ecological risk assessment and soil quality

Anton M Breure, Christian Mulder, Michiel Rutgers
outline

• soil quality
• generic protection of soil quality using $EC_x$ - values
• site specific risk assessment
• development of ecological indicators for soil quality
• conclusions
soil quality

• the **capacity** of a specific kind of soil **to function**, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation

  *(Doran and Parkin, 1994; Karlen et al., 1997)*

• optimal quality is dependent on soil type and management type
important ecological functions of soil

- degradation of organic materials and formation of soil organic matter
  conversion of 10 tons of organic matter $\text{ha}^{-1} \text{year}^{-1}$
- nutrient cycles, nutrient mineralization
  important in the global element cycles
  production of 100 kg mineral nitrogen $\text{ha}^{-1} \text{year}^{-1}$
- natural pest control
  reduction of pesticide use
important ecological functions of soil

- degradation of organic pollutants
  clean groundwater, quality agrarian products
- structure formation in the soil
  aeration, water infiltration, water retention, retention of nutrients, growth of plant roots
ecological performers in soil: soil biodiversity

- 0.5 % of soil volume
- < 10 % of SOM
- 10,000 bacterial species per gram of soil
- 1,000,000,000 bacteria per gram of soil
- 10 - 1000 meter of fungal hyphae per gram of soil
- 10 - 100 nematodes per gram of soil
- 100 - 1,000,000 enchytraeids per m²
- up to 1,000 earthworms per m²
- up to 5000 kg living organisms per hectare
toxicity tests

single species
single toxicant

response:
• growth
• movement
• survival
• activity
• ...........

\[ \text{log toxicant concentration} \]
\[ \% \text{ survival} \]

\[ \text{EC}_{50} \]
\[ \text{NOEC} \]

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derivation of quality criteria

• few NOECs:
  – PNEC = Lowest NOEC / assessment factor = target value
  – assessment factor is dependent on available information:
    EC50 short-term test 1000
    NOEC long-term test 100
    NOEC 2 trophic levels 50
    NOEC 3 trophic levels 10

• enough NOECs
  – application SSDs
derivation of soil quality criteria from an SSD

- $\text{HC}_5$ basis for a target value
- $\text{HC}_{50}$ (MTR) basis for the intervention value
problems with the SSD approach

• extrapolation from lab to field:
  – bioavailability, temperature, redox state, soil type, pH, presence of other organisms, single stressor

• application of healthy lab species under optimal conditions
  – species in the field live under marginal conditions where there is competition for nutrients, space, food

• toxicity tests monitor parameters which are easily to measure
  – survival, growth, reproduction

• in the field more subtle parameters determine survival
  – competition, escape from predators, disease resistance, survival under adverse conditions like cold, drought and starvation
sites with the same concentration of pollutants

SITE A

SITE B
SSD is purely statistical interpretation of lab single species, single toxicant lab results

no site specific information no ecology involved
uncertainty: multiple lines of evidence

aim: use pragmatism to reduce conceptual uncertainties

tactics: independent ‘lines of evidence’

chemistry

risk

toxicity

ecology

TRIAD
requirements TRIAD to be used in a DSS

- quantitative
- tiered approach

ingredients

- measurements should be ecological relevant
- answers should be scaled for quantification 0 (no effect) to 1 (maximum effect level)
- integration on the level of separate TRIAD leg
- final judgement based on this information (judgement of conceptual uncertainty)
site specific ecological risk assessment

1. description of of actual / desired landuse

2a. formulation of site- specific ecological aspects
2b. set up assessment tools

3. site- specific data
   - chemistry
   - toxicity
   - ecology
   - determination relative risk, hazards, effects

land - owner

land - owner

(local) authorities experts

experts

remediation
soil management
timetable

contamination unacceptable

in future contamination will be acceptable with respect to Landuse and measures

contamination acceptable with respect to the landuse

monitoring

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### TRIAD matrix tier 1 (basic level)

<table>
<thead>
<tr>
<th>Triad Aspect</th>
<th>Parameter</th>
<th>Sample A</th>
<th>Sample B</th>
<th>Sample C</th>
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</thead>
<tbody>
<tr>
<td>Chemistry</td>
<td>sum TP metals</td>
<td>0.00</td>
<td>0.49</td>
<td>0.77</td>
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<tr>
<td></td>
<td>microtox</td>
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<td>0.95</td>
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<tr>
<td></td>
<td>nematodes biomass</td>
<td>0.00</td>
<td>0.00</td>
<td>0.68</td>
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<tr>
<td>Toxicology</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Ecology</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Integrated risk deviation</td>
<td><strong>0.00</strong></td>
<td><strong>0.70</strong></td>
<td><strong>0.83</strong></td>
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<tr>
<td></td>
<td></td>
<td><strong>0.00</strong></td>
<td><strong>0.82</strong></td>
<td><strong>0.27</strong></td>
</tr>
</tbody>
</table>

Risk levels:
- Risk 0 - 0.2
- Risk 0.2 - 0.5
- Risk 0.5 - 1
advantages site specific TRIAD approach

- multiple lines of evidence
  - chemistry
  - ecotoxicity
  - ecology
- tiered approach
- integration of different stressors
- location specific quality criteria
  - land-use type
  - soil type
bottle necks with site specific TRIAD approach:

• application heavily dependent on chemistry
  – concentration of pollutants triggers application of the TRIAD

• choice of the tests in the TRIAD
  – standard toolbox of tests to be applied for toxicity testing or for determination of ecology is under development

• ecological leg is poorly related with processes
  – vegetation survey, determination of biodiversity or amount of species of a specific group of soil organisms

• choice of the tests and interpretation of the results are strongly dependent on expert judgment
future developments

- policy change: protection soil quality → sustainable use of soil
- development of ecological indicators for soil quality to assess “fitness for use”

- quality assessment based on:
  - ecological insights
  - chemical data
  - physical data
  - (desired) land-use
  - monitoring data
  - multiple stressors
derivation of references / targets

• based on monitoring data
• based on ecological insights
• based on integration of chemical, ecological and physical data
• based on (desired) land-use

• references may contain
  – soil type and land-use
  – environmental conditions
  – species lists (diversity and abundance)
  – ecological process parameters
  – integration procedure
existing soil biodiversity monitoring

- United Kingdom
- New Zealand
- France two monitoring systems are under development:
  - 16 x 16 km grid
  - monitoring sewage application on forest soils
- Netherlands
- Italy
- Switzerland
- Czech Republic
- Germany 800 sites in different schemes
  - agricultural soils (BBSK)
  - forest soils
prediction presence species

PO = f(pH) + f(P) + f(OC) + f(CD) + f(clay content) + f(ttp) + …

(Generalised linear modelling = autecological description)
species interactions / foodweb information

flux of elements between trophic groups

proportion of biomass in trophic groups


distance to target indicator

0 % 100 %

quality shortage

A B C D

length of the ruler

A = negative reference
B = actual situation
C = target situation
D = positive reference
integration of information

Abiotic indicator 1 $\rightarrow$ $n_1$ $\rightarrow$ Abiotic index $\rightarrow$ $n_i$

Abiotic indicator 2 $\rightarrow$ $n_2$

Biotic indicator 1 $\rightarrow$ $n_3$

Biotic indicator 2 $\rightarrow$ $n_4$

Biotic indicator 3 $\rightarrow$ $n_5$ $\rightarrow$ Biotic index $\rightarrow$ $n_j$

Overall Indicator $\rightarrow$ $n_i$
recommendations for better ERA and soil quality assessment:

- development of a coupling of ecotoxicology with ecology end ecological processes
- set-up and maintenance of monitoring activities
- development of indicators (interpretation of monitoring data for different users of information)
- derivation of (location specific) quality criteria dependant on soil type, and (desired) soil use (fitness for use)
thank you for your attention