ICT, MONITERING

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.

Our suggestion: Applying advanced control on a continuous feed SBR to improve treatment performance, reduce operational costs and stabilize the process.

Material and methods

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 periods. 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 in the sewage inflow.

Pilot study

A pilot study was conducted at the R&D-facility Hammarby Sjöstadsverk (Sweden) as part of the long-term collaboration between Xylem and IVL. 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.

Full scale tests

Full scale tests were performed in a continuous feed SBR of type ICEAS at Green Lake, WI. The plant was designed for 1900 m³/day and operated with average flow of 600 m³/day and temperatures down to 7 C. As the plant had no TN permit, their treatment cycle did not include anoxic periods.

Results

The process controller optimized the use of each SBR cycle to the current conditions. By adjusting to diurnal and weekly variations in load, aeration could be reduced when possible and replaced by mixing. This not only avoided over-aeration and energy waste, but also enabled time for additional denitrification and provided conditions for biological phosphorus removal.

Reduced energy consumption

Energy consumption 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.

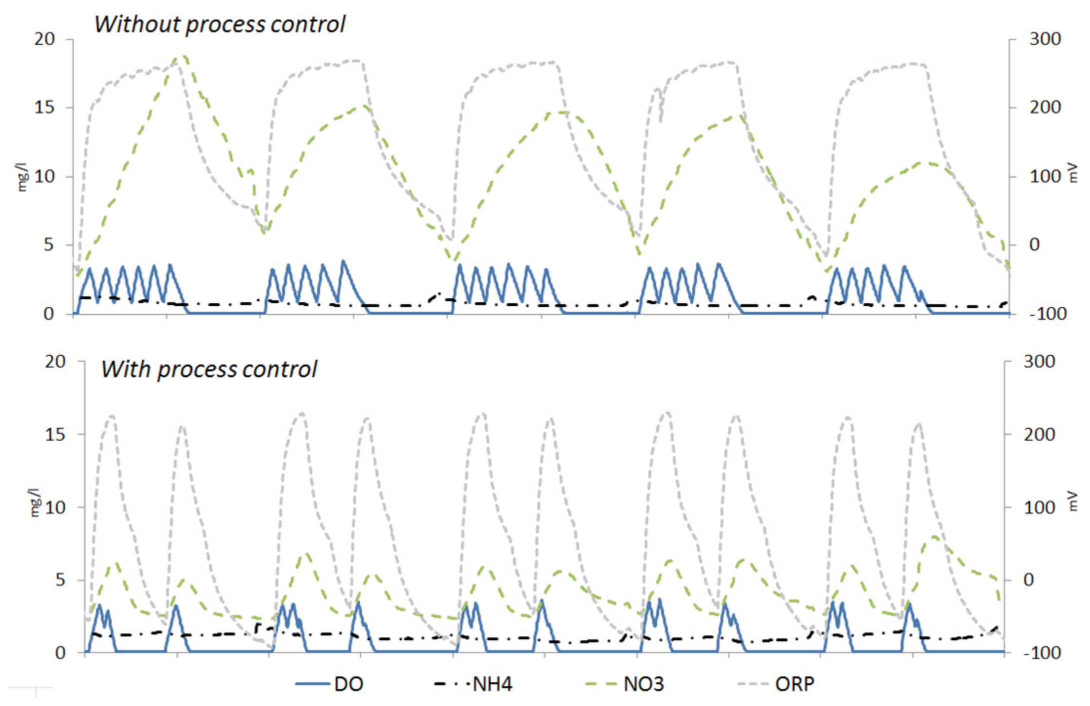

Figure 1: Basin data before and after upgrade to the process control at Green Lake

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

	Pilot plant	Full Scale
Energy saved (kWh/day)	10%	21%
Reduced blower starts	33%	34%

Nitrogen removal

The reduced aeration, together with the continuous carbon source of the influent, improved conditions for denitrification. When tested during winter operation, the pilot plant reached and average effluent NH4 of 0.3 mg/L and NO_3 of 1.4 mg/L, despite operating at full load capacity. In the same period, the full scale plant reached an average effluent NH_4 of 0.6 mg/L and NO_3 of 1.1 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 7.4 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.

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