Phosphorus-Recovery from Waste Activated Sludge (WAS) in Enhanced Biological Phosphorus removal (EBPR) Processes

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Phosphorus -- Not Reusable Resource

- Pollution
- Decreasing Stock
- Increasing Requirement

Background
Objectives
Approaches
Results
Conclusions

World Population Growth

Peak phosphorus ‘Hubbert’ curve Source: Cordell, Drangert & White
P-Recovery Potential from wastewater

**Background**

**Objectives**

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**Conclusions**

Influent

TP = 8-10 mg/L

Primary Clarifier

Return Sludge

Secondary Clarifier

Effluent

TP = 7-8 mg/L

Centrifuge

Biosolids treatment

Centrate (P-rich stream)

Thickener

Sludge

Sludge

Centrifuge

Background Objectives Approaches Results Conclusions
P-Recovery Potential in EBPR System

Source: Cornel and Schaum (2009)

90% in Sludge
Approaches to Recovery P from Wastewater

Baur et al., 2009
Approaches to Recovery P from Wastewater

PhoStrip

Kaschka et al., 1999
## Objectives

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Approaches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluate the operation conditions impacts on P-release</td>
<td>Lab scale SBRs</td>
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<tr>
<td>Investigate the mechanisms of P-release in the Bio-P anaerobic digestion during 0-24 hrs</td>
<td>24hrs endogenous digestion tests</td>
</tr>
<tr>
<td>Explore the effect of anaerobic digestion process on the PAOs</td>
<td>Live/Dead</td>
</tr>
<tr>
<td></td>
<td>Phosphate and metal ion concentration</td>
</tr>
<tr>
<td></td>
<td>FISH</td>
</tr>
<tr>
<td></td>
<td>P-release tests with VFA addition</td>
</tr>
</tbody>
</table>
Methods: SBRs operation

- HRT: 12 hours
- Temperature: 20 °C
- DO: < 0.1 mg/L (AN)
  > 4 mg/L (AE)
- Weekly monitoring of TSS/VSS, effluent phosphate concentration.

Influent filling (7mins)

Anaerobic mixing (110 mins)

Aerobic mixing (180 mins)

Settling (60 mins)

Withdraw
Methods: P: release activity

- End of Aerobic Phase
- WAS Anaerobic Phase
- N₂ gas

0 hour
- pH
- DO monitoring

Sample Collection (P, N, Mg)

Start Point
End Point
24 hours
Methods: Microbial analysis

Fluorescence in situ hybridization (FISH) → specific PAOs and GAOs

Live/Dead Analysis

Fluorescent nucleic acid stain → Cell

propidium iodide

Live cell

Dead cell

Source: nature.com
How does SRT effect the P-Recovery Potential?

![Graph showing effect of SRT on P-Recovery Potential](image)

- **Background**
- **Objectives**
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- **Conclusion**
How does COD/P effect the P-Recovery Potential?

**5-day SRT**

- COD/P=10
- COD/P=25

**30-day SRT**

- COD/P=10
- COD/P=25
What’s the Mechanisms of P release under AN Condition?

**Diagram Description:**
- The graph illustrates the soluble Mg (mg/L) over time (hours) for different soluble COD/P ratios and SRT (sludge retention time) conditions.
- The x-axis represents time in hours, ranging from 0 to 28.
- The y-axis represents the soluble Mg concentration in mg/L, ranging from 0 to 250.
- The graph includes lines for 20-day SRT, 10-day SRT, 30-day SRT, and 5-day SRT.

**Table Description:**
- The table shows the average Mg/P concentrations for different SRT (days) and time intervals (0-12 hrs, 12-24 hrs).
- The table includes SRT days for 5, 10, 20, and 30.
- For each SRT, the table lists the averages for 0-12 hrs, 12-24 hrs, and overall average.

**Table Data:**

<table>
<thead>
<tr>
<th>SRT (days)</th>
<th>0-12 hrs</th>
<th>12-24 hrs</th>
<th>Average*</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.15</td>
<td>0.07</td>
<td>0.17</td>
</tr>
<tr>
<td>10</td>
<td>0.25</td>
<td>0.03</td>
<td>0.11</td>
</tr>
<tr>
<td>20</td>
<td>0.49</td>
<td>0.11</td>
<td>0.38</td>
</tr>
<tr>
<td>30</td>
<td>0.15</td>
<td>0.14</td>
<td>0.15</td>
</tr>
</tbody>
</table>
How Microorganism Population Change?

COD/P=10
How Microorganism Population Change?

COD/P=10

PAOs Abundance

<table>
<thead>
<tr>
<th>SRT (days)</th>
<th>Total PAOs/DAPI (%)</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
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<tr>
<td>30</td>
<td></td>
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</tr>
</tbody>
</table>

Total PAO (%)
- Before
- After

Difference (%)
- Before
- After

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**Results**

PAOs Activities

COD/P=10

- **P release rate** (mg P/gVSS*hr)
- **SRT (days)**

- **Before**
- **After**
- **Difference %**

Graph showing the change in P release rate over different SRT (days) with COD/P=10.
Conclusions

- Lower influent COD/P ratio perform better in terms of quantity and rate of P release under anaerobic conditions -- might be preferable when operating P-recovery scheme.

- SRT in the range between 10-20 days showed also the highest P released, in terms of both quantity and rate -- lower footprint for the P release tank.

- The majority of released P was due to poly-P depletion at all SRTs condition.

- Different mechanisms are responsible at different time intervals.

- PAO activity was reduced after the digestion test.
Northeastern University

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- Annalisa Onnis-Hayden
- April Gu
- Philip Larese-Casanova

PhD students:
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- Nick Tooker
Thank you!

Questions?

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Approaches to Recovery P from Wastewater

WASSTIP

Baur et al., 2009
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