Spatial distribution of metallic trace elements in soils contaminated by atmospheric fallouts

Case study: Sclaigneaux (Belgium)

Bari (Italy), 3rd July 2012

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Aims

1. Spatial distribution of metallic trace elements (MTE) at the landscape scale in the topsoil, in the subsoil and in sediments

2. Impact of land uses, soil types, wind directions and distance from contaminants source on the MTE content

3. Risk assessment for agricultural soil utilizations
Study area: localization

Belgium

Wallonia
Study area: characteristics

Loyse river
Situation of old chimney
Meuse valley
Study area: characteristics

- Different soil types
- Land uses (crops, grasslands and forests)
- Old factories
- Rural zones
What about spatial distribution in topsoil?
Topsoil study

Sampling Strategy - Map projections

1. Main soil types
2. Land use
3. Wind directions

Sampling points are distributed between 3 distinct soil types, 3 land uses and 4 wind directions (36 combinations)

- Loamy soil with good drainage
- Loamy soil with imperfect drainage
- Loamy stony soil with silexite and gravels
Methodology

• 250 topsoil samples were collected according to this stratified design

• All samples were prepared for analyses:
  - Pseudo-total contents in inorganic elements
  - pH
  - Total Organic Carbon
  - N

• Statistical analyses:
  - Anova (AV3)
  - Ancova (AV3) with distance as covariate
  - PCA
Distance from source:
The main factor influencing MTE content in topsoil

- Content in each MTE decreases with distance
- \( P \)-value < 0.001 and \( R^2 > 0.5 \)

Relation Cadmium - Distance

\[ y = 30877x^{-1.248} \]
\[ R^2 = 0.5281 \]
Direction of dominant winds:
A second factor which influences MTE content in topsoil

- Typical wind direction in Wallonia is South-West toward North-East
- MTE dispersion is higher along this axe
Soil types:
A third factor which influences the MTE content in topsoil
- Loamy stony soils with silexite and gravels contain more MTE than loamy soils
- Effect most likely due to their position in the landscape
Land use:
A last factor which influences the MTE content in topsoil

- Forest content in MTE is always higher (2X) than the other land uses
- Likely due to higher content in organic matter, lower pH,...
Confirmation by PCA analysis

Principal Component Analysis (MTE - Soils - Land uses - Wind directions - Distance)

First Component

Second Component

- Loamy soil - imperfect drainage
- Loamy soil - good drainage
- Loamy pebbles rich soil

Directions:
- North
- South
- East
- West

Uses:
- Crop
- Forest
- Grassland

Metals:
- Cu
- Zn
- Pb
- Cd
Topsoils
Risk assessment study

In a 1km radius around the source, there is 80% chance for each contaminant to be above the allowed regional intervention value.

<table>
<thead>
<tr>
<th></th>
<th>Cadmium</th>
<th>Lead</th>
<th>Zinc</th>
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<tbody>
<tr>
<td>Natural reference</td>
<td>0.2</td>
<td>25</td>
<td>67</td>
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<tr>
<td>Critical level</td>
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<td>200</td>
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<td>Intervention value</td>
<td>10</td>
<td>400</td>
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</table>
What about sediments?
Comparison of topsoil and sediment samples taken very close from each other (max 3m)
Comparison of speciation elements from topsoil and sediments

Sediments

Topsoil

Residual fraction
Fraction related to crystallized oxides
Fraction related to the organic matter
Fraction related to amorphous oxides
Fraction related to carbonate
Available fraction
What about MTE leaching?
Atmospheric dusts are at the origin of the contamination

- MTE evolution is different according to the kind of soil
Conclusions

• Factors influencing spatial distribution of MTE in the topsoil may be classified in the following order:
  – Distance >> Wind directions > Soil type ≈ Land use
  – Forests and loamy-stony soils are the most contaminated

• The greatest risk is met in an area of 1 km radius around the old chimney - should be decontaminated

• Sediments present in the river are contaminated and the available fraction is gone

• In a soil profile the contamination decreases with depth and the evolution depends on soil types and land uses
Thank you for your attention...

Thank you to my collaborators:
- Colinet Gilles
- Bock Laurent
- Members of Soil Unit of Gembloux Agro-Bio Tech (Ulg - Belgium)