Achieving Low Effluent Phosphorus Concentrations with the Blue PRO® Process

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Problems for Lake Windermere

- Largest lake in England
- Attracts 14.8M visitors a year
- Visitors spent £994M in 2012

- Water quality of lake under question
- Presence of algal blooms
- Great North Swim - CANCELLED
Advanced Phosphorus Removal Required at Windermere WwTW

- 12 month catchment wide sampling survey initiated
- United Utilities (UU) shown to contribute >55% of total phosphorus (TP) load
- Modelling used to assess the impact of in-lake TP concentrations on the occurrence of algal blooms
- To reduce occurrence of blooms UU must reduce TP load from Windermere WwTW by >65%
- Windermere WwTW has a current TP final effluent permitted concentration of 1mg/l annual average

CONCLUSION: Windermere WwTW will need to meet a final effluent standard of between 0.2-0.1mg/l TP in AMP6, under a Biodiversity driver
Requirement for Advanced TP Removal Across UU Region

- Requirement to meet low TP effluent concentrations driven by the Water Framework Directive (WFD) and other initiatives

<table>
<thead>
<tr>
<th>TP Consent (mg/l)</th>
<th>Number of UU Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-0.2</td>
<td>30</td>
</tr>
<tr>
<td>0.2-0.6</td>
<td>50</td>
</tr>
<tr>
<td>0.6-1</td>
<td>17</td>
</tr>
<tr>
<td>&gt;1</td>
<td>16</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>113</strong></td>
</tr>
</tbody>
</table>

- Conventional dosing of metal salts can achieve 0.5-0.6mg/l
- Therefore is a requirement for development of advanced TP removal technology
Blue PRO® Process

- Continuous moving bed sand filter
- Influent dosed with ferric chloride
- Results in formation of a hydrous ferric oxide (HFO) coating on sand
- Removal of P by reactive filtration
  - Adsorption of phosphate onto HFO
  - Co-precipitation of phosphate into HFO structure
- Sand continuously washed and contaminants (Fe and P) removed in reject stream
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>0.91m</td>
</tr>
<tr>
<td>Surface area</td>
<td>0.65m²</td>
</tr>
<tr>
<td>Sand depth</td>
<td>1.53m</td>
</tr>
<tr>
<td>Flow rate</td>
<td>1.5 l/s</td>
</tr>
<tr>
<td>Hydraulic load</td>
<td>8.2 m/h</td>
</tr>
<tr>
<td>Feed TSS</td>
<td>&lt;25mg/l</td>
</tr>
<tr>
<td>pH</td>
<td>6-7</td>
</tr>
<tr>
<td>Feed alkalinity</td>
<td>&gt;70mg/l CaCO₃</td>
</tr>
</tbody>
</table>
Performance of Blue PRO® at Windermere WwTW

- Effluent Total P (mg/l)
- Effluent Iron (mg/l)
- Total P Removal (%)
Trial at Windermere - Conclusions

- Running under optimised conditions Blue PRO® achieved:
  - >90% removal of TP
  - Average effluent TP of <0.1mg/l
  - Average effluent iron of 0.3mg/l

- Optimised conditions defined as:
  - 12mg/l ferric chloride (>5:1 molar ratio)
  - Max upflow velocity of 8.2m/h
  - Ave solids loading of 0.1 kg/m²/h

How would the upstream process affect performance?
Trial at Howich WwTW

Inlet works

PSTs

ASP

Settlement tanks

Ferric dosing

Blue PRO

Nitrifying filter
P Removal by Blue PRO® at Horwich WwTW

Performance of Blue PRO® at Horwich WwTW

- **Concentration mg/L**
  - Effluent Total P (mg/L)
  - Effluent Iron (mg/L)
  - Total P Removal (%)

- **Dates**
  - 08/09/2012 to 23/10/2012
Effect of Ferric Dose on P Removal

Iron Dose Versus Percentage Removal of Total P

TP Removal (%) vs Iron Dose (mg/l as Fe)
Importance of the Backwash

Concentration of TP and Iron in Effluent from Blue PRO® at Horwich WwTW

- Mechanical problems experienced on pilot
Characteristics of the Reject Steam

- Reject - 13% of influent flow rate
- 86% of solids in reject settle in 15 mins
- Only 0.14% of iron in reject is soluble

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Supernatant (mg/l)</th>
<th>Sludge (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>11.3</td>
<td>8530.6</td>
</tr>
<tr>
<td>Ortho-P</td>
<td>0.3</td>
<td>1.3</td>
</tr>
<tr>
<td>TP</td>
<td>0.6</td>
<td>212.6</td>
</tr>
<tr>
<td>SS</td>
<td>41.6</td>
<td>24931.0</td>
</tr>
</tbody>
</table>
Trial at Horwich - Conclusions

- Under optimised conditions removal similar to Windermere
  - >90% removal of TP
  - Average effluent TP of <0.2mg/l (influent conc higher)
  - Average effluent iron of 0.5mg/l
- Upstream process had no effect on performance of Blue PRO®
Blue PRO® Performance – Conclusions and Implications for Full Scale Design

- 90% removal of TP or an average effluent concentration of 0.1mg/l TP
- Iron dose can be reduced based on removal requirements
- Inlet alkalinity concentration important
- Robust to changes in flow or solids load
- Efficiency of backwash/ sand turnover rate important
- Currently Blue PRO® only suitable for sites of <30MI/d
- Inlet screening needs to be effective and basket strainer required upstream
- Impact of solids loading in reject on PST performance must be considered
- To meet TP of 0.1mg/l plant will need diligent operation, monitoring and control
What Next for Windermere WwTW?
What Next For Blue PRO®?

With thanks to:

Vicky Wilson & Carle Redwood (Welsh Water)

Robert Mannion (Evergreen Engineering)
Thank you for listening