AirPrex™: Process for Optimization of Biosolids Treatment with the option of Phosphate Recovery

July 2015
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• Biological Phosphate-Removal
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  Magnesium-Ammonium-Phosphate (MAP/ Struvite) crystallization
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Enhanced Biological Phosphate Removal

**Aerobic Biological Zone**
- Increased $\text{PO}_4$ intake due to the formation of polyphosphates

**Anaerobic Zone / Digester**
- $\text{PO}_4$ release due to the hydrolysis of polyphosphates

Diagram:
- PHA
- Glycogene
- Polyphosphate
- Energy
- Oxygen (Nitrate)
- Ortho Phosphate
- Fatty acids
- Electrons
- Poly Phosphate
- Inner cell structure
Phosphorus flow and concentrations in the WWTP

Inlet
100 % ~ 1.80 g P/(E*d)

Outlet
10 % ~ 0.18 g P/(E*d)

Primary Sludge
10 % ~ 0.18 g P/(E*d)

Waste Activated Sludge (WAS)
80 % ~ 1.45 g P/(E*d)

WAS is main carrier for phosphate

Quelle: UBA, 2007
Possible areas for P-Recovery

Areas for recovery:
1. Sludge
2. Sludge liquor
3. Sludge ash
Integration of the AirPrex® Process
Biological Phosphate Elimination in the Water phase Summary

• Internal recycling of ortho-phosphate (PO$_4$-P)
• Uncontrolled Struvite crystallization and deposits
• Negative influence on the sludge dewatering (lower DS and / or higher Polymer usage)
• High internal P-recycling by sludge liquor
Formation of Magnesium-Ammonium-Phosphate (MAP/Struvite)

<table>
<thead>
<tr>
<th>Chemical equation:</th>
<th>Mg$^{2+}$ + NH$_4^+$ + HPO$_4^{2-}$ + 6H$_2$O = MgNH$_4$PO$_4$ * 6H$_2$O + H$^+$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molar weights [g/mol]: Struvite: 245</td>
<td>Mg</td>
</tr>
<tr>
<td></td>
<td>24.3</td>
</tr>
<tr>
<td>Share in per cent [%]:</td>
<td>9.9</td>
</tr>
</tbody>
</table>
\[ \text{Mg}^{2+} + \text{NH}_4^+ + \text{H}_2\text{PO}_4^- + 6\text{H}_2\text{O} = \text{MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O} + 2\text{H}^+ \]

- \text{Mg}^{2+}: 40 \text{ mg/L}
- \text{HCO}_3^-: 2500 \text{ mg/L}

Struvite precipitation area

Struvite crystallisation relation P-content and pH

Mg\text{ }^2+ \text{ in solution}

Ortho-Phosphat [mg/ l] PO\textsubscript{4}-P
Uncontrolled Struvite precipitations
Influence of Ortho-Phosphates on the water absorption capacities of digested sludge

Water absorption by hydrogels (EPS), shown with polysaccharides, proteins, etc.

Stabilisation due to phosphates and increased pH values

Consequence:
Increased water absorption capacity
AND
therefore decreasing sludge dewatering efficiency (less cake dryness and higher Polymer consumption)
Influence of the PO4-P concentration on the dry solid content during dewatering
CO₂ stripping by aeration
Increase of pH to 7.8 – 8.2
Addition of Magnesium chloride (MgCl₂)
Growing and sedimentation of Struvite
Struvite separation and cleaning
AirPrex® Process for selective MAP - Precipitation

- Aeration for CO₂ stripping and circulation
- Addition of Magnesiumchloride (MgCl₂)
- MAP - crystal growth and sedimentation
- MAP - Separation and MAP - Cleaning
AirPrex® Process for selective MAP - Precipitation
AirPrex® Process for selective MAP - Precipitation
Economic drivers for AirPrex®

1. Increase of cake dryness by appr. 3 to 4% (e.g. 22% → 26%)
2. 95% reduction of Ortho-P concentration in the sludge liquor
3. Elimination / prevention of crystallization in the entire sludge- and centrate area
4. Production of Struvite
AirPrex® Process - The perfect location for maximum savings
The following WWTP already use an AirPrex® System:

- Berlin Waßmansdorf (Germany), 1.200.000 P.E. (2010)
- Mönchengladbach Neuwerk (Germany), 650.000 P.E. (2010)
- Wieden-Echten (Netherlands), 190.000 P.E. (2013)
- Amsterdam-West (Watemeer, Netherlands), 1.000.000 P.E. (2013)
- Uelzen (Germany), 83.000 P.E. (since March 2015)
- ASG Salzgitter Nord (Germany), 120.000 P.E. (since April 2015)
- Tianjin (China), 1.000.000 P.E. (Start-up Nov. 2015)
- Wolfsburg (Germany), 120.000 P.E (Start up July 2016)
Berliner Wasserbetriebe (BWB), Germany
Berlin-Wassmannsdorf WWTP (1,000,000 P.E. or People Equivalent)

Capacity AirPrex®: 2,000 m³/d anaerobically digested (AD) sludge
Struvite production: approx. 2,500 kg/d
Start-up: 2010
Problem:
uncontrolled Struvite precipitation
Struvite as bulk delivery

Struvite packaged for sale to public
Daily Phosphorus Balance of Berlin Wassmannsdorf WWTP

Inlet
180,000 m³/d
appr. 13 mg/l P_{tot}

2355 kg P_{tot}/d
2278 kg P_{el}/d

Screens
Grit Trap

Primary Clarifiers

Aeration

Secondary Clarifiers

Outlet
77 kg P_{tot}/d
appr. 0.3 mg/l P_{tot}

57 kg PO_{4}^-P
Backcharge

WAS Thickening

Mixed Sludge Storage Tank

Digested

MgCl_{2} (5 l/m³)

PO_{4}^-P
350 mg/l
2,000 m³/d
700 kg/d

AirPrex® Reactor

Sludge Dewatering (Centrifuges)

Dryer

Incineration

2,9 t MAP in the sludge (54%)
367 kg P
5 kg P/t DS

2,025 kg P_{tot}
in the ash

57 kg PO_{4}^-P
Backcharge

PO_{4}^-P Outlet
<20 mg/l
95% Reduction

MAP Recovery:
2,0 t/d=37% of total MAP
253 kg P/d = aprr. 11% of P_{el} (In-/Outlet)

10.04.2016 Andreas Lengemann
AirPrex® Installation
Moenchengladbach-Neuwerk WWTP (Germany)
AirPrex® Installation
Moenchengladbach-Neuwerk WWTP (Germany)
AirPrex® Installation
Moenchengladbach-Neuwerk WWTP (Germany)

Niersverband, Germany
MG-Neuwerk WWTP (995,000 P.E.)

Capacity AirPrex®: 1,500 m³/d digested sludge
Struvite production: 1,500 kg/d
Start-up: 2009
AirPrex® Process
M‘gladbach-Neuwerk Economy

A. Only Bio-P: 3.150.000 € p.a.
B. Bio-P plus AirPrex®: 2.600.000 € p.a.
C. chem. P-Precipitation (FeCl₂): 3.200.000 € p.a.

DS after dewatering (%)

Total Costs (Disposal and Polymer) in [Euro/yr]

β = 1.3

Data: Niersverband

Basis 2005/2006
Reest & Wieden, NL
Echten WWTP (190,000 P.E.)

Capacity AirPrex®: 400 m³/d AD sludge
Struvite production: appr. 500 kg/d
Start-up: 2013
AirPrex® Installation
Amsterdam WWTP (Netherlands)

Waternet, NL
Amsterdam-West WWTP (1,000,000 P.E.)

Capacity AirPrex®: 2,500 m³/d AD sludge
Struvite production: 4,000 – 5,000 kg/d
Start-up: 2014
Daily Phosphorus Balance of Amsterdam West WWTP

Inlet 168.000 m³/d
  appr. 8 mg/l P<sub>tot</sub>
  1.561 kg P<sub>tot</sub>/d
  1.426 kg P<sub>el</sub>/d

Screens Grit Trap

Primary Clarifiers
  PS Sludge: 800 m³/d
  44 t DS/d

Aeration

Secondary Clarifiers

Outlet 135 kg P<sub>tot</sub>/d
  appr. 0.8 mg/l P<sub>tot</sub>

Screens Grit Trap

External Sludge (PS / WAS Mixture)
  600 m³/d; 26 t DS/d

Secondary Clarifiers

WAS Thickening
  (684 m³/d; 47 t DS/d)

Mixed Sludge Storage Tank

PO<sub>4</sub>-P Backcharge

Digestion

PO<sub>4</sub>-P
  300 mg/l
  2.084 m³/d
  625 kg/d

AirPrex® Reactor

4.8 t/d MAP Production

Sludge Dewatering (Centrifuges)

Incineration

MAP Recovery:
  2.5 t/d = 52% of total MAP
  315 kg P/d = ~ 22% of P<sub>el.</sub> (In-/Outlet)

PO<sub>4</sub>-P Outlet
  AirPrex®
  <30 mg/l
  (63 kg/d)

PO<sub>4</sub>-P in the ash
  290 kg P/d

PO<sub>4</sub>-P Outlet
  1.050 kg P<sub>tot</sub>

MgCl<sub>2</sub>
  (3.5 l/m³)

PO<sub>4</sub>-P in the ash
Uelzen WWTP, Germany (83,000 P.E.)

Capacity AirPrex®: 120 m³/d AD sludge
Struvite production: no MAP recovery
Start-up: April 2015
Salzgitter WWTP, Germany (120,000 P.E.)

Capacity AirPrex®: 240 m³/d AD sludge
Struvite production:
Start-up: July 2015
Wolfsburg WWTP, Germany (185,000 P.E.)

Capacity AirPrex®: 280 m³/d AD sludge
Struvite production: 
Start-up: November 2015
Jing Nan Tianjin WWTP, China (1,000,000 P.E.)

Capacity AirPrex®: 1,608 m³/d AD sludge
Struvite production:
Start-up: Nov. 2015
Use of Struvite

- Struvite: By-product with a good use as a fertilizer
- Nutrients have been proven in accordance with the German law (certified as fertilizer)
  - low heavy-metal content
  - slow release of nutrients (no wash-away effect)
- REACH certified
Summary and Outlook

• The specific phosphate precipitation by Struvite crystallization (AirPrex®) leads to the following advantages
  
  • **Minimize the crystallization** potential
  
  • **Positive impact on the sludge dewatering** by a constant P-Elimination rate between 90 and 95%
  
  • AirPrex® is an **approved and reliable technology** with large-scale references
  
  • Good quality **fertilizer** as a by-product
Thank you for your attention and interest!