Food Safety and soil quality
Conceptual framework and examples

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Outline

- Conceptual framework and soil standards for agriculture in Dutch legislation
- Case study Kempen area (Netherlands and Belgium)
- Scenario studies for the Netherlands
Food safety and soil quality: the concept

Soil → Vegetables, wheat, rice etc. → Humans

Soil → Fodder crops → Animals → Animal products
Food safety and soil quality: tools

Soil

Soil-plant models

Vegetables, wheat, rice etc.

Consumption patterns

Humans

Fodder crops

Animal products

Animals

Consumption patterns/soil intake

Transfer model
Soil policy in NL: management versus cleanup

- One framework but two legal instruments

Standards for soil quality (and aquatic sediments)

Decree on soil Quality & Regulation (Besluit Bodemkwaliteit)
- Resuse of soil/dredging
- Maintain suitability of land
- Generic versus local standards

Decree on soil remediation
- Setting standards for clean-up
- Based on unacceptable risks
- National standards only

Tools-concepts!
Soil standards for Agriculture

- Back calculation from relevant criteria to protect human and animal health (e.g. critical levels in food) to critical levels in soil taking into account:
  - Bio-availability
  - Differentiation between crops / land use (grass land / arable land)
  - Chain analysis (soil inputs) -> soil -> plant -> animal -> human
Standards for Agriculture: what to protect?

- Relevant criteria for protection
  - Fodder quality (for Cd = 1 ppm at 12% moisture)
  - Health criteria cattle (critical levels in kidney and liver)
  - Food quality criteria animal products
  - Food quality criteria for arable crops (vegetables, rice etc.) and animal products (meat, milk etc.)
  - TDI for human beings (0.5 for Cd and 3.6 for Pb)
Food quality criteria / Fodder quality

soil plant relation

Critical soil content

\[ \log(\text{Cd-plant}) = \text{int} + a \cdot \text{pH} + b \cdot 10 \log[\text{SOM}] + c \cdot 10 \log[\text{Cd-soil}] \]
Chain model
Soil - animal

Tolerable Daily Intake (TDI)

Critical soil content
Chain model

Soil - animal

Critical concentration
organ

Critical soil content
Soil – plant relation

content

consumption pattern

Intake animal

Soil content

Content Fodder

intake animal

Soil

content

organ

carry over

Soil – plant relation

content

consumption pattern

Intake animal

Soil content

Content Fodder

intake animal

Soil

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content

consumption pattern

Intake animal

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Content Fodder

intake animal

Soil

content

organ

carry over
### Local Standards for Agriculture: examples

#### Land Use

<table>
<thead>
<tr>
<th>Soil type:</th>
<th>Arable Crops</th>
<th>Fodder production</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>sand</td>
</tr>
<tr>
<td>Arsenic As</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Cadmium Cd</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Chromium Cr</td>
<td>100</td>
<td>180</td>
</tr>
<tr>
<td>Copper Cu</td>
<td>50</td>
<td>160</td>
</tr>
<tr>
<td>Mercury Hg</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Lead Pb</td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>Nickel Ni</td>
<td>15</td>
<td>50</td>
</tr>
<tr>
<td>Zinc Zn</td>
<td>150</td>
<td>350</td>
</tr>
</tbody>
</table>

- Values must be higher or equal to Background values
- Values cannot exceed Intervention value
- Values in red changed
- Model calculated values sometime less strict than fixed values
Internet tools

As of 2007, Internet based tools are available to calculate national/local maximal values
Example 2: Kempen area

Kempen Area (NL/B):

- Input of Cadmium (and Zinc) to soil through thermal ore processing until mid-1970’s
- Affected area pm 350 km²
- Soils: sandy, acid, low organic matter
- High mobility and (bio)availability of cadmium in soil
- Leaching to ground/surface water: impact on ecosystem
- Intake by grazing animals: animal health/quality animal products
- Uptake by crops: quality of arable crops
- Exposure of human beings: health effects?
The Kempen Area: cross border problem
What impact has cadmium in soil on exposure of cattle and humans?
The Approach: chain model (from soil to salad)

1. Soil to Crop model (field data) by ALterra
2. Animal Consumption Patterns by ASG
3. Animal Carry-over Model by RIVM
4. Food consumption and dietary exposure model by RIKILT
Basic Needs

- Soil map: organic matter, pH, clay content
- Soil cadmium map
- Data on soil and crop quality: soil – plant model (field data!): fodder and arable products
- Data on consumption of cows of different age
- Data on levels of Cd in different animal products
- Data on average (and range in) consumption patterns of people
Soil – Plant Model

- Soil : plant
  - non-linear Freundlich-type model including effect of pH, organic matter and Cd-soil (Brus et al., 2005)

\[10\log(Cd_{plant}) = INT + a \times pH + b \times 10 \log[\text{Org Mat}] + c \times 10 \log[\text{Cd-soil}]\]

- Calibration based on field data
Soil – Plant Model

Measured vs predicted levels of Cd and Zn in fodder

[Graphs showing measured vs predicted levels of Cd and Zn in maize data and calculated values]
Accumulation of Cadmium in kidneys

Conclusions:
1. No excretion (Cd) in kidney
2. Derivation of linear BTR
3. Short term study....

Model derivation: Beresford et al. (1999, 2001)
Food Consumption and Exposure

- Based on 12500 measured food consumption patterns
- Intake based on MCRA (Monte Carlo Risk Assessment program version 6 (de Boer et al., 2007)).
- Variability distribution of short-term intakes
- The exposure was modeled for the total population (1-97 years, 36.3 years, 62.8 kg, n=6250) and for children (1-6 years, 3.6 years, 17.1 kg, n=530).
Human Exposure: scenarios

A. NL scenario (average consumption from non-polluted areas)

B. Kempen scenarios (100% consumption from Kempen)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Cadmium level soil (mg kg(^{-1}))</th>
<th>pH</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5</td>
<td>4.5</td>
<td>Clean – low pH</td>
</tr>
<tr>
<td>2</td>
<td>0.5</td>
<td>5.5</td>
<td>Clean – high pH</td>
</tr>
<tr>
<td>3</td>
<td>1.0</td>
<td>4.5</td>
<td>Average – low pH</td>
</tr>
<tr>
<td>4</td>
<td>1.0</td>
<td>5.5</td>
<td>Average – high pH</td>
</tr>
<tr>
<td>5</td>
<td>2.5</td>
<td>4.5</td>
<td>Contaminated – low pH</td>
</tr>
<tr>
<td>6</td>
<td>2.5</td>
<td>5.5</td>
<td>Contaminated – low pH</td>
</tr>
</tbody>
</table>
Quality of organ meat in the Kempen area

Predicted Cadmium levels in kidneys of cows (6 yr)

Conclusion: Cd in organ meat exceeds acceptable level as set by EU regulations
Quality of Arable products in scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Cd (mg kg(^{-1}) fw)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5</td>
<td>4.5</td>
</tr>
<tr>
<td>2</td>
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<td>5.5</td>
</tr>
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Quality of products like beans, cucumber is OK in all scenarios.
Human Exposure: Results

- Contribution to exposure:
  - wheat (47)
  - potato (27)
  - vegetables (16)
  - meat (2.5)
  - fruit (2.9)
  - other (4.6)
Exposure: variability and distribution

Worst case scen.

Nat. monitoring data

1 – 97 yrs

< 6 yrs yrs

Source: Franz et al. (2008)
Practical Solutions: Look-up Tables

Example 1: Cd-soil 1.0, pH 4.5  
Quality insufficient

Example 2: Cd-soil 3.0, pH 6.5  
Quality Sufficient
Conclusions (I)

- Chain model gives insight in impact of soil quality on exposure in food chain;
- Small additional exposure in Kempen area;
- Risk area (soils > 2 ppm and pH < 5) is small
Conclusions (II)

- Measures to reduce risks relatively easy (increase soil pH);
- Advice not to grow lettuce, endive and celery in peoples gardens;
- Model approach can be easily adapted to local/regional conditions;
- Applicable on field level and regional/(inter)national level;
- Uncertainty in some model parts can be considerable (transfer into animal organs).
Examle 3: scenario studies metal balances

“in the long term input of heavy metals resulting from applications of manure and fertilisers must be balanced by the output, which is the amount leaving the system via crops and leaching to groundwater. The balance must be set in such a way that the ecological health of soil is maintained, concentrations of substances in crop or animal products do meet standards for food safety and the flux to groundwater does not lead to pollution of ground- and surface water”

Source: REPORTS OF THE TECHNICAL WORKING GROUPS STABLISHED UNDER THE THEMATIC STRATEGY FOR SOIL PROTECTION VOLUME – IV CONTAMINATION AND LAND MANAGEMENT
Inputs: fertilizers, manure, atmospheric deposition, sludge

Yield crops

Uptake by crops

Soil moisture

partitioning

Leaching to ground- and surface water
Regional scale

Netherlands in 6405 unique units: combinations of soil type, hydrology and land use
scenario studies

Cu: huidig/LAC+
- < 0.1 x norm
- 0.1 - 0.5 x norm
- 0.5 - 1 x norm
- 1 - 2 x norm
- 2 - 10 x norm
- > 10 x norm

Cu: 100 jr/LAC+
- < 0.1 x norm
- 0.1 - 0.5 x norm
- 0.5 - 1 x norm
- 1 - 2 x norm
- 2 - 10 x norm
- > 10 x norm

GIS Sol 8 June Paris
- Framework can be used from local to national scale
- Concept is general applicable (not country specific)
- EU: harmonisation of concepts rather than harmonisation of standards
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