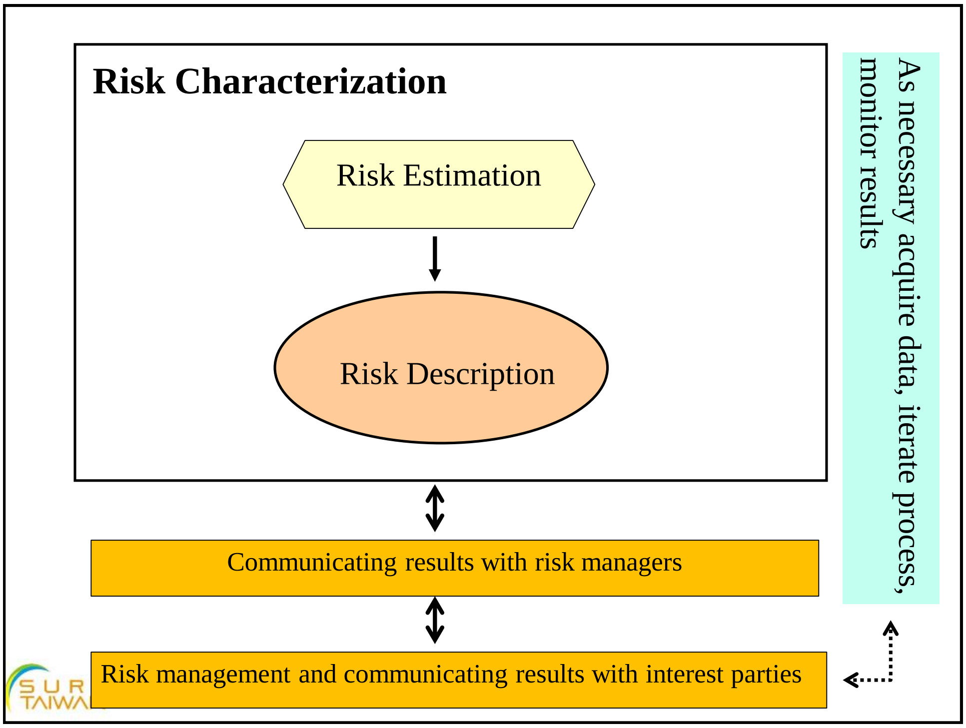

Risk characterization

- Risk characterization includes a summary of assumptions, scientific uncertainties, and strengths and limitation of the analyses.

- The final product is a risk description in which the results of the integration are presented, including an interpretation of ecological adversity and description of uncertainty and lines of evidence.

Risk Characterization

- Develop an estimate of the risk posed to ecological entities included in the assessment end-points identified in the problem formulation
- Describe the risk estimate in the context of the significance of any adverse effects and the strength of evidence supporting it
- Qualify the risk estimates by summarizing uncertainties and assumptions.

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Screening-level calculation

- Risk Estimation

$$EEQ = \frac{EEC}{ERC}$$

- EEQ: ecological effect quotient
- EEC (expected environmental concentration): the aqueous concentration of contaminant (C_w)
- ERC (ecological risk criterion): the lethal concentration of contaminant to affect 50% of individuals within a species (i.e., LC_{50}). Obtained from the ECOTOX database system using toxicological endpoint concentration.

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Risk Quantification with Aquatic Ecological Risk Assessment model

- Aquatic Ecological Risk Assessment model

$$\log P = \alpha + \beta \log(\text{mean } LC_{50}) + e$$

P: the probability of an effect at a specific concentration of the COPCs,

mean LC_{50}: the species mean LC_{50}

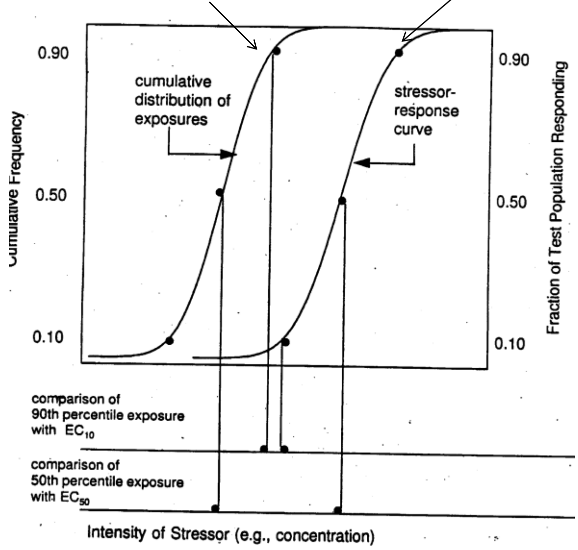
α and β: empirical constants

e: error

Incorporating the entire Stress-Response Relationship

Chronic toxicity

Acute toxicity



Risk estimation involving multiple species

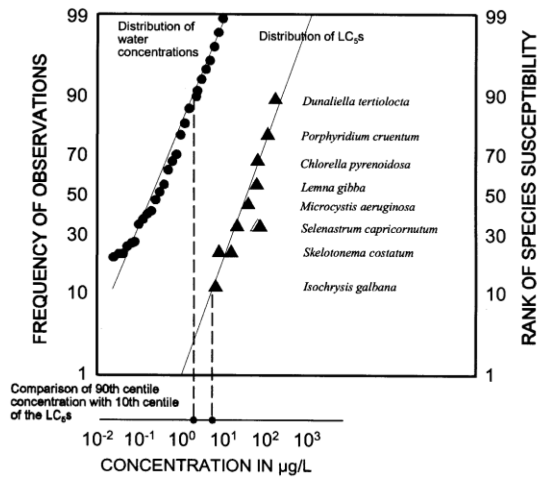
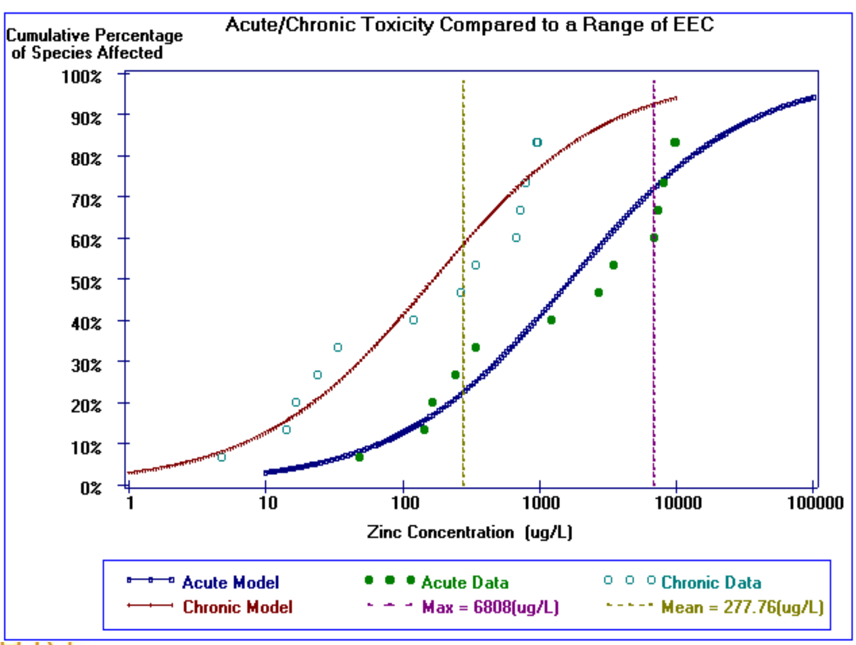
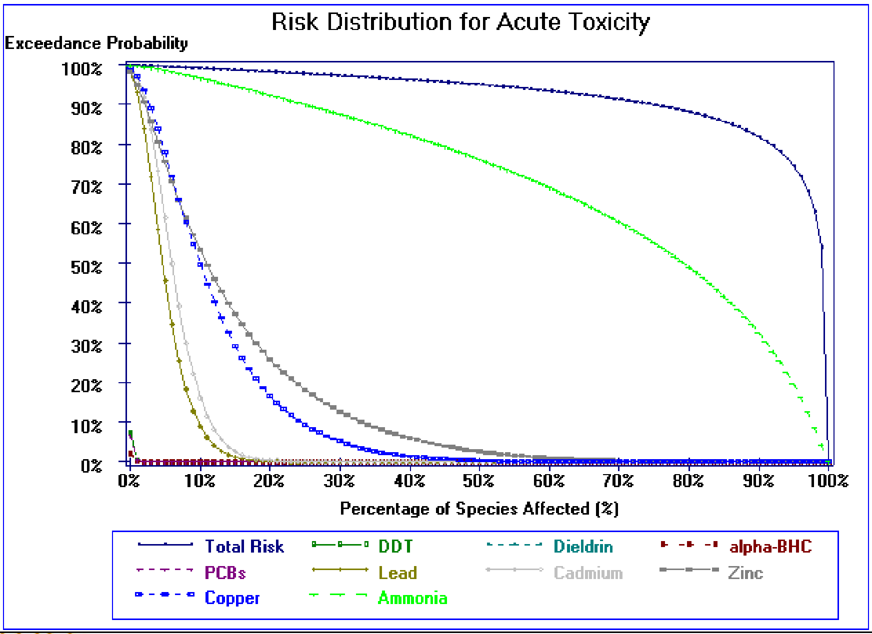


Figure 5-5. Risk estimation techniques: comparison of exposure distribution of an herbicide in surface waters with freshwater single-species toxicity data. See text box 5-4 for further discussion. Redrawn from Baker et al., 1994. (Centile ranks for species LC_5 data were obtained using the formula (100 x n/[N+1]), where n is the rank number of the LC_5 and N is the total number of data points in the set; adapted from Parkhurst et al., 1995).




Risk Distribution for Acute Toxicity
Exceedance Probability
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of Species Affected (%)
Total Risk
DDT
Dieldrin
alpha-BHC
PCBs
Lead
Cadmium
Zinc
Copper
Ammonia


Case Study: Ecological Risk Assessment of Guandu Plain

Guandu Plain

- The site is located in the north-west suburban Taipei, 10 km next to Tamsui River estuary
- Area designated as Guandu Nature Reserve
- Soil contains high concentration level of arsenic from beudantite ($PbFe_3(AsO_4,SO_4)(OH)_6$), not from anthropogenic activity
- Concentration of arsenic in top soil ranged from 4.75 to 458 mg/kg in TEPA investigation

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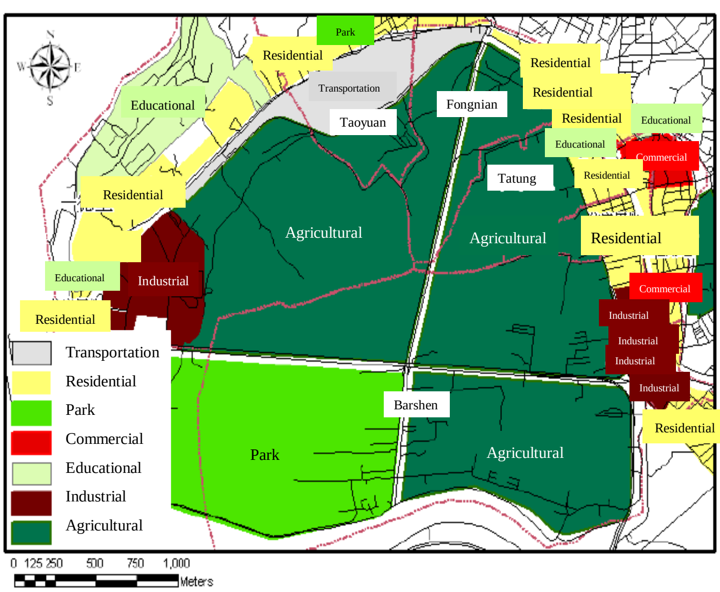
Guandu Plain



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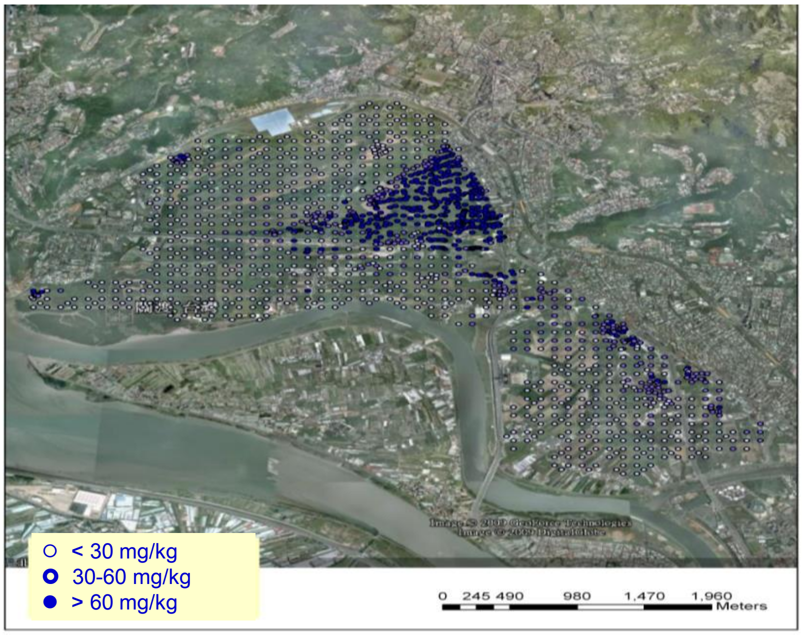
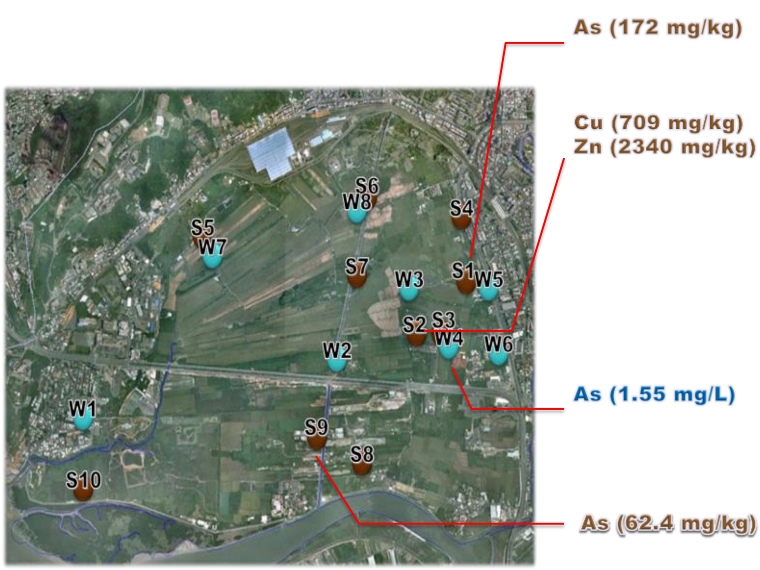
Distribution of Arsenic in Soil



Characterization of Soil and Groundwater



Soil quality standard (As) : 60 mg/kg
Groundwater standard (As) : 0.5 mg/L

Chemical of Potential Concern (COPC)

Soil samples	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
(mg/kg)										
Depth	0-0.5	0-0.5	0-0.5	0-0.5	1.5-2	0-0.5	0-0.5	0-0.5	0-0.5	1.5-2
Pb	589	92.6	752	21.8	56.7	34.0	18.5	24.0	156	20.8
Cd	ND	1.03	5.65	ND	ND	ND	ND	ND	ND	ND
Cr	6.02	37.8	91.5	27.7	27.2	17.8	24.0	22.2	15.8	14.2
Cu	37.9	136	709	19.8	45.0	102	33.9	33.4	114	83.4
Zn	32.1	388	2340	102	127	147	173	221	134	65.7
Ni	ND	29.7	126	33.9	25.4	14.7	25.6	24.7	15.2	13.1
Hg	0.328	0.496	2.72	ND	0.133	0.368	ND	0.191	0.396	0.113
As	**172**	21.3	29.6	10.8	14.1	18.3	7.92	14.3	**62.4**	13.5

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Chemical of Potential Concern (COPC)

Groundwater	G1	G2	G3	G4	G5	G6	G7	G8
(mg/L)								
Pb	ND	0.0004	ND	0.0012	ND	ND	0.0011	ND
Cd	ND	ND	ND	ND	ND	ND	ND	0.002
Cr	ND	ND	ND	ND	ND	ND	ND	ND
Cu	ND	ND	ND	ND	ND	ND	ND	0.006
Zn	0.019	0.022	0.014	0.013	0.015	0.012	0.020	0.040
Ni	ND	ND	ND	ND	ND	ND	ND	ND
In	0.057	0.037	0.013	0.028	ND	ND	ND	0.038
Mo	ND	ND	ND	ND	ND	ND	0.016	ND
Hg	0.0002	0.0001	0.0001	0.0002	ND	0.0001	0.0002	0.0002
As	0.0053	0.422	0.110	**1.55**	0.122	0.0871	0.0305	0.0552

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Ecological Survey

- Four day Biomonitoring survey conducted in July 2014 and December 2014
- Target species: plants, terrestrial species (birds, mammals)

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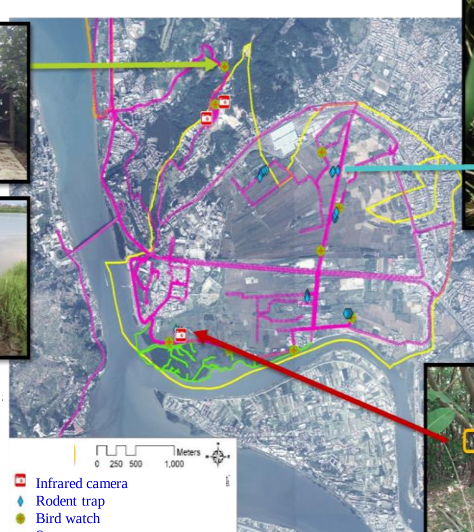
Ecological Survey

Bird watch



Rodent trap

Infrared camera

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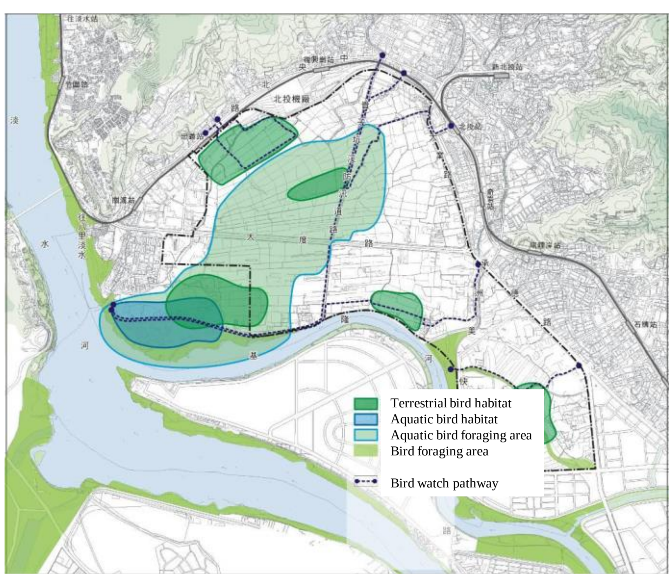
Diversity of birds in Guandu Plain

- Around 280 species of migrant bird and 50 species of resident bird (17%) in the area
- The majority of them are predatory migration birds (76.5%) like the snipe families.
- In the summer, it is the breeding grounds for egrets & water-tails, and in winter, migratory birds will take residence.
- During spring and autumn, it will act as habitat for transiting birds.
- North zone serves as habitats for terrestrial birds, mangrove wetland serves as habitats of aquatic birds

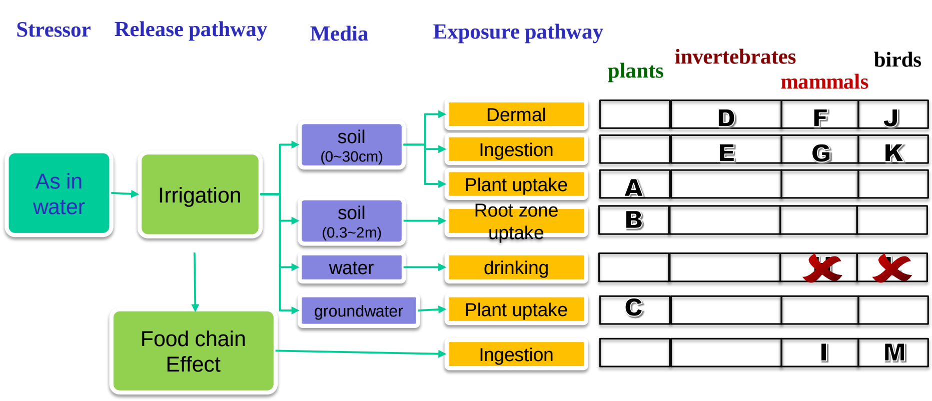
Habitat of birds in Guandu Plain



Valued Ecosystem Components

Trophic level	Species	Habitat
Granivores	Crested myna (*Acridotheres cristatellus formosanus*)	agricultural land, shrub land, woodland
Insectivores	Eastern collared pratincole (*Glareola maldivarum)*	fallow land
	Collared scops owl (*Otus bakkamoena)*	bush
	Brown shrike (*Lanius cristatus)*	grassland
Carnivores	Black-winged kite (*Elanus caeruleus)*	agricultural land
	Crested serpent eagle (*Spilornis cheela)*	secondary forest
	Crested goshawk (*Accipiter trivirgatus)*	secondary forest
	Common kestrel (*Falco tinnunculus)*	agricultural land

Exposure Analysis



Risk Estimation

- Assuming HQ=1 as ecological criteria in the site
- No single species assessment
- 100% conversion of contaminant to organisms

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Risk Description

- HQ of plants, mammals, and birds >1

Species	Ecological Risk Criterion (mg/kg)	Concentration of COPC (mg/kg) (95% of UCL)	HQ
Plants	18	72.3	4.0
Mammals	43	72.3	1.7
Birds	46	72.3	1.6

- Ecological survey indicated that population of birds did not decline

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Uncertainty

- Uncertainty in ecological risk assessment was associated with variability in ecosystem stressors, exposure data, ecological effect data, risk characterization, and lack of knowledge
- Physical and biological stressors were not evaluated in the study
- Toxicological data were available for relatively small number of species
- Effect of minor contaminants was not characterized
- Bioavailability, bioaccumulation were assumed 100%
- Site specific parameters may be required

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Thank you for your attention

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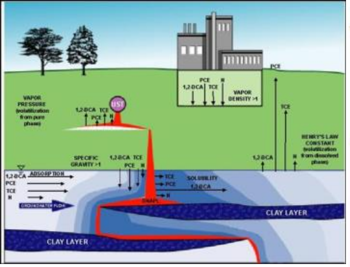

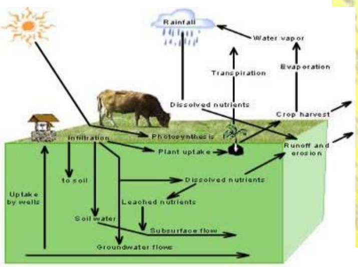



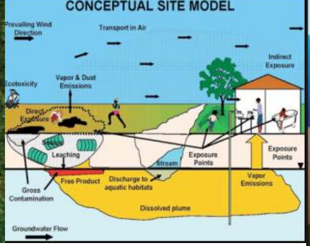

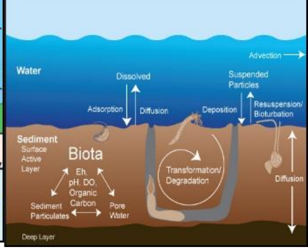

Sustainable Contaminated Site Remediation: Theories and Approaches

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Outline

- Green and Sustainable Remediation (GSR)
- GSR development road map
- GSR framework
- GSR tools
- Case studies
- Challenges for promoting GSR

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Green and Sustainable Remediation (GSR)

What Is "Sustainability"?

To create and maintain conditions, under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations

— U.S. Presidential Executive Order of 2007

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What is "Green Remediation"?

The practice of considering all environmental effects of remedy implementation and incorporating options to maximize the net environmental benefit of cleanup actions

— U.S. EPA Office of Solid Waste and Emergency Response

Sustainable Practices for Site Remediation

- Consider all environmental effects of remedy implementation
- Use natural resources and energy efficiently
- Use a holistic approach to site cleanup that reflects reuse goals
- Minimize cleanup "footprints" on air, water, soil, and ecology
- Reduce greenhouse gas emissions contributing to climate change
- Return formerly contaminated sites to long-term, sustainable, and productive use

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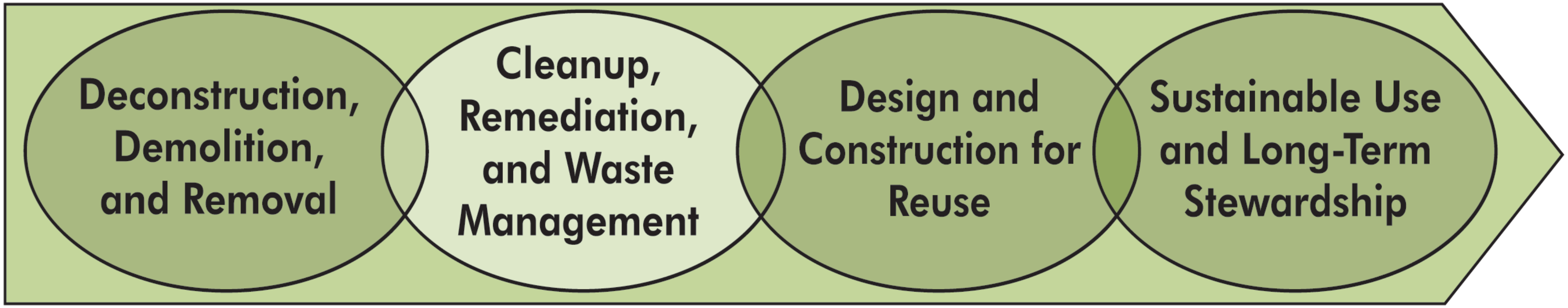
Integration of Green Remediation in Site Revitalization

- Sustainable strategies carry forward throughout stages of land revitalization
- Remediation decision-makers consider the role of cleanup in community revitalization
- Revitalization project managers maintain an active voice during remediation



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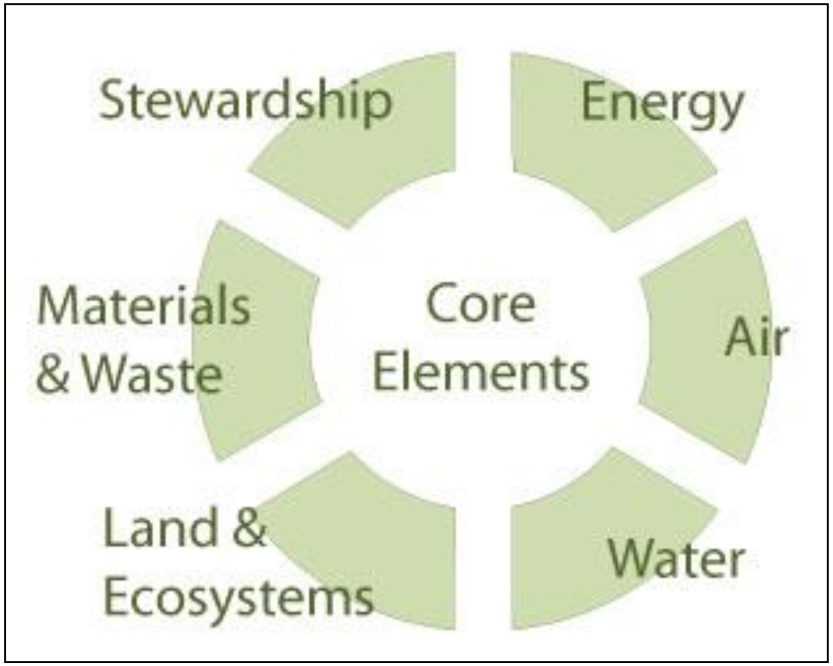
Opportunities to Increase Sustainability of Cleanups

- Apply to all cleanup programs within U.S. regulatory structure
- Exist throughout site investigation and remedy design, construction, operation, and monitoring
- Address core elements of green remediation



Current Practices

- Increasing energy efficiency
- Conserving water
- Improving water quality
- Managing and minimizing toxics
- Managing and minimizing waste
- Reducing emission of greenhouse gases and toxic or priority air pollutants

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Current Practices (continued)

- Many strategies of green remediation already used to a degree but not labeled “green”
  - Using drought resistant and hardier native plants instead of non-native plants
  - Re-injecting treated water for aquifer storage instead of discharging to surface water
  - Choosing passive sampling devices when possible, reducing subsurface invasion and waste generation
  - Minimizing bioavailability of contaminants through source and plume controls

What is SURF?

- About Sustainable Remediation Forum (SURF)
  - Started in U.S.A. in 2006
    - The first meeting held in Wilmington, Delaware in November 13, 2006
    - Officially registered as a non-profit organization in 2010
  - Members
    - Industry
    - Consulting
    - Contractor
    - Academia
    - USEPA (individually)

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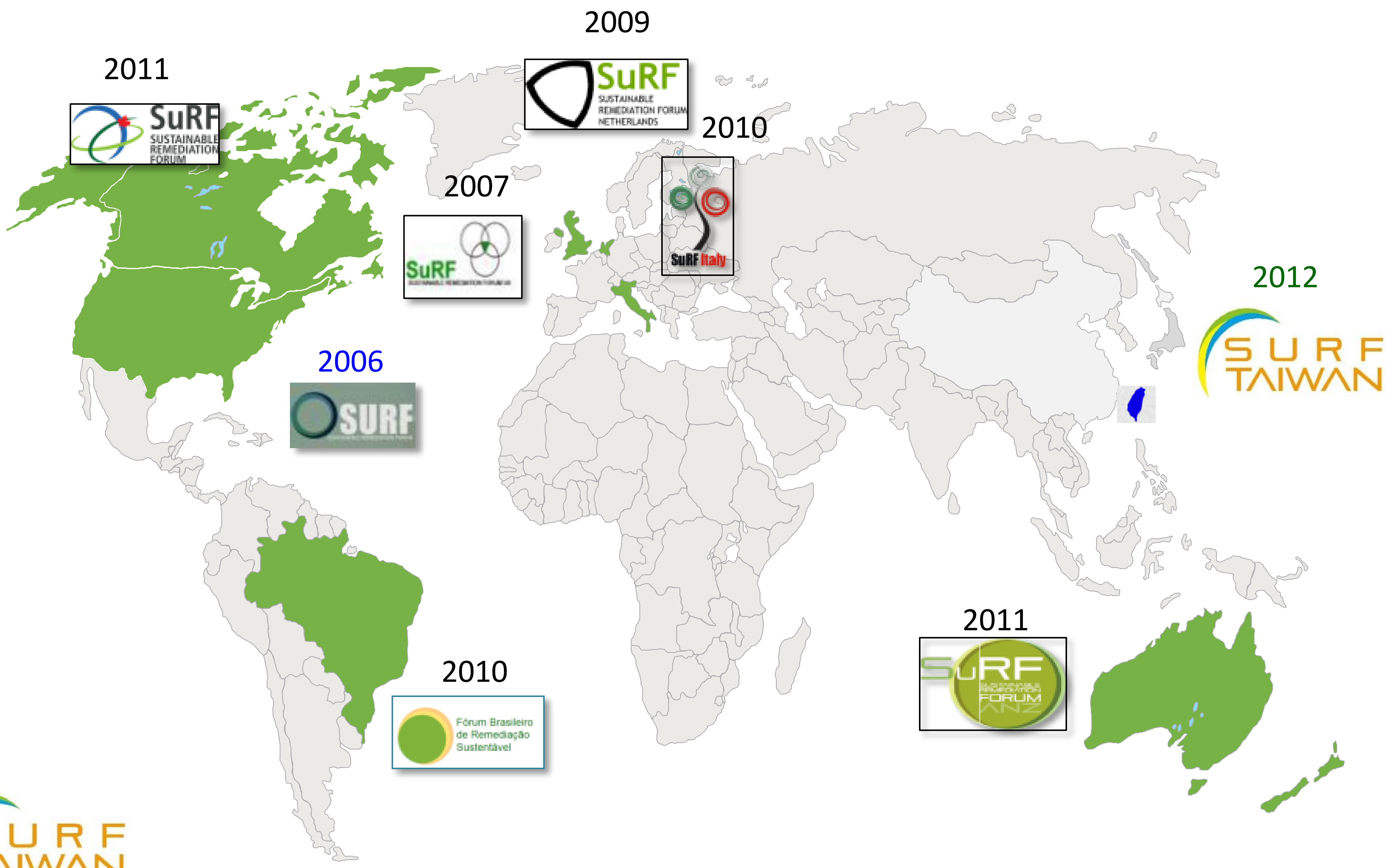
SuRF organizations worldwide



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Sustainable Remediation Forum Taiwan (SuRF-Taiwan)

- SuRF-Taiwan founded in 2012 under Taiwan Association of Soil and Groundwater Environmental Protection (TASGEP)
  - Advocate GSR concept
  - All soil and groundwater remediation designs can balance the environmental, social, and economic factors and provide an optimal remediation strategy and engineering
  - Integrating fit-for-use technology/measures or management process to resolve contamination problems, elevate the living quality while satisfy social and economic development needs

GSR Framework

GSR Framework

- Incorporate GSR into the life-cycle of site management
- Adopt GSR in the early stage of site management

1. Site Investigation
2. Remedy selection and design
3. Remedy system construction
4. Remedy system O&M
5. Site closure

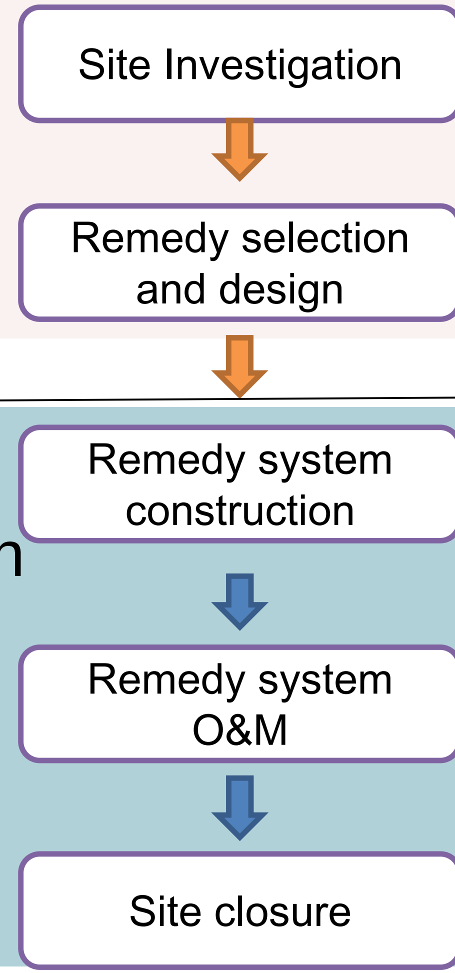
- ☐ Environmental footprint assessment, local resident questionnaire
- ☐ Implement BMPs

- ☐ GSR semi-quantitative decision support tool
  - Comparison of Alternatives
  - Environmental, social, economic evaluation tools
  - Selecting the most sustainable remedy

- ☐ Best management practice (BMPs) planning
  - Environmental – conduct environmental footprint assessment，identify potential emission “hot spots”, reduce footprint
  - Economic – economic efficiency
  - Social – Human health risk、stakeholder involvement、information publicity and mitigate disturbance

GSR Framework

- Key issues
  - Remedy selection
  - BMPs planning and implemetation



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GSR Tools

GSR tools

- GSR Semi-quantitative decision support tool
  - Compare the environmental, social and economic effects of different remedies to select the one which most fits the sustainable requirements
- Quantitative tool
  - Environmental: environmental footprint assessment
  - Social: local resident questionnaire, health risk assessment
  - Economic: cost / benefit and impact assessment
- Qualitative tool
  - Best Management Practices screening list

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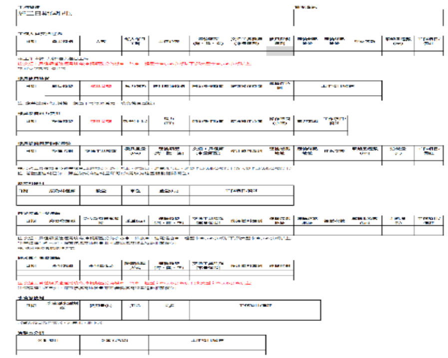
GSR Semi-quantitative decision support tool

- Initial screening
  - Time, technology, financial feasibility
- Decision support tool
  - Selection of assessment metrics
  - Define weighting factors
    - Invite stakeholder
  - Scoring system
    - Systematic scoring principle
  - Total Score
    - Select the remedy with highest overall score

Footprint analysis

- Inventory sheet
  - Labor/equipment/material transportation, equipment operation, solid/liquid waste treatment, lab analysis, water usage
- Out put
  - CO_2, NOx, SOx, PM_{10}, MJ
  - Hot spot Identification



input

原物料輸入

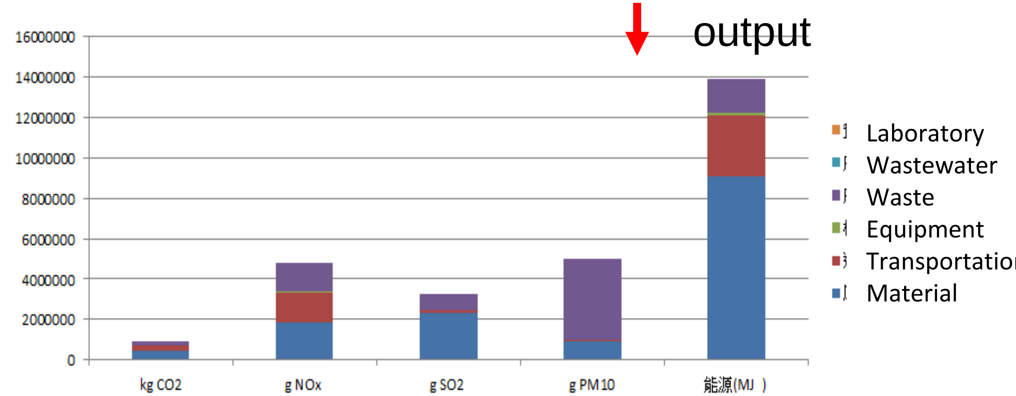
監測/整治井設置-由井數推估	監測井種類一	監測井種類一	監測井種類一	監測井種類一	監測井種類一
監測井數目					
監測井深度(m)					
開篩長度(m)					
井管型式					
井篩型式					
井頂蓋型式					
監測井直徑(in)					
PVC (kg)	#N/A	#N/A	#N/A	#N/A	#N/A
石英砂(kg)	#N/A	#N/A	#N/A	#N/A	#N/A
皂土(kg)	#N/A	#N/A	#N/A	#N/A	#N/A
水泥(kg)	#N/A	#N/A	#N/A	#N/A	#N/A
不鏽鋼(kg)	0.00	0.00	0.00	0.00	0.00
鋼(kg)	0.00	0.00	0.00	0.00	0.00

原物料輸出

監測/整治井設置-直接盤查	監測井型號一	監測井型號二	監測井型號三	監測井型號四	監測井型號五	Sum	
PVC (kg)	0.00					PVC (kg)	#N/A
石英砂(kg)	0.00					石英砂(kg)	#N/A
皂土(kg)	0.00					皂土(kg)	#N/A
水泥(kg)	0.00					水泥(kg)	#N/A
不鏽鋼(kg)	0.00					不鏽鋼(kg)	0.00
鋼(kg)	0.00					鋼(kg)	0.00

原物料 / 運輸 / 機具設備轉置 / 機械設備 / 廢棄物 / 原物料輸出 / 運輸輸出 / 機械設備輸出 / 廢棄物輸出 / 監測井設置計算表單 / look up table

output



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Social & Economic Aspect

- Social
  - Communucation Questionnaire
    - Negative impacts (noise , dust ,odor...etc)
  - Human health risk assessment
    - Baseline risk & risk due to remediation of local residents and remediation workers
    - occupational safety during remediation
- Tiered Economic cost-benefit prediction model
  - Land value influence prediction
  - Economic Benefit Prediction Model
    - Based on I/O Model
      - Land value influence prediction
      - Effect of increasing employment
      - Effect of increasing related industrial income
      - Effect of increasing national income

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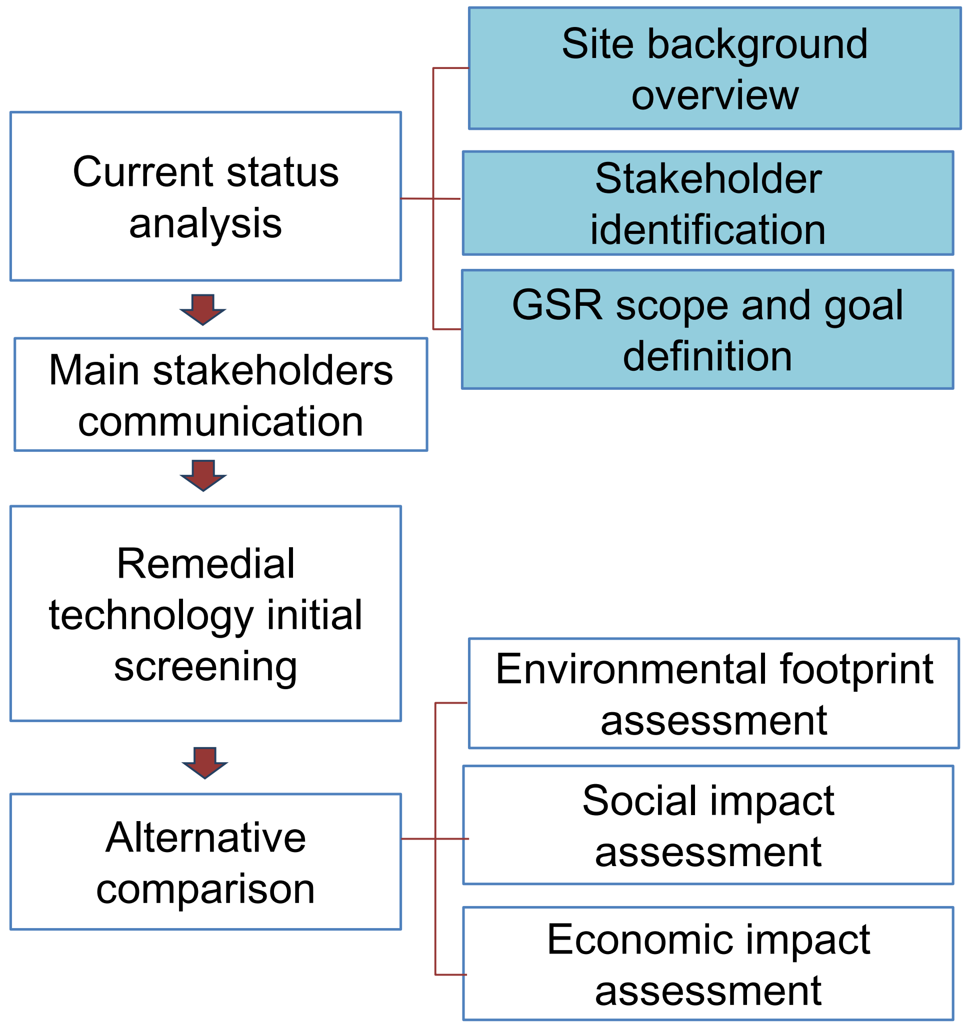
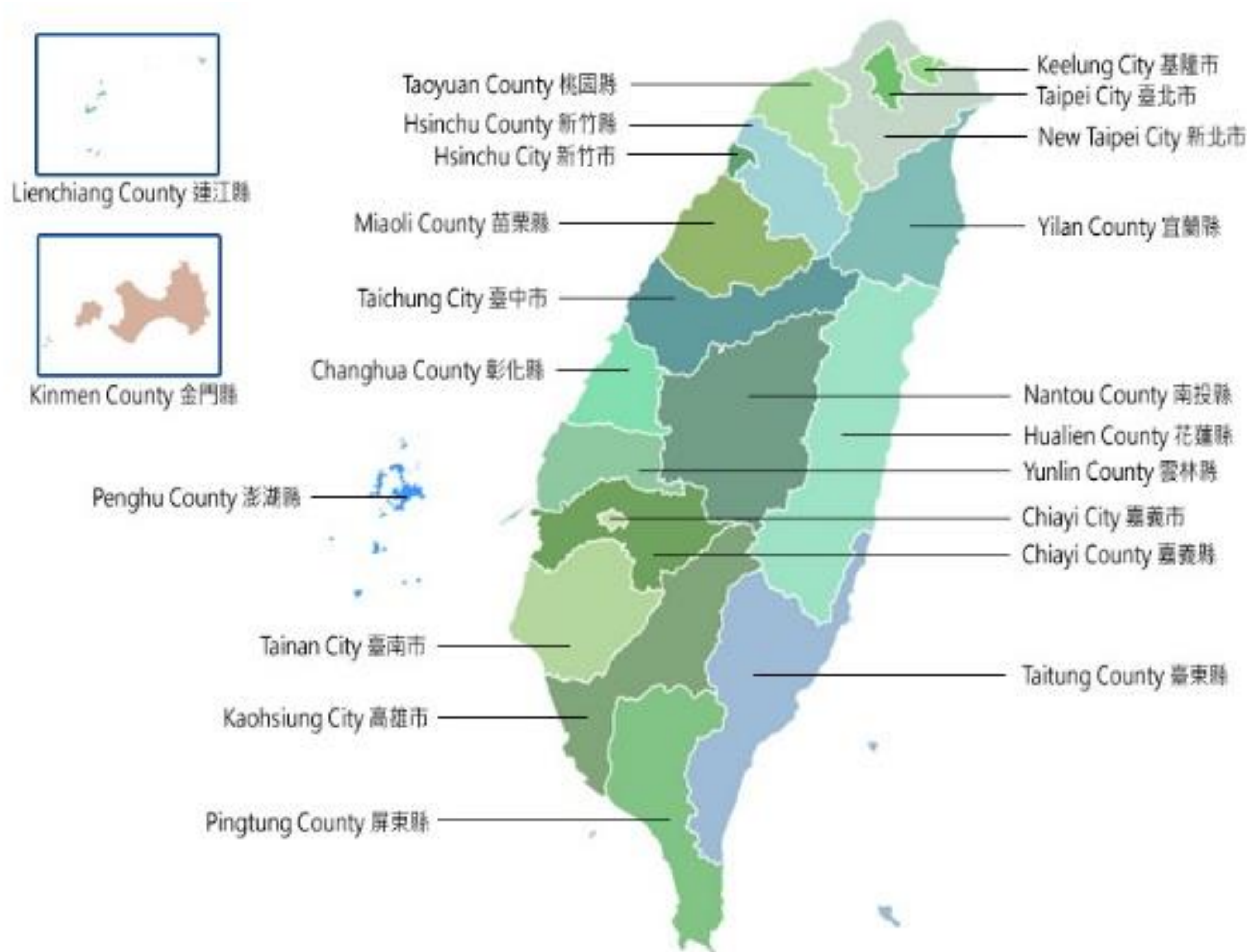
Case Study

Case Study 1

- Site backgorund
  - Milirary port for ship maintenance with multi-facotories and outdoor fuel storage areas
  - Comtaminated media : Soil
  - Contaminants : TPH and heavy metals
- Stakeholder identification
  - Navy, City Environmental Protection Bureau
- GSR scope and goal definition
  - Remedy selection through GSR assessment



SURF TAIWAN

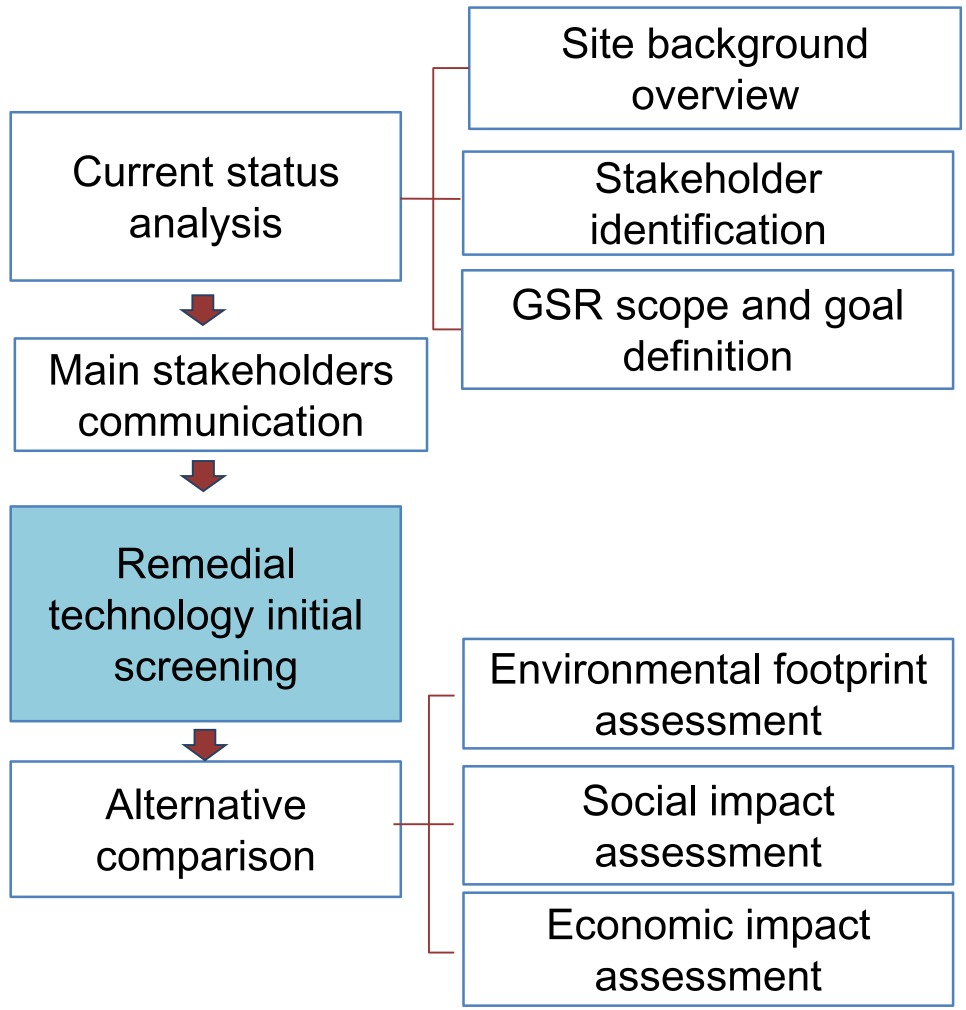

Lienchiang County 連江縣
Kinmen County 金門縣
Taoyuan County 桃園縣
Hsinchu County 新竹縣
Hsinchu City 新竹市
Miaoli County 苗栗縣
Taichung City 臺中市
Changhua County 彰化縣
Penghu County 澎湖縣
Tainan City 臺南市
Kaohsiung City 高雄市
Pingtung County 屏東縣
Keelung City 基隆市
Taipei City 臺北市
New Taipei City 新北市
Yilan County 宜蘭縣
Nantou County 南投縣
Hualien County 花蓮縣
Yunlin County 雲林縣
Chiayi City 嘉義市
Chiayi County 嘉義縣
Taitung County 臺東縣

SURF
TAIWAN

Case Study 1

- Remedy initial screening
  - After considering the need of stakeholders, excavation and soil replacement and soil washing were considered suitable for site

alternatives	TPH	Heavy metal
Scenario 1	excavation and treatment	excavation and soil replacement
Scenario 2	excavation and treatment	Soil washing
Scenario 3	Soil washing	excavation and soil replacement
Scenario 4	Soil washing	Soil washing



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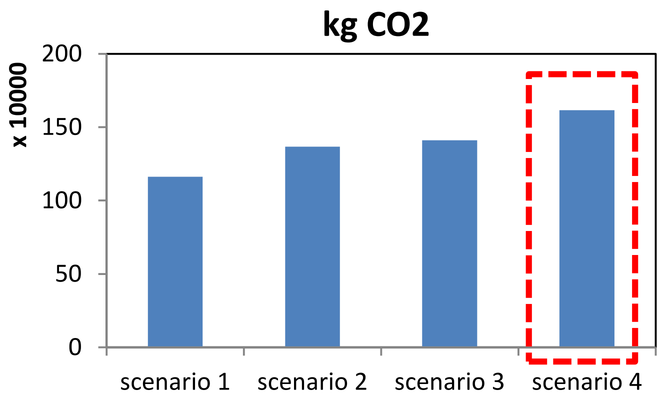
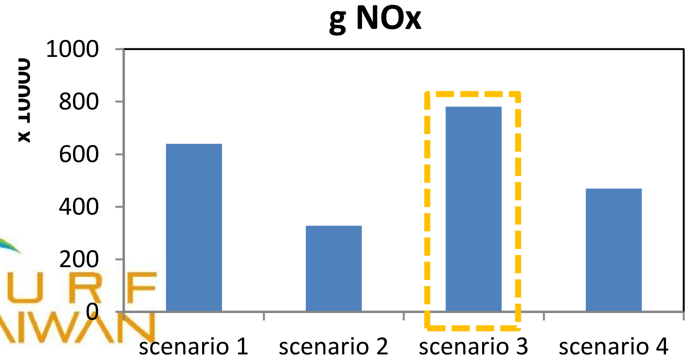
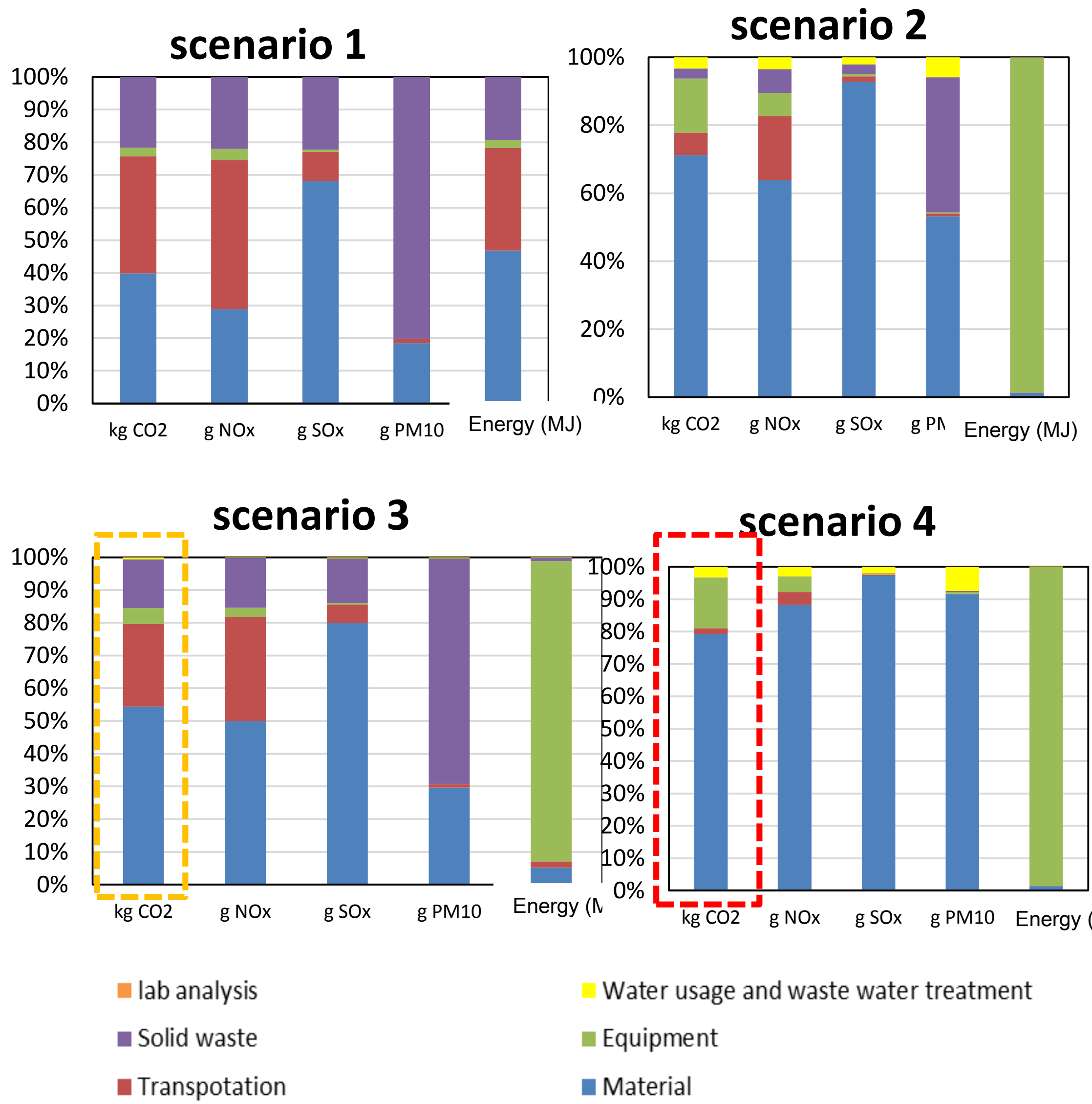
Case Study 1

- Alternative comparison
  - Environmental footprint differences
  - Identify high contribution activities







Case Study 1

– Human health risk assessment

- Area specific (area A, area C , area D)
- Area B is excluded due to lack of data
- Assumption : soldiers do not have cross area activities , remedial worker work in multi-areas

Alternatives	risk	area			Total risk
		A	C	D	
excavation	Carcinogenic	3.92×10^{-9}	5.6×10^{-8}	1.02×10^{-8}	7.01×10^{-8}
	Non-carcinogenic	0.25	0.357	0.115	0.619
Soil washing	Carcinogenic	6.13×10^{-8}	8.88×10^{-7}	1.6×10^{-7}	1.11×10^{-6}
	Non-carcinogenic	0.25	0.357	0.115	0.619

– Economic impact assessment

Alternatives	Project cost	Change in the land value
1	3166	5000
2	10600	11100
3	4466	4933
4	12066	12533

Alternatives	Industries output effect	Value added effect	Job effect (person)
1	5000	3000	128
2	17600	10600	450
3	7400	4466	189
4	20000	12066	512

(thousand $US)

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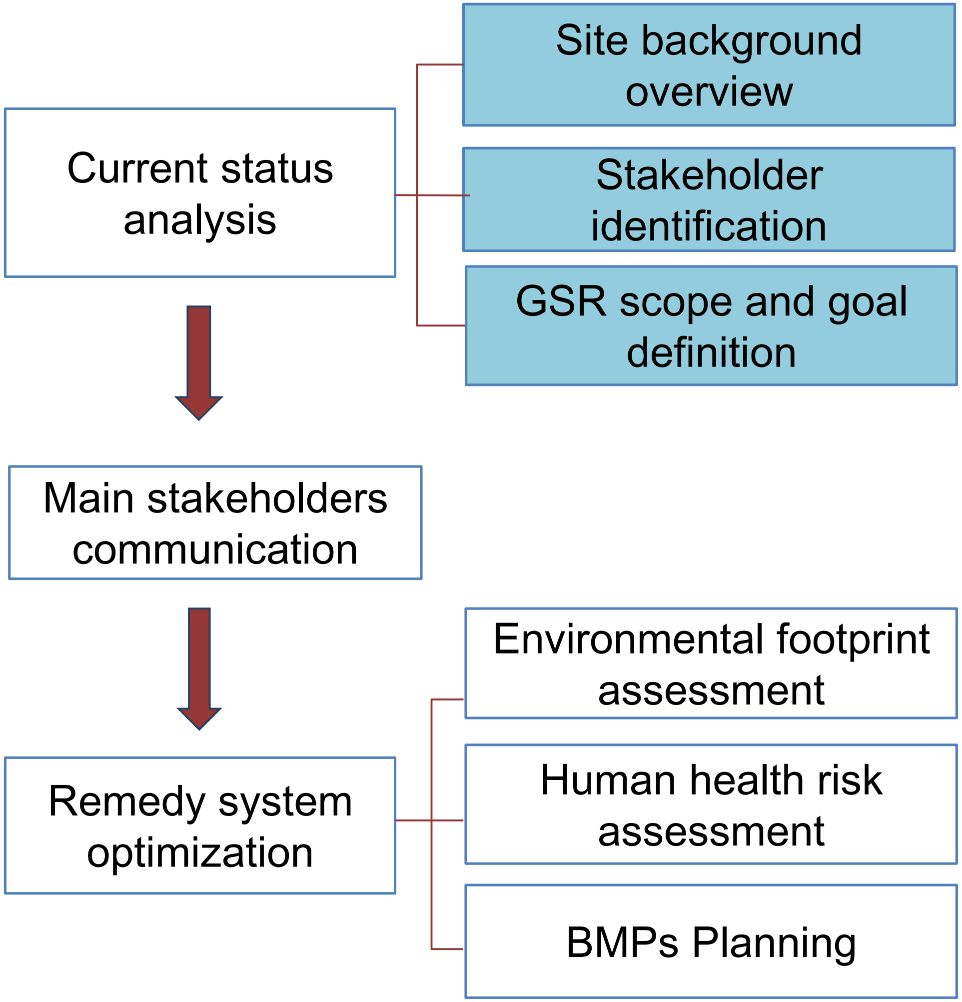
Case Study 2

- Site backgorund
  - Milirary base
  - Comtaminated media : groundwater
  - Contaminant :Trichloroethylene
  - Current remediation : Enhanced bioremediation
- Stakeholder identification
  - Army, County Environmental Protection Bureau
- GSR scope and goal definition
  - Footprint assessment
  - Human health risk for soldiers and remedial workers
  - BMPs planning



YA-MW2	
Groundwater level (m)	12.327
Contaminant	Conc (mg/L)
cis-1,2-dichloethylene	0.0958
TCE	0.00489

YA-MW1	
Groundwater level (m)	9.242
Contaminant	(mg/kg)
cis-1,2-dichloethylene	0.00421
TCE	**0.286**

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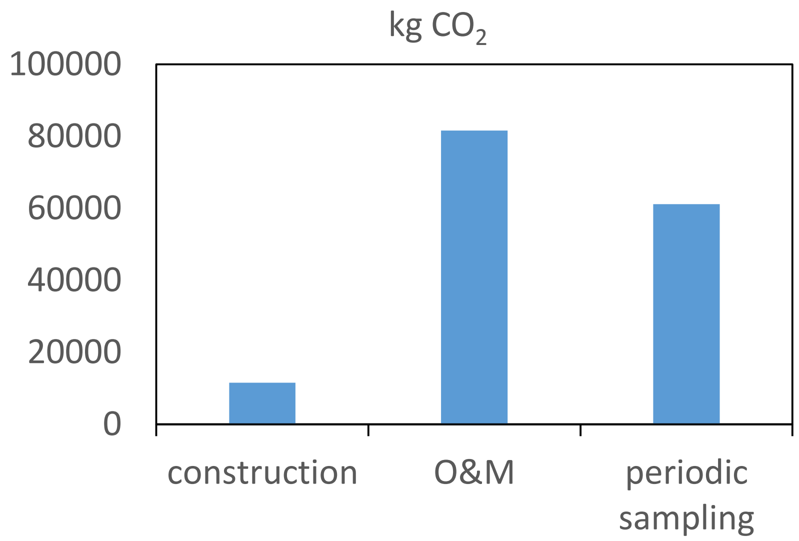
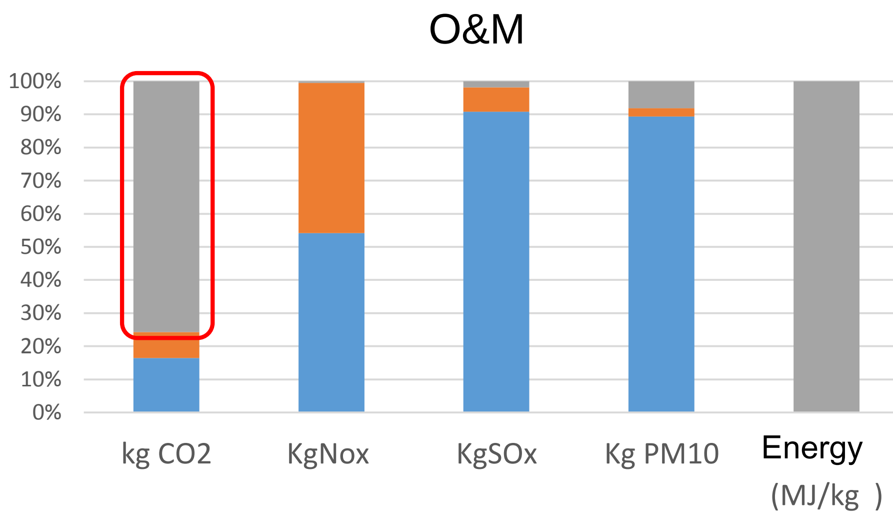
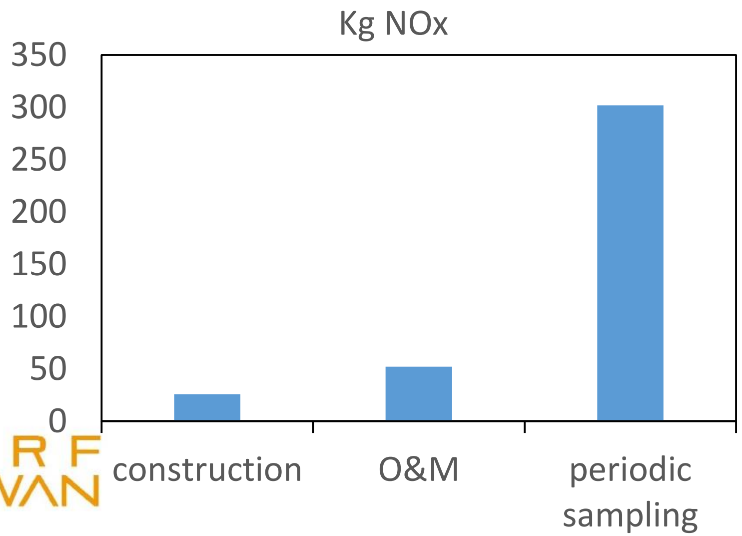
Case Study 2



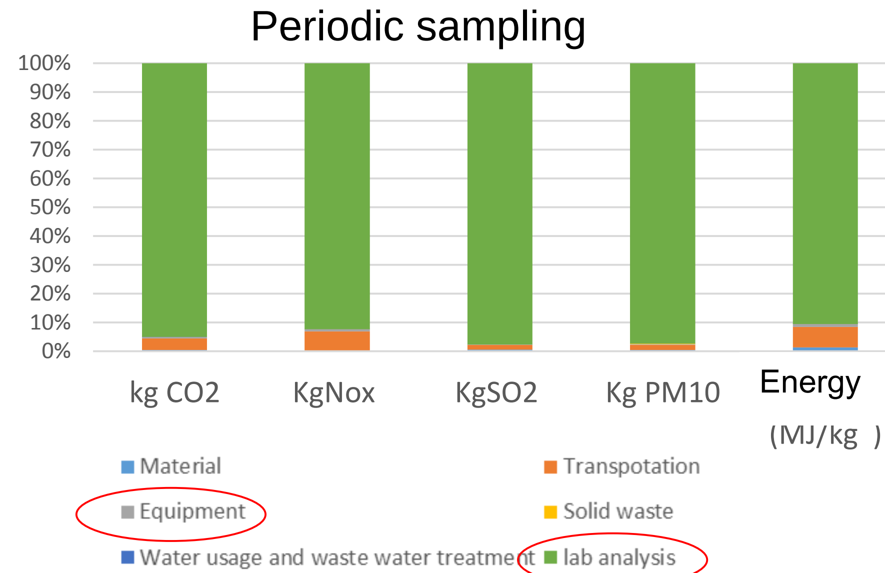
kg CO_2
100000
80000
60000
40000
20000
0
construction
O&M
periodic sampling



O&M
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
kg CO2
KgNox
KgSOx
Kg PM10
Energy (MJ/kg)



Kg NOx
350
300
250
200
150
100
50
0
construction
O&M
periodic sampling



Periodic sampling
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
kg CO2
KgNox
KgSO2
Kg PM10
Energy (MJ/kg)
Material
Transpotation
Equipment
Solid waste
Water usage and waste water treatment
lab analysis

Case Study 2

- Economic cost-benefit prediction model

Categories of indicators		Impact (thousand $US)
Change in the land value		976
Project cost	Initial activities cost	433
	Annual O & M cost	117
	Periodic activities cost	260
Economy impacts	Industries output effect	1,467
	Value added effect	873
	Job effect	23 (person)

- Human health risk assessment
  - Carcinogenic risks:
    - Soldiers : 4.13E-11
    - Remediation workers : 1.00E-14
  - Non-carcinogenic risks:
    - Soldiers : 1.55E+03
    - Remedial workers : 1.99E-01

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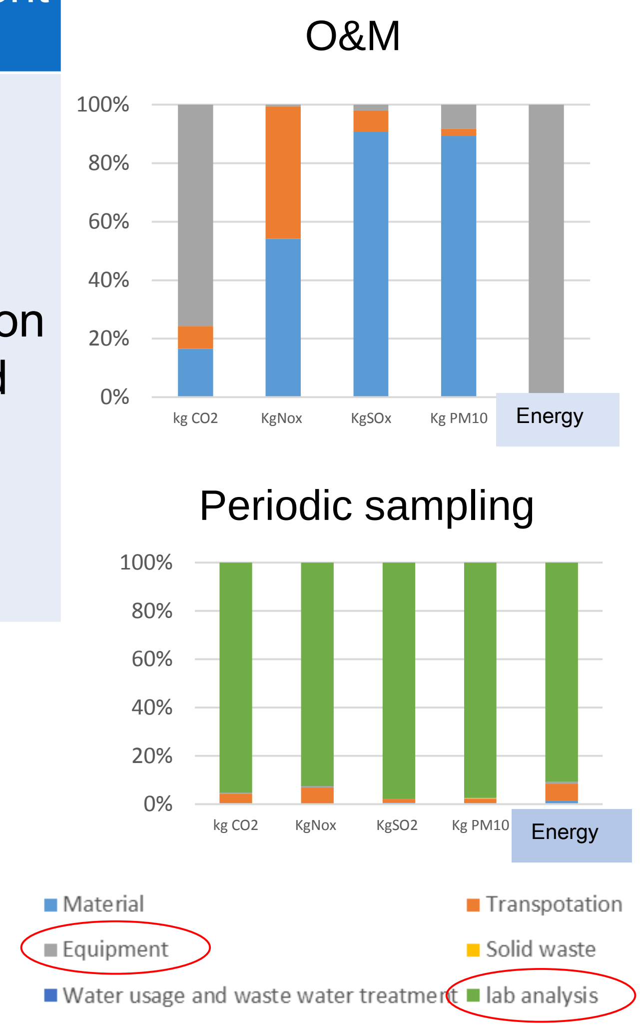
Case Study 2

- BMPs Planning

category	BMPs	GSR principle	Documentation
Power and fuel	Use pulsed rather than continuous injections when delivering amendments	Energy conservation increase energy efficiency	Operation record
	Consider using gravity flow to deliver amendments	Energy conservation	



- Conversion factor for Laboratory is based on cost
  - Suggestion
    - Need detailed footprint assessment to optimize the accuracy for lab analysis

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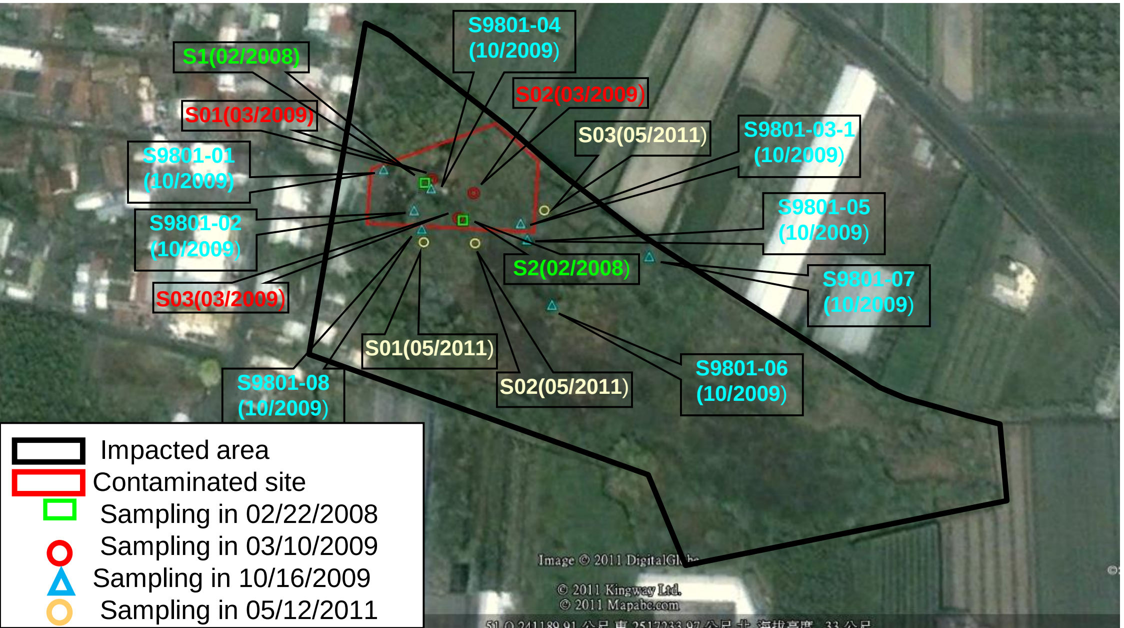
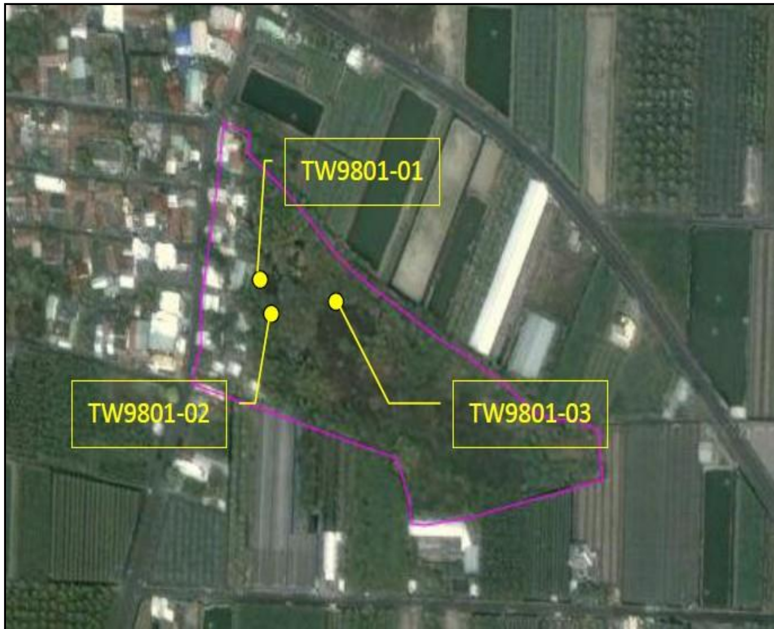
Case study 3
Waste oil recycling site in Pingtung County

- The impacted area is 27,550 m^2
- The site was originally used for illegal waste oil recycling operation
- The major contaminants in soil: TPH, Zn, Cu, Cr

  TPH: 24,400-110,000 mg/kg

  Zinc: 51800 mg/kg

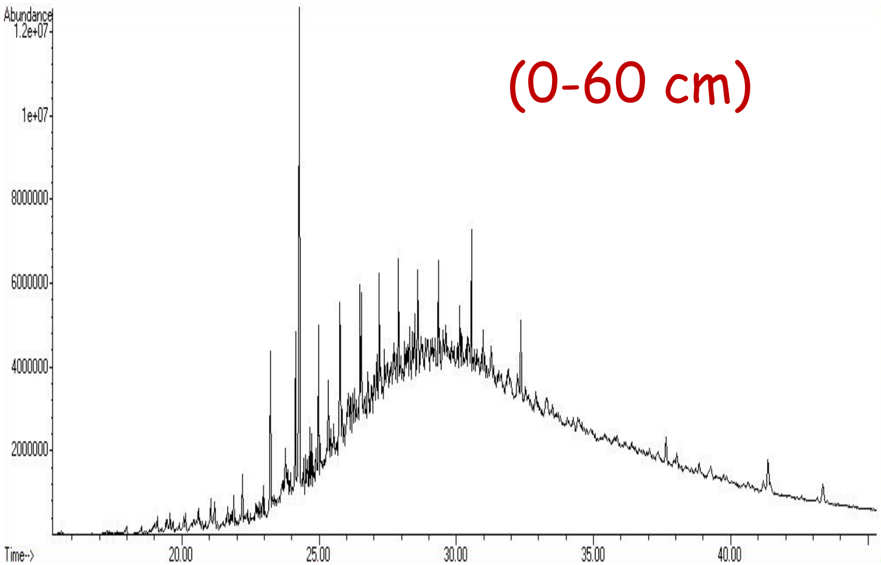


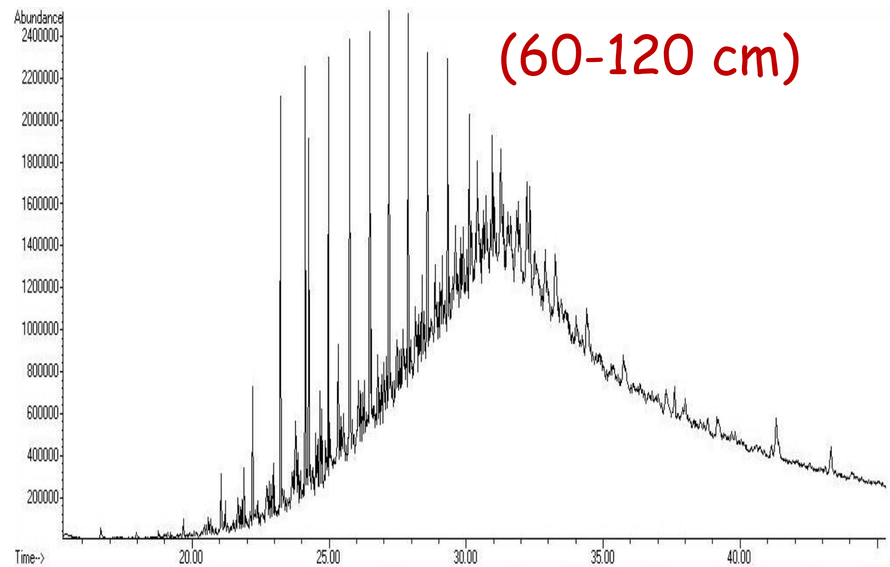


Case Study 3-Field Study Design

- Three treatment plots (6×6m) for bioremediation and phytoremediation (i.e., BP1, BP2, and BP3) .
- Two plots were designed for phytoremediation (i.e., PR1 and PR2).
- One control plot (CK)

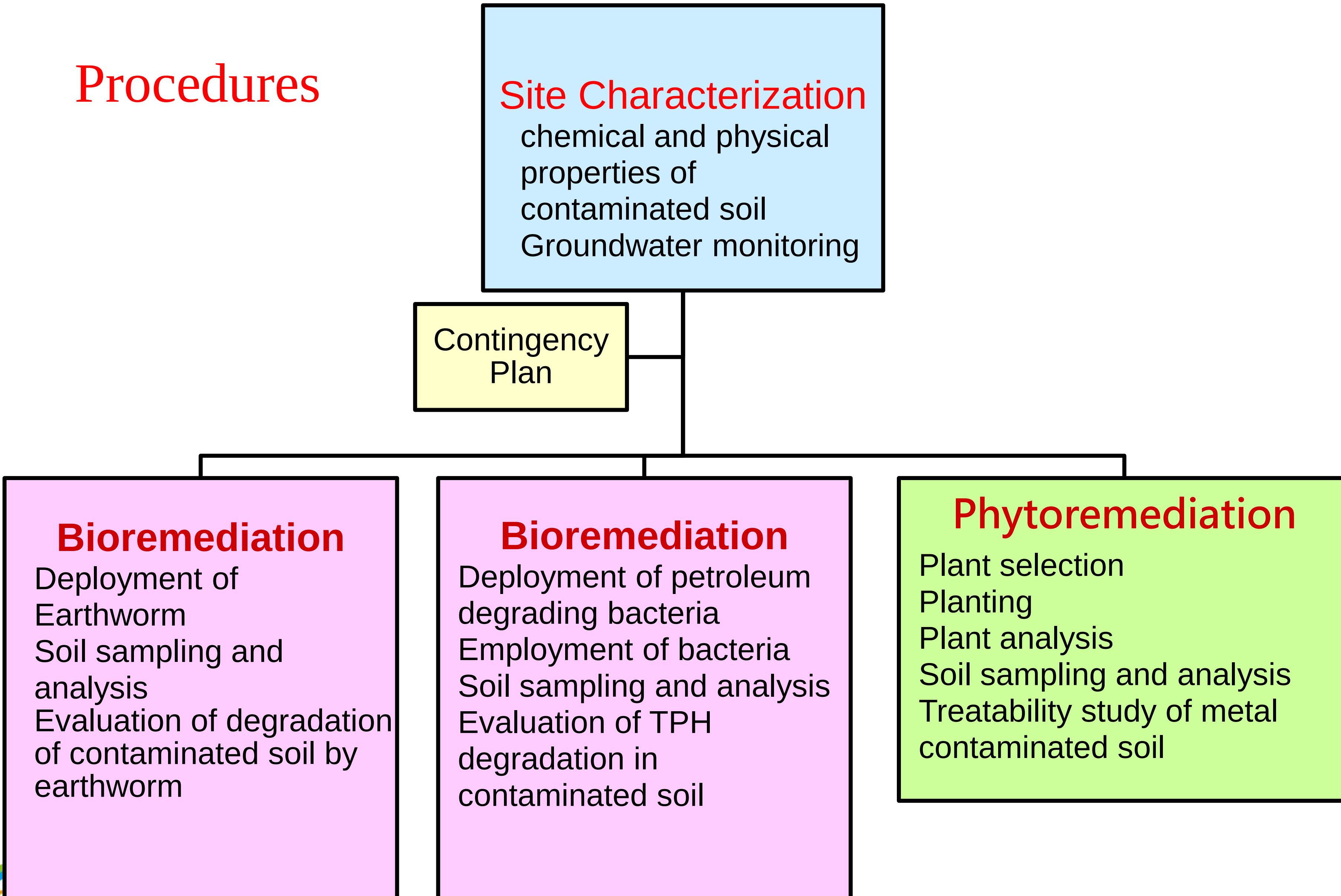
Soil Analysis





Depth (cm)	Contaminants	Cd	Cr	Cu	Ni	Pb	Zn	TPH
	Analytical Methods	NIEA S361.63B						NIEA S703.61B
0-60		1.678	**2765**	**1204**	**1268**	57.83	**52167**	**136752**
60-120		0.572	8.378	14.74	27.54	7.178	103.3	804.4
120-180		0.750	9.339	12.33	28.45	7.178	92.39	-
180-240		0.256	10.06	12.23	27.62	6.667	94.39	-
Regulation		20	250	400	200	2000	2000	1000

Procedures



Site Characterization
chemical and physical properties of contaminated soil
Groundwater monitoring
Contingency Plan
Bioremediation
Deployment of Earthworm
Soil sampling and analysis
Evaluation of degradation of contaminated soil by earthworm
Bioremediation
Deployment of petroleum degrading bacteria
Employment of bacteria
Soil sampling and analysis
Evaluation of TPH degradation in contaminated soil
Phytoremediation
Plant selection
Planting
Plant analysis
Soil sampling and analysis
Treatability study of metal contaminated soil

Design of Bioremediation

BP1

BP2

BP3

- 5.4 kg of earthworm (*Eisenia fetida*) was employed in BP1, BP2, and BP3 at four month interval (on May 15 and September 7, 2012 and Feb 4, 2013)

Design of Bioremediation

- Twenty liter of petroleum-degrading bacteria (*Pseudomonas* sp. NKNU01) was applied in BP1, BP2, and BP3 on August 2012 and February 2013 to enhance bioremediation in the contaminated site.

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Design of Phytoremediation

Poplars (*Populus bonatii Levl.*)

Sun Hemp (*Crotalaria juncea L*.)

- 12 poplar trees were planted in BP-1 and BP-2,respectively
- 10 poplars in BP3, 9 in PR1, 18 in PR2, and 25 in CK with a spacing of approximately 2.5 m between trees to obtain rapid production of a dense biomass
- Approximate 150 sun hemp were installed in the area of 1 m^2

Growth of Poplars in Treatment Plots

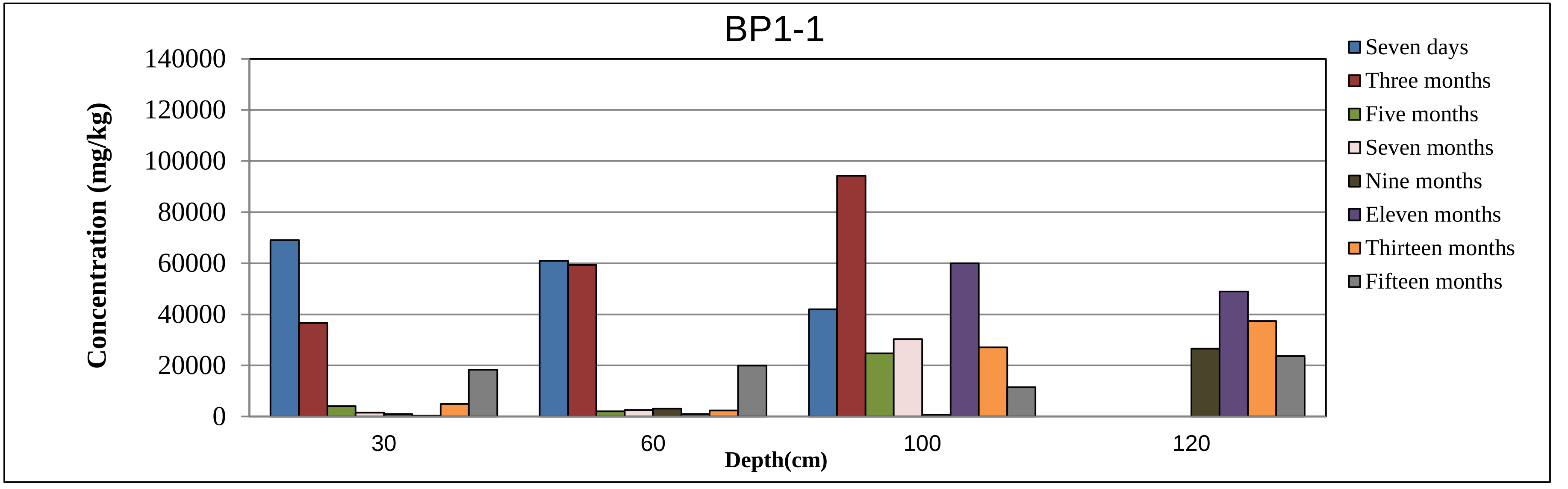


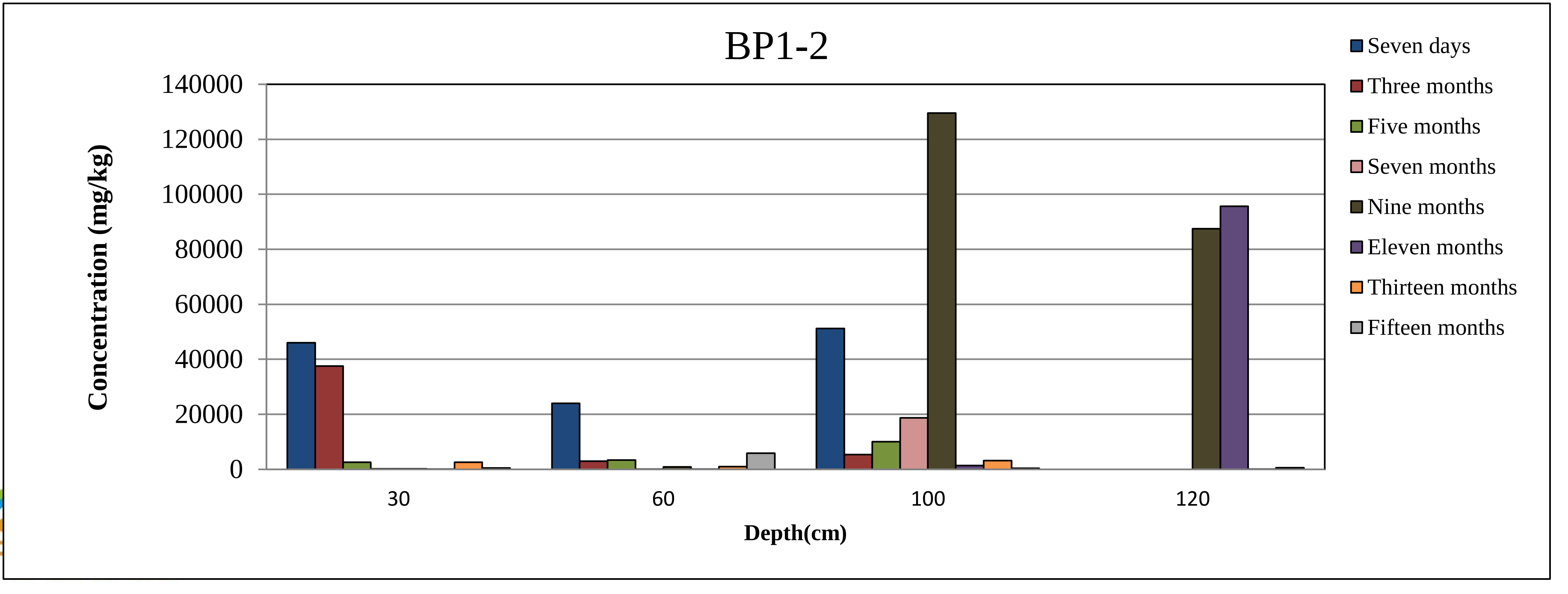
BP1 BP2 BP3

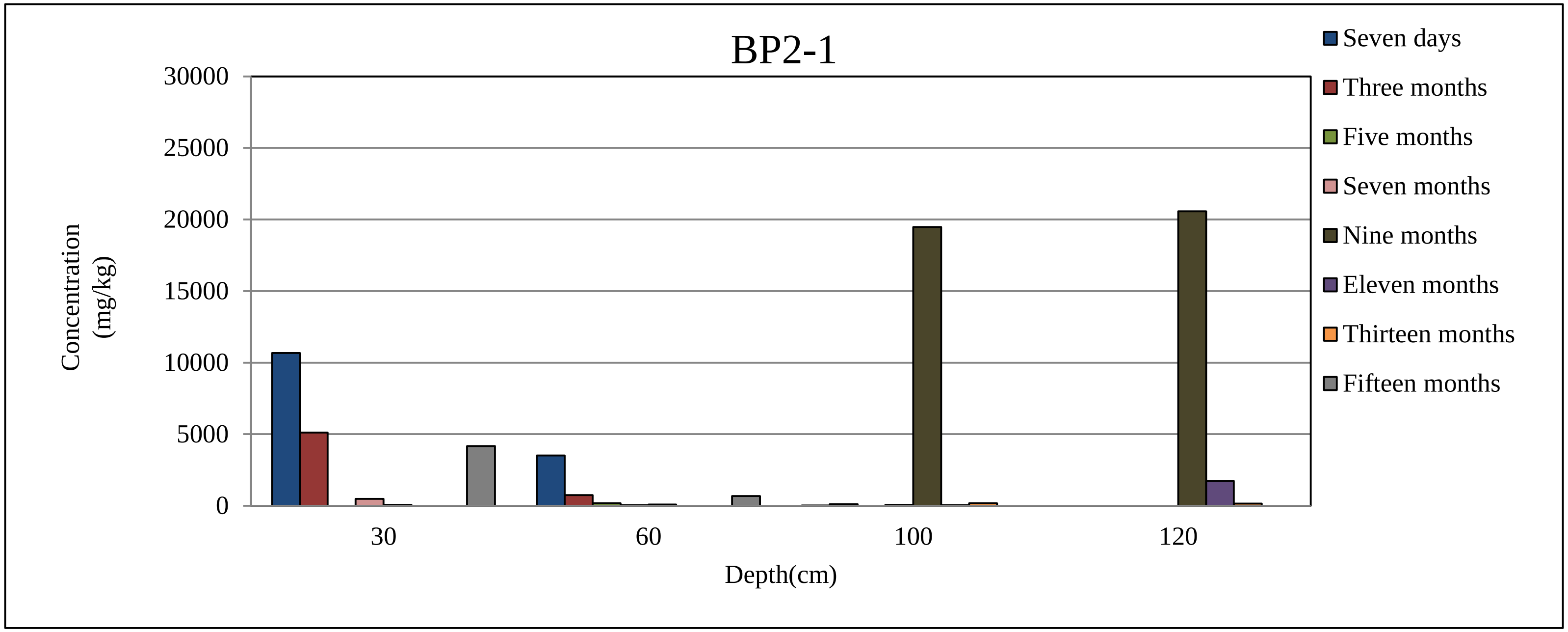


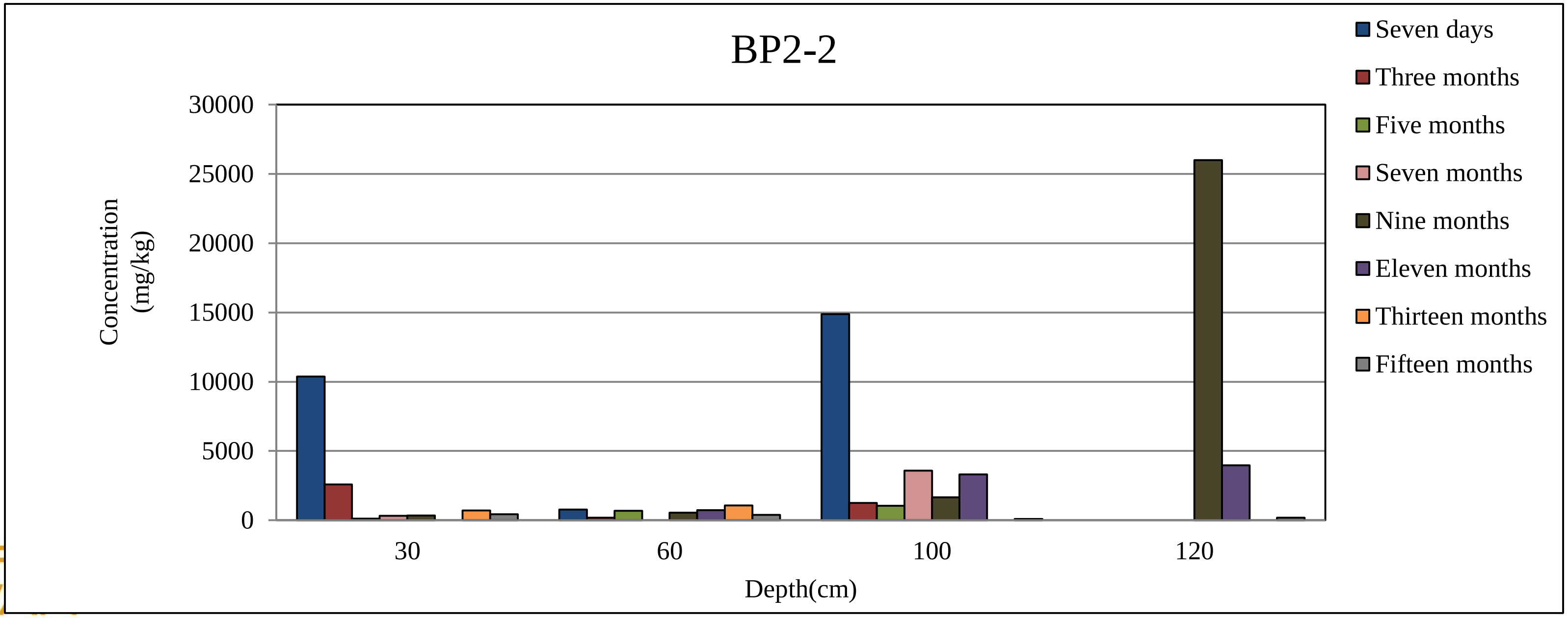
PR1 PR2 CK

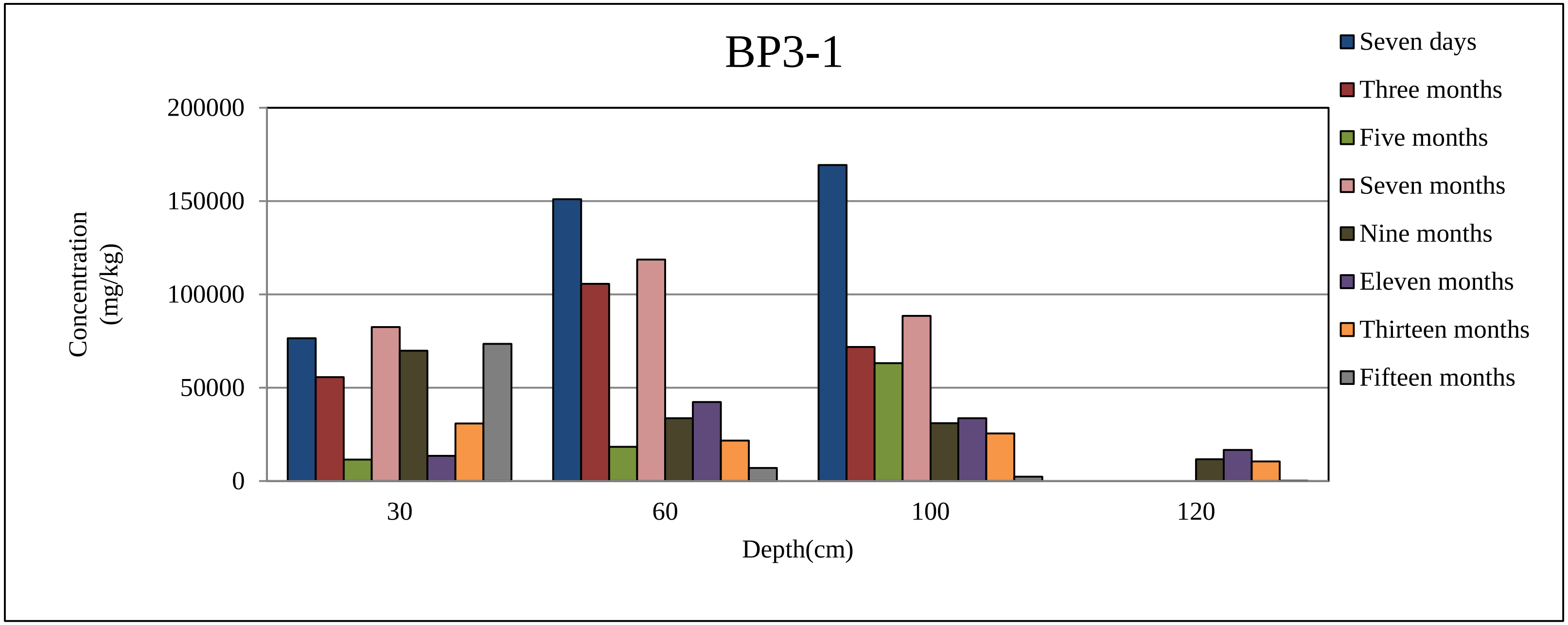
Bioremediation Treatment

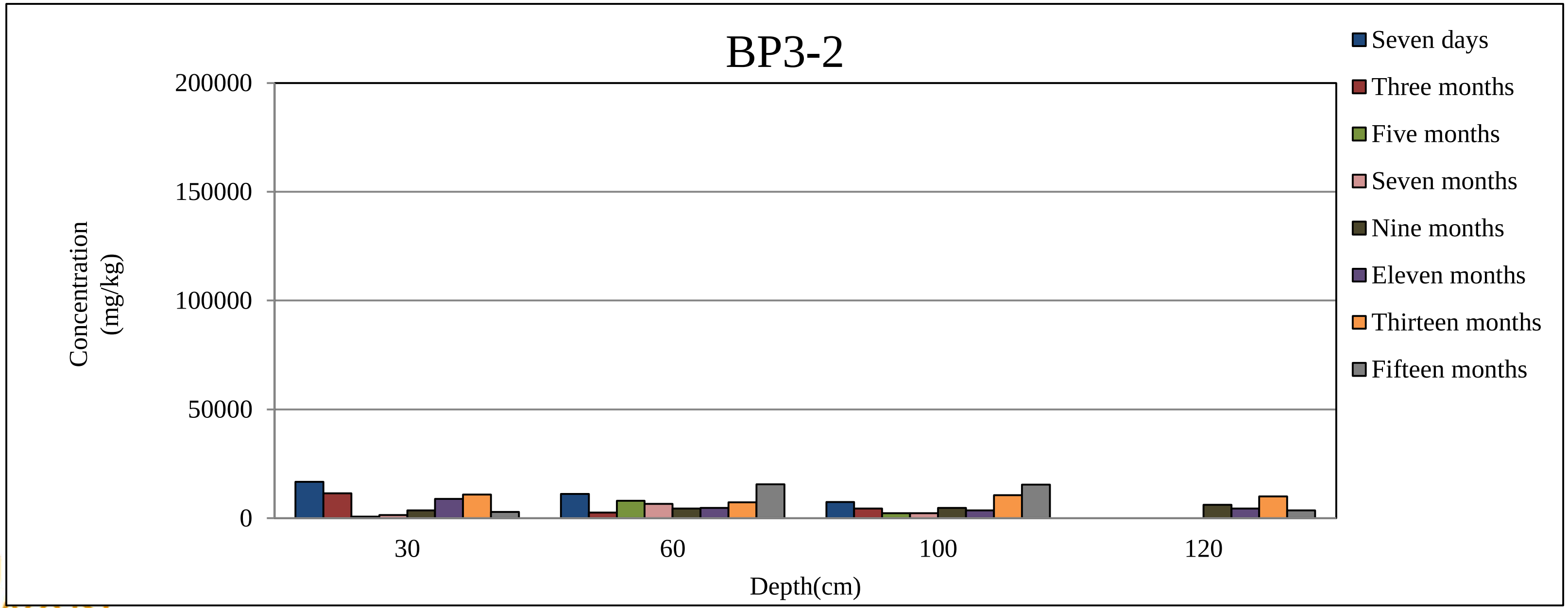




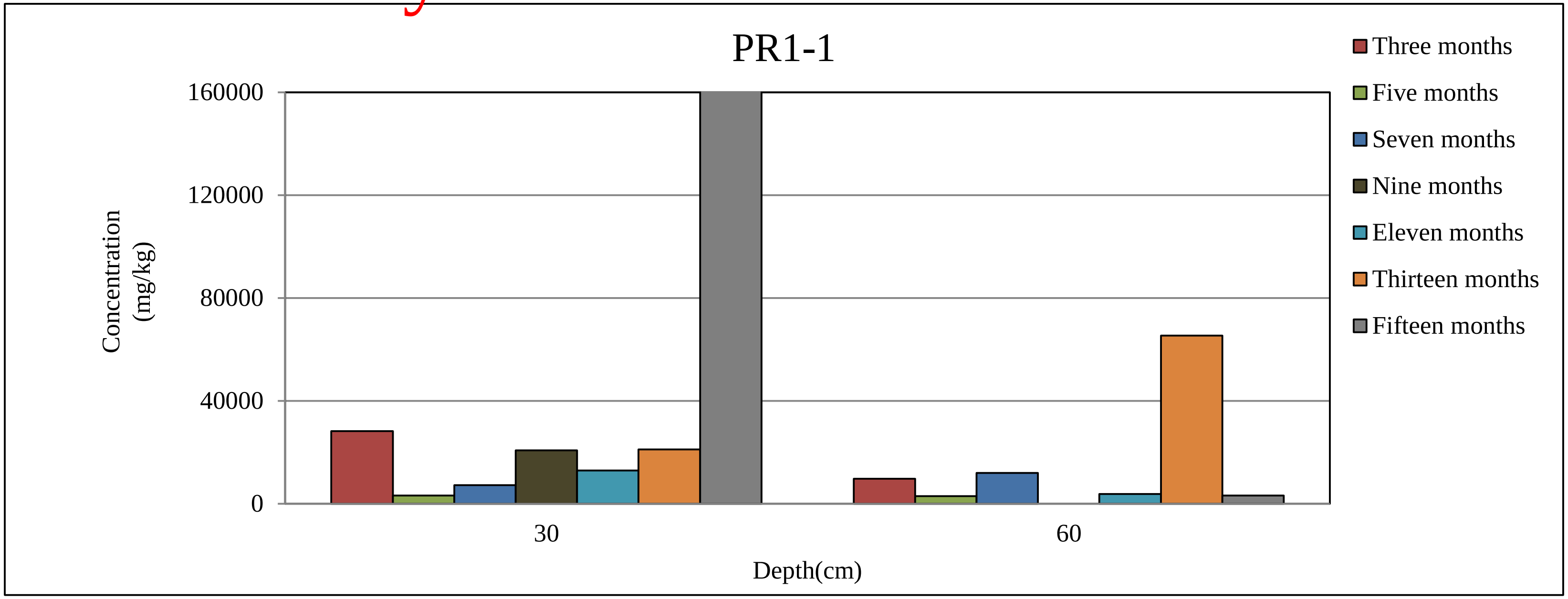

BP2-1
Seven days
Three months
Five months
Seven months
Nine months
Eleven months
Thirteen months
Fifteen months
Concentration (mg/kg)
30000
25000
20000
15000
10000
5000
0
30
60
100
120
Depth(cm)

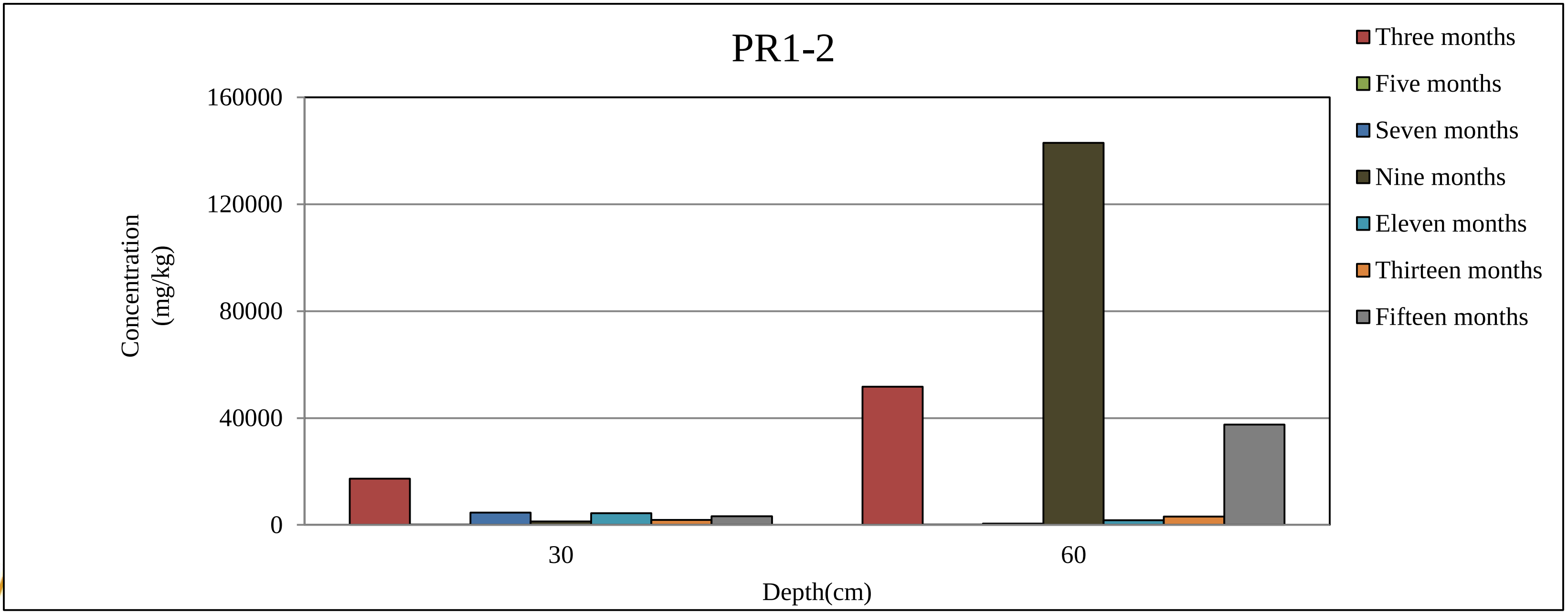

BP2-2
Seven days
Three months
Five months
Seven months
Nine months
Eleven months
Thirteen months
Fifteen months
Concentration (mg/kg)
30000
25000
20000
15000
10000
5000
0
30
60
100
120
Depth(cm)

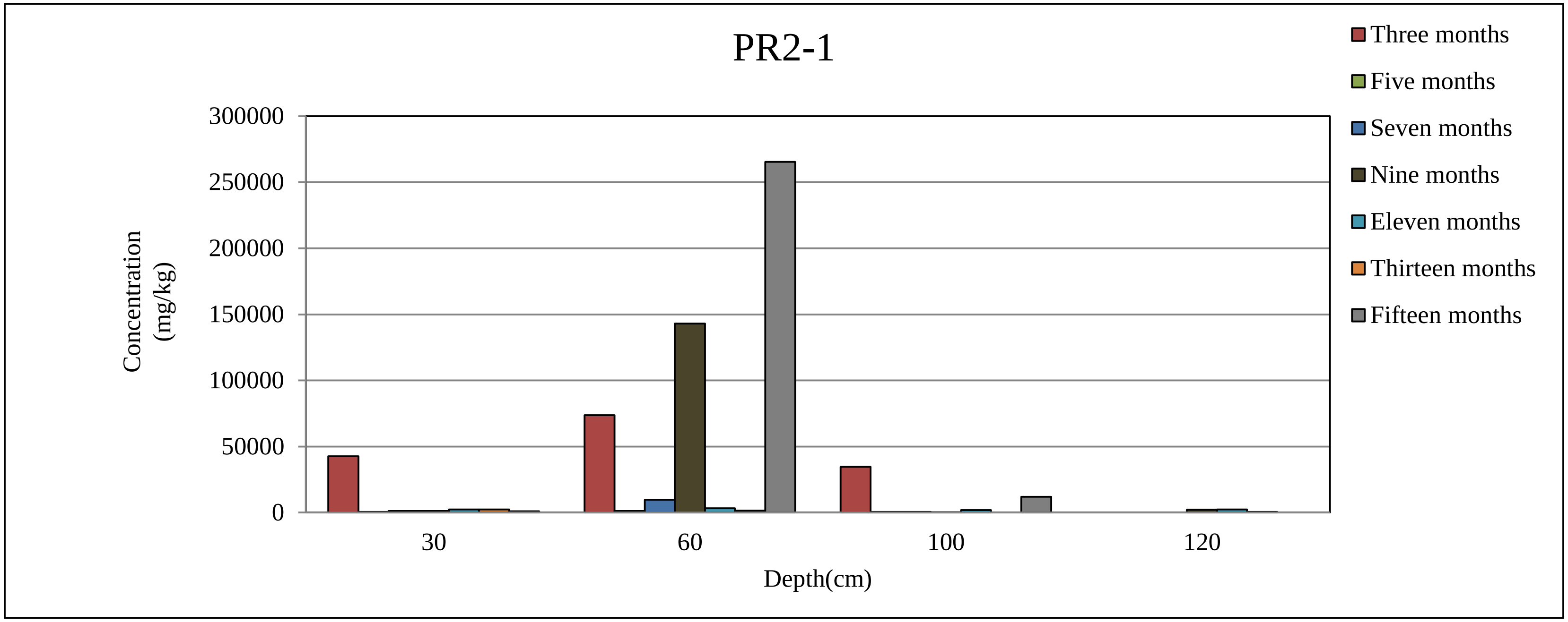

BP3-1
Seven days
Three months
Five months
Seven months
Nine months
Eleven months
Thirteen months
Fifteen months
200000
150000
100000
50000
0
Concentration (mg/kg)
30
60
100
120
Depth(cm)

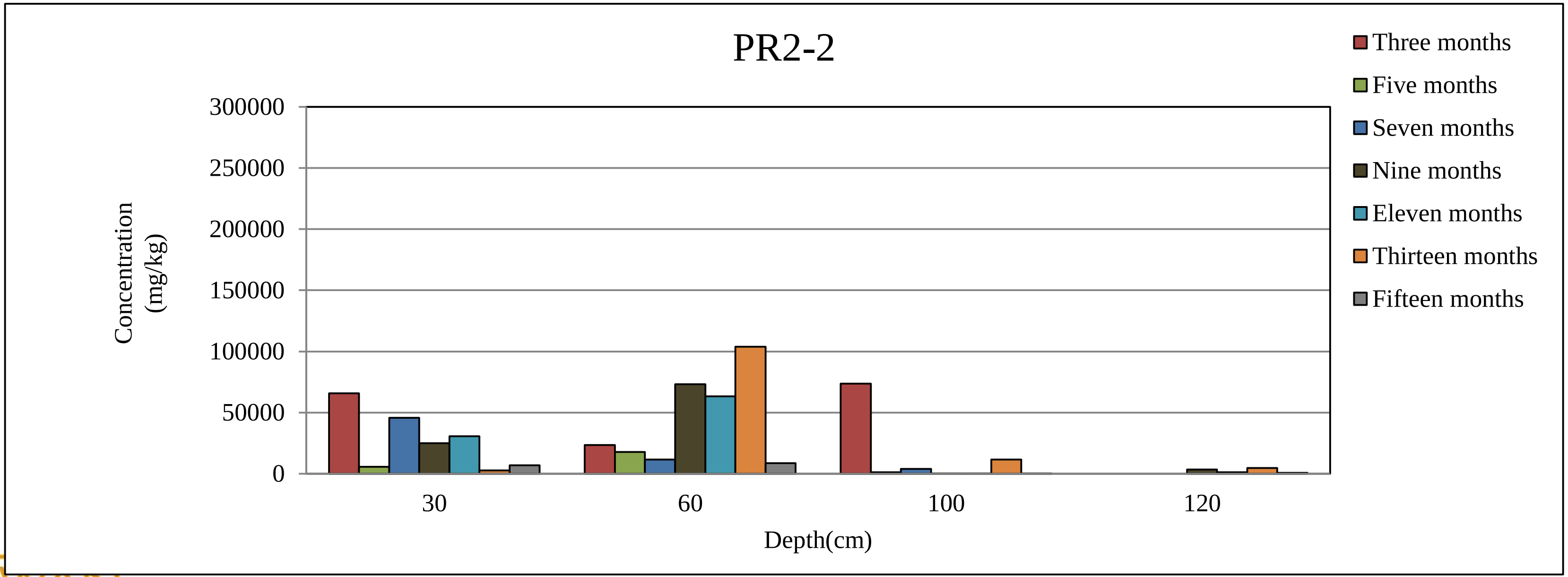

BP3-2
Seven days
Three months
Five months
Seven months
Nine months
Eleven months
Thirteen months
Fifteen months
200000
150000
100000
50000
0
Concentration (mg/kg)
30
60
100
120
Depth(cm)

Phytoremediation Treatment






PR2-1
Three months
Five months
Seven months
Nine months
Eleven months
Thirteen months
Fifteen months
300000
250000
200000
150000
100000
50000
0
Concentration (mg/kg)
30
60
100
120
Depth(cm)


PR2-2
Three months
Five months
Seven months
Nine months
Eleven months
Thirteen months
Fifteen months
300000
250000
200000
150000
100000
50000
0
Concentration (mg/kg)
30
60
100
120
Depth(cm)

Lesson learned and challanges

- TEPA Top-down appraoch
  - Clear rule
    - Core element, principles, systematic approach
  - Need for a tiered GSR assessment
    - When to adopt the GSR desicion support tool?
    - Different criteria for different type of sites
      - Ex: sites in urban area/ ecological impact
        private sites / econimoc benefit prediction
        farm land / soil impact
  - Stakeholder involvement
    - Weighting , Number of people to be involved
  - BMPs planning based on quantitative assessment? Or simple BMPs planning?
    - Site area? Site concentration? Site location?

SURF TAIWAN

Thank you for your attention

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Health Risk Assessment and Sustainable Remediation

Speaker: Hwong-wen Ma

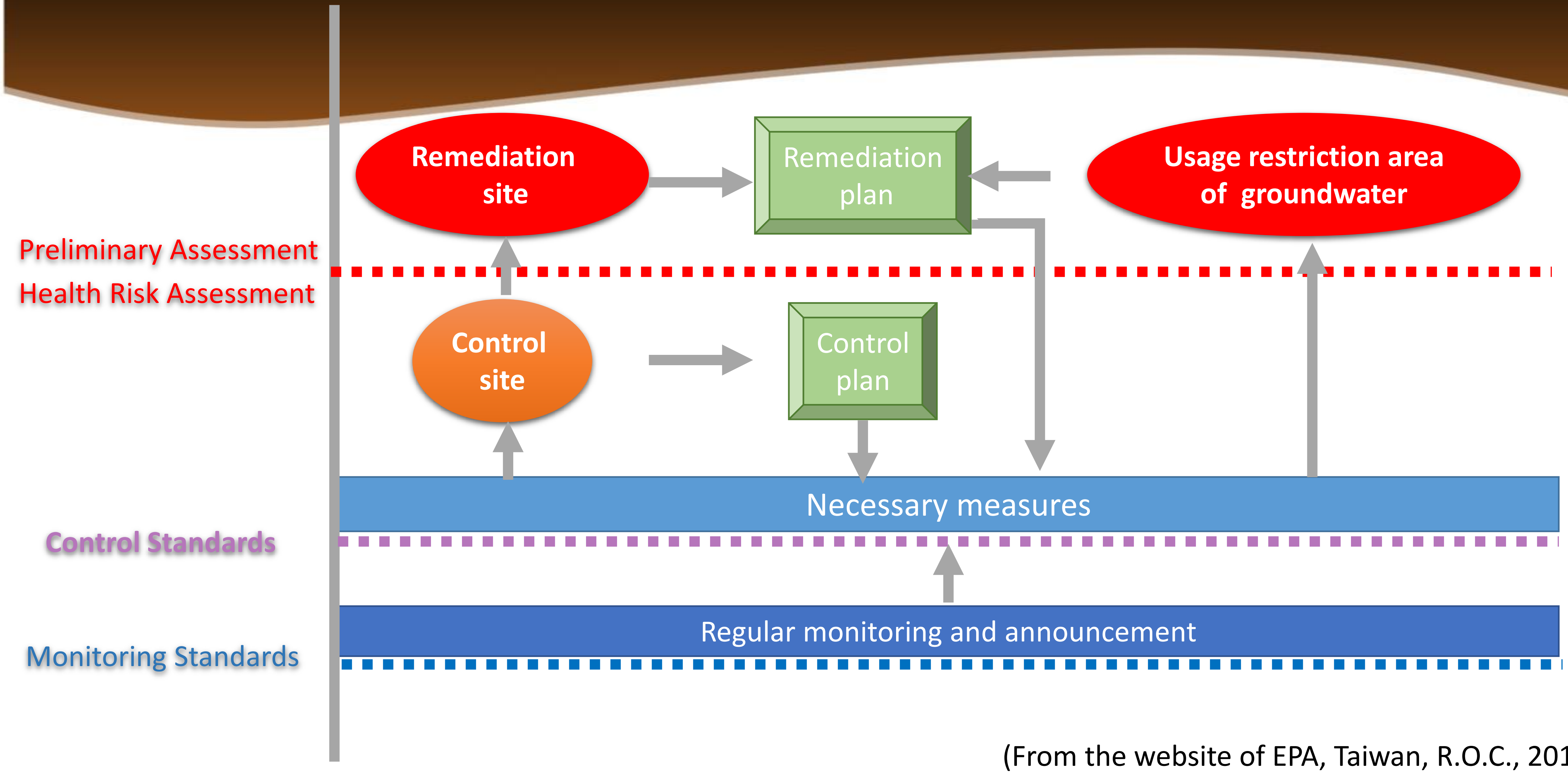
Graduate Institute of Environmental Engineering

National Taiwan University

Outline

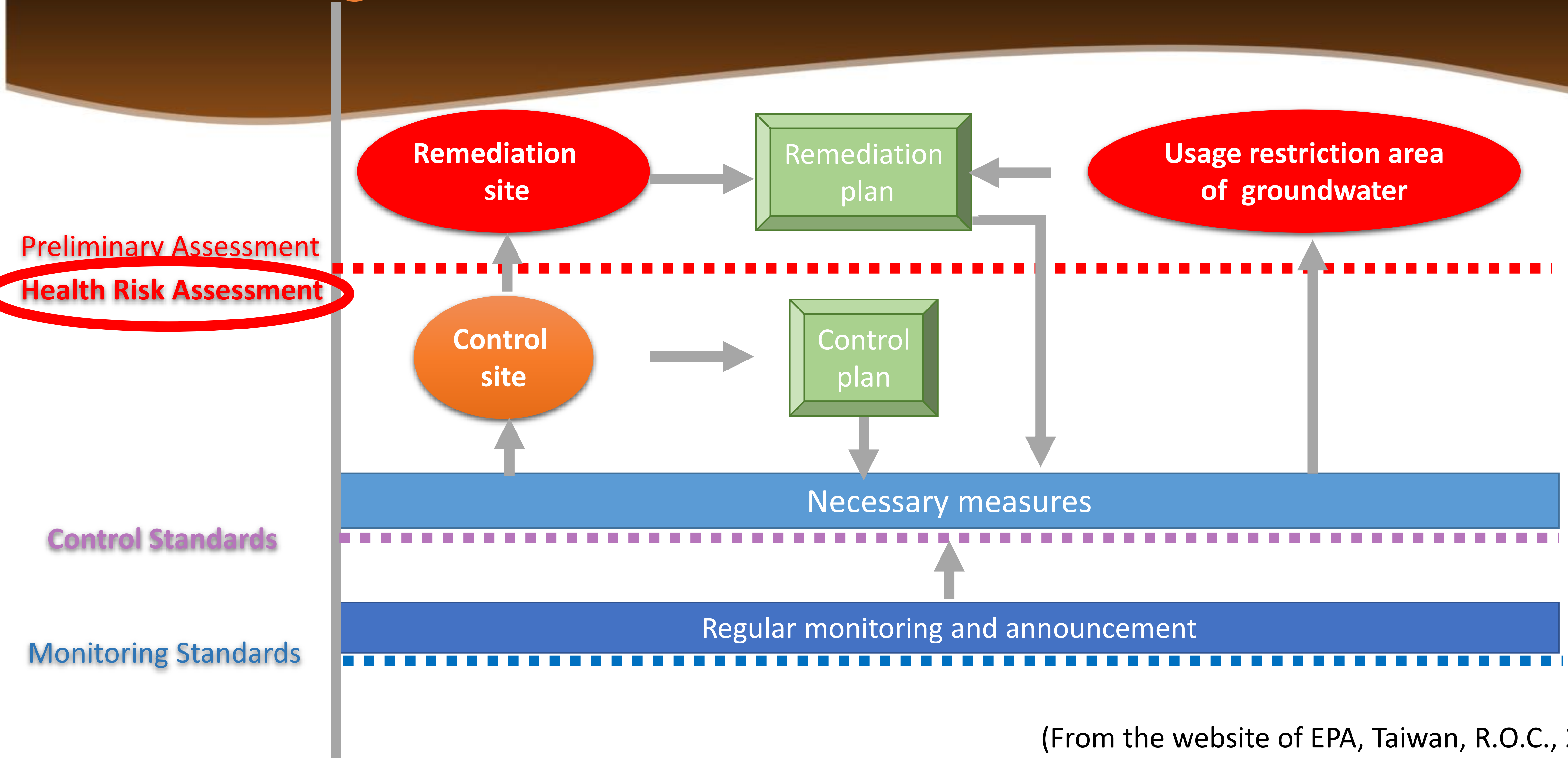
- Introduction to Health Risk Assessment
- Risk Management and Health Risk Assessment
- A Case study for Health Risk Assessment
- Management of contaminated sites
  - Decontamination
  - Brownfield
  - Green Remediation
  - Sustainable Remediation
- A Case Study for Sustainable Remediation

Determining contaminated sites in Taiwan



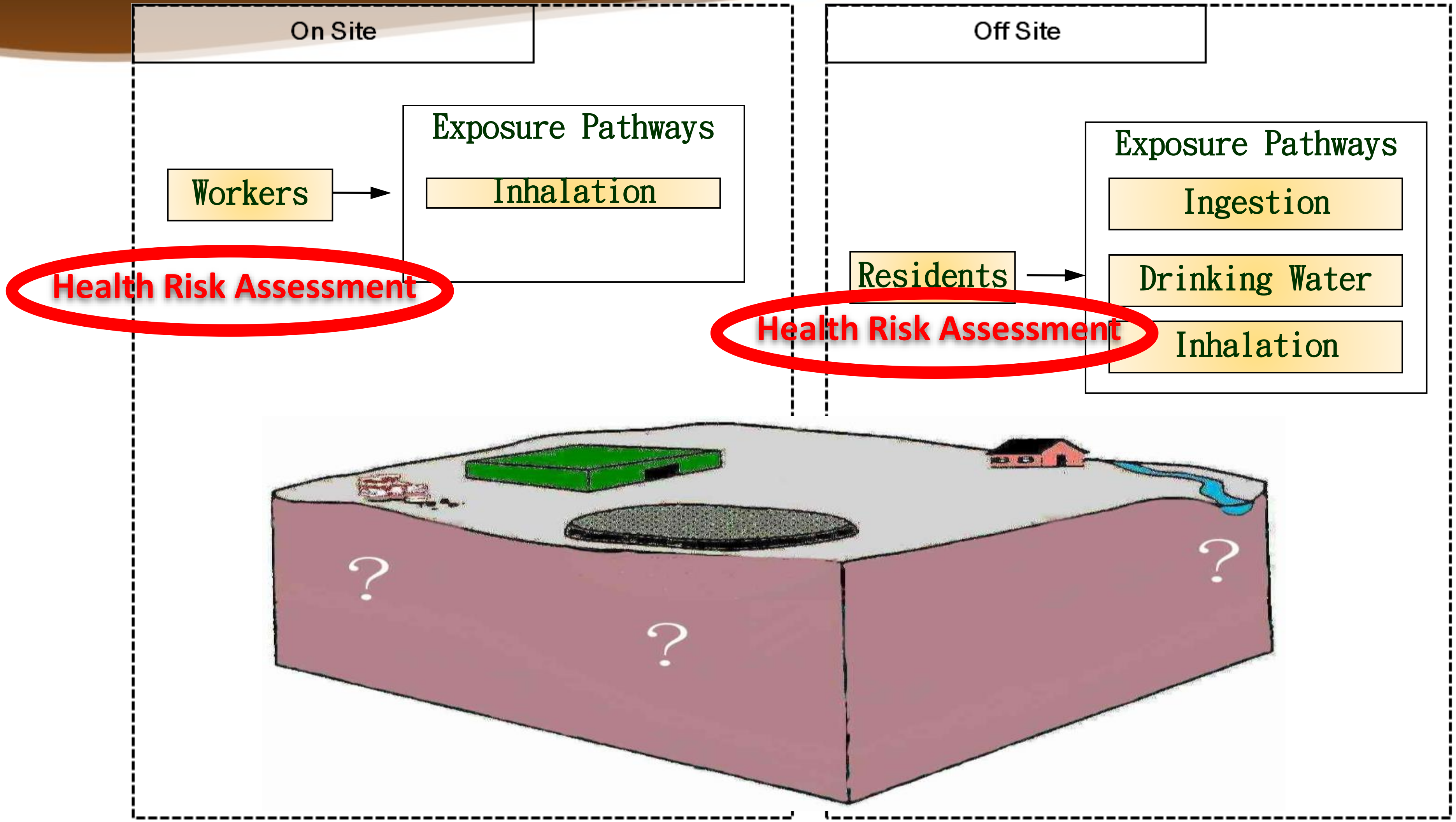
(From the website of EPA, Taiwan, R.O.C., 2013)

Determining contaminated sites in Taiwan

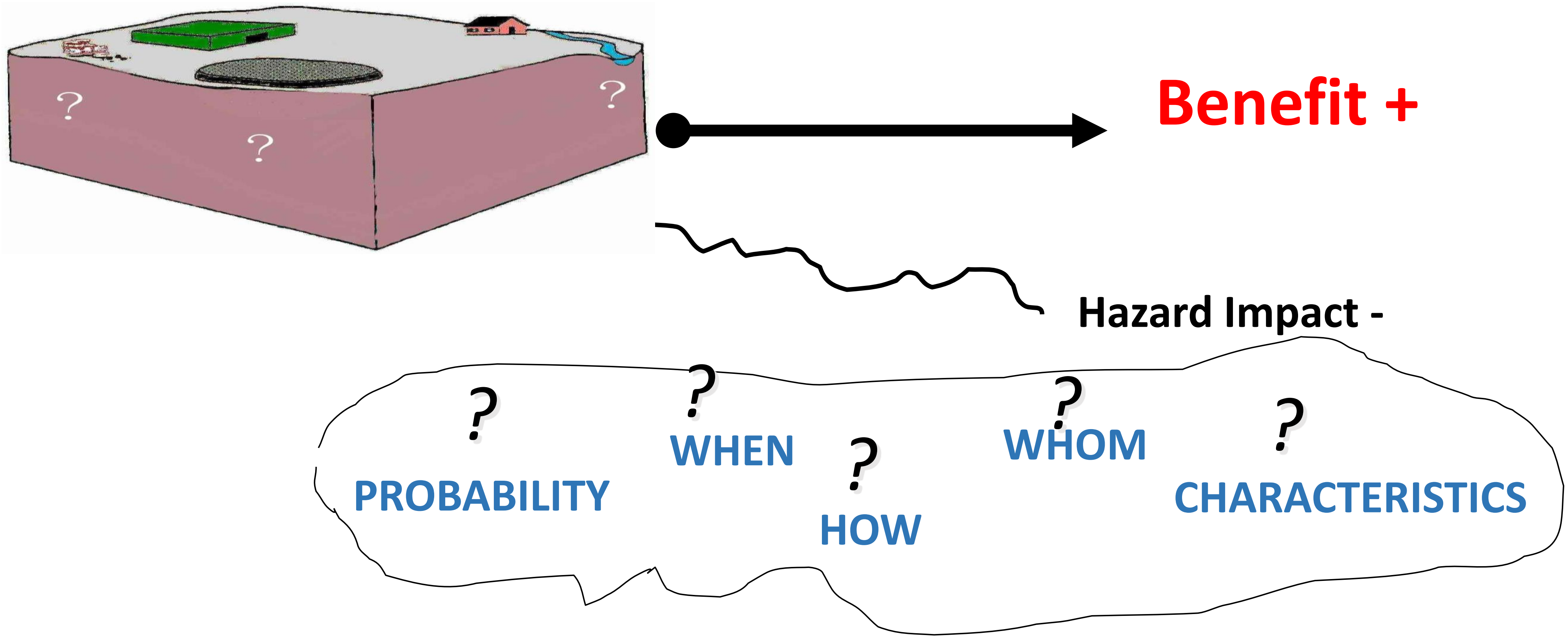


(From the website of EPA, Taiwan, R.O.C., 2013)

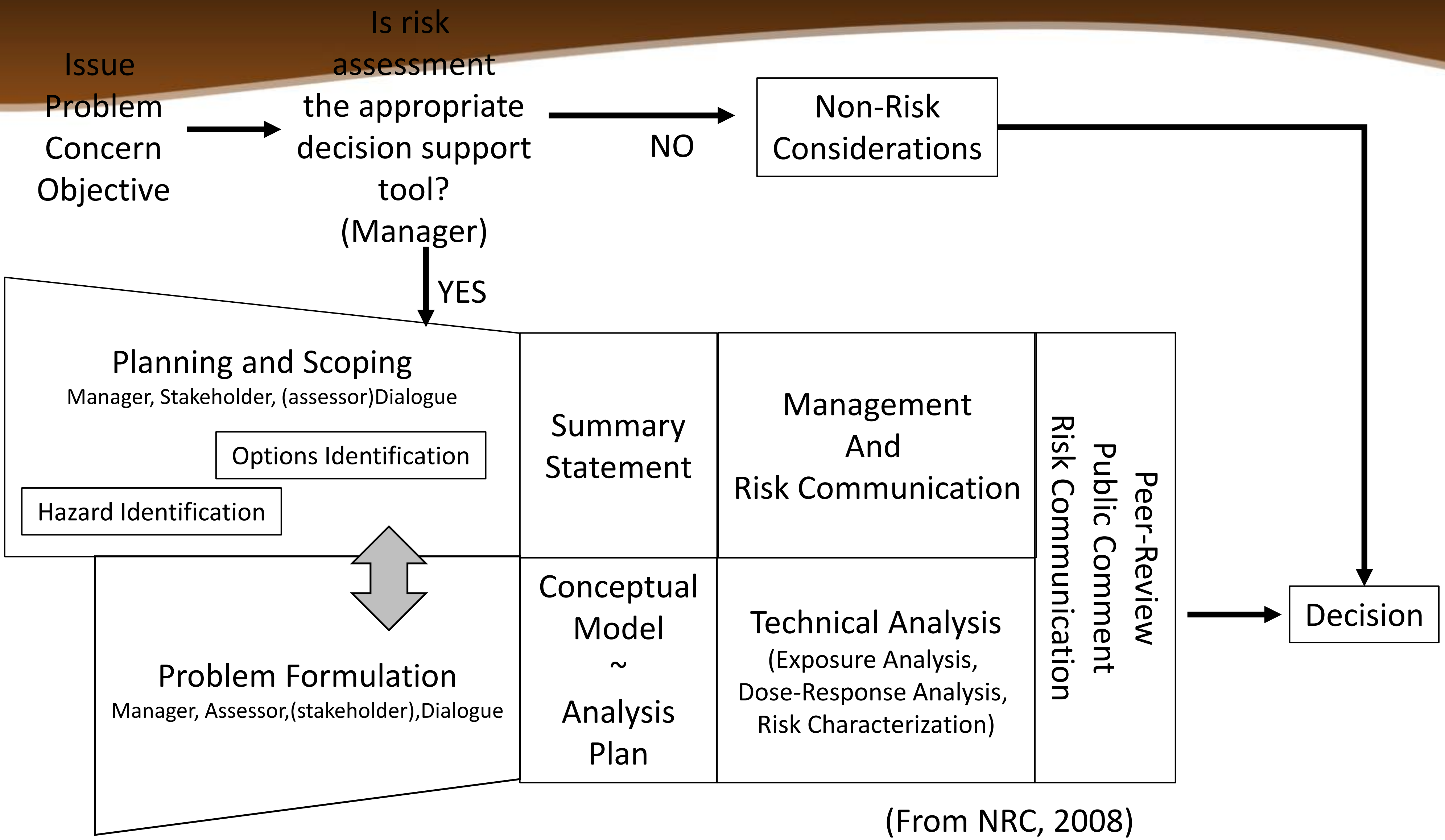
Health risk assessment (HRA) and contaminated Site



Risk thinking

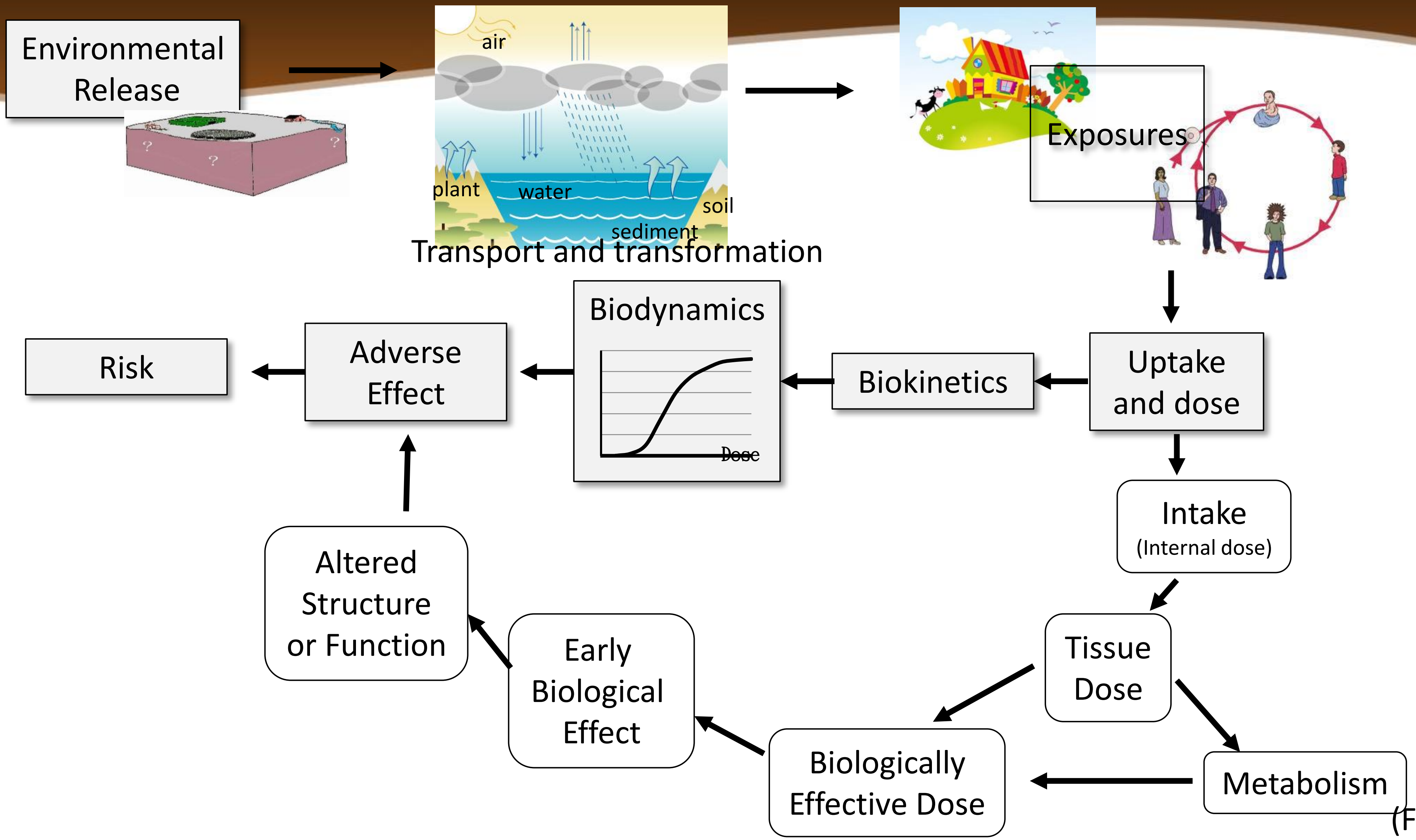


Schematic representation of risk assessment stages



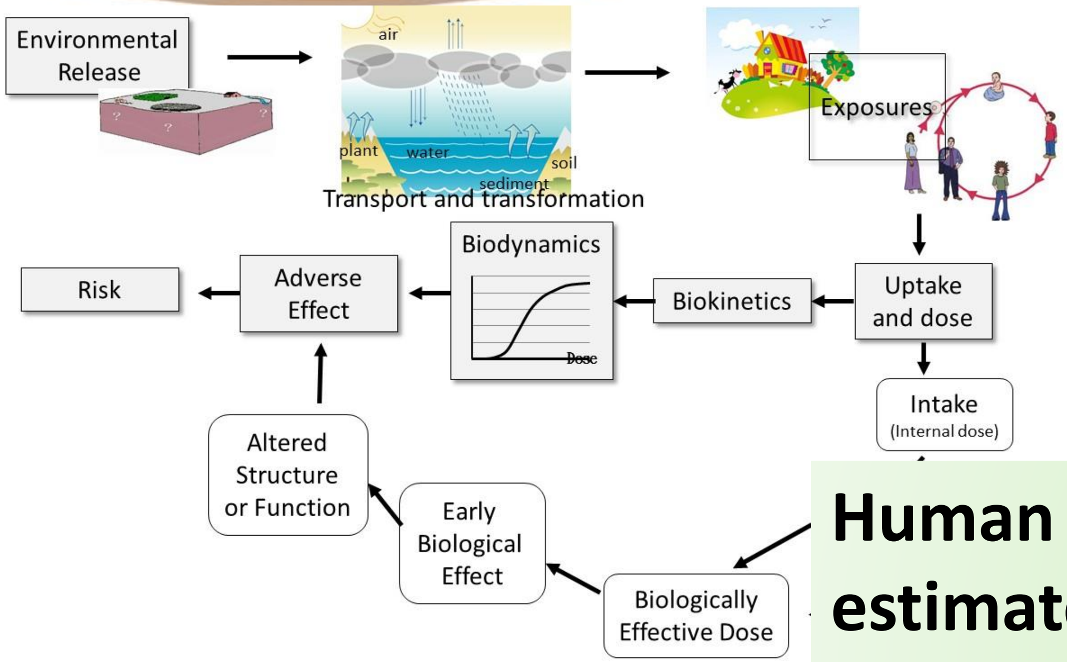
(From NRC, 2008)

Key components in human health risk assessment



(From NRC, 2008)

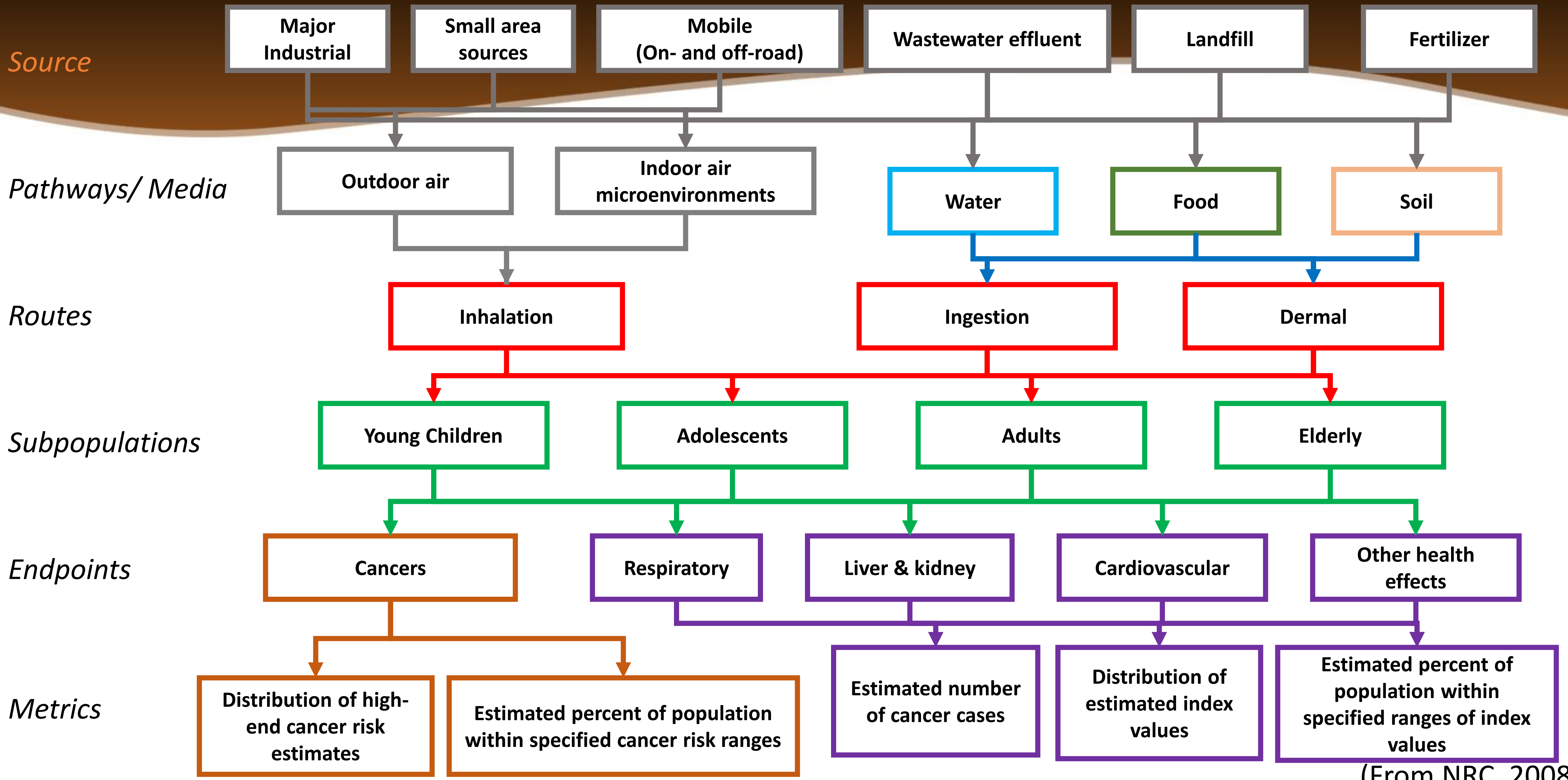
Key components in human health risk assessment



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.

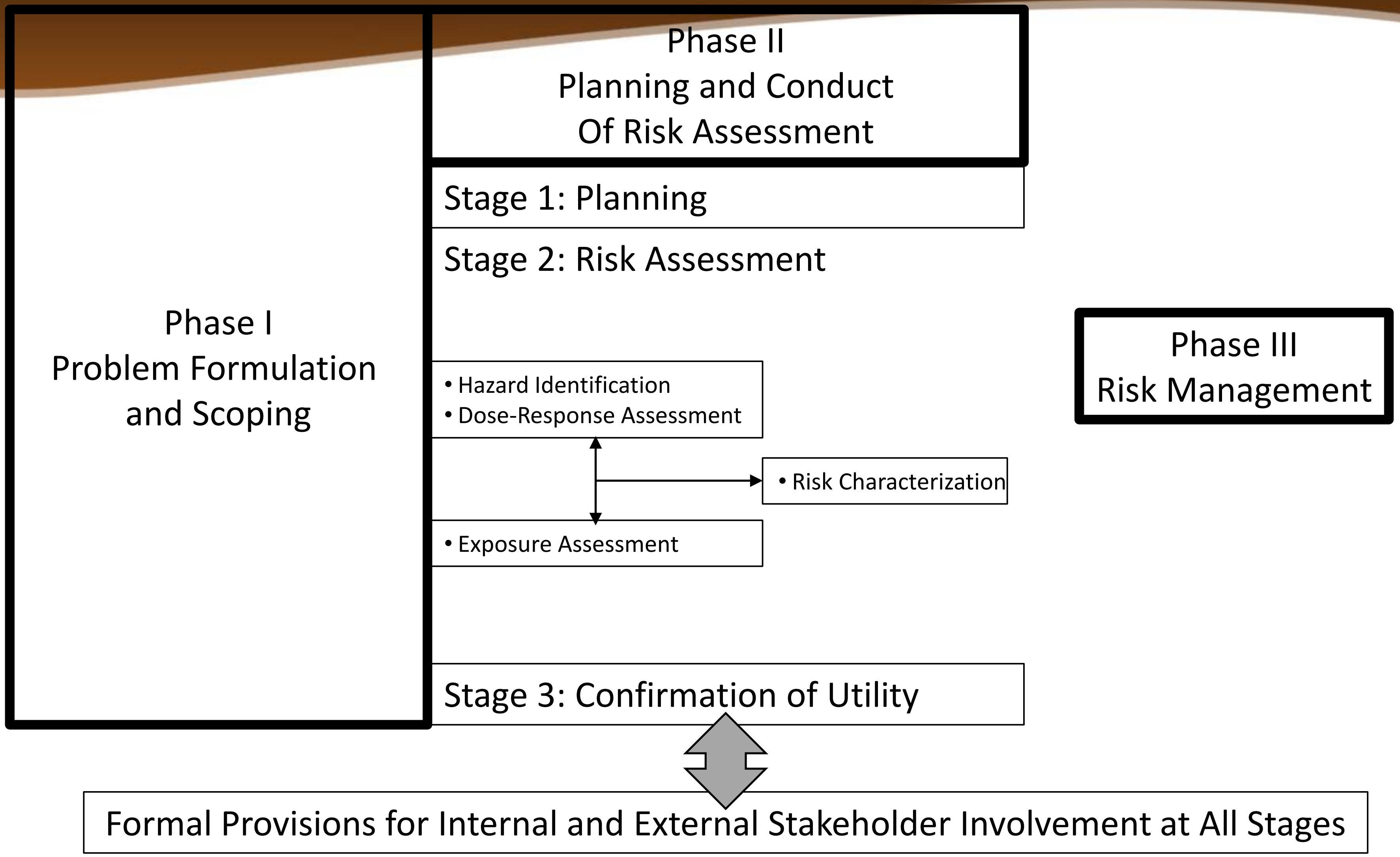
(From the website of U.S.EPA, 2013)

Scope of risk assessment



(From NRC, 2008)

A framework for risk-based decision-making that maximizes the utility of risk assessment



(From NRC, 2008)

Elements in health risk assessment

Hazard Identification

What adverse health or environmental effects are associated with the agents of concern?

Dose-Response Assessment

For each determining adverse effect, what is the relationship between dose and the probability of the occurrence of the adverse effects in the range of doses identified in the exposure assessment

Exposure Assessment

What exposures/doses are incurred by each population of interest under existing conditions?

How dose each option affect existing conditions and resulting exposures/doses ?

Risk Characterization

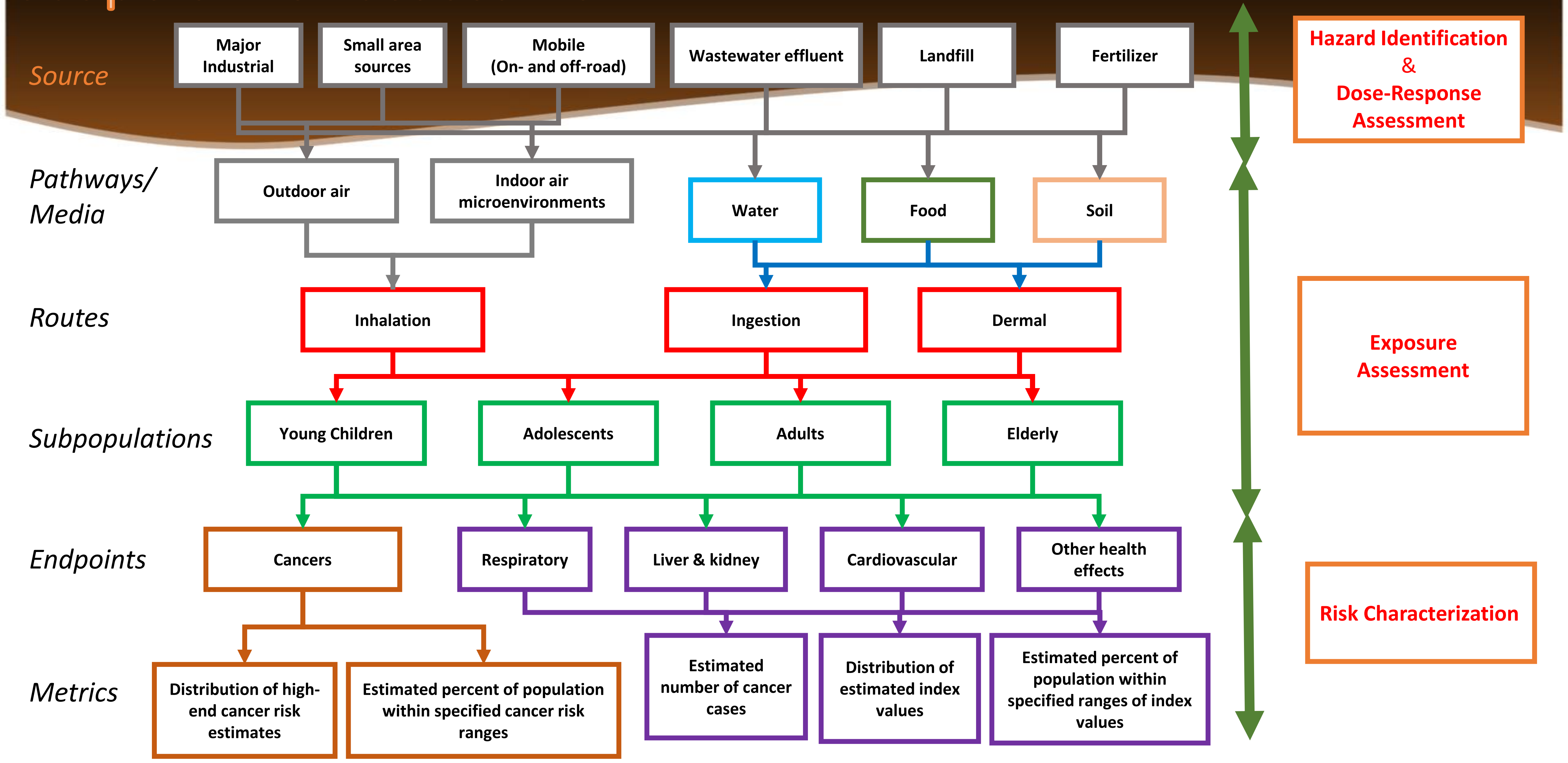
What is the nature and magnitude of risk associated with existing conditions

What risk decreases (benefits) are associated with each of the options?

Are any risks increased? What are the significant uncertainties?

(From NRC, 2008)

Scope of risk assessment



Hazard identification

- What adverse health or environmental effects are associated with each of the agents of potential interest?
- What is the weight of scientific evidence supporting the classification of each effect?
- What adverse effects are the likely risk determinants?

(From NRC, 2008)

Database used in hazard identification

- Integrated Risk Information System, IRIS
- WHO Concise International Chemical Assessment Document, CICAD
- International Agency for Research on Cancer, IARC
- USEPA Provisional Peer Reviewed Toxicity Values, PPRTVs
- Agency for Toxic Substance and Disease Registry, ASTDR
- Health Effects Assessment Summary Tables, HEAST

(From NRC, 2008)

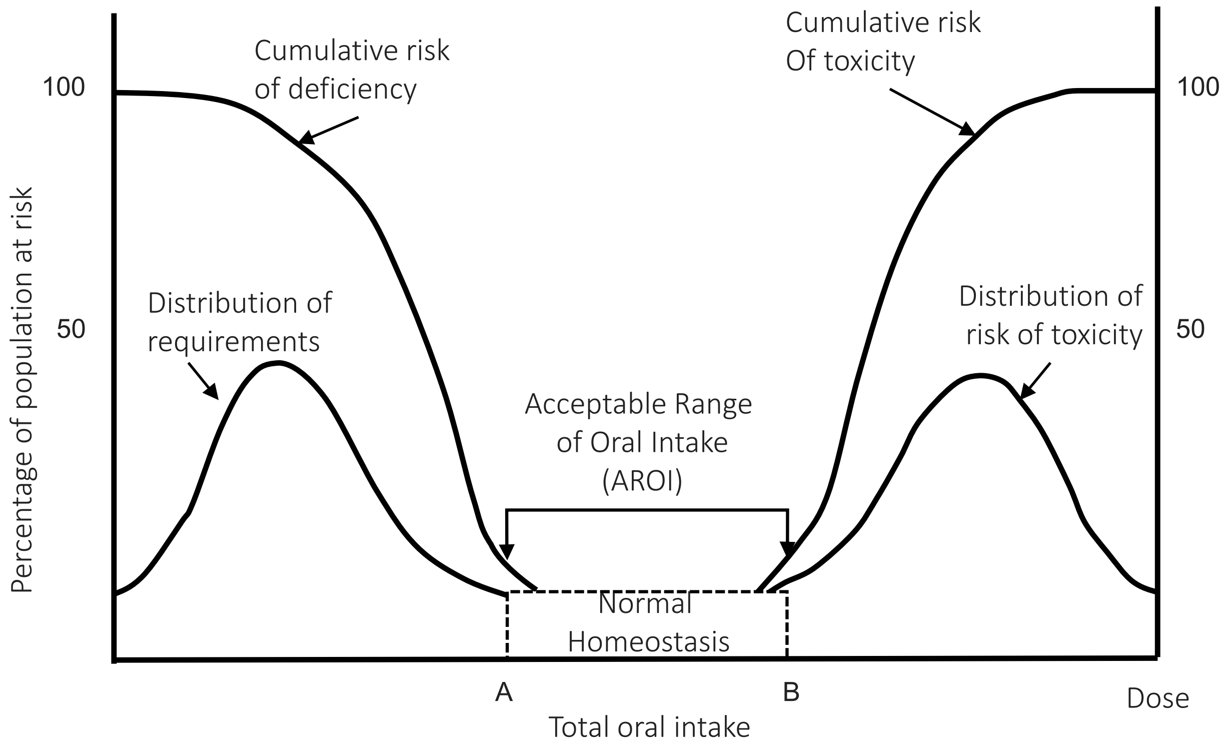
Factors concerned in hazard identification

- High concentration of pollutants of release
- Persistent pollutants (bioconcentrated and bioaccumulative)
- Long-distance transportation
- Critical hazard (HAPs, metal, and radiation)
- Toxicity (cancer, mutations, birth defects, reproductive toxicity, immunological toxicity, neurobehavioral toxicity, organ-specific effects, endocrine modulation or disruption, ecosystem

(From NRC, 2008)

Dose-response assessment

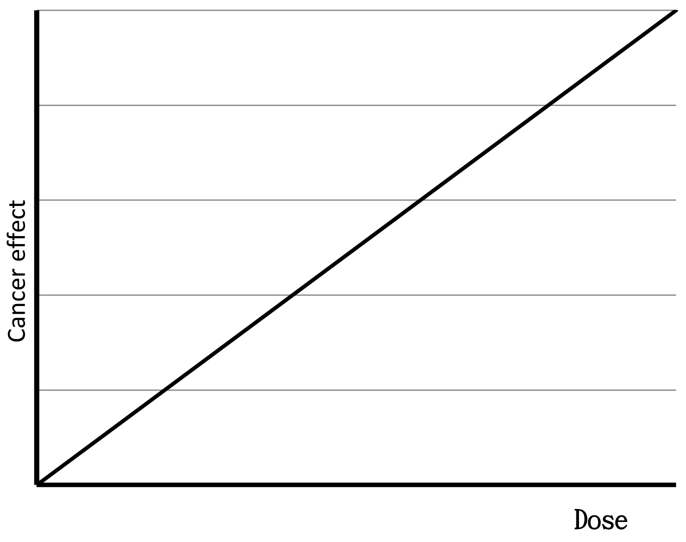
- For each adverse effect, what is the relationship between dose and the probability of the occurrence of the adverse effect in the dose region identified in the exposure assessment



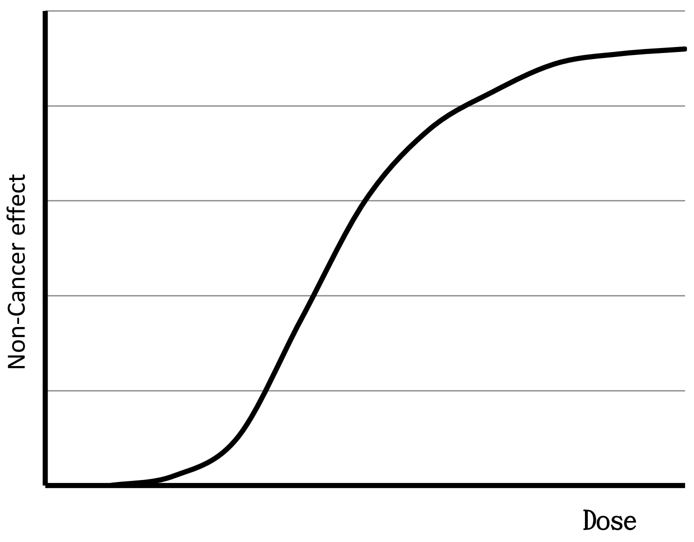
(From NRC,2008;WHO, 2002)

Parameters of dose-response assessment in HRA

Cancer Slope Factor (CSF)
in risk(dose)/(mg/kg-day)

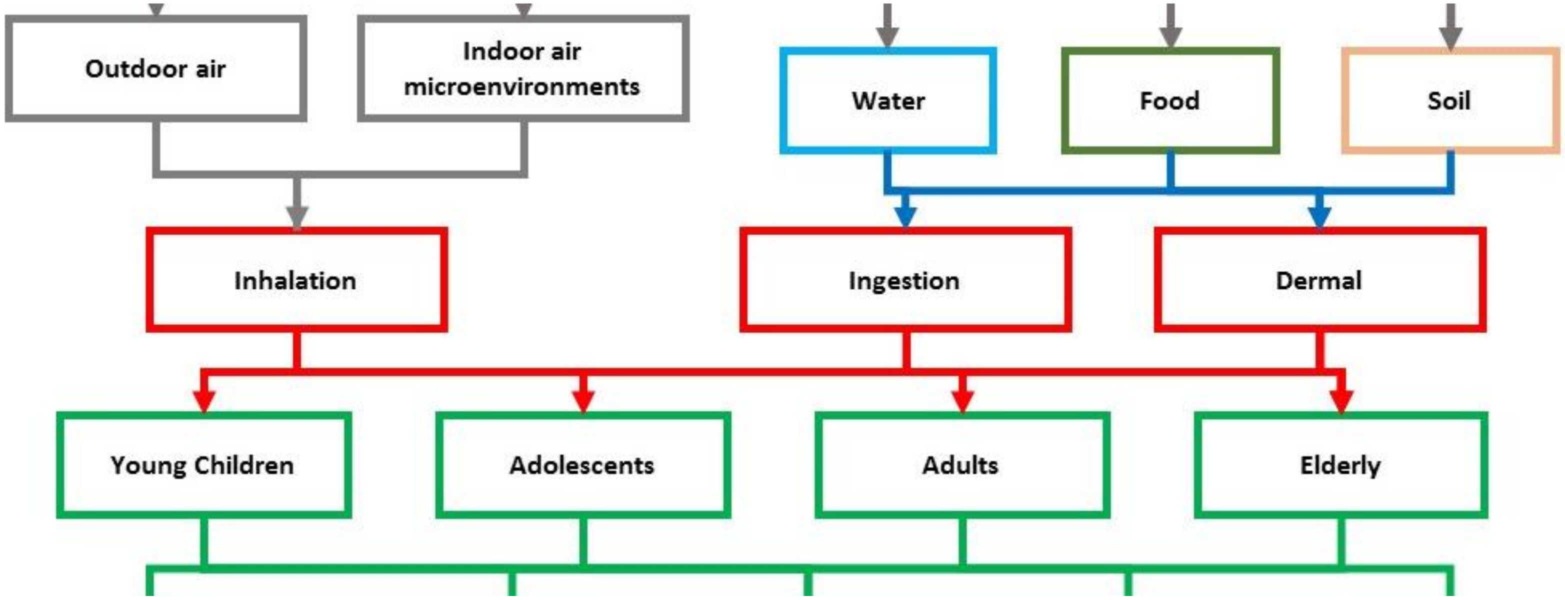


Reference Dose(RfD)
in (mg/kg-day)



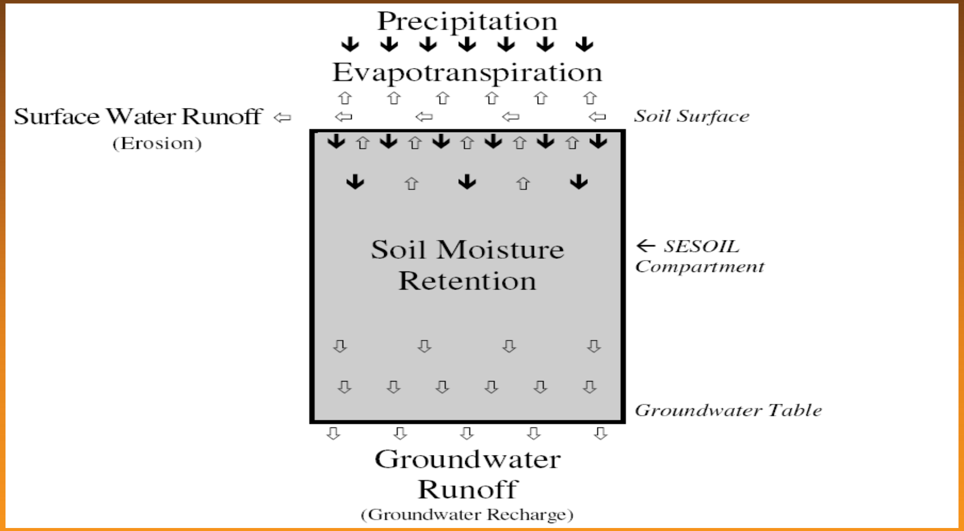
Exposure assessment

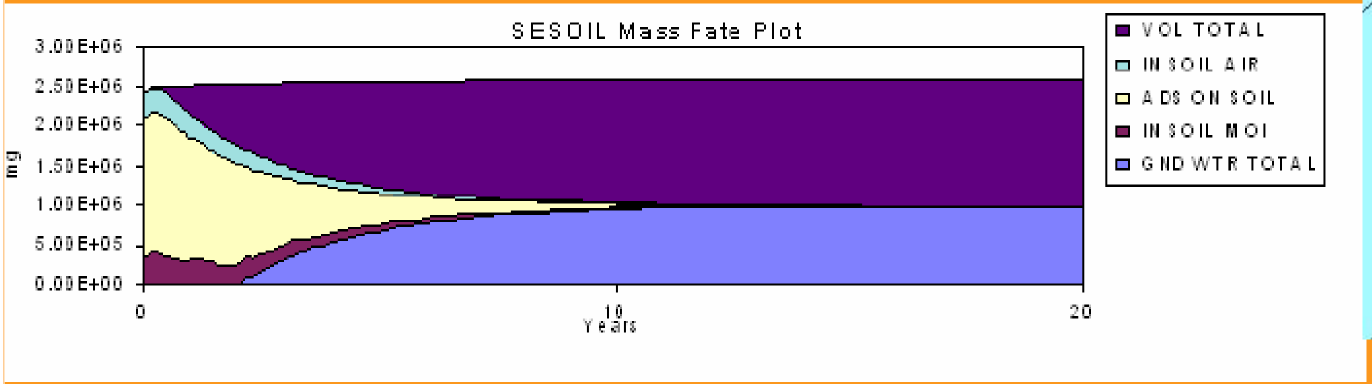
- For the agents under study, what exposures and resulting doses are incurred by each relevant population under existing conditions?
- What do the technical analyses reveal about how existing conditions and resulting exposures/doses would be altered by each proposed risk management option?

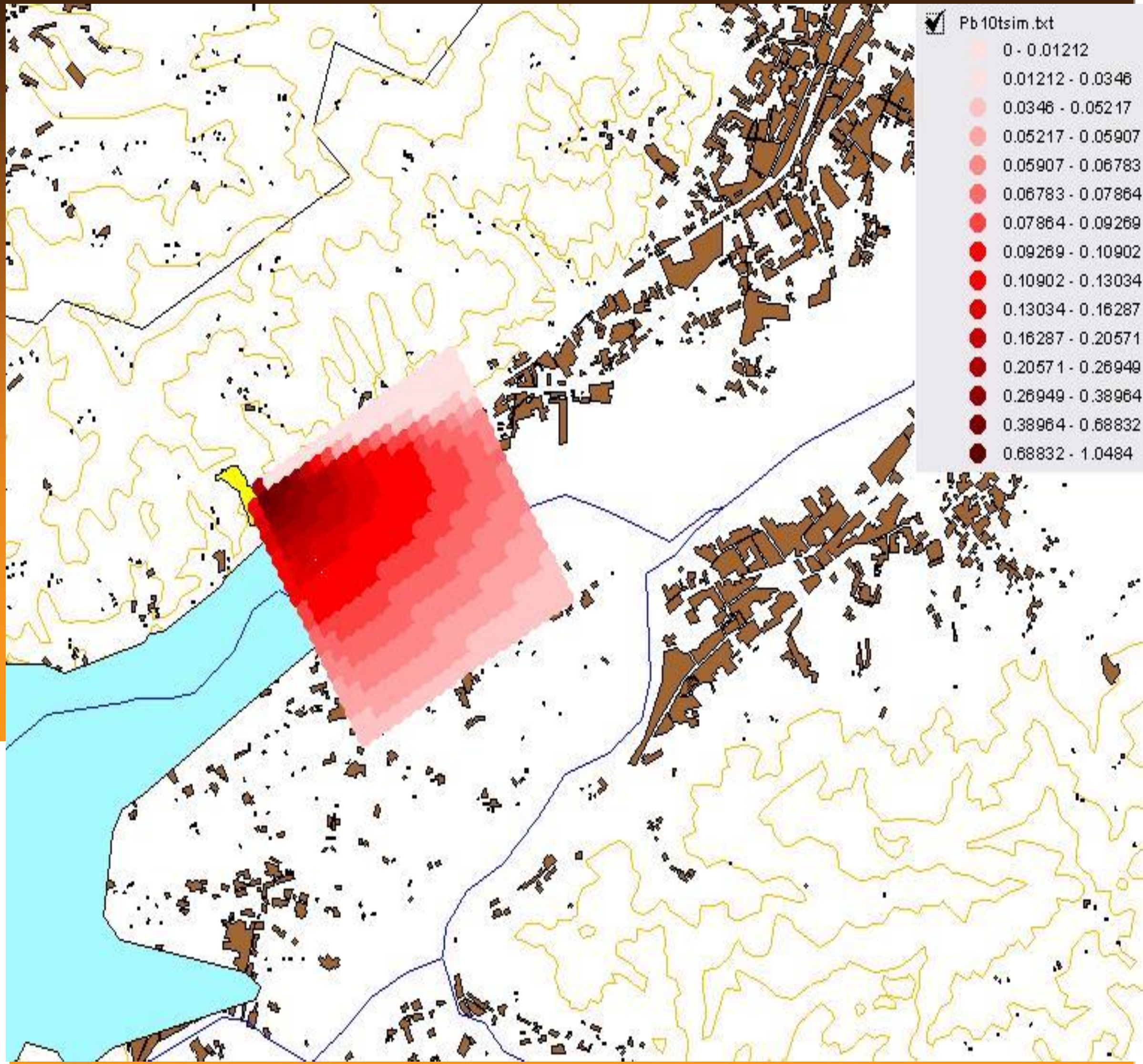


(From NRC, 2008)

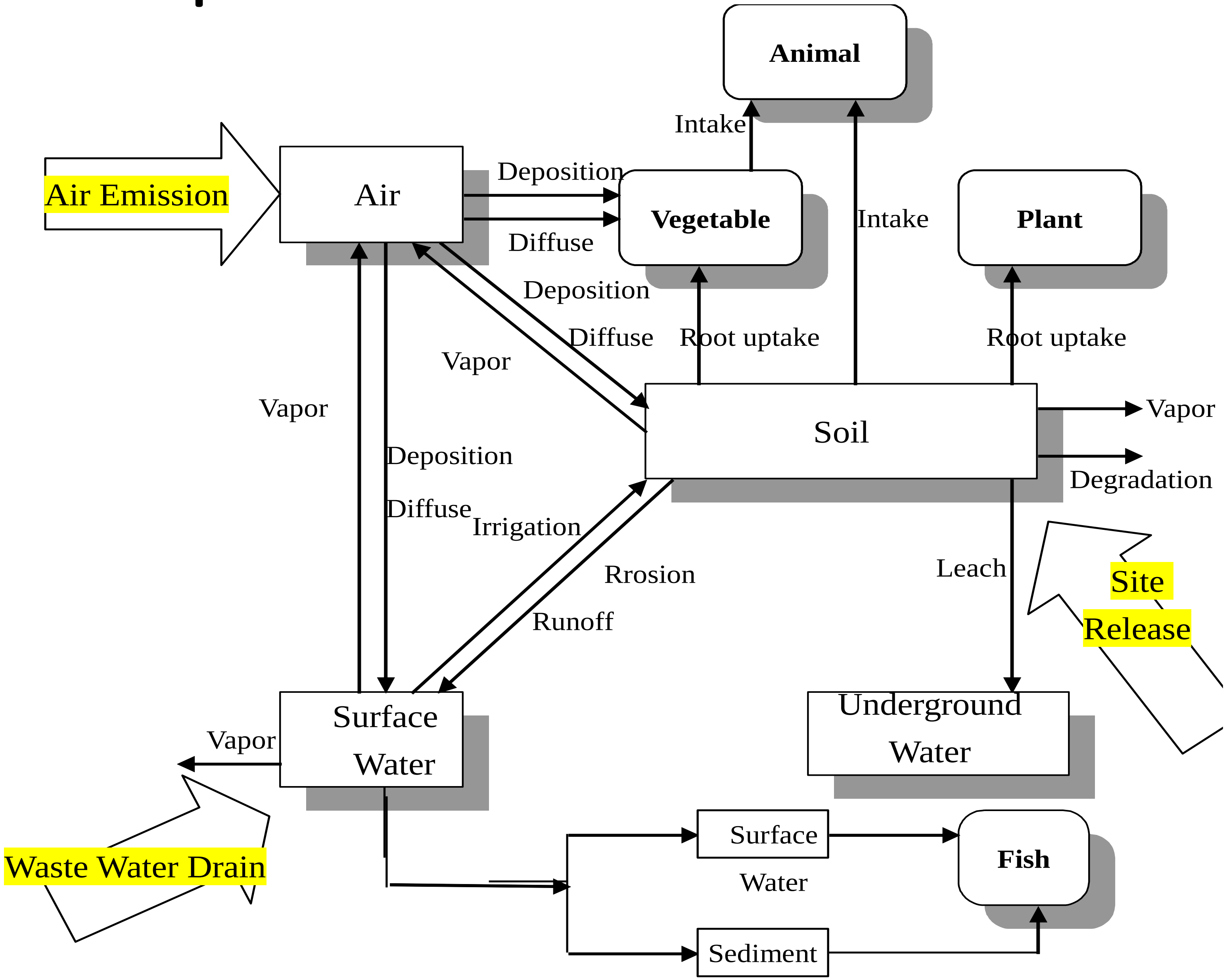
Environmental transport in exposure assessment



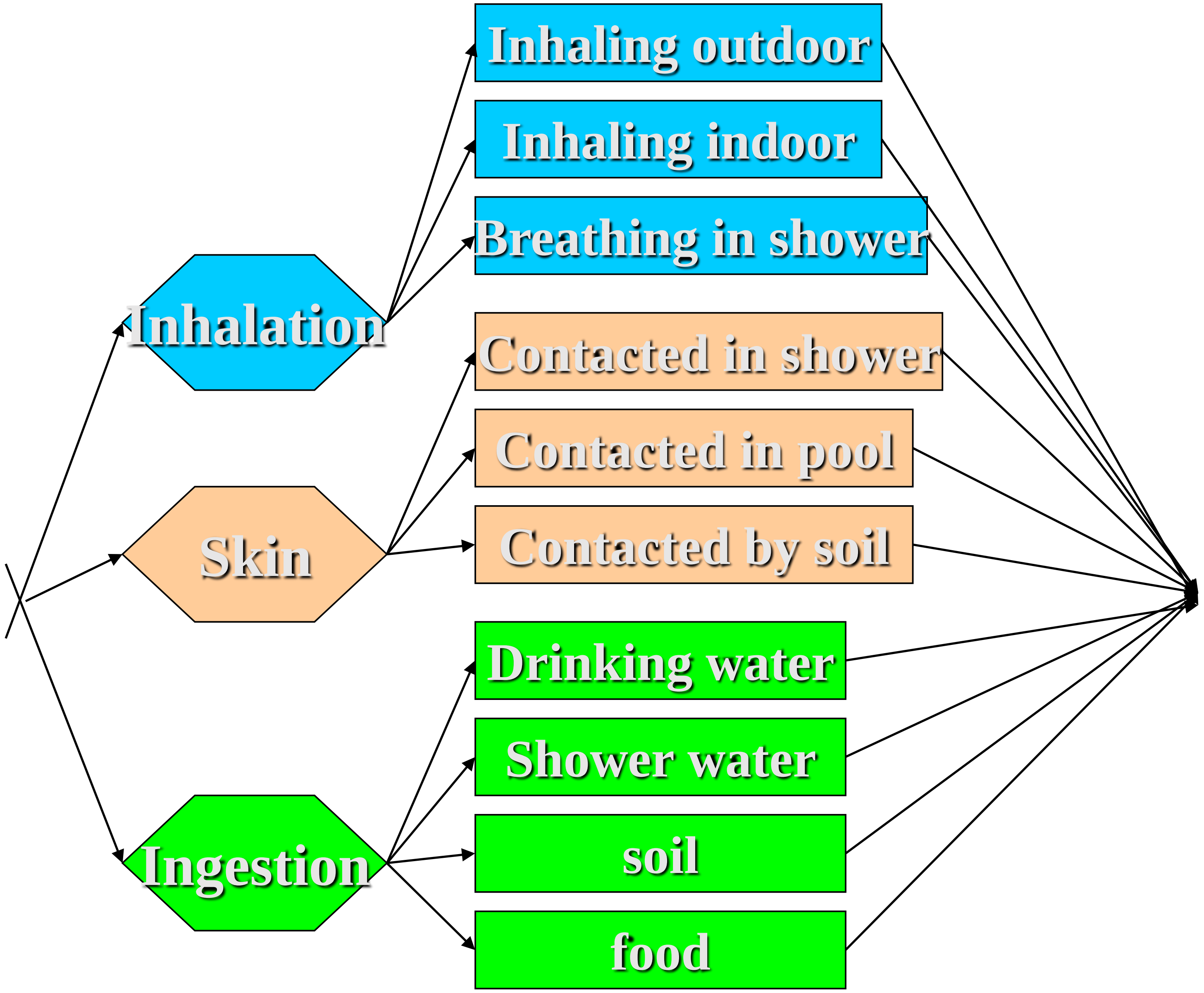




Multimedia transport in exposure assessment



Multi-pathway in exposure assessment



Intake dose in exposure assessment

$$\mathrm{CDI} = \frac{C\left(\frac{mg_{Chemical}}{kg_{Medium}}\right) x\, CR\left(\frac{kg_{Medium}}{day_{Contact}}\right) x\, EF\left(\frac{days_{Contact}}{year}\right) x\, ED\,(years)}{BW\,(kg)\, x\, AT\,(days_{Averaging})}$$

$$= \frac{mg_{Chemical}}{kg - day_{Averaging}}$$

where
CDI means chronic daily intake
C = the concentration of pollutant (mg/L or mg/kg)
CR= consumption rate (L/day or kg/day)
EF= exposure frequency (days/year)
ED= exposure duration (years)
BW= the body weight (kg)
AT= the average life time (days)

Risk characterization

- For each population, what is the nature and magnitude of risk associated with existing conditions?
- How are risks altered by each risk management option(both decreases and increases)?
- What is the distribution of individual risks in the population and subpopulations if concern, and what is the distribution of benefits under each option?
- Considering the weight-of-evidence classification of hazards, the dose-response assessment, and the exposure assessment, what degree of scientific confidence is associated with risk characterization?
- What are the important uncertainties, and how are they likely to affect the risk results?

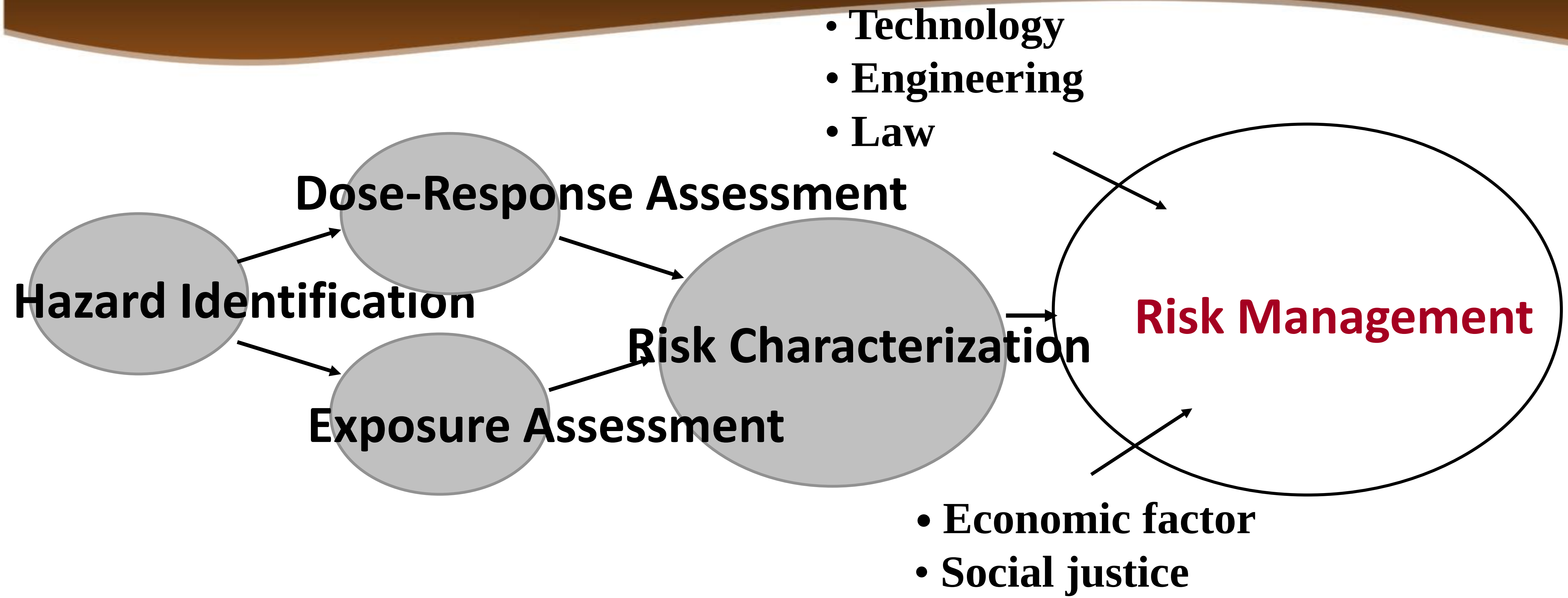
(From NRC, 2008)

Risk characterization

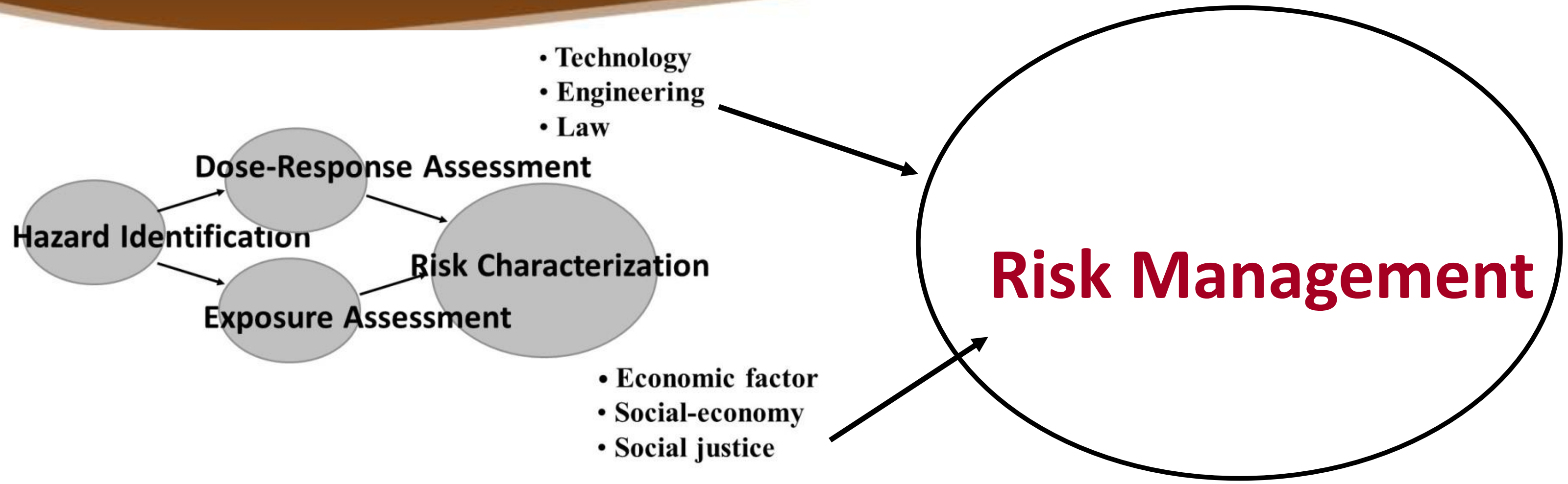
- **RA** (Risk Assessment) & **HQ** (Hazard quotient)
- **PEC** (predicted environmental concentration)
  & **PNEC** (predicted no effect concentrations)
- **DALY** (Disability Adjusted Life Years per affected person)

………

Risk management and risk characterization



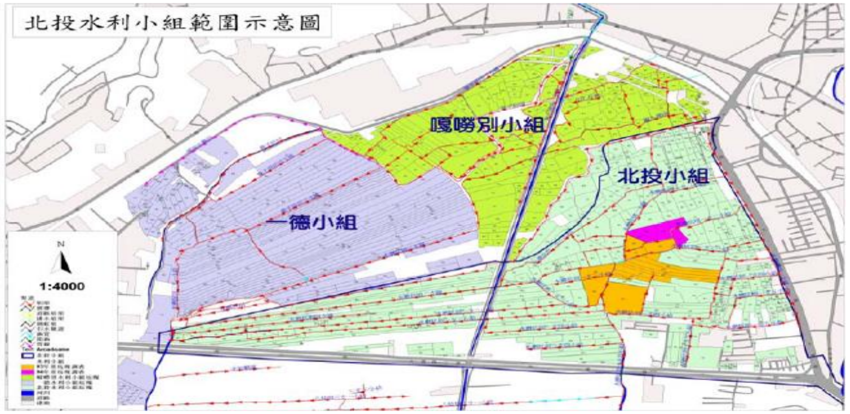
Risk management



- What are the relative health or environmental benefits of the proposed options?
- How are other decision-making factors (technologies, costs) affected by the proposed options?
- What is the decision, and its justification, in light of benefits, costs, and uncertainties in each?
- How should the decision be communicated?
- How is the effectiveness of the decision evaluated?

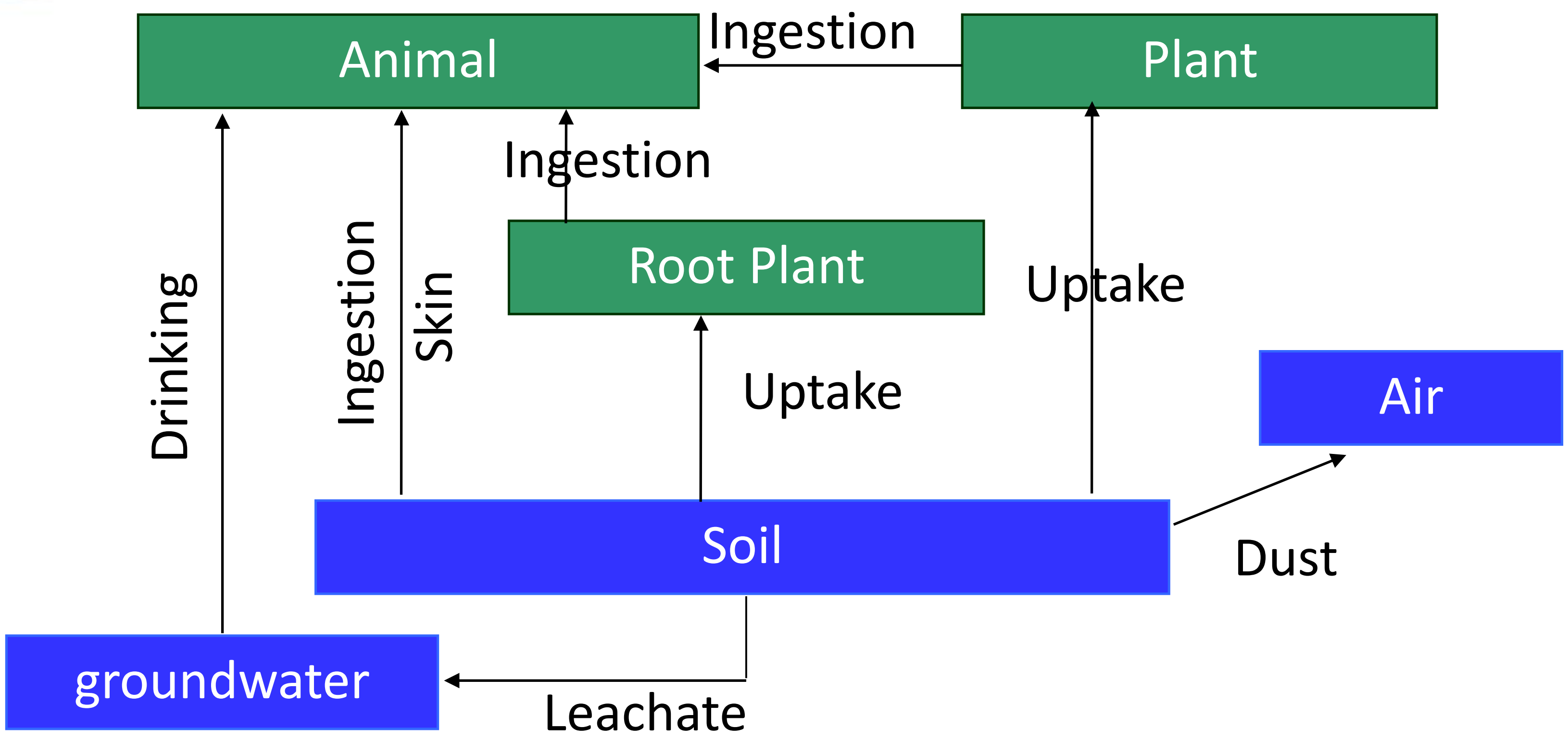
(From NRC, 2008)

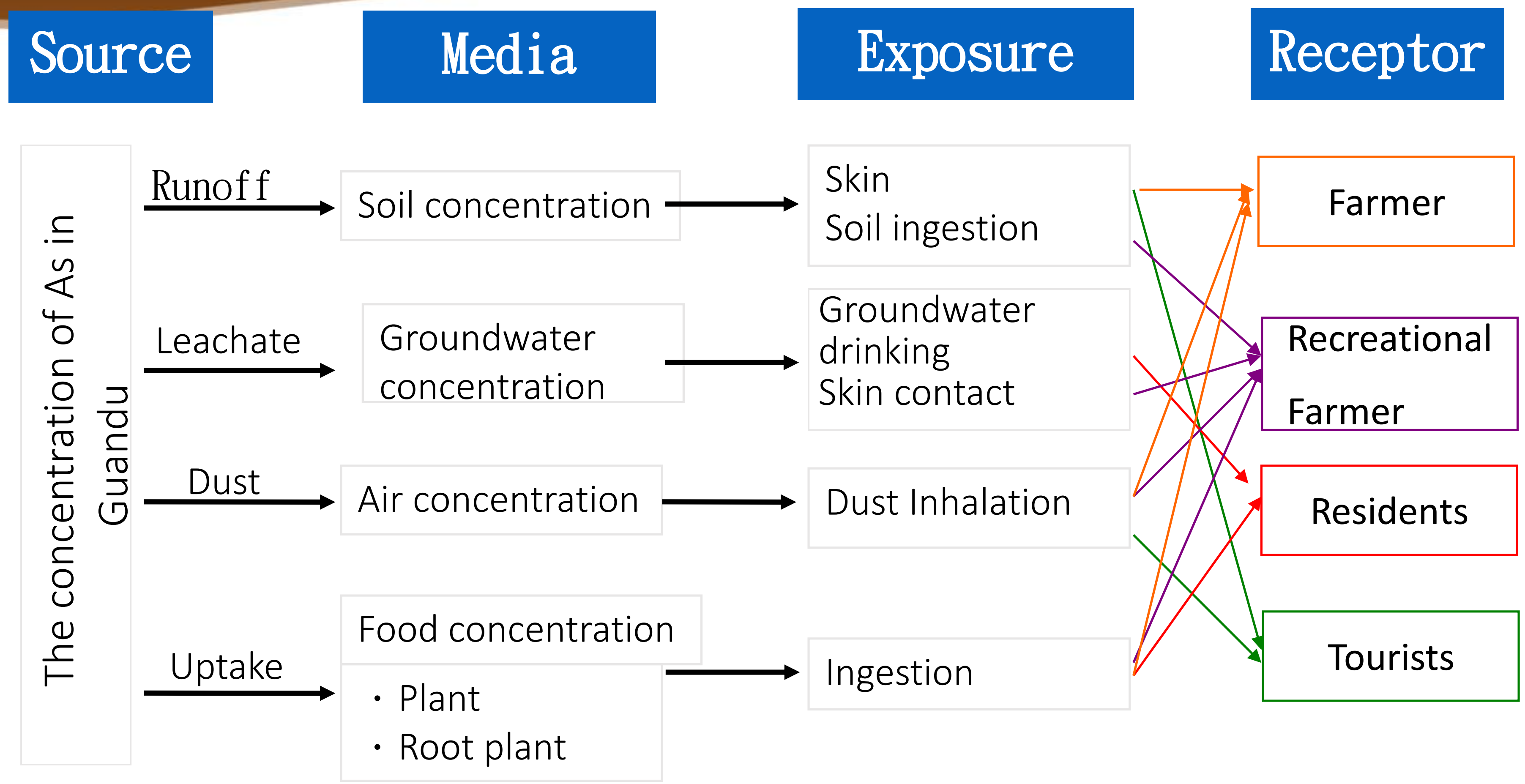
Case study for health risk assessment
a case study



Location	In the northwest of Taipei, a wetland between Keelung River and Tamsui River
Weather	Average rainfall is 2220 mm; average temperature is 22.1℃
Pollution Situation	■The concentration of As is more than the control standard （≧60 mg/kg) ■The weight of As is more than 61.5 tons

Case study for health risk assessment a case study




Source
Media
Exposure
Receptor
The concentration of As in Guandu
Runoff
Leachate
Dust
Uptake
Soil concentration
Groundwater concentration
Air concentration
Food concentration
・Plant
・Root plant
Skin
Soil ingestion
Groundwater drinking
Skin contact
Dust Inhalation
Ingestion
Farmer
Recreational Farmer
Residents
Tourists

Concentrations in media

Source	Receptor	Media	Concentrations
The concentration of As in Guandu	Farmer	Soil	148.03 (mg/kg)
		Dust	146E-6 (ug/m^3)
		Outdoor burning	0.00099 (ug/m^3)
	Recreational Farmer	Soil	148.03 (mg/kg)
		Dust	146E-6 (ug/m^3)
		Food chain	5.74E-4/7.26E-4(mg/kg)
		groundwater	2.75E-8 (mg/kg)
	Residents	Food chain	5.74E-4/7.26E-4(mg/kg)
		groundwater	2.75E-8 (mg/kg)
	Tourists	Soil	148.03 (mg/kg)
		Dust	146E-6 (ug/m^3)

Results for farmer

	Receptor : Farmer								
	Soil			Air		Groundwater			Total risk
	Food chain	Soil ingestion	Skin	Dust	Outdoor burning	Drinking	Drinking Shower water	Skin with Shower water	
Cancer Risk	9.54E-07	2.99E-09	3.26E-6	8.22E-07	2.48E-10	-	-	-	5.04E-06
Percentage	18.93%	0.06%	64.69%	16.31%	0.00%	-	-	-	100%
Cancer Risk	2.12E-03	6.64E-06	7.23E-03	1.83E-03	5.50E-07	-	-	-	1.12E-02
Percentage	18.95%	0.06%	64.63%	16.36%	0.00	-	-	-	100%

Results for recreational farmer

	Receptor : Recreational Farmer								
	Soil			Air		Groundwater			Total risk
	Food chain	Soil ingestion	Skin	Dust	Outdoor burning	Drinking	Drinking Shower water	Skin with Shower water	
Cancer Risk	1.14E-06	2.99E-09	3.26E-6	8.22E-07	-	1.88E-09	1.88E-11	3.74E-12	5.23E-06
Percentage	21.81%	0.06%	62.37%	15.73%	-	0.04%	0.00%	0.00%	100%
Cancer Risk	2.54E-03	6.64E-06	7.23E-03	1.83E-03	-	4.17E-06	4.17E-08	8.31E-09	1.16E-02
Percentage	21.88%	0.06%	62.27%	15.76%	-	0.04%	0.00%	0.00%	100%

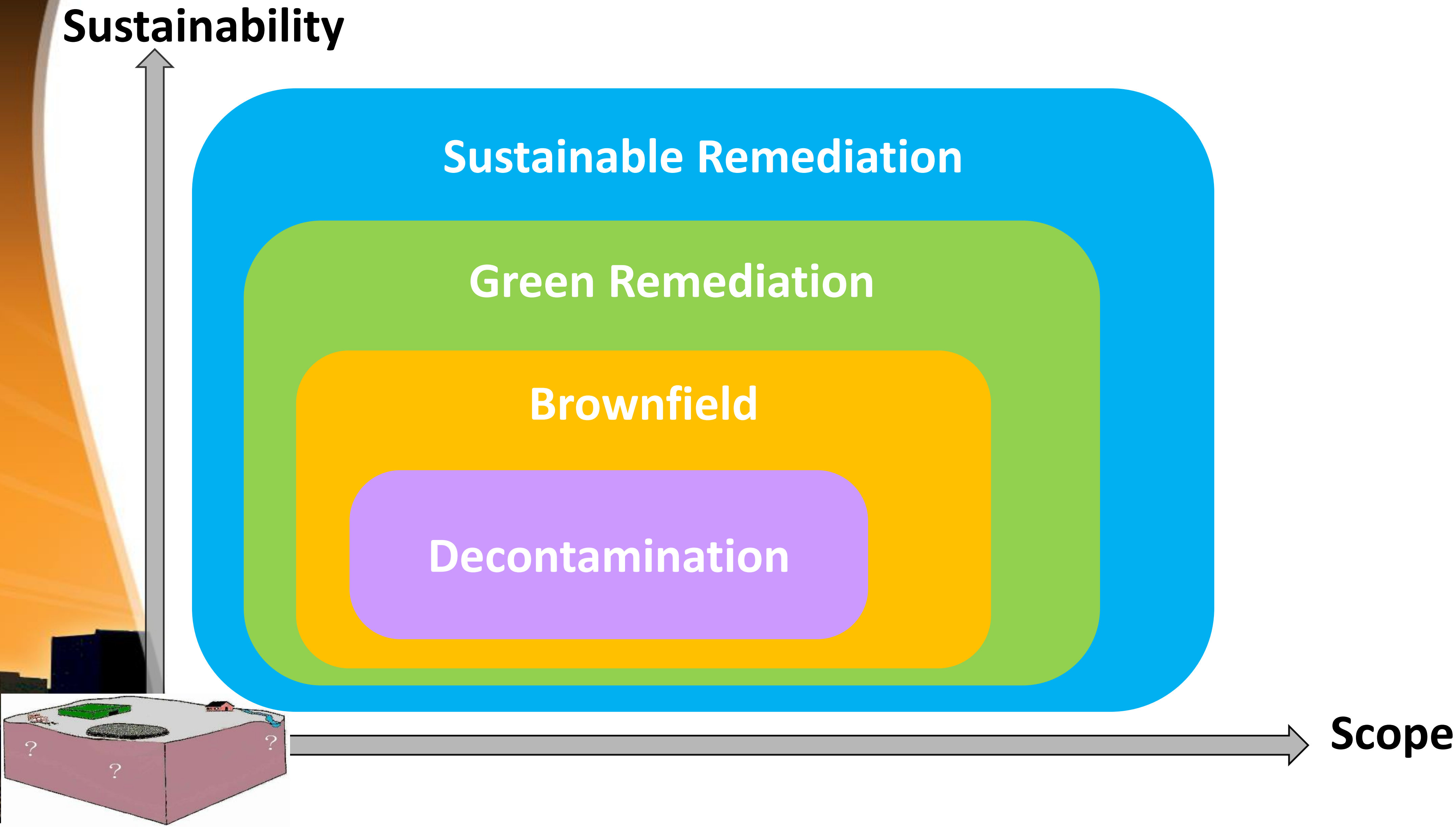
Results of resident

	Receptor : Residents								
	Soil			Air		Groundwater			Total risk
	Food chain	Soil ingestion	Skin	Dust	Outdoor burning	Drinking	Drinking Shower water	Skin with Shower water	
Cancer Risk	9.54E-07	-	-	-	-	1.88E-09	1.88E-11	3.74E-12	9.56E-07
Percentage	99.80%	-	-	-	-	0.2%	0.00%	0.00%	100%
Cancer Risk	2.12E-03	-	-	-	-	4.17E-06	4.17E-08	8.31E-09	2.12E-03
Percentage	99.80%	-	-	-	-	0.20%	0.00%	0.00%	100%

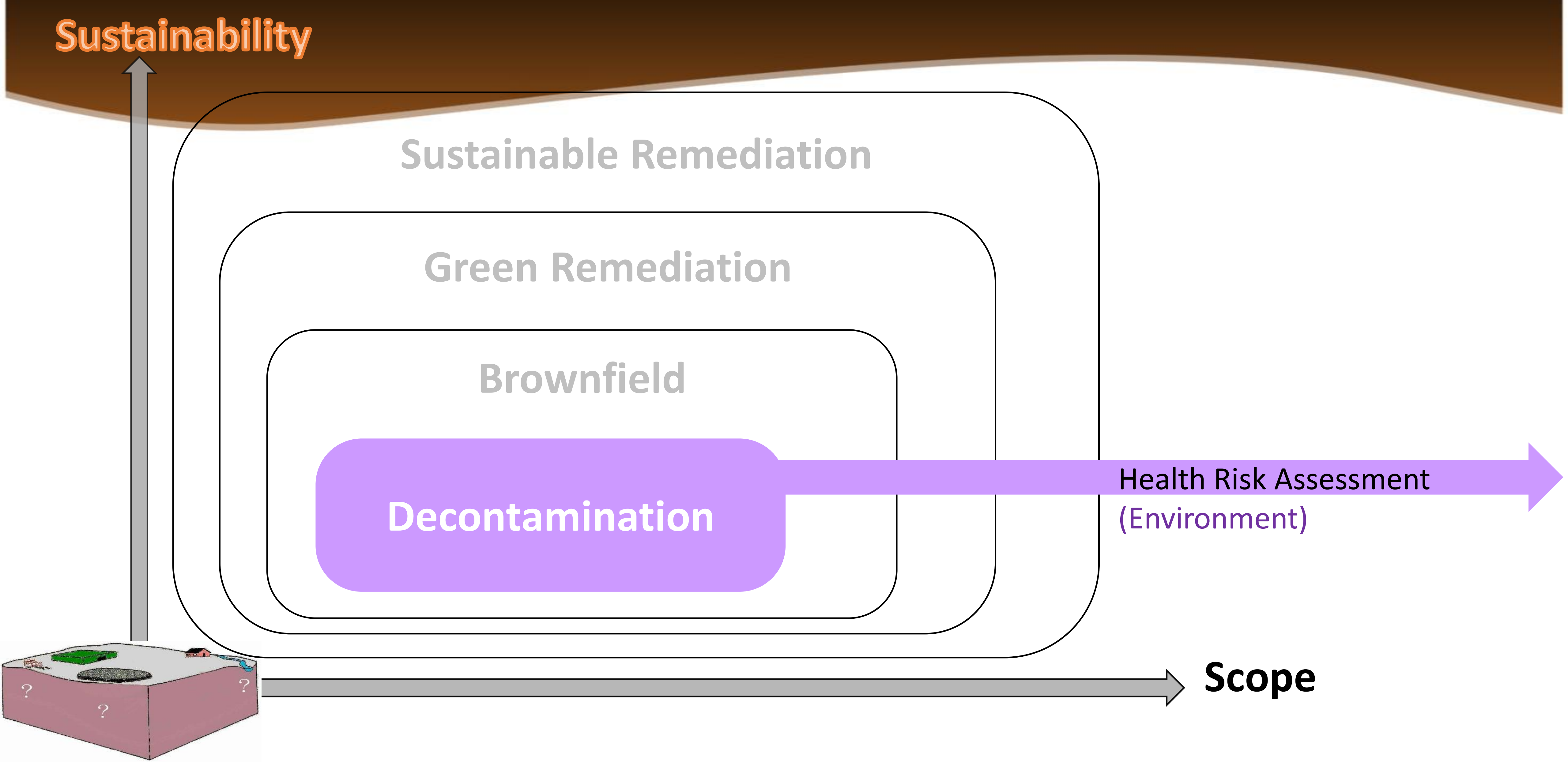
Results for tourist

	Receptor : Residents								
	Soil			Air		Groundwater			Total risk
	Food chain	Soil ingestion	Skin	Dust	Outdoor burning	Drinking	Drinking Shower water	Skin with Shower water	
Cancer Risk	-	6.22E-11	6.78E-08	1.71E-08	-	-	-	-	8.49E-08
Percentage	-	0.07%	79.84%	20.09%	-	-	-	-	100%
Cancer Risk	-	1.38E-07	1.51E-04	3.80E-05	-	-	-	-	1.89E-04
Percentage	-	0.07%	79.84%	20.09%	-	-	-	-	100%

Management of contaminated sites



Decontamination



Remedial process of contaminated sites in the US for Decontamination

- Preliminary Assessment (PA)/ Site Inspection (SI)
- Hazard Ranking System (HRS)/ National Priorities List (NPL)
- Remediation Investigation(RI)/ Feasibility Study (FS)
- Record of Decision (ROD)
- Remedial Design (RD)
- Remedial Action (RA)
- Construction Completion
- Post Construction Completion
- NPL Delete
- Reuse

PA is designed to determine whether a site poses little or no threat to human health and the environment or if it poses a threat, whether the threat requires further investigation.

SI identifies sites that enter the NPL site listing Process and provides the data needed for Hazard Ranking System (HRS) scoring and documentation, typically collect environmental and waste samples to determine what hazardous substances are present at a site.

(From the website of U.S.EPA, 2013)

Remedial process of contaminated sites in the US for Decontamination

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- Post Construction Completion
- NPL Delete
- Reuse

RI serves as the mechanism for collecting data to (1) characterize site conditions, (2) determine the nature of the waste,(3) assess risk to human health and the environment,(4) conduct treatability testing to evaluate the potential performance and cost of the treatment technologies that are being considered.

FS is the mechanism for the development, screening, and detailed evaluation of alternative remedial actions.

RI/FS process includes (1) scoping, (2) site characterization, (3) development and screening of alternatives, (4) treatability investigation, and (5) detailed analysis..

(From the website of U.S.EPA, 2013)

Remedial process of contaminated sites in the US for Decontamination

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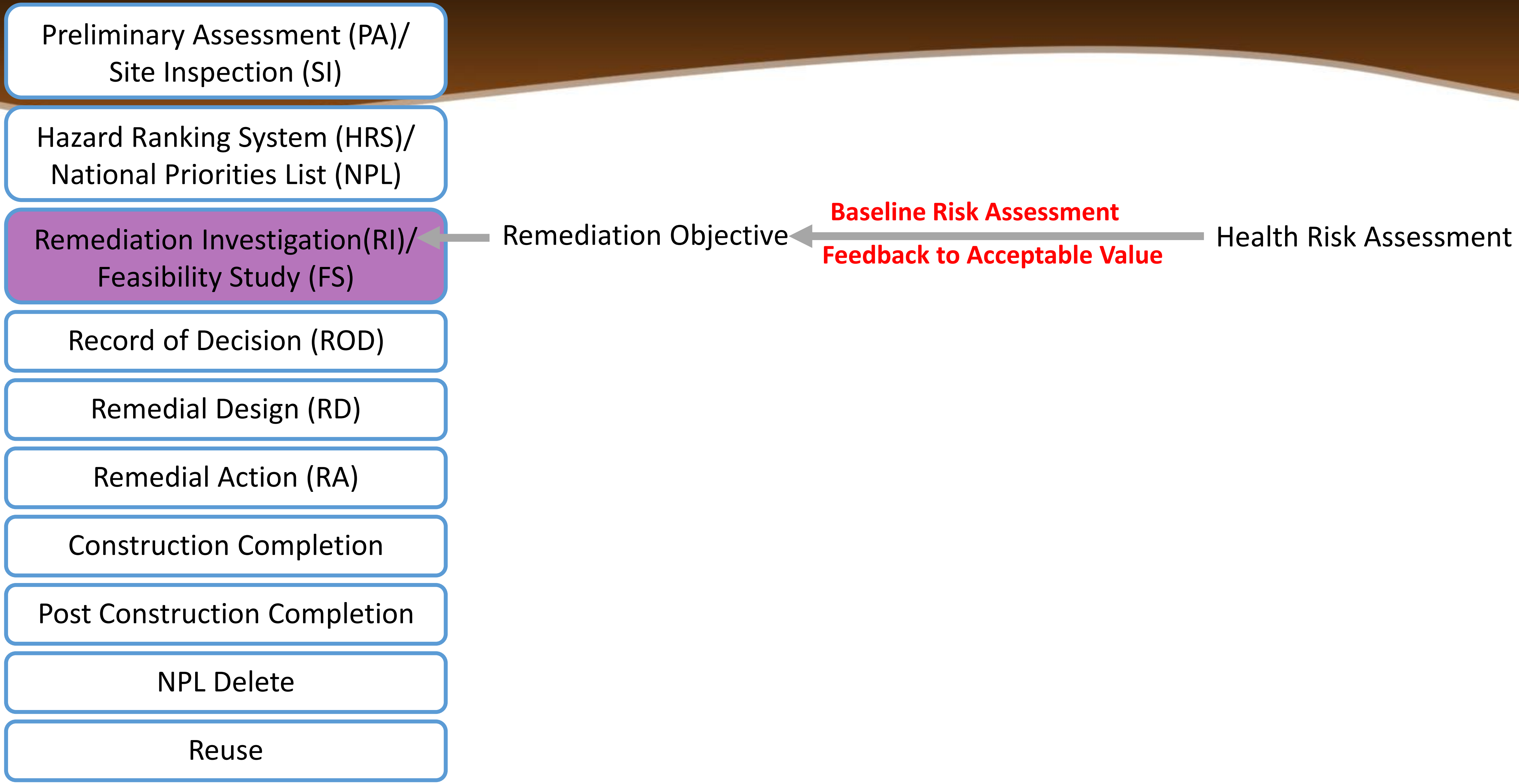
- Record of Decision (ROD)
- Remedial Design (RD)
- Remedial Action (RA)
- Construction Completion
- Post Construction Completion
- NPL Delete
- Reuse

RD is the phase in contaminated site cleanup where the technical specifications for cleanup remedies and technologies are designed.

RA follows the RD phase and involves the actual construction or implementation phase.

(From the website of U.S.EPA, 2013)

Remedial process of contaminated sites in the US for Decontamination



Remedial Process of Contaminated Site in the USA for Decontamination

- Preliminary Assessment (PA)/ Site Inspection (SI)
- Hazard Ranking System (HRS)/ National Priorities List (NPL)
- **Remediation Investigation(RI)/ Feasibility Study (FS)**
- Record of Decision (ROD)
- Remedial Design (RD)
- Remedial Action (RA)
- Construction Completion
- Post Construction Completion
- NPL Delete
- Reuse

Remediation Objective ← Health Risk Assessment

Baseline Risk Assessment

Feedback to Acceptable Value

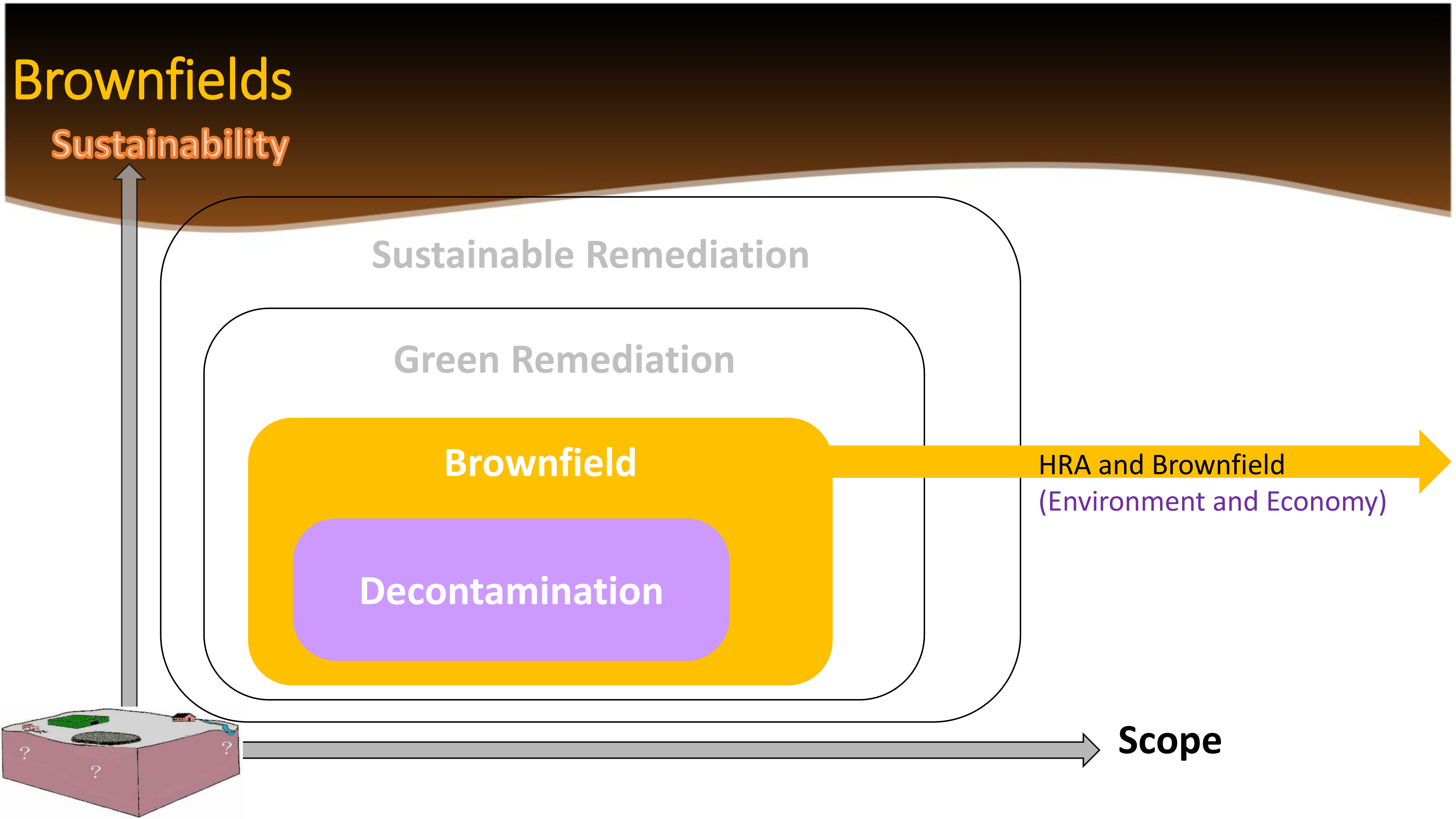
Health Risk Assessment → Analysis of potential alternatives

Short-term risk

Long-term risk

Analysis of potential alternatives ← Criteria

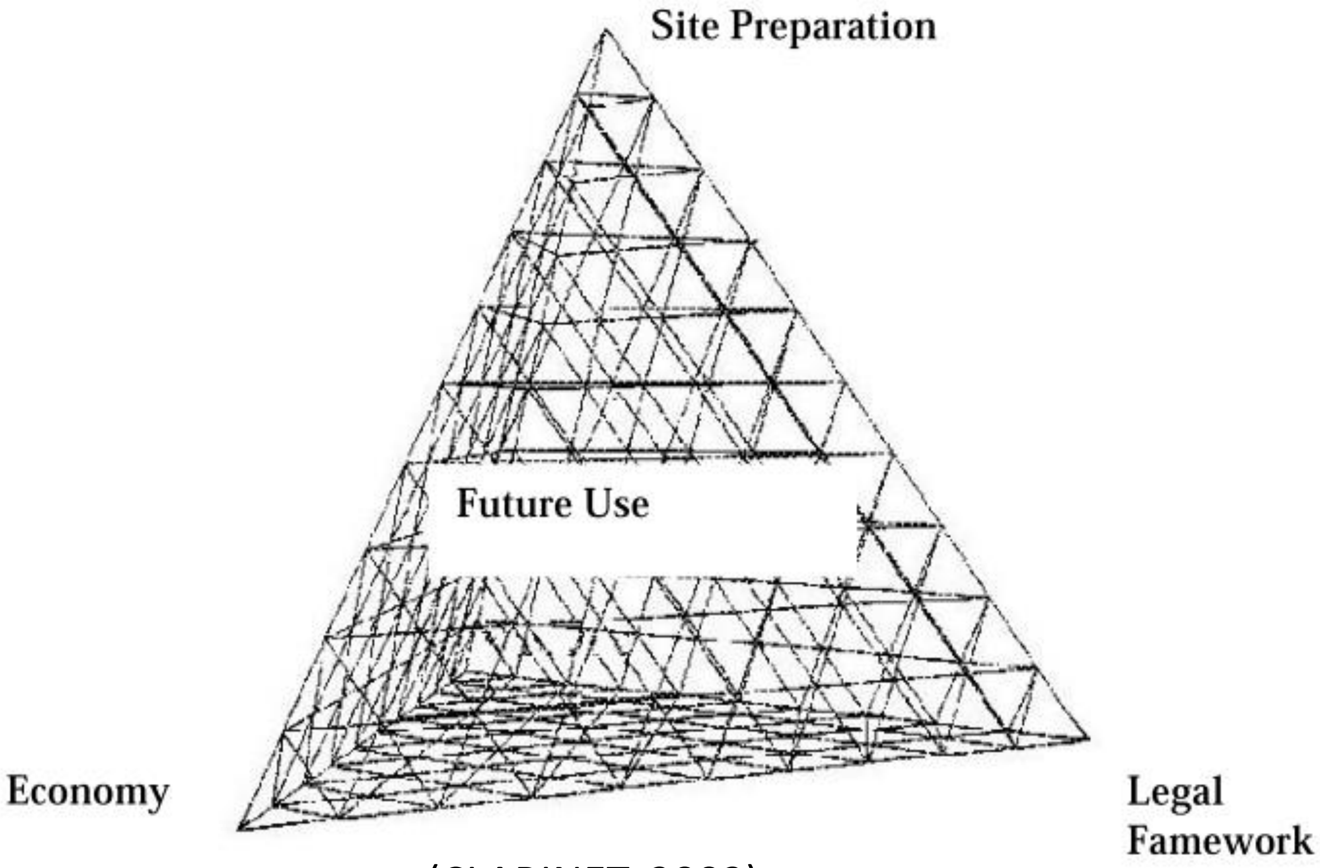
Overall protection of human health
Overall protection of environment
Long − term effectiveness and permanace
Short − term effectiveness
Reduction in toxicity, mobilityand volume through treatment
Implementability
Cost
Community acceptance



Brownfields
Sustainability
Sustainable Remediation
Green Remediation
Brownfield
Decontamination
HRA and Brownfield
(Environment and Economy)
Scope

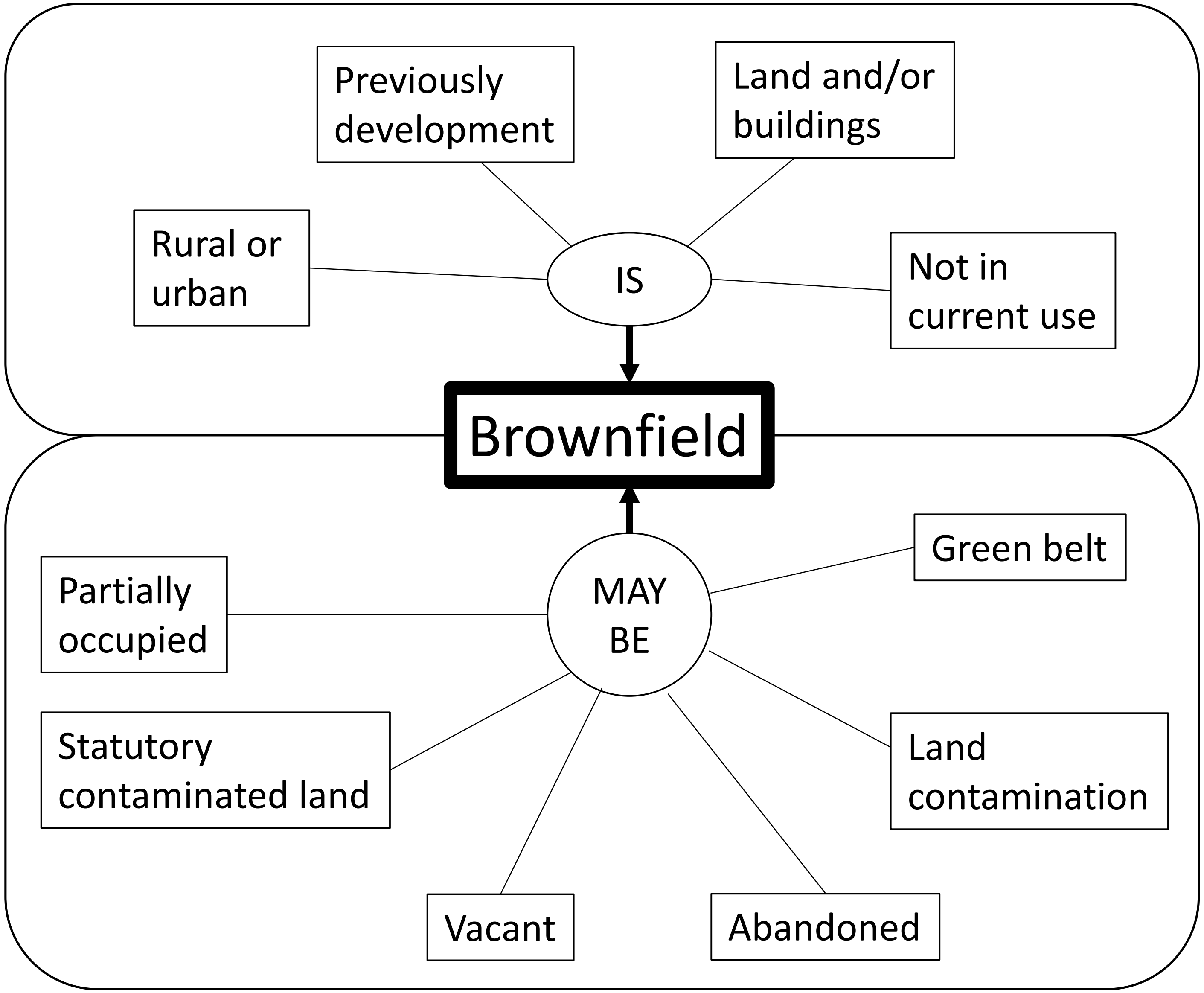
Essentials in brownfields

The tetrahedron represents the connection and interdependency of four key factors for brownfield redevelopment.



(CLARINET, 2002)

Definition of brownfields



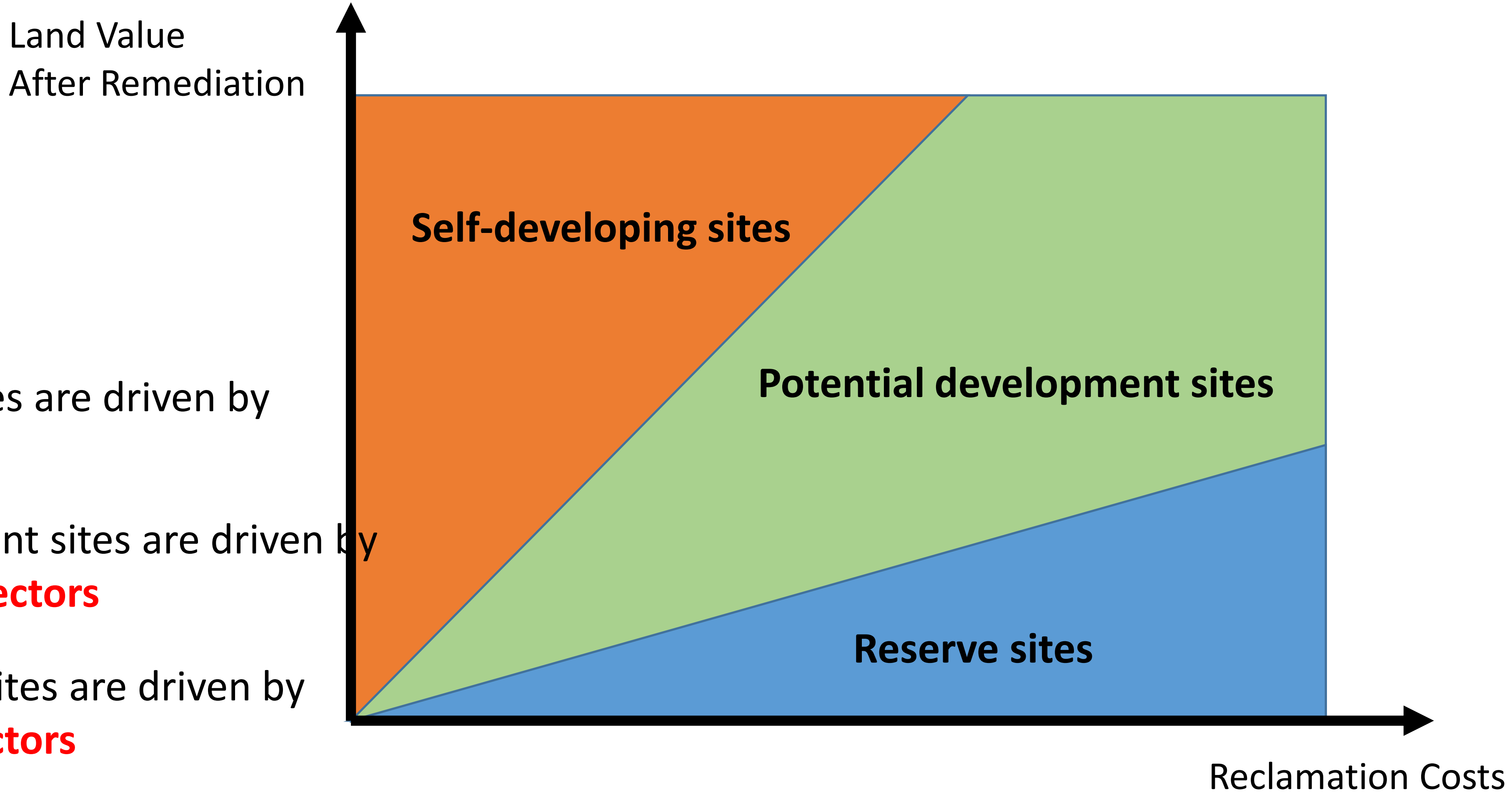
(Alker et al., 2000)

Process of brownfield assessment

Urban/Regional Redevelopment		Environmental Remediation Aspects
Analysis of demand for further development purposes Analysis of existing land use plan	Data Evaluation	Analysis of actual situation Evaluation of existing data Determine need for additional investigations
Communication/consultation with major stakeholder groups		
Development of preliminary development concepts, and evaluation of viability of different development scenarios	Pre-Feasibility	Risk Assessment Initial evaluation
Definition of site specific remediation goals and target, taking into account of current development concepts. Further stakeholder participation to elicit views on willingness to bear risks		
Financing and investment possibilities for available draft development concepts-detailed development appraisals	Feasibility	Remediation options and concept evaluation of Environmental Impact Assessment
Detailed design phase: the chosen options for remediation and for development are planned in detail, and the costs are precisely calculated. Public relations campaign to explain choices.		
Implementation of site development work	Implementation	Implementation of remediation activities Monitoring of results

(World Bank, 2010)

Categories of brownfields



Self-developing sites are driven by
Private sectors

Potential development sites are driven by
Public and private sectors

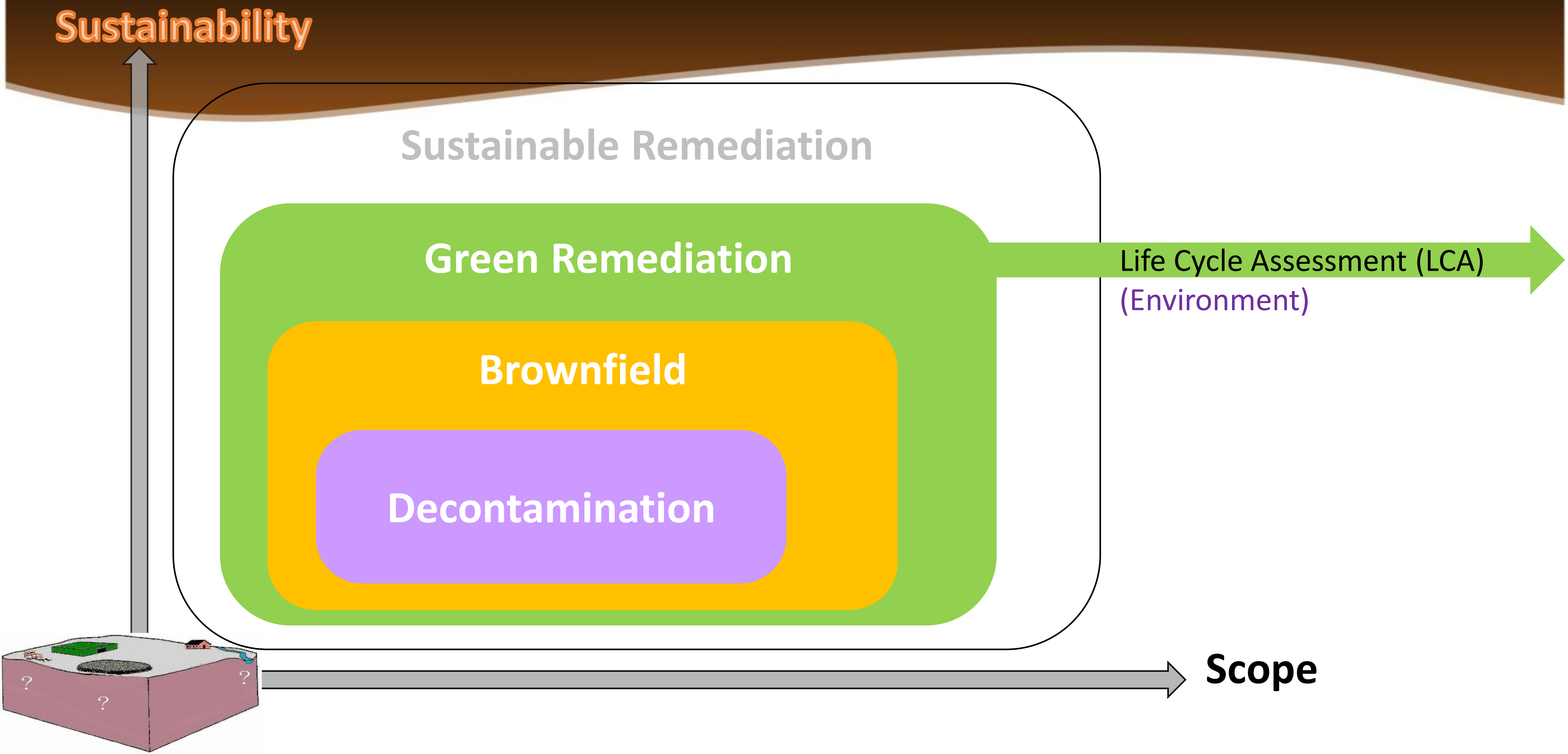
Reserve sites are driven by
Public sectors

(RESCUE, 2004)

Connection between Brownfields and Sustainability

(Wedding and Crawford-Brown, 2007)

Green remediation



Green remediation

Green Remediation

The practice of considering all environmental effects of remedy implementation and incorporating options to minimize the environmental footprint of cleanup Actions

Scope

Objective of green remediation

Objective of Remediation

- Achieve remediation action goals
- Increase operational efficiencies

Objective of Finance

- Achieve greater long-term finance from investments

Objective of Sustainability

- Support use and reuse of remediated parcels
- Increase sustainability of site cleanup
- Conserve nature resources

Objective of Environment

- Minimize impacts to water quality and water cycle
- Reduce air emission and greenhouse gases
- Reduce total pollutant and waste burdens on the environment
- Minimize degradation or enhance ecology of the site and other affected area

(U.S.EPA, 2008; 2010)

Green remediation in Superfund

- Preliminary Assessment (PA)/ Site Inspection (SI)
- Hazard Ranking System (HRS)/ National Priorities List (NPL)
- Remediation Investigation(RI)/ Feasibility Study (FS)
- Record of Decision (ROD)
- Remedial Design (RD)
- Remedial Action (RA)
- Construction Completion
- Post Construction Completion
- NPL Delist
- Redevelopment

Minimize field mobilization, materials and natural resource consumption, and waste generation

Avoiding unnecessary consumption of materials and natural resource during a remedial action.

(U.S.EPA, 2010)

Green Remediation in Superfund

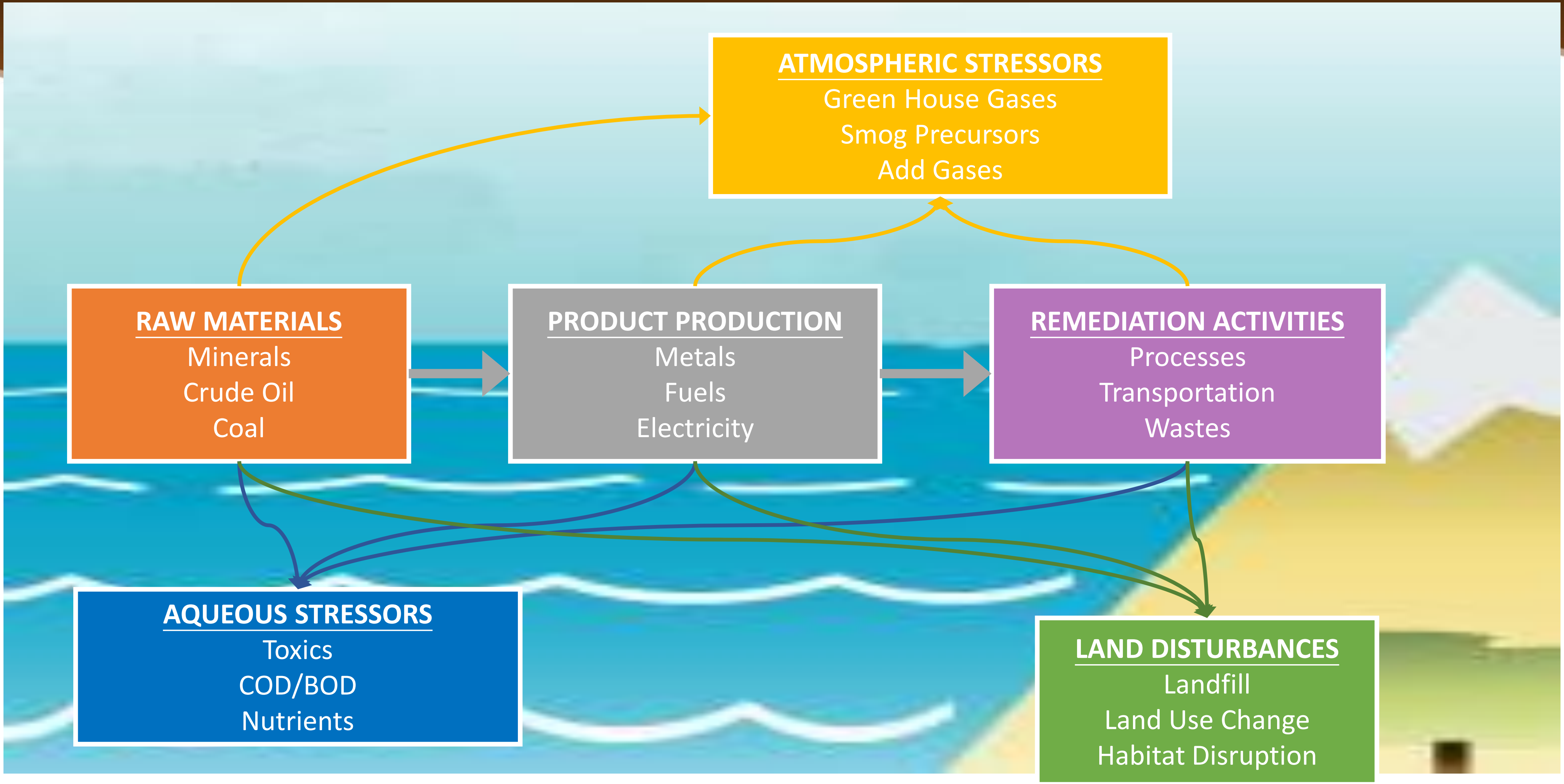
- Preliminary Assessment (PA)/ Site Inspection (SI)
- Hazard Ranking System (HRS)/ National Priorities List (NPL)
- Remediation Investigation(RI)/ Feasibility Study (FS)
- Record of Decision (ROD)
- Remedial Design (RD)
- Remedial Action (RA)
- Construction Completion
- Post Construction Completion
- NPL Delist
- Redevelopment

Reducing onsite and offsite footprints of a cleanup.
Using clean fuel and renewable energy sources for vehicles and equipment, retrofitting diesel machinery and vehicles for improved emission controls.
Reusing construction and routine operational materials, reclaiming demolition or processing and installing maximum controls for storm water runoff.

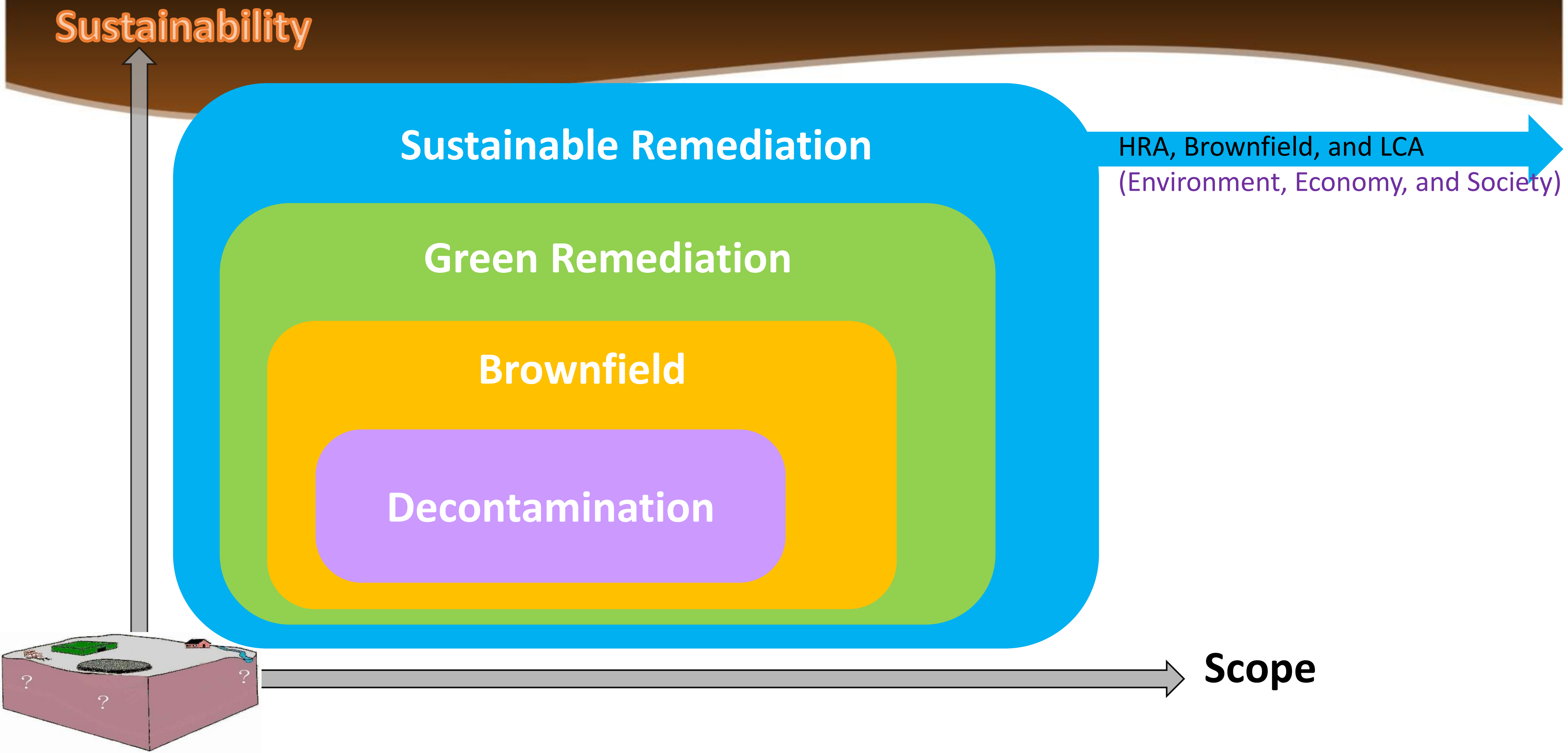
Short-and Long term remedy operations and five year review

(U.S.EPA, 2010)

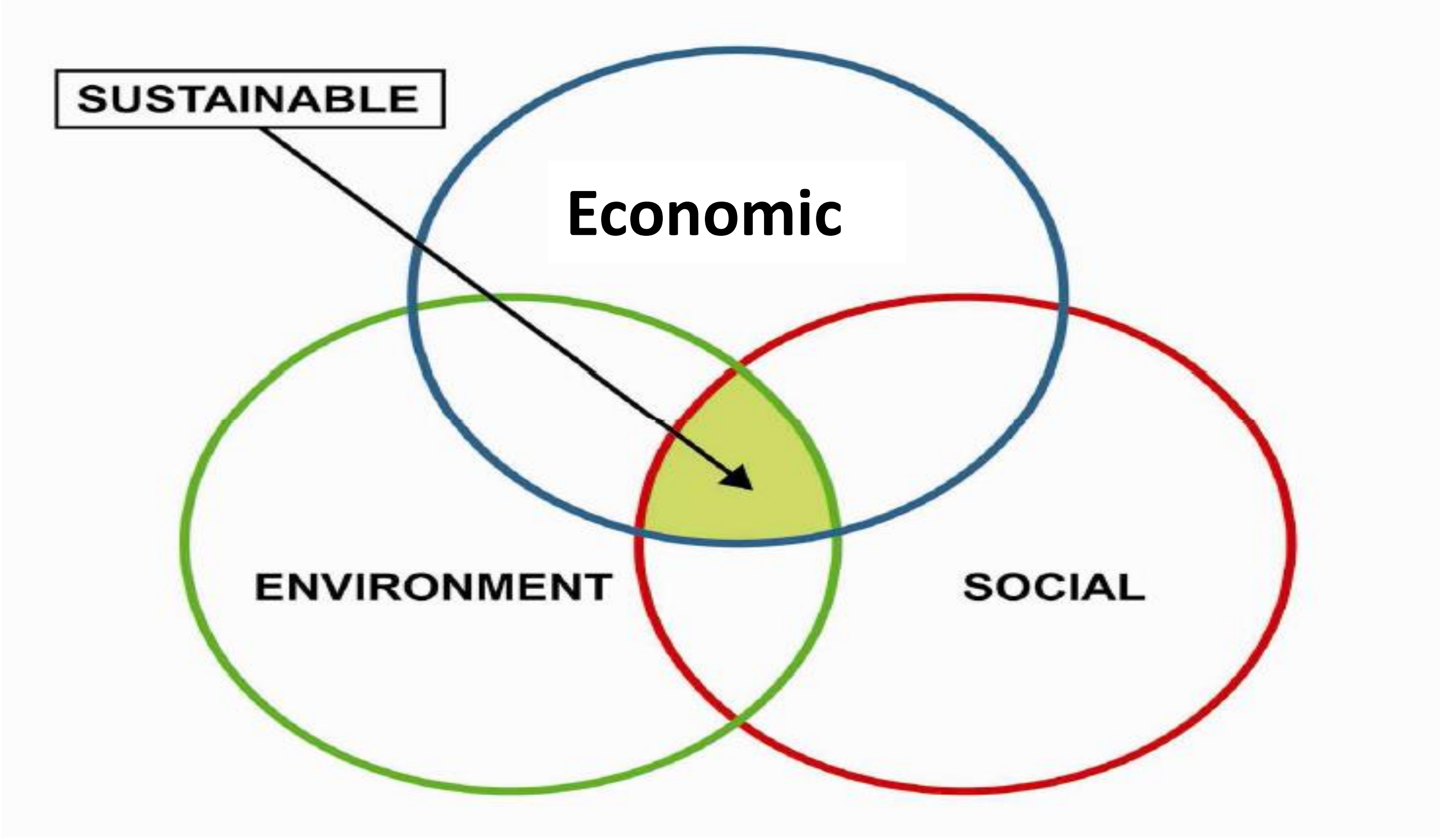
Life cycle framework in Green Remediation



Sustainable remediation

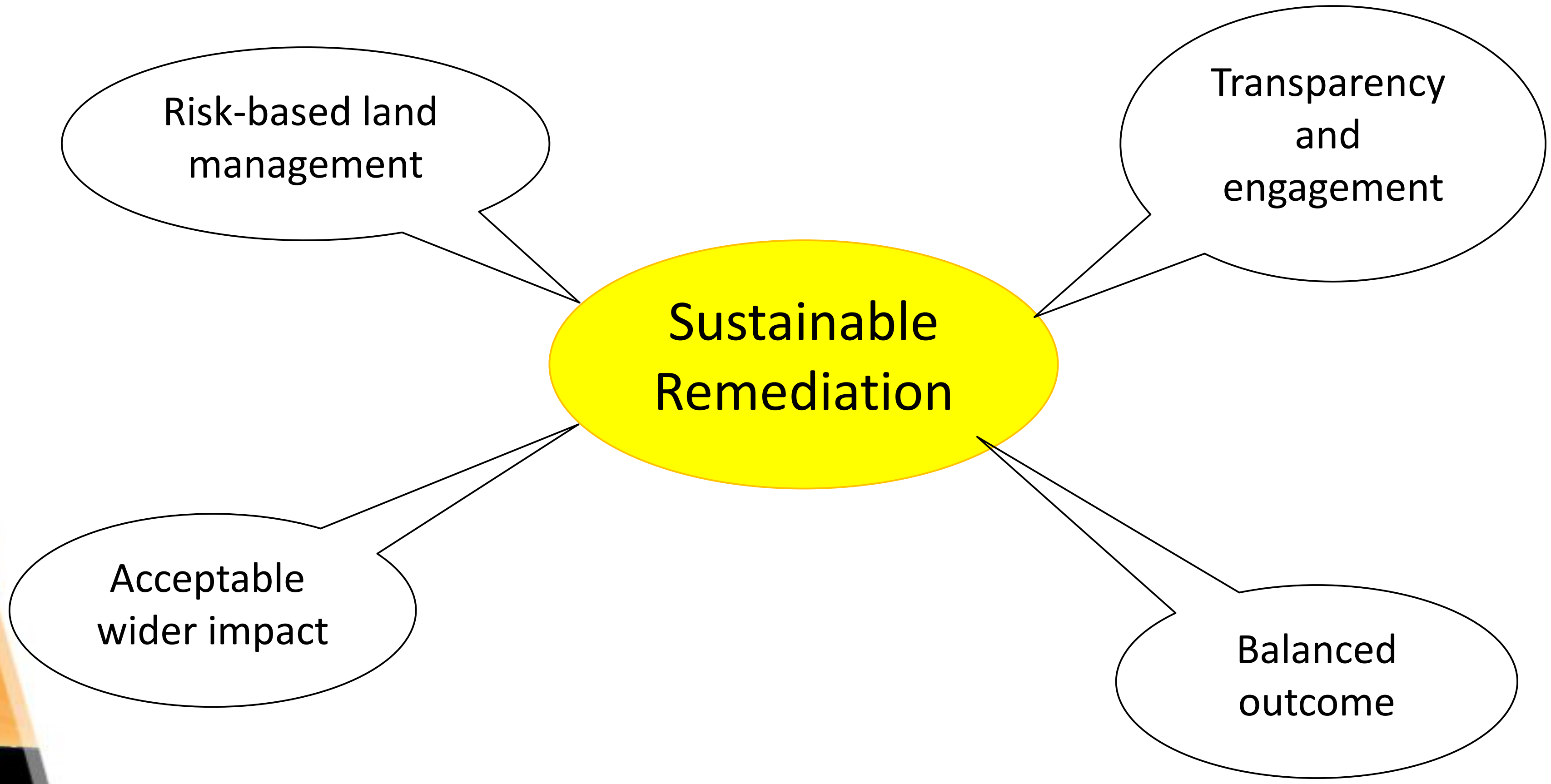


Sustainable development is a balance between environmental, social and economic factors

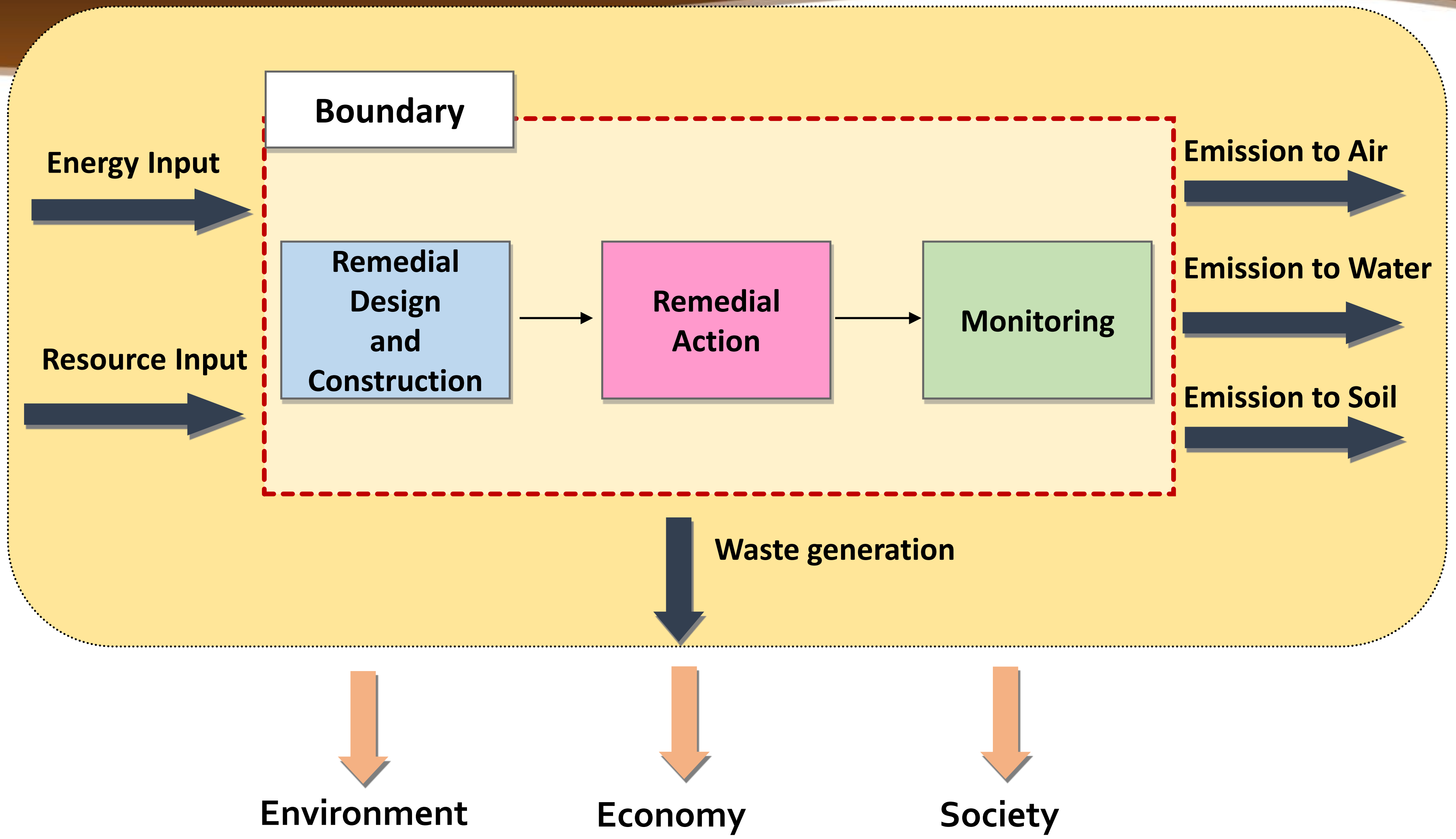


(SuRF-Australia, 2009)

Broad aims of sustainable remediation



The property lifecycle concept in Sustainable Remediation

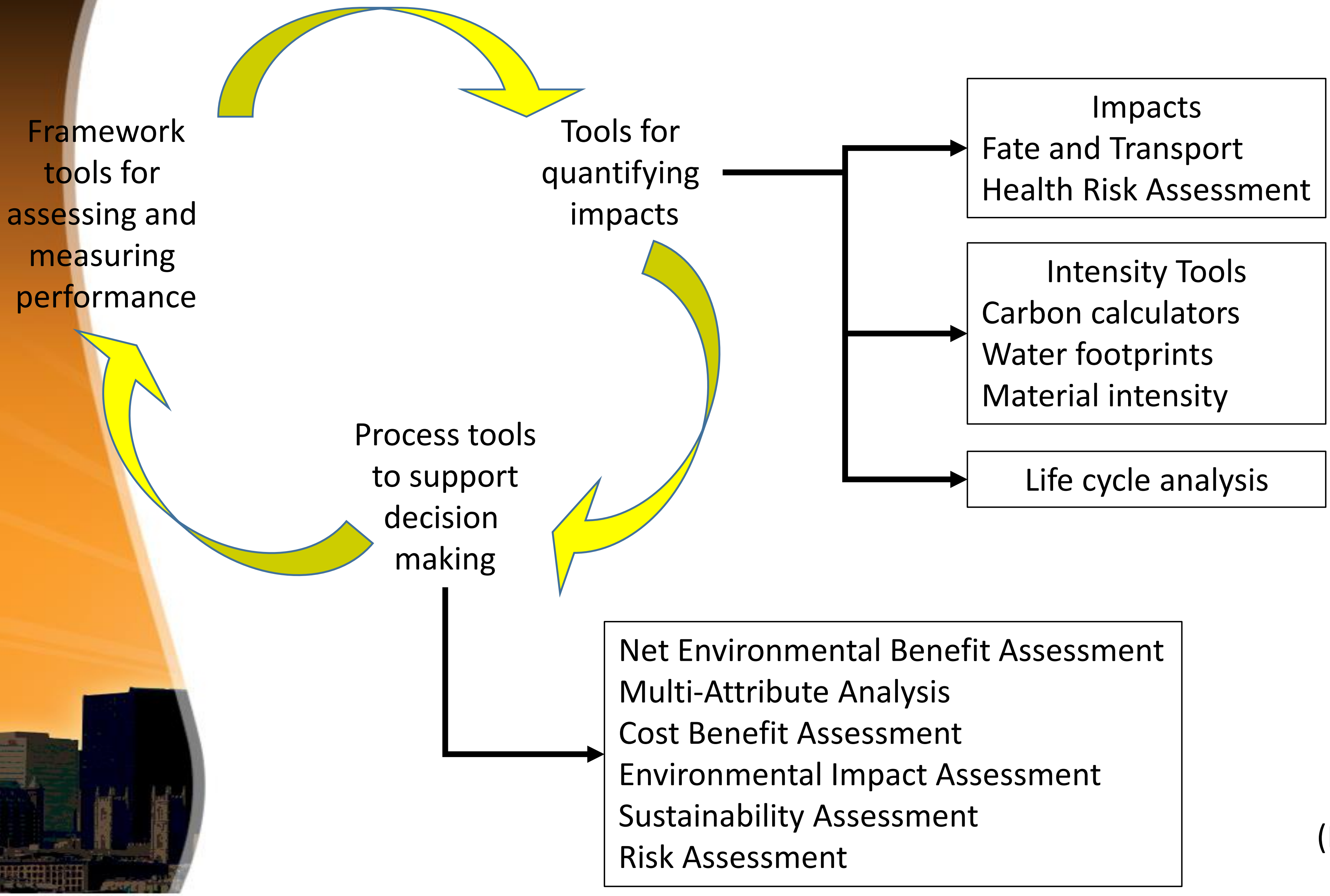


Possible indicators for a Sustainability assessment of remediation options

Environmental	Social	Economic
impacts on air	Impacts on human and safety	Direct economic costs and benefit
impacts on soil	Ethical and equity consideration	Indirect economic costs and benefit
impacts on water	Impacts on neighborhoods or regions	Employment and capital gain
impacts on ecology	Community involvement and satisfaction	Gearing
use of natural resources and generation of wastes	Compliance with policy objectives and strategies	Life-span and project risks
intrusiveness	Uncertainty and evidence	Project flexibility

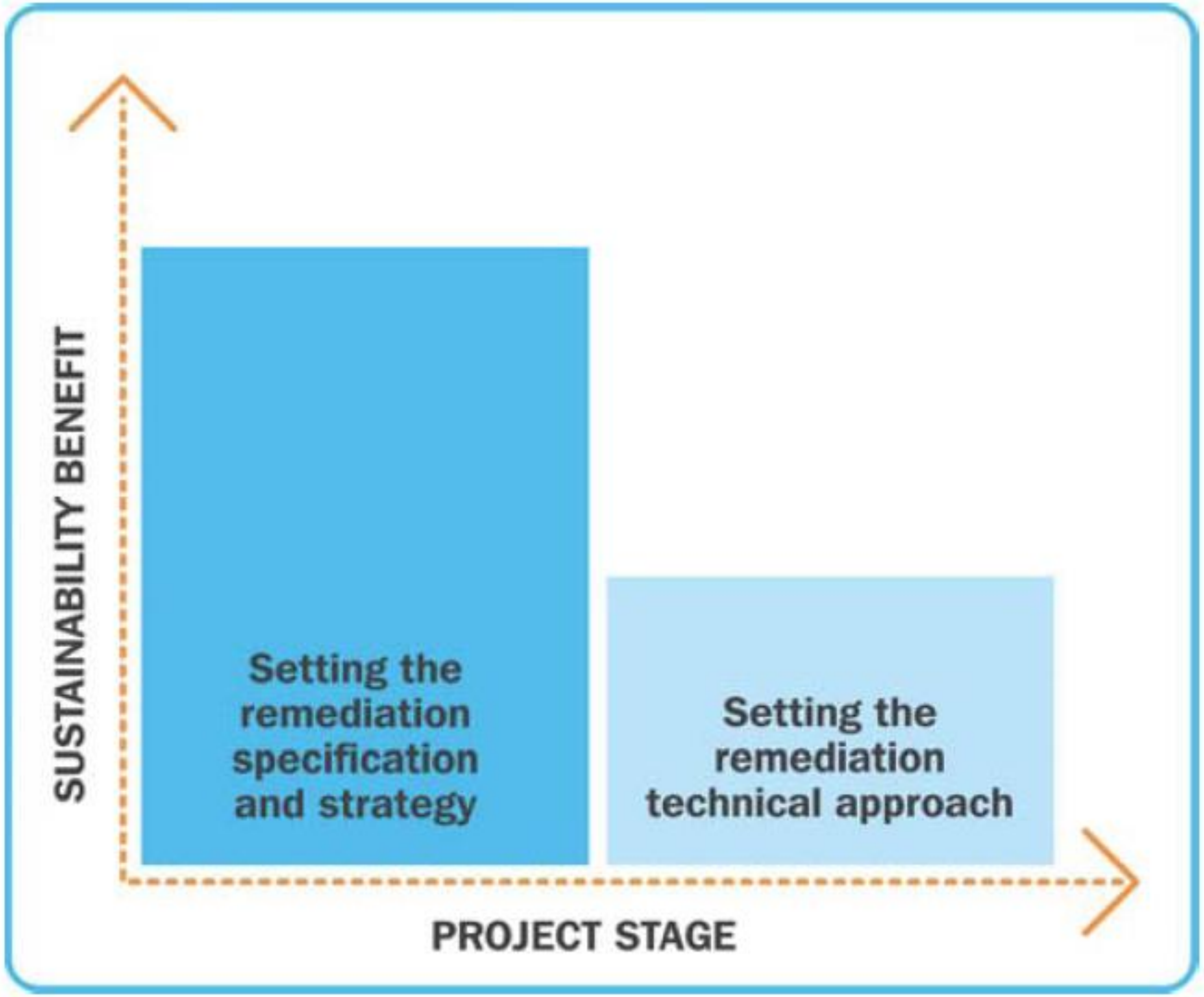
(SuRF-Australia, 2009)

Sustainability framework tool



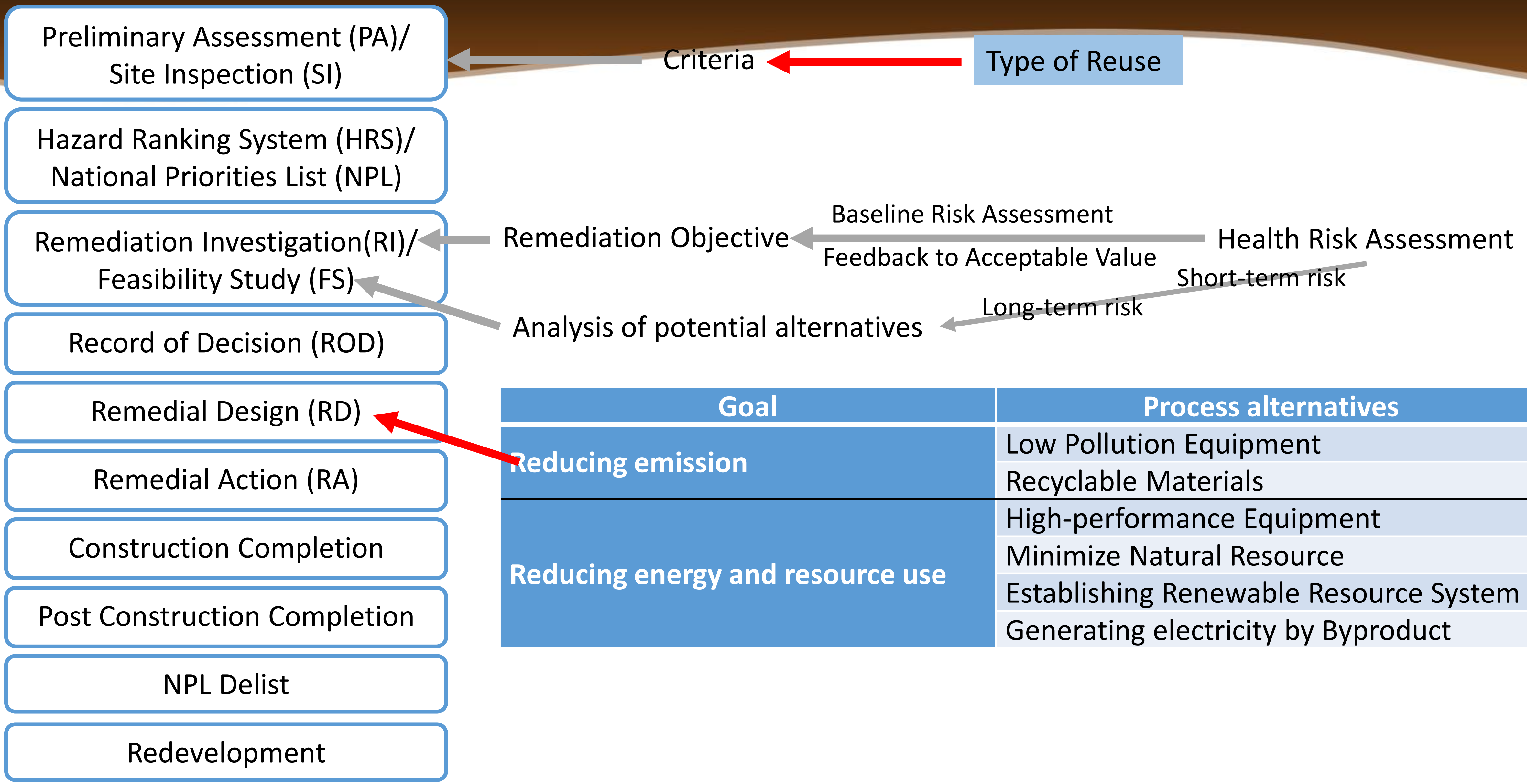
(NICOLE, 2012)

Stage of a Project



(NICOLE, 2010)

Sustainable remediation of contaminated Sites



Goal	Process alternatives
Reducing emission	Low Pollution Equipment
	Recyclable Materials
Reducing energy and resource use	High-performance Equipment
	Minimize Natural Resource
	Establishing Renewable Resource System
	Generating electricity by Byproduct

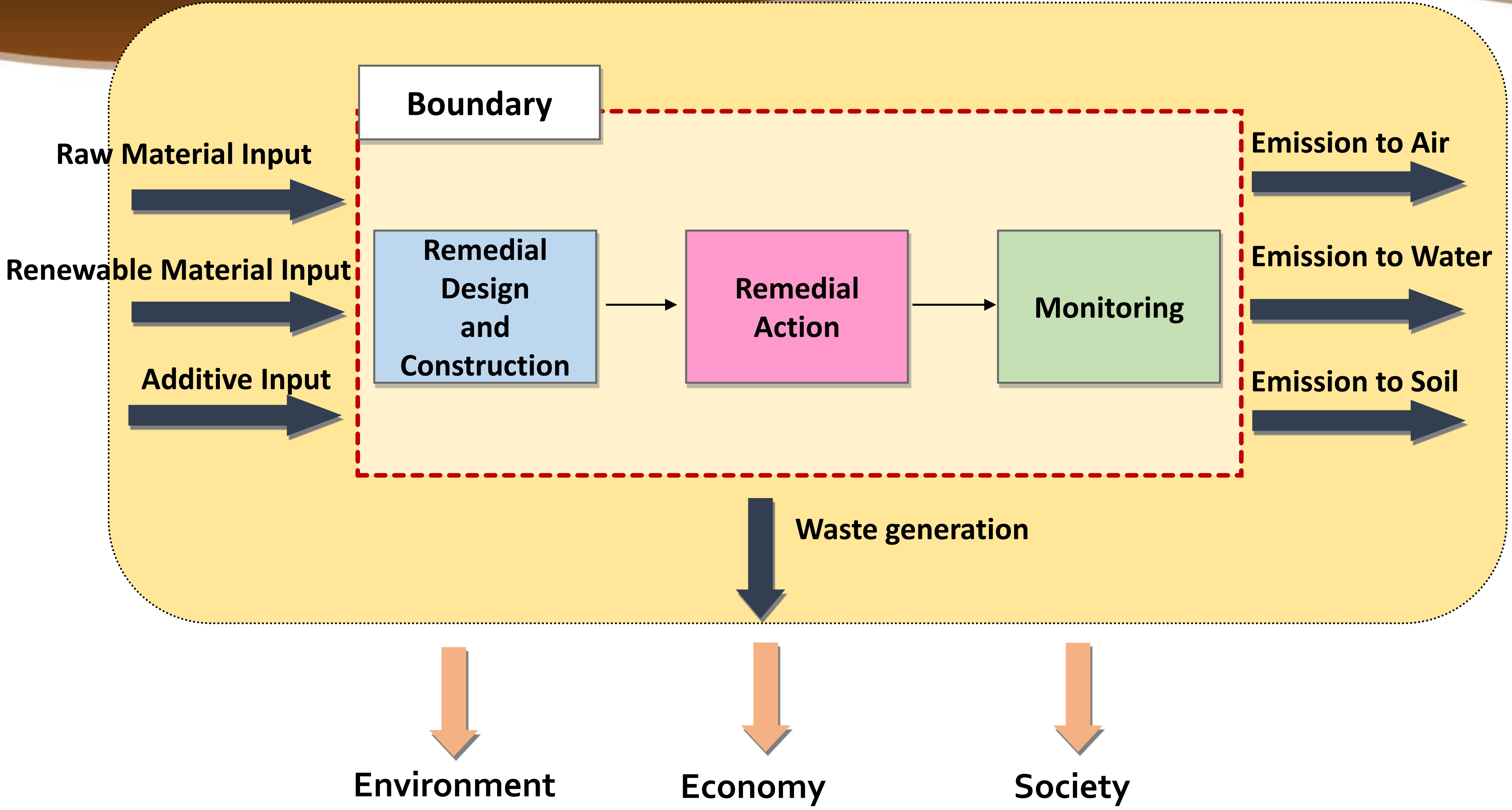
Case study for sustainable remediation

- Pollutant Trichloroethylene (TCE), with cancer and non-cancer effects
- Sampling concentration 5mg/L, more than the control standard (0.05mg/L)
- Remediation cost high, when the remediation target is the control standard; health risk chosen to be the criteria of remediation
- In Industry area with use potential
- Through preliminary investigation, the remediation duration is 10 years, and the cost is 250 millions NT dollars
- Based on the pollutant, geology, groundwater, the duration and cost, Groundwater Circulation Wells (GCW)and Enhanced Reductive Dechlorination (ERD) were chosen as the best technology.

Remediation alternatives

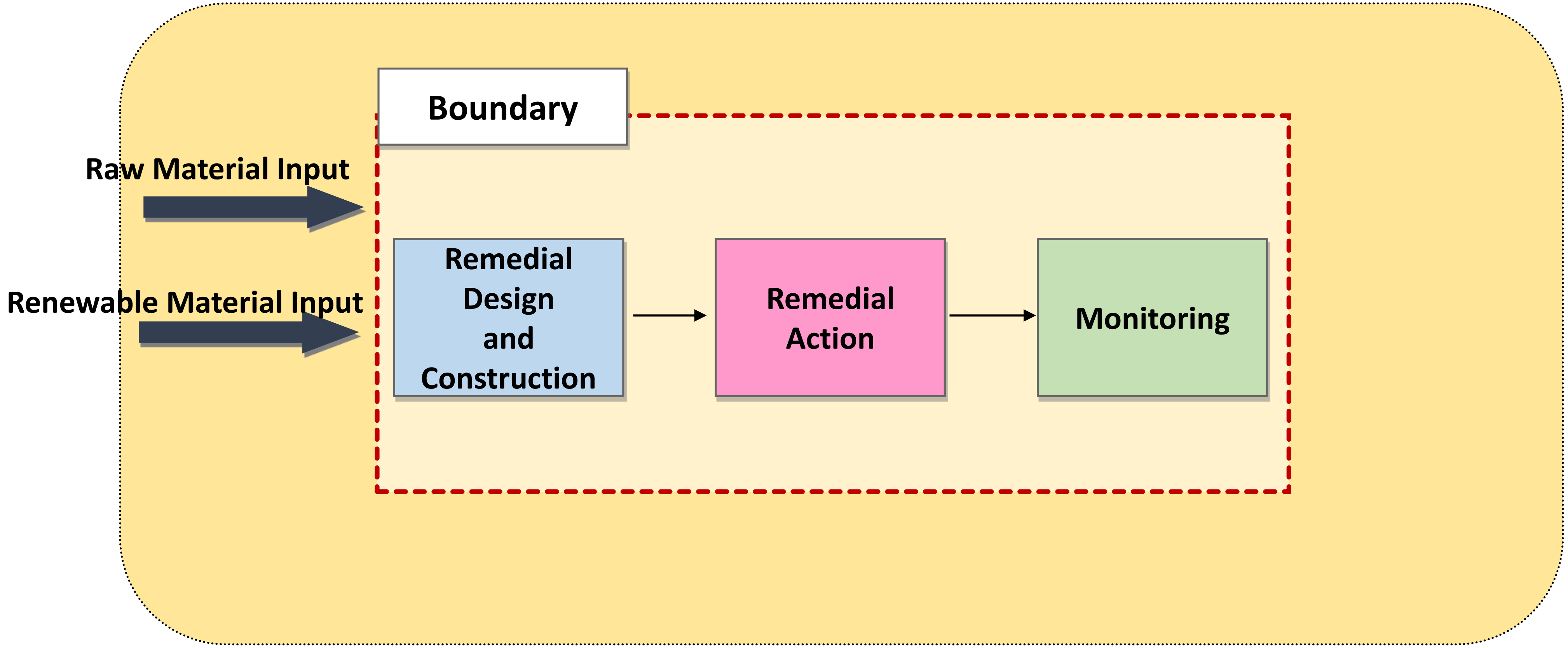
	Remediation Technology	**Procedural Design**
Alternative1	Groundwater Circulation Wells (GCW)	● Using alcohol gasoline ● Employing local workers ● Using recycle steel ● Establishing acoustic barriers
Alternative 2	Enhanced Reductive Dechlorination (ERD)	● Using alcohol gasoline and Biofuel ● Establishing working place ● carbon compensation ● Establishing rainfall recycled system
Alternative 3	Enhanced Reductive Dechlorination (ERD)	● Employing local workers ● Establishing working place ● Establishing rainfall recycled system ● Electricity generated by solar energy ● Aggregate reused ● Establishing acoustic barriers

System boundary

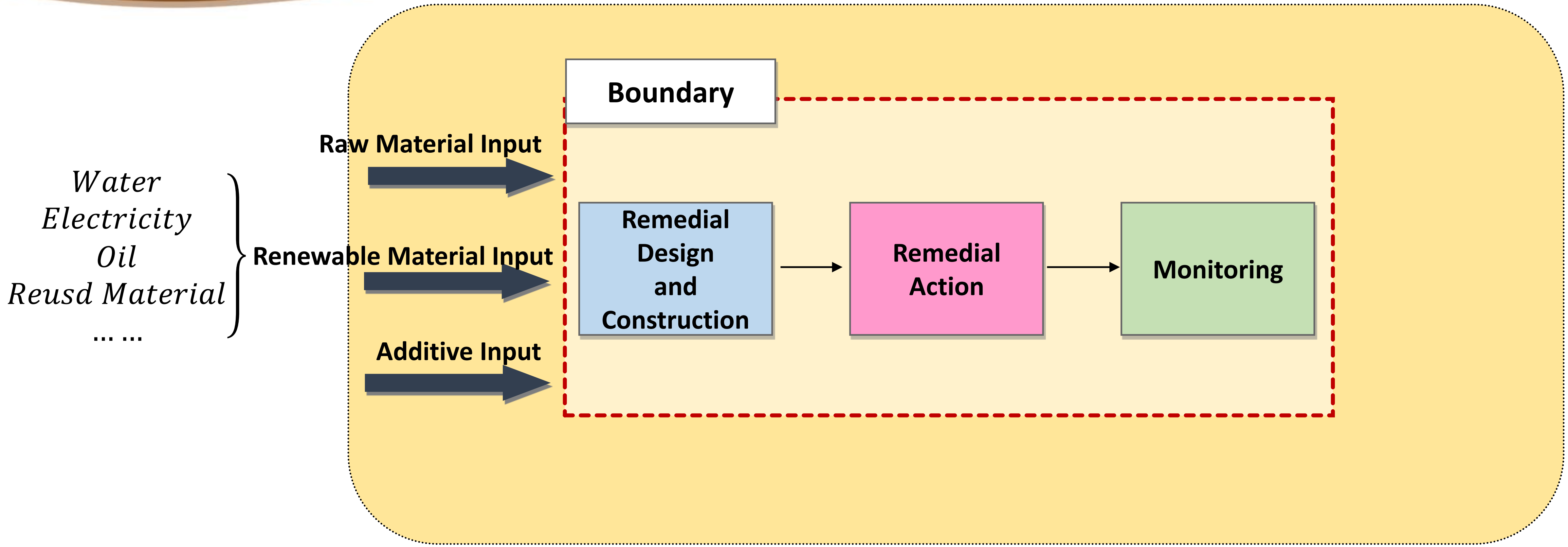


Inventory

Water
Electricity
Oil
Asphalt
Cement
Paint
Concrete
Aggregate
Steel
PVC
Metal
Wool
… …

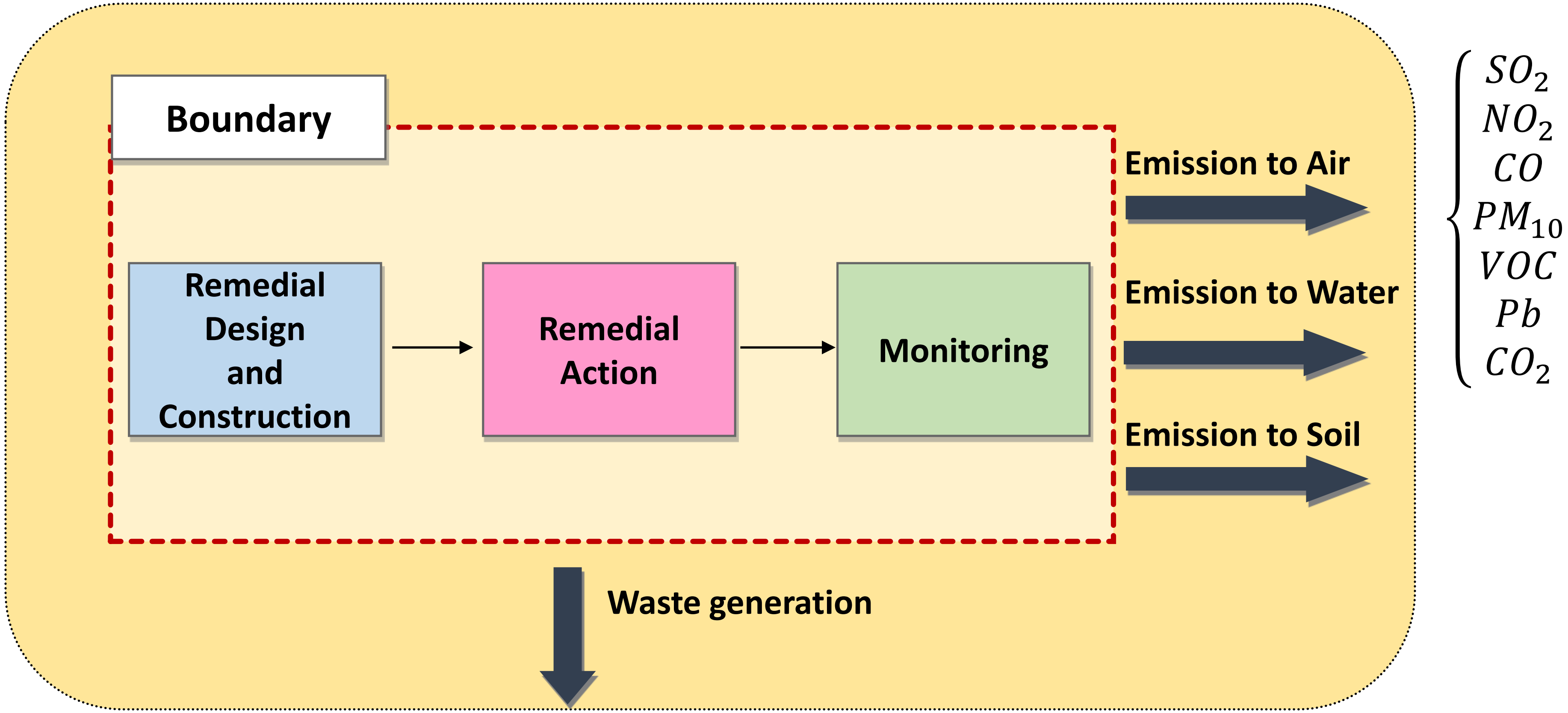


Inventory



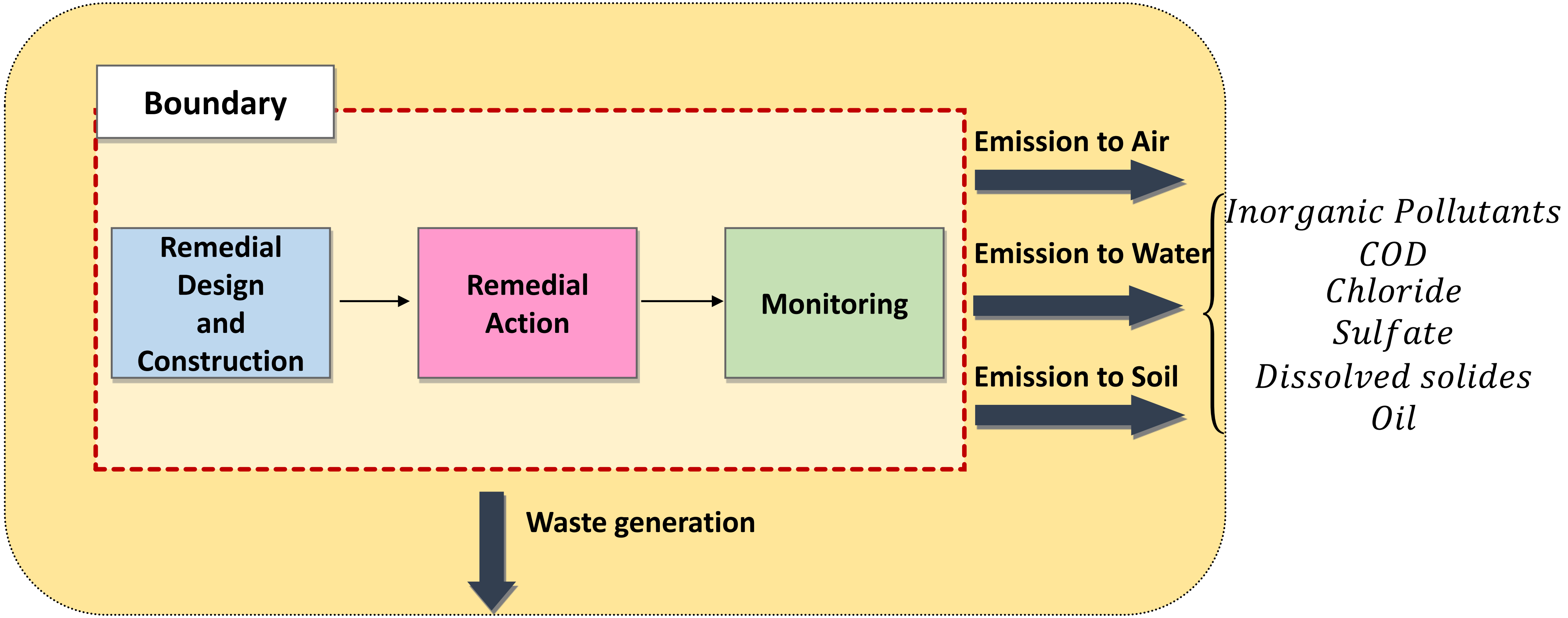
Water
Electricity
Oil
Reusd Material
… …
Raw Material Input
Renewable Material Input
Additive Input
Boundary
Remedial Design and Construction
Remedial Action
Monitoring

Inventory

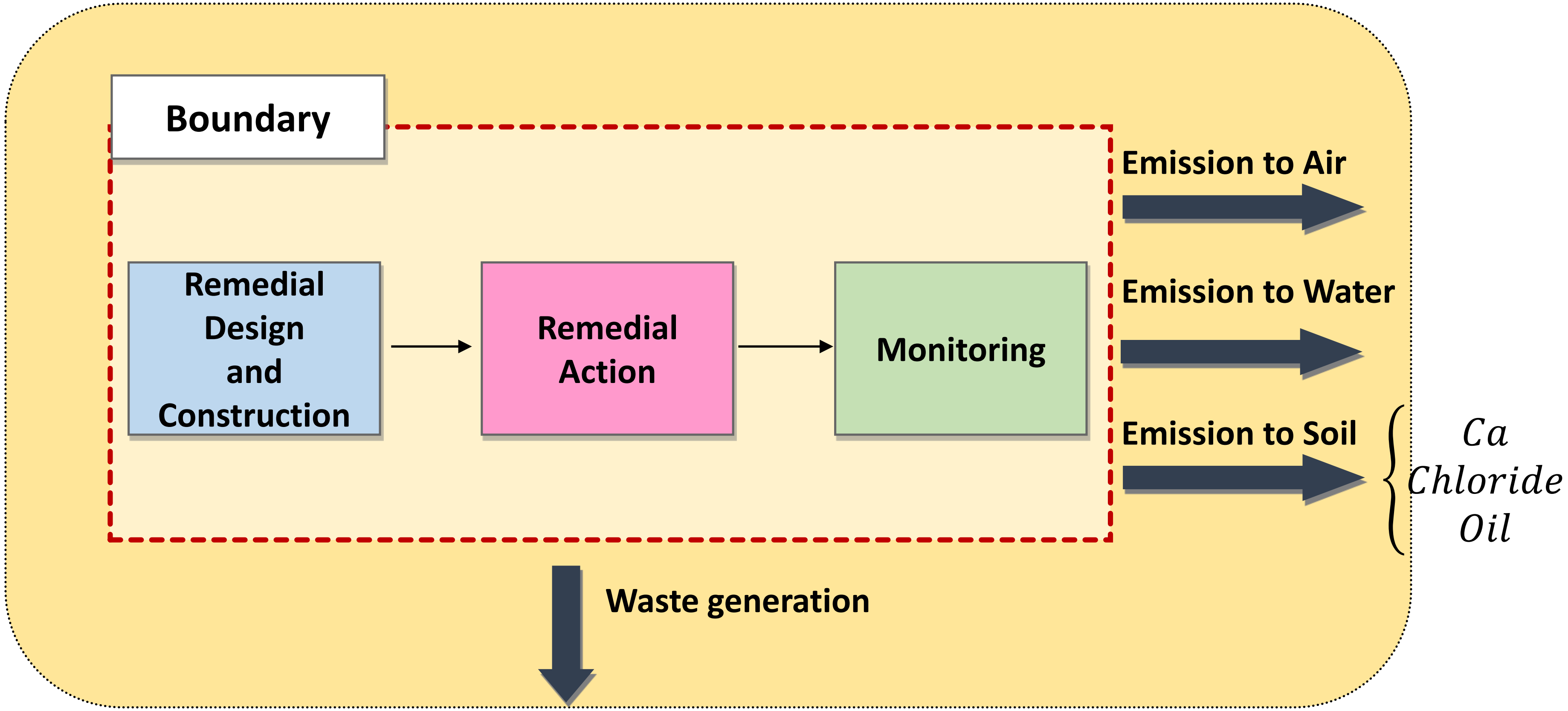


Boundary
Remedial Design and Construction
Remedial Action
Monitoring
Emission to Air
Emission to Water
Emission to Soil
Waste generation
SO_2
NO_2
CO
PM_{10}
VOC
Pb
CO_2

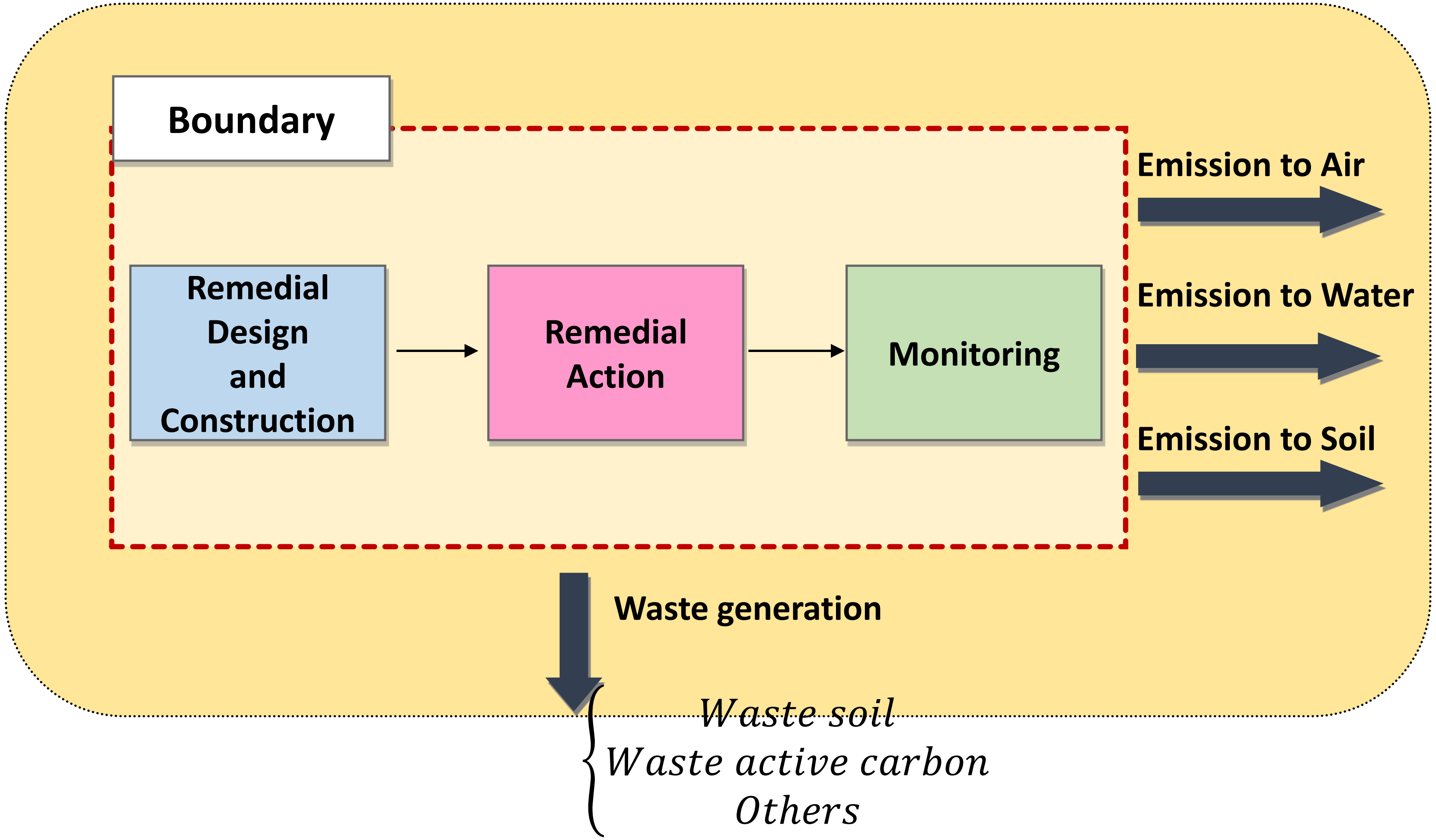
Inventory


Boundary
Remedial Design and Construction
Remedial Action
Monitoring
Emission to Air
Emission to Water
Emission to Soil
Inorganic Pollutants
COD
Chloride
Sulfate
Dissolved solides
Oil
Waste generation

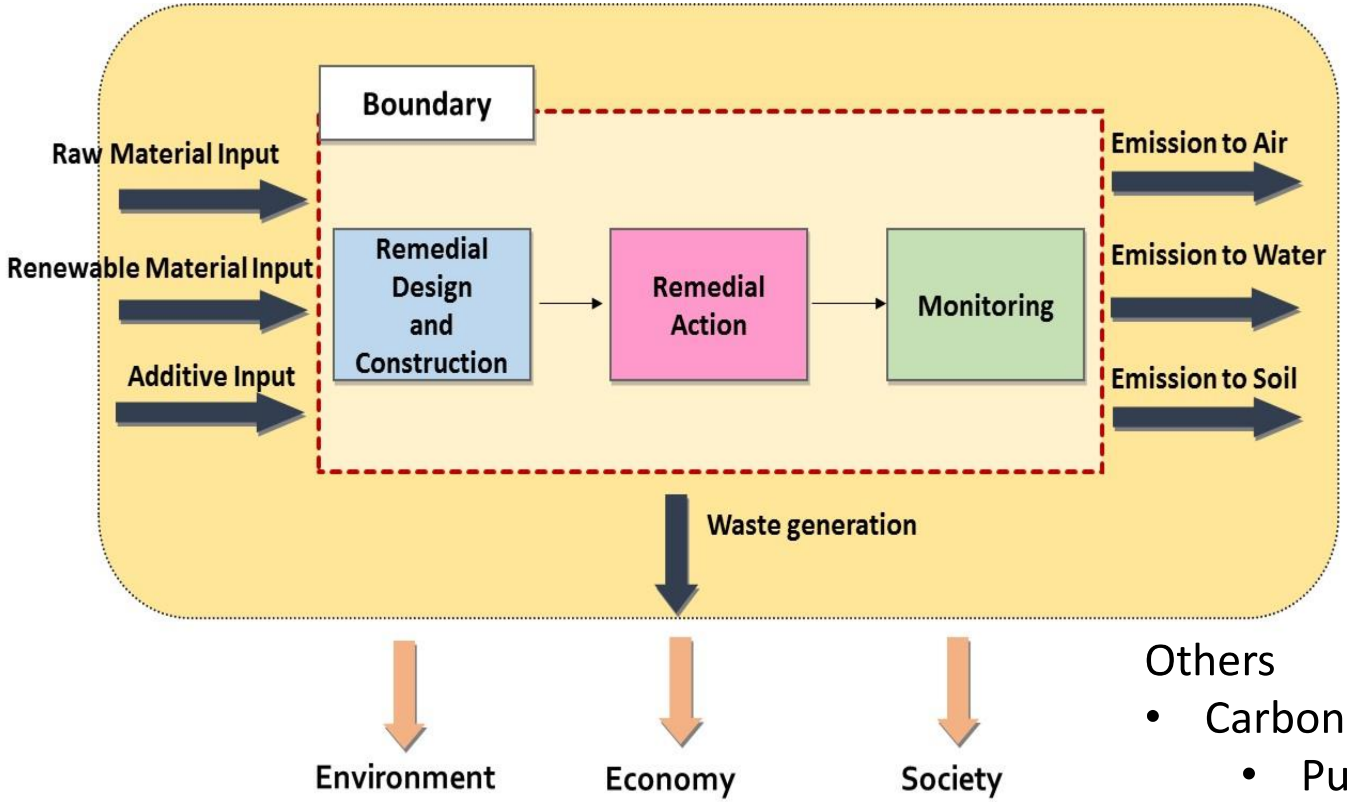
Inventory


Boundary
Remedial Design and Construction
Remedial Action
Monitoring
Emission to Air
Emission to Water
Emission to Soil
Ca
Chloride
Oil
Waste generation

Inventory


Boundary
Remedial Design and Construction
Remedial Action
Monitoring
Emission to Air
Emission to Water
Emission to Soil
Waste generation
Waste soil
Waste active carbon
Others

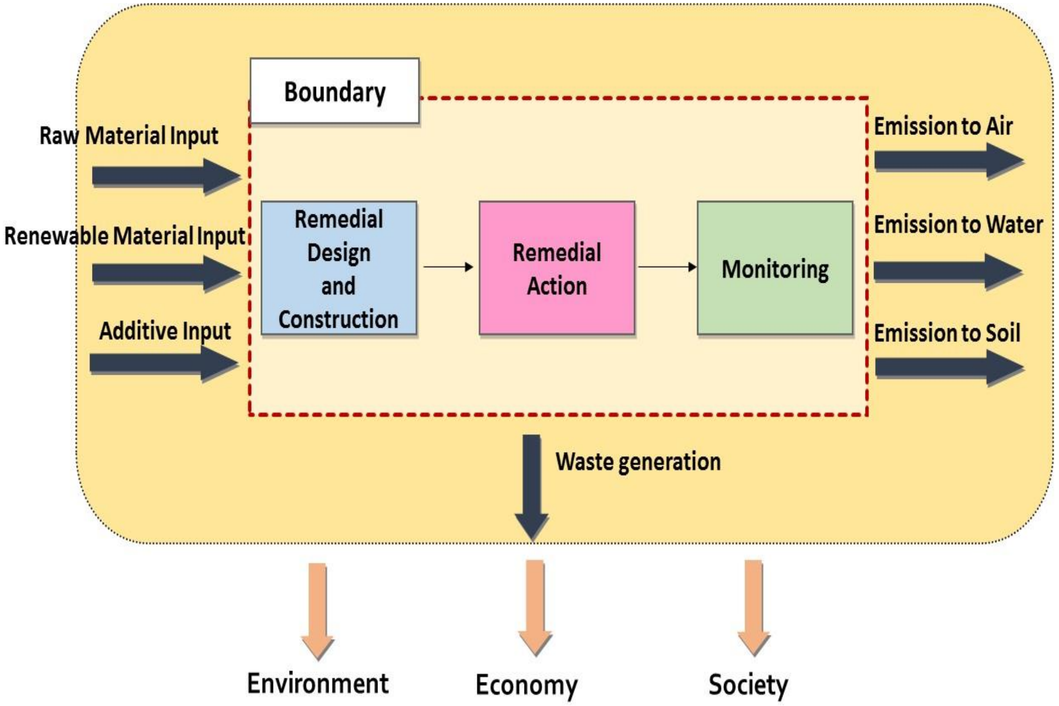
Inventory



Others

- Carbon Compensation
  - Purchase
  - Deduction by planting
- Employee
  - Local
  - Foreign
- Cost
- Subsidy

Indicators

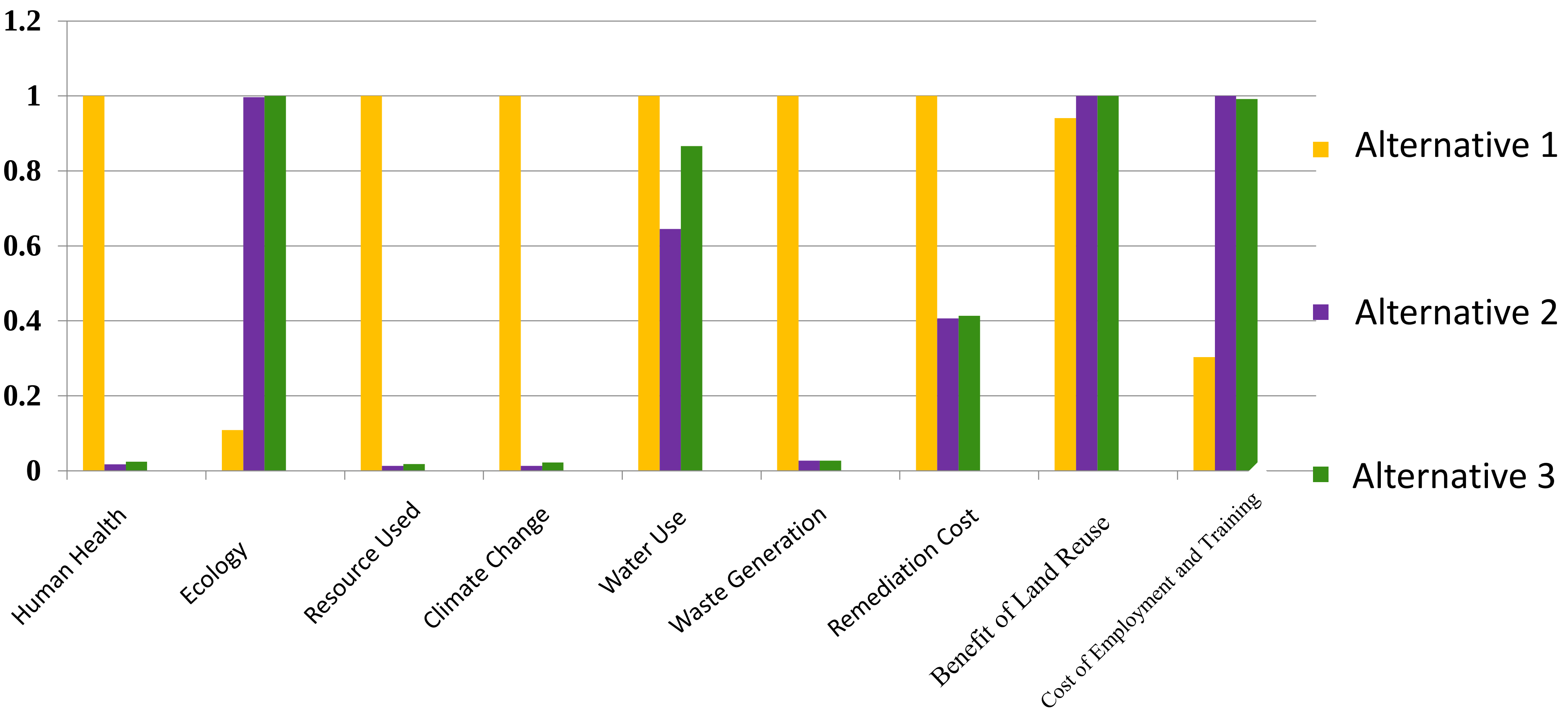


Direction	Indicator
Environment	Human Health
	Ecology
	Resource Used
	Climate Change
	Water Use
	Waste Generation
Economy	Remediation Cost
	Benefit of Land Reuse
	Cost of Employment and Training
Society	Noise、Odor and Dust
	Traffic Problem
	Community Engagement
	Commonalty acceptance

Results

Indicator	Alternative 1	Alternative 2	Alternative 3
Human Health (DALY)	13.630	0.234	0.333
Ecology (Species*yr)	0.00169	0.0155	0.0156
Resource Used ($)	103,674,428	1,365,319	1,880,410
Climate Change(kg CO2 eq)	21,366,932	280,413	479,116
Water Use (m3)	4,213	2,717	3,648
Waste Generation(kg)	3,497,607	95,782	94,981
Remediation Cost ($)	201,699,340	81,980,935	83,452,743
Benefit of Land Reuse ($)	5,803,840,000	6,166,580,000	6,166,580,000
Cost of Employment and Training ($)	1,470,000	4,842,000	4,802,000

Results



	Human Health (DALY)	Ecology (Species*yr)	Resource Used ($)	Climate Change (kg CO_2 eq)	Waste Generation (kg)	Remediation Cost ($)
GCW	1.17E+01	9.77E-04	8.79E+07	1.79E+07	2.94E+06	9.62E+07
ERD	8.05E-05	6.73E-09	6.05E+02	1.23E+02	2.03E+01	6.62E+02

Results

	Alternative 2		Alternative 3			
	clean fuel	Carbon Compensation	Local Employee	Project of Solar Energy	Reused Materials	Acoustic barrier
Human Health (DALY)	-2.00E-04	0	-6.30E-04	-1.27E-03	-6.16E-05	9.95E-02
Ecology (Species*yr)	2.54E-05	0	-2.60E-06	-8.00E-08	-7.40E-07	6.79E-05
Resource Used ($)	-1.07E+04	0	-1.13E+04	-1.40E+04	-5.92E+02	5.05E+05
Climate Change(kg CO2 eq)	-1.72E+03	-1.00E+05	-1.98E+03	-2.82E+03	-1.36E+02	9.74E+04
Water Use (m3)	-2.30E+00	0	-6.66E+00	2.93E+01	-3.69E+00	8.94E+02
Waste Generation(kg)	0	0	0	-5.50E+02	0	0
Remediation Cost ($)	0	1.20E+04	0	1.82E+05	-3.19E+02	1.62E+06
Benefit of Land Reuse ($)	0	0	0	0	0	0
Cost of Employment and Training ($)	0	0	-1.12E+05	0	0	0

Thank you for listening…

ENVIRONMENTAL RISK MAPPING FOR EVALUATION THE IMPACT OF THE BROWNFIELD SITES

Ming-Chien Su

Department of Natural Resources and Environmental Studies, National Dong Hwa University

The course contents:

- Brownfield
  - Definition
  - Regulations
- Brownfields problems
- Assessing and Mapping Technology
  - Brownfield Sites Assessment
  - Risk Assessment Methodology
- Brownfield Regeneration Solution

USA Brownfield Definition

- ***Brownfields Site***: means real property, may related to the presence or potential presence of a hazardous substance, pollutant, or contaminant.

- **The 2002 Brownfields Law defines *"the term to include a site that is "contaminated by a controlled substance; contaminated by petroleum or a petroleum product excluded from the definition of 'hazardous substance;' or mine-scarred land."***

- In the USA a brownfield site often refers to an abandoned "***industrial land***" that has been contaminated with the levels of hazardous waste and pollutants.

EU Brownfield Definition

- EU: Brownfield sites are sites that have been affected by the former uses of the site and surrounding land, are derelict or underused, may have real or perceived contamination problems, are mainly in developed urban areas and require intervention to bring them back to beneficial use.
- *No specific law or regulation for the “Brownfield sites”*
- In the UK a brownfield site is defined as "previously developed land" that has the potential for being redeveloped. It is often (but not always) land that has been used for industrial and commercial purposes and is now derelict and possibly contaminated.

Brownfield Regulations

- US: The 2002 Small Business Liability Relief and Brownfields Revitalization Act (the "Brownfields Law")

Brownfields problems

- Older industrial properties -- even those with just small amounts of environmental contamination that could easily be remediated -- are placed at a considerable disadvantage in the real estate market, compared to clean greenfield locations.
- A property owner -- unable to sell a contaminated property – simply abandons it, undermining the local tax base.
- Vacant facilities deteriorate and invite abuse -- unsupervised stripping of parts or material, vandalism or arson, and "midnight" dumping.
- Untended pollution may worsen and spread, further diminishing the property value and adding to its cleanup cost, as well as threaten the economic viability of adjoining properties.
- The site becomes an unwanted legal, regulatory, and financial burden on the community and its taxpayers.

Charles Bartsch, 2006

The common characteristics of brownfields

- Abandoned
- often but not always contaminated,
- require reclamation/revitalization
- relict of industry, construction, agriculture, military or other anthropogenic activities

(G. Siebielec (ed.), 2012)

Before….Industrial site….

Underused post-industrial site in Piekary, Poland (G. Siebielec (ed.), 2012)

(TEPA 2013)

After Regeneration….

(TEPA 2013)

Brownfield Sites Assessment

- analysis of the soil, groundwater and surface water through testing for hazardous compounds, and ensures that appropriate measures are taken to reduce identified risks and liabilities.
- **Environmental Site Assessment (ESA), ASTM and AAI Standards**
  - **Phase I ESA.** Often conducted before a property transfer, this process assesses site history and helps determine whether a site has potential for contamination.
  - **Phase II ESA.** A Phase II ESA involves on-site sampling and helps to determine the extent, types, and probable sources of contamination; risks to human health and the environment; and the need for cleanup.
  - **Expedited Site Assessment.** This process is used to more rapidly characterize underground storage tank sites by analyzing and interpreting data on the site as it is collected.

ASTM Standards for Conducting Environmental Site Assessments

ESA type	ASTM standards	Other requirements
Phase I	E 1527- 13 E 2247- 08	AAI in 40 CFR 312; ISO 14015
Phase II	E 1903- 11	

1. American Society for Testing and Materials (ASTM)
2. "All-Appropriate-Inquiry" (AAI)

Sources: DNR-WI, AM-465 2014

Phase I ESA

Basic Information Profile & Identified potential Contamination

- a review of records,
- a site inspection,
- interviews with owners, occupants, neighbors and local government officials.
- **Phase One Conceptual Site Model (CSM)**

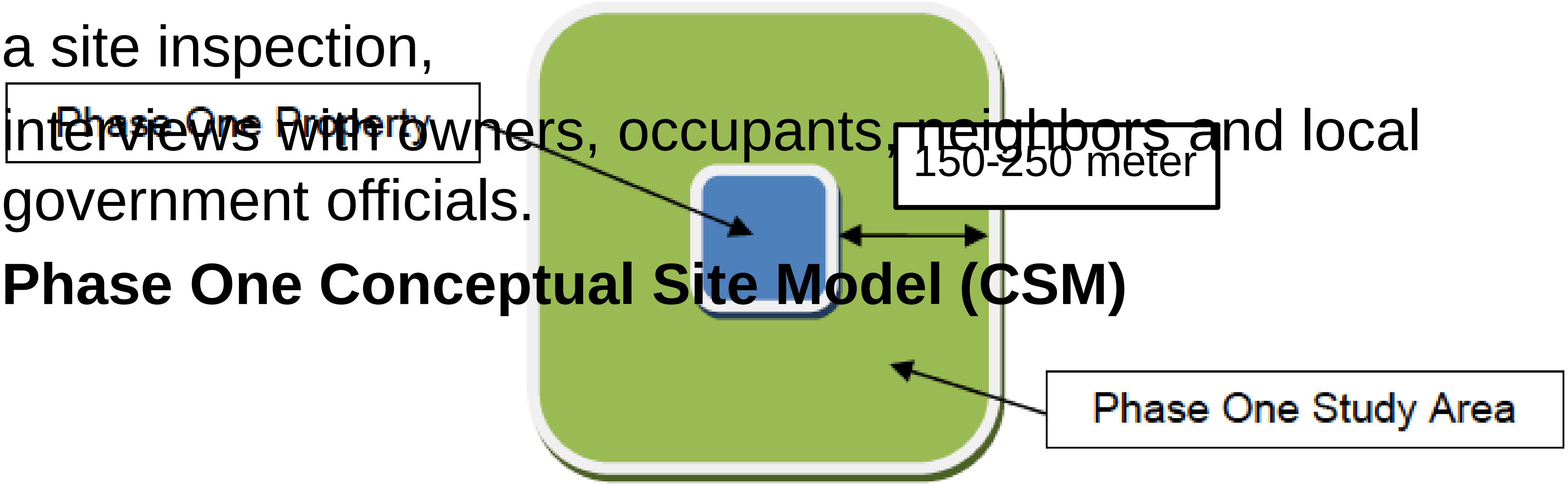


Table of Areas of Potential Environmental Concern
(Refer to clause 16(2)(a), Schedule D, O. Reg. 153/04)

Area of Potential Environmental Concern[1]	Location of Area of Potential Environmental Concern on Phase One Property	Potentially Contaminating Activity[2]	Location of PCA (on-site or off-site)	Contaminants of Potential Concern[3]	Media Potentially Impacted (Ground water, soil and/or sediment)

Notes:

[1] area of potential environmental concern means the area on, in or under a phase one property where one or more contaminants are potentially present, as determined through the phase one environmental site assessment, including through,
(a) identification of past or present uses on, in or under the phase one property, and
(b) identification of potentially contaminating activity.

[2] potentially contaminating activity means a use or activity set out in Column A of Table 2 of Schedule D that is occurring or has occurred in a phase one study area

[3] when completing this column, identify all contaminants of potential concern using the Method Groups as identified in the "Protocol for in the Assessment of Properties under Part XV.1 of the Environmental Protection Act, March 9, 2004, amended as of July 1, 2011, as specified below:

ABNs	PCBs	Metals	Electrical Conductivity	SAR
CPs	PAHs	As, Sb, Se	Cr (VI)	
1,4-Dioxane	THMs	Na	Hg	
Dioxins/Furans, PCDDs/PCDFs	VOCs	B-HWS	Methyl Mercury	
OCs	BTEX	Cl^-	high pH	
PHCs	Ca, Mg	CN^-	low pH	

* When submitting a record of site condition for filing, a copy of this table must be attached.

Guide for Completing Phase One Environmental Site Assessments under Ontario Regulation 153/04

Table of Current and Past Uses of the Phase One Property
(Refer to clause 16(2)(b), Schedule D, O. Reg. 153/04)

Year	Name of Owner	Description of Property Use	Property Use[1]	Other Observations from Aerial Photographs, Fire Insurance Plans, etc.

Notes:

[1] for each owner, specify one of the following types of property use (as defined in O. Reg. 153/04) that applies:

Agriculture or other use
Commercial use
Community use
Industrial use
Institutional use
Parkland use
Residential use

* When submitting a record of site condition for filing, a copy of this table must be attached.

Phase II ESA

- Sampling and laboratory analysis to confirm the presence of hazardous materials.
  - surficial soil and water samples
  - subsurface soil borings
  - groundwater monitoring well installation, sampling, and analysis (may be appropriate on neighboring properties as well to determine the presence of contamination)
  - drum sampling (if any were left on the property)
  - sampling of dry wells, floor drains and catch basins
  - transformer/capacitor sampling for Polychlorinated Biphenyls (PCBs)
  - geophysical testing for buried tanks and drums
  - testing of underground storage tanks

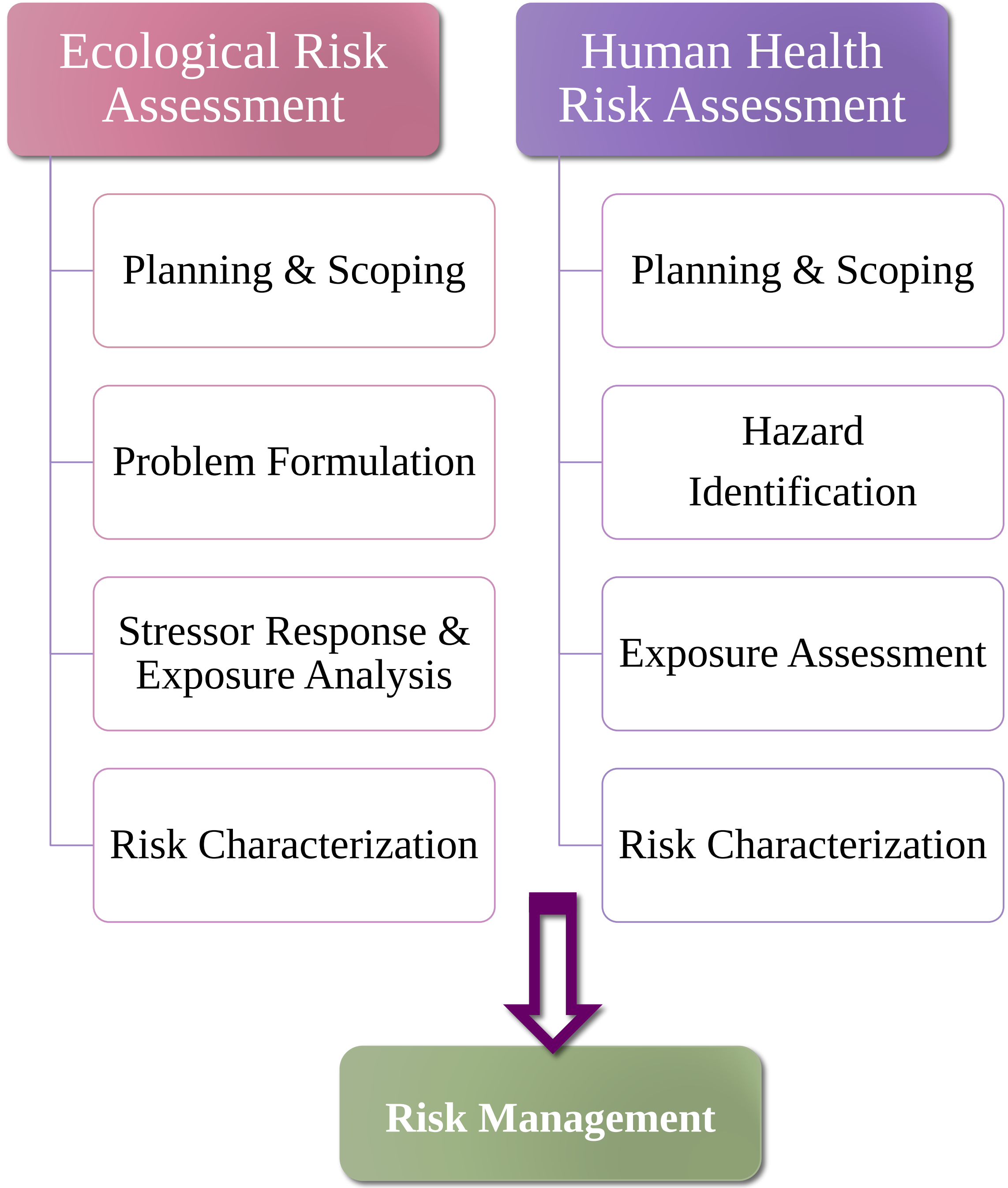
Site Inspection

Field Survey

Sampling

(TEPA 2013)

Risk Assessment Paradigm

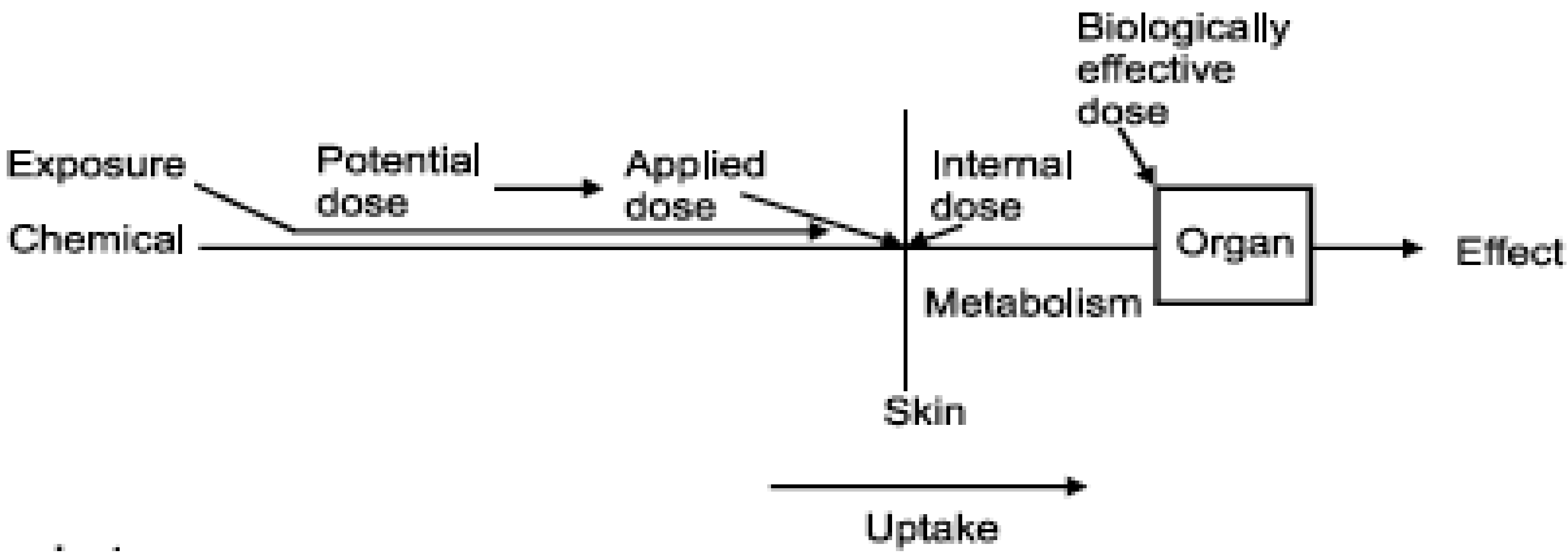


Risk Assessment Methodology

1. Identified Hazards, Scenarios & Assumption
2. Exposure Assessment
3. Risk assessment
4. Risk mapping

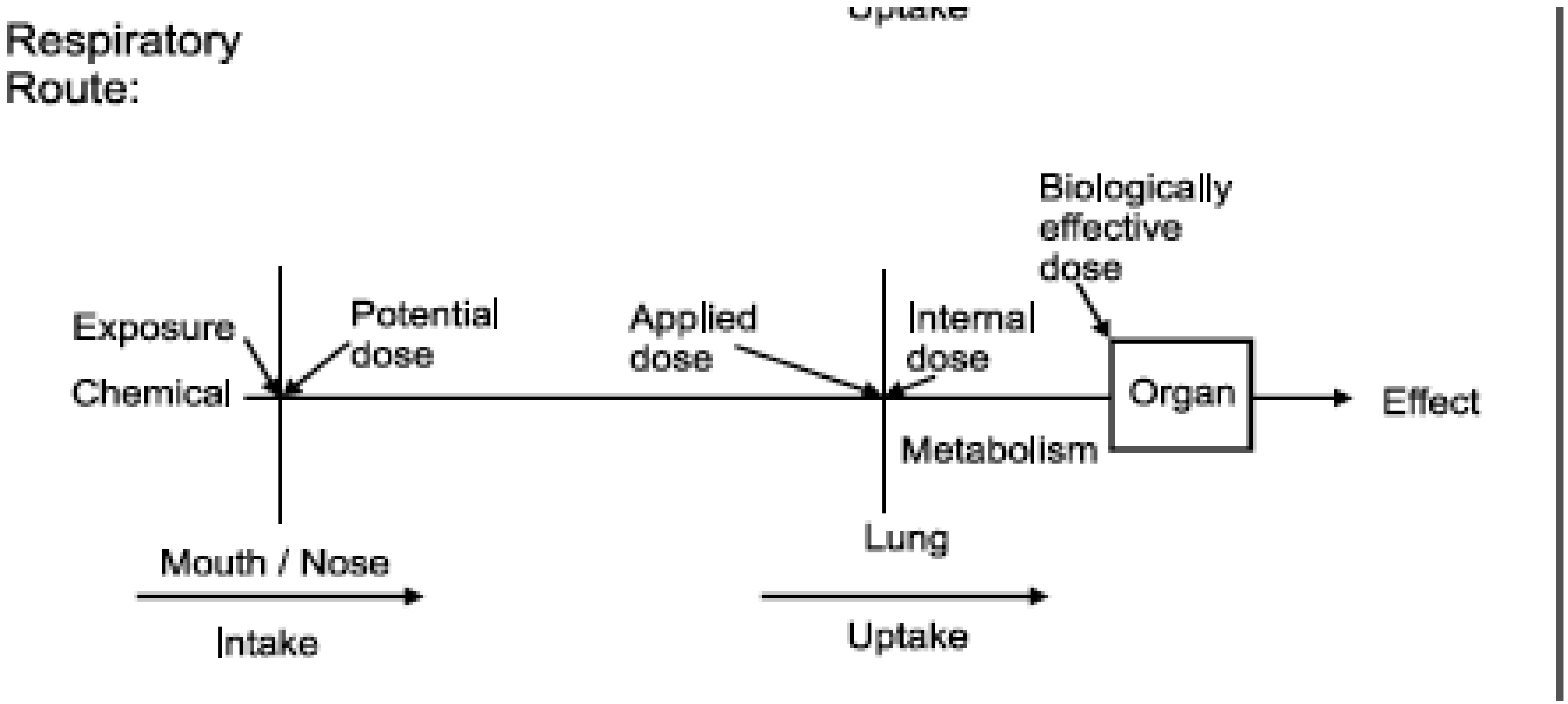
Exposure assessment

Dermal
Route:



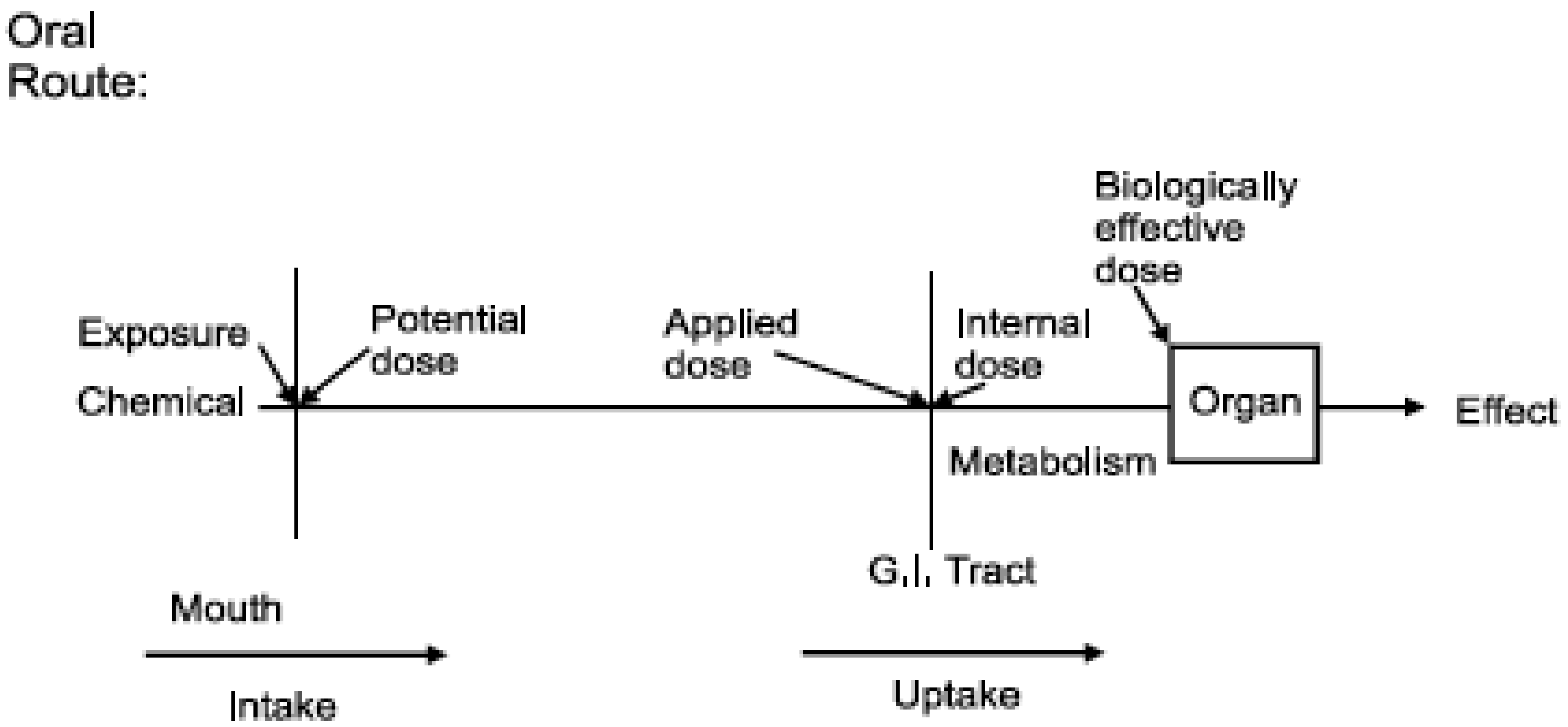
(USEPA, 1992)

Exposure assessment



(USEPA, 1992)

Exposure assessment

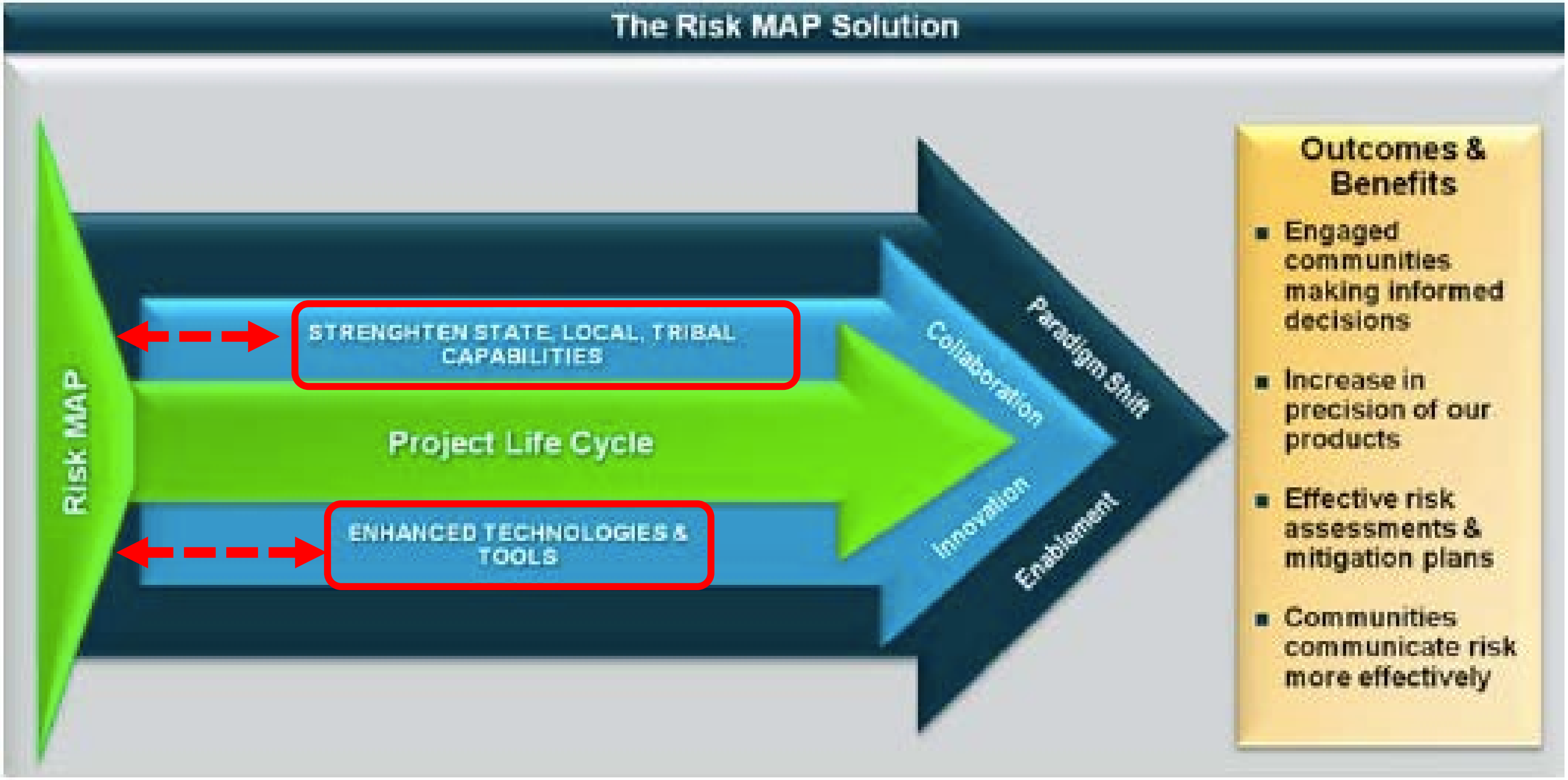


(USEPA, 1992)

3 Ways to Approach the Quantitative Exposure Estimate

- The exposure can be measured at the point of contact (the outer boundary of the body) while it is taking place, measuring both exposure concentration and time of contact and integrating them (point-of-contact measurement),
- The exposure can be estimated by separately evaluating the exposure concentration and the time of contact, then combining this information (scenario evaluation),
- The exposure can be estimated from dose, which in turn can be reconstructed through internal indicators (biomarkers,[17] body burden, excretion levels, etc.) after the exposure has taken place (reconstruction).

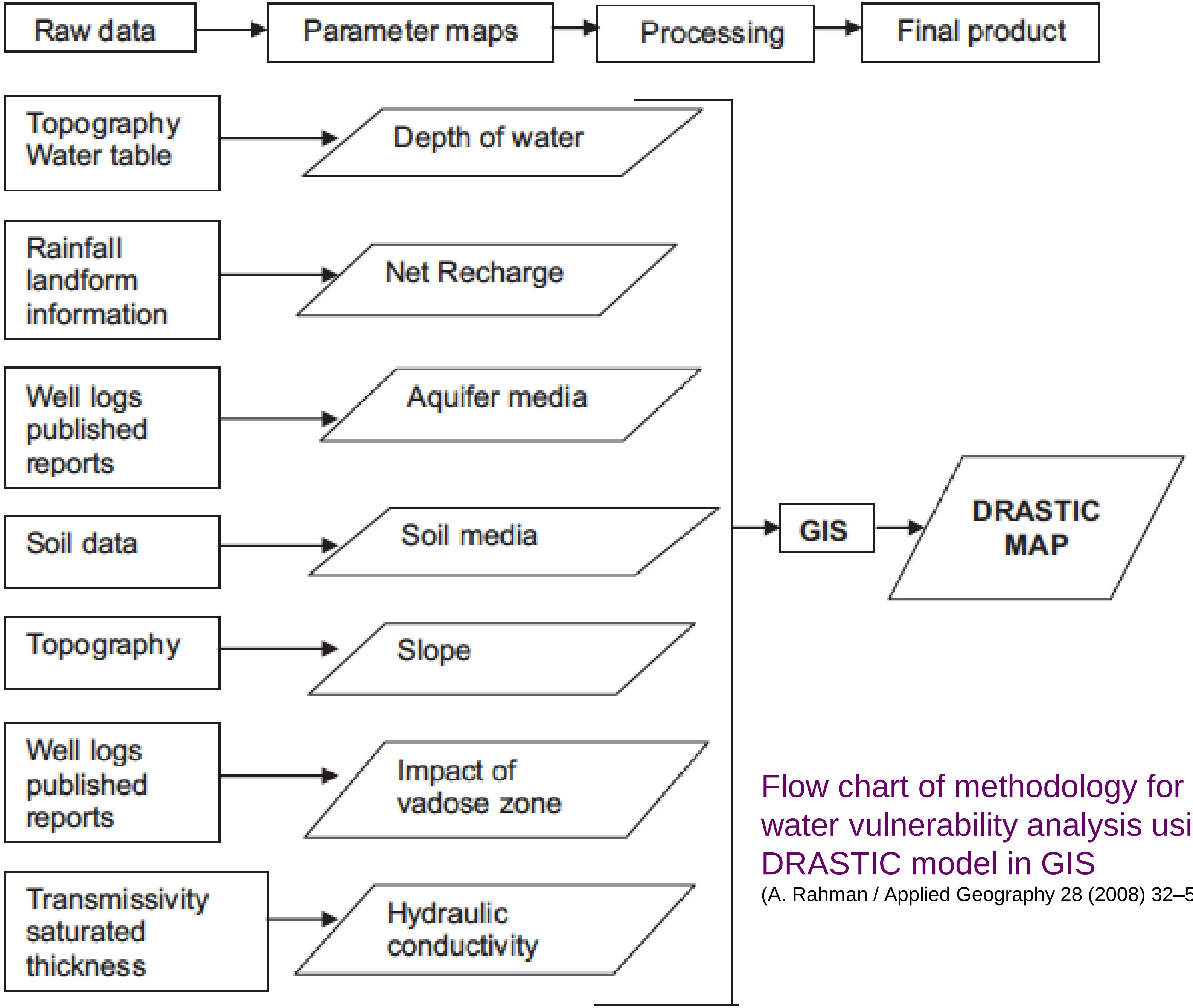
(USEPA, 1992)



What is Risk Map? 2012. www.fema.gov/plan/prevent/fhm/rm_main.shtm · 1 – 877 – FEMA MAP

Mapping Tools: DRASTIC Method

- US-EPA developed method for evaluating ground water contamination.
  - 4 Assumptions: (a) the contaminant is introduced at the ground surface; (b) the contaminant enters the groundwater by precipitation; (c) the contaminant has mobility; and (d) the area should be 400 m2 or larger
  - Seven parameters: parameters—depth to water table(D), net recharge(R), aquifer media(A), soil media(S), topography(T), impact of vadose zone material(I), and hydraulic conductivity(C)
- DRASTIC Index=$D_R D_W + R_r R_w + A_r A_w + S_r S_w + T_r T_w + I_r I_w + C_r C_w$
  - r is the rating and w the weight.
- Risk Index = DRASTIC Index + $L_r L_w$
  - L: land use



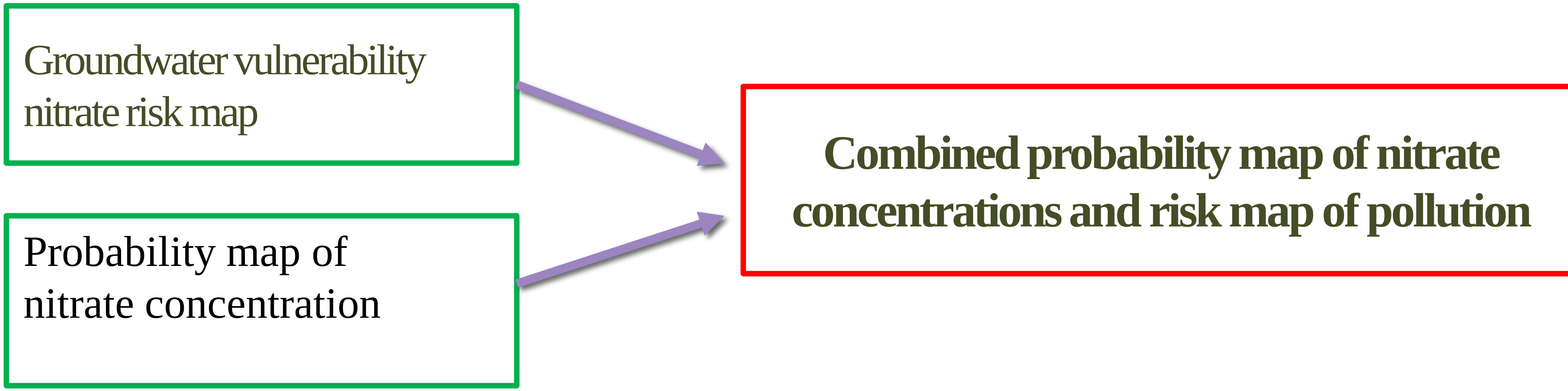
Flow chart of methodology for ground water vulnerability analysis using DRASTIC model in GIS

(A. Rahman / Applied Geography 28 (2008) 32–53)

DRASTIC parameters

rating	(D) Depth to water (m)	(R) Net recharge (mm)	(A) Aquifer media	(S) Soil media	(T) Topography (% slope)	(I) Impact of Vadose zone material	(C) Conductivity (m/d)
1	>30.4	50.8	-	No shrinking Clay	>18	Confining layer	0.04–4.1
2	22.8–30.4	-	Massive shale	Muck	-	-	4.1–12.3
3	15.2–22.8	50.8–101.6	Metamorphic igneous clay	Clay loam	12–18	Silt/clay Shale limestone	-
4	-	-	Weathered metamorphic	Silty loam	-	-	12.3–28.7
5	9.1–15.2	-	Glacial till	Loam	6–12	-	-
6	-	101.6–177.8	Bedded sandstone limestone	Sandy loam	-	Sandstone bedded limestone and limestone shale, gravel and w. silt	28.7–41
7	4.6–9.1	-	-	Shrinking clay	-	-	-
8	-	177.8–254	Massive limestone sand and gravel	Peat	-	Sand and gravel	41–82
9	1.5–4.6	-	basalt	Sand	2–6	Basalt	-
10	0–1.5	>254	Karsts limestone	Thin or absent Gravel	0–2	Karsts limestone	>82
weight	5	4	3	3	1	5	3

(Yeganeh et.al.,2013)



Source: Narany et.al., Spatial Assessment of Groundwater Quality Monitoring Wells Using Indicator Kriging and Risk Mapping, Amol-Babol Plain, Iran. Water 2014, 6, 68-85

(Yeganeh et.al.,2013)

Mapping Tool: ARCGIS software

- GIS can serve as a database and create geographic models by analyzing different sets of data in the GIS (Lerner and Lerner, 2008).
  - Inverse Distance Weighted (IDW) (Soil Contamination): assumed the influence of the sampling point decreased with distance (ESRI).

Spatial variation (IDW) in Zn concentration in soils of Ladhran district.

Ahmad et.al., CH15, Soil Remediation and Plants. 2015 Elsevier Inc.

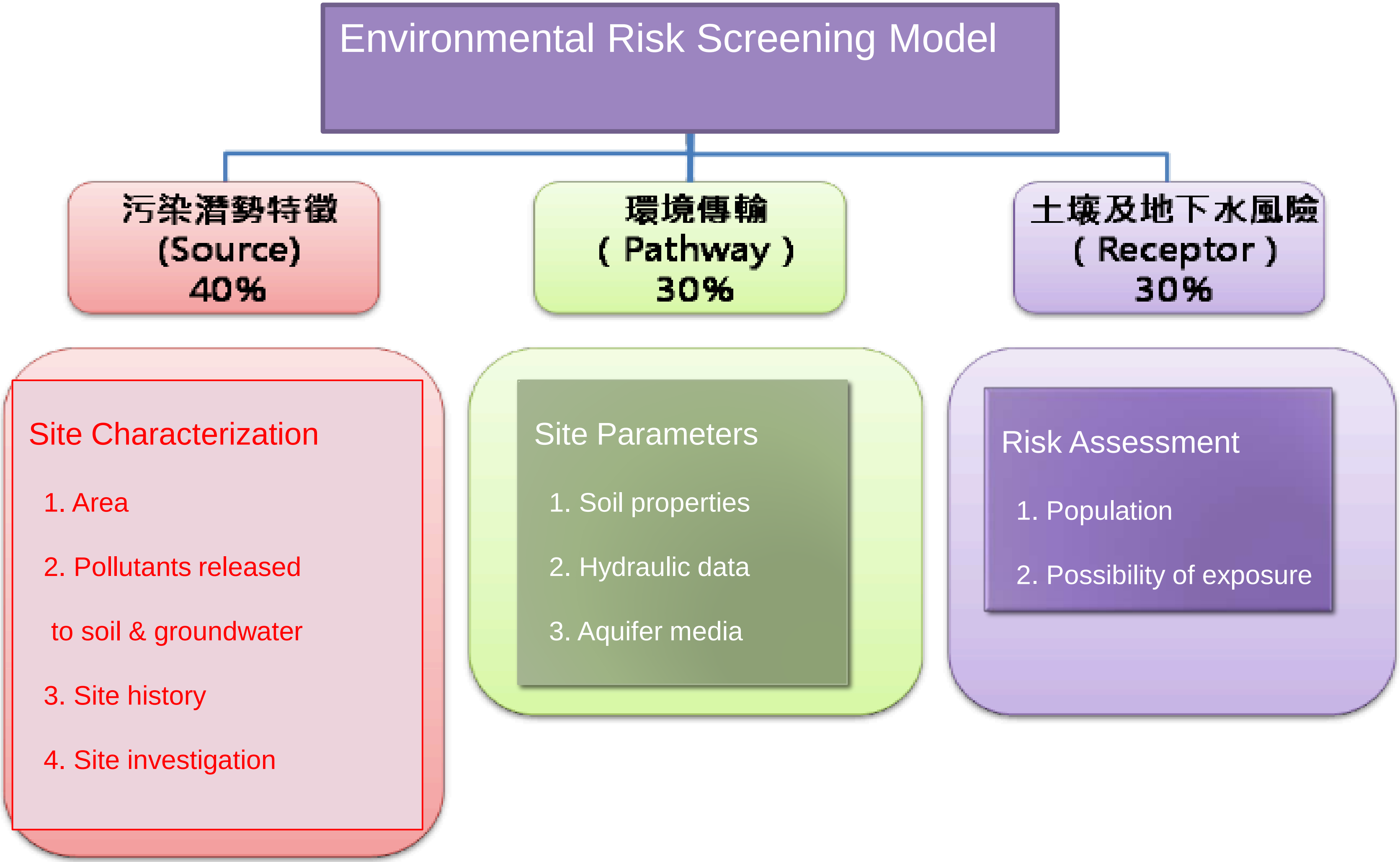
Mapping Tool: ARCGIS software

- Krigging to forecast the values at non-sampling sites.

Spatial variation (Krigging) in Cd concentration in soils of Jinnah Town .

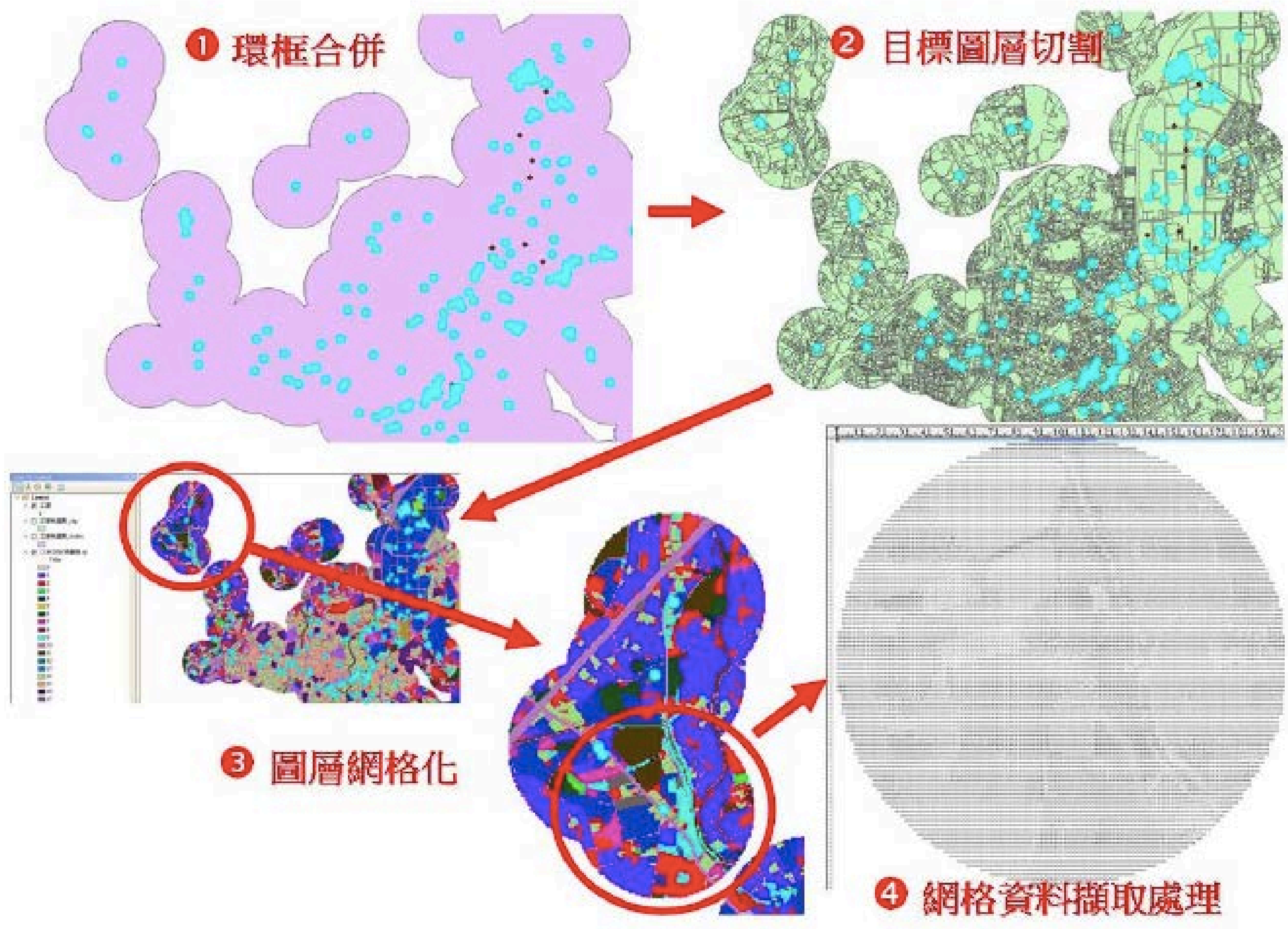
Ahmad et.al., CH15, Soil Remediation and Plants. 2015 Elsevier Inc.

A Framework of Brownfield Environmental Risk Screening Model



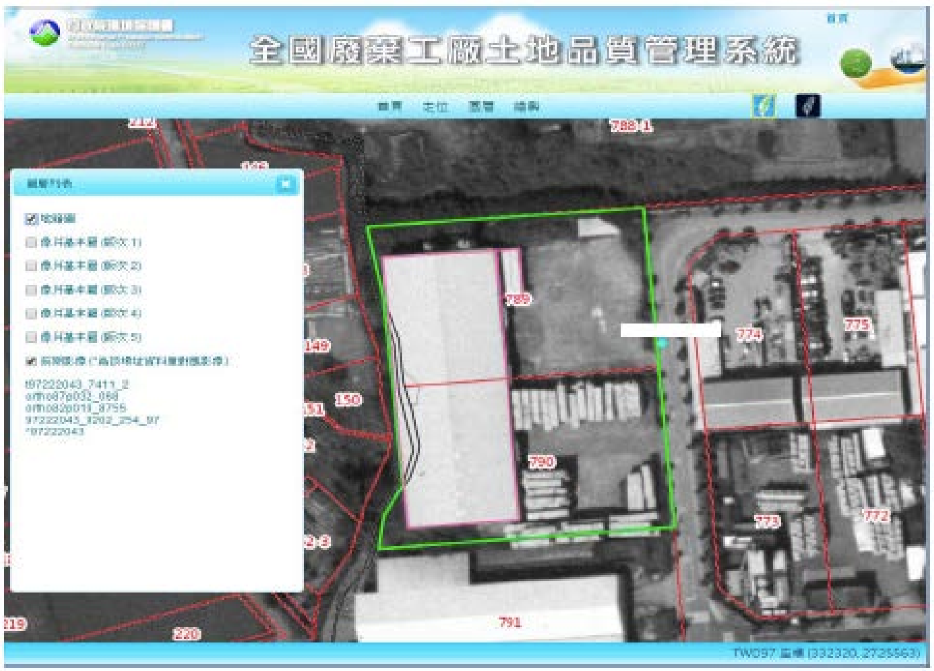
資料來源：環保署，環境風險整合與土地污染篩檢網建置計畫，2012 (TEPA 2013, p.4-20)

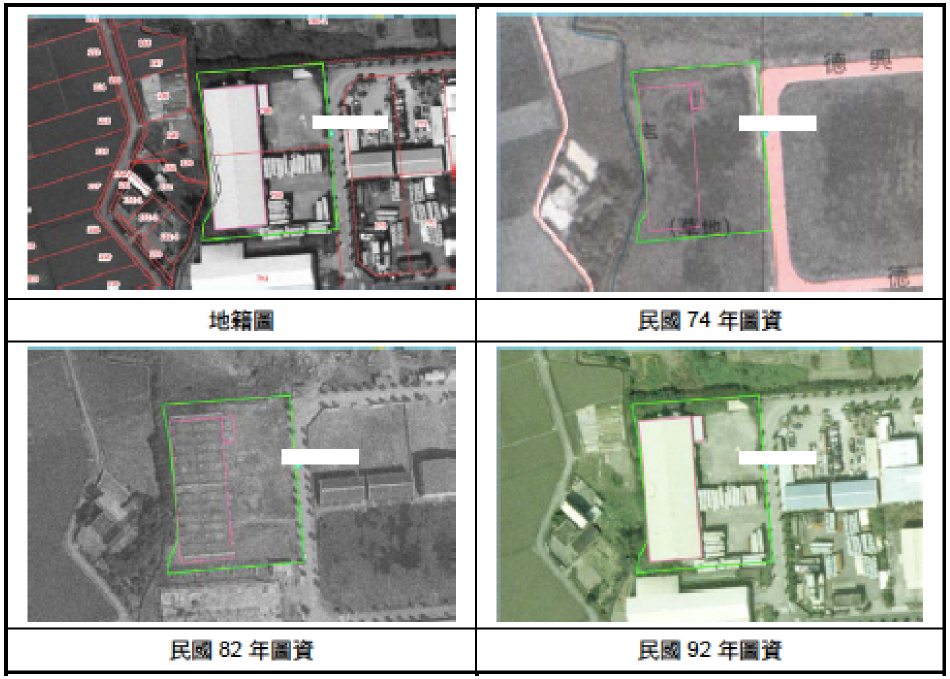
Environmental Risk Mapping of Brownfields



資料來源：環保署「環境風險整合與土地污染篩檢網建置計畫」 (TEPA, 2013, p. 4-169)

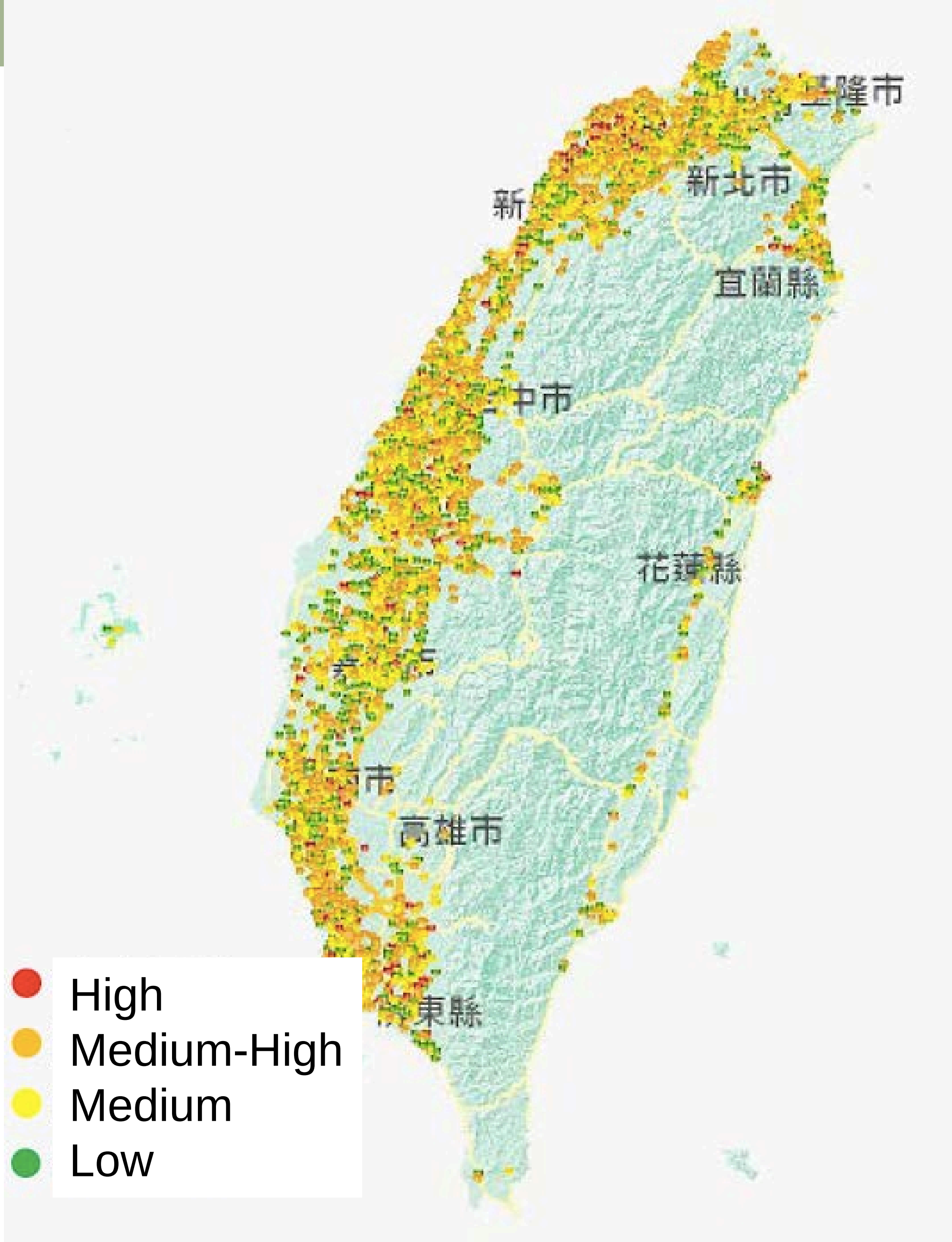
Developed Mapping Model by Taiwan EPA





(TEPA 2013)

Environmental Risk Maps Developed By Taiwan EPA



TEPA, 2013 (p.4-470)

Brownfield Regeneration Solution

Common Examples of Brownfields

- light-industrial factory sites
- gas stations in cities
- dry-cleaning stores
- manufactured gas plants
- metal-plating, electronics, pharmaceutical plants, chemical, automobile, tannery, textile…factories
- oil-tank farms, rail corridors
- municipal buildings with asbestos insulation
- municipal landfills and illegal dumping sites
- military reservation land, included house listed as industrial uses, munitions storage, firing ranges, and proving grounds

Hollander et. al., 2010

Approaching Brownfield Redevelopment

- ***STEP 1:***

  FIGURE OUT WHO WILL BE INVOLVED

- ***STEP 2:***

  CREATE A COMMUNITY OUTREACH PLAN

- ***STEP 3:***

  FIND RESOURCES AND SUPPORT SERVICES

Hollander et. al., 2010

Steps to a Brownfield Remediation

1. Initial Site Investigation
2. Comprehensive Site Assessment
3. Identification, Evaluation, and Selection of Comprehensive Remedial Action Alternatives
4. Implementation of Selected Remedial Action Alternative
5. Operation, Maintenance, and/or Monitoring of Comprehensive Response Actions

Hollander et. al., 2010

Phase I Initial Site Investigation

- street address of site
- topographic map
- number of workers on site
- residential population within a fixed radius
- uses of surrounding land
- institutions with 500 feet of site
- natural resources with 500 feet of site
- site records (included previous site operations)
- hazardous material usage records
- waste management
- environmental permits and site compliance
- site hydrogeological characteristics, including soil type (porosity and
- permeability)
- groundwater flow conditions
- nature and extent of contamination
- potential
- exposure ways

Hollander et. al., 2010

Phase II Comprehensive Site Assessment

- Advanced Analyze all Phase I data
- Decide on the environmental fate and transport
- Determine the nature and extent of contamination.
- Update the history of disposal of industrial waste materials on the site.
- Update assessment of hydrogeological characteristics. Assess exposure levels.
- Characterize risk.

Hollander et. al., 2010

Phase III: Identification, Evaluation, and Selection of Comprehensive Remedial Action Alternatives

- Planning alternatives
- Analysis of alternatives: bench-scale or pilot testing
- Selection of optimum remedial action alternative to implement on-site
- Preparation of a remedial action plan

Hollander et. al., 2010

Phase IV: Implementation of Selected Remedial Action Alternative

- Documentation of construction
- Implementation of remedial action plan and final inspection

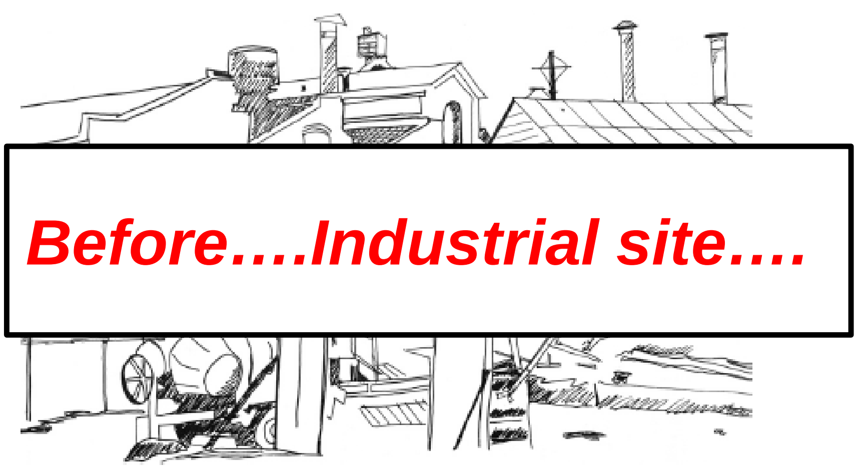
Hollander et. al., 2010

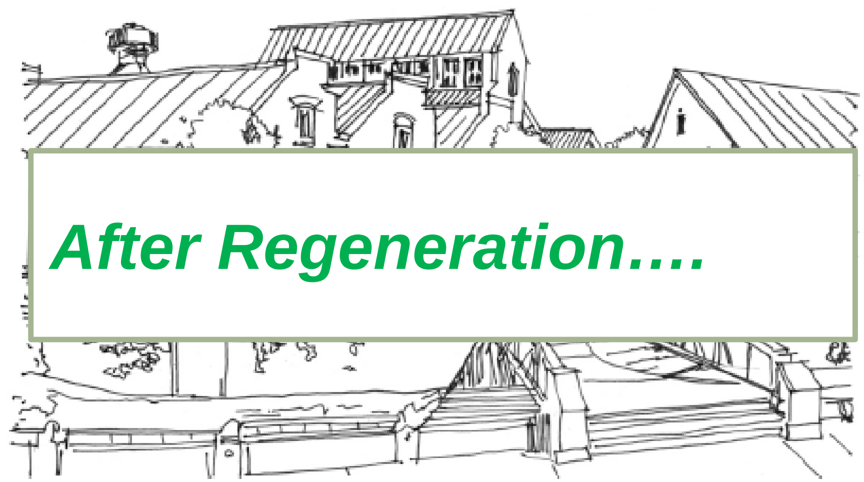
Phase V: Operation, Maintenance, and/or Monitoring of Comprehensive Response Actions

- Operations and Maintenance
- Performance monitoring
- “fine tuning” the ongoing long-term remediation, such as pump-and-treat installations.

Hollander et. al., 2010

Land Use and Design Considerations





(Hollander et. al., 2010, illustration by Luisa Oliveira)

WHAT ARE THE LAND USE AND DESIGN CONSIDERATIONS IN A BROWNFIELD PROJECT?

- Urban brownfield lands have appropriate ***"public infrastructure"*** such as: road and often rail access as well as public transport, power, communications, and sewerage.
- Also be considered to be extended to new IT businesses, educational facilities, and residences;
- Redeveloped need to have a new or reworked storm-water systems to capture rainwater before it leaves the site;

Hollander et. al., 2010

Three Indices of Brownfield Sites Redevelopment

Socio-economic

- population density
- property values
- reducing unemployment

Smart Growth

- accessibility

to utilities and transport,

- provision of employment opportunities and housing

Environmental

- source of potential contamination,
- soil permeability, proximity to water

bodies and parks and presence of wetland and floodplains

Design the evaluation Indices model for the brownfield redevelopment projects ought to base on the individual needs, but which it can be served as a preliminary screening tool. (Chrysochoou et.al., 2012; UWE Ed., 2013)

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THANK YOU FOR YOUR ATTENTION

YOUR QUESTIONS & COMMENTS ARE ALWAYS WELCOME

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International Workshop on Soil and Groundwater Remediation, 2016, Taipei, Taiwan

Exposure Assessment Involving the Fates of Pollutants and their Transferring through Food Webs in Soil and Sediment

Shian-chee Wu 吳先琪

National Taiwan University

Graduate Institute of Environmental Engineering

March 21-28, 2016

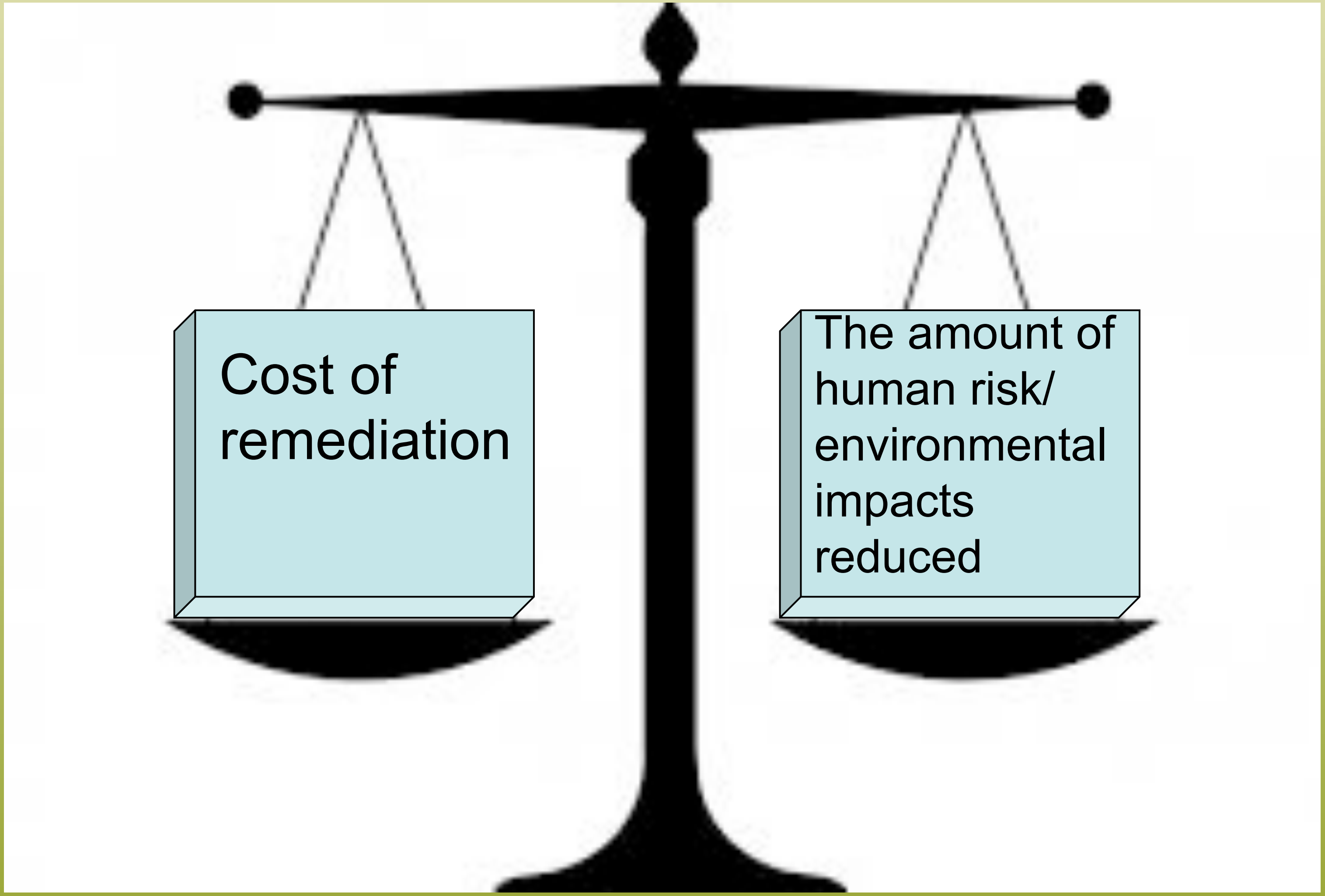
1. Save money and save lives by making right decision

- Are you going to apply the same remediation standard for these contaminated sites?

What choices do we have?

- No action
- Site management only
- Site remediation
  - In-situ vs excavation/off-site
  - Phytoremediation (slow) vs chemical injection (fast)
- Land use restriction
  - Prohibition of entry, etc.
  - Ban agricultural use, etc.

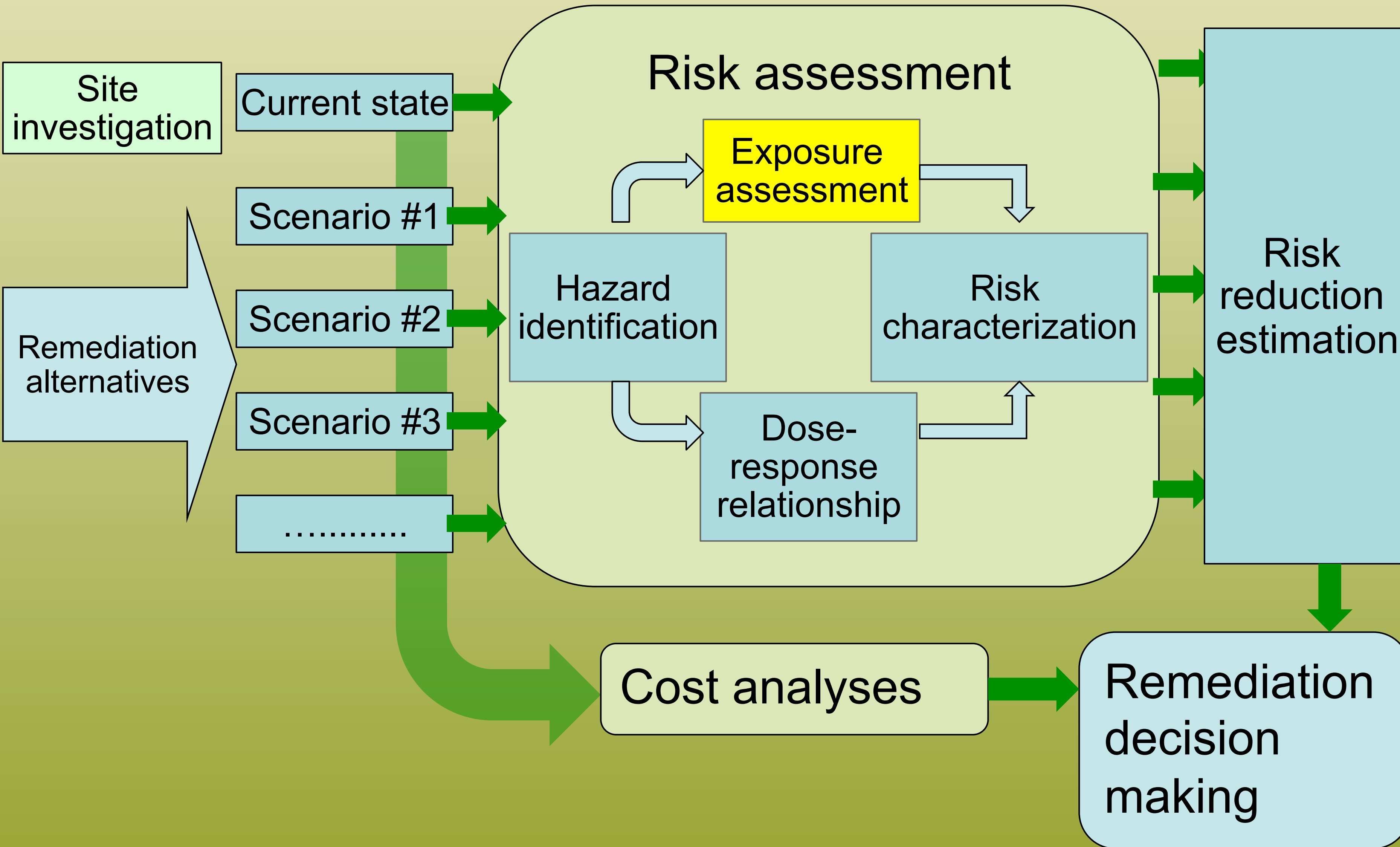
How to make a decision?



2. Risk assessment is the scientific basis of remediation decision-making

- Baseline risk assessment (to identify people under high risk and protect them)
- Setting remediation goals/clean-up standards
- Risk assessment for hypothetical scenarios of remediation alternatives

The role of exposure assessment in a risk-based decision making process



3. The elements in an exposure pathway

Human behavior

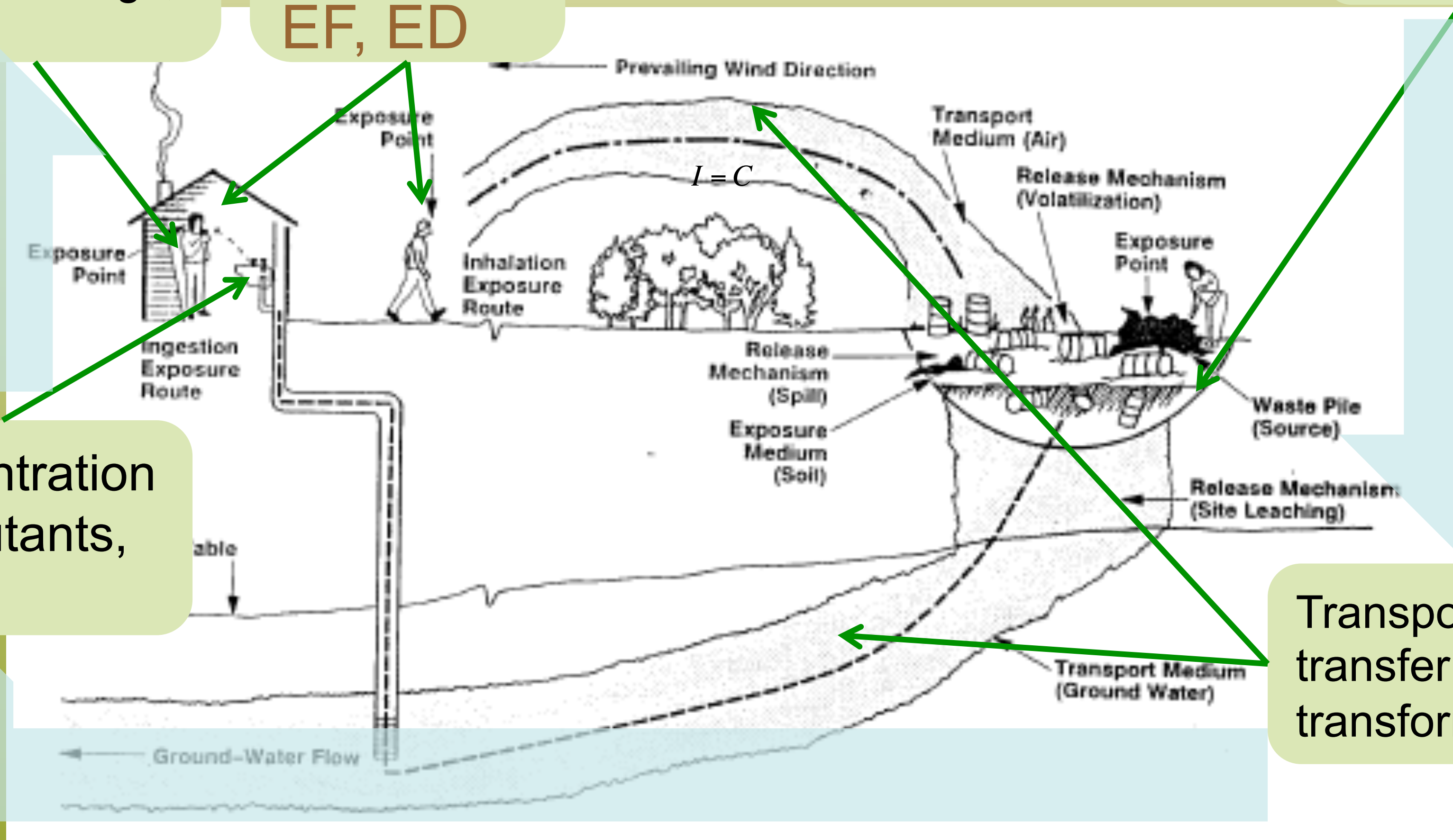
Scenario #1

Intake rate (expose) by human beings, IR

exposure duration and frequency EF, ED

$$I = C \times \frac{IR \times EF \times ED}{BW} \times \frac{1}{AT}$$

source of pollutants



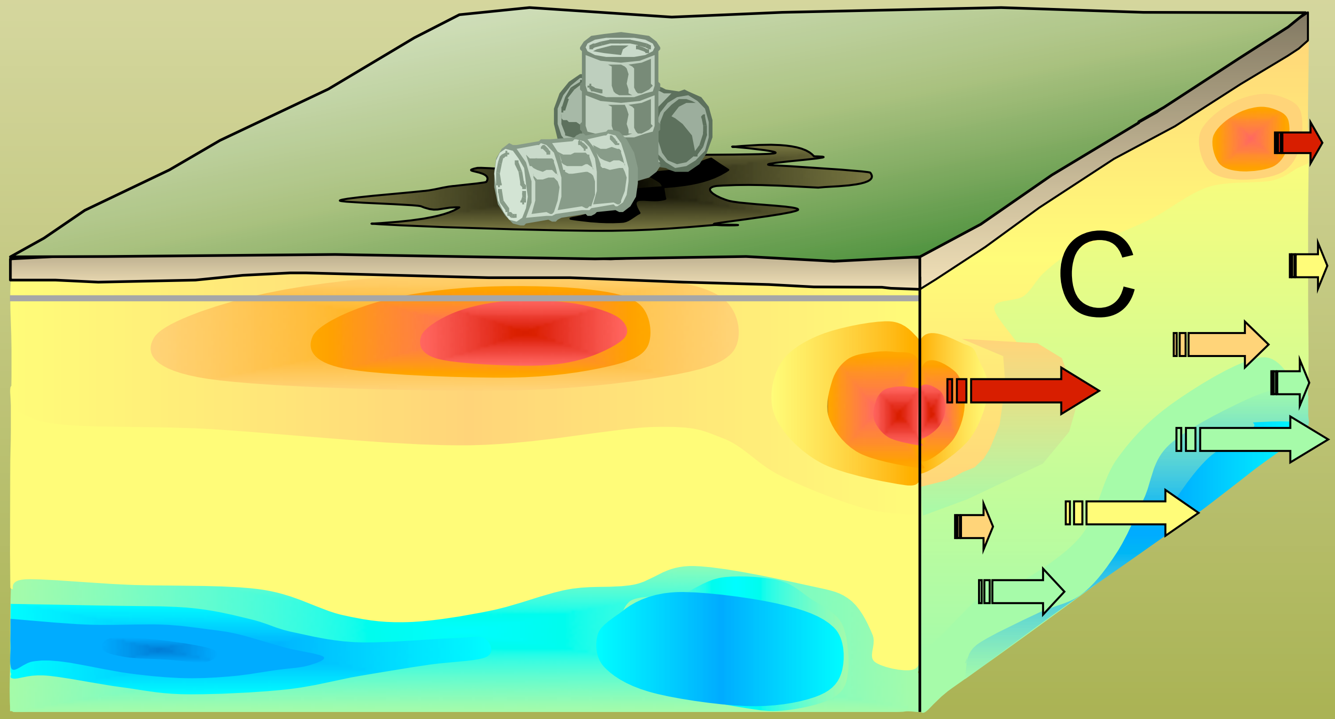
Concentration of pollutants, C

Transport, transfer and transformation

$$I = C \times \frac{IR \times EF \times ED}{BW} \times \frac{1}{AT}$$

- I = exposure factor (mg/Kg-BW/day)
- C = the concentration of the pollutant (mg/L)
- IR = intake rate (L/day)
- EF = exposure frequency (day/year)
- ED = exposure duration (year)
- BW = body weight (Kg)
- AT = average time (year) (lifetime for cancer risk)

4. How to estimate the concentration, C



4.1. Transport of contaminants

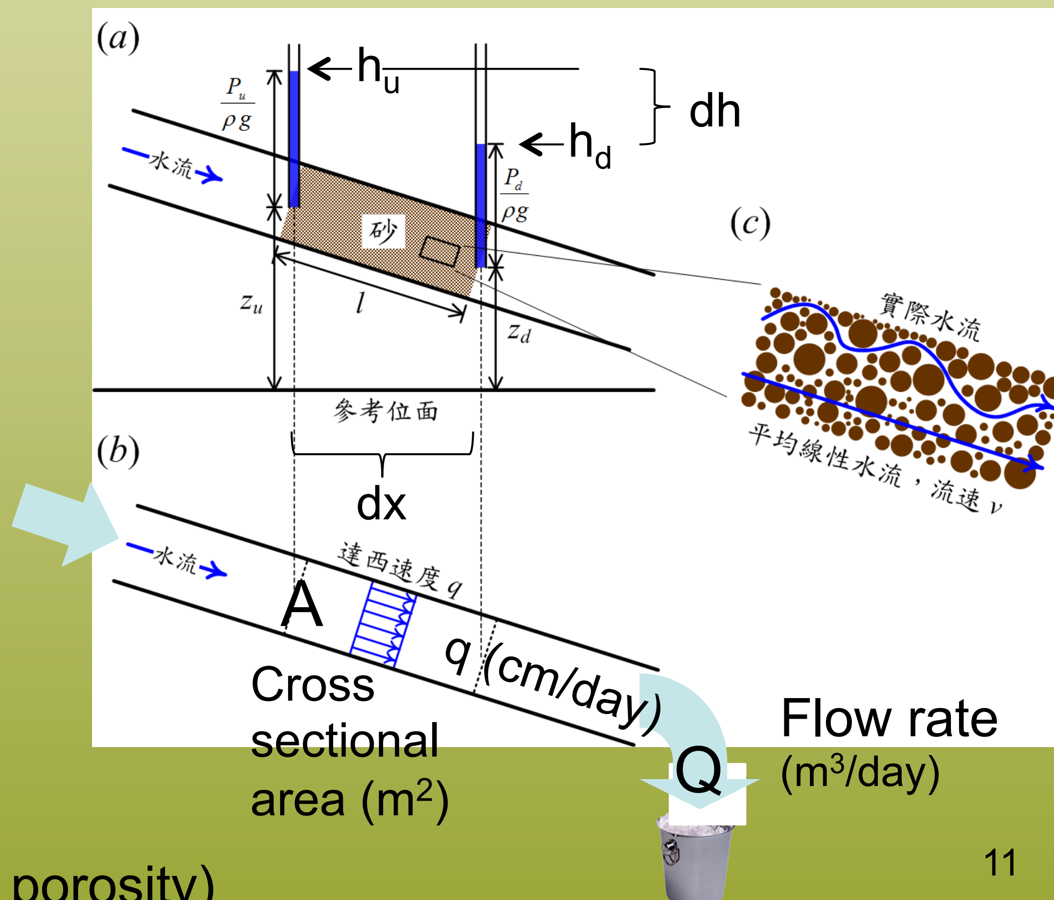
- How fast the contaminants move?
  - The contaminants move as fast as the carrying fluids (air, groundwater) as long as there is no adsorption by soils and no diffusion/dispersion
- Then, how fast the fluids move?

4.1.1. Movement by advection

- 4.1.1.1. Linear velocity of water in groundwater aquifer
- Darcy's Law
  - Darcy velocity

    $q = Q/A = - K\, dh/dx$ (m/d)
  - h = water head (m)
  - x = distance (m)
  - K = Hydraulic conductivity (m/d)

  – Linear velocity
  - $v_x = q/n$ (m/d) (n = porosity)



How to estimate K

- Hydraulic conductivity, K, is function of soil type, texture, moisture content (in unsaturated zone) and (maybe) direction.
- Very often you have to measure it in lab with soil columns or in the field by pumping test or slug test.

TABLE 3-1 Representative Hydraulic Conductivity Estimates for Several Types of Porous Media[a]

Unweathered marine clay
Glacial till
Silt, loess
Silty sand
Clean sand
Gravel

K (cm/sec)	10^{-10}	10^{-9}	10^{-8}	10^{-7}	10^{-6}	10^{-5}	10^{-4}	10^{-3}	10^{-2}	10^{-1}	1	10	10^{2}
K (gal/day/ft^2)	10^{-6}	10^{-5}	10^{-4}	10^{-3}	10^{-2}	10^{-1}	1	10	10^{2}	10^{3}	10^{4}	10^{5}	10^{6}

[a]Adapted from Freeze and Cherry (1979).

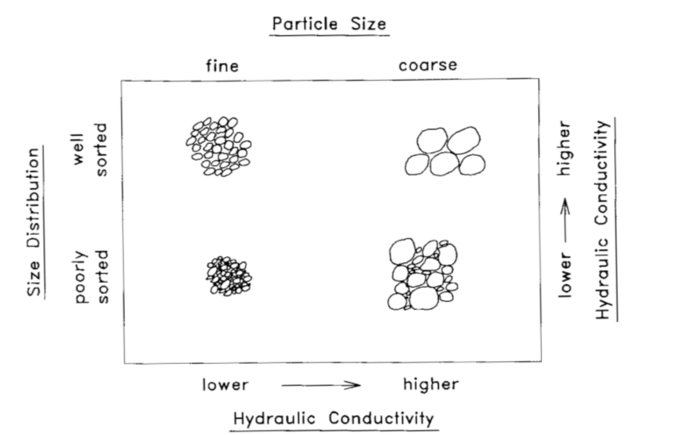


FIGURE 3-3 Particle size, size distribution, and hydraulic conductivity in soil. *Well-sorted* means that all the particles are similar in size, giving the soil a relatively high hydraulic conductivity compared to an otherwise similar but *poorly sorted* soil in which small soil particles block the pore spaces between larger particles, thereby decreasing the hydraulic conductivity of the soil.

Simplified example for calculate the travelling time, t

- A groundwater well has just been contaminated with a chemical and has a water level of 30 m above sea lever (asl). If there is no decay of the chemical in the aquifer, no dispersion and only one direction for the flow, when will the chemical plume reach another well 100 m down stream with a water level of 25 m asl? (K is 10^{-2} cm/s, soil porosity is 0.4 cm^3/cm^3).
- Answer:
  - Darcy velocity: q = 10^{-2} cm/s x (30-25)m/100 m = 0.5 x 10^{-3} $cm^3/cm^2/s$,
  - Linear velocity: v_x = 1.25 x 10^{-3} cm/s,
  - Travelling time: t = 8000000 seconds = 93 days

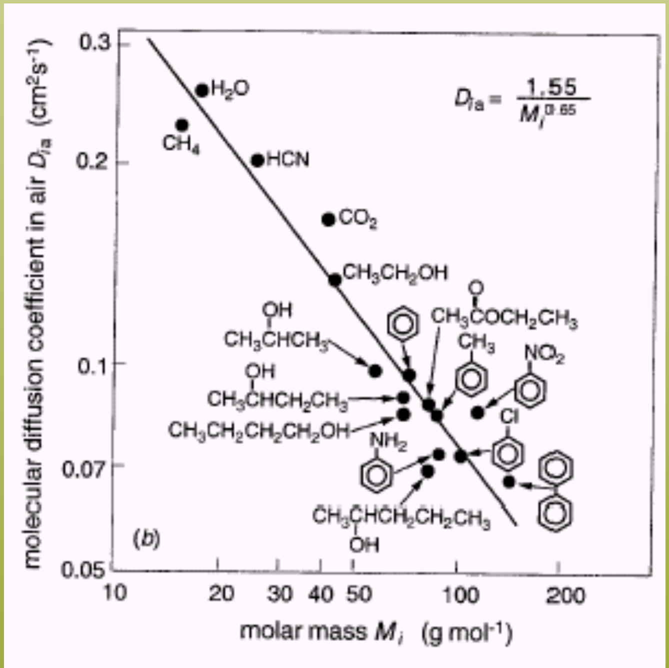
- 4.1.1.2. Mass transported by advection
  - Flux $f_x = v_x n C$ ($g/m^2/d$)
    - n = porosity
    - C = concentration (g/m^3)

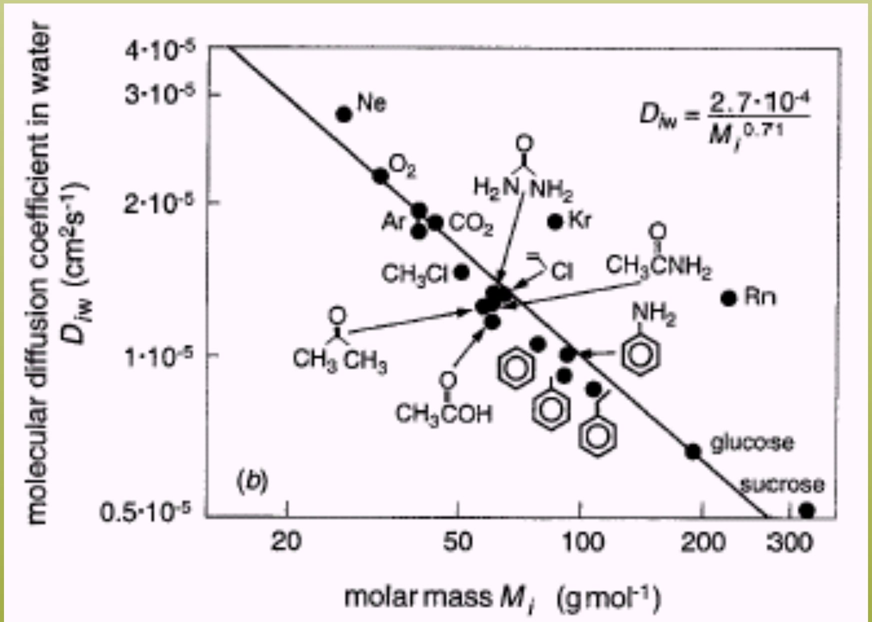
4.1.2. Diffusion and dispersion

- Mass transported by diffusion and dispersion
  - Diffusion/dispersion flux in x direction
  - $f_x = -n\ D_d\ (dC/dx) - n\ D_x\ (dC/dx)$
  - Diffusion/dispersion flux in y direction
  - $f_y = -n\ D_d\ (dC/dy) - n\ D_y\ (dC/dy)$
    - D_d = molecular diffusion coefficient
    - D_x, D_y = dispersion coefficient, which is related to v_x, v_y
  - Longitudinal dispersivity, $a_x = D_x/v_x$
  - Transverse dispersivity, $a_y = D_y/v_y$

How to estimate molecular diffusion coefficient and dispersion coefficient?

- molecular diffusion coefficients
  - You may check some reference book for the molecular diffusion coefficients in air (~ 10^{-1} cm^2/s) and in water (~ 10^{-6} cm^2/s)





(e.g. Schwarzenbach et al.,2003, Environmental Organic Chemistry)

- dispersion coefficients
  - are function of soil structure and fluid velocity
  - You have to do tracer test in the field or estimate from the dispersivity, which is function of soil structure and site scale
    - Longitudinal dispersivity, $a_x = D_x/v_x$,
    - $D_x = v_x \cdot a_x$
    - Transverse dispersivity, $a_y = D_y/v_y$
    - $D = v_y \cdot a_y$

4.1.3. The change of concentration with time

$$-\frac{\partial C}{\partial t} = \frac{\partial}{\partial x}\left(f_{x,adv} + f_{x,dis}\right) + \frac{\rho_b}{n}\frac{dS}{dt} \pm kC$$

For 1-D problem

$$\frac{\partial C}{\partial t} = \frac{\partial}{\partial x}\left(D_x \frac{\partial C}{\partial x}\right) - \frac{\partial}{\partial x}\left(vC\right) - \frac{\rho_b}{n}\frac{dS}{dt} \mp kC$$

- ρ_b = bulk density of soil (g/cm^3)
- n = porosity (cm^3/cm^3)
- S = adsorbed concentration in solid (mg/g)
- k = degradation or reaction rate constants (1/d)

4.1.4. With adsorption and reactions

- Retardation of the transport by sorption
- Adsorption effects

Freudlich isotherm: $S = K_d C^b$

Linear isotherm $S = K_d C$, if $b = 1$

- S = adsorbed concentration (mg/g)
- C = aqueous concentration (mg/cm^3)
- K_d = distribution coefficient (cm^3/g)
- b = constant

1-D example

- If there is no difference of concentration in y direction and z direction (i.e. 1-dimension problem)
- If the adsorption follows linear isotherm ($S = K_d C$)
- If all parameters are constant with time and place

$$\frac{\partial C}{\partial t} = \frac{\partial}{\partial x}\left(D_x \frac{\partial C}{\partial x} \right) - \frac{\partial}{\partial x}\left(vC \right) - \frac{\rho_b}{n} \frac{dK_d C}{dt} \mp kC$$

$$\frac{\partial C}{\partial t} = \frac{D_x}{R} \frac{\partial^2 C}{\partial x^2} - \frac{v}{R} \frac{\partial C}{\partial x} \mp k'C$$

All transport processes are retarded by a factor of R

$$R = 1 + \frac{\rho_b}{n} K_d$$

Retardation factor

How to solve the equation to get the value of concentration at any time and place?

Transport of a Conservative Substance from Impulse and Continuous Sources

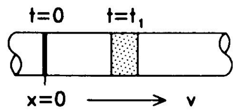
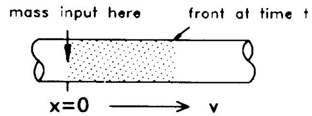
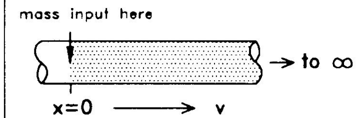
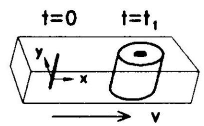
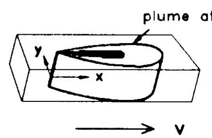
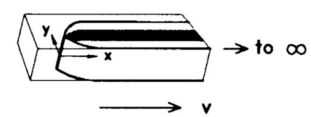
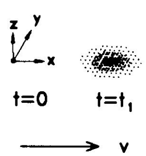
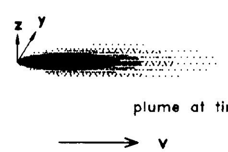
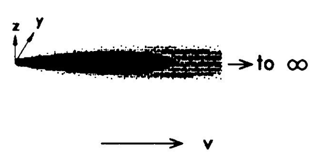
<table>
<tr><th>Dimensions</th><th>Pulse input of mass M</th><th>Continuous input of mass per unit time $\dot{M}$ starting at time t=0</th><th>Continuous input of mass per unit time $\dot{M}$ in steady state</th></tr>
<tr><td>1−D
$M, \dot{M}$ are instantaneous or continuous plane sources
$M \left[\frac{M}{L^2}\right]$
$\dot{M} \left[\frac{M}{L^2 T}\right]$</td>
<td>$C = \frac{M}{2n\pi^{1/2} t^{1/2} \sqrt{D_x}} \exp-\left[\frac{(x-vt)^2}{4D_x t}\right]$

Hunt, 1978</td>
<td>$C = \frac{\dot{M}}{2nv} \operatorname{erfc}\left(\frac{x-vt}{2\sqrt{D_x t}}\right)$

Hunt, 1978</td>
<td>$C = \frac{\dot{M}}{nv}$ (for $x > 0$)
</td></tr>
<tr><td>2−D
$M, \dot{M}$ are instantaneous or continuous line sources
$M \left[\frac{M}{L}\right]$
$\dot{M} \left[\frac{M}{L \cdot T}\right]$</td>
<td>$C = \frac{M}{4n\pi t\sqrt{D_x D_y}} \exp-\left[\frac{(x-vt)^2}{4D_x t} + \frac{y^2}{4D_y t}\right]$

Wilson and Miller, 1978</td>
<td>$C = \frac{\dot{M}}{4n\pi^{1/2} (vr)^{1/2} \sqrt{D_y}} \exp\left[\frac{(x-r)v}{2D_x}\right] \operatorname{erfc}\left(\frac{r-vt}{2\sqrt{D_x t}}\right)$

Wilson and Miller, 1978</td>
<td>$C = \frac{\dot{M}}{2n\pi^{1/2} (vr)^{1/2} \sqrt{D_y}} \exp\left[\frac{(x-r)v}{2D_x}\right]$

Wilson and Miller, 1978</td></tr>
<tr><td>3−D
$M, \dot{M}$ are instantaneous or continuous point sources
M [M]
$\dot{M} \left[\frac{M}{T}\right]$</td>
<td>$C = \frac{M}{8n\pi^{3/2} t^{3/2} \sqrt{D_x D_y D_z}} \cdot \exp-\left[\frac{(x-vt)^2}{4D_x t} + \frac{y^2}{4D_y t} + \frac{z^2}{4D_z t}\right]$

Hunt, 1978</td>
<td>$C = \frac{\dot{M}}{8n\pi r\sqrt{D_y D_z}} \exp\left[\frac{(x-r)v}{2D_x}\right] \operatorname{erfc}\left(\frac{r-vt}{2\sqrt{D_x t}}\right)$

Hunt, 1978</td>
<td>$C = \frac{\dot{M}}{4n\pi r\sqrt{D_y D_z}} \exp\left[\frac{(x-r)v}{2D_x}\right]$

Hunt, 1978</td></tr>
</table>

TABLE 3-4 The Complementary Error Function

x	erfc(x)	x	erfc(x)
0	1.0		
0.05	0.943628	1.1	0.119795
0.1	0.887537	1.2	0.089686
0.15	0.832004	1.3	0.065992
0.2	0.777297	1.4	0.047715
0.25	0.723674	1.5	0.033895
0.3	0.671373	1.6	0.023652
0.35	0.620618	1.7	0.016210
0.4	0.571608	1.8	0.010909
0.45	0.524518	1.9	0.007210
0.5	0.479500	2.0	0.004678
0.55	0.436677	2.1	0.002979
0.6	0.396144	2.2	0.001863
0.65	0.357971	2.3	0.001143
0.7	0.322199	2.4	0.000689
0.75	0.288844	2.5	0.000407
0.8	0.257899	2.6	0.000236
0.85	0.229332	2.7	0.000134
0.9	0.203092	2.8	0.000075
0.95	0.179109	2.9	0.000041
1.0	0.157299	3.0	0.000022

$\mathrm{Erfc}(x) = 1 - (2/\sqrt{\pi})\int_0^x e^{-\epsilon^2}\, d\epsilon$

$\mathrm{Erfc}(-x) = 2 - \mathrm{erfc}(x)$

[a]Adapted from Freeze and Cherry (1979).

FIGURE 3-19 Solutions to the advection–dispersion equation (Eq. [1-5]) for a conservative solute. Cases for continuous input of mass at time $t = 0$ are adapted from references cited, assuming x and/or r are much larger than D/v; r equals $(x^2 + y^2 D_x / D_y)^{1/2}$ in two dimensions or $(x^2 + y^2 D_x / D_y + z^2 D_x / D_z)^{1/2}$ in three dimensions. Note that the definitions of M and $\dot{M}$ vary with the number of dimensions.

Hemond and Fechner, 2000

Example of transport of a conservative substance by using Excel

Example 1 2-D Pulse Input of Mass

parameters	Mass	porosity (n)	dispersion coefficient, Dx	dispersion coefficient, Dy	linear velocity in x	π
	1	0.3	1.00E-02	1.00E-03	0.1	3.1416
	(g/m)	unitless	(m2/day)	(m2/day)	(m/d)	
symbal	M	n	Dx	Dy	v	pi

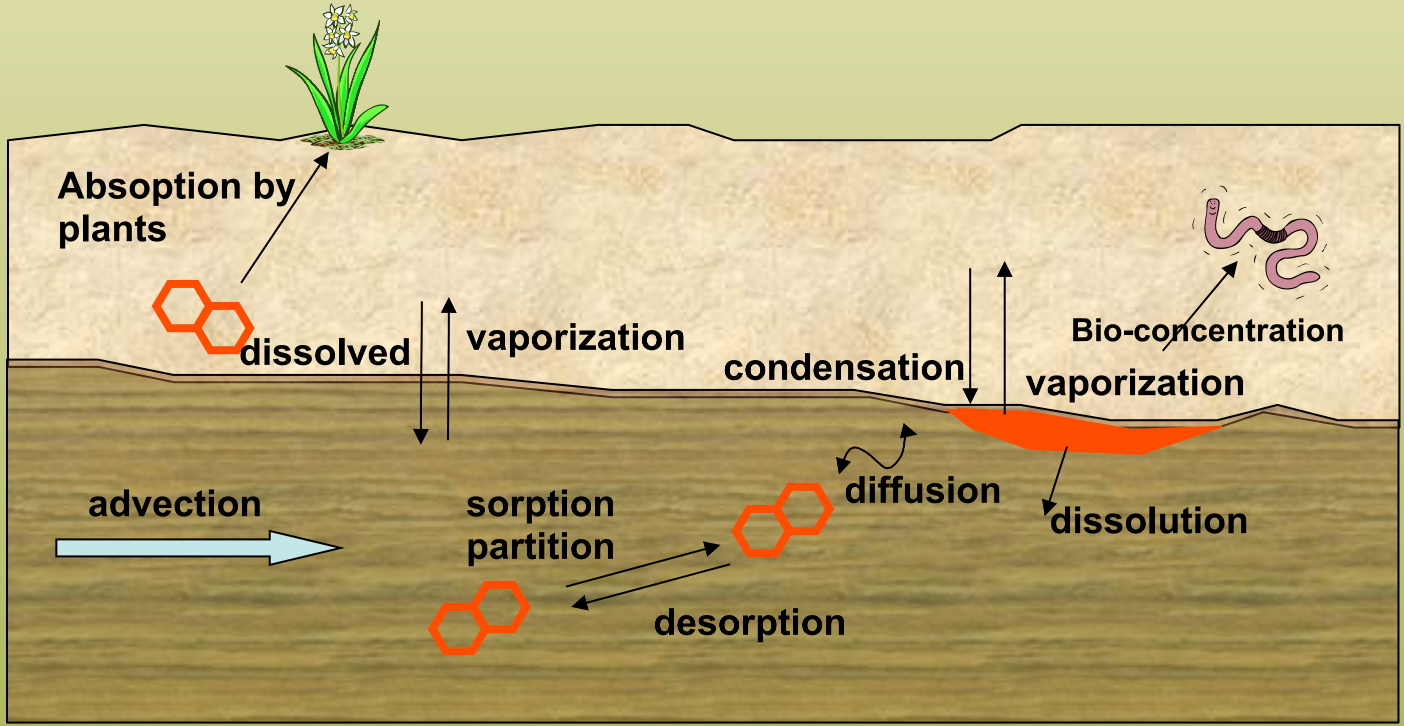
Time:	1

distance in x direction (m)

distance in y direction (m)		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
distance in	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
y direction	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(m)	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	1.7437E-107	3.5941E-116	1.4288E-146	1.0956E-198	1.6202E-272	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	65.327383	1.3465E-07	5.35293E-38	4.10444E-90	6.07E-164	1.7314E-259	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-1	1.7437E-107	3.5941E-116	1.4288E-146	1.0956E-198	1.6202E-272	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

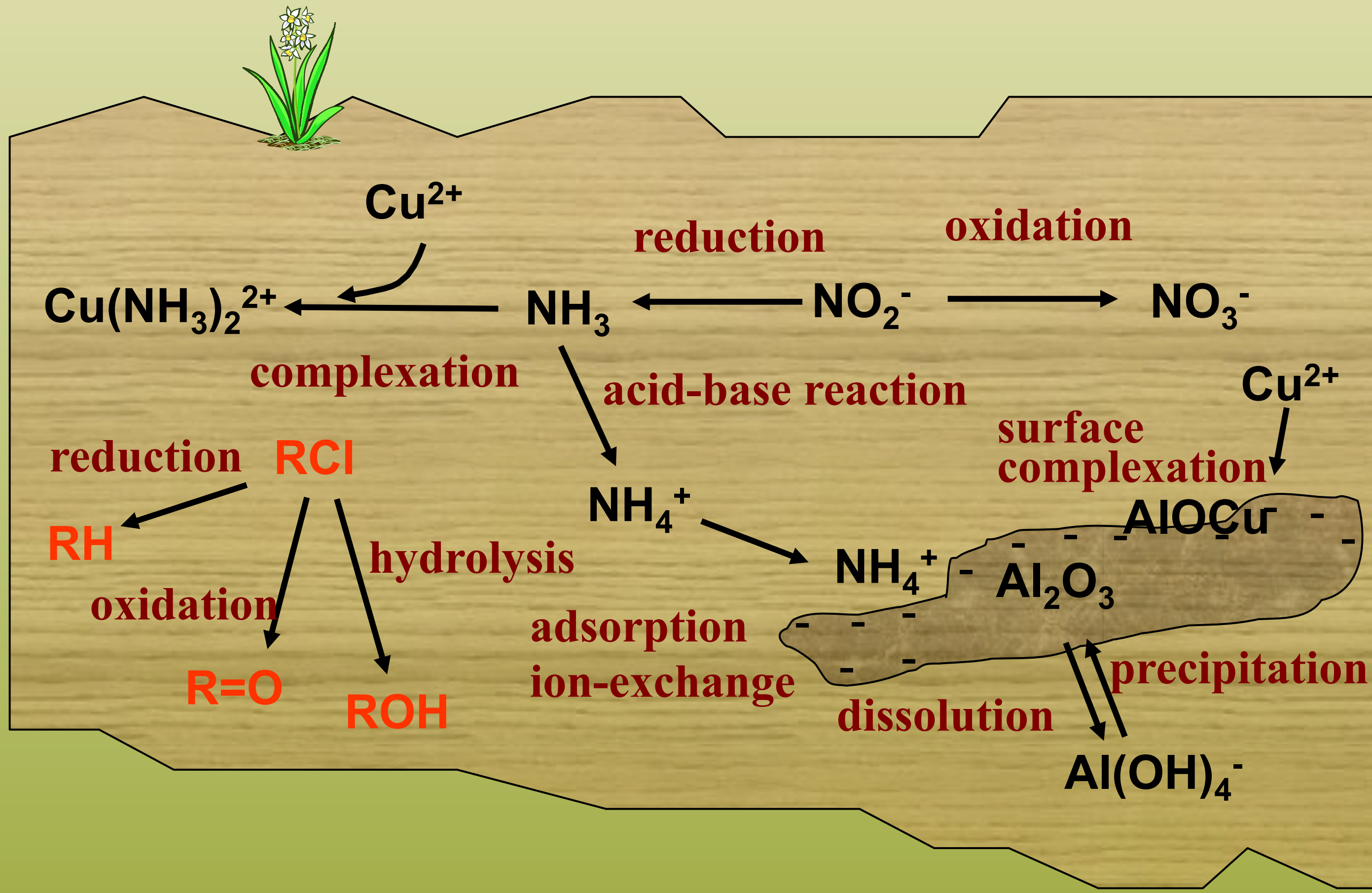
distance in y direction (m)		20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
distance in	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
y direction	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(m)	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

4.2. Transfer of pollutants among phases



- The transferring direction depends on the distribution coefficient, partition coeff., Henry's law constant, etc.
- The mass transfer rate depends on the boundary layer thickness and the diffusivity of the pollutant

4.3. Transformation processes



Chemical processes

- inorganic
  - acid/base reaction
  - dissolution/precipitation
  - oxidation/reduction
  - surface reaction: adsorption, complexation,
- organic
  - hydrolysis
  - oxidation/reduction
- first-order approach
  - Disappearing rate = $d[C]/dt = - k [C][A]^a[B]^b\ldots$

    $= - k' [C]$ if [A] , [B], … are all constant

Biological processes

- biodegradation: aerobic, anaerobic
  - Microorganisms are catalyst

  first-order approach

  Disappearing rate = $d[C]/dt = - k_{bio} [C][D]^a[E]^b$

  $= - k'_{bio} [C]$ if [D] , [E], are all constant
- bioaccumulation

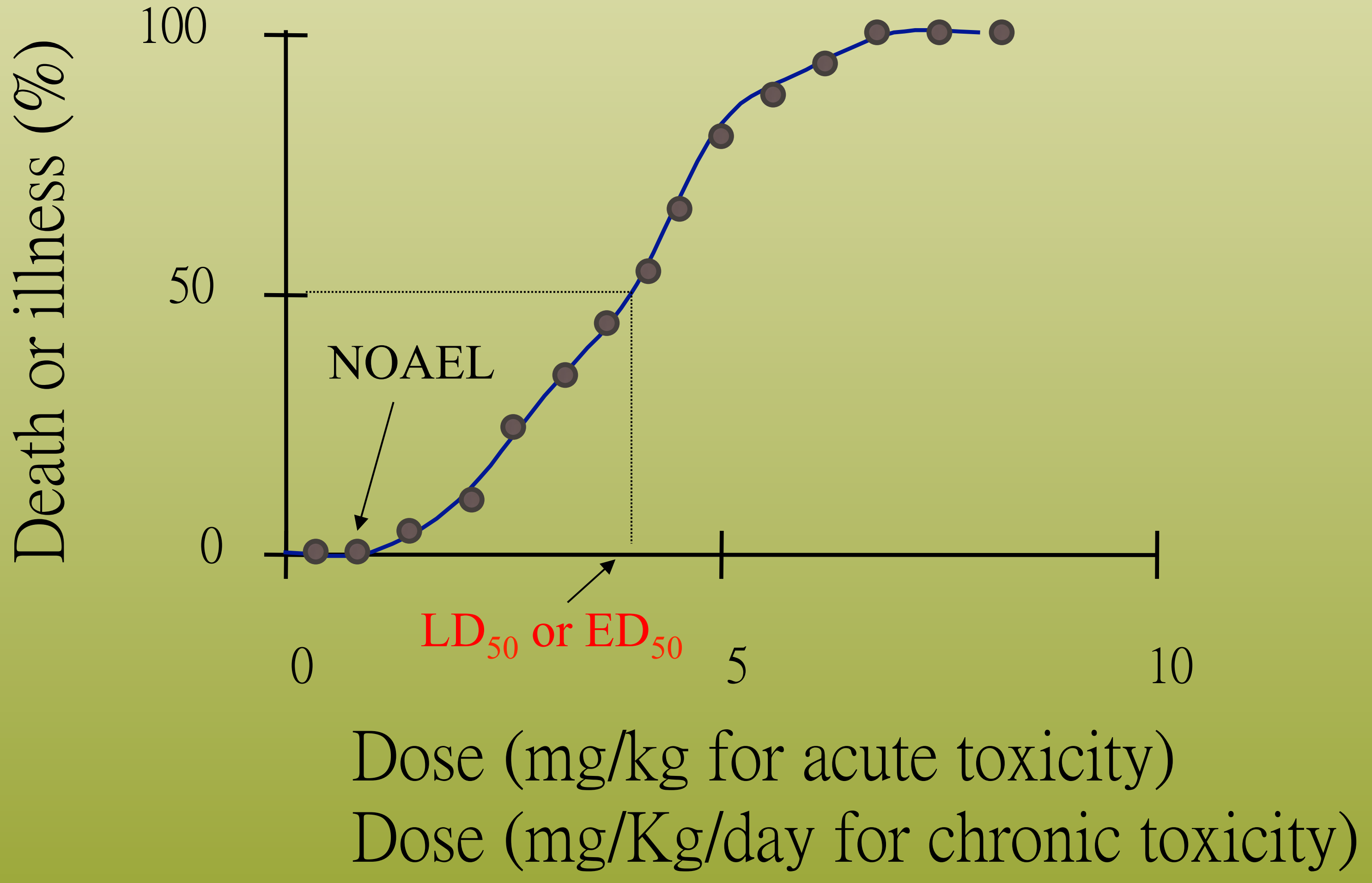
5. Dose-response relationship

- Health risk of toxic substance

5.1. Non-carcinogenic substances

- Acute toxicity
  - Quantified with the Lethal dose (LD_{50}) or Effective dose (ED_{50}) of a chemical
- Chronic toxicity
  - Quantified with non-observable adverse effect level (NOAEL)
- Uncertainty factors (UF) are added to obtain ADI

Dose-response relationship for non-carcinogenic acute toxicity and chronic toxicity



- Lethal Dose-50% (LD_{50})
  - "The amount of the substance required (usually per body weight) to kill 50% of the test population"
    - Wikipedia- http://simple.wikipedia.org/wiki/LD50
- Effective Dose-50% (ED_{50})
  - Amount of a substance required to produce a specific effect in half of an animal population comprising a test sample.
    - businessdictionary.com - http://www.businessdictionary.com/definition/effective-dose-50-ED50.html

NOAEL and RfD

- NOAEL：No-Observable-Adverse Effective Level (mg/Kg-bw/day)。
- CDI: chronic daily intake

  CDI = chronic uptake rate x C/BW

  (mg/kg-bw/day)
- RfD: Reference Dose (the dose that will not make harm to the human)

$$RfD = \frac{NOAEL}{UF}$$

Factors providing UF and the values of UFs

TABLE 3. Range of Values Generally Adopted for the Inter- and Intraspecies Variation UFs by the Jurisdictions Under Review

UFs	Canada WQHB	U.S. EPA	WHO	Australia
Interspecies variation	1–10	1–10	1–10	10
Intraspecies variation	1–10	1–10	1–10	10

TABLE 4. Additional UFs Used by the Jurisdictions Under Review When Deriving Drinking-Water Limits

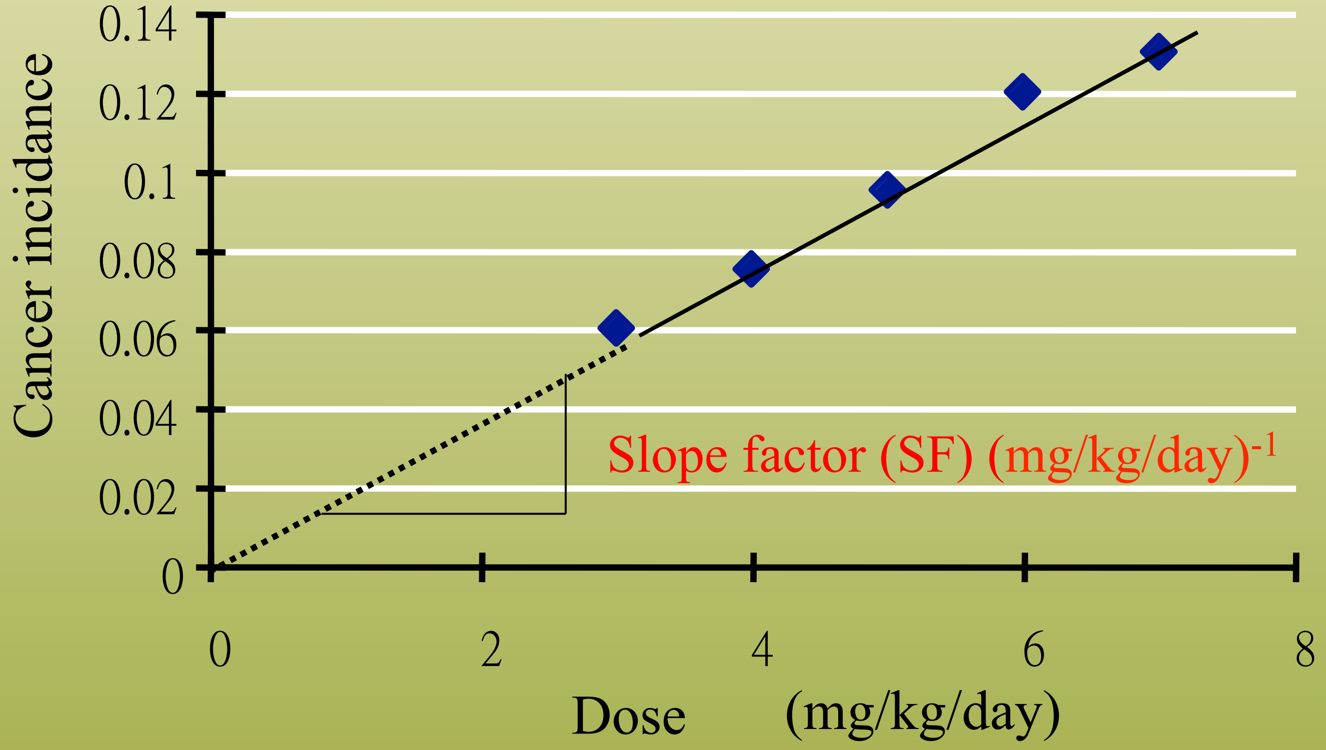
UFs	Canada WQHB	U.S. EPA	WHO	Australia
Database/studies deficiency	1–10	1–10	1–10	
LOAEL instead of NOAEL	1–10	1–10		1–10
Subchronic to chronic extrapolation		1–10		10
Nature and severity of effect	1–10		1–10	
Potential interaction with other chemicals	1–5			
Carcinogenic compounds acting only above a threshold	1–10	1–10	1–10	10
Modifying factors	1–10	1–10		

Ritter et al. J of Toxicology and Environmental Health, Part B, 10(7), 2007.

5.2. Carcinogenic substances

- Cancer risk
  - No threshold
  - Usually by extrapolation from animal to human, high dosage to low dosage
  - Acceptable risk, $10^{-6} \sim 10^{-4}$
- Quantified by cancer slope factor (SF) or cancer potency

Dose-response relationship for carcinogenic toxicity



Dotted line is the extrapolation from test results

6. Risk characterization

- 6.1. For non-carcinogenic contaminants

  Hazardous Quotient, HQ

  HQ = CDI/RfD

  Acceptable risk: HQ < 1

6.2. For carcinogen

- Example: Risk from drinking contaminated groundwater

$$\text{Cancer risk} = \frac{\text{IR (L/day)} \times \text{C (mg/L)} \times \text{SF (mg/kg/day)}^{-1} \times \text{EF} \times \text{ED}}{\text{BW (Kg)} \times \text{AT}}$$

$$= \text{I} \times \text{SF}$$

- Example: What will be the allowable maximum contaminant level in groundwater (clean-up goal)

$$\text{Clean-up goal (mg/L)} = \frac{\text{Allowable risk } (10^{-6}) \times 70 \text{ (kg)}}{2 \text{ (L/day)} \times \text{SF (mg/kg/day)}^{-1}}$$

- Hazardous Quotient, HQ

  $$HQ = CDI/RfD$$

- Acceptable risk: $HQ < 1$

7. Intake of pollutants from agricultural products

- We want to know the human health risk due to intake agricultural products (the intake factors)
- The exposure factor from intake:
- $Intake_{food} = \sum_i [C_i \times IR_i] \times ED \times EF /(BW \times AT)]$
- We need to estimate the values of C_i, IR_i, ED and EF

7.1. Predicting the concentration of pollutants in vegetables and animals, C_i, from the concentrations in soil

- 7.1.1. Vegetables belowground

$$C_{bg} = Pr_{bg} = \frac{C_{soil} * RCF * VG_{bg}}{Kd_s}$$

C_{bg}: conc. of pollutant in vegetables below ground, mg/kg

Pr_{bg}: concentration in below-ground vegetable due to root uptake, mg/kg

C_{soil}: soil concentration, mg/kg

RCF: root concentration factor (= C_{root}/C_{water}), cm^3/g

VG_{bg}: empirical correction factor for root crops, unitless

Kd_s: soil-water partition coefficient (= C_{soil}/C_{water}), cm^3/g

- 7.1.2. Vegetables aboveground

$$C_{ag} = C_{soil} \times Br$$

C_{ag} : total concentration of aboveground vegetable

C_{soil} : soil concentration

Br : plant-soil bioconcentration factor for aboveground vegetable

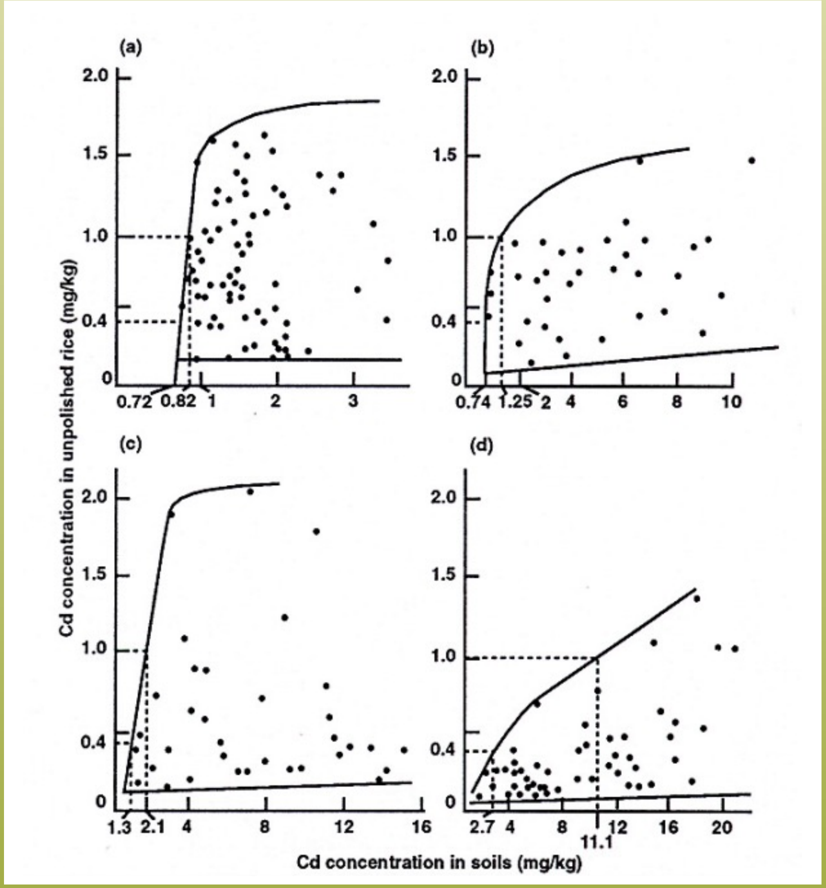
- 7.1.3. Animal tissues

$$C_{animal} = \left(\sum_i F_i * Qp_i * Pr_i + Q_{soil} * C_{soil} * Bs\right)_{animal} * Ba_{animal}$$

- C_{animal} : Concentration of animal tissue, mg/kg
- F_i : fraction of plant grown on contaminated soil and eaten by the animal, unitless
- Qp_i : quantity of plant type i ingested by the animal, kg/d
- Pr_i : concentration of the plant type i due to root uptake
- Q_{soil} : quantity soil eaten by the animal, kg-soil/d
- Bs : soil bioavailability factor, unitless
- C_{soil} : soil concentration, mg/kg
- Ba_{animal} : biotransfer factor for animal, day/kg

How to obtain the plant-soil bioconcentration factor, Br

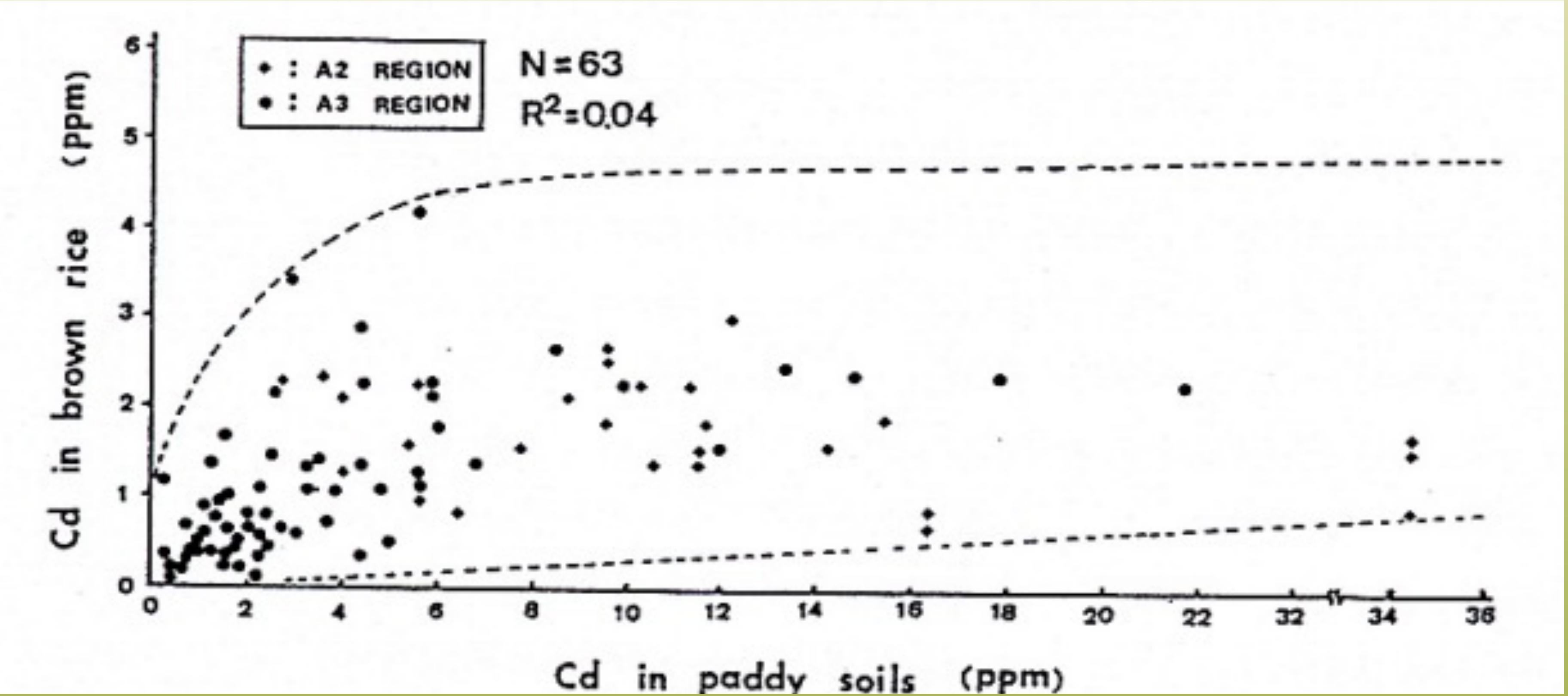
- 1. The type of soils matters



The relationship between Cd concentration in brown rice and its concentration in soils in four different Japanese counties: (a)Fuchu、(b)Kurobe、(c)Annaka及 (d)Bandai (Morishita, 1975)

EPA, ROC, 2003, The Investigation of Regulation of Heavy Metals in Contaminated Soils, EPA-91-H103-02-150 , National Taiwan University, Department of Agricultural Chemistry

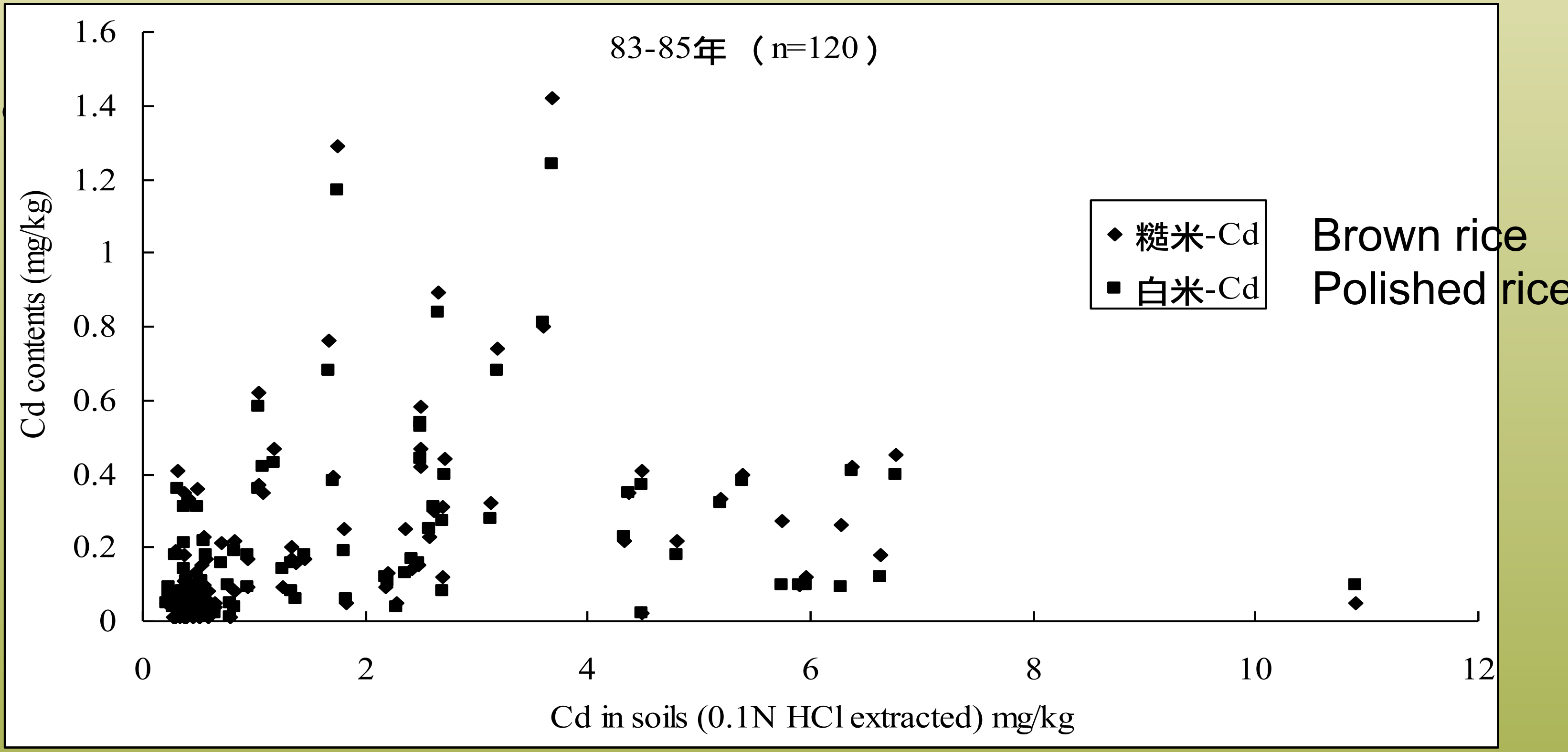
- Higher Cd conc. in polluted soils but no correlation with conc. in soils



The relationship between Cd concentration in brown rice and its concentration in soils (Chen, 1991)

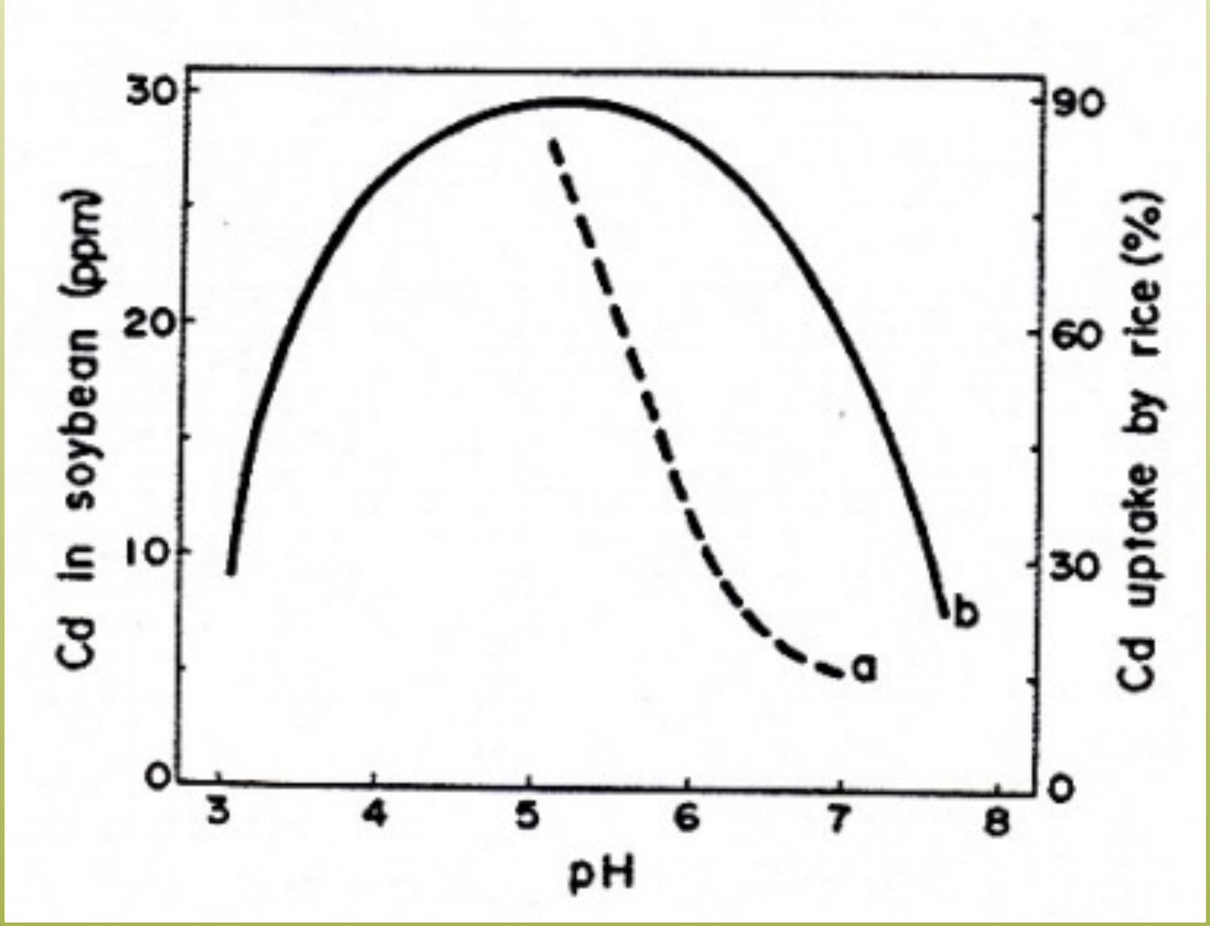
EPA, ROC, 2003, The Investigation of Regulation of Heavy Metals in Contaminated Soils, EPA-91-H103-02-150 , National Taiwan University, Department of Agricultural Chemistry

Bio-available Cd in soil vs Cd in rice grains and brown rice



83-85年(六期作)水稻之白米與糙米中鎘含量與土壤中鎘含量(0.1N HCl萃取)的相關分布(資料整理自劉黔蘭等人(1998))

- 2. The pH of soil matters



(a) Cd content in leaves (b) uptake by young rice sooth under different pH

EPA, ROC, 2003, The Investigation of Regulation of Heavy Metals in Contaminated Soils, EPA-91-H103-02-150 , National Taiwan University, Department of Agricultural Chemistry

3. Oxidation-reductive state of soils matters

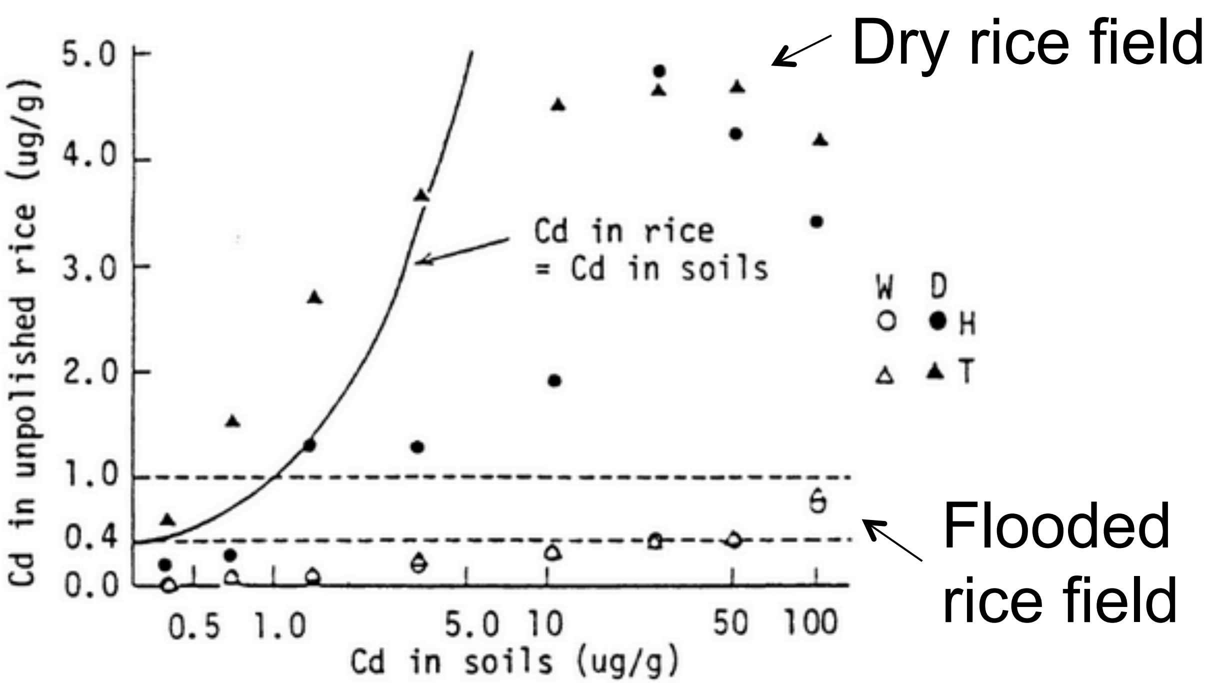


FIG. 3 — Influence of water management of paddy soils on Cd contents in unpolished rice in pot culture experiment. D, drained after tillering stage; W, submerged during whole growth period; H, soil of Hokuriku Natl. Agric. Exp. Stn.; T, soil of Toyama City (16).

(18) Ito, H., and Iimura, K. 1976. The absorption and translocation of cadmium in rice plants and its influence on their growth in comparison with zinc. Bull. Hokuriku Natl. Agric. Exp. Stn. No. **19**: 71–139.

In: Nriagu, J. O. Editor, Changing Metal Cycles and Human Health, Springer-Verlag, Berlin Heidelberg New York Tokyo 1984.

- 4. The estimation of *RCF* or *Br*
  - Difficult to extrapolate from one soil to other soils
  - May be different under different soil conditions
  - *Br* is function of soil texture, soil composition, pH, ORP, moisture content, etc.

7`.2. Human intake rates for agricultural products (IR_i, EF, ED)

- 7.2.1. Intake rates, IR
  - Resources of the values of intake rates
    - National Food Intake Data Bases
      - e.g. 335 g/person/day of leaf vegetables for age 19 to 65 in Taiwan
      - More detailed: 122 g/p/d of small leafy vegetables, 66.7 g/p/d of bulking leaf vegetables (like cabbage), etc.
      - Or further detailed: 119 g/p/d of fresh small leafy vegetables and 3 g/p/d of processed small leafy vegetables
      - But, what is the problem of using this data?

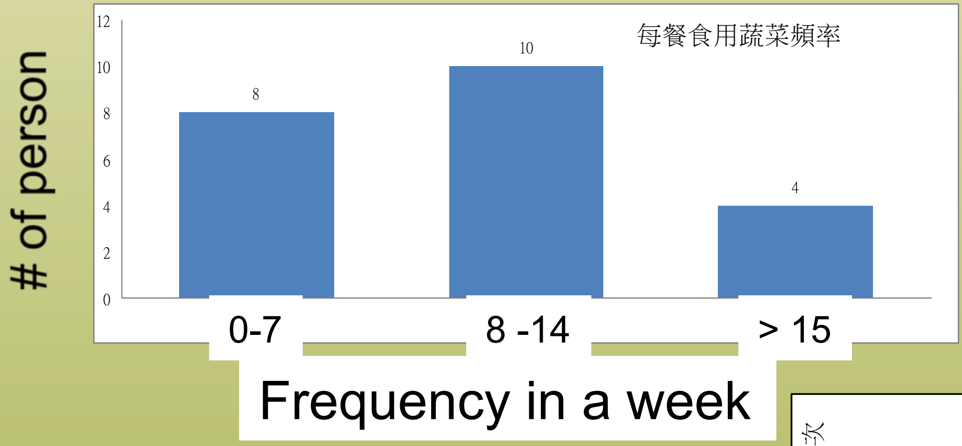
But, what are the problems of using these data?

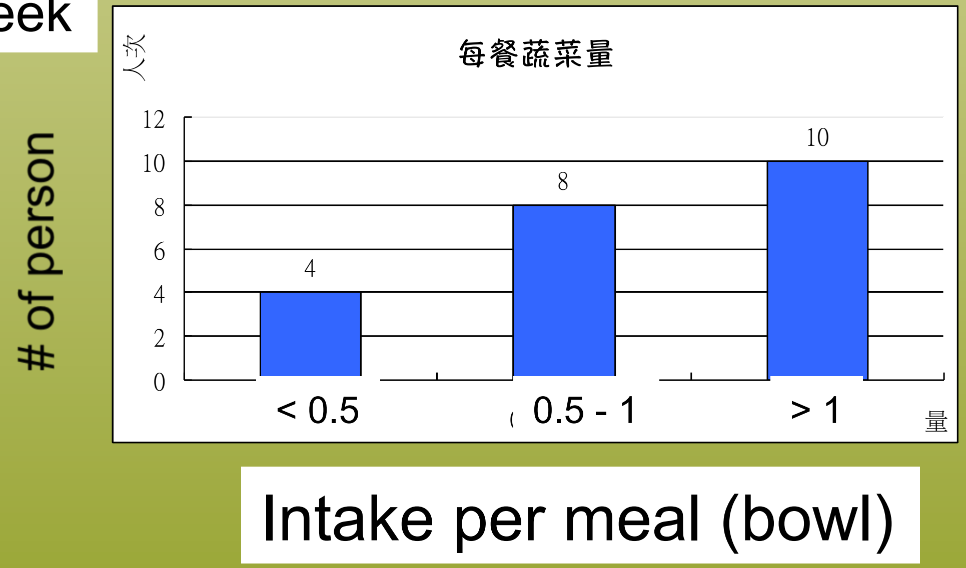
- The farmers on the contaminated site may not grow certain kind of vegetable all year around. They grow different kinds of vegetables, which may have different concentrations of the concerned pollutant.
- The person at the contaminated site may not all eat the vegetables or animals produced on the site.
- The person in the neighborhood may not either.
- The person purchases vegetables from the market may not have purchased the products from the contaminated site not mention that the products produced on the site may be distributed to several different markets.

- Conducting a survey by questionaires on the site, neighborhood, the distributing system, the vendors in the market and the customers in the markets.

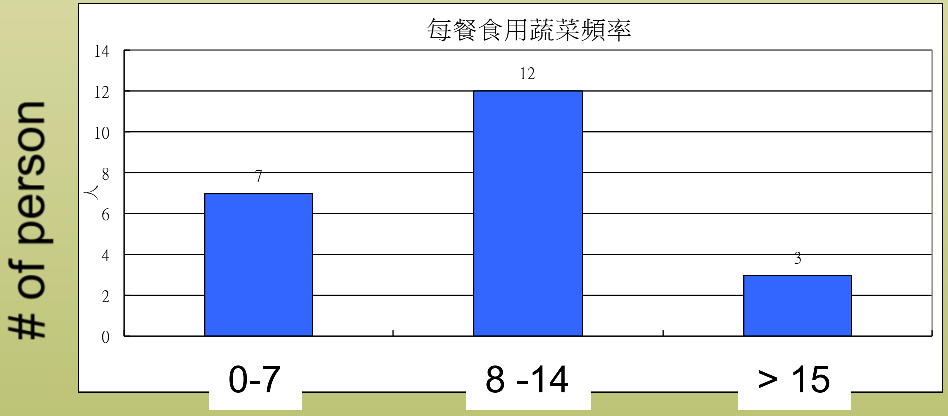
Some interesting results of a survey of a As-contaminated agricultural site

- Rate of intake of on-site vegetables by farmers on the site before the disclosure of the contamination

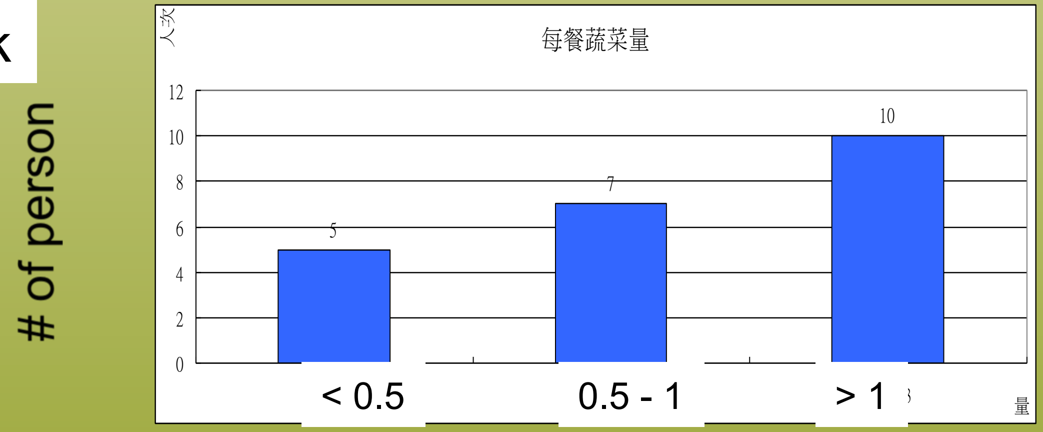




- Intake rate of vegetables after the disclosure of the contamination
  - Not changed much.
  - Why?



Frequency in a week



Intake per meal (bowl)

- 7.2.2. Frequency (EF) and duration (ED) depend on the
  - Location of the residence
  - Diet habit
  - Shopping behavior
  - Distribution system of the agricultural products

- 7.3. Management of contaminated agricultural land
  - Change the plants to less sensible, less accumulating species
    - But it is very difficult because of the habit, the business connections, the availability of skill and other reasons.
  - Modify the properties of soils to lower the activity of the pollutants
    - For example, adjusting the pH, adding calcium carbonate and others.
  - To identify the most vulnerable group of people and protect them from the risk

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Using Human Health Risk Assessment as the Basis for Soil and Groundwater Contamination Site Remediation and Management

Power Liang
Sinotech Engineering Consultants, Ltd.

March 28, 2016

Contents

- Introduction
- Risk Assessment and Soil and Groundwater Pollution Remediation Act
- Human Health Risk Assessment Protocol
- Human Health Risk Assessment Tools and Application
- Conclusion

Introduction

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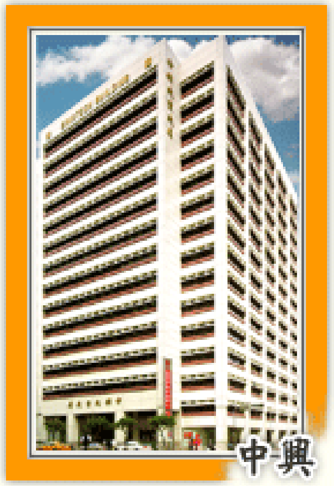

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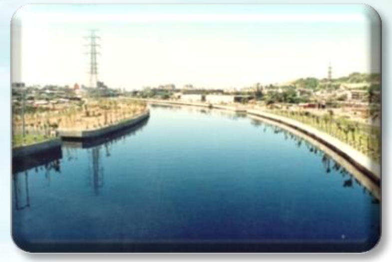
Company Profile

- As of Feb, 2016:
    - 1,459 employees
    - 47% of staffs hold advanced degrees(M.S. or Ph.D.)
    - 282 licensed professional engineers
    - 89% of staffs have 5+ years of experience
- Scope of services:
    - study, investigation, planning, design, inspection, construction supervision, project management and turnkey contract
- Fields of expertise:
    - electric power, hydraulic, urban development, industrial and agricultural development, environmental, civil, transportation, architectural, mechanical and electrical engineering








Company Profile

- $106.5 million USD net revenue in 2014
- Up to date, completed ~4,500 domestic assignments, ~240 overseas assignments

Reputation from clients for efficient, high-quality service

ISO certified

Service guaranteed

Our quality policy

- Ethics and Integrity
- Commitment to Quality
- Pursuit of Excellent
- Creativity and Innovation

Awarded an international certificate of the ISO 9001 Quality Management System

Company Profile

- Batutegi Dam, Lampung, Indonesia
- Cirata Hydroelectric Power Plant (Phase II), West Java, Indonesia
- Kuching Power Plant, Malaysia
- Various industrial parks development in Indonesia, Vietnam and Philippines

- Urban development for Semarang, Palembang, Bogor, Surakarta and Malang in Indonesia
- Java provincial highway improvement project (phase III), Indonesia
- Cirebon and Rengtang irrigation projects, Java, Indonesia
- Denpasar Sewerage Development Project (Phase I), Bali, Indonesia

http://www.sinotech.com.tw/econtent/download/download01.asp

Environmental Engineering Department:

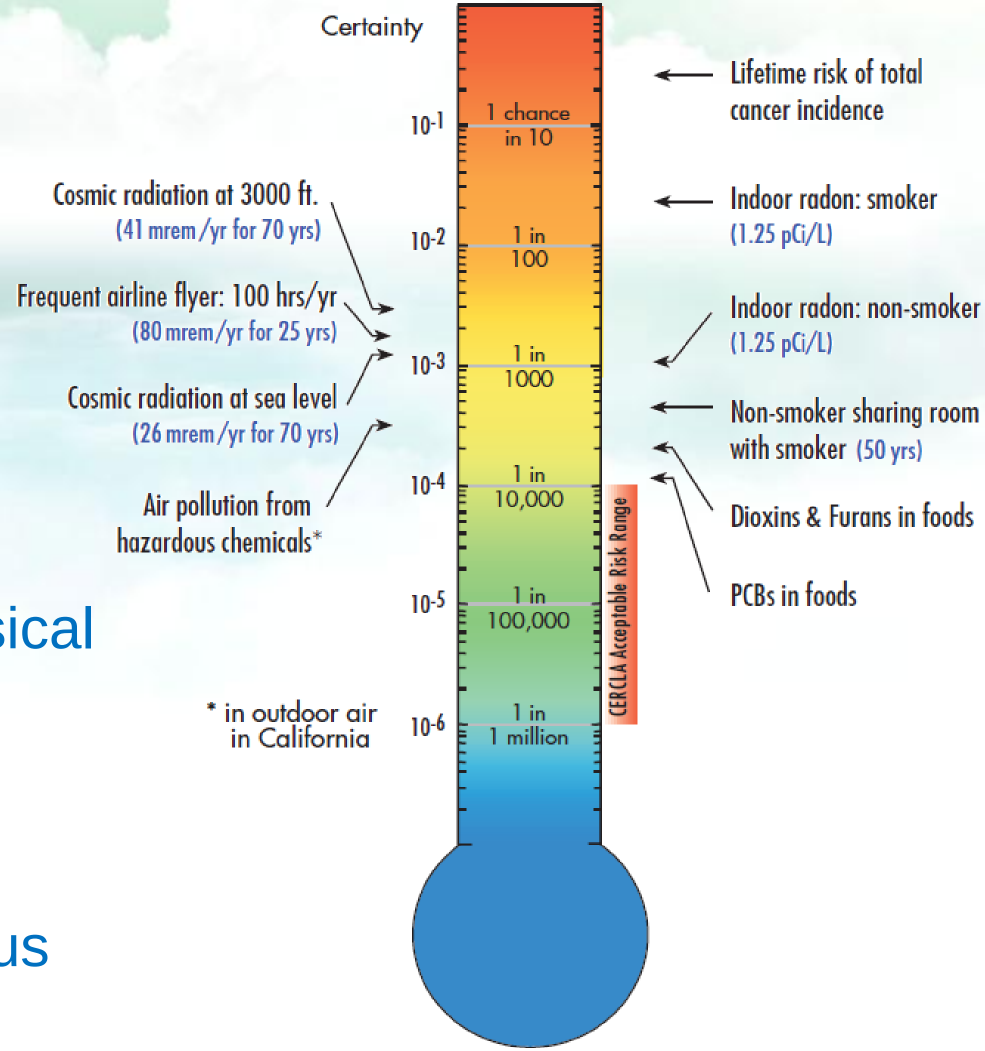
EIA & EM	Water & Wastewater Treatment and Pipeline	Air pollution, Noise & Vibration Control	Waste Management	Soil & Groundwater Investigation and Remediation

Our Services：

- Environmental site assessment (ESA Phase I/II); health risk assessment; groundwater monitoring; design, construction, and operation of remediation work
- Extensive field experiences:
  - ✓ petrochemical factories and oil refineries
  - ✓ gas stations and oil depots
  - ✓ abandoned factories
  - ✓ illegal dumping sites
  - ✓ chlorinated solvent contaminated sites
  - ✓ heavy metal contaminated farmland
  - ✓ military bases
  - ✓ contaminated sites with accidental leakage

What is Risk?

1. Risk
   - Probability of adverse consequences
   - Quantitative description
2. Hazard
   - Potential threat to health, property or environment
   - Chemical, biological, physical
   - Qualitative description
3. Health Risk
   - Probability of diseases or death caused by hazardous substances

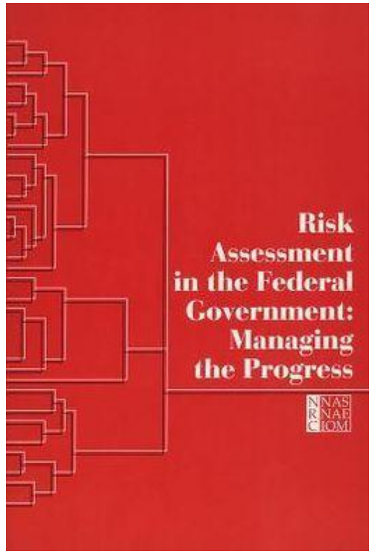


Risk = Probability (or Frequency) x Consequence

Origin of Risk Assessment System

- Risk assessment started in 1940's
- United States National Research Council proposed a 4-step risk assessment process
  - Hazard Identification
  - Dose-Response Assessment
  - Exposure Assessment
  - Risk Characterization

Risk Assessment in the Federal Government: Managing the Process (National Research Council, 1983)



Definition of Health Risk Assessment

Risk assessment is the use of the factual data to define the adverse health effects of individual or population exposure to hazardous materials and situations

- Factual data
  - Field measured data or authentic research paper and database
- Hazardous materials
  - Materials could possibly cause adverse health effect
- Exposure
  - Exposure pathways, frequency and intake dose of hazardous substances
- Adverse health effect
  - Abnormal function on organs, diseases, illness or death

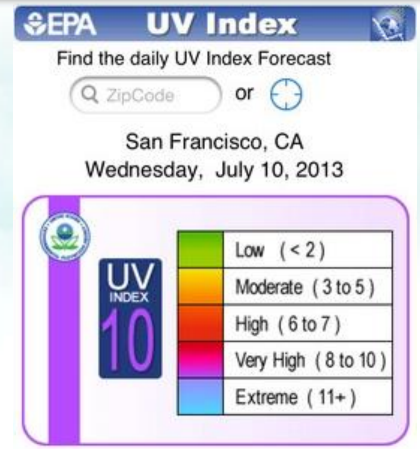
Purpose of risk assessment：

Using scientific assessment tools to make management decision

Risk Assessment
Quantify the risk with existing scientific information and exposure assumption

Risk Communication
1. Within project team
2. With public or interested parties

Risk Management
1. Risk management goal
2. Planning management measures according to risk assessment and risk communication results



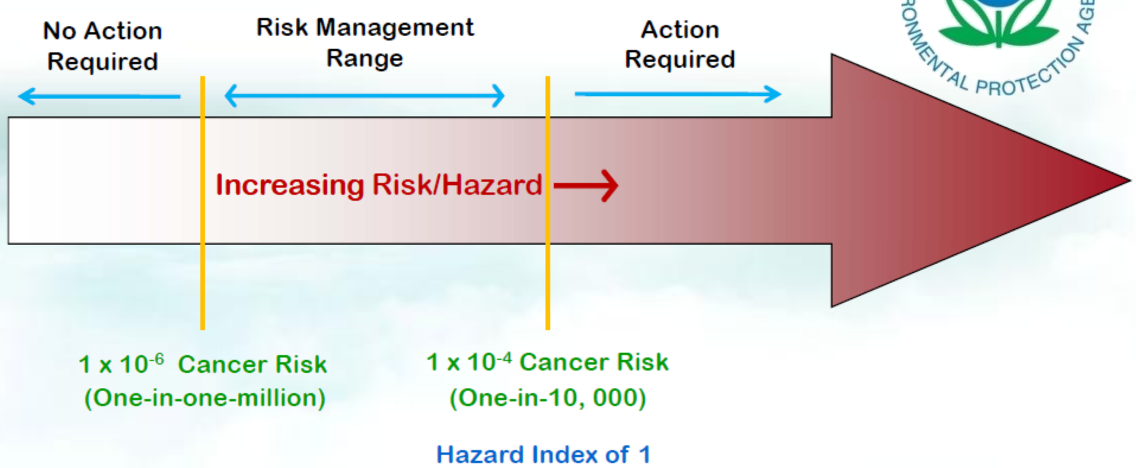
Why Do We Need Risk Assessment?

Environmental Pollution

Degree of Contamination?

Type of Actions Taken?

Remediate to what extent?



Risk Management

Plans and actions to reduce, control or prevent exposure to contamination

Managing exposure to contaminated media

Remediate media ("closure" risk management) ↔ **Prevent exposure** ("ongoing" risk management)

Remediation

- **Physical, Chemical or Biological Treatment**

Regulatory Goal:

Reduce contaminant concentrations to acceptable (protective) levels of risk for a range of use and function within a particular land category.

Exposure Prevention

- **Exposure Barriers**
  examples:
  - Hydrocarbon vapor control
  - Reducing chemical bioavailability
  - Capping and other barrier systems
- **Administrative Controls**
  examples:
  - Land Title record
  - Development restrictions
  - Site access restrictions

Cancer Risk	Risk Management Method
$<10^{-6}$	negligible risk, no action taken is necessary
10^{-6}~10^{-4}	acceptable risk, risk management measures shall be decided based upon site condition
$>10^{-4}$	Unacceptable risk, remedial actions must be taken

Purpose of Contaminated Site Risk Assessment

- Regulator：
  - Decide on the remedial and management measures and ensure can provide protection to human health
- Responsible Party：
  - Establish risk management measures which can 1)remediate contamination; 2)protect human health and 3)be economical
- Public：
  - Understand risk hazard and appropriateness of risk management measures
  - Put forth the health benefits demand

What is Acceptable Risk?

1. The current acceptable cancer risk(10^{-6}) was originally from Food and Drug Administration (FDA). The number was chosen for political reason at the time; not scientific calculation results. Since it is not possible to achieve zero risk, 10^{-6} was chosen and designated as no risk.
2. Netherland uses cancer risk 10^{-4} to estimate the "maximum permissible risk value". However, 10^{-6} was used to determined whether remediation is needed
3. Health Canada uses 10^{-4}~10^{-7} to develop soil quality standards.

What is Acceptable Risk?

4. Working area standard (i.e. ACGIH) usually use 10^{-3} or higher as the acceptable risk. This type of risk categorizes as voluntarily risk and employers have the right to notify before commencing work.
5. USEPA is using cancer risk 10^{-6} as the basis for preliminary remediation goal and remediation method selection. When proposing final remediation goal, acceptable cancer risk will be adjusted depending on site characteristic, environmental conditions, public opinions, treatment technology, community acceptance, uncertainty factors, etc. Risk is usually adjusted between 10^{-4} ~ 10^{-6}.

What is Acceptable Risk?

6. In U.S., one in a million (10^{-6}) cancer risk is usually being adopted as negligible risk

7. ***Political decision****-Water Quality: Guidelines, Standards and Health, World Health Organization (WHO)*

Varies with people and situation

- ✓ Lower than existing risk
- ✓ Cost to lower risk is far greater than benefits receive
- ✓ Experts say "Acceptable"
- ✓ Public say "Acceptable"

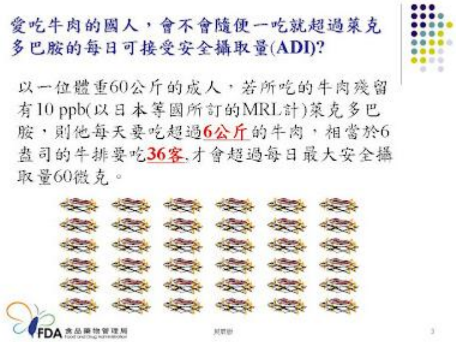
Risk Assessment and Soil and Groundwater Pollution Remediation Act (SGPRA)

Laws and Regulations in Taiwan

Risk Assessment and SGPRA

- Article 22 of Basic Environment Act (2002) indicated "Government entities at all levels shall actively conduct research and establish environmental and health risk assessment systems…"
- In 2002, National Council for Sustainable Development Network decided to form "Health Risk Assessment Group"
- Dec. 2003, Ministry of Health and Welfare published "National Health Risk Assessment Guidelines"


中科健康風險評估資料不完整
民眾喪失對政府的信任



Health risk assessment has been utilized and seen in various field, e.g., environmental impact assessment, food safety

Integrating Risk Assessment into SGPRA

- In 2000, when Soil and Groundwater Pollution Remediation Act (SGPRA) was first promulgated, risk assessment concept was already incorporated
- When contamination is discovered, environmental and human health impacts "must" be assessed
- Contaminated site management can use health risk as the basis for necessary remedial strategy design
- Combining with contaminated land redevelopment and reuse, sustainable land reuse is set as the ultimate management goal

Integrating Risk Assessment into SGPRA

2000 | 2006 | 2007 | 2010 | 2011 | 2013

2000

- Soil and Groundwater Pollution Remediation Act (SGPRA) was promulgated. Concept of environmental impact and human health risk assessment was included in contaminated site management decision

2006

- Completed "Soil and Groundwater Contaminated Site Human Health Risk Assessment Protocol and Report Guidelines" and built "Human Health Risk Assessment System"
- Amended "Regulations Governing the Preliminary Assessment of Soil and Groundwater Pollution Control Sites". Human health risk assessment results were included as one of the decision factor for declaring contamination site

2007

- Announced "Human Health Risk Assessment Reviewing Guidelines for Control Sites"

2010

- SGPRA was amended to include risk assessment applicability of soil contamination remediation sites

2011

- Started establishing ecological risk assessment methods
- Established the protocol for TPH risk assessment

2013

- Continue strengthen health risk assessment and localized parameters
- Establishing ecological risk assessment protocol

SGPRA Contents Related to Risk Assessment

SGPRA	Details
Article 12, Paragraph 5	Upon receiving the notification in the foregoing paragraph, the special municipality, county, or city competent authority shall test the sediment, and may order the manager of the surface water body to perform an assessment on the basis of environment impact, health risk, technology, and economic effectiveness. When, after reviewing the assessment results, the central competent authority feels that remediation is necessary and feasible, a remediation plan must be drafted and submitted to the central competent authority for approval before remediation may be implemented.
Article 12, Paragraph 9, 10	If the processes of scouring, dispersion, deposition, or irrigation cause the on-site concentrations of pollutants existing in the natural environment to reach the situations prescribed in Paragraph 2, … With regard to the site in the foregoing paragraph, the special municipality, county, or city competent authority may perform an assessment on the basis of environment impact, health risk, technology, and economic effectiveness. When it is felt that remediation is necessary and feasible, a remediation plan shall be implemented after submission to the central competent authority for approval.

SGPRA Contents Related to Risk Assessment

SGPRA	Details
Article 24, Paragraph 2	With regard to the soil and groundwater pollution remediation plan in the foregoing paragraph, if factors such as the geological conditions, pollutant characteristics, or pollution remediation technologies preclude remediation until pollutant concentrations are less than soil and groundwater pollution control standards, soil and groundwater pollution remediation goals based on environmental impact and health risk assessment results may be submitted after requesting and obtaining the central competent authority's approval.
Article 24, Paragraph 3	…a special municipality, county, or city competent authority may submit soil and groundwater pollution remediation goals wherein pollutant concentrations are less than soil and groundwater pollution control standards; or may submit an environmental impact and health risk assessment on the basis of financial and environmental circumstances, submit soil and groundwater pollution remediation goals in accordance with assessment results, and additionally draft a soil and groundwater pollution control plan, which shall be implemented following the regulations of Article 22 Paragraphs 2 and 4.
Article 24, Paragraph 8	In the environmental impact and health risk assessment in Paragraphs 2 and 3, the central competent authority shall determine regulations governing hazard identification, dose-response assessment, exposure quantification, description of risk characteristics, and other binding matters.

Risk Assessment and SGPRA

SGPRA

Art.12, Para. 5
Evaluation of sediment contamination

Art. 12, Para. 10
Evaluation of contamination caused by natural environment

→ Evaluation of the necessity and feasibility of remediation →

- Ensure whether contamination will affect health and environment
- Decide the necessity of remediation and to what extent

Art. 24, Para. 2
Unable to reach standards due to site characteristics

Art. 24, Para. 3
Developing remediation goal due to environmental and economic considerations

→ Submit remediation goal according to environmental impact and health risk assessment results →

Submit remediation goal and remediation plan

Human Health Risk Assessment Protocol

Object

- Only applies to sites with soil and groundwater contamination, which can affect human health. Other types of contamination are not applicable.

Purpose

- To allow responsible parties using risk assessment to develop less stringent control standards but still can able to protect human health.

Toxicity consideration

- Only assess the chronic toxicity to human caused by contaminants

Limitation

- Currently, human health risk assessment protocol doesn’t apply to total phenol, nitrate and nitrite.

Basic Risk Assessment Framework

Hazard Identification

What health problems are caused by the pollutant?

Dose Response Assessment

What are the health problems at different exposures?

Exposure Assessment

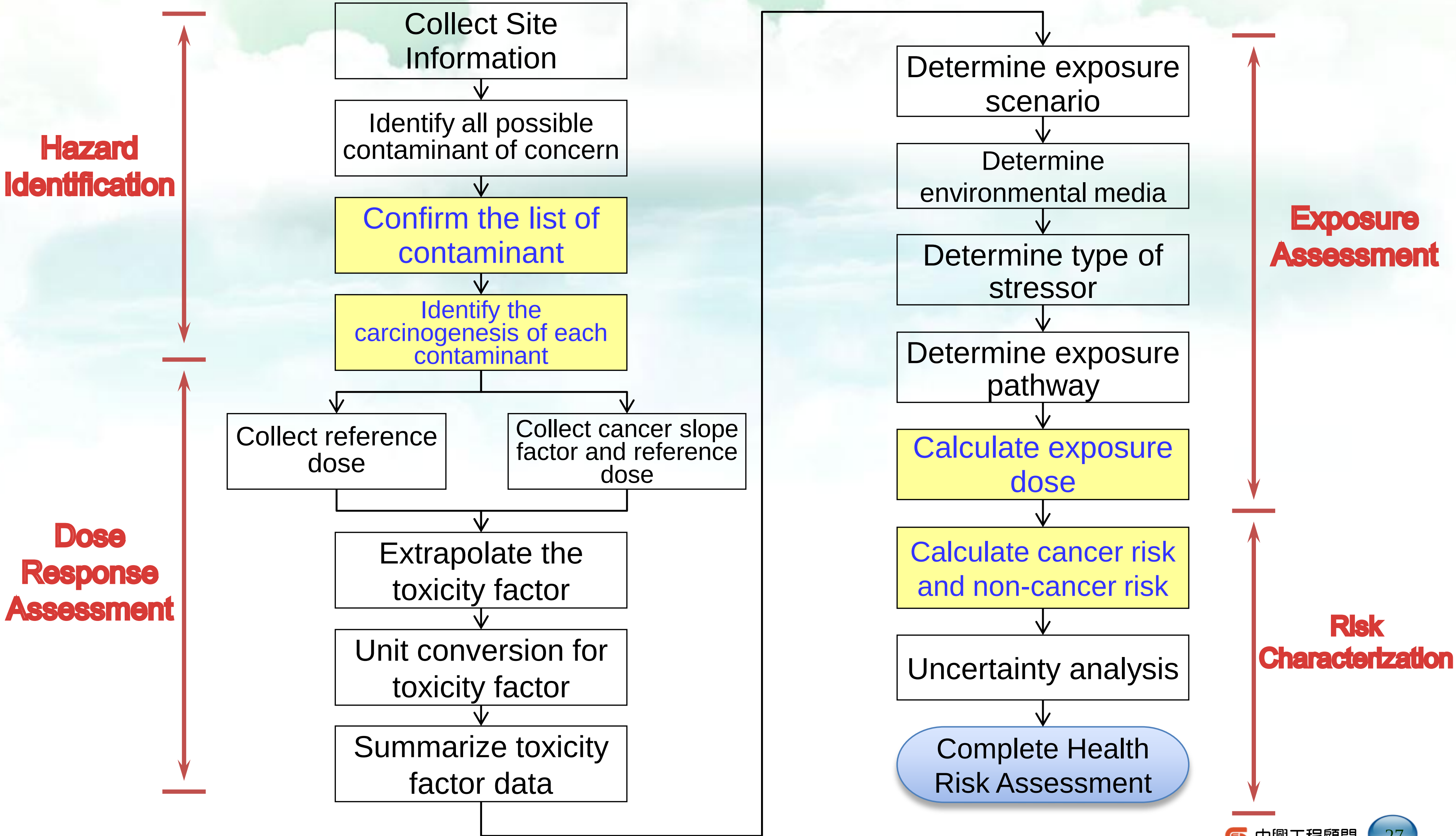
How much of the pollutant are people exposed to during a specific time period?

Risk Characterization

What is the extra risk of health problems in the exposed population?

Risk Assessment Steps

Human Health Risk Assessment Protocol



Tiered Risk Assessment

Tiered approach is established for management needs

Tier-1 Risk Assessment
- Default scenario and parameters
- Exposure calculation is fixed

Tier-2 Risk Assessment
- Default scenario
- Exposure calculation uses actual investigation data
- Able to choose suitable contaminant transport model

Tier-3 Risk Assessment
- Customized exposure scenario
- Exposure calculation uses actual investigation data
- Able to choose suitable contaminant transport model

Exposure dose calculation varies with parameters and scenarios

- Tier-1：2 exposure scenarios; default parameters and calculation method
- Tier-2：2 exposure scenarios; default human body parameters; hydrogeological parameters are from actual investigation data
- Tier-3：exposure scenarios, pathways, human body and hydrogeological parameters are obtained from investigation data; calculation method can be chosen by assessor.

Choose tier that fits assessment needs

Exposure Scenario and Exposure Parameter

		Tier 1	Tier 2	Tier 3
Exposure Scenario		Residential, industrial/commercial	Residential, industrial/commercial	Varies by site
Stressor		Residential：Adult and child Industrial/commercial：Adult	Residential：Adult and child Industrial/commercial：Adult	Varies by site
Exposure Pathway		soil, water, air---> ingestion, inhalation, dermal absorption	soil, water, air---> ingestion, inhalation, dermal absorption	soil, water, air, food chain---> ingestion, inhalation, dermal absorption
Exposure Dose Calculation Method		Using default parameters, maximum concentration and default calculation formula	1.Default parameters, default calculation formula, estimated concentration 2.Using model to simulate offsite concentration	1.Default parameters, default calculation formula, estimated concentration 2.Using statistic distribution of parameters and estimated concentration in calculation formula or fate and transport model 3.Using model to simulate offsite concentration
Parameters	Contaminant concentration	Maximum concentration detected on-site	1.Maximum concentration detected on-site 2. Using actual sampling data to calculate 95% UCL	1.Maximum concentration detected on-site 2. 95% UCL 3. Monte Carlo simulation
	Hydro-geological	Default	1. Default 2. Actual sampling data	1. Default 2. Actual sampling data 3. Monte Carlo simulation
	Human body	Default	Default	1. Default 2. Actual sampling data 3. Monte Carlo simulation

Hazard Identification

1. Definition

1) The 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)

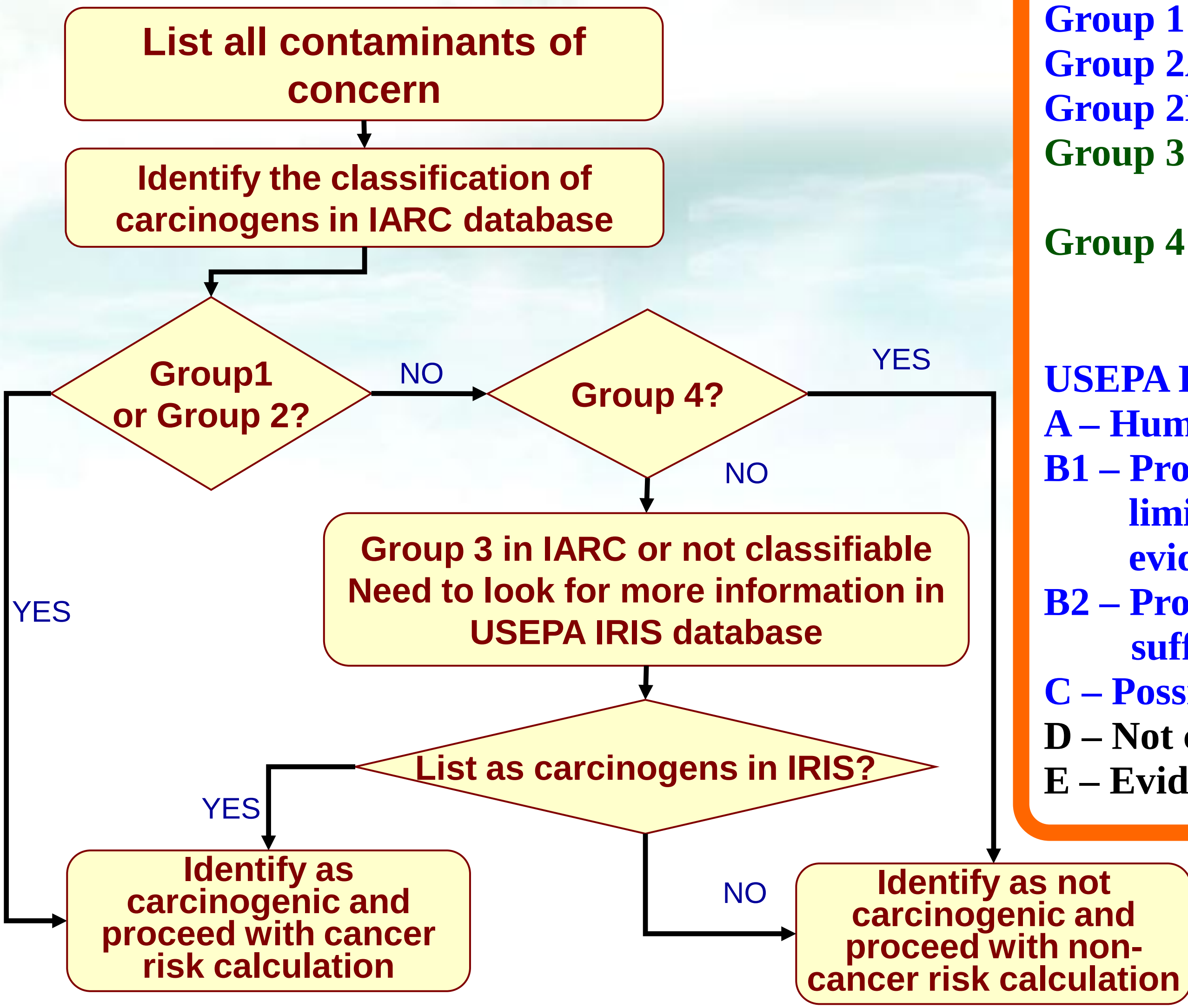
2) Using LD_{50} or organ damage of animal testing results to determine hazard

Carcinogen?

Health hazard? Toxicity?

Extent of damage?

2. Determining toxicity



IARC carcinogens classification

Group 1 – definitely carcinogenic to humans
Group 2A – probably carcinogenic to humans
Group 2B – possibly carcinogenic to humans
Group 3 – not classifiable as carcinogenicity to humans
Group 4 – probably not carcinogenic to humans

USEPA IRIS classification

A – Human carcinogen
B1 – Probable human carcinogen - based on limited evidence in humans and sufficient evidence in animals
B2 – Probable human carcinogen - based on sufficient evidence in animals
C – Possible human carcinogen
D – Not classifiable as human carcinogen
E – Evidence of human non-carcinogen

Hazard Identification

3. Data collection
   1) Site information, site history, sampling results
   2) Official published data, academic research, field investigation data
   3) General rule is to assess 1km-radius area within the site
4. Determining contaminants of concern
   1) All contaminants which are above the control standards
   2) Contaminants required by competent authorities or examination committees
   3) Contaminants toxicity (carcinogenicity)

5. Determining assessment scope
    1) Contaminant concentration is higher than control standards
    2) Stressor is affected by contaminant
6. Questionnaire
    1) Understand the stressors' living behavior pattern and parameter
    2) To be used as the reference for exposure assessment

三、受體暴露情形與暴露參數蒐集

1.水體暴露途徑

(1). 受體是否使用地下水情況（☐是 ☐否 ☐不確定）

使用地下水型態	使用地下水水量(升)	使用地下水頻率	接觸地下水途徑
☐ 洗澡		______小時/日	☐吸入 ☐食入 ☐皮膚接觸
☐ 灌溉		______次/日	☐吸入 ☐食入 ☐皮膚接觸
☐ 其他		______次/年	☐吸入 ☐食入 ☐皮膚接觸

(2). 受體是否使用地表水情況（☐是 ☐否 ☐不確定）

使用地表水型態	使用地表水水量(升)	使用地表水頻率	接觸地表水途徑
☐ 洗澡		______小時/日	☐吸入 ☐食入 ☐皮膚接觸
☐ 灌溉		______次/日	☐吸入 ☐食入 ☐皮膚接觸
☐ 其他		______次/年	☐吸入 ☐食入 ☐皮膚接觸

2.土壤、底泥暴露途徑

(3). 受體是否接觸土壤情況（☐是 ☐否 ☐不確定）

接觸土壤型態	接觸土壤頻率	接觸土壤途徑
☐ 工作	______次/日	☐吸入 ☐食入 ☐皮膚接觸
☐ 遊憩	______次/日	☐吸入 ☐食入 ☐皮膚接觸
☐ 其他	______次/日	☐吸入 ☐食入 ☐皮膚接觸

(4). 受體是否接觸底泥情況（☐是 ☐否 ☐不確定）

接觸底泥型態	接觸底泥頻率	接觸底泥途徑
☐ 工作	______次/日	☐食入 ☐皮膚接觸
☐ 遊憩	______次/日	☐食入 ☐皮膚接觸
☐ 其他	______次/日	☐食入 ☐皮膚接觸

3.食物鏈暴

(5). 受體是否攝食當地作物情況（☐是 ☐否 ☐不確定）

食用當地作物類型	食用量(克/次)	食用頻率（次/年）	食物種類
☐ 海產			☐ 魚類 ☐ 甲殼類
☐ 肉品			☐ 紅肉 ☐ 白肉 ☐ 雞禽
☐ 穀物			
☐ 蔬菜			

Dose Response Assessment

1. Definition

1) A dose-response relationship describes how the likelihood and severity of adverse health effects (the responses) are related to the amount and condition of exposure to an agent (the dose provided)
2) Exposure dose is usually extrapolated from high dose to low dose; animal to human

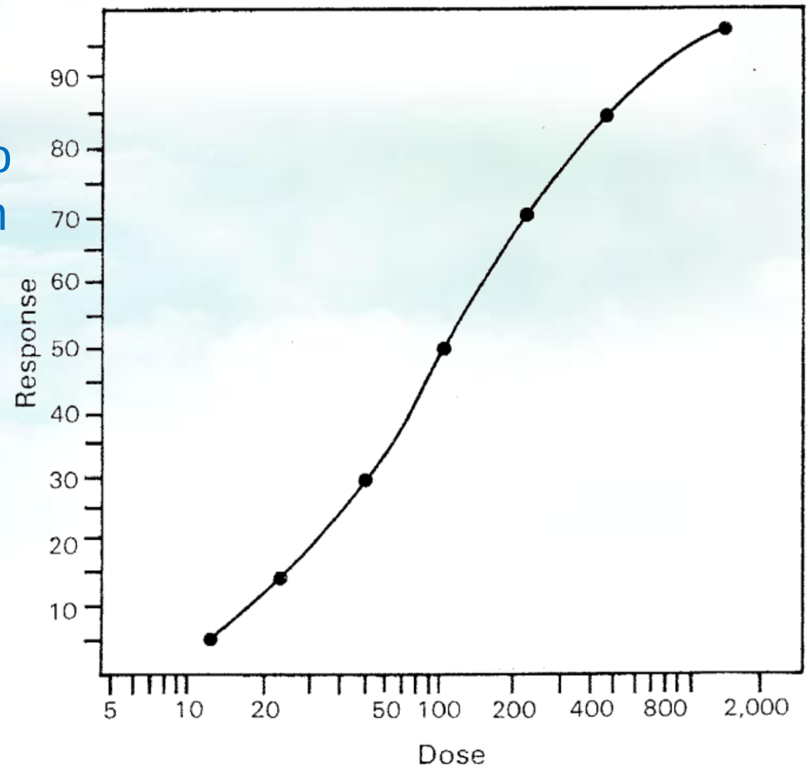


Figure 2–2. Diagram of dose-response relationship. Dosage is most often expressed as mg/kg and plotted on a log scale.

2. Decision factor

1) Threshold effect (linear, non-carcinogenic assessment)
2) Reference dose (RfD) or reference concentration (RfC)
3) Non-threshold effect (non-linear, carcinogenic assessment)
4) Slope factor $(mg/kg\text{-}day)^{-1}$

3. Toxicity factor database

1) USEPA Integrated Risk Information System (IRIS)
2) WHO Concise International Chemical Assessment Document (CICAD), WHO Environmental Health Criteria (EHC)
3) USEPA Provisional Peer Reviewed Toxicity Values (PPRTVs)
4) Minimal Risk Level (MRL) in USEPA Health Effect Assessment Summary Table (ATSDR)
5) USEPA Health Effect Assessment Summary Table (HEAST)
6) Toxicity factor established by US California Environmental Protection Agency (Cal/EPA)

DECREASING PRIORITY

Exposure Assessment

Definition

- The process of measuring or estimating the magnitude, frequency, and duration of human exposure to an agent in the environment, or estimating future exposures for an agent that has not yet been released
- Exposure can be measured through various exposure pathways into human and assess the damage done

Principle of estimation

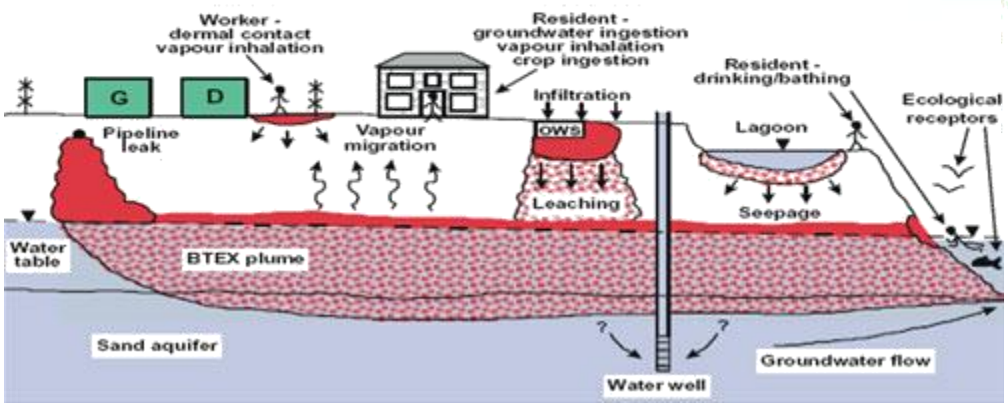
- Evaluate contaminants in different environmental media
- Key element of evaluation – contact probability and time

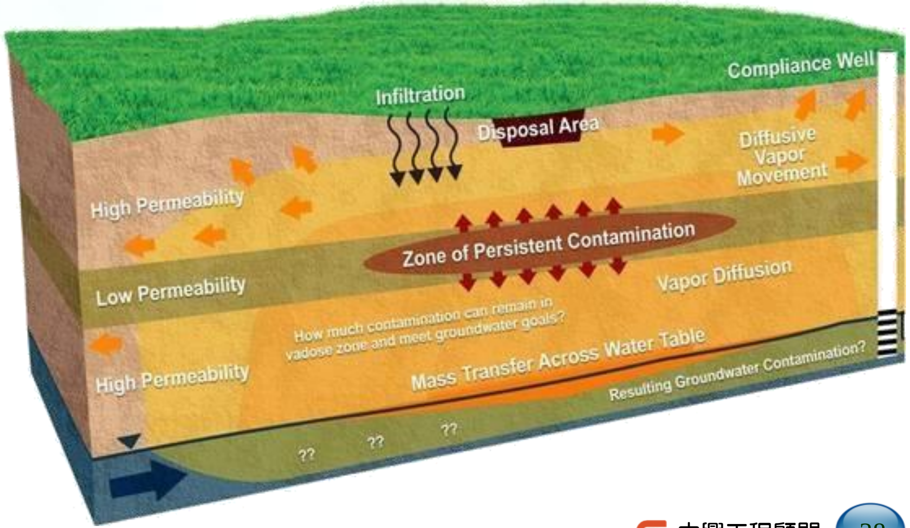
1. Exposure scenario, environmental media and type of stressor selection

Default Scenario	Selection Principle	Stressor
Residential	If the site is located or near residential area, exposure scenario should be set as residential	Residents – including adults (12 or older) and children (12 or younger)
Industrial/ Commercial	If the site is located or near current or future industrial/ commercial area, scenario should be set as industrial/ commercial	Workers

2. Site Conceptual Model

- Using words, charts or graphs to describe the actual investigation and research data on contamination, surrounding area and hydrogeological situations
  - Describe exposure scenarios and all possible exposure pathways
  - Add detailed geology, hydrogeological data

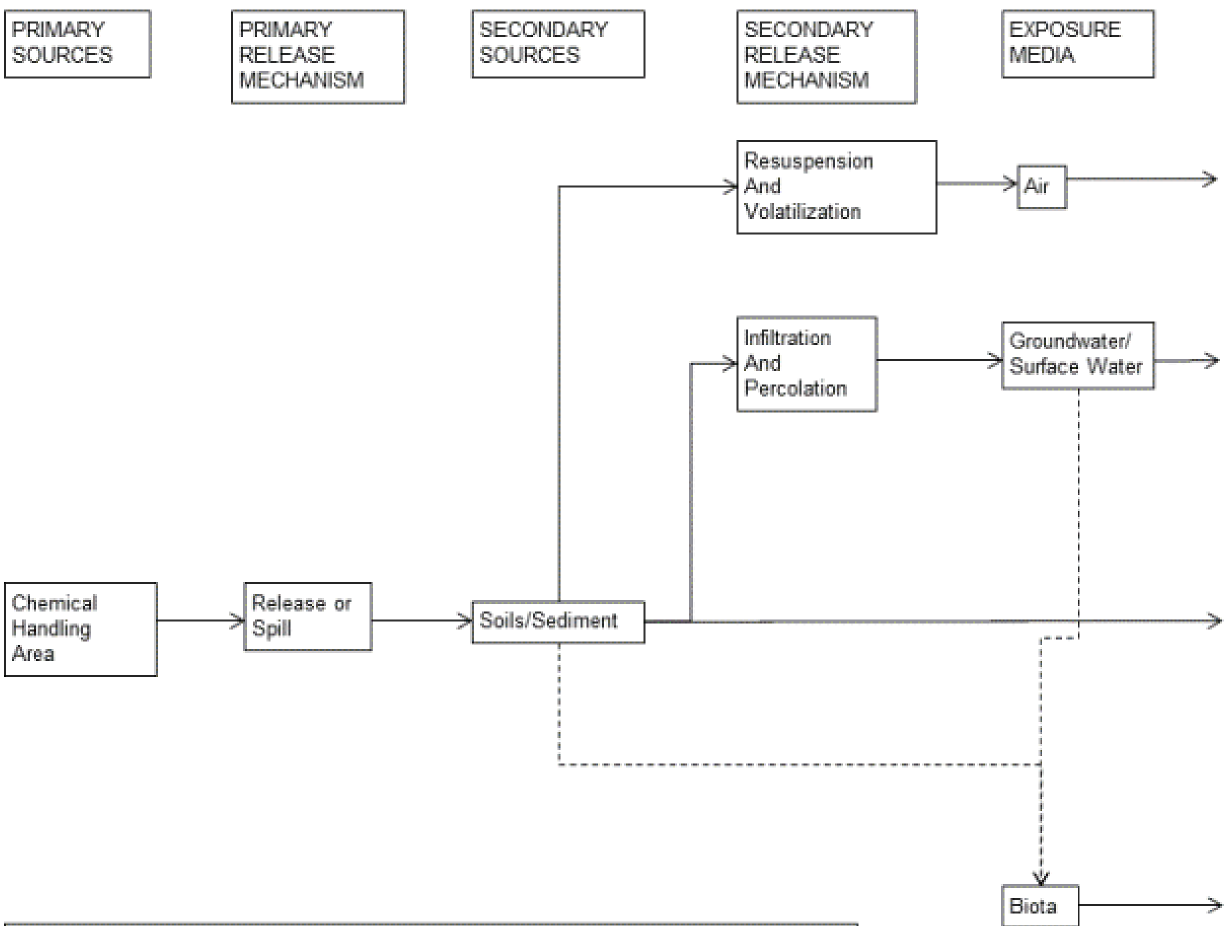




3. Choose exposure pathways

1. Risk assessment protocols provides default exposure pathways
2. Complete exposure pathways must have：
   - contamination source or release point
   - point of exposure which is in contact with contaminants
   - exposure pathways which point of exposure is in contact with contaminants

Exposure Assessment



Exposure Route	Resident	Outdoor Worker	Indoor Worker	Comp. Worker	Recreator
Inhalation	●	●	●	●	

Exposure Route	Resident	Outdoor Worker	Indoor Worker	Comp. Worker	Recreator
Ingestion	●				●
Inhalation	●				
Dermal	●				●

Exposure Route	Resident	Outdoor Worker	Indoor Worker	Comp. Worker	Recreator
Ingestion	●	●	●	●	●
Inhalation	●	●	●	●	●
Dermal	●	●		●	●

Exposure Route	Resident	Outdoor Worker	Indoor Worker	Comp. Worker	Recreator
Fish	●				

Conceptual Site Model of Quantified Exposure Pathways for Regional Screening Levels.
Black lines are direct exposure routes.
Dashed black lines are indirect exposure routes.

Exposure Assessment

3. Special exposure pathways

- Since many contaminated gas stations in Taiwan use groundwater for outdoor watering or vehicle washing; therefore, this kind of exposure pathway is specially considered to be included in the risk assessment protocol

4. How to choose parameters?

1) Source

- default = most conservative
- research paper and questionnaire
- actual field investigation

2) Contaminant concentration

- highest sampling concentration within a year
- Exposure dose can be calculated using the 95% UCL of the sampling concentration onsite

Parameters	Description	Value	Unit
f_{sa}	Ratio of upper arm skin surface area to body skin surface area	0.2	no unit
IR_{inh}	Inhalation rate	Adult 17.14/ Child13.95	m^3/day
$IR_{oral\text{-}soil}$	Ingestion rate (soil)	Adult 100/Child 200	mg/day
$IR_{oral\text{-}water}$	Ingestion rate (water)	Adult 3/Child 1.3	l/day
SA	Skin surface area available for contact	Residential Adult 17300 Residential Child 11400	cm^2
t_1	Shower duration (time in contact with skin)	0.5	hour
t_2	Time stay in bathroom after shower	0.2	hour

5. Exposure dose calculation

Inhalation

$$Intake_{inh} = \frac{(C_{air} \times IR_{inh} \times EF \times ED)}{(BW \times AT)}$$

Ingestion

$$Intake_{ingestion} = \frac{(C \times IR_{ingestion} \times AF \times LFC \times ED)}{(BW \times AT)}$$

Dermal absorption

$$Intake_{dermal} = \frac{(C \times M_s \times SA \times AF_{skin absorption} \times ED)}{(BW \times AT)}$$

Food chain assessment

- **Meat and dairy product**

$$C_{beef/milk} = BTF_{food}\left[\sum_i (C_i \cdot CR_i \cdot f_i) + (C_{soil} \cdot CR_{soil} \cdot FBio_{soil})\right] + BTF_{water}(C_{water} \cdot IR_{water})$$

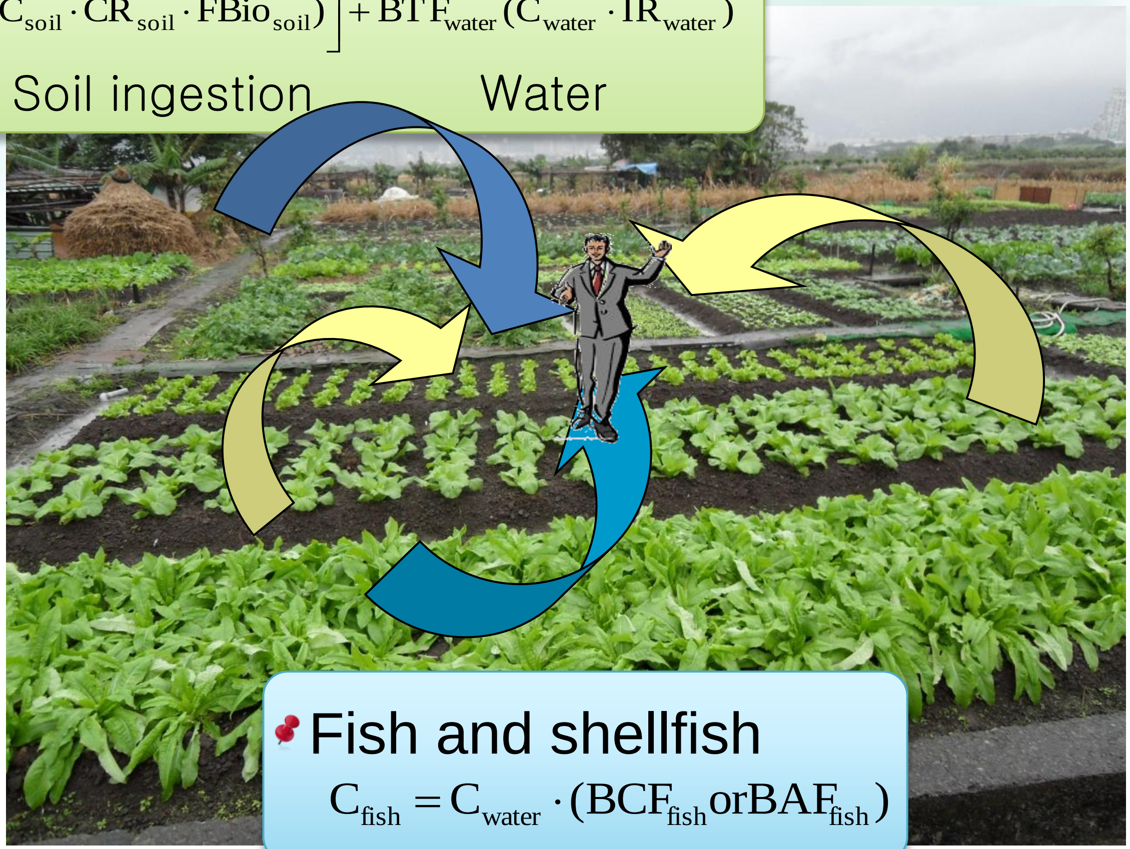
Feed Soil ingestion Water

- **Produce**

$$C_{aboveground\ produce} = C_{soil-RZ} \cdot BCF_{soil-plant}$$

$$C_{root\ produce} = \frac{C_{soil-RZ} \cdot BCF_{root} \cdot ECF_{root}}{K_d}$$

Conversion factor for root vegetables



- **Fish and shellfish**

$$C_{fish} = C_{water} \cdot (BCF_{fish}\ or\ BAF_{fish})$$

Risk Characterization Description

1. Risk calculation
    1) Overall analysis on contaminants exposure dose and toxicity
    2) Carcinogenic and non-carcinogenic risk are calculated separately
    3) If one of the two kinds of risk is exceeding the acceptable risk, it might cause damage to human health and remedial actions are needed immediately

Risk Characterization Description

Carcinogenic Risk Calculation

1. Calculate cancer risk of all exposure pathway

$$R_{oral} = Intake_{oral} \times SF_{oral}$$

$$R_{inh} = Intake_{inh} \times SF_{inh}$$

$$R_{dermal} = Intake_{dermal} \times SF_{dermal}$$

2. Sum up all risk to get total cancer risk

$$R_{total} = \sum R_{oral} + \sum R_{inh} + \sum R_{dermal}$$

3. Acceptable cancer risk can be between 10^{-6} to 10^{-4} depending on exposure scenario

Non-Carcinogenic Risk Calculation

1. Calculate the hazard quotient (HQ) of all exposure pathway

$$HQ_{inh} = \frac{Intake_{inh}}{RfD_{inh}}$$

$$HQ_{oral} = \frac{Intake_{oral}}{RfD_{oral}}$$

$$HQ_{dermal} = \frac{Intake_{dermal}}{RfD_{dermal}}$$

2. Sum up all HQ to get total hazard index

$$HI = \sum HQ_{oral} + \sum HQ_{inh} + \Sigma HQ_{dermal}$$

3. Acceptable hazard index (HI) should be below 1

2. Uncertainty analysis

1) Qualitative Description

- Will site specific data over or under estimate the risk?
- Is fate and transport modeling result different from actual site conditions due to selecting wrong model or misjudging site condition due to insufficient information?
- Is there any toxicity cannot be quantified?
- Using historical sampling results to extrapolate concentration trend over time might over or under estimate the risk

Uncertainty can be minimized by collecting more reliable or site specific information

Risk Characterization Description

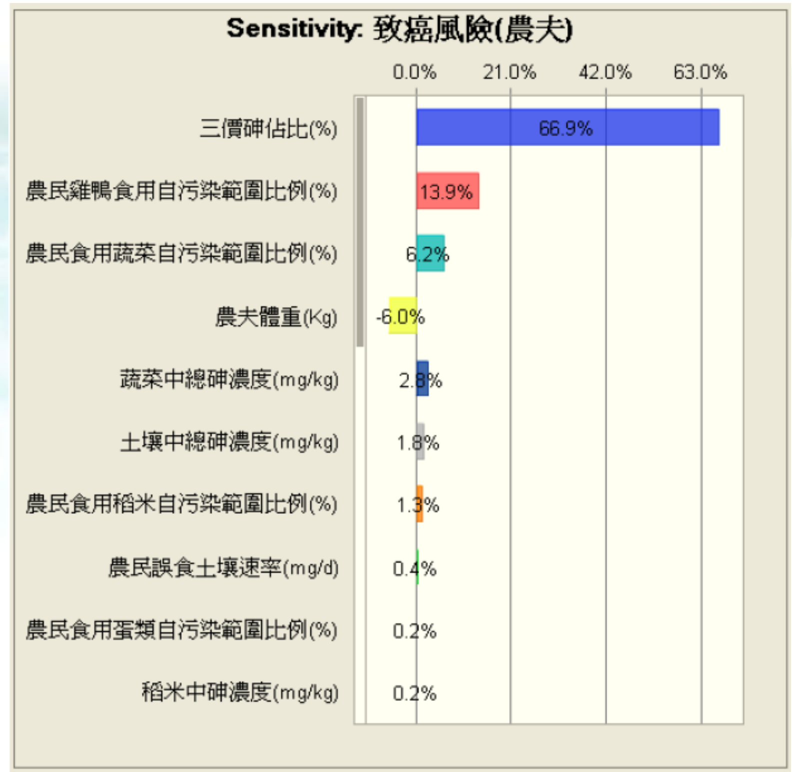
2) Quantitative Description

- Sensitivity Ratio (SR)
- Contribution percentage of each exposure pathways and contaminants
- Monte Carlo analysis
  - Deterministic risk assessment vs. Probabilistic risk assessment
  - Deterministic risk assessment uses a single & fixed value to calculate risk; thus, the assessment result is a fixed value and tend to be over conservative sometimes
  - Based on the probabilistic distribution of parameter, probabilistic risk assessment can utilize Monte Carlo analysis to obtain probabilistic risk assessment results

Risk Characterization Description

Sensitivity Ratio

- If SR is high → parameter influence is great and should be used in a more cautious way
- Helpful for planning out future risk management decision
- Concentrating resources on parameters/exposure pathways that are more sensitive

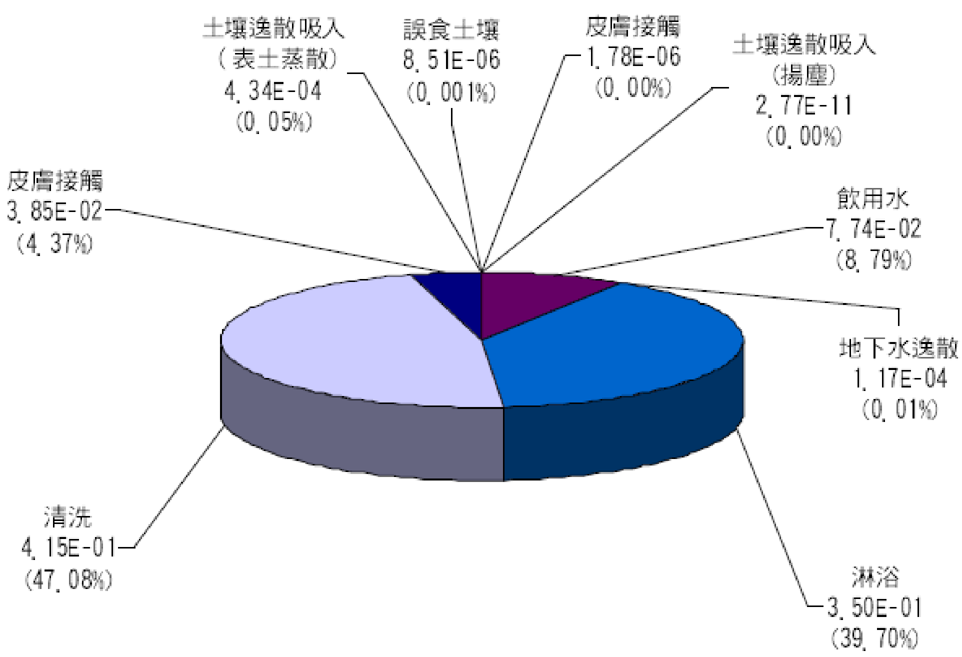


Contribution percentage of exposure pathways

$$RiskPercentage = \frac{R_i}{R_{total}} \times 100\%$$

R_i : Risk for each contaminant or exposure pathway (carcinogens or non-carcinogens)

R_{total} : Total risk value

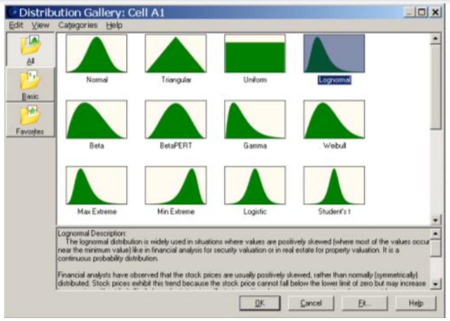


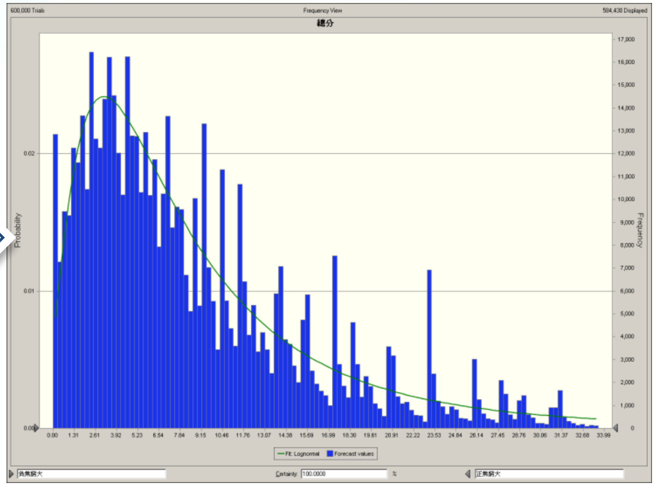
Risk Characterization Description

Monte Carlo Analysis

- Demonstrate the distribution of calculation results when changes in different parameters
- Illustrated as probability distribution, not a single evaluation result

Parameter	Distribution Type	Unit	Define parameters
Body Weight	normal	kg	Average, standard deviation
Consumption amount	triangular	L/day	Maximum, minimum, highest probability
Contact time when using groundwater for showering	normal	hour	Average, standard deviation

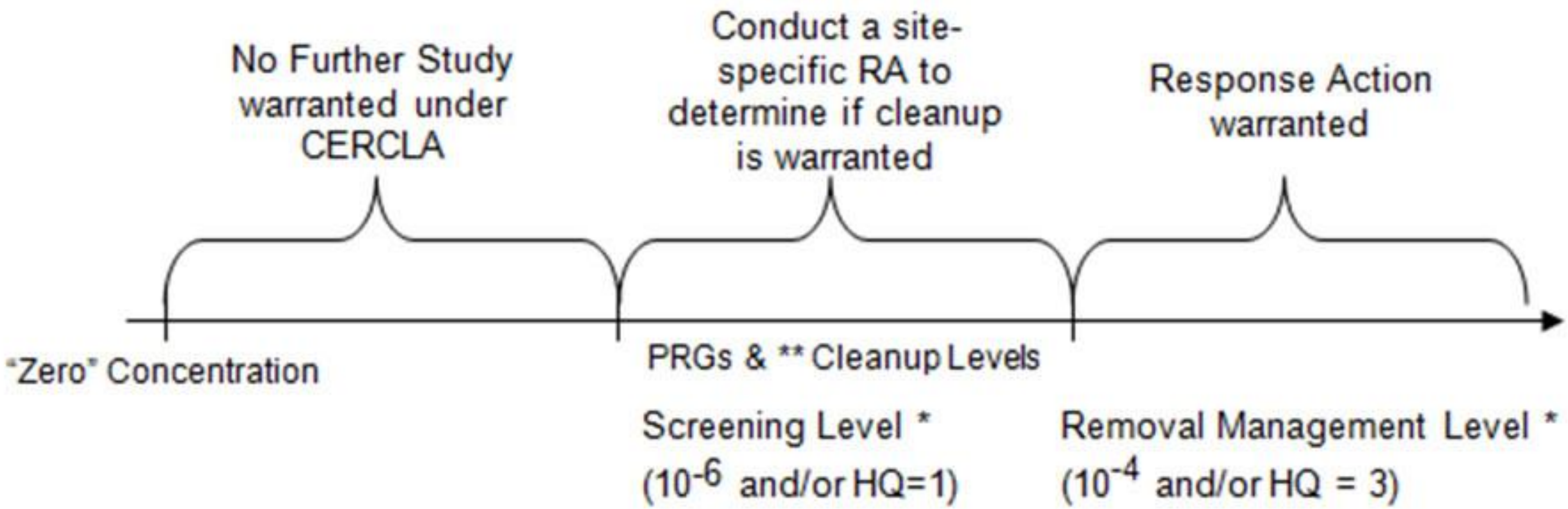




Different Parameters Combination

Human Health Risk Assessment Tools and Application

Site screening and classification



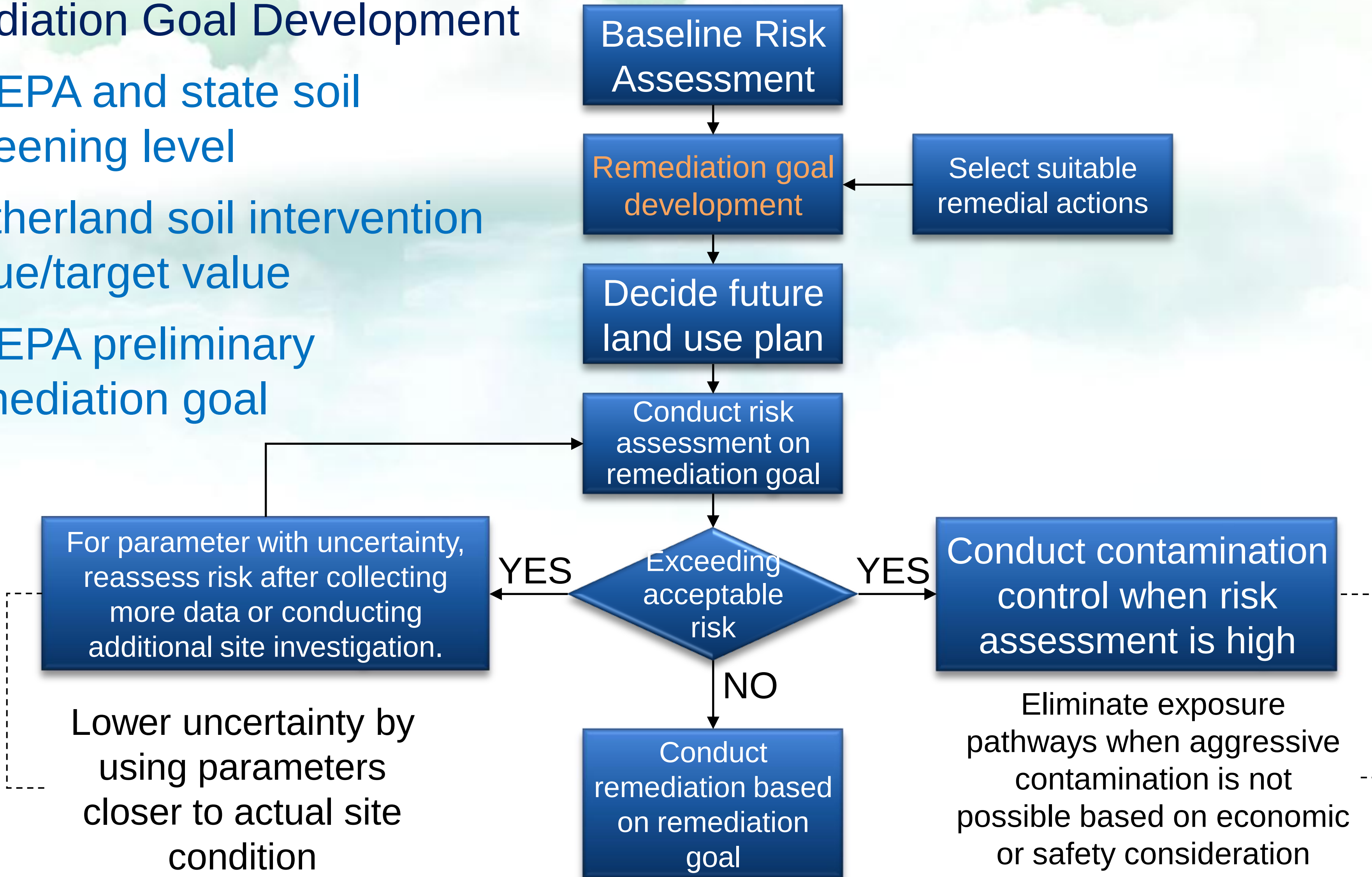
* - Screening Levels and RMLs are for individual chemicals

** - Cleanup levels take into account exposure to multiple chemicals

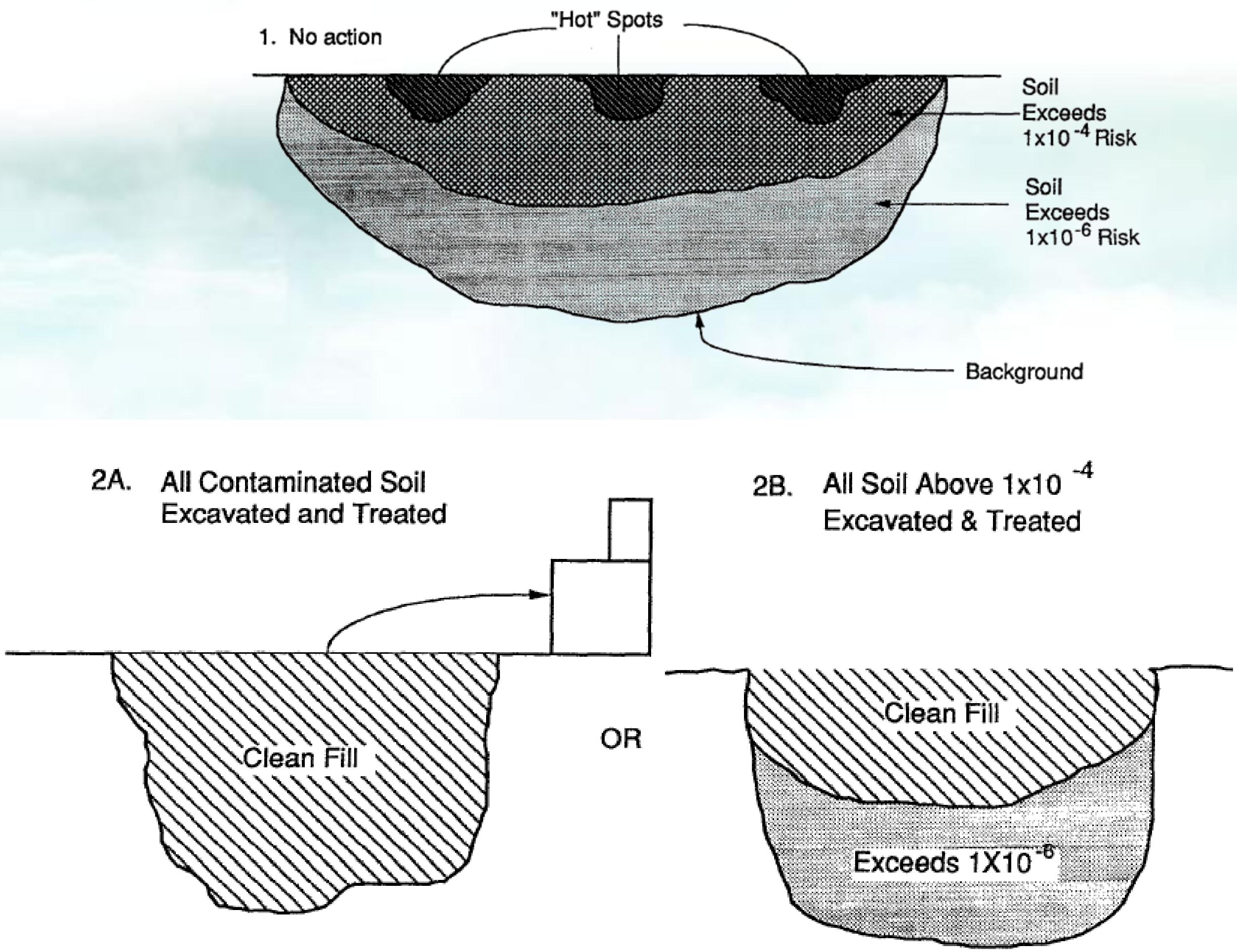
Risk Assessment Application

Remediation Goal Development

- USEPA and state soil screening level
- Netherland soil intervention value/target value
- USEPA preliminary remediation goal



Remedial Actions Planning



Human Health Risk Map

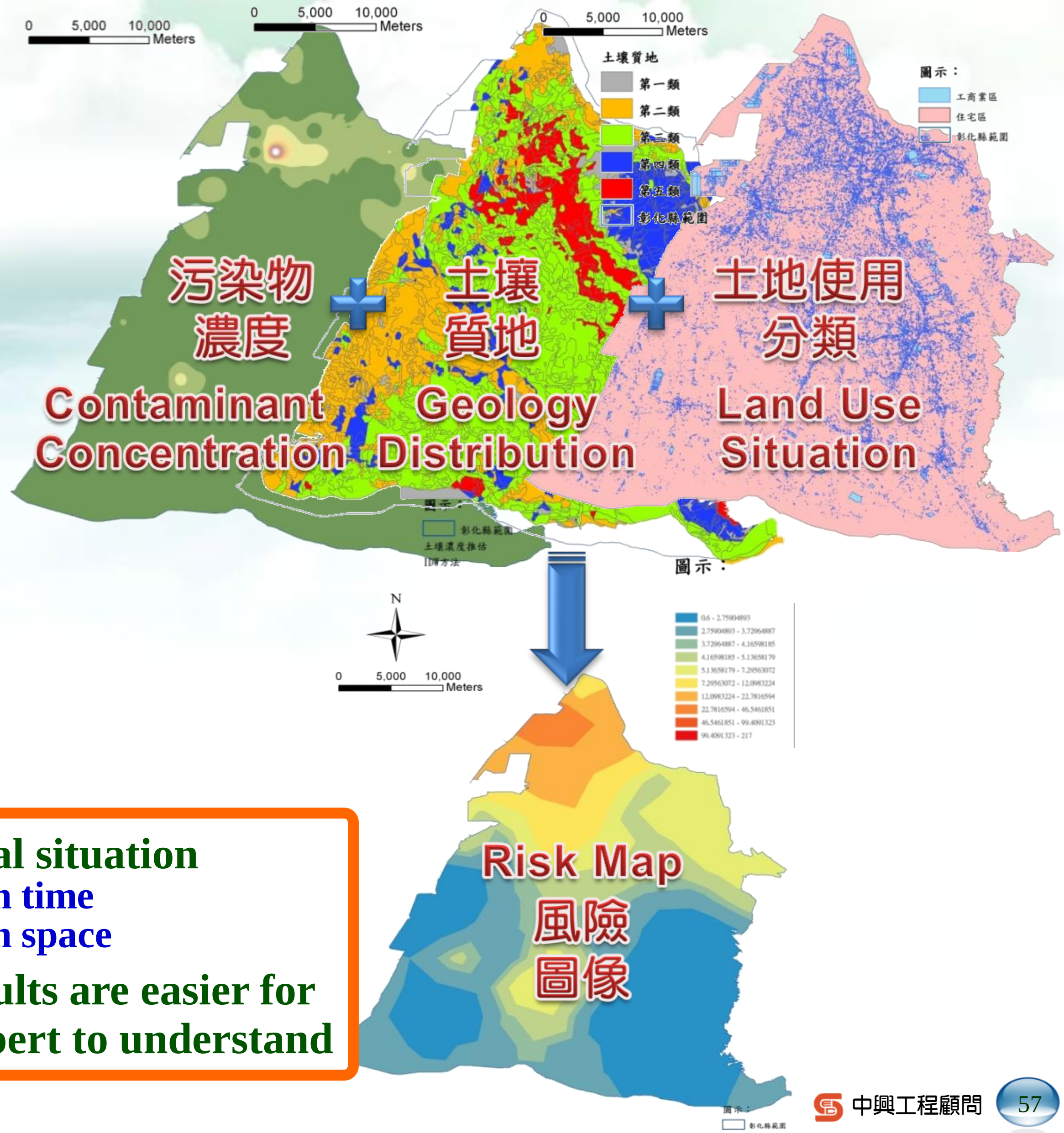
- Currently, it is lacking efficient tool to conduct contaminated site management using risk assessment as the basis
- Starting from 2015, EPA started planning, researching and drafting the guidance and protocols for developing risk maps
- Long term goal is to fully utilize risk map tool for contaminated site management and risk communication

Human Health Risk Map

HHRA Tools and Application

MAIN CONCEPT

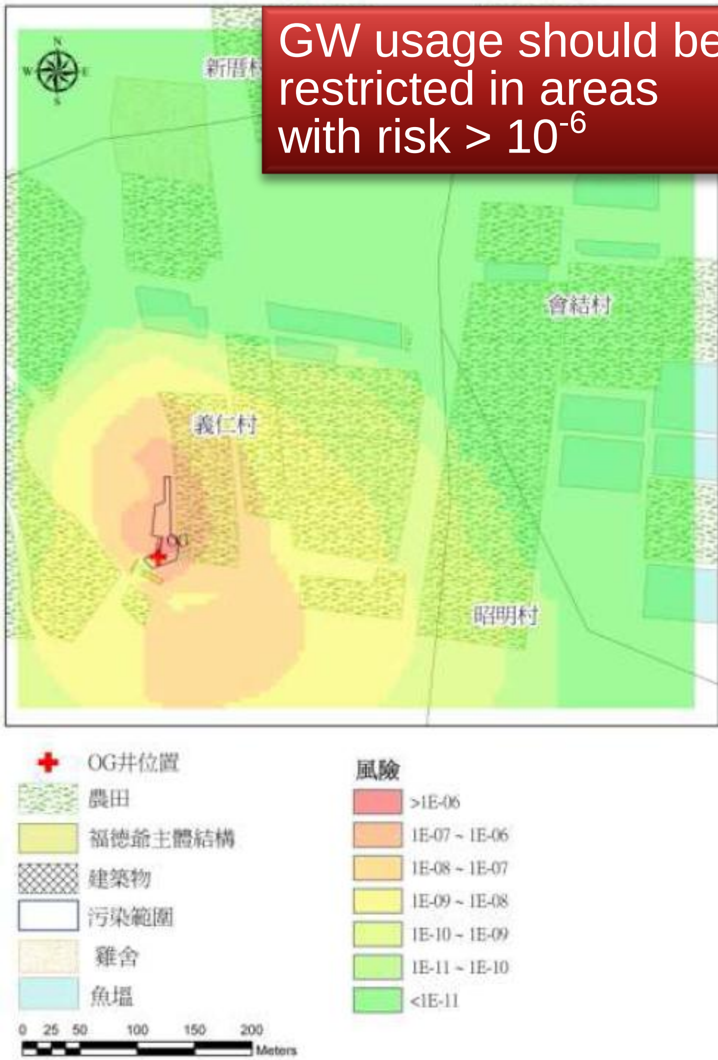
Combine GIS tool and risk assessment calculation, turn single-value risk assessment result into 2-D spatially varied risk assessment result



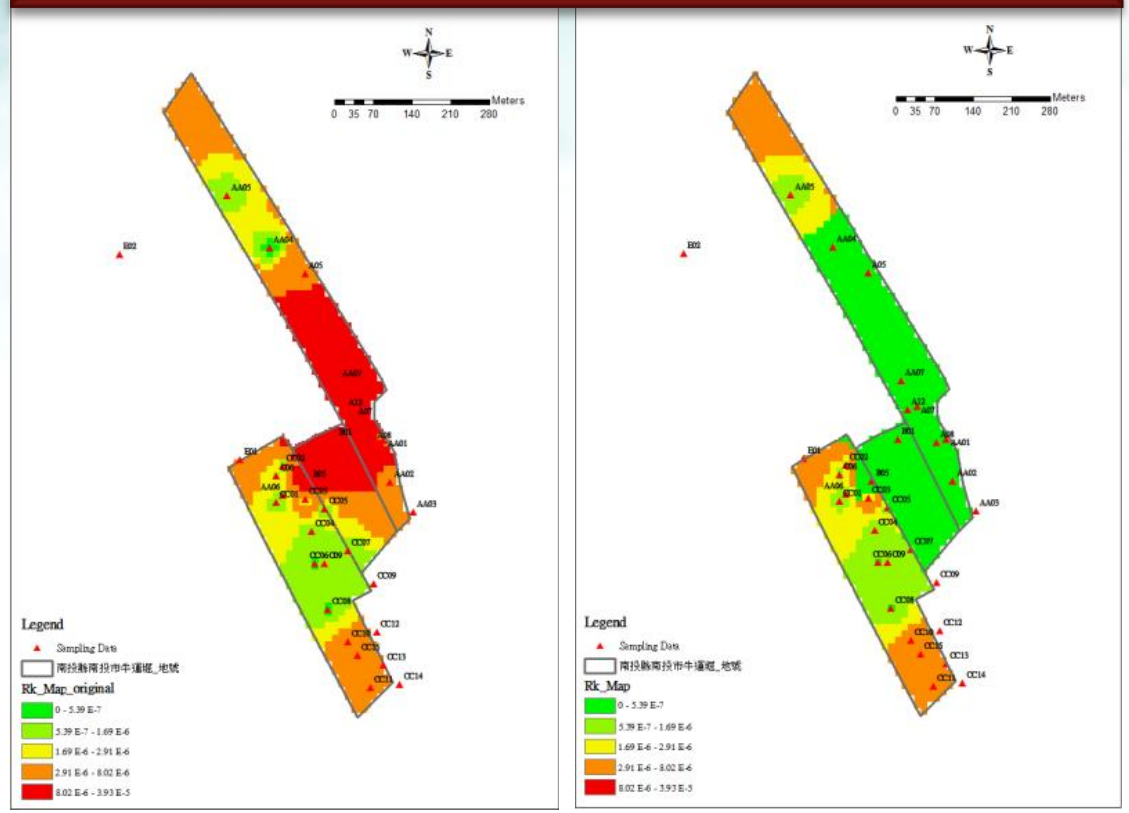
- ✓ **Closer to actual situation**
  - **risk varies with time**
  - **risk varies with space**
- ✓ **Visualized results are easier for public/non expert to understand**

Risk Map Application Example

GW usage should be restricted in areas with risk > 10^{-6}

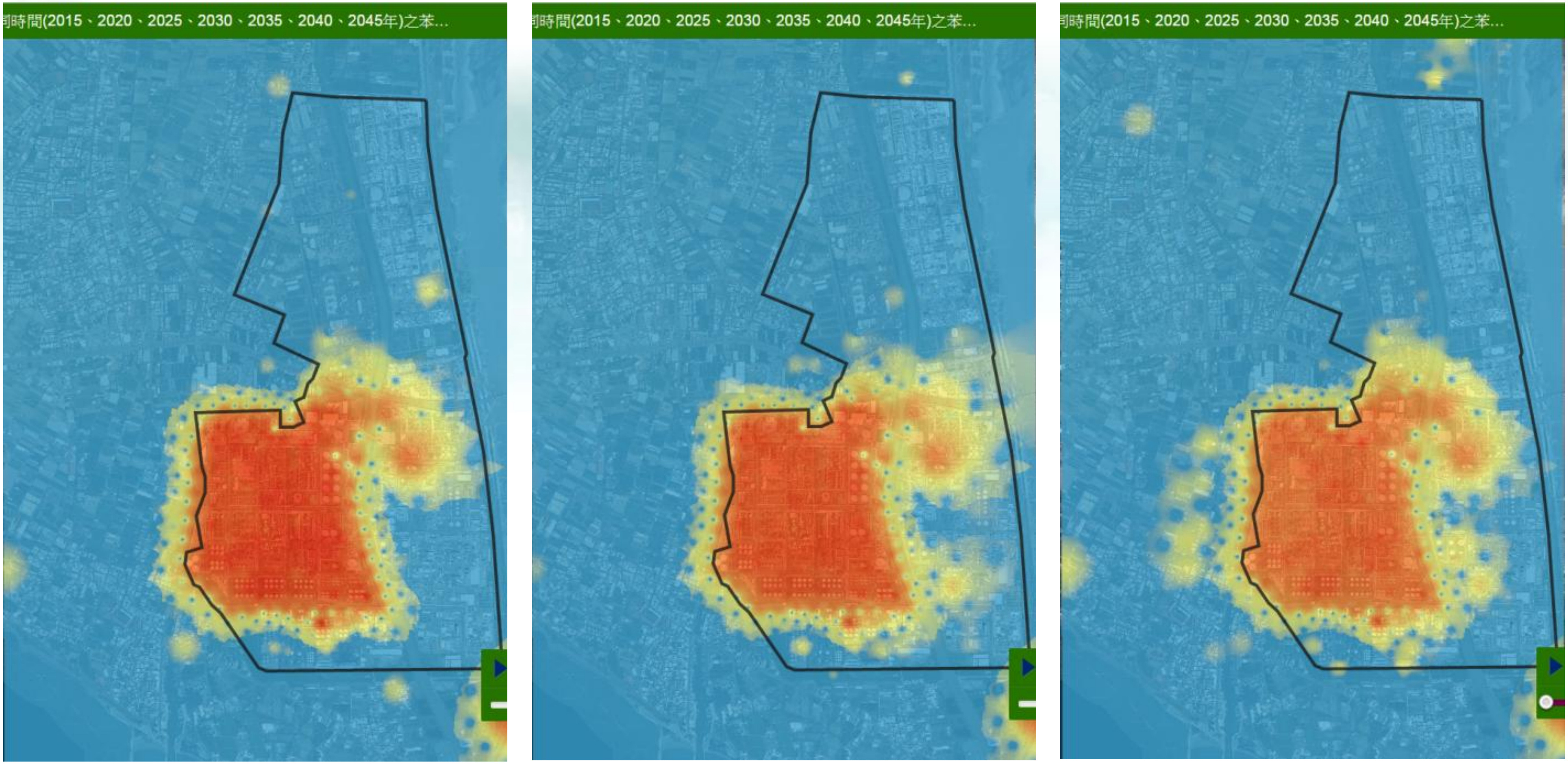


Risk management measures should be planned for the high risk area => restricted land redevelopment



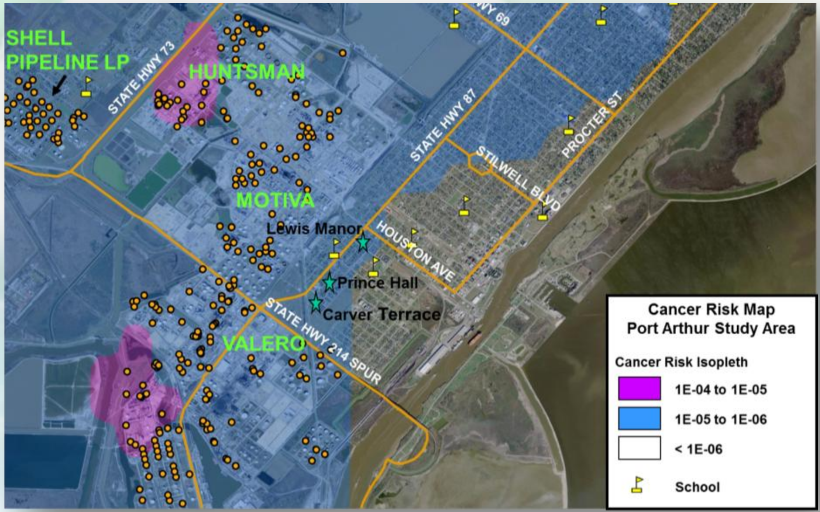
Human Health Risk Map

Health risk changes with time when assuming no remediation is done



Human Health Risk Map

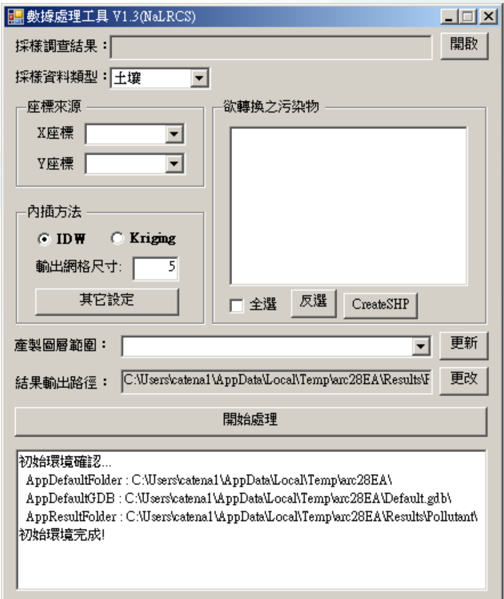
Risk Management Measures Planning Example

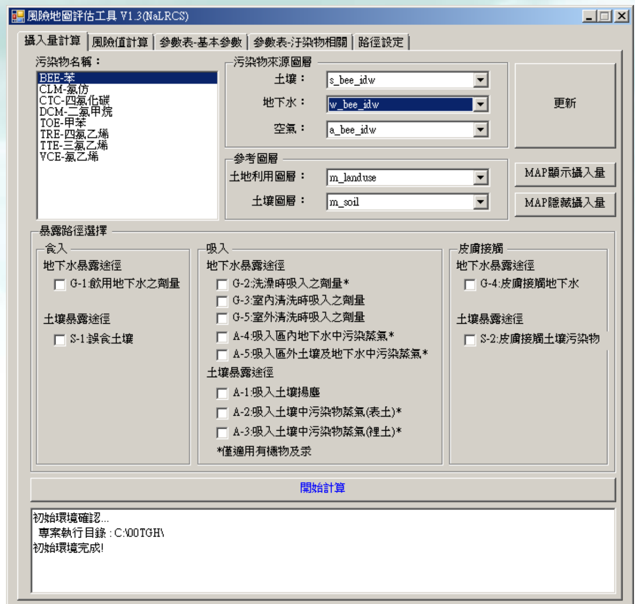


Site	Type	Risk Management Measures	Land Usage after Remediation
A Z decasing company	Battery Reuse and Storage Plant	■ Prohibited constructing senior medical center ■ Prohibited constructing daycare center ■ Prohibited constructing hospital ■ Signing of land usage agreement ■ Prohibited destroying pavement without proper agreement ■ Routinely inspected for cracks ■ Health and safety plan should be drafted before any underground work	Residential

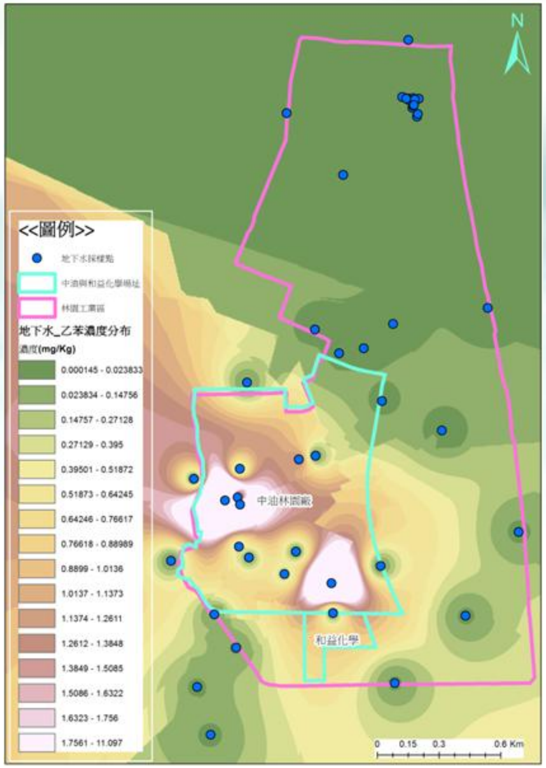
Soil and Groundwater Health Risk Map (still under development)

Data Pre–Treatment Tool → Exposure Dose Assessment Tool → Risk Assessment Tool

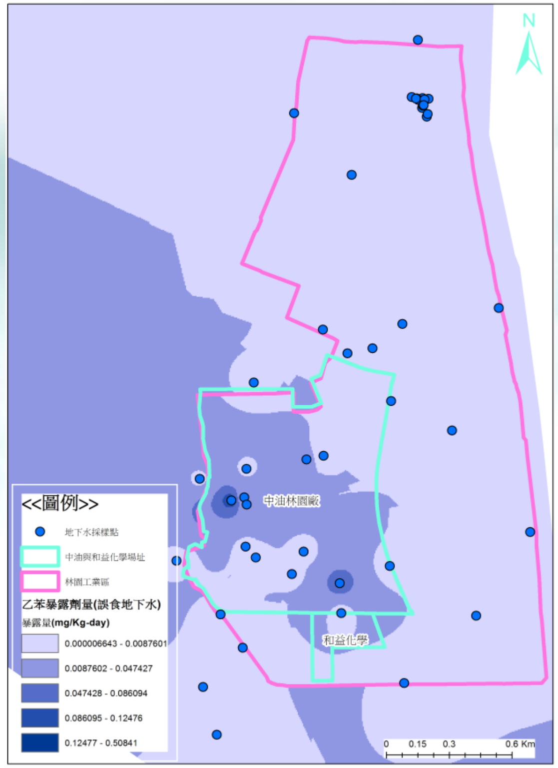




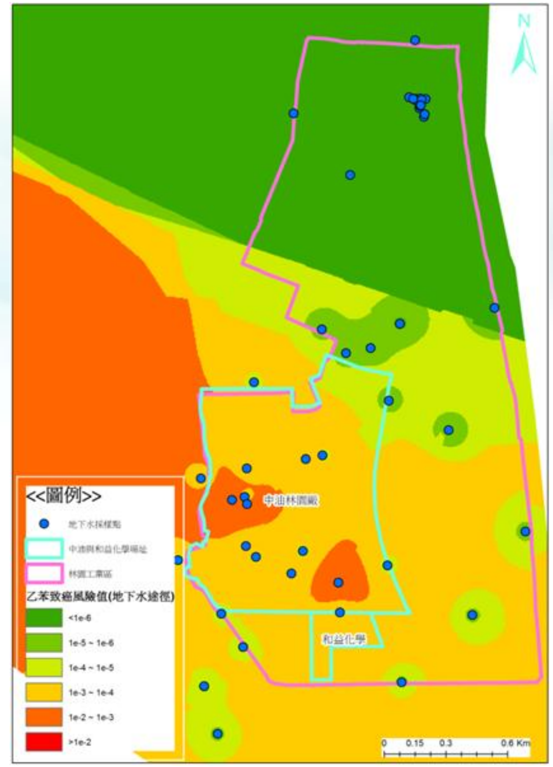
Soil and Groundwater Health Risk Map (still under development)



Groundwater contamination extrapolation and modeling results



Exposure dose for groundwater digestion



Total carcinogenic risk for groundwater

- EPA established online risk assessment system for the ease of conducting risk assessments on contaminated sites
- According to different needs, the system has built-in parameter database for risk calculation; other functions include uncertainty analysis, sensitivity analysis and data distribution test

http://sgw.epa.gov.tw/Risksystem/Default.aspx

Basic System Structure

Project Management

- Start new project
- List of projects(edit existing projects)

Online Risk Assessment

- Risk calculation
- Uncertainty analysis
- Data quality analysis
- Normal distribution test

Parameter Database

- Contaminant parameter
- Default exposure parameter
- Other parameter

Reference

- Risk assessment related links
- Health risk assessment related news/information

- ✓ Start and add new projects
- ✓ Enter project basic information

健康風險評估系統
Health Risk Assessment System

沈穎 您好!! 個人資料 登出!!

專案建立與維護 線上風險運算 參數資料庫 參考資訊 系統管理

- ✓ Search and open old projects under personal account
- ✓ View project basic information or assessment history

專案查詢

專案名稱
所屬帳號
關鍵字搜尋(專案及場址名稱)

搜尋 重設

①

專案列表

②

專案名稱	場址名稱	場址編號	所屬帳號	修改時間	評估紀錄筆數	詳細資料	評估紀錄
TestProject	20150120	20150120	柯欽彬	2015/01/20 11:07	共 1 筆	詳細資料	評估紀錄
test01			賴宜欣	2015/01/21 09:54	共 1 筆	詳細資料	評估紀錄
test02			黃裕仁	2015/01/28 09:40	共 0 筆	詳細資料	評估紀錄
南投示範場址			黃裕仁	2015/01/28 09:47	共 2 筆	詳細資料	評估紀錄
20150128	大園工業區	001	楊慧庭	2015/01/28 10:34	共 2 筆	詳細資料	評估紀錄
test1040204			沈穎	2015/02/04 16:53	共 0 筆	詳細資料	評估紀錄

Select tiered assessment

1

1 選擇專案 | 2 選擇評估層次 | 3 選擇暴露情境 | 4 選擇暴露途徑 | 5 輸入污染物相關資訊 | 6 輸入參數 | 7 開始風險評估 | 8 檢視結果與資料

2

請點選評估層次以進入下一步

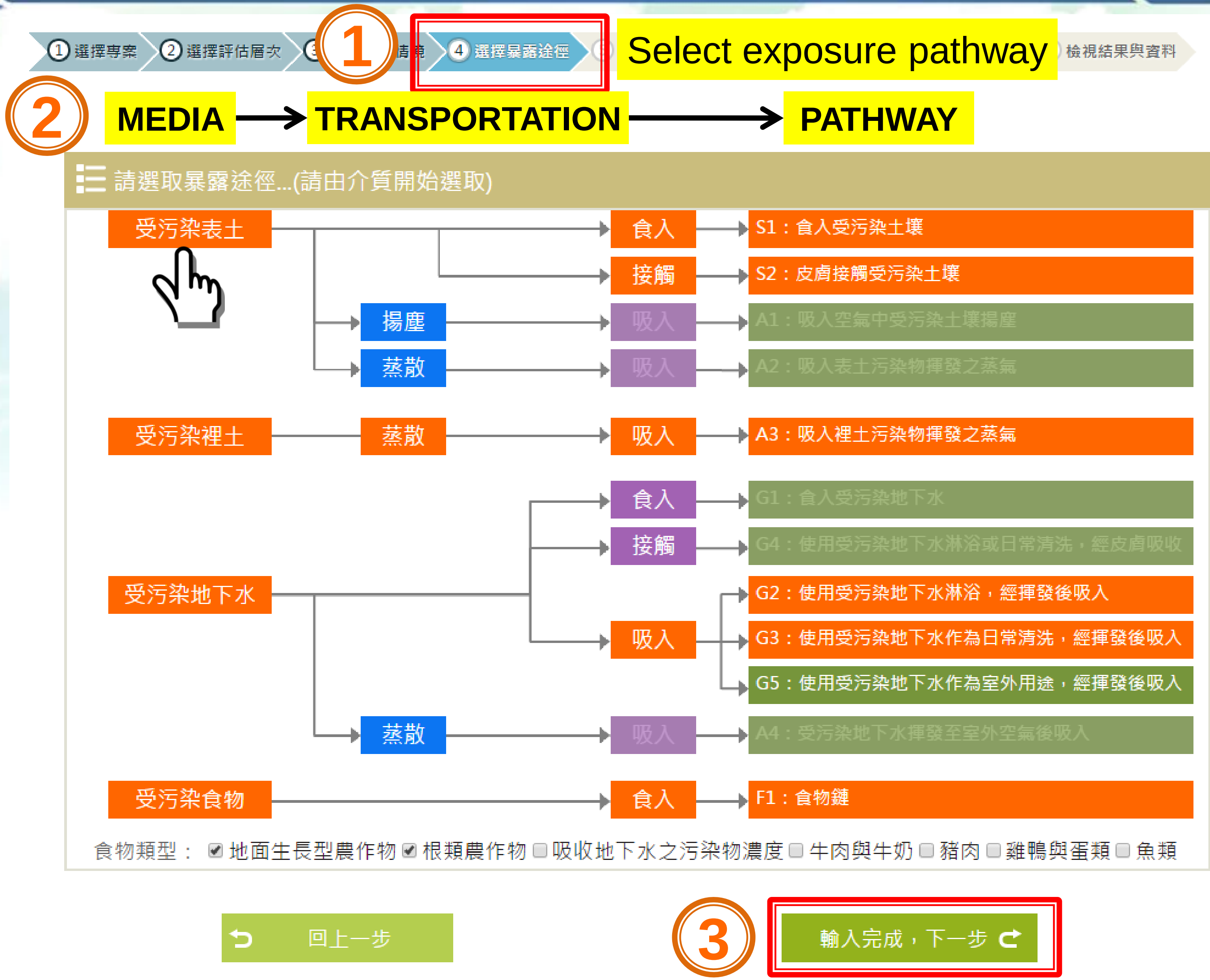
評估層次	第一層次風險評估	第二層次風險評估	第三層次風險評估
受體	僅評估場址內受體	可評估場址內、外受體	可評估場址內、外受體
暴露情境	住宅區及工商業區	住宅區及工商業區	依場址狀況而定
暴露途徑	土壤、地下水、空氣之食入、吸入、皮膚接觸途徑	土壤、地下水、空氣之食入、吸入、皮膚接觸途徑	土壤、地下水、空氣、食物鏈之食入、吸入、皮膚接觸途徑
暴露參數	所有參數皆引用預設參數	僅水文地質參數開放更改，受體及其他參數皆引用預設參數	評估者需自行提出適用於自訂暴露情境及食物鏈使用之特定參數所有參數皆開放更改

✓ If choose to start with new project, select appropriate tier and its associated exposure scenarios, pathways and parameters


Select exposure scenario
1
① 選擇專案
②
③ 選擇暴露情境
④ 選擇暴露途徑
⑤ 輸入污染物相關資訊
⑥ 輸入參數
⑦ 開始風險評估
⑧ 檢視結果與資料
請輸入暴露情境及受體資訊...
2
暴露情境
住宅區
工商業區
受體
場址內
Tier 1
Simple
回上一步
3
輸入完成，下一步
請輸入暴露情境及受體資訊...
暴露情境
住宅區
工商業區
自訂暴露情境
暴露期間ED：
暴露頻率EF：
受體
場址內
場址外(距
公尺)
Tier 3
Complex

Online Human Health Risk Assessment System

HHRA Tools and Application



Online Human Health Risk Assessment System

HHRA Tools and Application

- ✓ Enter COCs, soil or groundwater concentration
- ✓ TPH is mixed compound, thus, it should be entered separately in hydrocarbon fraction format

請輸入污染物採樣資料

增加欄位

關切污染物	土壤(mg/kg)	地下水(mg/L)	刪除資料
加扶保	多筆	多筆	刪除

☐總石油碳氫化合物(TPH)

請輸入多筆污染物採樣濃度

請輸入土壤採樣濃度(mg/kg)

新增

編號	採樣濃度	
1	10	刪除
2	11	刪除
3	12	刪除
4	10.1	刪除
5	10.2	刪除
6	10.3	刪除
7	10.4	刪除

常態分布檢定 檢定結果為 "對數常態分布",評估值採95% ucl = 11.201 (t-distr.)

傳回評估結果

- ✓ Contaminants can be consisted of multiple sampling results
- ✓ System offers normal distribution test and can calculate 95% UCL

Online Human Health Risk Assessment System

HHRA Tools and Application

① 選擇專案 ② 選擇評估層次 ③ 選擇暴露情境 ④ 選擇暴露途徑 ⑤ 輸入污… ⑥ 輸入參數

1 Input parameters

- ✓ Tier 1 only can select soil type
- ✓ All other parameters are default value

- ✓ Tier 2 can enter parameters manually
- ✓ Any modified parameters must state reasons and source

2 請選擇土壤種類：A.砂石質土壤與石礫

水文地質參數

2 3

參數名稱	中文名稱	參數值	單位	參數卡	修改原因、文獻來源說明
δ_{air}	污染源上方空氣混合區高度	200	cm	檢視參數卡	
δ_{gw}	地下水混合層高度	200	cm	檢視參數卡	
f_{oc}	土壤中有機碳含量	依土壤種類而定	g-carbon/g-soil	檢視參數卡	
I	入滲率	依土壤種類而定	cm/year	檢視參數卡	
L_s	土壤污染源頂端深度	100	cm	檢視參數卡	
θ_{as}	土壤中空氣含量	$\theta_T - \theta_{ws}$	cm^3-water/cm^3-soil	檢視參數卡	
θ_T	孔隙度	依土壤種類而定	cm^3/cm^3-soil	檢視參數卡	
θ_{wcap}	毛細管邊緣水分含量	$0.9\theta_T$	cm^3-water/cm^3-soil	檢視參數卡	
θ_{ws}	土壤中水分含量	依土壤種類而定	cm^3-water/cm^3-soil	檢視參數卡	
ρ_s	土壤密度	依土壤種類而定	g/cm^3	檢視參數卡	
U_{air}	污染源上方風速	200	cm/sec	檢視參數卡	
U_{gw}	地下水流速	2500	cm/year	檢視參數卡	

Assessment Results

✓ Results are organized and shown in 4 different tabs

Basic Input Data

風險評估結果

基本輸入資料 | 攝入量計算結果 | 各污染物風險值計算結果 | 各暴露途徑之風險值計算結果

基本資料

污染物項目及濃度資料

代碼	中文名稱	土壤採樣濃度(mg/kg)	地下水採樣濃度(mg/L)	地下水傳輸濃度(mg/L)	空氣傳輸濃度(mg
CUM	銅	1.111E+03	1.000E+00	3.316E-26	2.875E-08
TT2	2,4,6-三硝基甲苯	1.000E+00	1.000E+00	3.316E-26	2.594E-09
DTA	順-1,2-二氯乙烯	1.110E+02	1.000E+00	3.316E-26	2.919E-01
CLM	氯仿	1.000E+00	1.000E+00	3.316E-26	3.219E-03

暴露參數資料

參數代號	參數名稱	參數值	單位
d	表土深度	100	cm
delta_air	污染源上方空氣混合區高度	200	cm
delta_gw	地下水混合層高度	400	cm
foc	土壤中有機碳含量	0.002	g-carbon/g-soil
I	入滲率	31.75	cm/year
Ls	土壤污染源頂端深度	100	cm
Pe	揚塵逸散速率	6.9E-13	g/cm^2-sec
theta_as	土壤中空氣含量	0.31	cm^3-water/cm^3-soil
theta_T	孔隙度	0.43	cm^3/cm^3-soil

Exposure Dose Calculation Result

各污染物攝入量計算結果

污染物代碼	污染物名稱	暴露途徑	攝入量(致癌)	攝入量(非致癌)
CUM	銅	S1	-	1.234E-03
CUM	銅	S2	-	2.989E-05
CUM	銅	A1	-	2.598E-44
CUM	銅	A2	-	無揮發或蒸散途徑
CUM	銅	A3	-	無揮發或蒸散途徑
CUM	銅	G2	-	無揮發或蒸散途徑
CUM	銅	G3	-	無揮發或蒸散途徑
CUM	銅	G5	-	無揮發或蒸散途徑
TT2	2,4,6-三硝基甲苯	S1	3.702E-07	1.111E-06
TT2	2,4,6-三硝基甲苯	S2	2.869E-08	8.608E-08
TT2	2,4,6-三硝基甲苯	A1	7.795E-48	2.338E-47
TT2	2,4,6-三硝基甲苯	A2	4.417E-44	1.325E-43
TT2	2,4,6-三硝基甲苯	A3	7.816E-46	2.345E-45
TT2	2,4,6-三硝基甲苯	G2	3.648E-04	1.094E-03
TT2	2,4,6-三硝基甲苯	G3	3.798E-04	1.139E-03
TT2	2,4,6-三硝基甲苯	G5	7.105E-04	2.131E-03
DTA	順-1,2-二氯乙烯	S1	-	1.233E-04
DTA	順-1,2-二氯乙烯	S2	-	2.986E-05

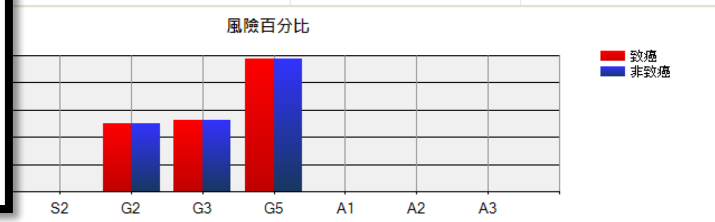
Assessment Results

✓ Health risk calculation results can be displayed by contaminants or by exposure pathways

Risk Assessment Results for Each Pathway

各暴露途徑之風險值計算結果

暴露途徑	致癌		非致癌	
	風險值	風險百分比	風險值	風險百分比
S1：食入受污染土壤	1.481E-08	<0.1%	1.249E+00	<0.1%
S2：皮膚接觸受污染土壤	8.608E-10	<0.1%	5.562E-02	<0.1%
G1：食入受污染地下水	-	-	-	-
G2：使用受污染地下水淋浴，經揮發後吸入	8.511E-04	25.1%	3.564E+02	25.0%
G3：使用受污染地下水作為日常清洗，經揮發後吸入	8.861E-04	26.1%	3.711E+02	26.1%
…日常清洗，經皮膚吸收	-	-	-	-
…用途，經揮發後吸入	1.658E-03	48.8%	6.942E+02	48.8%
…	6.964E-49	<0.1%	9.357E-42	<0.1%
…	1.629E-43	<0.1%	6.706E-38	<0.1%
…	7.856E-41	<0.1%	2.645E-35	<0.1%
…氣後吸入	-	-	-	-
	-	-	-	-
總合	3.395E-03		1.423E+03	



Risk Assessment Results for Each Contaminant

風險評估結果

基本輸入資料 | 攝入量計算結果 | 各污染物風險值計算結果 | 各暴露途徑之風險值計算結果

各污染物風險值計算結果

污染物代碼	關切污染物	致癌風險值					非致癌風險值				
		土壤	地下水	空氣	食物鏈	總合	土壤	地下水	空氣	食物鏈	總合
CUM	銅	-	-	-	-	-	1.286E+00	-	9.084E-42	-	1.286E+00
TT2	2,4,6-三硝基甲苯	1.197E-08	1.213E-05	3.750E-46	-	1.215E-05	2.393E-03	2.425E+00	7.493E-41	-	2.427E+00
DTA	順-1,2-二氯乙烯	-	-	-	-	-	1.531E-02	1.416E+03	2.644E-35	-	1.416E+03
CLM	氯仿	3.702E-09	3.383E-03	7.872E-41	-	3.383E-03	1.380E-04	3.132E+00	7.289E-38	-	3.132E+00

健康風險評估系統
Health Risk Assessment System

沈穎 您好!! 個人資料 登出!!

專案建立與維護 線上風險運算 參數資料庫 參考資訊 系統管理

Uncertainty Analysis

✓ Select parameter and distribution type

1

Parameter	參數名稱	參數值	分布類型	進行不確定分析
BW_{adult}	體重(成人)	61.67	常態分布	☑
BW_{child}	體重(孩童)	17	常態分布	☑
EF	暴露頻率，一年暴露的天數	350	常態分布	☑
$IR_{soil\text{-}orl\text{-}adult}$	攝食土壤速率(成人)	100	常態分布	☑
$IR_{soil\text{-}orl\text{-}child}$	攝食土壤速率(孩童)	200	常態分布	☑
WHF	每天用水流量	1000	常態分布	☑
ER	室內換氣率	21.6	常態分布	☑
Q	使用水源之水流速率	30	常態分布	☑

Distribution Type：
1.Normal
2.Triangular
3.Uniform
4.Log-normal

2

下一步(Step 2)

2:設定分布參數

1

常態分布

參數名稱	平均值	標準偏差
體重(成人)	61.57	10
體重(孩童)	17	2
暴露頻率	350	10
攝食土壤速率(孩童)	200	10

均勻分布

參數名稱	最大值	最小值
室內換氣率	30	20
每天用水流量	2000	500

三角型分布

參數名稱	上限	低限	
攝食土壤速率(成人)	200	50	100

對數常態分布

參數名稱	平均值	標
使用水源之水流速率	30	3

回分布型態選擇

2

下一步(Step 3)

3

3:設定不確定性分析次數

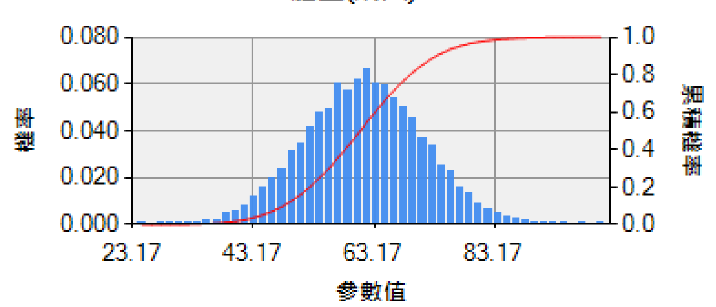
不確定性分析次數(5,000~20,000)： 10000

回分布參數設定　進行不確定性分析

Uncertainty Analysis

- ✓ According to type of distribution, entering required input accordingly, i.e. mean, SD, maximum, minimum, etc.
- ✓ # of analysis can be performed between 5,000~20,000 times

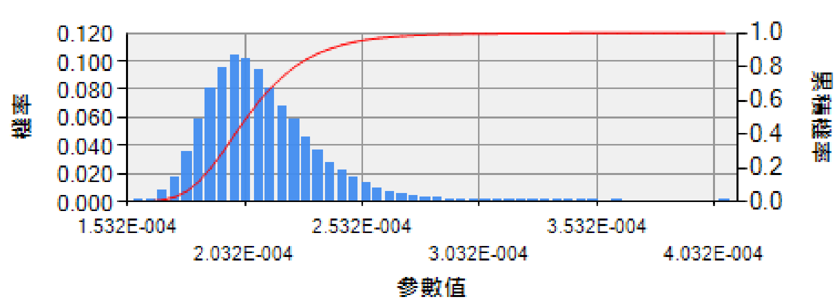
參數值分布型態



風險值不確定性分析結果

1.76E-004 LCL < 95 %信賴區間 < 2.66E-004 UCL

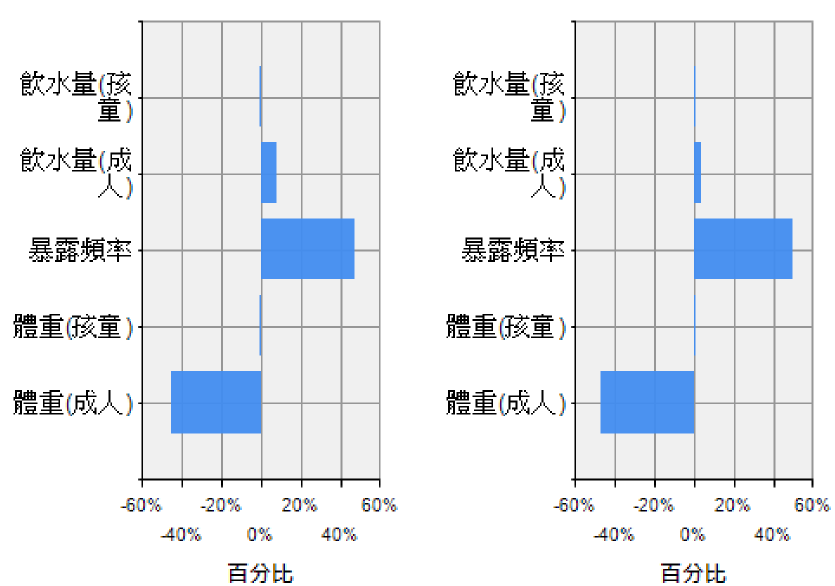
致癌最高機率風險值為1.99E-004



Uncertainty Analysis

- ✓ Enter desired confidence level manually
- ✓ Analysis results can be shown in probabilistic distribution

風險值參數敏感性分析結果



Online Human Health Risk Assessment System

Parameter Database

- ✓ Parameters are grouped into 3 categories： contaminants, exposure and other parameters
- ✓ More than 80 soil & groundwater contaminants related parameters
- ✓ Can be filtered by key words or contaminants characteristics, i.e. organic compound, carcinogenic, etc.

污染物參數詳細資料表

代碼: DDT			
中文名稱:	二氯二苯基三氯乙烷及其衍生物	英文名稱:	DDT,4-Dichlorodiphenyl-trichloroethane
CAS Number:	50-29-3		
IARC致癌性分類:	Group 2B	IRIS致癌性分類:	B2
地下水管制標準值/第二類(mg/L):	-1	地下水管制標準值/第一類(mg/L):	-1
土壤管制標準值(mg/Kg):	3	為食用作物之農地管制標準:	-1
致癌性(以IARC分類判定為主):	☑	非致癌毒性:	☑
滲透係數(Kp*):	0.27	Bdermal值:	1.9
tevent:	10.45	FA:	0.7
ABSd:	0.03	H:	0.000341
Koc:	2630000	Kd:	-1
Dair:	0.0137	Dwat:	4.95E-06
S(溶解度)	0.025	是否為有機物:	☑
非致癌毒性因子(RfD)/口服(oral):	0.0005	非致癌毒性因子(RfD)/口服(oral)來源:	-1
非致癌毒性因子(RfD)/吸入(inhal):	0.0005	非致癌毒性因子(RfD)/吸入(inhal)來源:	-1
非致癌毒性因子(RfD)/皮膚吸收(dermal):	0.0005	非致癌毒性因子(RfD)/皮膚吸收(dermal)來源:	-1
致癌毒性因子(SF)/口服(oral):	0.34	致癌毒性因子(SF)/口服(oral)來源:	-1
致癌毒性因子(SF)/吸入(inhal):	0.34	致癌毒性因子(SF)/吸入(inhal)來源:	-1
致癌毒性因子(SF)/皮膚吸收(dermal):	0.34	致癌毒性因子(SF)/皮膚吸收(dermal)來源:	-1
屬於總石油碳氫化合物(TPH):	☐		
備註:			

是否啟用: ☑

編輯 刪除

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Parameter Database

- ✓ Detailed contaminant data sheet includes control standards, toxicity factors, exposure parameters, physico-chemical parameters, etc.

Parameter Database

- ✓ Under default exposure parameter data sheet, detailed parameter information, source and data quality can be examined

參數類型 受體之暴露參數

暴露途徑參數資料

名稱	中文名稱	參數值	單位	詳細資料	其它
AF_{adult}	土壤對皮膚之吸附係數(成人)	0.07	mg/cm^2	詳細資料	參數卡 參數品質
AF_{child}	土壤對皮膚之吸附係數(孩童)	0.2	mg/cm^2	詳細資料	參數卡 參數品質
B_{adult}	淋浴呼吸速率	1	$m^3/hour$	詳細資料	參數卡 參數品質
B_{child}	淋浴呼吸速率	0.58	$m^3/hour$	詳細資料	參數卡 參數品質
			kg	詳細資料	參數卡 參數品質 統計參數
			kg	詳細資料	參數卡 參數品質 統計參數

參數詳細資料

參數名稱	AF_adult
中文名稱	
參數值	
單位	
備註	
參數文獻來源	
參數文獻發表年份	
參數資料型態	
參數資料發表單位	
資料調查區域特性	
資料母體類型	
資料調查目的	
資料調查年齡層	
參數資料發表單位分類	

編輯

回上一

參數來源說明

(土壤對皮膚之吸

一、參數名稱：土壤對皮膚之吸附係數(AF)
二、評析原則數值：成人：0.2 mg/cm²，孩童：0
三、評析原則使用數值來源：目前採用之數值是「Preliminary Remediation Goal PRG Intercalc 中所引用之數值。
四、國內本土化更新數值來源：略。
五、國外最新數值來源：略。
六、參考資料
1. Preliminary Remediation Goal PRG Interca USEPA Region 9 Office, 2004.

參數基本資料

參數項目/代號	土壤對皮膚之吸附係數(成人) / AF_{adult} 新增參數品質資料
目前系統預設值	0.07 mg/cm^2

歷次品質評估列表

無資料!!

參數品質詳細資料

參數項目/代號	土壤對皮膚之吸附係數(成人) / AF_{adult}		
原參數值		原參數積分	
更新文獻基本資料	名稱：	年份：	
更新參數值			

評定項目	評估級距分數 5分計	3分計	0分計	小計
資料公告/發表單位	政府機關	大型研究機構	非政府機關或大型研究機構	0
調查區域之特性	本國地區	生活型態相近之國家或區域	生活型態非相近之國家或區域	0
調查母體之代表性	全國性	區域/地區性	無法判別/不適用	0
調查母體之年齡層	與評析方法之受體設定一致	與評析方法之受體設定部分一致	與評析方法之受體設定部分不一致	0

Reference

- ✓ Links to other toxicity information database or risk assessment related guidance documents

Conclusion

Conclusion

1. Risk assessment is established on the basis of toxicology, biological testing, contaminant transport model simulation, etc. This systematic, quantifiable evaluation tool is not an accurate science but still can be used in site management decision making.
2. SGPRA is one of the few laws or regulations that includes risk assessment concept and assign it a clear and specific role.

Conclusion

3. Risk assessment involves with many assumption and test results. Quantify the possible adverse effect helps the communication between government and public.

4. Risk assessment is only an assessment tool. In order to reach the goal of protecting human health and environment, risk assessment must be combining with proper and sufficient risk communication and risk management.

Thank you for your time!

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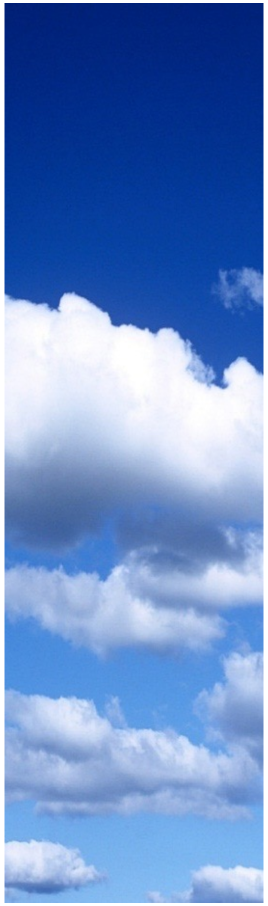
International Workshop on Soil and Groundwater Remediation, 2016, Taipei, Taiwan



Case Studies in Application of HHRA to Contaminated Site Management

Chih Huang, Ph.D., P.E., P.M.P.
General Manager
InnoFusion Environmental Management (iFEM)

iFEM

Outline

- About Human Health Risk Assessment (HHRA)
- Myth about Acceptable Risk
- Application in Contaminated Site Management
- Case Study

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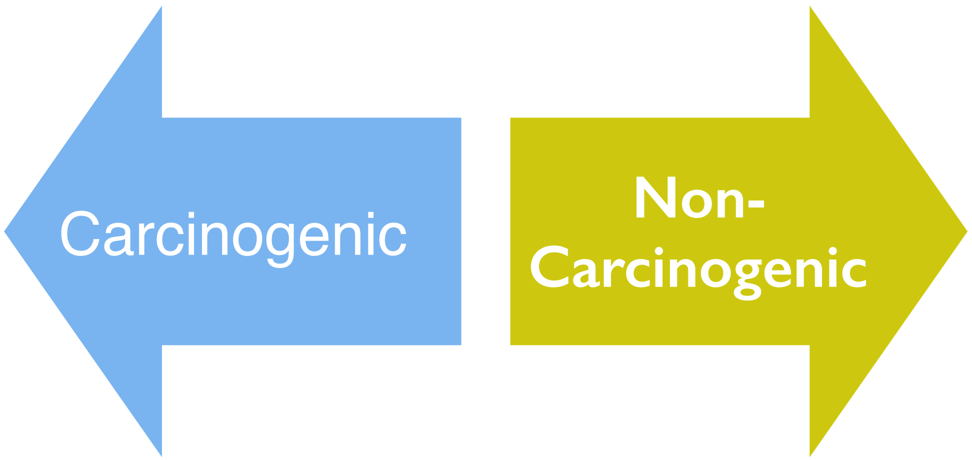
About HHRA

- What is risk
  - Risk
    - Probability of the occurrence of adverse consequence (injury, illness, or even death)
    - Quantitative concept
  - Human Health Risk
    - Probability of illness and death caused by the hazardous materials (e.g., contaminants)



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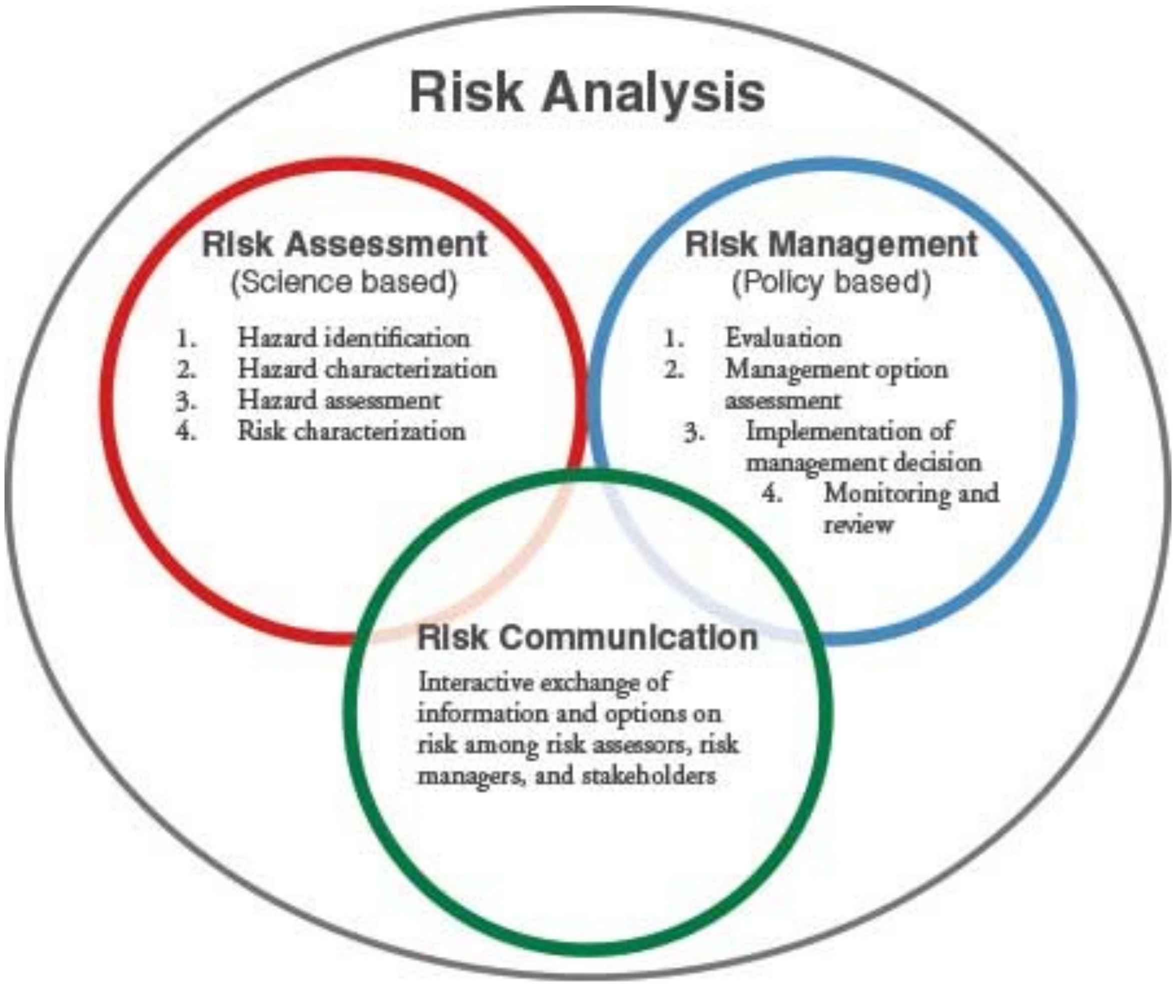
About HHRA

- Role of Risk Assessment
  - A scientific tool within risk analysis system



About HHRA

- The occurrence of risk consists of three elements

S-P-R Model

About HHRA

- Basic Concept and Framework

Hazard Identification

Examines whether a stressor has the potential to cause harm to humans and/or ecological systems, and if so, under what circumstances.

Dose Response Assessment

Examines the numerical relationship between exposure and effects

Exposure Assessment

Examines what is known about the frequency, timing, and levels of contact with a stressor.

Risk Characterization

Examines how well the data support conclusions about the nature and extent of the risk from exposure to environmental stressors

About HHRA

- hazard identification
  - Define CoC
  - Site (assessment) boundary
- dose-response assessment
  - Toxicity information
  - Define toxicity factors to be uses (carcinogenic slope factor and non-carcinogenic reference dose)
- exposure assessment
  - Site conceptual model (SCM)
  - Fate and transport of CoCs
  - Intake
- risk characterization
  - Carcinogenic risk and non-carcinogenic hazard index
  - Uncertainty analysis

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About HHRA

- Sources of uncertainty
  - One value representing the risk (non probabilistic)
  - conservative assumption (often over-conservative)

Hazard identification
- completeness of site information

Exposure assessment
- transport of contaminants
- model selection
- exposure parameters

Dos-response assessment
- toxicity factors
- interaction of contaminants

Risk characterization
- interaction of toxicity
- rationale of acceptable risk

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Risk Assessment Objectives

- Assessment target
  - Potential effects on human (public) health by the soil and groundwater contamination
- Objectives
  - Decision makers: decisions on remediation and management measures to protect environment and human health
  - Polluters: Implementation of cost-effective risk management to protect environment and human health
  - Public: Understand the risk and appropriateness of the risk management strategy so that rational demands can be proposed based on proper benefits

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Myth About Acceptable Risk

- General accepted rules
  - carcinogenic risk: 1×10^{-6}
  - non-carcinogenic (hazard index, HI): 1
- Two dimensional drivers
  - Objective definition
    - quantitative risk
    - scientific based
  - Subjective perception
    - Public awareness and knowledge
    - social based

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Myth About Acceptable Risk

- A research in 1991 tried to reveal the myth or origin of acceptable risk (1×10^{-6})

Agencies

- The White House
- The U.S. Environmental Protection Agency (EPA)
- The EPA's Science Advisory Board
- The EPA's Risk Assessment Forum
- The U.S. Food and Drug Administration (FDA)
- The U.S. Department of Agriculture
- The U.S. Conference of Mayors
- Oak Ridge National Laboratories
- The Congressional Office of Technology Assessment
- The Natural Resources Defense Council
- Citizen's Clearinghouse for Hazardous Waste
- Greenpeace
- Two former EPA Administrators
- A former state environmental commissioner
- Rockefeller University
- Environmental divisions of major law firms
- Staff members of several Congressmen
- And many other contacts in government and industry

Responses

- "My mind is a complete blank."
- "My, what an interesting question!"
- "I think it came from pesticides legislation or the Delaney Clause."
- "It came from the FDA in the 1950s."
- "It was derived from the Virtually Safe Dose used in the Safe Drinking Water Act."
- "It's an economic criterion."
- "It's based on the chance of being hit by lightning, which is one in a million."
- "I just assumed it was because one-in-a-million sounded like such a nice phrase."
- "It was selected because it was 'doable.' Or at least that's what we thought at the time."
- "It was a purely political decision made by several of the major agencies behind closed doors in the 1970s. I doubt very much you'll get anyone to talk to you about it."
- "You really shouldn't be asking these questions"

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Myth About Acceptable Risk

- Phrases about acceptable risk
  - Lower than a specific value
  - (much) lower than existing risk
  - Cost for lowering the risk less than benefit
  - Experts recognize/endorse the risk to be acceptable
  - Public say acceptable (no objection)

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TPH-The Characteristics

- Methodology
  - Similar to single contaminant risk assessment

- CoC
  - Benzene, Toluene, Ethylbenzene, Xylene (BTEX)
  - Naphthalene
  - Total Petroleum Hydrocarbons (TPH)

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TPH-The Characteristics

- Property of TPH
  - Structural complex
  - Wide spectrum of carbon numbers
  - Difference resulted from refinery process

- Challenges
  - Difficult to conduct ALL compounds individually
  - Employ method for mixture
    - More toxic compounds (indicator)
    - Divide into different ranges of carbon number (fraction)

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TPH-Conducting the Assessment

- Hazard Identification
  - Toxicity and physical chemical properties vary with the number of carbon of compounds
  - Divided into aliphatic and aromatic
  - Major carcinogenic components
    - smaller oxidant
    - aromatic

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TPH-Conducting the Assessment

- Dose-Response Assessment
  - Lack of TPH mixture toxicity data
  - TPHCWG recommended to divide TPH into 6 groups and compiled existing researches to obtain reference dose for the 6 groups

Structural Group	Carbon Number	RfD (mg/kg/day)		
		Ingestion	Inhalation	Dermal
Aliphatic	$C_{5\text{-}8}$	5.00×10^{0}	5.26×10^{0}	4.00×10^{0}
	$C_{>8\text{-}16}$	1.00×10^{-1}	2.86×10^{-1}	8.00×10^{-2}
	$C_{>16\text{-}35}$	2.00×10^{0}	NA	1.00×10^{0}
Aromatic	$C_{5\text{-}8}$	2.00×10^{-1}	4.00×10^{-1}	1.60×10^{-1}
	$C_{>8\text{-}16}$	4.00×10^{-2}	2.00×10^{-1}	3.20×10^{-2}
	$C_{>16\text{-}35}$	3.00×10^{-2}	NA	1.50×10^{-2}

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TPH-Conducting the Assessment

- Dose-Response Assessment
  - TPHCWG recommended to use representative components for carcinogenic risk assessment (including benzene and PAH)

CoC	CAS Number
Benzene	71-43-2
Toluene	108-88-3
Ethylbenzene	100-41-4
Xylenes	1330-20-7
Total Naphthalene	91-20-3
n-Hexane	110-54-3
MTBE	1634-04-4
Ethylene Dibroide (EDB)	
1,2 Dichloroethane (EDC)	107-06-2
Benzo(a)anthracene	56-55-3
Benzo(b)fluorancthene	205-99-2
Benzo(k)fluoranthene	207-08-9
Benzo(a)pyrene	50-32-8
Chrysene	218-01-9
Dibenzo(a,h)anthracene	53-70-3
Indeno(1,2,3-cd)pyrene	193-39-5

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TPH-Conducting the Assessment

- Exposure Assessment
  - Follow the general principles of risk assessment
  - TPHCWG compiled physical-chemical properties for the six groups
    - solubility
    - vapor pressure
    - Log K_{oc}
    - boiling point
    - Henry's constant
    - Molecular weight
    - Diffusivity in air
    - Diffusivity in water

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TPH-Conducting the Assessment

- Risk characterization
  - From exposure and dose-response assessment
  - Higher uncertainty
  - Uncertainty analysis is similar to single compound
- Challenges
  - Regulatory rationale
  - Acceptable risk or not
  - Public acceptance
  - Technical and scientific sound or not
  - Availability of tool (e.g., standard analytical method)

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Application in Contaminated Site Management

- Principles of risk management
  - Employ proper remediation and institutional control to unlink/ mitigate the S-P-R
- Non-technical factors
  - comply with regulatory requirement
  - avoid future liability
  - planning for future use of land
  - cost effective remediation or measures

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Application in Contaminated Site Management

- HHRA Applied in
  - The environmental impact and risk by different remedy strategies and subsurface contamination
  - Land use strategy and condition
  - With the risk identified, assessing the risk in space, remedy effectiveness, and remediation time needed
  - Remediation decision making
  - Regulatory decision

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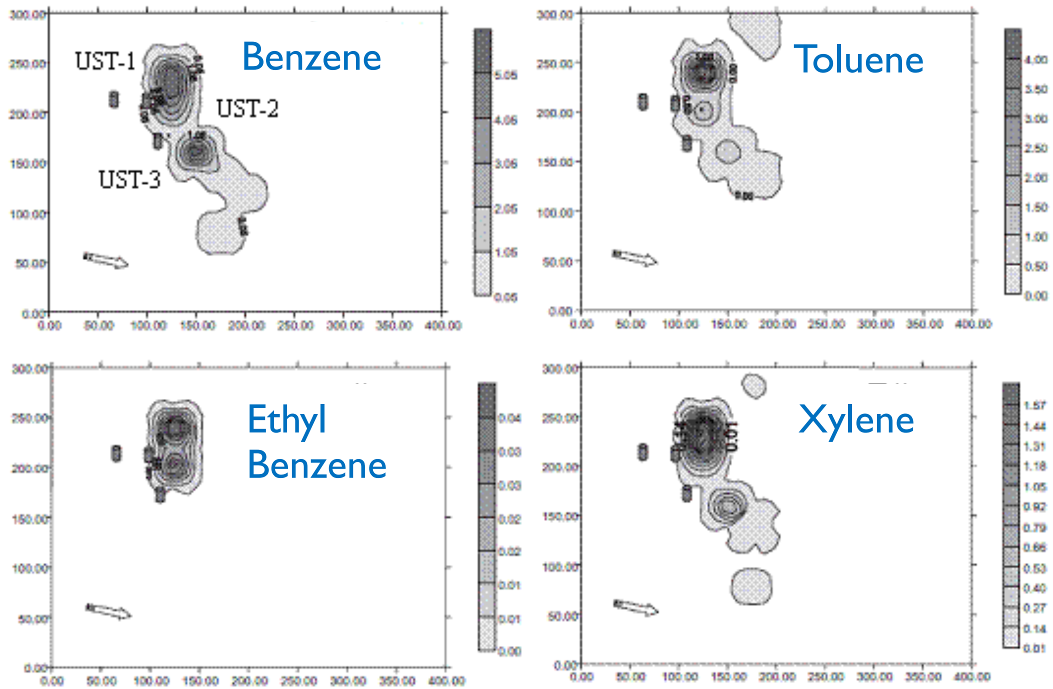
Case Study-Remediation Decision Making

- Site
  - Natural Gas Manufacturing Plant in Canada
- CoC
  - Total Petroleum Hydrocarbons (TPH)
  - BTEX



Objective

What happen in subsurface?
What impacts there exist?

What to do?
How to do it?
How much to spend?

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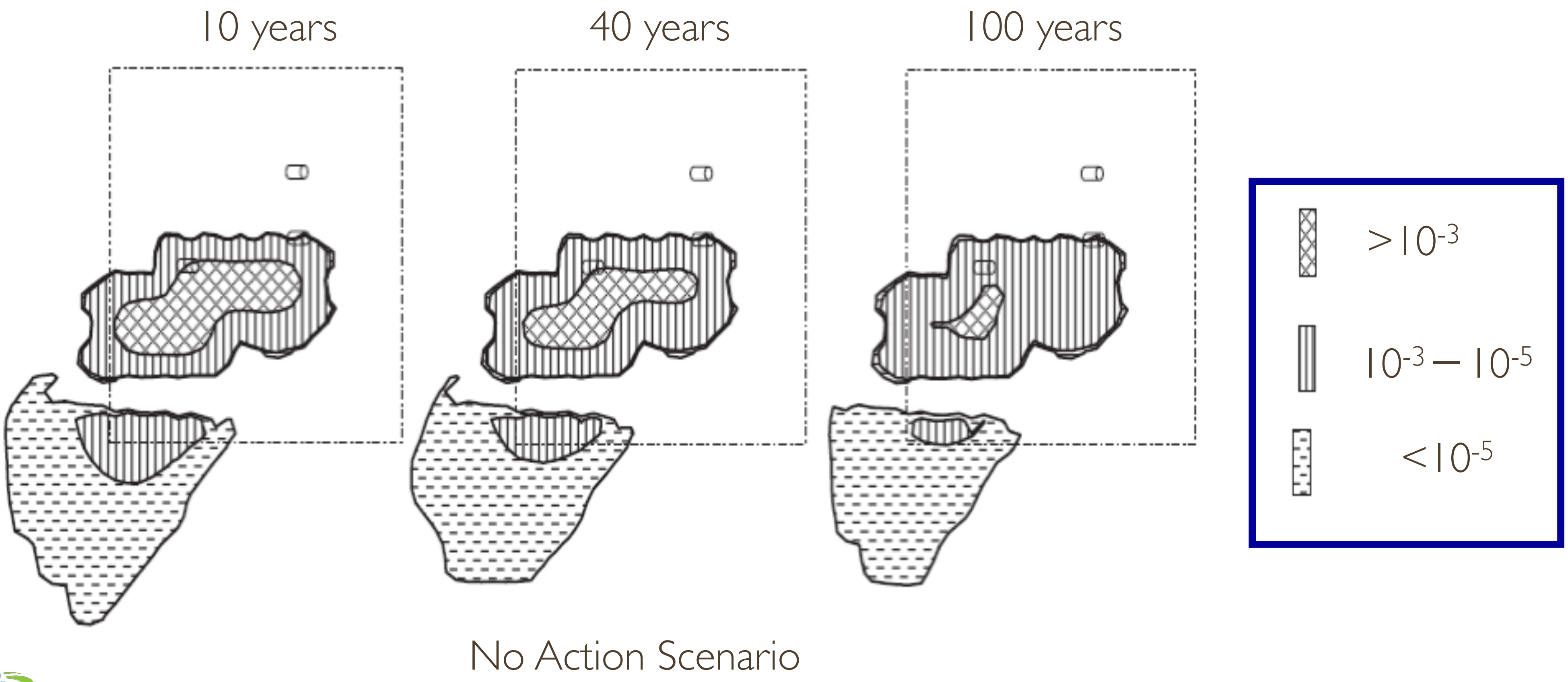
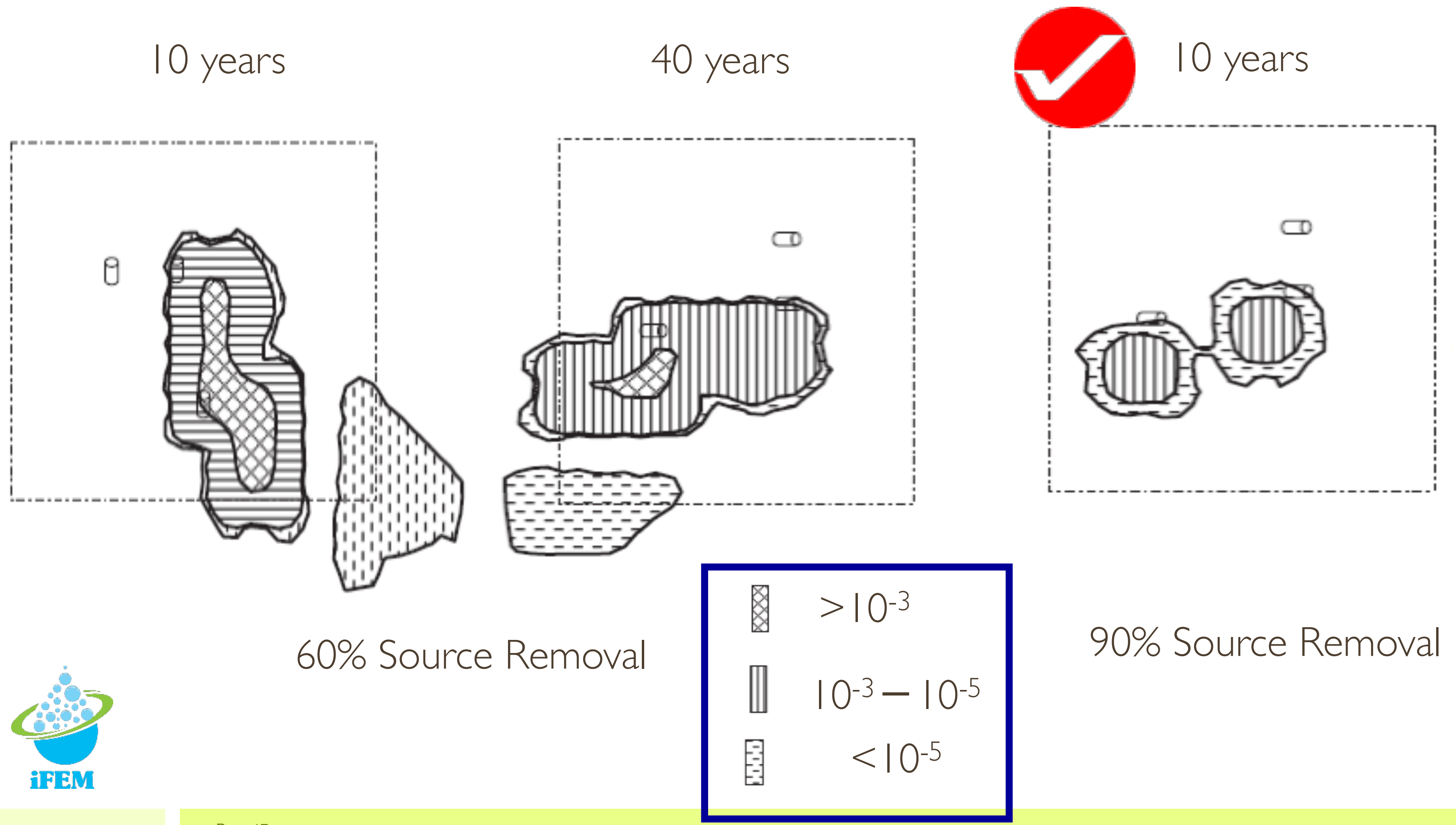
Case Study-Remediation Decision Making

- HHRA and baseline assessment



Case Study-Remediation Decision Making

- HHRA and different remediation scenario assessment



Case Study-Remediation Decision Making

- Risk management and remedy decision considerations
  - To close the site in a reasonable time frame, excavation the source is a necessary measure
  - Integrated remediation strategy is needed (treatment-train)
  - Clustered management
  - Prohibit use of groundwater
- Remediation strategy assessment
  - Excavation and Landfarming
  - Excavation+SVE+*in-situ* bioremediation
  - Excavation and Landfarming+AS/SVE+*in-situ* bioremediation
  - Excavation and Low-Temperature Desrpption+*in-situ* Bioremediation

Technically Feasible?

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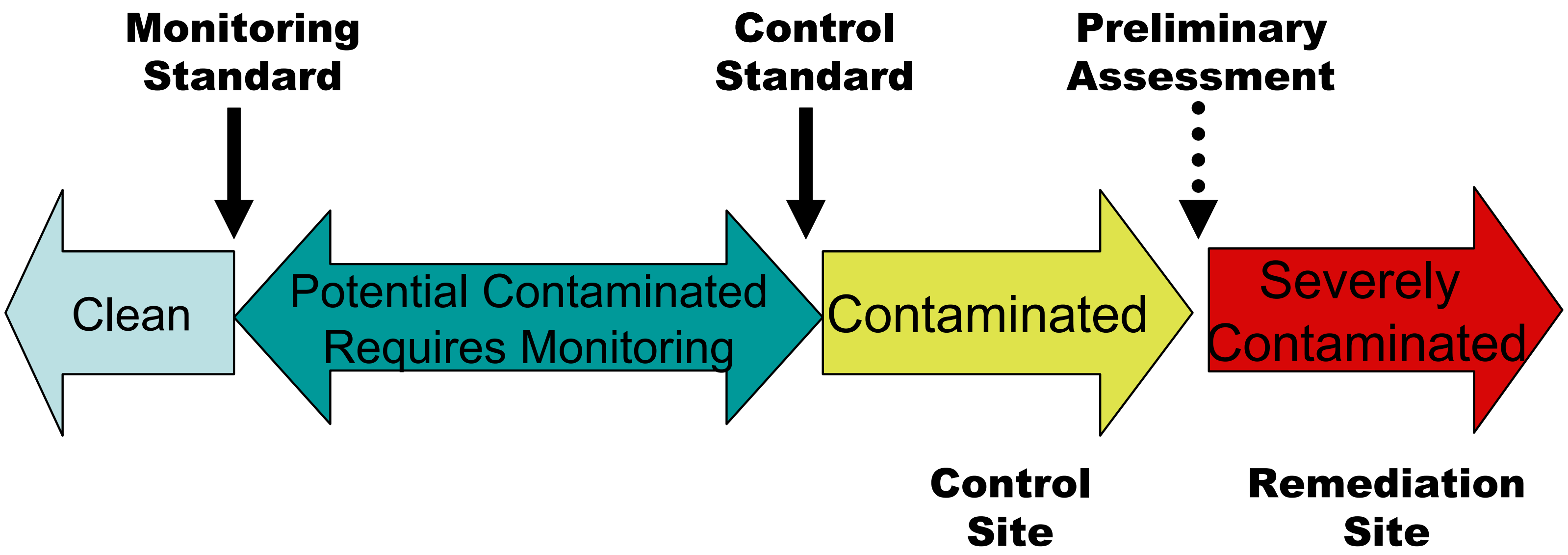
Case Study- Regulatory Standard

- Introduction
  - Regulatory standards need to be revisited after 10 years since the promulgation of Soil and Groundwater Pollution Remediation Act (SGPRA)
  - Standards requires attention and revision for better contaminated site management practices



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Case Study- Regulatory Standard

- Risk Based Control Standard Has been in practice for decades
  - Soil Screen Level (USEPA)
  - Soil Guideline Value (UKEA)
  - Target and Intervention Values (Netherlands)
- Localization for actual needs
- Availability of risk assessment protocol

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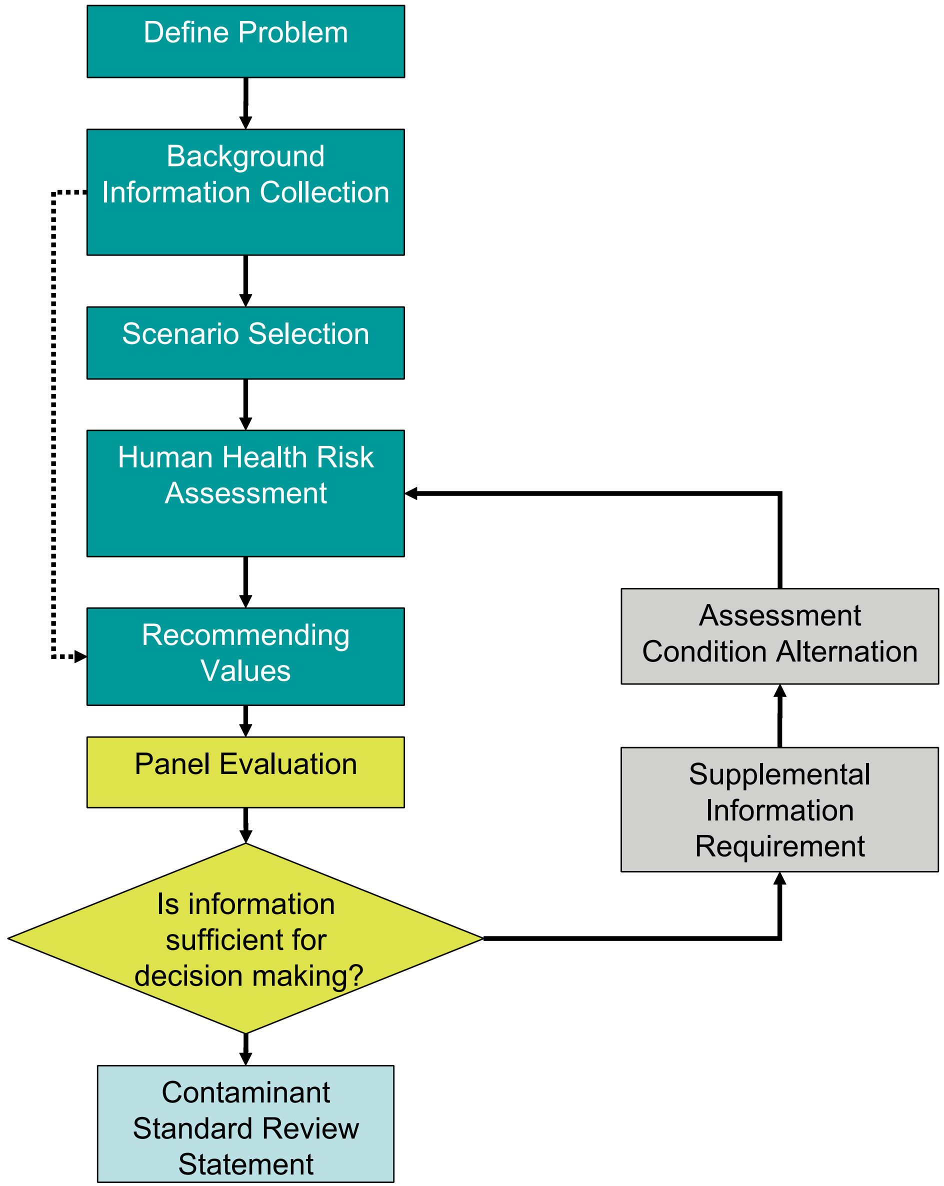
Case Study- Regulatory Standard

- Conceptual Approach



Case Study- Regulatory Standard

- Approach
  - Defining problem
    - management objective clarified
    - prioritizing the targets of concerned
  - Background information collection
    - regarding the management target
  - Risk assessment
    - the Human Health Risk Assessment Guideline for Soil and Groundwater Contaminated Sites published by TWEPA
    - Acceptable risks for carcinogenic and non-carcinogenic are defined as 1×10^{-6} and 1, respectively
    - Represents residential use assessment

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Case Study- Regulatory Standard

- Panel Evaluation
  - recommendation values are then submitted to a panel for evaluation
  - the economic and policy resource are taken into account along with the multiple decision choices for a feasible standard setting
- Standard Review Statement
  - provided as the basis for public comment and discussions
  - offer a scientific sound information
  - a vehicle for better communications

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Case Study- Regulatory Standard

- Control Standards for MTBE
- Current Status
  - the Soil Control Standard and Groundwater Control Standard do not include Methyl *tert*-butyl ether (MTBE) which is a common gasoline additive used as an oxygenate
  - recent comprehensive gas station investigation, MTBE contamination has been found in soil and groundwater
- Defining Objective and Scenarios
  - historical investigation results suggested that the gas station is the main source of contamination
  - mitigate the MTBE contamination to the most probable receptors and reducing the risk by limiting the migration
  - based on the characteristics of MTBE, the Control Standard for groundwater is more important than the Control Standard for soil

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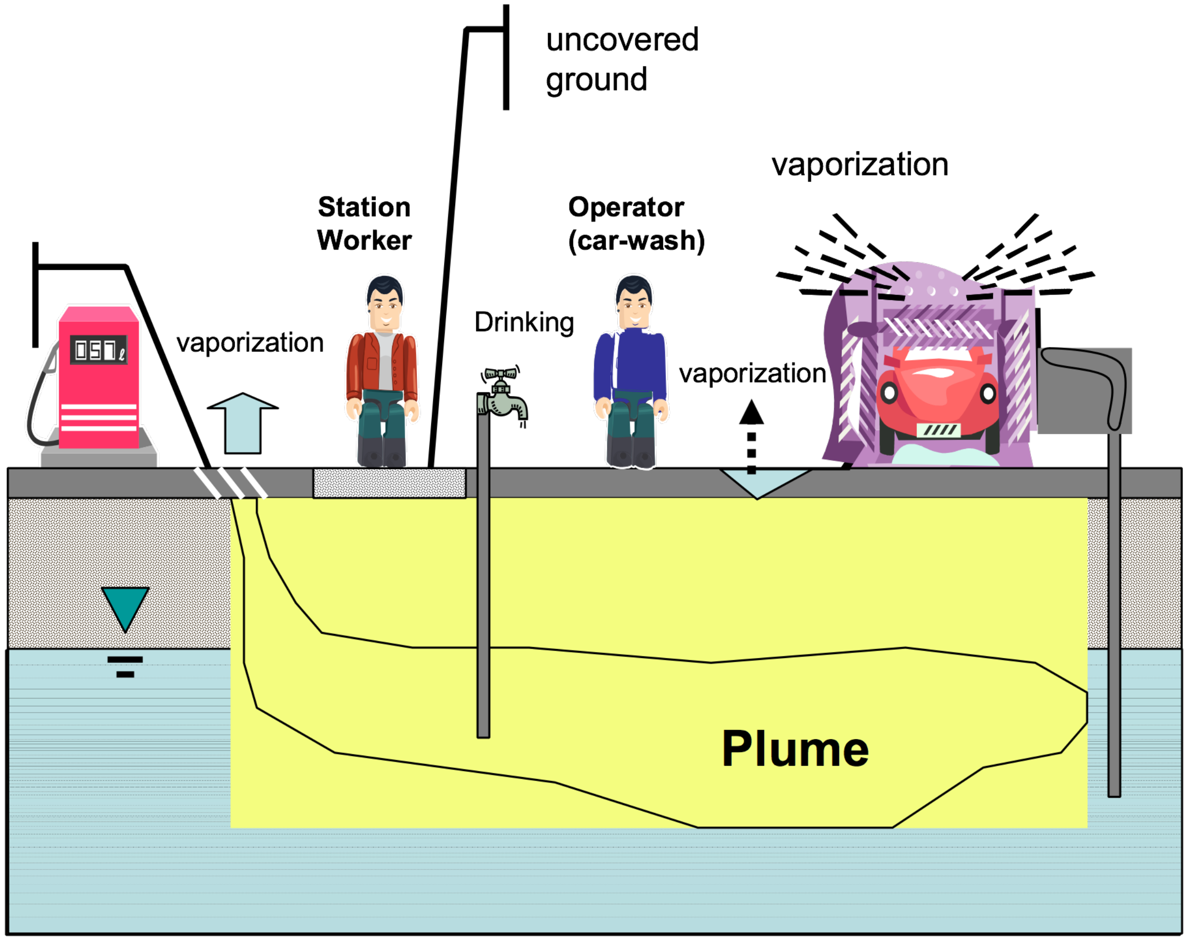
Case Study- Regulatory Standard

- Control Standards for MTBE
  - Defining Objective and Scenarios



Case Study- Regulatory Standard

- Basis for Decision Making
  - operator of car washing machine exhibits the higher exposure risk than the general station worker

Exposure Pathways	Recommending Soil Concentration (mg/kg)	
	cacinogenic based	non-carcinogenic based
Inhalation (Dust)	2.29E+07	4.08E+09
Inhalation (vaporization from soil)	9.51E+03	1.69E+06
inhalation (car washing machine)	3.22E+01	1.74E+02
Ingestion of soil	1.50E+03	6.17E+03
ingestion of groundwater*	6.00E-01	N/A

*: based on the groundwater MCL of 0.03 mg/L recommended by USEPA.

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Case Study- Regulatory Standard

- Lesson Learned
  - groundwater MTBE concentration dominates the decision for soil regulatory standard
  - recent investigation data

Percentile (%)	MTBE Concentration (mg/L)
20	<0.01
30	0.01
40	0.01
50	0.03
60	0.05
70	0.12
80	0.28
90	0.98

MTBE Control Standards promulgated in 2013 are 0.1 mg/L and 1 mg/L for protected areas and general areas, respectively.

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Case Study- Regulatory Standard

- Focus of panel evaluation
  - the MCL might create a demanding resource input for site management
  - might face a challenge of listing over 50% of gas stations as contaminated sites
  - the policy and economic factors come into play at panel evaluation

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Case Study- Regulatory Standard

- Lessons Learned
  - The risk-based Control Standard setting can provide a scientific sound basis and a defensible regulatory statement
  - The panel evaluation plays an important role in final decision making due to the characteristics of economic and policy making, the qualitative indicators should be defined and evaluated along with the quantitative risk assessment results

- Challenges
  - process of defining assessment target
  - parameters used for the risk assessment
  - comprehensive investigation and background information

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Case Study- Regulatory Standard

- Summary
  - TWEPA recognizes risk-based approach is the best practice for setting regulatory standards
  - While the supporting tool and past experience are vital, practicing the concept involves economical and political considerations
  - The rational decision could be made through a panel evaluation to compensate the probable doubt

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Thank you for your attention

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