Linking HOC (bio)availability with soil properties and biomimetic methods in predicting the fate of pollutants in remediation applications

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Overview

- Limits to biodegradation
- Biomimetic extraction
- Soil properties
- Contaminated site management: linking bioavailability to biomimetic techniques and soil characteristics

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Limitations to biodegradation

Abiotic

Bioavailability & Biodegradation

- Soil & site properties
- Pollutant characteristics:
  - Molecular structure
  - Physico-chemical character (water solubility, K_{ow})

Conditions that influence **biological** processes

- Environmental parameters:
  - Moisture (40-70% WHC_{max})
  - pH (3-9)
  - Nutrients (C:N:P:K)
  - Temperature (> 5 ^{o}C)
  - Electron donors & acceptors

How these factors govern retention and release = largely unclear

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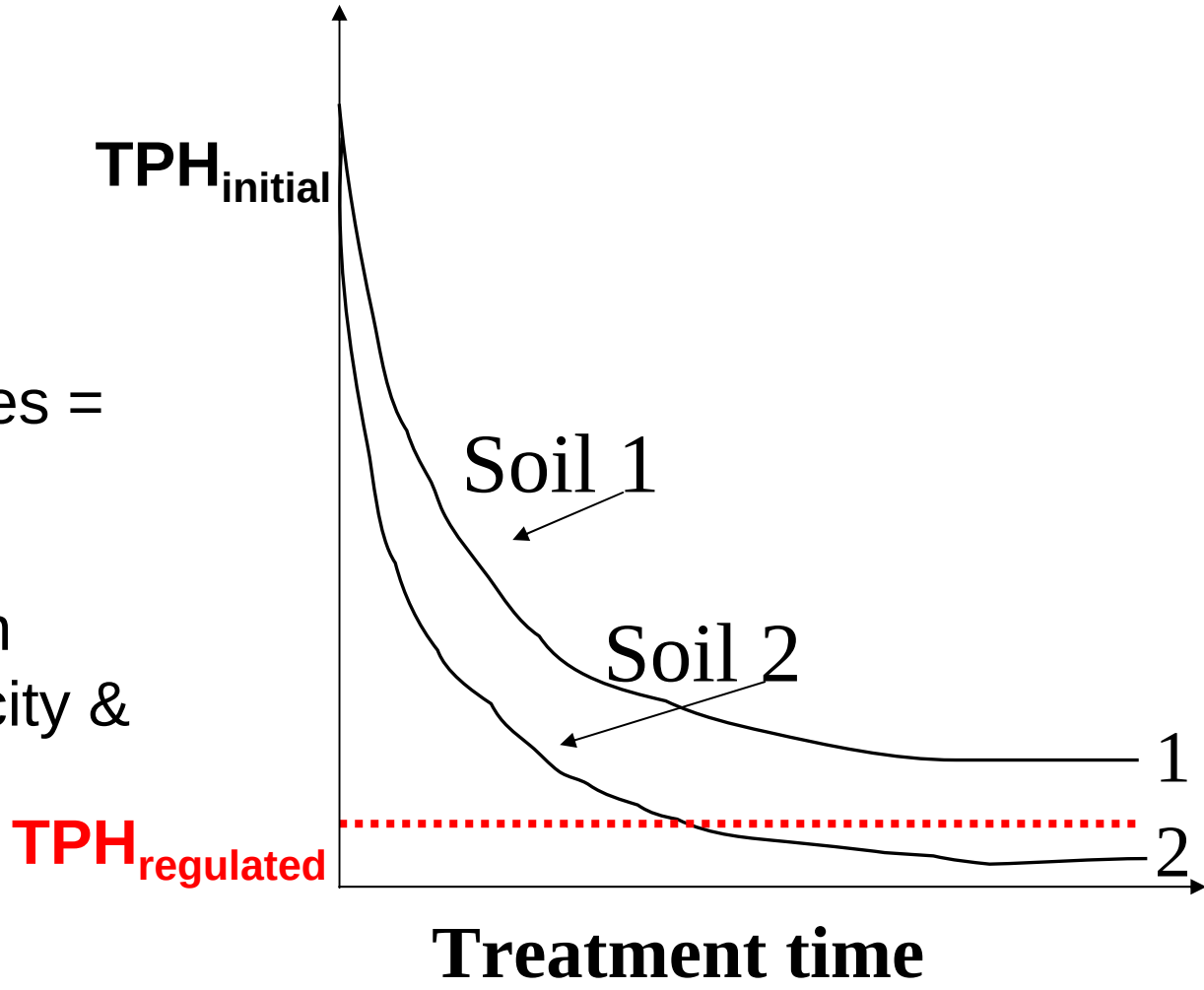
Case study: Bioremediation of hydrocarbon-contaminated soils

- Complex mixtures
- Residual fraction following rapid biodegradation
- Pollution by mixtures = Biodegradable + Recalcitrant or unavailable fraction (also consider toxicity & environmental conditions)



Huesemann 1997

An approach to evaluate biodegradation performance

- Predicting contaminant behaviour in remediation applications and the potential for site cleanup
- Sound scientific invesitgation and principles
- Link between bioavailability, soil properties & biomimetic techniques

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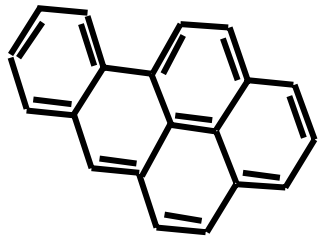
Characterisation of SOM.
Molecular-level: descriptor factor

Sorption

Desorption prediction:
Biomimetic tools



Pollutant

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An approach to evaluate biodegradation performance

- Tools to quantify available contaminant fraction
- Improve our understanding of pollutant transport in soil environments and its effect on biodegradation and remediation
- Measures can be included in estimation of risk

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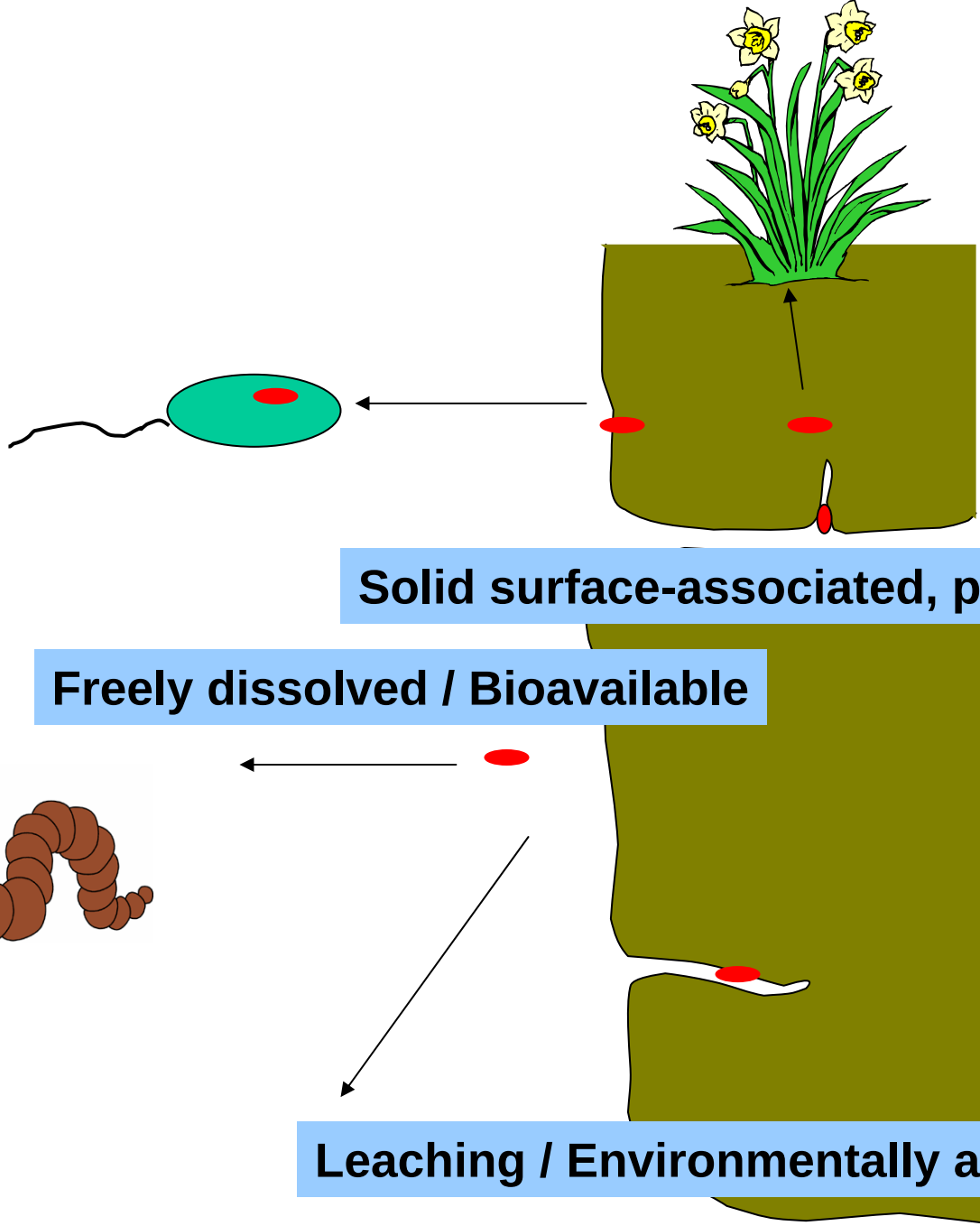
Solid surface-associated, pore-diffused adsorbed
Freely dissolved / Bioavailable
Leaching / Environmentally available

Estimation of available contaminant fraction: Biomimetic extraction

- Mimic (bio)availability - non-exhaustive desorption from sorbents
- Selective partitioning of contaminants to a surrogate phase/sampler
- Physical-chemical and biological
- Type of biomimetic method can be grouped according to the goal of availability testing

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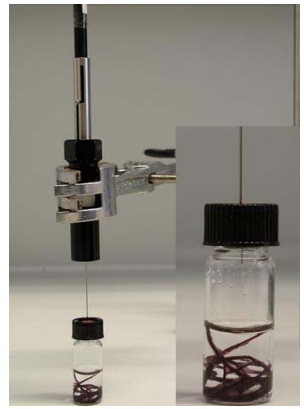
Principle physical-chemical biomimetic tools

- Chemical extractants
- Surfactants and solubilising agents
- Supercritical fluid extraction
- Solid-phase extraction
- Solid-phase microextraction



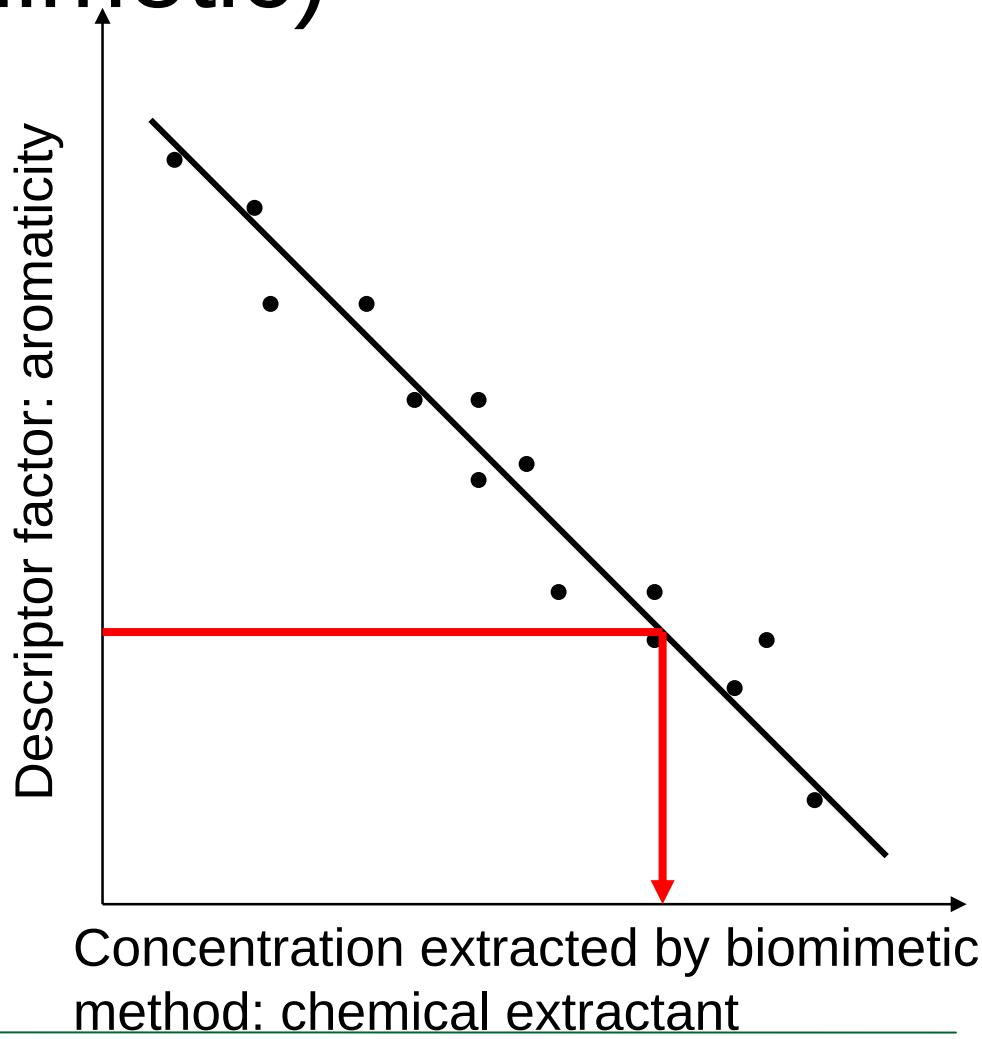
Biological: Validation of physical-chemical testing by correlating outcome of bioassay (e.g. biodegradation, accumulation or toxicity) with chemical assay (e.g. mild chemical extraction)

Binding and immobilisation by soil matrices

- Structure and composition of soil organic matter affects binding affinitiy of organic hydrophobic pollutants
- Molecular/constitutional descriptors used: Molar or weight ratios e.g. polarity index [(O+N)/C]; aromaticity index (aryl-C/alkyl-C)

Molecular descriptor factor - prediction of availability (biomimetic)

- Indication of how these factors are linked
- Behaviour of HOC in soil environments



Contaminated site management

- Tools to quantify bioavailable fraction for bioremediation application ➡ potential for site cleanup given the fact that availability impacts biodegradation
- Remedy: surfactants and solubilising agents
- More representative picture of risk posed by the contamination

Contaminated site management

- Implementation in site management: successful application of bioremediation
- Integration of these tools into a decision support system
- Validated, standardised battery of tools to model and predict availability

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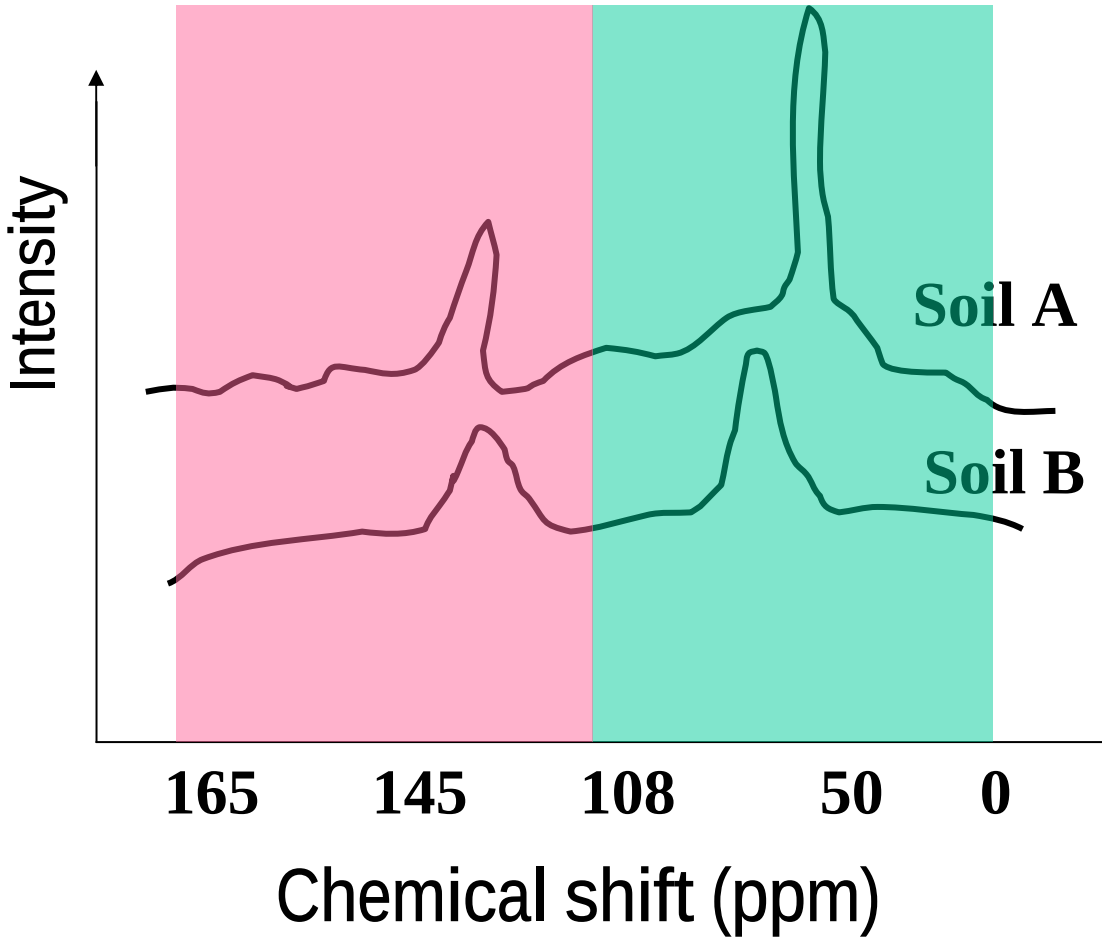
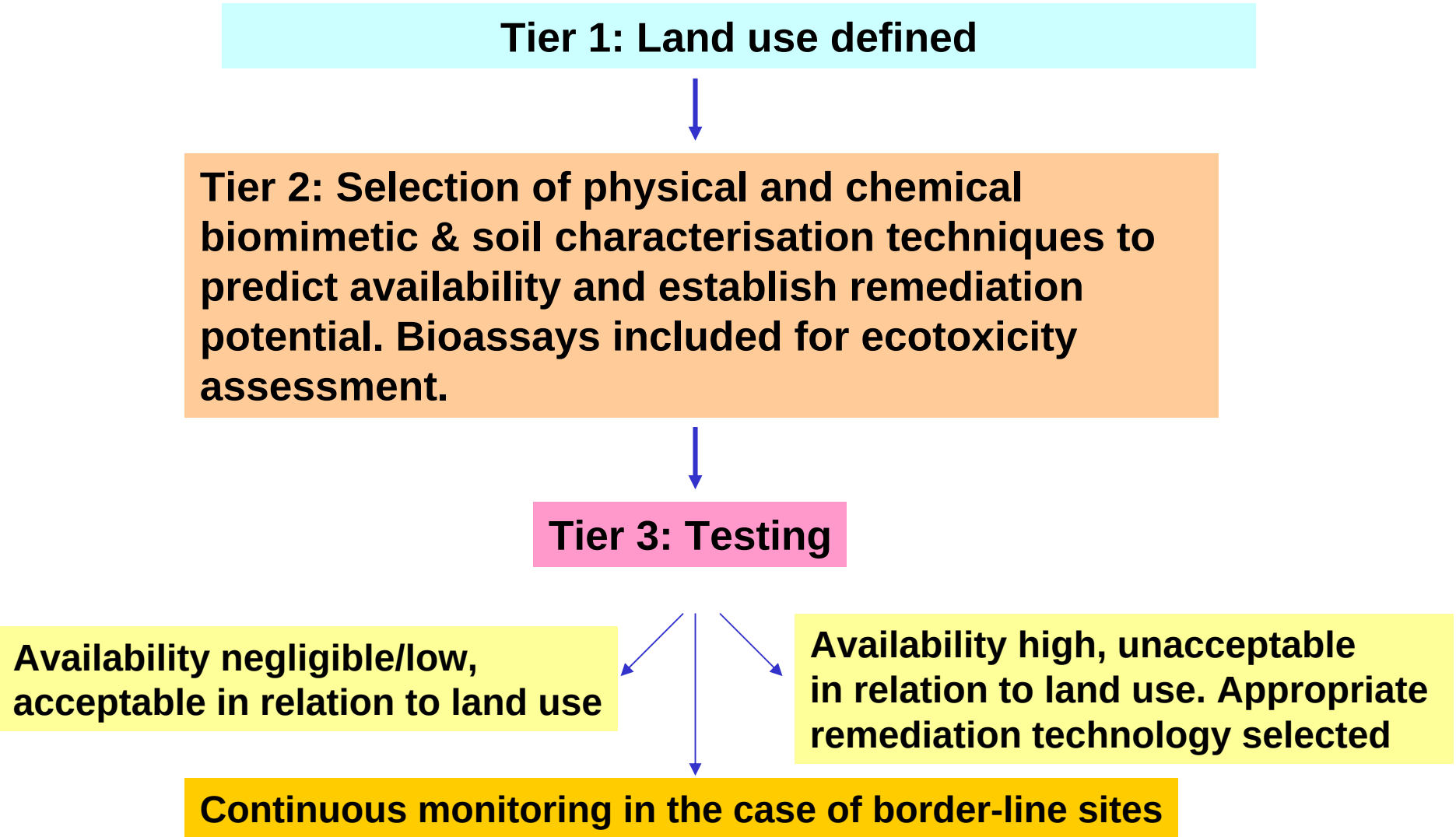
Microscopic characteristics of soil organic matter

- Solid-state nuclear magnetic resonance (NMR) spectroscopy
- Molecular descriptors
- Aromatic carbon / aliphatic carbon ratio



NMR spectra of two soils

Decision support system (tiered approach): Evaluating contamination for bioremediation purpose



Biodegradation of HOC

- These factors influence fate of HOC in terms of (bio)availability and concomitantly impact biodegradation
- Case study: petroleum hydrocarbon contamination

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