DIGESTATE MANAGEMENT IN FLANDERS: Nutrient removal versus nutrient recovery

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IV. Why recover nutrients?
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I. INTRODUCTION VCM

- Flemish Coordination Centre for Manure processing (VCM)

- Independent platform and intermediate between government and the manure processing sector

- Activities
  - **Platform:**
    - to coordinate consultation between government and private sector
  - **Policy support**
    - Yearly enquiry on processing capacity and techniques
    - Detecting bottlenecks and suggesting solutions
    - Thematic studies (e.g. preparation of new legislation)
  - **First line support**
    - Selection of technology, regulatory aspects, environmental permits, ...
  - **Knowledge centre**
    - All aspects of manure processing (technical, regulatory, economic)
    - Focus on recovery and valorization of nutrients
II. BIOGAS PRODUCTION IN FLANDERS

- 35 biogas plants (active in 2011) in Flanders
- 1,744,300 Ton input/year → 70.3 MWe/year installed
  → 300 GWh green energy
- 27 biogas plants have manure input
- 400,000 Ton manure/year digested
III. DIGESTATE MANAGEMENT IN FLANDERS
III. DIGESTATE MANAGEMENT IN FLANDERS: situation

- Organic and inorganic fertilisers → water pollution
- Limit nutrient dosage on fields
- Strong limit on animal manure (170 kg N/ha)
- Biogas-installations that take in manure → Digestate equals animal manure status
- Raw digestate disposal is difficult, esp. in nutrient rich regions (West-Flanders, Antwerp)

- Most co-digestion plants invest in digestate processing techniques
III. DIGESTATE MANAGEMENT IN FLANDERS: situation

Mestproductiedruk (kg N/ha) in Vlaanderen, 2010
(bron: Mestbank)

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Omschrijving mestproductiedruk

- <85 kg N/ha
- 85-170 kg N/ha
- 170-340 kg N/ha
- >340 kg N/ha

Biomass for Energy
III. DIGESTATE MANAGEMENT IN FLANDERS: manure processing

- **Liquid manure**
  - Mechanical separation
  - **Liquid fraction**
    - Biological treatment
    - Ammonia stripping
    - Liming
    - Electrolysis
    - Membrane Filtration
    - Evaporation/condensation
  - Constructed wetlands

- **Solid manure**
  - Drying
  - Pelletizing
  - Composting
  - Liming

- **Solid fraction**
III. DIGESTATE MANAGEMENT IN FLANDERS: digestate processing

- Third party disposal
- Digestate 938,700 ton\(^1\) 36 AD plants\(^2\)
- Separation
- Export
- Pellets
- Composting
- Composting
- ...
III. DIGESTATE MANAGEMENT IN FLANDERS: digestate processing

- Third party disposal: 3
- Separation: 23
- Composting: 2
- Drying: 8

![Graph showing digestate management methods and their usage.](image)
III. DIGESTATE MANAGEMENT IN FLANDERS:
SF Digestate

- Solid fraction
  - Drying
    - Export
    - Pellets
    - Composting
  - Third party disposal
    - Export
    - Pellets
    - Composting
  - Composting
III. DIGESTATE MANAGEMENT IN FLANDERS:
sf digestate

- Third party disposal: 7
- Composting: 3
- Drying: 13

Legend: AD plants
III. DIGESTATE MANAGEMENT IN FLANDERS:
If digestate

Third party disposal

Liquid fraction

Evaporation

Biological nitrification/denitrification

Membrane filtration

NH₃ stripping

Evaporation

Filtration

Export

Membrane filtration

Agriculture

Agriculture

Agriculture

Agriculture

Agriculture
III. DIGESTATE MANAGEMENT IN FLANDERS: If digestate

- Evaporation: 11
- Biological nitr/denitr: 9
- Membrane filtration: 6
- Third party disposal: 4
- NH3 stripping: 1

AD plants
IV. WHY RECOVER NUTRIENTS?

- Awareness of phosphorus depletion
- Awareness of increasing artificial fertiliser use
  - Energy consuming
  - Economical burden for farmer

- Question: how can digestate be valorised as a valuable source of nutrients?
- OR: how can digestate be turned into a ‘green’ substitute for artificial fertilisers?

Extract nutrients!
V. NUTRIENT RECOVERY TECHNIQUES

- Hard to define

- Interpretation:
  - End-product with a higher concentration of NPK than raw digestate
  - Techniques that separate NPK of organic matter
  - Goal: end-product that can substitute artificial fertiliser or as a feedstock in industrial processes
IV. Nutrient recovery techniques

- **Digestate**
  - **Evaporation**
  - **Mechanical separation** (with or without addition of polymers)
    - **Solid fraction**
      - **Composting**
      - **Thermal drying**
      - **Combustion**
        - **Gasification**
        - **Pyrolysis**
      - **P-extraction from ashes/biochars**
    - **Liquid fraction**
      - **Evaporation**
      - **Acid air washer**
      - **Biological nitrification/denitrification**
        - **Membrane filtration**
        - **Electrodialysis**
        - **Transmembrane chemosorption**
        - **Forward osmosis**
        - **Precipitation of P-crystals**
        - **Ammonia stripping**
        - **Biomass production & harvesting**
V. NRT (1): Acid air washer

- **Drying, composting, evaporation, ...**

- **Important: treat drying gases!**
  - Dust, ammonia, odorous gases
  - Acid air washer that captivates NH$_3$
    - End-product: (NH$_4$)$_2$SO$_4$
    - Flanders: artificial fertiliser
    - Variable N-content
    - Low pH, high salt content
    - Sulphur content

- **Status: full scale**

$\rightarrow$ Restrains use
V. NRT(6): Ammonia stripping

- **Aeration in packed column**
  - Elevated pH & T
  - Bottlenecks: precipitation of salts & fouling of the packing material, periodical cleaning necessary

- **Acid air washer**
  - Stripgas + sulphuric acid $\rightarrow$ ammonia sulphate
  - Higher N-content than air washer drying gases/stables

- **Lime softening step with Ca(OH)$_2$**
  - Removes Ca$^{2+}$, Mg$^{2+}$, carbonates
  - Preferred pH-increase

- **Status**
  - Full-scale
V.NRT(2): Extraction of organically bound P

- Ashes: P-, K-, Al- & Si-components + heavy metals (Cu, Zn, Cd)

- Several processes
  - Thermochemical
    - Addition of MgCl$_2$ & heating up to 1000°C
    - Heavy metals in the gaseous phase
    - Production of e.g. CaHPO$_4$
  - Wet-chemical extraction techniques
    - Acid extraction
    - Fertilising value (Kuligowski et al., 2010)

- Status
  - Full scale for ashes of sludge WWT, poultry manure (NL)
  - Lab scale testing
V. NRT(3): Pressurised membrane filtration

- **Types**
  - Pressure: RO > UF > MF
  - Pore size: MF > UF > RO
  - Concentrate: suspended solids (MF), macromolecules (UF), ions (RO)
  - Other pre-treatment: DAF (+ flocculants)

- **Bottleneck: blocking of membranes**
  - Suspended solids, salts with reduced solubility, biofouling
  - Higher tangential flux, anti-scalants, cleaning agents (NaOH & H₂SO₄)

- **Pilots mineral concentrates (NL)**
  - Agronomic, economic & environmental effects of MC
  - Goal: recognition as an artificial fertiliser
    - EU 2003/2003 (EU-fertiliser)
    - Nitrate Directive

- **Status: full-scale (4 biogas plants in Flanders)**
V. NRT(4): Other membrane techniques

- **Forward osmosis**
  - Draw solution in stead of pressure
  - Status
    - Full-scale in other sectors, no testing (?) with digestate

- **Electrodialysis**
  - Ion exchange membrane + electrical voltage
  - Transfer of $\text{NH}_4^+$, $\text{K}^+$ en $\text{HCO}_3^-$
  - Status
    - *No full-scale on digestate, tests on lab-scale in literature*

- **Transmembrane chemosorption**
  - Innovative pig slurry treatment in NL
  - Gaseous $\text{NH}_3$ diffuses through membrane & is captured in sulphuric acid
  - Status: pilot in NL
V. NRT (5): P-precipitation

- Soluble P (ortho-phosphate) can be precipitated by:
  - $\text{Ca}^{2+} \rightarrow \text{Ca}_3(\text{PO}_4)_2$
  - $\text{Mg}^{2+} \rightarrow \text{MgNH}_4\text{PO}_4 \text{ or MgKPO}_4$ (MAP of struvite)
  - $\text{K}^+ \rightarrow \text{K}_2\text{NH}_4\text{PO}_4$ (potassium-struvite)

- Commercial processes in development:
  - Reactors
  - Large, pure crystals (seeding)
  - Full-scale in WWT

- Status: full-scale for calf manure and in other sectors + pilot testing on digestate

- Optional: dissolve organically bound P
  - Acid extraction
  - Creates a P-low solid fraction
V. NRT (7): Biomass production & harvest

- **Research on algae & duckweed**
  - Removal of P&N by plant uptake
  - Bottleneck: suspended solids, humic acids,... → reduction of penetration of light
  - Max. additions in growing medium
  - Large surface
  - Valorising harvested biomass
    - Biobased chemicals
    - Biofuels
    - Fertilisation
    - Feed (GMP)

- **Status**
  - Lab tests + pilot on duckweed
## VI. END-PRODUCTS

<table>
<thead>
<tr>
<th>TECHNIQUE</th>
<th>STARTING FROM</th>
<th>END-PRODUCT</th>
<th>CHARACTERISTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid air washer</td>
<td>Air charged with NH₃</td>
<td>(NH₄)₂SO₄ solution</td>
<td>(NH₄)₂SO₄ solution : 30-70 kg N/m³, pH 3-7</td>
</tr>
<tr>
<td>P-extraction</td>
<td>Ashes/biochar/SF digestate</td>
<td>Acid P-extract/CaHPO₄</td>
<td>Acid P-extract: P&lt;sub&gt;tot&lt;/sub&gt;: 0.192 g/kg</td>
</tr>
<tr>
<td>Reversed osmosis</td>
<td>UF/MF/DAF-permeate</td>
<td>RO-concentrate (NK-fertiliser)</td>
<td>N&lt;sub&gt;tot&lt;/sub&gt;: 7.3 g/kg, K&lt;sub&gt;tot&lt;/sub&gt;: 2.9 g/kg, P&lt;sub&gt;tot&lt;/sub&gt;: 0.42 g/kg</td>
</tr>
<tr>
<td>Forward osmosis</td>
<td>UF/MF/DAF-permeate</td>
<td>FO-concentrate (NK-fertiliser)</td>
<td>?</td>
</tr>
<tr>
<td>Electrodialysis</td>
<td>LF digestate</td>
<td>NK-fertiliser</td>
<td>?</td>
</tr>
<tr>
<td>TMCS</td>
<td>LF filtered on 10 µm</td>
<td>NK-fertiliser</td>
<td>(NH₄)₂SO₄ solution: 50 - 150 kg N/m³</td>
</tr>
<tr>
<td>P-precipitation</td>
<td>(LF) digestate</td>
<td>MgNH₄PO₄/MgKPO₄/CaNH₄PO₄</td>
<td>12.65/11.62/11.86% P</td>
</tr>
<tr>
<td>NH₃-stripping &amp; acid air washer</td>
<td>LF digestate</td>
<td>(NH₄)₂SO₄ solution</td>
<td>30-70 kg N/m³, pH: 3-7</td>
</tr>
<tr>
<td>Biomass production</td>
<td>Diluted LF digestate</td>
<td>Biomass</td>
<td>Duckweed: 30% CP (dm)</td>
</tr>
</tbody>
</table>
VII. NEED FOR FURTHER RESEARCH

- **Technical bottlenecks**
  - WWT-techniques translated to digestate → bottlenecks

- **Marketing**
  - Added value of the end-product vs investment to be made
  - End-users: farmers or industrial users?

- **Legislative**
  - Redefine “artificial fertiliser”

- **Sustainability**
  - Comparative analysis of environmental impact (LCA)
  - Consumption of heat, electricity & chemicals, risk for emissions
  - Reduction of the artificial fertiliser use
VIII. CONCLUSIONS

- **High nutrient pressure + P depletion**
  - Digestate treatment is inevitable
  - As a valuable source of nutrients

- **Techniques**
  - Full-scale
    - Acid air washers, membrane filtration, ammonia stripping
  - Breakthrough full-scale
    - Struvite precipitation
  - Potentially long-term
    - Electrodialysis, forward osmosis, TMCS, biomass production
  - Questionmark
    - P-extraction from ashes/biochars

- **Further developments will only take place if recovery is profitable**
  - Price for recuperated nutrients = price for nutrients in artificial fertilisers
IX. RELATED PROJECTS

- **ARBOR**
  - Interreg IV.B
  - Accelerate development of renewable energy in NW-Europe
    - Inventory of nutrient recovery techniques + LCA + EA
    - Characterisation of end-products
    - Field trials
    - Market study

- **MIP Nutricycle**
  - Flemish project
  - Produce artificial fertiliser replacers
    - Pilots on ammonia stripping & preconditioned separation
    - Lab tests with struvite

- **BIOREFINE**
  - Interreg IV.B, kick-off meeting 3/2013
  - Nutrient recycling
  - European platforms: Transnational cooperation to identify and solve bottlenecks
QUESTIONS

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