Principles of environmental risk assessment
(focusing on contaminated land)

EnviTox webinar

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Jussi Reinikainen
Senior Advisor
Finnish Environment Institute (SYKE)

SYKE

ENVIRONMENTAL RISK ASSESSMENT (RA) OF CHEMICALS

- General procedure:
  1) Risk/hazard identification
  2) Exposure-effects assessment (risk determination)
  3) Risk characterization

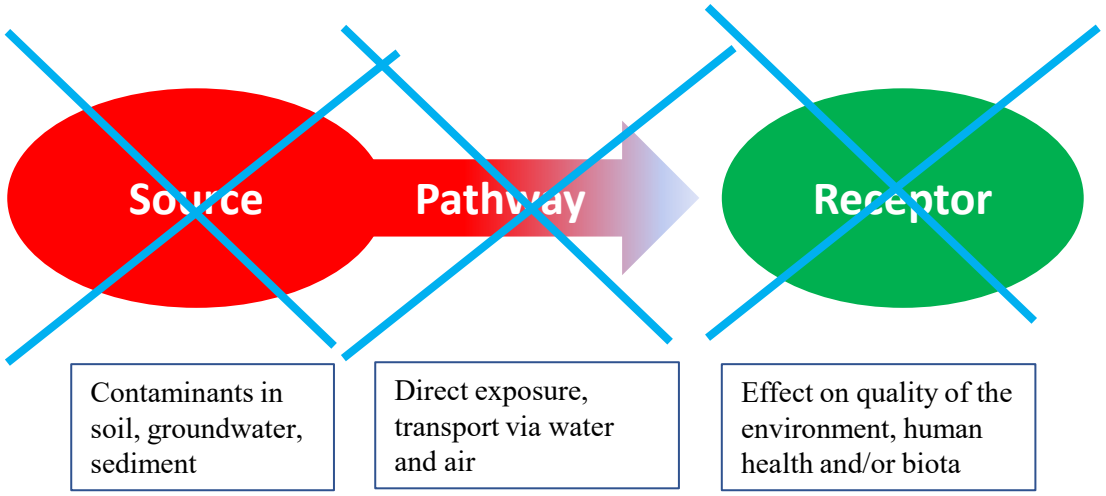
- Different tiers
  - Screening -> baseline -> detailed
- Different scales
  - Spatial and temporal dimensions
- Different targets and endpoints
  - Humans, biota, groundwater, surface water etc.
  - Cancer, reproduction, n:o of species, groundwater usage
- Different protection levels
  - Cancer risk 10^{-4} … 10^{-6}; PNEC -> HC5 – > HC50
- Different tools
  - Reference values, laboratory and site measurements, models

→ **Essential: why is RA done and how are its results used?**

- Prospective vs. retrospective (prevention vs. management of risks)
- Generic vs. case-specific (conservative vs. realistic)
- Legal requirements vs. scientific interest
- Strict vs. flexible approach

Risk assessment in contaminated land management (CLM)

- Both scientific and regulative procedure / desision support tool
  - Are risks big enough to warrant actions /remediation and to what extent? Risk assessment -> risk management
- Based on *source–pathway–receptor* linkage
  - Always site-specific; incl. human and ecological receptors, and multiple chemicals in different env. compartments
  - Tiered approach often applied; screening -> baseline -> detailed; conservative -> realistic
- Targets, desired level of protection etc. depend on regulatory demands
  - Risk assessment includes political elements, not only toxicological aspects



NO RISK
(Note: risk is hardly ever ”zero”, but it may be insignificant and acceptable)

RISK ASSESSMENT PROCESS (CLM)

SITE INVESTIGATIONS AND SURVEYS

SITE HISTORY

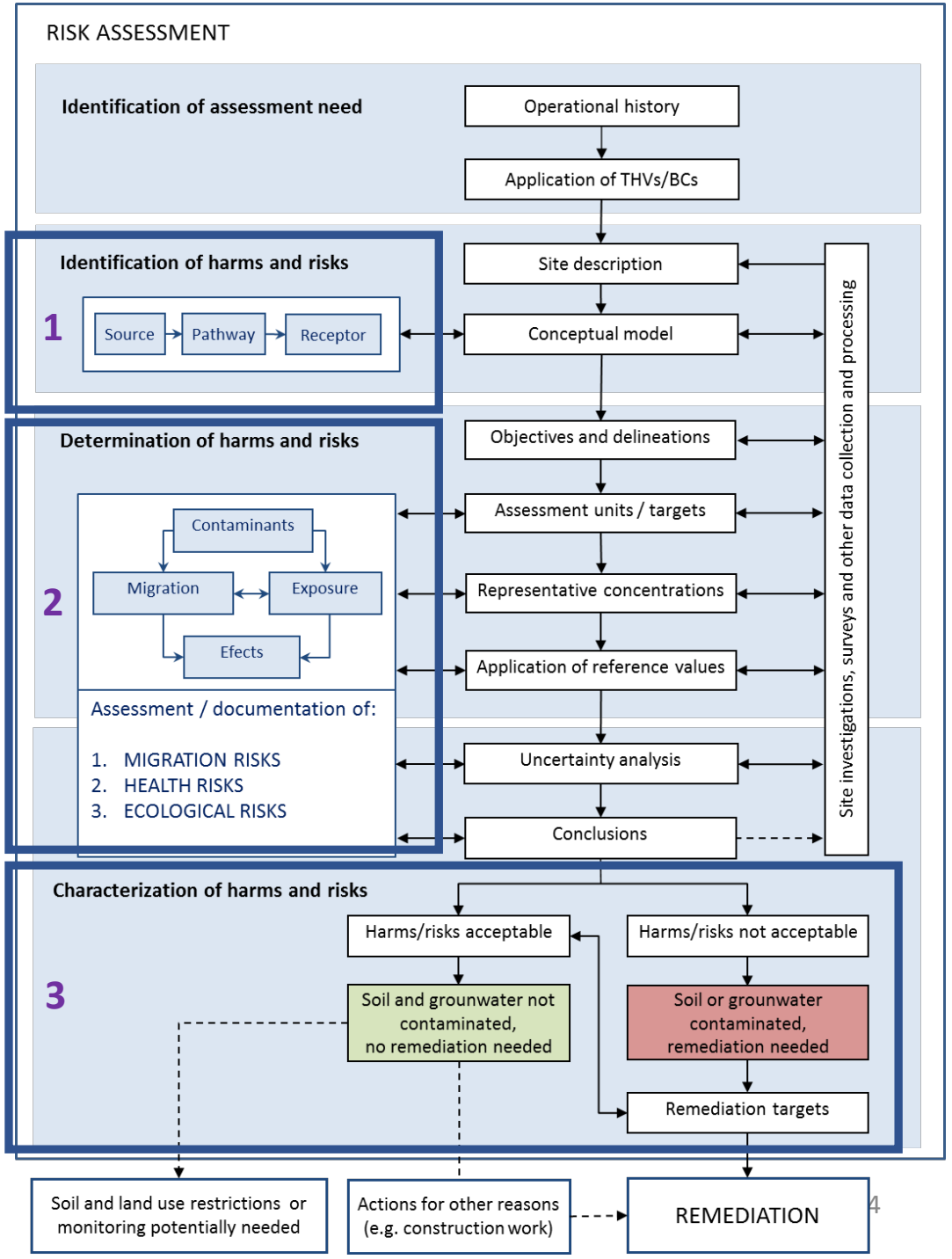
CONCEPTUAL SITE MODEL

OBJECTIVES / TARGETS

RISK ESTIMATES

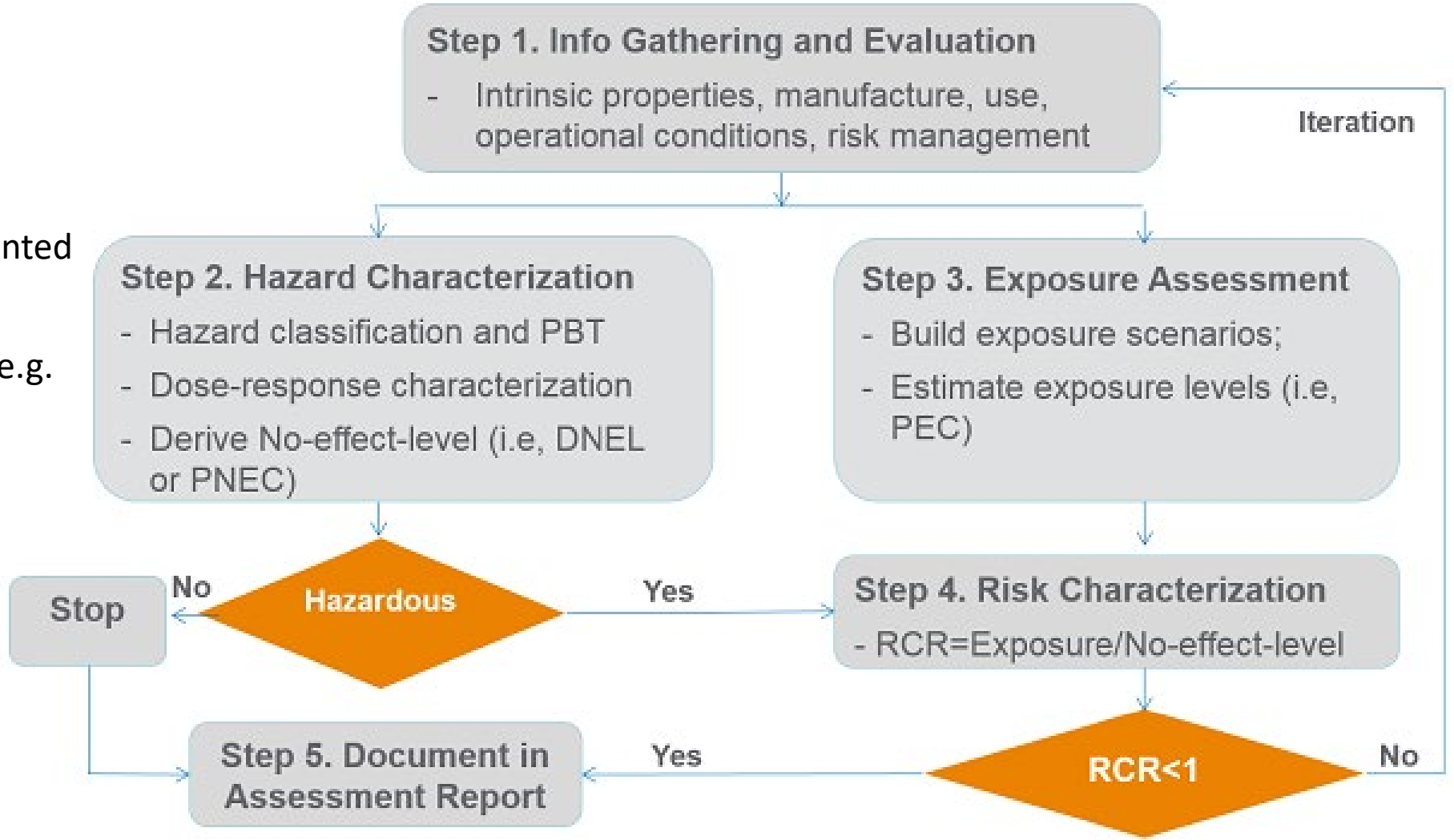
RISK MANAGEMENT DECISION

IMPLEMENTATION OF RISK MANAGEMENT ACTIONS / REMEDIATION



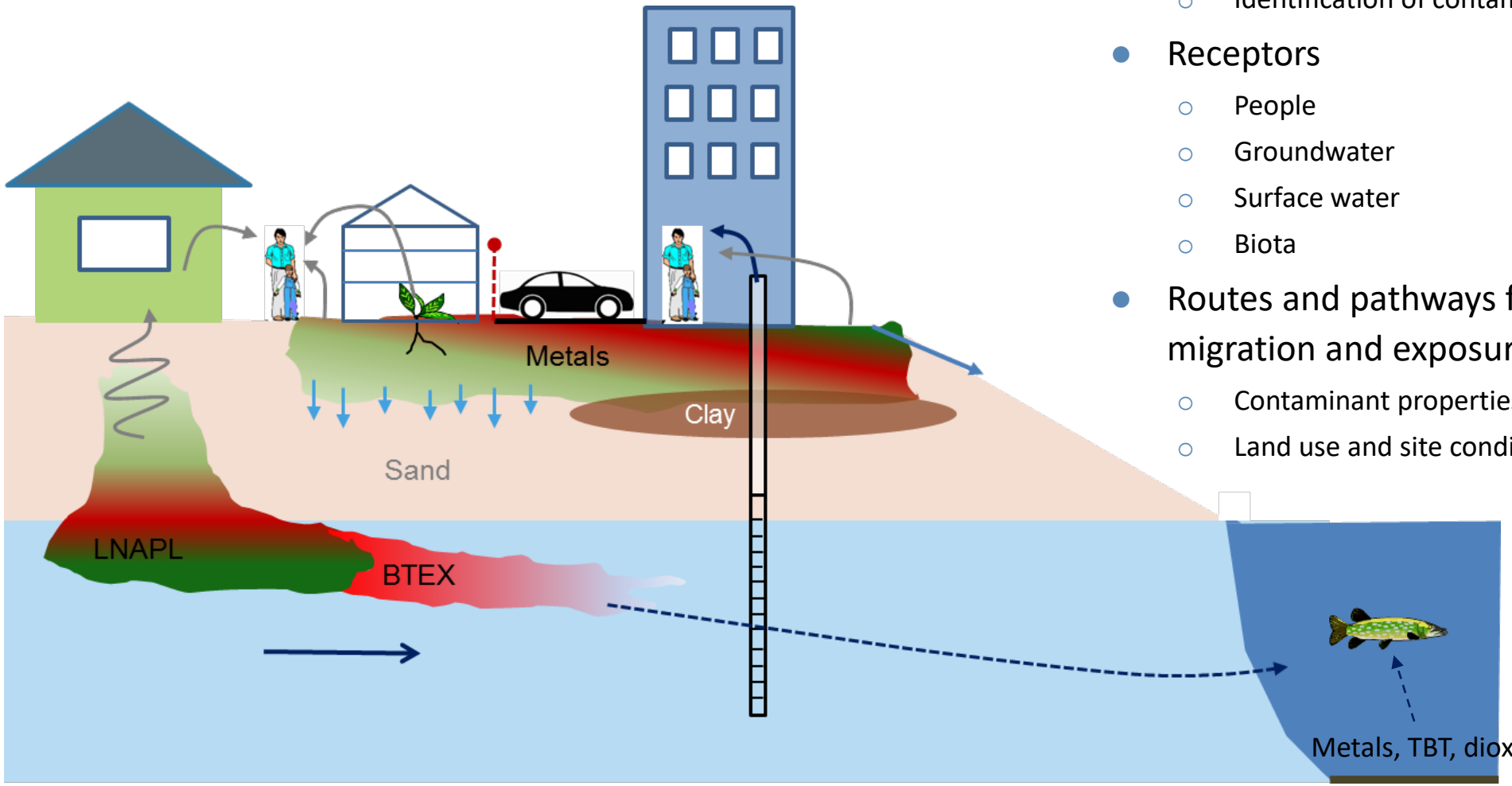
RISK ASSESSMENT IN REACH (EU CHEMICAL REGULATION)

- (Mostly) prospective
- Generic (=theoretical)
- Screening level
- (Mostly) single-chemical oriented
- Strict approach
- Conservative risk estimates (e.g. PNEC)



RISK IDENTIFICATION (CLM) - CONCEPTUAL SITE MODEL

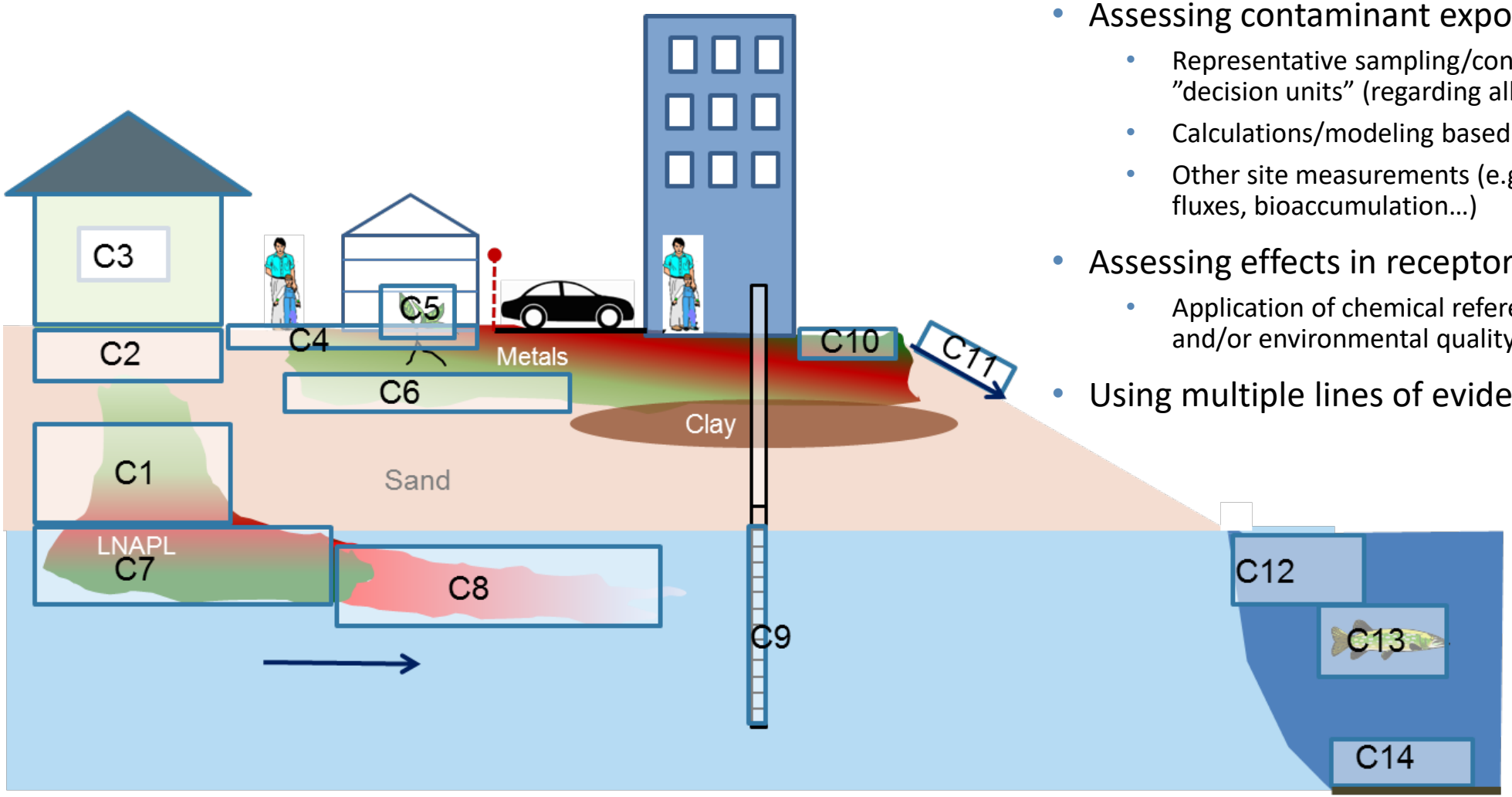
Outlining content and targets of further risk assessment



- Sources of contamination
  - Soil (vadoze and saturated zone), sediment
  - Original emission (e.g. gasoline spill), waste disposal
  - Identification of contaminants of concern
- Receptors
  - People
  - Groundwater
  - Surface water
  - Biota
- Routes and pathways for contaminant migration and exposure
  - Contaminant properties and source location
  - Land use and site conditions

RISK DETERMINATION AND CHARACTERIZATION (CLM)

Assessing actual risks with defined decision units or comparing measured concentrations with generic quality standards?



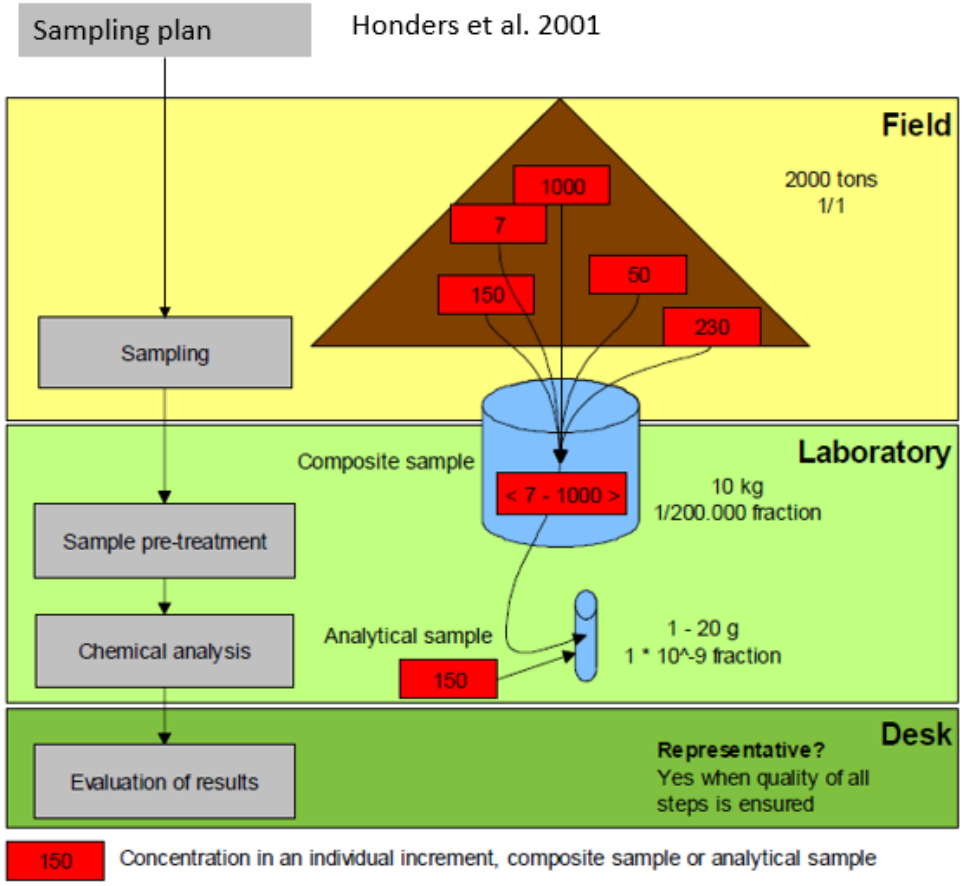
- Setting clear objectives
  - Definition of protection goals and ”decision units” (e.g. exposure areas, main sources for migration, receptors)
- Assessing contaminant exposure and transport
  - Representative sampling/concentrations on defined ”decision units” (regarding all relevant media)
  - Calculations/modeling based on sampling results
  - Other site measurements (e.g. water balances, mass fluxes, bioaccumulation…)
- Assessing effects in receptors
  - Application of chemical reference values for toxicity and/or environmental quality
- Using multiple lines of evidence

REPRESENTATIVE SAMPLING - FOUNDATION OF SITE-SPECIFIC RISK ASSESSMENT

" Representative sample is a sample in which the characteristic(s) of interest is (are) present with a reliability appropriate for the purposes of the testing programme" (EN 14899)

- Setting clear objectives
  - What are the exact questions to which you want answers from sampling?
  - Representative for one question is often not respresentative for another (e.g. source characterization vs. exposure assessment)
  - → Different sampling plan for different questions/purposes
- Defining proper "decicion/assessment units" (= sampling units)
  - What is the population of interest defined by your questions?
  - In RA sampling targeted at exposure and transport routes or receptors
  - → Exact delineation of area/mass/volume of soil, water, air, biota etc.
- Ensuring sufficient quality assurance
  - How reliable do your results have to be (acceptable sampling error; 99%, 75%, etc)?
  - Tackling the matrix heterogeneity in space (and in time)
  - → Selection of appropriate sampling design

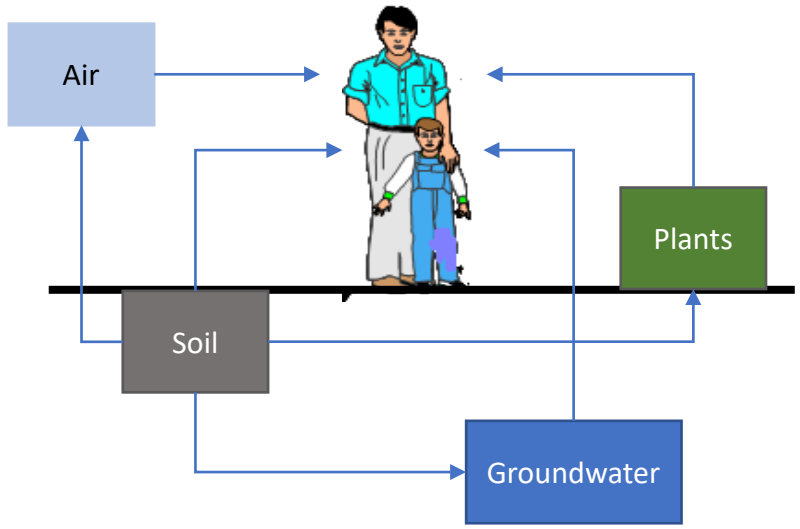
Example: sampling from soil pile



⟶ Chasing "hot spots" is often not practical and in RA, not even necessary

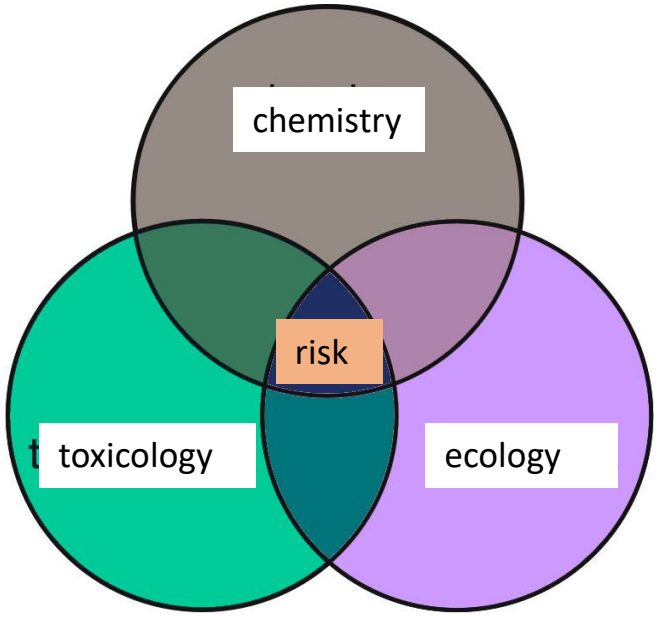
Health risk assessment (CLM)

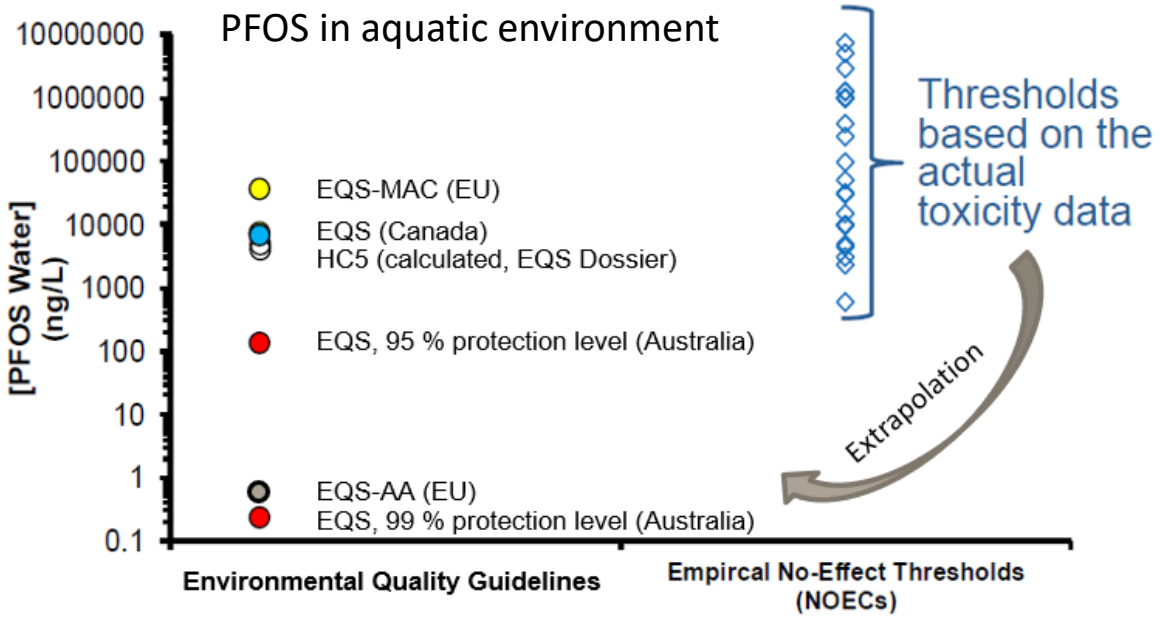
- Assessment of exposure mainly
  - Ingestion, inhalation and dermal
- Main exposure pathways
  - Ingestion and inhalation of soil and dust (contaminants in top soil)
  - Inhalation of indoor air (volatile compunds)
  - Ingestion of groundwater (soluble compounds)
  - Ingestion of vegetables (bioconcentrated compunds)
- Average daily intake via all exposure routes
  - Obs! Representative concentrations on exposure patways
- Exposure vs. tolerable/acceptable daily intake
  - Incremental cancer risk for carcinogens
  - Biomonitoring and epidemiolgical studies sometimes possible



ECOLOGICAL RISK ASSESSMENT

- Potential effects on biota
  - Soil, water and sediment organisms and microbiological functions
  - Mammals, birds, fish etc.
- Literature data, ecotoxicogical/biological tests, exposure assessments…
- Often not relevant on industrial or paved areas, but potential effects off site have to be taken into account
  - Migration to surface waters, bioaccumalation and biomagnification





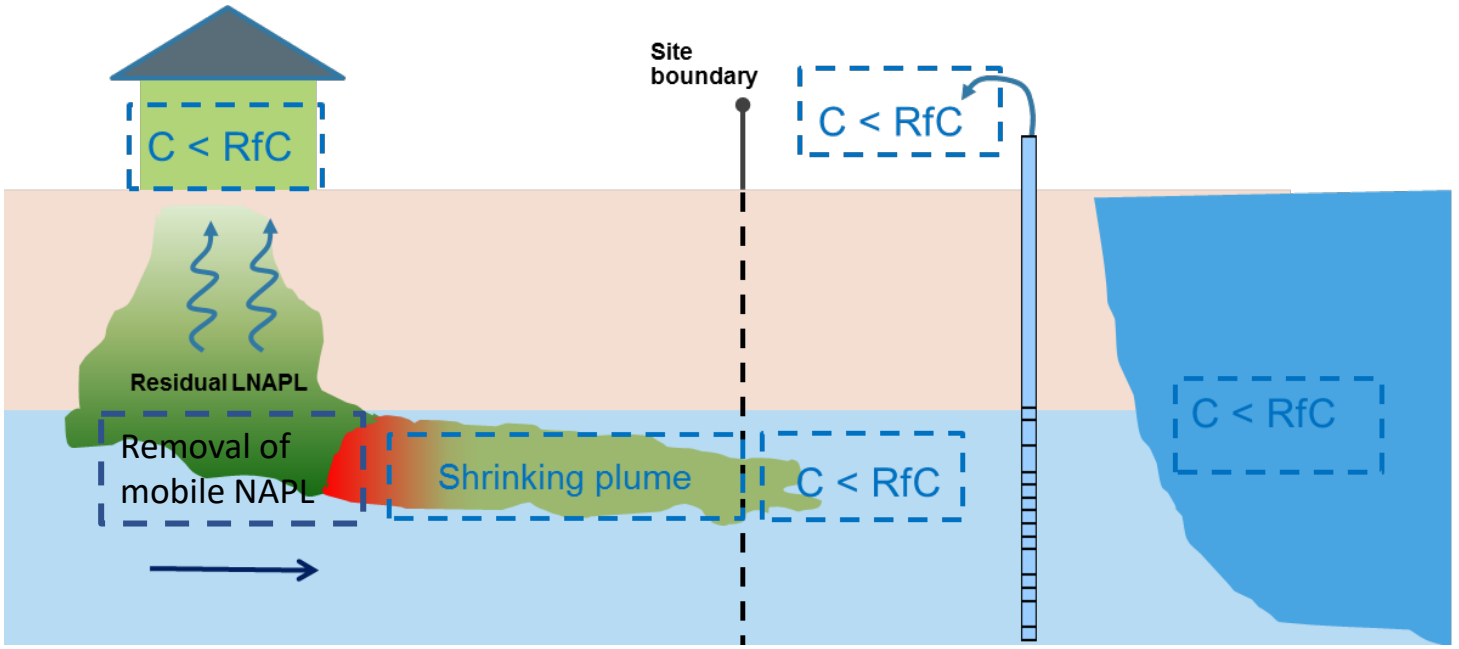
Modified from Jason Conder, presentation at CleanUp Conference, Adelaide 2019

Regulatory requirements may differ from toxicological risks

- Removal of mobile NAPL or waste materials
- Shrinking (or stable) groundwater plume
- No (significant) off-site migration
- Generic quality standards for groundwater, surface water or indoor air
- Odor and taste thresholds in drinking water

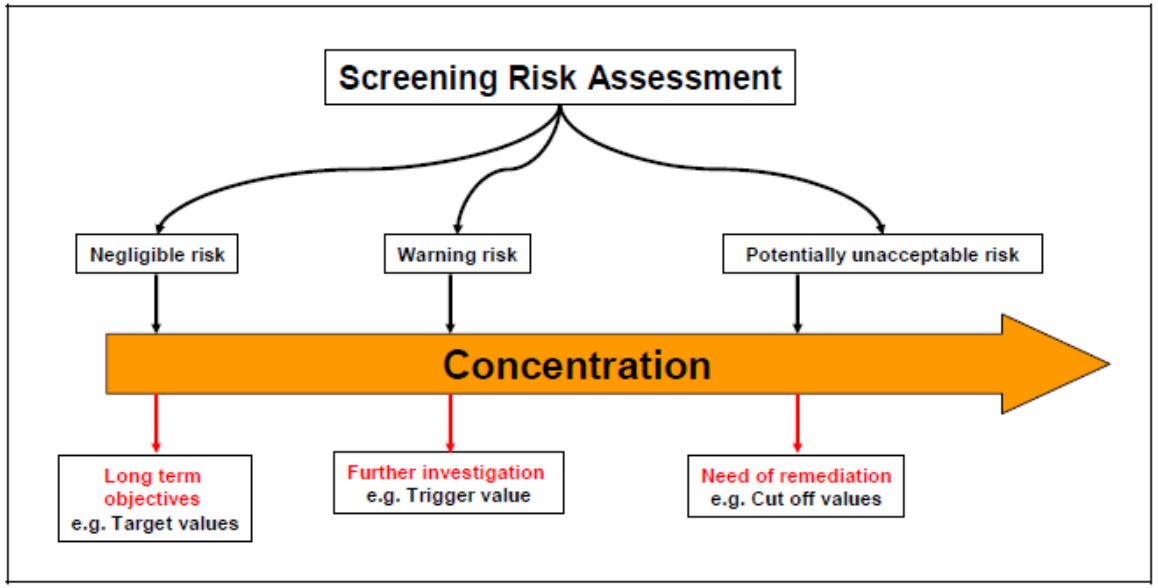
In Finland:

1. Health risks
2. Ecological risk
3. Risks due to contaminant migrtation

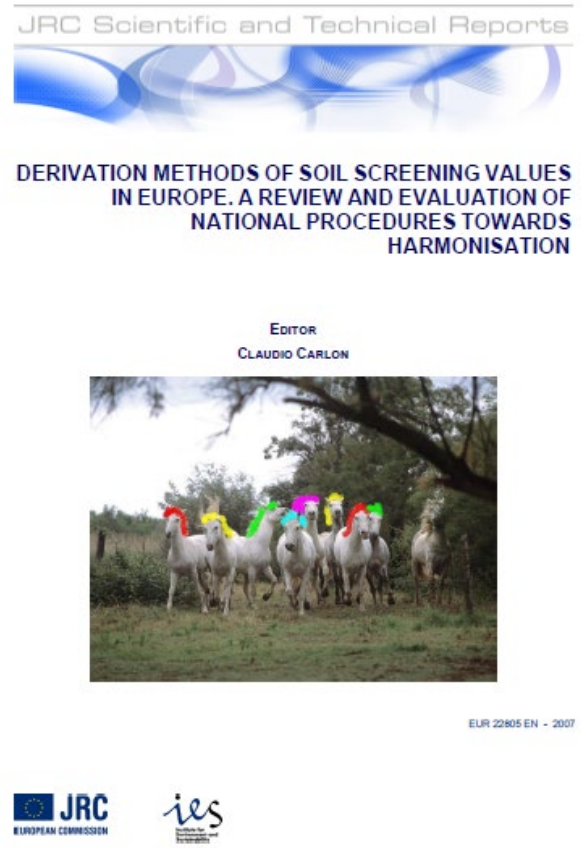


Environmental quality standards /guideline values

- Commonly used tools to regulate environmental contamination
  - Regulatory values especially for soil, but also for other environmental compartments (e.g. groundwater and surface water)
- Risk-based concentration values with predefined conditions and land use
  - Include toxicological, political, technical and socio-economic elements
- Application depends e.g. on regulatory context
  - Long-term quality objective, warning, trigger, cut-off for remediation...
  - May not be legally binding (like the soil values in FIN)



HERACLES report on soil screening values (EUR 22805 EN - 2007)



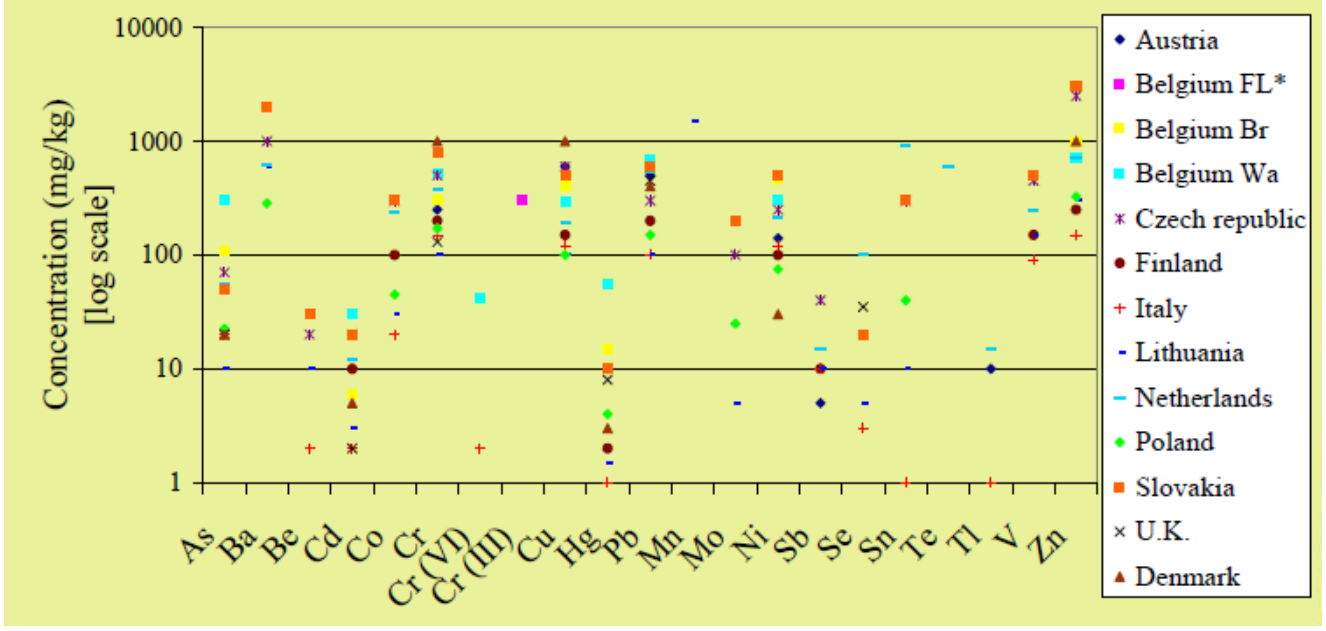
VARIATION IN NATIONAL SOIL GUIDELINE VALUES

HERACLES REPORT ON SOIL SCREENING VALUES (EUR 22805 EN - 2007)

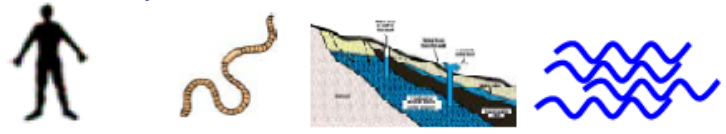
- Variation of extreme values ca. 1 order of mag. for metals, and between 1 and 2 (OoM) for organics
  - Policy aspects; e.g. protection targets (health, ecol.) and levels (e.g. cancer risk 10-4…10-6; “eco risk” HC5…HC50) , considered land uses
  - Scientific aspects; e.g. algorithms and input parameters
  - Geographical aspects; e.g. soil properties, depth to groundwater, foundation of buildings, climate conditions)
  - Socio-cultural aspects; e.g. production of home-grown vegetables, drinking water usage from private groundwater wells

→ **Same variation applies to site-specific risk assessments, too**

Example: SGVs for potential unacceptible risk, metals (residential site use)



Protected receptors considered in SGVs



	Human health	Terrestrial Ecosystem	Groundwater drinking	Surface Water
Austria				
Walloon (BE)				
Flanders (BE)				
Czech Rep.				
Denmark				
Germany				
Finland				
Italy				
Lithuania				
Netherlands				
Poland				
Spain				
Sweden				
UK				

EXAMPLE – HOW SGVS MAY COMPROMISE RISK-BASED APPROACH

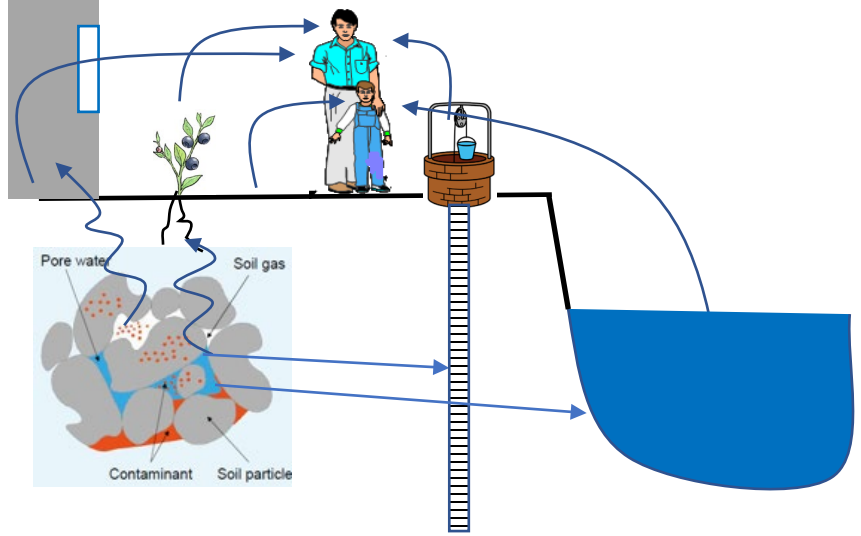
- Local soil ecosystem is often NOT the primary protection target in FIN...
- ...yet soil ecotoxicity-based soil guideline values (SGV) are often used as remediation criteria
  - e.g. SGVeco for Zn and Cu 250 and 150 mg/kg, while SGVhealth > 10 000 mg/kg
- In addition, ”dig and dump” is the most common remediation option

→ **So, is this really a risk-based approach and does it even protect the local soil ecosystem…?**

RISK CALCULATIONS/MODELING

- Often needed to assess exposure and contaminant migration
  - Requires knowledge on site conditions and fate&transport of contaminants
- A lot of quantitative tools and default chemical / exposure parameters available
  - Even simple partioning / transport /mass balance / exposure equations often do the job
- Risk assessment should NEVER be based on modeling only
  - Validation with site history, conditions and measurements (e.g. representative concentrations in exposure areas; theoretical vs. observed transport)
  - Many ”risks” (-> targets of RA) can be measured directly without modeling

$$ADD_i = \frac{C_i \times IR \times EF \times ED}{BW \times AT}$$



$$HQ = \frac{ADD_{\text{oral/dermal}}}{TDI\ tai\ CR_{oral}} + \frac{C_{ia} + C_{oa}}{TCA\ tai\ CR_{inhal}}$$

SUMMARY (REGARDING CONTAMINATED LAND RA IN PARTICULAR)

- Develop sound conceptual site model (CSM)
  - Source-pathway-receptor linkage
  - Eloborate the CSM with new data during the assessment
- Set clear objectives for each step in risk assessment using the CSM
  - Detailed site investigations, exposure assessment etc.
- Assess contaminant migration and exposure by using representative sampling, other relevant site investigations and calculations
  - Use multiple lines of evidence
  - Validate calculation/modeling results with site data
- Avoid putting too much emphasis on generic concentration thresholds (if possible)
  - Generic concentration thresholds can never replace a proper site-specific risk assessment in risk-based decision making

→ **Reliable risk assessment is a precondition for justified decision making and reasonable (sustainable) risk management / remediation**

Thank you!

Jussi Reinikainen

Finnish Environment Institute (SYKE)

jussi.reinikainen@syke.fi

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