Advanced process control for efficient biological nutrient removal

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Background/Motivation
Effluent discharge limits on nitrogen and phosphorus are becoming stricter. Rising energy costs and sustainability directives set new demands on carbon footprint reduction and energy efficiency. WWTPs strive to improve their operational excellence through increased automation and process transparency. Operational cost at a low capital expense by making full use of their SBR system.

Material and methods
The process control algorithm was tested in SBRs with continuous influent feed of type ICEAS. Testing was done both in a pilot scale and in a full scale and conducted of different test phases for a total of one year including seasonal temperature and load variation. The goal of the algorithm is to adjust the treatment cycle to the current conditions to save energy and increase the treatment capacity.

Sites of implementation
The process control algorithm was tested in SBRs with continuous influent feed of type ICEAS. Testing was done both in a pilot scale and in a full scale and conducted of different test phases for a total of one year including seasonal temperature and load variation.

Process control system
A process control algorithm for SBRs was developed which automatically adjust the timing of aeration and mixing within the SBR cycle. The algorithm use online measurements of ammonia (NH4) and temperature to determine the nitrification requirement and expected nitrification rate, which together is used to predict when aeration can be replaced with non-aerobic period. The reduced aeration, together with the continuous feed SBR, of type ICEAS, was designed for total nitrogen (TN) removal and loaded at maximum treatment capacity for Nordic temperatures with the same sewage as the main WWTP Henriksdal.

The process controller optimized the use of each SBR process controller compared to operating with a standard time-based cycle controller (Table 1). By avoiding over-aeration and energy waste, but also enabled time for additional denitrification and provided conditions for biological phosphorus removal.

Results
Energy consumption is in both the high loaded pilot and lower loaded full-scale site was reduced compared to standard time-based cycle control (Table 1). By avoiding aeration during low loaded conditions, the oxygen control was also stabilized which reduced the number of wearing blower starts.

Reduced energy consumption
Nitrogen removal
Excluding the first 150 days, the controller reduced effluent nitrate rate down to 0.6 mg/L, despite operating at full load capacity. In the same period, the full-scale plant reached an average effluent nitrate of 0.6 mg/L and N2O of 1.3 mg/L, despite not being designed for TN removal and operating at temperatures down to 7 °C.

Biological phosphorus removal
In lower loaded cycles, the controller could reduce aeration sufficiently to provide anaerobic conditions, enabling biological phosphorus removal. In the pilot plant, an average influent TP of 7.6 mg/L was reduced to 1 mg/L without any chemical addition. In the full-scale plant, implementing the controller enabled the operators to reduce their chemical consumption with over 50% without violating their permit.

Conclusions
By implementing process control in a continuous feed SBR, this study shows that the SBR cycle can be optimized to the current treatment requirement to reduce energy consumption, stabilize oxygen control and improve conditions for denitrification and biological phosphorus removal. Smart controls can help operators meet the demand of high effluent quality and low operational cost at a low capital expense by making full use of their SBR system.

Table 1: Reduced energy and blower starts with the process controller compared to operating with a standard time-based cycle controller

<table>
<thead>
<tr>
<th>Condition</th>
<th>Pilot plant</th>
<th>Full scale</th>
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</thead>
<tbody>
<tr>
<td>Energy (kWh/m³)</td>
<td>14.6%</td>
<td>15.4%</td>
</tr>
<tr>
<td>Reduced blower starts</td>
<td>33%</td>
<td>34%</td>
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</tbody>
</table>

Figure 1: Basin data before and after upgrade to the process control at Green Lake