Cost-efficient Phosphorus removal in rural WWTPs

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Effluent standards of communal WWTP in Germany

<table>
<thead>
<tr>
<th>Size class (SC)</th>
<th>COD (mg/L)</th>
<th>BOD$_5$ (mg/L)</th>
<th>NH$_4$-N (mg/L)</th>
<th>N* (mg/L)</th>
<th>Total P (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 &lt; 1000 PE</td>
<td>150</td>
<td>40</td>
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<tr>
<td>&lt; 60 kg BOD$_5$/d</td>
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<tr>
<td>2 &lt; 5000 PE</td>
<td>110</td>
<td>25</td>
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<tr>
<td>&lt; 60 kg BOD$_5$/d</td>
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<tr>
<td>3 &lt; 10000 PE</td>
<td>90</td>
<td>20</td>
<td>10</td>
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<tr>
<td>&lt; 600 kg BOD$_5$/d</td>
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<tr>
<td>4 &lt; 100000 PE</td>
<td>90</td>
<td>20</td>
<td>10</td>
<td>18</td>
<td>2</td>
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<td>&lt; 6000 kg BOD$_5$/d</td>
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<tr>
<td>5 &gt; 100000 PE</td>
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<td>15</td>
<td>10</td>
<td>13</td>
<td>1</td>
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<tr>
<td>&gt; 60000 kg BOD$_5$/d</td>
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</tbody>
</table>

N* = NH$_4$-N + NO$_3$-N + NO$_2$-N
Which technologies are used and how is their performance?

Percentage of P-load divided in size classes:

- >100,000 PE: 10%
- 10,001 - 100,000 PE: 29%
- 1,000 - 5,000 PE: 24%
- 5001 - 10,000 PE: 10%
- <1,000 PE: 27%

Percentage of P-load in the range of size class 1 to 3:

- Activated sludge system: 68%
- Individual solution: 8%
- SBR-plant + sewage pond: 2%
- Oxidation ditch: 4%
- Trickling filter: 5%
- Sewage pond: 13%
- Total P-load = 62.58 t

n = 552 WWTP
Which technologies are used and how is their performance?

**Graphs showing COD, N, and P elimination efficiency for different technologies:**

- COD elimination efficiency
- N elimination efficiency
- P elimination efficiency

**Technologies:**
- ASS: Activated Sludge System
- SP: Sewage Pond
- BS: Biofilm System
- OD: Oxidation Ditch
- CW: Constructed Wetlands
Key questions

1. potential P-removal efficiency of a specific plant?

2. Operational reasons for plants with low efficiency?

3. Plants without significant potential of improvement?
   → alternative solutions?
Model for activated sludge systems

- Applicable for standard activated sludge plants, SBR systems and oxidation ditches
- General approach: P removal without precipitation only by biomass growth
  \[ \rightarrow \text{maximation of biomass yield} \]
  \[ \rightarrow \text{increase of P incorporation into biomass} \]
  (Enhanced biological P-removal)

Design parameters

Operational parameters

Inflow

Calculating heterotrophic Biomass
(COD based approach (DWA-A 131 (2015))

P uptake conventional: 2.5% of produced biomass
P uptake EBPR: 5% of produced biomass
How is the removal efficiency influenced by the SRT?

Graph showing P-elimination efficiency (%) against SRT (days) for different P/CSB values. The graph compares ASS with Bio-P and ASS without Bio-P.

Flowchart: reduction of SRT leads to stabilization necessary? yes → SRT = 25 d, no → further analysis.