Examples of Health Risk Assessment Applications for Contaminated Sites in the Upper Silesia, Poland

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Demonstration projects

ASE STUDY 1

zechowice Oil Refinery Project - Petroleum Waste Lagoon

IETU/U.S. DoE/Florida State University/Ames Laboratory/Savannah River Techn

ASE STUDY 2

hytoremediation Project – Agricultural Site

IETU/U.S. DoE/Florida State University)

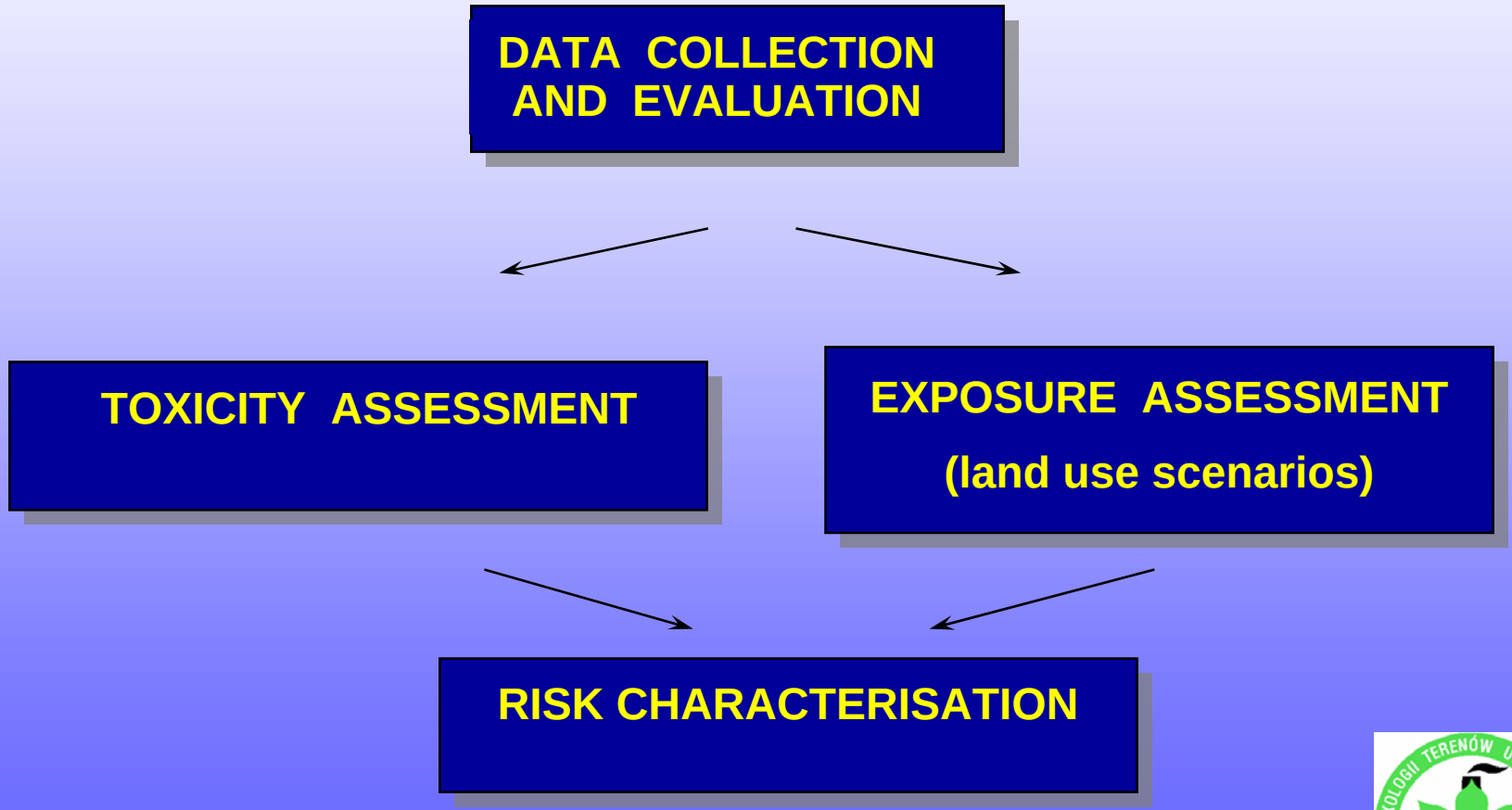
ASE STUDY 3

Risk assessment process in contaminated sites

U.S. EPA methodology for Superfund sites

- **Baseline human health risk assessment**
- **Development of Risk-Based Preliminary Remedial Goals(RBPRGs)/ Risk-Based Concentrations(RBCs)**

Baseline human health risk assessment



Risk characterisation

- **Non-carcinogenic effects - Hazard Quotient**

  HQ = CDI/RfD

- **Carcinogenic effects**

  Cancer Risk = CDI x CSF

- **Summing Hazard Quotients and Cancer Risks across all chemicals and pathways (Hazard Index, Total Hazard Index, Cancer Risks, Total Cancer Risk)**

Risk characterisation

Target Risk (TR) levels

Comparing Total HI and Total Cancer Risk with TR levels

Target Hazard Quotient (HQ)/

Hazard Index (HI) = 1

Target Cancer Risk= 1E-06

Development of Site-Specific Risk-Based Concentrations (RBCs)

Concentration levels for individual chemicals, also termed Risk-Based Preliminary Remedial Goals, which corresponded to a Target Cancer Risk Level equal to 1E-06 or Target Hazard Quotient or Hazard Index equal to 1

Case Study 1

Czechowice Oil Refinery Project

- 100-year old refinery located in an urban industrialised area

- 120,000 tons of acidic petroleum sludges in three open, unlined waste lagoons, 3 meters deep, covering 3.8 ha

- Project objective:
  to characterise, assess and remediate one of these lagoons

- the smallest of the waste lagoons selected for demonstration of bioremediation technology, 0.3-hectare site

Bioremediation

Case Study 1

Czechowice Oil Refinery Project

Contaminants of Potential Concern (COPCs)

Benzene, Toluene, Ethylbenzene, Xylenes (BTEX)
Polycyclic Aromatic Hydrocarbons (PAHs)
Heavy metals

Exposure scenarios/Receptors

SCENARIO I - Industrial workers (on-site surface soil)
SCENARIO II - Irrigation workers (on-site groundwater)

Case Study 1

Czechowice Oil Refinery Project

Industrial exposure scenario (I)

- Occupational exposure to contaminants in surface soil during work-related activities at the sludge lagoon site
- Exposure frequency – 50 days per year (1 day/week, 50 weeks/year)
- Exposure duration – 25 years of 70 year lifetime
- Exposure pathways
    - incidental soil ingestion
    - dermal contact
    - inhalation of volatiles and respirable particulates

Case Study 1

Czechowice Oil Refinery Project

Irrigation exposure scenario (II)

- On-site groundwater potentially used for irrigation purposes
- Exposure frequency – 25 days per year
- Exposure time – 1 hr per day
- Exposure duration – 25 years of 70 year lifetime
- Groundwater exposure pathways
    - inhalation of volatiles
    - incidental groundwater ingestion
    - dermal contact

Case Study 1

Czechowice Oil Refinery Project

Risk characterisation results/RBCs

Industrial scenario (I)

Total HI = 0.016

Total Cancer Risk = 3.7E-06

BaP RBC = 2.03 mg/kg

Irrigation scenario (II)

Total HI = 0.15

Total Cancer Risk = 7.4E-06

Benzene RBC = 0.5 mg/L

Case Study 1

Czechowice Oil Refinery Project

Conclusions

- **both groundwater and surface soil in the sludge lagoon represented a limited potential cancer risk under the developed exposure scenarios**

- **risk was mainly associated with potential oral exposure to BaP in surface soil, and dermal and inhalation exposure to benzene in groundwater under the industrial scenario and the irrigation scenario, respectively**

- **remedial goals were developed for the purposes of guiding bioremediation activities**

Bioremediation

Before

After

CASE STUDY 2
Phytoremediation Project

- Collective Farm used for agricultural purposes for 30 years, located in the Bytom town, in the vicinity of an abandoned zinc and lead smelter

- Project objective:
  to demonstrate and refine phytoremediation technology for removing heavy metals from soil

- experimental field was approx. 0.6 ha in size

- risk assessment concentrated on surface soil in the experimental field

CASE STUDY 2
Phytoremediation Project

Contaminants of Potential Concern
cadmium, lead

Exposure scenarios/Receptors

SCENARIO I - Agricultural workers
SCENARIO II - Consumers of edible plants
SCENARIO III - Potential future residents

CASE STUDY 2

Phytoremediation Project

Agricultural worker scenario (I)

- Exposure of agricultural workers during on-site field activities
- Exposure pathways
  - incidental soil ingestion
  - dermal contact
  - inhalation of respirable soil particulates

CASE STUDY 2

Phytoremediation Project

Plant consumer scenario (II)

- Exposure of adults by ingestion of edible plants which may be cultivated in contaminated soils

- Focus on edible plants most often cultivated in the region and locally consumed, i.e., potatoes, root and leafy vegetables (carrot, red beet, parsley, celery, cabbage)

CASE STUDY 2

Phytoremediation Project

Residential scenario (III)

Different ways of assessing residential exposures to lead and cadmium

Cadmium: for non-carcinogenic effects – young children exposure through incidental soil ingestion, dermal contact and inhalation of soil particulates; for carcinogenic effects - aggregate residents exposure (children and adults)

Lead: IEUBK model was used according to U.S. EPA recommendations for residential scenario; exposures from multiple sources (soil/dust, diet, air, drinking water) for children aged six months to seven years were evaluated

CASE STUDY 2

Phytoremediation Project

Risk characterisation results

Metal	Agricultural Worker (Scenario I)	Consumer of Edible Plants (Scenario II)	Resident (Scenario III)
	Combined Risk (unitless)	Oral Risk (unitless)	Combined Risk (unitless)
Noncarcinogenic effects (Hazard Indices)			
Cadmium Lead	6.1E-03 NC	1.3E+00 NC	2.6E-01 (Young Child) NC
Carcinogenic effects (Upper Bound Risks)			
Cadmium	3.7E-09	NC	1.0E-08 (Aggregate Resident)

NC - not calculated

CASE STUDY 2

Phytoremediation Project

Risk-Based Concenations

Metal	Agricultural Worker (Scenario I)	Consumer of Edible Plants (Scenario II)	Resident (Scenario III)
	Combined RBCs (mg/kg)	Oral RBCs (mg/kg)	Combined RBCs (mg/kg)
Noncarcinogenic effects			
Cadmium	3.05E+03	1.59E+01	7.70E+01 (Young Child)
Lead	NC	NC	
Carcinogenic effects			
Cadmium	5.01E+03	NC	2.01E+03 (Aggregate Resident)

NC - not calculated

CASE STUDY 2

Phytoremediation Project

IEUBK model outputs

Calculated Blood Lead Levels and Lead Uptakes						
Year	Blood Level (µg Pb/dL)	Total Uptake (µg/day)	Soi+ Dust Uptake (µg/day)	Diet Uptake (µg/day)	Water Uptake (µg/day)	Air Uptake (µg/day)
0.5 -1	15.3	29.68	7.53	21.11	0.98	0.06
1 -2	15.1	36.36	12.20	21.54	2.51	0.10
2 -3	13.8	37.97	12.68	22.39	2.72	0.18
3 -4	13.4	39.37	13.13	23.17	2.87	0.20
4 -5	12.4	37.75	10.18	24.26	3.11	0.20
5 -6	11.5	37.89	9.39	24.86	3.36	0.28
6 -7	10.7	38.00	9.00	25.24	3.48	0.28

CASE STUDY 2

Phytoremediation Project

Conclusions

- **cadmium in surface soil at the Bytom site could pose a non-cancer risk only for potential consumers of edible plants which might be cultivated at the site;**
  in order to reduce this risk to the level safe for consumers, cadmium concentrations in soil should be reduced to the level of 15.9 mg/kg

- **in the case of lead, diet was predicted to be the primary contributor to the total lead uptake in children;**
  mitigation strategies should concentrate on reducing lead content in diet

CASE STUDY 2
Phytoremediation Project
Conclusions

- findings of the risk assessment are important for the evaluation of phytoremediation by potential users of this technology

- findings may be used by environmental managers while applying phytoremediation to other sites

CASE STUDY 3
Warynski Brownfield Project

- Warynski lead and zinc smelter site (WSS) - abandoned industrial site at the Piekary Slaskie town

- Warynski smelter was in operation from 1927 to 1990; approx. 3,500,000 ton of wastes deposited in piles; waste material piles used to level the terrain

CASE STUDY 3
Warynski Brownfield Project

- **WSS was not used by the property owner; the Piekary Slaskie officials were interested in acquiring this property after redevelopment**

- **Project goal: to work out an effective redevelopment strategy for WSS**

- **area of abandoned WSS covers approx. 60 ha but the study area was limited to 6 ha area**

CASE STUDY 3
Warynski Brownfield Project

Contaminants of Potential Concern
Cadmium, Copper, Iron, Manganese, Lead, Zinc

Exposure scenarios/Receptors

SCENARIO I - **Industrial workers (small businesses)**
(on-site surface waste material)

SCENARIO II - **Recreational users**
(on-site surface waste material)

CASE STUDY 3

Warynski Brownfield Project

Industrial exposure scenario (I)

- Occupational exposure to contaminants in dust driven from surface waste material during work-related activities at WSS
- Exposure pathways
  - incidental soil ingestion
  - dermal contact
  - inhalation of waste material respirable particulates

Lead - methodology for assessing industrial adult exposures to lead in soil recommended by the U.S. EPA Technical Review Workgroup for Lead was used

CASE STUDY 3

Warynski Brownfield Project

Recreational exposure scenario (II)

- Exposure of recreational users through incidental soil ingestion, dermal contact, inhalation of waste material respirable particulates

- Different ways of assessing recreational exposures for non-carcinogenic and carcinogenic effects:

  for non-carcinogenic effects – young children exposure
  for carcinogenic effects - aggregate residents exposure (children and adults)

WARYNSKI SMELTER SITE

WARYNSKI SMELTER SITE

WARYNSKI SMELTER SITE

WARYNSKI SMELTER SITE

CASE STUDY 3

Warynski Brownfield Project

Risk characterisation results/RBCs

Industrial scenario (I)

Total HI = 3.1

Total Cancer Risk = 1.6E-06

Cadmium RBC = 1,170 mg/kg

Lead RBC = 1,620 mg/kg

Recreational scenario (II)

Total HI = 3.2

Total Cancer Risk = 2.6E-07

Cadmium RBC = 1,180mg/kg

Wcislo E. et al.., Chemosphere 47 (2002) 507-515

CASE STUDY 3

Warynski Brownfield Project

Conclusions

- heavy metals in the surface waste material at the site posed a potential health risk under both developed exposure scenarios (industrial and recreational)

- risks were mainly associated with exposures to cadmium (industrial and recreational scenarios) and lead (industrial scenario)

CASE STUDY 3

Warynski Brownfield Project

Conclusions

- risk results and remedial targets were comparable for both scenarios; it was impossible to prioritise land use patterns based on these results

- when choosing a future land use pattern or an appropriate redevelopment option, different factors would be decisive in decision making (e.g., social, market needs, or acceptance of local community)

Summary

- **the presented case studies were attempts to apply the general U.S. risk-based approach to remediation or revitalisation of contaminated sites in Poland**

Summary (cont.)

- **risk-based approach allows to:**
  - **assess potential health risks to human receptors**
  - **determine the needs for remedial action, aimed at reducing risk**
  - **determine remedial goals based on the protection of human health**
  - **select a remedial/revitalisation option appropriate for a given site**
  - **design and guide remediation or revitalisation activities at contaminated sites**

Summary (cont.)

- it is advisable to introduce into Polish Law the regulations allowing the use of risk assessment procedures for contaminated land management