Phosphorus recovery process

Phosphogreen

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Phorwater Workshop – May 12th, 2016
Context
Context
Facts and figures about phosphorus

today, a nutrient
• essential to life (creation of DNA, cell membranes…)
• non-substitutable
• intensively used as an additive in food industry and agriculture

tomorrow, a geopolitical issue?
• depletion foreseen by the end of 21st century
• reserves unequally distributed throughout the world: 95% of the reserves located in only 9 countries
• complicated geopolitical situation in some countries
• Europe has no phosphate reserves

Solution
Phosphorus recovery

considering that

• 20% of current world demand of phosphorus could be covered by recovery from wastewater
• 80% of phosphorus extracted from phosphate ores is intended for fertilizers

the solution is

to convert phosphorus present in wastewater into a valuable fertilizer
to help our clients take a step forward towards sustainable development and circular economy
Phosphorus recovery processes
P-recovery processes

**one aim**
extract phosphorus from wastewater in a form that can be used directly as a fertilizer or as a raw material for industries.

**various processes**

<table>
<thead>
<tr>
<th>origin</th>
<th>recovery process</th>
</tr>
</thead>
<tbody>
<tr>
<td>wastewater</td>
<td>adsorption</td>
</tr>
<tr>
<td>mixed liquor</td>
<td>precipitation</td>
</tr>
<tr>
<td>digested sludge</td>
<td>crystallization</td>
</tr>
<tr>
<td>centrates</td>
<td>chemical extraction</td>
</tr>
<tr>
<td>dried sludge</td>
<td>thermal treatment</td>
</tr>
<tr>
<td>ashes</td>
<td></td>
</tr>
</tbody>
</table>

- Small plants
- High CAPEX/OPEX Done externally
Dissolved phosphate ions can be converted into solid phase by precipitation-crystallization.

<table>
<thead>
<tr>
<th>Possible recovery of phosphorus?</th>
<th>Use of the product as fertilizer?</th>
</tr>
</thead>
<tbody>
<tr>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>yes (electrothermal treatment)</td>
<td>no</td>
</tr>
<tr>
<td>yes (electrothermal treatment)</td>
<td>low bioavailability</td>
</tr>
<tr>
<td>yes (as is)</td>
<td>yes</td>
</tr>
</tbody>
</table>

- $\text{PO}_4^{3-} + \text{Fe}^{3+} \rightarrow \text{FePO}_4$
  - ferric chloride, FeCl₃
- $\text{PO}_4^{3-} + \text{Al}^{3+} \rightarrow \text{AlPO}_4$
  - aluminum sulphate, Al₂(SO₄)₃
- $2\text{PO}_4^{3-} + 3\text{Ca}^{2+} \rightarrow \text{Ca}_3(\text{PO}_4)_2$ - HAP
  - lime, Ca(OH)₂
- $\text{PO}_4^{3-} + \text{Mg}^{2+} + \text{NH}_4^+ \rightarrow \text{MgNH}_4\text{PO}_4, 6\text{H}_2\text{O}$ - MAP
  - struvite
  - magnesium chloride, MgCl₂
Phosphogreen
Technology description
Phosphogreen

Principle

**application field**

- WWTP capacity > 40,000 PE
- Bio-P removal
- Anaerobic digestion
- Phosphorus in digested sludge centrates ≥ 70 mg/L

**position in the treatment line**

- Primary and/or secondary sludge
- Anaerobic digestion
- Dewatering
- Sludge cake for disposal
- Water back to the headworks
- Phosphogreen
- Struvite

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**Phosphogreen**

**Process overview**

- **Fluidized bed reactor** with recirculation
- **Addition of MgCl₂ and NaOH** (if pH needs to be adjusted)
- **Airlift system for CO₂ stripping** (pH ↗)
- **Struvite** harvested from the bottom of the reactor

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*Diagram showing the process of struvite extraction and processing.*

- Air inlet (centrates) → Fluidized bed reactor → Struvite extraction → Water recirculation → Washing → Drying → Packaging
- MgCl₂ and NaOH added (if pH needs to be adjusted)
- Airlift system for CO₂ stripping (pH ↗)

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*Image of the reactor with labels for air, water outlet, inlet, NaOH, MgCl₂, struvite extraction, water recirculation, washing, drying, and packaging.*
Phosphogreen
Struvite characteristics

Struvite ↔ MgNH₄PO₄·6 H₂O

- granule size: 1 to 3 mm
  - including
  - 12.2% w/w phosphorus
  - 5.8% w/w nitrogen
  - 10.4% w/w magnesium

- heavy metals content (mg/kg):

<table>
<thead>
<tr>
<th></th>
<th>struvite</th>
<th>Danish standards for sludge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cd</td>
<td>0.06</td>
<td>0.8</td>
</tr>
<tr>
<td>Hg</td>
<td>&lt;0.1</td>
<td>0.8</td>
</tr>
<tr>
<td>Pb</td>
<td>&lt;0.2</td>
<td>120</td>
</tr>
<tr>
<td>Ni</td>
<td>0.5</td>
<td>30</td>
</tr>
<tr>
<td>Cr</td>
<td>4.5</td>
<td>100</td>
</tr>
<tr>
<td>Zn</td>
<td>7.4</td>
<td>4000</td>
</tr>
<tr>
<td>Cu</td>
<td>0.8</td>
<td>1000</td>
</tr>
</tbody>
</table>
References
Phosphogreen references
Åby (Aarhus, Denmark)

plant’s characteristics

- 84,000 PE
- No primary treatment
- P-recov. unit start-up date: 2013

**WWTP’s inlet:**
- 450 kg/d \(N_{\text{tot}}\)
- 105 kg/d \(P_{\text{tot}}\)

**Outlet:**
- 300 kg/d struvite
  (incl. 37 kg P/d)
- ~35% of P recovered
Phosphogreen references
Åby (Aarhus, Denmark)

Excess act. sludge → Bio-P-release → Thickening → Anaerobic Digestion → Dewatering → Dewatered sludge

- No primary treatment
- Bio-P removal

Water line:

P-recovery
Phosphogreen

STRUVITE

Reject water
Phosphogreen references
Herning (Denmark)

plant’s characteristics

• 150,000 PE

• Primary treatment

• P-recov. unit start-up date: 2015

• WWTP’s inlet:
  1200 kg/d $N_{tot}$
  240 kg/d $P_{tot}$

• Outlet:
  290 kg/d struvite
  (incl. 36 kg P/d)

~ 15 % of P recovered
Phosphogreen references
Herning (Denmark)

Primary sludge

Excess activated sludge

Bio-P-release

Thickening

Anaerobic Digestion

Dewatering

Dewatered sludge

P-recovery

Phosphogreen

STRUVITE

Reject water

Water line:
- Primary treatment
- Bio-P removal
Benefits
Phosphogreen
Benefits

- **financial revenue**
  - Sale of struvite as fertilizer (75 to 300 €/t)
  - ROI 5 to 10 years

- **savings on various levels of the process**
  - reduction of chemicals consumption for phosphorus physicochemical treatment
  - less energy consumed for biological treatment (removal of a part of nitrogen by struvite precipitation)
  - increased equipment service life thanks to controlled and localized precipitation of struvite
  - reduction of sludge disposal costs by minimization of sludge volumes

- **commitment to sustainable development**
  - resource recovery (phosphorus, nitrogen): contribution to the circular economy
  - lower environmental footprint through energy savings, sludge volume reduction, increased equipment service life, reduced chemical consumption
Regulation constraints
the regulatory framework is complex for phosphorus recovery projects:

- limited quantities
- many quality controls

European legislative and regulatory framework

- spreading plan
- fertilizer regulations
- national approval (usually necessary)
- national standards
- EU directive on fertilizers

A significant number of laws and regulations apply in Europe, which complicates the phosphorus recycling projects. Simplification’s works are underway (end of waste status).
Regulation constraints

- Struvite homologated as a fertilizer in some countries (DK, UK), but not in others (FR, …)
  - No standardized European regulation
  - Slow down the development of P recycling plants

- Difficulties to import/export struvite between EC members while there is a market

Diagram:

1. Pilot plant built in exporting country
2. Struvite production starts
3. REACH application
4. Agreement with transport company
5. Delivery to fertilizer company

Import approvals:
- Reusable substance approval / certificate obtained for the state in exporting country
- Self declaration of using the same production methods as in importing country
- Relevant laboratory analyses of product quality made by exporter
Thank you for your attention