How to retrieve nutrients from organic wastes

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www.jki.bund.de
Outline

• Nutrient recovery potential from organic wastes
• Challenges
• Nutrient recovery from
  – Waste water treatment (process water, sewage sludge, sewage sludge ash)
  – Urine
  – Manure
  – Meat and bone meal
• Summary and recommendations
## Recovery potential

**Estimation of the potential amounts of nutrients in selected organic waste materials in the EU (1000t/year) (Werner, 2008)**

<table>
<thead>
<tr>
<th>Material</th>
<th>N</th>
<th>P</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure</td>
<td>6700</td>
<td>1583</td>
<td>6534</td>
</tr>
<tr>
<td>Sewage sludge</td>
<td>330</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>Animal meals</td>
<td>120</td>
<td>155</td>
<td></td>
</tr>
<tr>
<td>Bio-/green waste</td>
<td>216</td>
<td>47</td>
<td>149</td>
</tr>
<tr>
<td>Residues from gelatine production</td>
<td>1.4</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>Residues from potato starch production</td>
<td>18.8</td>
<td>2.9</td>
<td>37.5</td>
</tr>
<tr>
<td>Fermentation filter cakes</td>
<td>3.6</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>Molasses production (vinasse)</td>
<td>37.4</td>
<td>0.9</td>
<td>58.0</td>
</tr>
<tr>
<td>Defecation lime sugar industry</td>
<td>18.7</td>
<td>27.4</td>
<td></td>
</tr>
</tbody>
</table>
Challenges

• Organic waste materials may contain:
  – Heavy metals
  – Organic pollutants
  – Pharmaceuticals
  – Pathogens

• Chemical and physical composition
  – Dustiness of raw material
  – Reactivity problems in the wet chemical processes

• Important: stability of chemical quality

• Possible solution: designing new process to produce NPK – or PK fertilisers from recycled materials

• Finding a suitable market to distribute the product
  – Agronomic efficiency
  – Financial viable and environmentally safe
Technologies for nutrient recycling
Nutrient-recovery from waste water, sewage sludge and sewage sludge ashes

Possible locations for P-recovery at a waste water treatment plant

1. effluent of WWTP (main stream)
2. process water / sludge liquor (side stream)
3. dewatered sewage sludge
4. sewage sludge ash

(Adam, 2009)
# Technologies for P Recycling

## Watery phase: waste water (treated) or process water (e.g. sludge liquor)

### Precipitation
- Process Berliner Wasserbetriebe/Air Prex (Heinzmann, 2008)
- Prisa process (Pinnekamp and Montag, 2007)

### Crystallization
- DHV-Crystalactor® (Giesen and De Boer, 2003)
- The OSTARA PEARL™ (Esemag, 2006)

## Dewatered or dried sludge

### Wet chemical
- Seaborne /Gifhorn process (Versterager, 2003; Müller, 2005)

### Crystallization
- CSH-process Darmstadt (Petzet, 2009)

### Thermal
- Mephrec process (Scheidig et al., 2009)

## Sewage sludge ash

### Wet chemical
- Sephos process (Cornel and Schaum, 2005)
- PASH process (Montag et al., 2005; Pinnekamp et al., 2007)

### Thermal
- BAM/AshDec process (Adam, 2009; Herrmann, 2009)
- Electro thermal P (Cornel, 2002; Korving and Schipper (2009)

(Adam, 2009)
OSTARA PEARL™ Process

- Recovering struvite \((\text{NH}_4)\text{Mg(PO}_4\text{)}*6\text{H}_2\text{O})\)
- Crystal Green® already sold as “slow release fertiliser”
  - 5% N + 28% P + 15% MgO
  - Inorganic
  - Free from pathogens
- > 85% of P and 40% of N can be recovered

http://www.scientificamerican.com/media-inline/sewages-cash-crop_1.jpg

www.ostara.com/technology
Sewage sludge - crystallization

- P-recovery from Bio-P sludges using calcium-silicate-hydrate (CSH) pellets (Petzet & Cornel 2009)
- Pellets are directly fed into the anaerobic reactor for sludge stabilisation
- P is directly ("in-situ") taken up by the CSH pellets
- Crystallisation of Ca-P is triggered
- P-loaded pellets are removed from the sludge and reused in the fertiliser industry
Sewage sludge - crystallization

- P-recovery approx. 30% of P contained in wastewater
- Costs: approx. 5€/kg P

1. Fresh CSH
2. Addition of CSH to waste activated sludge
3. Reaction within anaerobic reactor
4. Separation of P-loaded CSH and P-depleted sewage sludge
5. Washing of the CSH
6. Recycling product: CSH after drying

(Petzet & Cornel 2009)
Sewage sludge ash – thermo-chemical

- Raw sewage sludge ash
  - P-forms: AlPO$_4$ and Ca$_3$(PO$_2$)$_2$ [whitlockite]
  - Free from organic pollutants
  - High heavy metal concentrations

- Thermo-chemically treated sewage sludge ash
  - Significant reduction (< 90%) of Cd, Cu, Pb, and Zn

(Adam, 2008)
Sewage sludge ash – thermal

- Reformation of P-forms:
  - \( \text{Ca}_5(\text{PO}_4)_3\text{Cl} \) [Chlorapatite]
  - \( \text{Ca}_4\text{Mg}_5(\text{PO}_4)_6 \) [Stanfieldite]
  - \( \text{Ca}_3(\text{PO}_4)_3\text{Cl} \) [Chlorapatite]

\[ \begin{align*}
\text{MgCl}_2 & \quad \text{CaCl}_2 \\
\end{align*} \]

- \( \text{MgCl}_2 \) Cl-donor: fertilisation performance of ashes close to SSP
- \( \text{CaCl}_2 \) Cl-donor: lower yield and P-uptake → post processing
  - Addition of a fully digested P fertiliser (i.e TSP)
  - Partial digestion e.g. with \( \text{H}_3\text{PO}_4 \) or \( \text{H}_2\text{SO}_4 \)

- Costs: approx 2.3€/kg P
Nutrient-recovery from urine

http://media.treehugger.com/assets/images/2011/10/nomix-toilet-photo_003.jpg
Fertiliser products from human urine

- **Problem:** risk of contamination with pharmaceuticals/synthetic estrogens
- **Solution:**
  - Struvite precipitation by adding MgO or MgCl₂ at pH ≤ 9
  - P recovery rates: 90-98%
- **Final product:**
  - Low in heavy metals and micro-pollutants
  - Represents a valuable market fertiliser
  - Fertilising effect comparable to commercial fertilisers (Ganrot, 2009)

### Distribution of N and P in human excretions (Vinneras, 2004; quoted after Kroiss et al., 2011)

<table>
<thead>
<tr>
<th></th>
<th>Urine g/(PE*a)</th>
<th>Faeces g/(PE*a)</th>
<th>Urine (%)</th>
<th>Faeces (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>4000</td>
<td>550</td>
<td>88</td>
<td>12</td>
</tr>
<tr>
<td>P</td>
<td>365</td>
<td>183</td>
<td>67</td>
<td>33</td>
</tr>
</tbody>
</table>
Nutrient-recovery from manure

http://www.tierschutzbund.de/information/hintergrund/landwirtschaft/ Schweine/schweinemast-anlage-allstedt.html
Slurry separation

- Slurry: improper N/P-balance which does not match plant need
- Solution: Separation of slurry
  - Sedimentation
  - Centrifugation
  - Drainage
  - Pressurised filtration
- Liquid fraction: high N:P ratio → on farm use as N-source
- Solid fraction: narrow N:P ratio → transport to farms with low livestock density
  - Substitution for mineral fertiliser P
- Problems:
  - Change of plant nutrient/heavy metal ratio in the biomass (depending on the separation process)
  - Fate of pathogens?
Nutrient-recovery from meat and bone meal
Thermal digestion of meat and bone meal

- Average nutrient concentration MBM: 8% N, 5% P, 1% K and 10% Ca (Chen et al., 2011)
- Bone fraction: apatite; meat fraction: organic P
- Slow release fertiliser on acid soils (< pH 5.5)
- Comparable to rock phosphate
- MBM-ash: also poor agricultural performance
- Digestion of MBM-ash in liquid converter slag (1600°C) increases:
  - P solubility (e.g. Citric acid from 53% up 87%)
  - DMY and P-uptake
  → comparable to fully digested P fertiliser
- Technique also applicable to SSA

(Rex, 2009)
Summary/conclusion

• Nutrient-recycling with focus on P is essential
• Different secondary raw materials can be used for recovery
  – Process water
  – Sewage sludge and sewage sludge ash
  – Manure
  – Urine
  – Meat and bone meal
• Different techniques can be used to recover nutrients
  – Precipitation
  – Crystallisation
  – Separation
  – Thermal treatment
  – Wet chemical process
Recommendations

Political:

– Formulation of threshold values for relevant heavy metals in the European fertiliser ordinance
– Mandatory mixing of recycling P with rock phosphate P
– Imposing charges/taxes on Cd and U in mineral P-fertilisers
– Supporting the development and improvement of technologies for P-recovery
Thank you for your attention!