Heavy Metal Thresholds in Compost with a View to Soil Protection – what Approach for the Community?

Florian Amlinger
Soil as Sink or Source for Metals

Source: Gupta (1999)

Critical Concentrations/
Guide Values

Sink

Source

Increasing Stresses due to Accumulation of Metals

Preventive Measures

- Multifunctionality of Soil

Curative Measures

Adverse Impacts on
- Soils and on
  - Plants, Animals, Men
  - Ground Water, Surface Water
  - Air

Source: Gupta (1999)
Sorption of Cd and Zn in a Compost Amended Soil .... 15 Years Later

Petruzelli & Pezzarossa (2001)

Sorption isotherms

Cadmium

Zinc

+ 27 %

+ 75 %
Heavy Metal Sorption and SOM

- Negative correlations between solubility of trace metals such as Cu, Hg and Cd, and SOM

- Correlation between levels of Cd, Cu, Zn, Pb and Ni and SOM (USA survey; Holmgren et al. 1993)

  \[
  Cd_T = 0.10 + 0.0094 \text{SOM} \quad r = 0.51 \quad (P<0.01)
  \]

- Soil sorption capacity is inversely related to the amount of metal sorbed

- Low-metal composts are more suitable to provide new sorbing sites

- Soil organic matter has probably the greatest capacity and strength of bonding with most trace metals of any soil component
Soluble fraction of Cd and Zn during composting

- Desolved organic carbon (DOC) declines
- Non-humic fraction of DOC decreases 90 → 8 %,
- Humuc fractions increase 72 % of DOC
- Soluble fraction of Cd and Zn decreased significantly

Leita et al. (2001)
Correlation of soluble Cd and Cu with non humic or humic fraction of DOC in composts

- The humic fraction of DOC and the insoluble organic complexes play an essential role for the removal of metals from soluble phase of soil.

Leita et al. (2001)
\[ \text{NH}_4\text{NO}_3 \text{ Extractable Cd in the Soil} \]

[Scherer et al., 1997]

![Graph showing NH\(_4\)NO\(_3\) extractable Cd in the soil for Cambisol and Luvisol.](image)
6 years, six locations: 5 t, 10 t, and 20 t d.m. ha\(^{-1}\) year\(^{-1}\)

- No effect on heavy metal contents of the products
- Mobile heavy metal contents of Cd, Ni and Zn decreased with rising applications of composts.
Cadmium in Grain & Potato

[Bartl et al. 1999]

<table>
<thead>
<tr>
<th></th>
<th>Oats '96</th>
<th>Dinkel '97</th>
<th>Potato '98</th>
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</thead>
<tbody>
<tr>
<td>0 mg/kg DM</td>
<td>0.05</td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>NPK</td>
<td>a</td>
<td>a</td>
<td>c</td>
</tr>
<tr>
<td>BWC 32 t</td>
<td>b</td>
<td>a</td>
<td>a</td>
</tr>
</tbody>
</table>

Superphos

Heavy Metals - Compost - Soil Protection

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Cadmium Concentration in Lettuce & White Mustard

[Luvisol; Scherer et al., 1997]

Cadmium:
- Soil: 0.6 mg/kg
- Comp 1: 1.7 mg/kg
- Comp 2: 1.1 mg/kg

### Lettuce
- Control: 4.00 mg/kg
- Comp 1: 3.00 mg/kg
- Comp 2: 2.00 mg/kg

### White Mustard
- Control: 2.00 mg/kg
- Comp 1: 1.00 mg/kg
- Comp 2: 1.00 mg/kg

* indicates significant difference compared to control.
## Heavy metal limits

- Soil vs Compost -

<table>
<thead>
<tr>
<th></th>
<th>Cd</th>
<th>Cr</th>
<th>Cu</th>
<th>Hg</th>
<th>Ni</th>
<th>Pb</th>
<th>Zn</th>
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<tbody>
<tr>
<td>Sand</td>
<td>0.4</td>
<td>30</td>
<td>20</td>
<td>0.1</td>
<td>15</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>Silt/loam</td>
<td>1.0</td>
<td>60</td>
<td>40</td>
<td>0.5</td>
<td>50</td>
<td>70</td>
<td>150</td>
</tr>
<tr>
<td>Clay</td>
<td>1.5</td>
<td>100</td>
<td>60</td>
<td>1.0</td>
<td>70</td>
<td>100</td>
<td>200</td>
</tr>
</tbody>
</table>

Compost heavy metal concentration Class 1 & 2
[mineralised to 0 % organic matter]

<table>
<thead>
<tr>
<th></th>
<th>Cd</th>
<th>Cr</th>
<th>Cu</th>
<th>Hg</th>
<th>Ni</th>
<th>Pb</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>1.0</td>
<td>143</td>
<td>143</td>
<td>0.71</td>
<td>71</td>
<td>143</td>
<td>286</td>
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<tr>
<td>Class 2</td>
<td>2.14</td>
<td>214</td>
<td>214</td>
<td>1.43</td>
<td>107</td>
<td>214</td>
<td>571</td>
</tr>
</tbody>
</table>
CADMIUM: Accumulation in the SOIL

precautionary soil (D):
- clay
- loam
- sand

atm. deposition - export

Cl. 1 [30 t dm ha⁻¹]
Cl. 2 [10 t dm ha⁻¹]
Cl. 1 [10 t dm ha⁻¹]
COPPER: Accumulation in the SOIL

**guide value (AUT):**

- soil AUT
- loam
- Cl. 1 [10 t dm ha⁻¹]
- Cl. 1 [30 t dm ha⁻¹]
- atm. deposition - export
- clay
- sand
- Cl. 2 [10 t dm ha⁻¹]

**Precautionary soil (D):**
ZINC: Accumulation in the SOIL

guide value (AUT):

mg kg⁻¹ soil [20 cm]

years

- AUT soil
- loam
- Cl. 1 [10 t dm ha⁻¹]
- Cl. 2 [10 t dm ha⁻¹]
- precautionary soil (D)
- clay
- sand
- atm. deposition - export

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Heavy Metals - Compost - Soil Protection
LEAD: Accumulation in the SOIL

precautionary soil (D):
- clay
- loam
- sand

- Cl. 1 [30 t dm ha⁻¹]
- Cl. 2 [10 t dm ha⁻¹]
- atm. deposition - export

years

mg kg⁻¹ soil [20 cm]
Measurable changes in the soil?

<table>
<thead>
<tr>
<th>Element</th>
<th>Cl. 2 [10 t]</th>
<th>Cl. 1 [10 t]</th>
<th>75%il</th>
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<tbody>
<tr>
<td>Cd</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cr</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cu</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ni</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pb</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zn</td>
<td></td>
<td></td>
<td></td>
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<table>
<thead>
<tr>
<th>Years</th>
<th>Cd</th>
<th>Cr</th>
<th>Cu</th>
<th>Hg</th>
<th>Ni</th>
<th>Pb</th>
<th>Zn</th>
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<tbody>
<tr>
<td></td>
<td>0.21</td>
<td>38</td>
<td>21</td>
<td>0.16</td>
<td>24</td>
<td>17</td>
<td>74</td>
</tr>
<tr>
<td></td>
<td>0.02</td>
<td>1.5</td>
<td>2.0</td>
<td>0.02</td>
<td>1.5</td>
<td>1.5</td>
<td>2.5</td>
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<tr>
<td></td>
<td>0.51</td>
<td>31</td>
<td>61</td>
<td>0.29</td>
<td>26</td>
<td>49</td>
<td>211</td>
</tr>
</tbody>
</table>

Background soil:
- Cd: 0.21
- Cr: 38
- Cu: 21
- Hg: 0.16
- Ni: 24
- Pb: 17
- Zn: 74

Measurable increase:
- Cd: 0.02
- Cr: 1.5
- Cu: 2.0
- Hg: 0.02
- Ni: 1.5
- Pb: 1.5
- Zn: 2.5

75%il BW C/AUT:
- Cd: 0.51
- Cr: 31
- Cu: 61
- Hg: 0.29
- Ni: 26
- Pb: 49
- Zn: 211

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## The reality of Compost Quality?

<table>
<thead>
<tr>
<th>Biowaste Compost</th>
<th>Cd</th>
<th>Cr</th>
<th>Cu</th>
<th>Hg</th>
<th>Ni</th>
<th>Pb</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mg/kg dm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Austria:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Med; n = 552 - 582</td>
<td>0.38</td>
<td>24</td>
<td>47</td>
<td>0.16</td>
<td>19</td>
<td>37</td>
<td>174</td>
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<td><strong>Belgium:</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Med; n = 195</td>
<td>0.82</td>
<td>22</td>
<td>45</td>
<td>0.15</td>
<td>12</td>
<td>69</td>
<td>229</td>
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<td><strong>France:</strong></td>
<td></td>
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<td></td>
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<tr>
<td>Mean; n = 20 - 28</td>
<td>0.9</td>
<td>29</td>
<td>96</td>
<td>0.6</td>
<td>24</td>
<td>86</td>
<td>289</td>
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<td><strong>Germany:</strong></td>
<td></td>
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</tr>
<tr>
<td>Med; n = 6414 - 6446</td>
<td>0.53</td>
<td>25</td>
<td>49</td>
<td>0.18</td>
<td>16</td>
<td>57</td>
<td>196</td>
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<td><strong>Catalunya (Spain):</strong></td>
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<td></td>
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<tr>
<td>Mean; n = 9</td>
<td>&lt; 1.5</td>
<td>30</td>
<td>123</td>
<td>0.4</td>
<td>30</td>
<td>77</td>
<td>239</td>
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<tr>
<td><strong>The Netherlands:</strong></td>
<td></td>
<td></td>
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<tr>
<td>Med</td>
<td>0.3</td>
<td>17</td>
<td>29</td>
<td>0.12</td>
<td>7</td>
<td>57</td>
<td>157</td>
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<tr>
<td><strong>United Kingdom:</strong></td>
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<tr>
<td>Med; n=60</td>
<td>0.51</td>
<td>16</td>
<td>50</td>
<td>0.20</td>
<td>18</td>
<td>102</td>
<td>186</td>
</tr>
</tbody>
</table>
Average Heavy Metal Limits in the EU Relative to Class II of WD

Percentages represent the relative limits of heavy metals compared to the Class II of the Waste Directive (WD) for different countries and categories.
The reality of Compost Quality?

Median of GC & BWC relative to Cl. 1 WD 2nd draft

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**Graph Description:**

- **Y-axis:** Percentages ranging from 0% to 250%
- **X-axis:** Heavy metals: Cd, Cr, Cu, Hg, Ni, Pb, Zn
- **Legend:**
  - **GC NL**: Green
  - **GC AUT**: Yellow
  - **GC FR**: Dark Green
  - **BWC NL**: Orange
  - **BWC AUT**: Red
  - **BWC FR**: Brown
  - **BWC WD cl. 1**: Pink
  - **BWC WD cl. 2**: Triangle

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**Data Analysis:**

- **Cd:** GC NL and GC AUT are below 100%, while BWC NL and BWC AUT are above 100%.
- **Cr:** GC NL, GC AUT, and BWC WD cl. 1 are below 100%.
- **Cu:** GC NL and GC AUT are below 100%, while BWC WD cl. 1 and BWC WD cl. 2 are above 100%.
- **Hg:** GC NL, GC AUT, and BWC WD cl. 1 are below 100%.
- **Ni:** GC NL and GC AUT are below 100%, while BWC WD cl. 1 and BWC WD cl. 2 are above 100%.
- **Pb:** GC NL and GC AUT are below 100%, while BWC WD cl. 1 and BWC WD cl. 2 are above 100%.
- **Zn:** GC NL and GC AUT are below 100%, while BWC WD cl. 1 and BWC WD cl. 2 are above 100%.
The reality of Compost Quality?

75th and 90th %ile of AUT and UK Composts relative to Cl. 1 WD 2\textsuperscript{nd} draft
Conclusions I

- Sorptive properties of compost can prevent the release of heavy metals and their excessive leaching or uptake by crops.
- Only clean / high quality compost guarantees the introduction sorptive surfaces for heavy metals in compost amended soils.
- Soluble, exchangable fraction and plant uptake of H.M. decrease in compost amended soils.
- H.M. accumulation has to be considered on the background of environmental standards for sustainable soil functions.
- The critical concentration of H.M. in the soil varies with local climatic and soil conditions.
- Thus: .... Precautionary soil values and compost application regimes should be established on MSt level.
Conclusions II

- Quality classes → an important tool
- **Class 1** in agreement with Organic Farming Regulation (adjustment at least of Ni, Pb and Zn)
- **Class 2** → Agriculture and hobby gardening
- **Class 1 & 2:**
  - Limitations for the quantity to be applied on land on MSt level
  - Labelling: Recommendations for the safe use on MSt level
- **Product - Class 3**
  - non food
  - Limitations for the quantity to be applied on EU level
  - market for sewage sludge compost
  - **MSt** → may allow the use in Agriculture within waste regime; heavy metal loads in compliance with the Sludge Directive
- **Stabilised Waste .... Not to be included in a Compost Directive**
Proposal for an Environmental Compost Classification within an EU Compost Directive

<table>
<thead>
<tr>
<th></th>
<th>Cd</th>
<th>Cr</th>
<th>Cu</th>
<th>Hg</th>
<th>Ni</th>
<th>Pb</th>
<th>Zn</th>
</tr>
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<tbody>
<tr>
<td>class 1 org. farming</td>
<td>0.7</td>
<td>100</td>
<td>100</td>
<td>0.5</td>
<td>50</td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>80</td>
<td>250</td>
</tr>
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<td>class 2 agriculture</td>
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<td>150</td>
<td>1</td>
<td>75</td>
<td>150</td>
<td>400</td>
</tr>
<tr>
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<td>0.7</td>
<td>120</td>
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<td>class 3 non food</td>
<td>3</td>
<td>250</td>
<td>500</td>
<td>3</td>
<td>100</td>
<td>200</td>
<td>1500</td>
</tr>
</tbody>
</table>