Economical and ecological removal and/or recuperation of organic matter and ammonium from landfill leachate:

IMOG as a full-scale example

V. Oloibiri, M. Chys, W. Audenaert, K. Demeestere and S.W.H. Van Hulle
Landfill/leachate/treatment
• Intergemeentelijke Maatschappij voor Openbare Gezondheid in Zuid-West-Vlaanderen (IMOG): works for 11 municipalities in South-West Flanders
• Moen site: green composting, landfilling and leachate treatment
• Intergemeentelijke Maatschappij voor Openbare Gezondheid in Zuid-West-Vlaanderen (IMOG)
• Consists of 11 municipalities
• It runs two sites whose core activities include:
  1. Harelbeke site: sorting of PMD and paper cardboards, plastics recycling, incineration
  2. Moen site: green composting, landfilling and leachate treatment
Flow diagram of IMOG treatment plant

Physical chemical measurements of leachate at various points

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Raw leachate AP1 (average values)</th>
<th>biologically treated AP 2 Leachate</th>
<th>Flemish STD</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>8.13</td>
<td>8.2 – 8.5</td>
<td>6.5-9.5</td>
</tr>
<tr>
<td>COD (mg/L)</td>
<td>1185</td>
<td>706 -1390</td>
<td>250</td>
</tr>
<tr>
<td>BOD$_5$ (mg/L)</td>
<td>189</td>
<td>50</td>
<td>25</td>
</tr>
<tr>
<td>BOD$_5$/COD</td>
<td>0.15</td>
<td>0.03</td>
<td>n.a.</td>
</tr>
<tr>
<td>UV254 absorbance (cm$^{-1}$)</td>
<td>n.a.</td>
<td>5.98-8.53</td>
<td>n.a.</td>
</tr>
<tr>
<td>NO$_3^-$-N (mg/L)</td>
<td>n.a.</td>
<td>3.9-19.5</td>
<td>n.a.</td>
</tr>
<tr>
<td>NO$_2^-$-N (mg/L)</td>
<td>n.a.</td>
<td>0.33-0.66</td>
<td>n.a.</td>
</tr>
<tr>
<td>NH$_4^+$-N (mg/L)</td>
<td>535</td>
<td>2.42-9.22</td>
<td>5</td>
</tr>
<tr>
<td>Conductivity (µS/cm)</td>
<td>10002</td>
<td>6870</td>
<td>6000</td>
</tr>
</tbody>
</table>
IMOG as example

- high N
- high COD
- large recalcitrant components
- low BOD
Current operational costs

• Daily flow rate: 150 m³/d (365 d)
  – Nitrification/denitrification: 0,57 euro/m³
    -> 31 000 euro/y
  – Activated carbon: 1,32 euro/m³
    -> 72 000 euro/y
  – Combined costs: +/- 100 000 euro/y
Current operational costs

<table>
<thead>
<tr>
<th></th>
<th>Euro/year</th>
<th>Euro/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrification/denitrification</td>
<td>31208</td>
<td>0,57</td>
</tr>
<tr>
<td>Activated carbon</td>
<td>72270</td>
<td>1,32</td>
</tr>
<tr>
<td>Combined costs</td>
<td>103478</td>
<td>1,89</td>
</tr>
</tbody>
</table>
How can we reduce these costs?

- Nitrogen removal
  - ANR instead of nitrification-denitrification
How can we reduce these costs?

• Nitrogen removal
  – ANR instead of nitrification-denitrification
  • Lab-scale (6l) and pilot-scale (2m³): 40% N removal (on average), up to 90% in some periods
How can we reduce these costs?

- Nitrogen removal
  - ANR instead of nitrification-denitrification
    - Nitrification/denitrification: 0,57 euro/m³
      -> 31 000 euro/y
    - Full ANR: 0,016 euro/m³
      -> 900 euro/y
    - 40% ANR and 60 % N-DN: 0,35 euro/m³
      -> 19 000 euro/y
How can we reduce these costs?

<table>
<thead>
<tr>
<th>Nitrification/denitrification:</th>
<th>Full ANR</th>
<th>40% ANR/60% N/DN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro/year</td>
<td>31208</td>
<td>876</td>
</tr>
<tr>
<td>Euro/m³</td>
<td>0.57</td>
<td>0.016</td>
</tr>
</tbody>
</table>
How can we reduce these costs?

• COD removal
  – Pretreating the leachate

  [Diagram showing treatment process: landfill leachate goes through primary treatment, then SBR, followed by F/C and GAC, and finally surface water. Methanol and (sludge) are indicated as separate streams.]

How can we reduce these costs?

• COD removal
  – Pretreating the leachate
  • UV based techniques
How can we reduce these costs?

• COD removal
  – Pretreating the leachate
    • UV based techniques
      – Colour removal >20% (at 500 nm)
      – Only 3% COD removal
      – Lower than expected, mainly due to low transparency and cost efficient use of UV-light (0.6 kWh/m³)

COD₀ = 859 ± 26 mg L⁻¹
Abs₀ = 0.10 cm⁻¹
How can we reduce these costs?

• COD removal
  – Pretreating the leachate
  • AOP techniques
    – UV/H$_2$O$_2$ (see above)
    – Fe$^{++}$/H$_2$O$_2$ (Fenton)
    – Foto Fenton (see above)
    – O$_3$
Fenton

<table>
<thead>
<tr>
<th></th>
<th>H₂O₂</th>
<th>Fe²⁺</th>
</tr>
</thead>
<tbody>
<tr>
<td>mg L⁻¹</td>
<td>1020</td>
<td>1117</td>
</tr>
<tr>
<td>g oxidant g⁻¹ COD₀</td>
<td>1.3</td>
<td>1.4</td>
</tr>
</tbody>
</table>

- **pH = 6**: Low pH = oxidation
- **pH = 4**: No significant effect by UV-light
- **pH = 2**: High pH = coagulation

Abs (cm⁻¹) @ 500 nm

COD (mg L⁻¹)
• COD: linear decrease

• Abs: linear decrease
254 nm < 350 nm < 500 nm

COD<sub>0</sub> = 724 mg L<sup>-1</sup>
Abs<sub>0, 254 nm</sub> = 6.4 cm<sup>-1</sup>
Abs<sub>0, 350 nm</sub> = 2.0 cm<sup>-1</sup>
Abs<sub>0, 500 nm</sub> = 0.47 cm<sup>-1</sup>
Comparison

<table>
<thead>
<tr>
<th></th>
<th>unit</th>
<th>untreated</th>
<th>UV/H₂O₂</th>
<th>O₃</th>
<th>Fenton</th>
</tr>
</thead>
<tbody>
<tr>
<td>COD</td>
<td>mg O₂ . L⁻¹</td>
<td>812</td>
<td>756</td>
<td>729</td>
<td>303</td>
</tr>
<tr>
<td>COD removal</td>
<td>%</td>
<td>-</td>
<td>7</td>
<td>10</td>
<td>63</td>
</tr>
<tr>
<td>BOD</td>
<td>mg O₂ . L⁻¹</td>
<td>58</td>
<td>58</td>
<td>96</td>
<td>47</td>
</tr>
<tr>
<td>ΔBOD/BOD₀</td>
<td>%</td>
<td>-</td>
<td>0.0</td>
<td>65</td>
<td>-19</td>
</tr>
<tr>
<td>ΔBOD/COD₀</td>
<td>%</td>
<td>-</td>
<td>0.0</td>
<td>47</td>
<td>-1.4</td>
</tr>
<tr>
<td>BOD/COD</td>
<td>-</td>
<td>0.07</td>
<td>0.08</td>
<td>0.13</td>
<td>0.16</td>
</tr>
<tr>
<td>UV₂⁵₄</td>
<td>cm⁻¹</td>
<td>6.0</td>
<td>5.9</td>
<td>4.9</td>
<td>14.1</td>
</tr>
</tbody>
</table>

- COD: decrease
- BOD: increase with O₃
How can we reduce these costs?

• COD removal
  – Pretreating the leachate
  • Coagulation/flocculation
    – Fe$^{+++}$ (Fenton)
    – PAC
    – ...

[Images of laboratory equipment and test tubes containing liquids]
• FeCl₃ <-> PAC
  – COD: (initially 955 mg O₂ /l)
– Conductivity, Turbidity, SVI

EC↑ and pH↓ -> problems with discharge limits?
SVI lower for FeCl₃ -> less sludge production
How can we reduce these costs?

- **COD removal**
  - Pretreating the leachate
- **Coagulation/flocculation**
  - Effect on activated carbon polishing: low (relative)
How can we reduce these costs?

• COD removal
  – Pretreating the leachate
• Coagulation/flocculation
  – Effect on activated carbon polishing: low (relative)
How can we reduce these costs?

• COD removal
  – Pretreating the leachate
• Coagulation/flocculation
  – Effect on activated carbon polishing: low -> except for more concentrated leachate/higher dosages
How can we reduce these costs?

• COD removal
  – Pretreating the leachate
    • Coagulation/flocculation vs. Ozone: colour removal during activated carbon polishing
C/F + AC
How can we reduce these costs?

• Daily flow rate: 150 m³/d (365 d)
  – Activated carbon: 1,32 euro/m³ 
    -> 72 000 euro/y (+ 31 000 euro/y for N/DN)
  – Pretreatment
    • Ozone: @0,1gO₃/gCOD: 1,2 euro/m³ 
      -> 65 700 euro/y (+ 31 000 euro/y for N/DN)
    • Fenton: @1gFe⁺⁺/gH₂O₂/gCOD: 1,39 euro/m³ 
      -> 76 000 euro/y (+ 31 000 euro/y for N/DN)
    • FeCl₃: @1gFeCl₃/gCOD: 0,88 euro/m³ 
      -> 48 000 euro/y (+ 31 000 euro/y for N/DN)
How can we reduce these costs?

<table>
<thead>
<tr>
<th></th>
<th>N/DN+AC</th>
<th>N/DN+O3+AC</th>
<th>N/DN+Fenton+AC</th>
<th>N/DN+FeCl3+AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro/year</td>
<td>103478</td>
<td>96908</td>
<td>107310</td>
<td>79497</td>
</tr>
<tr>
<td>Euro/m³</td>
<td>1.89</td>
<td>1.77</td>
<td>1.96</td>
<td>1.45</td>
</tr>
</tbody>
</table>
Integration of techniques

• Coupling biological treatment to physical-chemical treatment
Integration of techniques

• Coupling biological treatment to physical-chemical treatment
  – e.g. ANR+O₃+AC
Integration of techniques

- Coupling biological treatment to physical-chemical treatment
  - e.g. ANR+O$_3$+AC
    - BOD increase (after O$_3$), mainly at lower COD concentration
Integration of techniques

- Coupling biological treatment to physical-chemical treatment
  - e.g. ANR+O₃+AC
    - (Partial) recirculation
      - increased COD and nitrate removal
      - Competition between anammox and denitrifiers for nitrite
Integration of techniques

• Daily flow rate: 150 m³/d (365 d)
  – ANR+O₃+AC: 1,1 euro/m³
    -> 60 000 euro/y
  – 40% reduction compared to original +/- 100 000 euro/y
Integration of techniques

<table>
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<tr>
<td>N/DN+AC</td>
<td>103478</td>
<td>1,89</td>
</tr>
<tr>
<td>ANR+O3+AC with recirculation</td>
<td>60225</td>
<td>1,1</td>
</tr>
</tbody>
</table>
Conclusion

• Operational costs can be reduced by combining techniques

• Future
  – More combinations will be tested
  – Full cost estimation (e.g. sludge disposal) should be implemented
  – Other parameters (e.g. metals) will be looked at
  – Pilot-scale testing
Thanks to the sponsors
Some references

C/F + Actief Kool