Understanding And Modeling Solids Stream Phosphorus Release, Precipitation, And Solids Handling

Thursday, January 24, 2019
1:00 - 3:00 PM ET
How to Participate Today

- Audio Modes
  - Listen using Mic & Speakers
  - Or, select “Use Telephone” and dial the conference (please remember long distance phone charges apply).
- Submit your questions using the Questions pane.
- A recording will be available for replay shortly after this webcast.

Today’s Moderator

John B. Copp Ph.D.
Primodal Inc.
Hamilton, Ontario
Solids Stream P – Jan. 24, 2019

An MRRDC Short Course
Solids Stream Phosphorus Modeling

• Topics:
  • Basics of Phosphorus Removal
  • Phosphorus Issues in the Solids Stream
  • Digestion Phosphorus Chemistry
  • Dewatering Impacts & Mitigation

Solids Stream P – Jan. 24, 2019

An MRRDC Short Course
Solids Stream Phosphorus Modeling

• Speakers:
  Patrick Dunlap
  Black & Veatch
  Murthy Kasi
  Smith & Loveless
  Hélène Hauduc
  Dynamita
  Mario Benisch
  HDR
Our Next Speaker

Patrick Dunlap, MS, PE
Process Engineer
Denver CO

Black & Veatch

Liquid Stream P Removal
Background to Impact on Residuals
Phosphorus Removal

Eutrophication

Phosphorus Limits

Phosphorus Scarcity

- Several hundred years of economically recoverable P reserved at current usage rates
- ... but the two largest P fertilizer producers (USA & China) will run out or recoverable reserves at current production rates within decades
- P Recovery potential at WWTPs is an important part of managing this challenge

<table>
<thead>
<tr>
<th>USGS 2017 Report</th>
<th>2017 Prod (Mt/yr)</th>
<th>Prod % of global</th>
<th>Reserves (Mt)</th>
<th>Reserves % of global</th>
<th>Life (yrs)</th>
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<tbody>
<tr>
<td>Morocco_and_Western_Sahara</td>
<td>27</td>
<td>10%</td>
<td>50,000</td>
<td>71%</td>
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<tr>
<td>China</td>
<td>140</td>
<td>53%</td>
<td>3,300</td>
<td>5%</td>
<td>24</td>
</tr>
<tr>
<td>United_States</td>
<td>28</td>
<td>11%</td>
<td>1,000</td>
<td>1%</td>
<td>30</td>
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<tr>
<td>Rest_of_the_World</td>
<td>68</td>
<td>26%</td>
<td>15,939</td>
<td>22%</td>
<td>234</td>
</tr>
<tr>
<td>World_total_rounded</td>
<td>283</td>
<td>100%</td>
<td>70,000</td>
<td>100%</td>
<td>266</td>
</tr>
</tbody>
</table>

(Vaccari, 2019)
Chemical vs Biological P Removal

Chemical P Removal
- Consistent Performance
- Less disruptive/simpler operation
- Additional operational cost for chemical & residuals disposal
- Nuisance precipitates

Biological P Removal
- Lower operational cost
- Creates opportunity for P Recovery
- Requires additional bioreactor vol.
- Dewatering Impacted
- Nuisance precipitates

Enhanced Biological Phosphorus Removal (EBPR)

PAOs
- Anoxic
- Aerobic (anaerobic)
- Settling
- Effluent

Mg$^{2+}$, K$^+$, Ca$^{2+}$

(Fuhs & Chen, 1975)
Chemical P Removal

- Phosphorus is removed by metal coagulants (Alum/Ferric) through co-precipitation and adsorption
- Metal:P molar ratio for additional removal increases lower PO₄-P concentrations.

Nitrogen vs Phosphorus Removal

- 1 Q, 5-9 mg/L P
- 50-1000 mg/L TP
- Initially as Particulate P
- ... but portion solubilizes
- -1 Q, < 1 mg/L P
- 0.5-1.5 % Q after thickening
Phosphorus Mass Balances - Chem. P

P Release in Digester

• Concentrations of Phosphate & other ions increase in ADs due EBPR P release, decay / lysis of cells, and dissolution of metal precipitates

• Phosphorus in recycle streams can be a significant source of P, up to 30% of the load with EBPR (heavily dependent on AD Chemistry).
Phosphorus Mass Balances - Recycles

30% of P Load to Secondary Treatment

Recycle Phosphorus Management

Options for recycle stream P reduction
- Addition of coagulants to digesters
- Addition of coagulants to dewatering

Options for recycle stream P reduction/recovery
- Phosphorus recovery (struvite/brushite precip.)
- Pre-digester P release w/ recovery
Impact of P Recovery

20% + of Inf. P Recovered as High Value Product
5-10% of P Load to Secondary Treatment

Impact of P Pre-Release / Recovery

30-40% of Inf. P Recovered as High Value Product
Mg²⁺
Conclusions

- When P is removed from the mainstream it is sent to residuals in concentrated forms
- How P is removed in the mainstream will impact the form of P sent to residuals and other ions (Fe, Al, Mg, K Ca) which go along
- This can cause problems with nuisance precipitates and dewatering performance
- Heavily dependent on digester chemistry
Our Next Speaker

Murthy Kasi, PhD, PE
Process Engineering Manager
Lenexa, KS

Smith & Loveless Inc.

Phosphorus Precipitates: Nuisance and Mitigation
Outline

• Phosphorus Precipitates & Formation
• Operational Impacts
• Mitigation Strategies

Common Phosphorus Precipitates

<table>
<thead>
<tr>
<th>Magnesium-based</th>
<th>Iron-based</th>
<th>Calcium-based</th>
</tr>
</thead>
<tbody>
<tr>
<td>Struvite ((\text{MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O}))</td>
<td>Vivianite ((\text{Fe}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}))</td>
<td>Hydroxyapatite (\text{Ca}_3(\text{PO}_4)_2\text{OH})</td>
</tr>
<tr>
<td>Magnesium Ammonium Phosphate</td>
<td>Ferrous ((\text{Fe}^{2+})) based</td>
<td>Octacalcium Phosphate (\text{Ca}_4(\text{PO}_4)_3)</td>
</tr>
<tr>
<td>Strengite ((\text{FePO}_4 \cdot 2\text{H}_2\text{O}))</td>
<td></td>
<td>Brushite (\text{CaHPO}_4 \cdot 2\text{H}_2\text{O})</td>
</tr>
<tr>
<td>Ferric ((\text{Fe}^{3+})) based</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

27

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Where in Wastewater Treatment do these form?

- Anaerobic digesters
- Digested sludge piping, valves, pumps, and mixers
- Dewatering equipment
- Filtrate and centrate piping, valves and pumps
- Rough surfaces preferred

Unintentional Precipitation is a Nuisance

Struvite is the most common nuisance

What Promotes Phosphorus Precipitation?

- Concentrations of chemical species (e.g. Mg$^{2+}$, PO$_4^{3-}$, NH$_4^+$, etc.)
- pH
- Temperature
Chemical Species for Phosphorus Precipitates

<table>
<thead>
<tr>
<th>Chemical Species</th>
<th>Formula</th>
<th>Ionic Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Struvite</td>
<td>MgNH₄PO₄·6H₂O</td>
<td>Mg, Fe²⁺ or Fe³⁺, Ca²⁺, NH₄⁺, PO₄⁻³</td>
</tr>
<tr>
<td>Vivianite</td>
<td>Fe₃(PO₄)₂·8H₂O</td>
<td>Fe³⁺, Ca²⁺, PO₄⁻³</td>
</tr>
<tr>
<td>Strengite</td>
<td>FePO₄·2H₂O</td>
<td>Fe²⁺ or Fe³⁺, Ca²⁺, PO₄⁻³</td>
</tr>
<tr>
<td>Hydroxyapatite</td>
<td>Ca₅H(PO₄)₃ OH</td>
<td>Ca²⁺, PO₄⁻³</td>
</tr>
<tr>
<td>Octacalcium Phosphate</td>
<td>Ca₄H(PO₄)₃</td>
<td>Ca²⁺, PO₄⁻³</td>
</tr>
<tr>
<td>Brushite</td>
<td>CaHPO₄·2H₂O</td>
<td>Ca²⁺, PO₄⁻³</td>
</tr>
</tbody>
</table>

Chemical Species Generation in Wastewater Treatment Processes

- **Conventional**
  - Higher conc. in EBPR and chem-P plants compared to Conventional
  - Locations with higher conc.
    - EBPR: all secondary solids lines and solids process units
    - Chem-P: plus primary solids line

- **EBPR**

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Concentrations in Solids Streams

• Several factors impact concentrations of chemical species in solids streams
  • Efficiency Thickening prior to digestion
  • Thermal hydrolysis process included?
  • WASSTRIP
  • Chemical type and addition points for phosphorus removal

% solids - 4, 5, 6, etc.

increased digestion and higher orthophosphate

Orthophosphate extracted from WAS before sent to digesters

Iron, aluminum, cerium;
Primary clarifier, aeration basins, secondary clarifiers

Concentrations in Anaerobic Digester

Concentrations for a specific scenario are presented here

Assumptions for the following Table:
- 4% Total Solids in Digester Feed for all 3 treatments
- No WASSTRIP
- Chemically Enhanced Primary Treatment with Fe-based salts

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Conventional</th>
<th>EBPR</th>
<th>Chemical P (CEPT)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg²⁺ (mg/L)</td>
<td>40</td>
<td>140</td>
<td>40</td>
</tr>
<tr>
<td>Fe²⁺ or Fe³⁺ (mg/L)</td>
<td>300</td>
<td>300</td>
<td>4000</td>
</tr>
<tr>
<td>Ca²⁺ (mg/L)</td>
<td>150</td>
<td>200</td>
<td>150</td>
</tr>
<tr>
<td>NH₄⁺ (mg N/L)</td>
<td>1,100</td>
<td>1,100</td>
<td>1,100</td>
</tr>
<tr>
<td>PO₄³⁻ (mg P/L)</td>
<td>300</td>
<td>750</td>
<td>750</td>
</tr>
</tbody>
</table>

*No Bio-P
**pH & Temperature**

<table>
<thead>
<tr>
<th>Location in Wastewater Treatment Plant</th>
<th>pH</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid Processes</td>
<td>6.7 to 8</td>
<td>10 to 25°C</td>
</tr>
<tr>
<td>(raw influent, primary clarifiers, aeration basins, etc.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solids Processes</td>
<td>6.5 to 7.5</td>
<td>35 to 55°C</td>
</tr>
<tr>
<td>(thickening, digestion, dewatering, phosphorus release, etc.)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Struvite Formation - Example Scenario**

Consider the following concentrations in an anaerobic digester:

- $\text{Mg}^{2+} = 40 \text{ mg}/\text{L}$
- $\text{NH}_4^+ = 1,100 \text{ mg}/\text{L}$
- $\text{PO}_4^{3-} = 300 \text{ mg}/\text{L}$

\[
K_{sp} = -\log \left( [C_{\text{Mg}^{2+}}] \cdot [C_{\text{NH}_4^+}] \cdot [C_{\text{PO}_4^{3-}}] \right)
\]

\[
K_w = -\log \left( \frac{40 \text{ mg}}{L} \cdot \frac{1100 \text{ mg}}{L} \cdot \frac{300 \text{ mg}}{L} \right)
\]

$K_{sp} = 6.5$
**Struvite Formation - Digester Scenario**

**EBPR**
- $\text{Mg}^{2+} = 140 \text{ mg/L}$
- $\text{NH}_4^+ = 1,100 \text{ mg/L}$
- $\text{PO}_4^{3-} = 750 \text{ mg/L}$
- $K_{sp} = 5.6$

**Chemical**
- $\text{Mg}^{2+} = 40 \text{ mg/L}$
- $\text{NH}_4^+ = 1,100 \text{ mg/L}$
- $\text{PO}_4^{3-} = 750 \text{ mg/L}$
- $K_{sp} = 6.1$

**Conventional**
- $\text{Mg}^{2+} = 40 \text{ mg/L}$
- $\text{NH}_4^+ = 1,100 \text{ mg/L}$
- $\text{PO}_4^{3-} = 750 \text{ mg/L}$
- $K_{sp} = 6.5$

**Vivianite Solubility**

\[
K_{sp} = -\log\left[C_{\text{Fe}^{2+}}\right]^3 \cdot \left[C_{\text{PO}_4^{3-}}\right]^2
\]

- Typical digester operations favor vivianite precipitation
  - Acidic conditions (lower pH)
  - Elevated temperatures
  - Low Oxidation-Reduction Potential (reduced environment)
  - Excess iron concentrations due to chemical addition
- Often preferred over struvite formation
  - Softer material than struvite
Calcium Phosphates Solubility

- Can be problematic in hard waters with high Ca$^{2+}$ concentrations
- Struvite and vivianite have greater phosphorus precipitation potential than calcium phosphates, especially in low pH conditions

Nuisance or Resource??

Unintentional precipitation can be a nuisance
Impact on Plant Operation - Pipes & Pumps

Deposits in pipes
Meridian, ID
Wastewater Resource Recovery Facility

Reduction of pipe diameter changes system curve

Pump @ 3850 rpm
Pump @ 4350 rpm

Head (ft)
Discharge (gpm)

Impact on Plant Operations - various processes/equipment

• Digesters
  - Decrease of mixer speeds due to struvite deposits on blades and impellers
  - Decrease in digester capacity and increased heating requirements

• Dewatering
  - Decrease in filter press efficiency due to filter blinding; increased filter press operational time
Impact on Plant Operation

- Deposits on digester wall
- Deposits on mixer blade in dewatering centrate storage tanks
- Deposits on belt filter press rollers

Conditions Leading to Phosphorus Precipitation

**Struvite**
- Excess concentrations of Mg$^{2+}$, NH$_4^+$, and PO$_4^{3-}$
- Increased pH of solution
- Turbulence
- Stripping of CO$_2$
- Rough surfaces

**Fe-phosphates**
- Excess iron and PO$_4^{3-}$ concentrations
- Lower pH conditions
- Elevated temperatures
Struvite Control

- Minimize CO2 stripping
- Short straight pipes
- Cleaning loops
- Removable pipe lining
- Pinch valves
- Selecting right pipe material
- Magnesium dosing (1.3 Mg:1P)
- Iron salts addition (1.5 Fe:1P)
- pH adjustment (reduce pH to <7.5)

Facility Design Example

- Benefits:
  - Optimized Bio-P
  - Alum use was reduced from 150 to 20 ppm
  - FeCl3 costs reduced by $15,000/yr

Centrate storage and conveyance system at Durham AWWTP and its struvite control features

Source: Baur, R., Beniach, M., Clark, D., Sprick, R.G., Struvite Control- Dealing With A Common and Nuisance, WEFTEC 2002
Other options?

Intentional Phosphorus Precipitation?

Phosphorus Recovery Benefits

- Reduces phosphorus concentrations in solids streams to anaerobic digester and dewatering processes
- Reduces the internal phosphorus recycle

30 - 40% inf. P recovered as struvite
50% reduction
20% reduction
Mg$^{2+}$
Recovery Options

- Can be recovered in all three forms
  - Struvite (magnesium-based)
  - Brushite or hydroxyapatite (calcium-based)
  - Vivianite (iron-based)
- Recovery as struvite is the most common
  - Commercial recovery methods available for Ca-P
  - Recovery as Fe-P is still in research stage

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P-recovery Methods

**As struvite**
- Ostara®
- Multiform harvest™
- Struvia™
- AirPrex™
- NuReSys™
- DHV Crystalactor

**As calcium phosphates**
- P-Roc®
- CalPrex™
- Quick Wash®
- ExtraPhos®

**As sludge ashes**
- EcoPhos®
  - Extracts as H₃PO₄ or Calcium phosphate
- P-Bac (Incore)®
  - Extracts as Struvite or Calcium phosphate

For additional information:
P-recovery Economics

<table>
<thead>
<tr>
<th>Struvite</th>
<th>Calcium phosphates</th>
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</thead>
<tbody>
<tr>
<td>Recovery</td>
<td>80 to 90%</td>
</tr>
<tr>
<td>Capital costs</td>
<td>$28 to $280 per ton per day</td>
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<tr>
<td>Market value</td>
<td>$50 to $1,800 per ton</td>
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</table>

1 ton = 2,000 lb


Conclusions

• EBPR or chemical-P removal:
  • Increase in concentrations of phosphorus precipitating species in solids streams
  • Struvite (magnesium-based phosphate) formation is the major nuisance

• Control options should be carefully evaluated before selection
  • Addition of iron salts - secondary nuisance due to vivianite formation; increased sludge production; high chemical costs; decreased P recovery
  • pH control by acid addition - agitation due to pumping and mixing still causes increase in pH
  • Proper pipe material - scratches/roughness over time favors struvite formation
Conclusions

• P-recovery can minimize impacts on downstream unit processes, e.g. digester, dewatering equipment
  ▪ May still require chemical addition to control struvite in digesters

• Several commercial P-recovery options are available

Our Next Speaker

Hélène Hauduc, PhD
Senior Process Engineer
Toulouse, France
Chemical Processes in Anaerobic Digesters

Outline

- P from EBPR and ChemP in AD
- Interactions between P, S and Fe cycles
- Mitigation Strategies
- Comprehensive model of relevant AD reactions
Chemical species in AD

<table>
<thead>
<tr>
<th>Chemical species</th>
<th>Plant Influent</th>
<th>Biomass lysis</th>
<th>P release by PAO</th>
<th>Chemical treatments</th>
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<tbody>
<tr>
<td>NH₄⁺</td>
<td>7%</td>
<td>1%</td>
<td>2%</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>0.08 mol Ca/mol</td>
<td>0.28 mol Mg/mol</td>
<td>0.28 mol Fe/mol</td>
<td></td>
</tr>
<tr>
<td>Ca</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mg</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>K</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fe</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Conventional [mg/L]</th>
<th>EBPR [mg/L]</th>
<th>ChemP [mg/L]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1100</td>
<td>1100</td>
<td>1100</td>
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<td>150</td>
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<td>750</td>
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<td>190</td>
<td>20</td>
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<tr>
<td></td>
<td>300</td>
<td>300</td>
<td>4000</td>
</tr>
</tbody>
</table>

Phosphate reactions

ChemP: Iron addition

Pourbaix diagram from Wilfert et al (2015)

Struvite

PO₄³⁻
Iron reactions in AD

Pourbaix diagram from Wilfert et al. (2015)

Chemical species in AD

Favorable conditions in AD

Supersaturation, pH, Temperature

RedOx

Plant Influent

Biomass lysis

P release by PAO

Chemical treatments

NH₄⁺

S

Ca

P

Mg

K

Fe²⁺

Struvite MgNH₄PO₄

Calcium phosphates

Calcium carbonates

Vivianite Fe₃(PO₄)₂
Sulfur reactions in AD

\[
\text{H}_2\text{SO}_4 \leftrightarrow \text{HSO}_4 \leftrightarrow \text{SO}_4^{2-} \quad \text{SO}_4^2- \quad \text{H}_2\text{S} \leftrightarrow \text{HS}^{-} \leftrightarrow \text{S}^{2-}
\]

3 main oxidation states

\[
\text{H}_2\text{S} \leftrightarrow \text{HS}^{-} \leftrightarrow \text{S}^{2-}
\]

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Sulfur reactions in AD

\[
\text{H}_2\text{SO}_4 \leftrightarrow \text{HSO}_4 \leftrightarrow \text{SO}_4^{2-}
\]

VFA, ASRO, CO₂, H₂, HSRO

\[
\text{H}_2\text{S} \leftrightarrow \text{HS}^{-} \leftrightarrow \text{S}^{2-}
\]

Odours, Biogas quality, Gas Stripping

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P-Fe-S reactions in AD

Chemical species in AD

Favorable conditions in AD

- Supersaturation
- pH
- Temperature
- RedOx

Plant Influent

- NH₄⁺
- Ca²⁺
- Mg²⁺
- K⁺
- Fe²⁺

Biomass lysis

- H₂S
- P

P release by PAO

- Struvite MgNH₄PO₄
- Calcium phosphates
- Calcium carbonates
- Vivianite Fe₃(PO₄)₂
- FeS

Chemical treatments

- 7% NH₄⁺
- 1% Fe²⁺
- 2% P

- 0.04 mol Ca/mol P
- 0.29 mol Mg/mol P
- 0.26 mol K/mol P

Odours

Biogas quality

Gas stripping

FeS

Fe₂⁺

Substrate

H₂PO₄ ↔ H₂PO₄⁻ ↔ HPO₄²⁻ ↔ PO₄³⁻

PO₄

H₂PO₄ ↔ H₂PO₄⁻ ↔ HPO₄²⁻ ↔ PO₄³⁻

H₂S ↔ HS⁻ ↔ S²⁻

H₂SO₄ ↔ HSO₄⁻ ↔ SO₄²⁻

S°
Precipitation in digester

From Roussel and Carliell-Marquet (2016)

Comprehensive model

- Biology
- pH (acid/base)
- RedOx
- Precipitation
- Gas transfer

Comprehensive Model

VFA
CO₂
H₂
ASRO
HSRO
SO₄

S²⁻
H₂S ↔ HS⁻ ↔ S²⁻

FeS

Gas Stripping

CaP
PO₄

H₃PO₄ ↔ H₂PO₄⁻ ↔ HPO₄²⁻ ↔ PO₄³⁻
Lander Street primary digester
Simulation of mitigation strategies

| Parameter                  | Unit | Data   | Model  
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Digester Total Solids</td>
<td>%</td>
<td>1.70%</td>
<td>2.10%</td>
</tr>
<tr>
<td>Digester VSS</td>
<td>% of TS</td>
<td>67%</td>
<td>66%</td>
</tr>
<tr>
<td>Digester pH</td>
<td>-</td>
<td>7.15</td>
<td>7.16</td>
</tr>
<tr>
<td>Alkalinity as CaCO3</td>
<td>mg/L</td>
<td>4100</td>
<td>3544</td>
</tr>
<tr>
<td>Gas production</td>
<td>Nm³/hr</td>
<td>176</td>
<td>172</td>
</tr>
<tr>
<td>Digester gas H₂S</td>
<td>ppm</td>
<td>2125</td>
<td>1926</td>
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<tr>
<td>Digester ammonia</td>
<td>mg N/L</td>
<td>1169</td>
<td>979</td>
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<tr>
<td>Digester phosphate</td>
<td>mg P/L</td>
<td>156</td>
<td>166</td>
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<tr>
<td>Struvite</td>
<td>mg TSS/L</td>
<td>?</td>
<td>842</td>
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<tr>
<td>Vivianite</td>
<td>mg TSS/L</td>
<td>0</td>
<td>578</td>
</tr>
<tr>
<td>Iron sulfide</td>
<td>mg TSS/L</td>
<td>0</td>
<td>146</td>
</tr>
</tbody>
</table>

Fe for H₂S control
- g FeCl₃/kg VSS
- 25
- 100

Fe for struvite control
- g FeCl₃/kg VSS
- 25
- 100

Conclusions on Chemical Processes in Anaerobic Digesters

- AD processes results in nuisances:
  - Struvite precipitation
  - H₂S in biogas
- Fe addition in water line and sludge line as mitigation strategy for P and S control
- Complex interactions of P-S-Fe cycles
Conclusions on a comprehensive model

• Optimisation of mitigation strategies
• Impact of mitigation strategies
  ▪ On return streams and mainstream processes
  ▪ On digestate chemical composition

Our Next Speaker

Mario Benisch PE
Senior Process Engineer
Portland, OR

HDR
IMPACT OF EBPR ON DEWATERABILITY

What do we know?

Water Distribution

Impact of EBPR

PO4-P or MV/DV

Implications

Mitigation
Key Takeaways

• EBPR decreases dewaterability
• Often occurs under the radar
• Struvite = indicator for EBPR
• There are mitigation options

What do we know

![Graph showing cake solids and polymer over time](image-url)
What do we know

• Dewatering performance varies in general
• Increase digester PO₄-P correlates with decline in dewaterability
• Removal of PO₄-P increases dewaterability
• Increase MV/DV ratio correlates with decline in dewaterability
• Ferric (usually) Increases Dewatering Performance

What do we know

• Alum sometimes increases dewatering performance
• Trivalent metal ions can coagulate biopolymers
• EPS holds water and aids flocculation
• Monovalent metal ions block bridging
Water Distribution

Only free water can be removed with mechanical dewatering

WHY DOES DEWATERING PERFORMANCE VARY?
Water distribution

Water distribution in sludge is a function of
- process design
  (liquid treatment, solids treatment, etc)
- influent composition
  (plant influent, external loads)
- chemical addition
  (alkalinity, polymer, coagulants)
Water distribution

- Thermo-Gravimetric Analysis of Water Fractions

![Bar graph showing water distribution](image)

Phosphate Concentration

- Dewaterability declines with increasing PO4-P

![Graph showing phosphate concentration](image)
## Impact of EBPR on Dewatering

### EBPR and Dewatering

- Denver Hite EBPR Pilot

<table>
<thead>
<tr>
<th>Cake TS [%]</th>
<th>Feed TS [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>83</td>
<td>84</td>
</tr>
</tbody>
</table>
EBPR and Dewatering

- Rock Creek AWWTP

Transition to Bio-P

Cake Solids

Polymer

Winter Peak

Dec-07 Dec-08 Dec-09 Jan-11 Jan-12 Jan-13

Polymer [lbs/ton]

Cake [%]

Dew, Poly Dose - Summer
Dew, Poly Dose - Winter
Centr Cake, TS

EBPR and Dewatering

- P-Uptake

nom

PO₄³⁻
K⁺
Mg²⁺

PAO

PAO
EBPR and Dewatering

• ANR P-Release

EBPR and Dewatering

• Digestion and Struvite Formation
EBPR and Dewatering

- Bio-P Transfer P to digester and Mg and K
- Mg$^{2+}$ Precipitates out as MgNH$_4$PO$_4$ 6H$_2$O

EBPR and Dewatering

- K$^+$ Remains
EBPR and Dewatering

• Bio-P Transfer P to digester and Mg and K

04 PO4-P vs. MV/DV
Monovalent/Divalent Cation Ratio (M/D)

- Divalent Cation Bridging

(Source: Nova, Higgins)

Monovalent/Divalent Cation Ratio (M/D)

(Source: Higgins) (Source: City of Lakehaven)
EBPR and Dewatering

• PO4-P Increase EPS stored Water

PO4-P vs. Dewaterability

• Phosphate (anions) in Food Processing
  ▪ Can dissolve proteins
  ▪ Act stabilizing on dispersions, suspensions, and emulsions
  ▪ When phosphate anions enter protein molecules they unfold the protein through electrostatic repulsion and bridge forming which impact its water binding ability
  ▪ Diphosphate have very specific impact on the water storage in muscle protein (casein and actomyosin)

(Source: Yvonne Matthei pp, PhD)
PO4-P vs. Dewaterability

• Use of Phosphate (anions) in Food Processing
  ▪ To reduce growth of gram positive microorganism (extend shelf live of cream cheese with poly-phosphates)
  ▪ Pyrophosphate used to restore water content in meat and to slow down auto-oxidation reactions by binding multivalent cations
  ▪ Phosphate is added to milk products to stabilize milk proteins, stabilize the pH, binding of multivalent cations, and to increase viscosity (i.e. for cream)
  ▪ To enrich food products with Ca, Mg, Fe, etc

(Source: Yvonne Matthei pp, PhD)
Implications

- Polymer  →  100% to 200% more
- Cake TS  →  3% - 5% less
- Operating cost  →  Polymer, Hauling
- Resiliency  →  Struvite
- Recovery option
- Procurement

(Source: Yvonne Matthei pp, PhD)
Mitigation through Sludge Conditioning

Metal Salt Addition

- Simplest Option
- Ferric or Alum
- Recycle P control
- Lower polymer demand
- Dryer cake
- More sludge
- Consumes alkalinity*
Metal Salt Addition

Stored Phosphorus release

103

104
Stored Phosphorus release

![Graph showing stored phosphorus release over time.]

- **Poly, 30 Day Ave**
- **Cake, TS 30-Day Average**

AirPrex

- Post digestion sludge treatment
- Simple process
- Air mixed reactor
- Adding MgCL₂ to bind PO₄-P
AirPrex Impact on Polymer Demand

- Added value in improved dewaterability
Thermo Hydrolysis

- Pre Digestion Process
- Cell lysis
- High Temperature and Pressure

(Kopp 2013)
CTHP (PONDUS)

- Chemical/Thermal Hydrolysis
- Simple Process
- 80% - 90% as effective as THP

(Kopp 2013)
Key Takeaways

• EBPR decreases dewaterability
• Often occurs under the radar
• Struvite = indicator for EBPR
• There are mitigation options
Final Q & A

An MRRDC Short Course
Solids Stream Phosphorus Modeling

• Final Q & A:

Moderator  →  John Copp  →  Primodal
Basics  →  Patrick Dunlop  →  Black & Veatch
Nuisance  →  Murthy Kasi  →  Smith & Loveless
Chemistry  →  Hélène Hauduc  →  Dynamita
Dewatering  →  Mario Benisch  →  HDR