# Sustainable real time optimization of energy and chemical consumption in a COD & Phosphorous removing MBBR plant in Norway

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**Abstract**: New real-time control strategies for aeration and coagulant/ polymer dosage were developed and implemented in a COD & Phosphorus removing wastewater treatment plant, consisting of a MBBR biological step followed by a high rate clarification treatment step. The aim was to optimise operations to make water processes smarter, safer, and more sustainable. The new real-time control strategies including a number of additional sensors have resulted in significant benefits, including enhancing automation level and process understanding, reducing energy consumption by 51%, reducing coagulant dosage by 26%, and reducing polymer dosage by 20%. The most important contribution to the significant aeration savings is the use of intermittent aeration, which is normally not normal operation practice in MBBR. This case study focuses on its implementation in Skreia, Norway. It has helped to reduce the climate footprint of the wastewater treatment plant with 50 tonnes of CO2-eq saved per year, adapt and increase resiliency towards variating loads from an industrial factory. A big issue was managing a variating reliability of sensors used.

**Keywords**: Real-time Control; Digital Twin; MBBR; wastewater; intermittent aeration

## INTRODUCTION

Normally, a wastewater treatment plant (WWTP) is designed for compliance with effluent standards at full loading/full hydraulic inlet flow at lowest design water temperature.

In reality, for the majority of the time, the WWTP will receive lower load, lower flow and the biomass will work with a higher water temperature i.e. higher biomass activity than the design capacity.

Normal operation of WWTP is ensuring sufficient high aeration and sufficient high dosage of chemicals in all the time to ensure compliance at the most peak load hours. This is the most easy and standard way of operation. The disadvantage of this operation is quite high operational costs and not sustainable operation in respect of GHG emissions.

This paper deals with a real-time based mainly on cascade controls techniques used in a new way and based on a few additional advanced sensors compared to normal operation practice. In that way automatically, aeration and dosage cost are adapted to a minimum and in the same way. The paper compares expected operation cost in design, with actual operation with and without real-time control.

The benefit of using more advanced tools for more efficient real-time control of the WWTP combined with additional sensors, is that aeration and dosage cost automatically are adapted to a minimum all the day around, but at the same time automatically with operator interference, ensuring a ramp-up of airflow and dosage as soon as conditions are changed on minutes basis.

## METHODS

*Skreia WWTP, design*

Skreia WWTP has a designed capacity of 18.350 PE (population equivalent based on $BOD_5$) and is located in Østre Toten Municipality, North of Oslo, in Norway. The WWTP was constructed in 2020-2023 and was commissioned in 2024. The WWTP is a biological COD removing plant with two independent parallel biological lines with MBBR each consisting of two process tanks followed with aeration. Downstream, two compact high rate clarification units (Actiflo® with micro-sand a ballasting compound for increased settling) of different size for removal of suspended solids (incl. waste activated sludge of MBBR) and TP. Coagulant and polymer dosage is supporting the SS and P-removal in the Actiflo.

The WWTP treats 3,600$m^3$ per day with a maximum hourly rate of 450 $m^3$/h
The discharge standards are COD < 125 mg/l or 75% reduction and TP < 0.3 mg/l and 95% reduction.

*Skreia WWTP, Instrumentation*

Original instrumentation setup of process measurements

- 2 x DO/Temperature in each MBBR line
- 2 x Airflow to each MBBR line
- 2 x water level in each MBBR line
- 2 x Turbidity in outlet of each Actiflo line
- 2 x pH in each MBBR line
- 2 x pH in each Actiflo line

Additional instrumentation setup used for new real-time optimization strategy.

- 1 x Turbidity in outlet of MBBR/inlet to both Actiflo lines
- 1 x NO3-N (nitrate) in outlet of WWTP
- 1 x TOC in outlet of WWTP
- 1 x TP (Total Phosphorus)/PO4-P (phosphate) in outlet of WWTP

*Real-time optimization tool used*

The Hubgrade Wastewater Plant Performance (HWP) is a digital platform designed to optimize operations and make water processes smarter, safer, and more sustainable. This state-of-the-art real-time control solution leverages live data, Veolia's expertise, and artificial intelligence to optimize the entire wastewater system.

*New aeration control strategy*

The standard control procedure from the construction of the WWTP is an operator defined fixed DO setpoint for continuous aeration, which is used to ramp up/down a blower within sudden airflow limits.

The new control strategy for aeration of the MBBR addresses two means of optimization:

- Dynamic DO setpoint
- Intermittent aeration, when possible - to reduce aeration / OPEX in low load periods.

Based on real-time measurements of DO, water temperature and air flow, the Oxygen Uptake Rate (OUR) is calculated in real-time. The OUR is used to provide a dynamic DO setpoint, and for the intermittent aeration a percent aeration (which can be 100 % = continuous aeration) and a cycle time.

Two compensation components are added to define the final setpoints:

- TOC- prevention against insufficient aeration.
  TOC provides feedback to the algorithms of COD if the outlet is either at risk of becoming non-compliant or if COD could be increased to save OPEX for the removal of COD. The dynamic DO setpoint and the aeration time (i.e. intermittent aeration) are dynamically adjusted to be closer to the optimal aeration and thereby ensure the lowest possible OPEX.
- NO3 - prevention of nitrification
  NO3 provides a feed-back to the algorithms if nitrification occurs, which is a risk at low load and/or too high biomass capacity expressed as increasing NO3. In such cases the DO setpoint and the aeration time (i.e. intermittent aeration, if possible) are dynamically reduced to prevent growth of nitrifying biomass. Thereby an increase of the oxygen demand due to nitrification is prevented, and OPEX is saved. The oxygen demand for nitrification and COD removal is twice that of COD removal alone, i.e. the savings potential is significant. By reducing the risk of nitrification, the emission of the very strong greenhouse gas N2O (nitrous oxide / laughing gas) is also reduced.

The benefit of having two independent controllers based on OUR in the two MBBR is to cope with performance variation between the two MBBR lines.

*New polymer and coagulant control strategy*

The standard control procedure from the construction of the WWTP is an operator defined dosage rate (ml/m3).

The new control strategy consists of a cascade PID controller. The first controller (PID1) uses the TP to calculate a turbidity target for two similar parallel second controllers (PID2), one for each high rate clarification unit. The reason for two PID2 controllers is to cope with individual performance variations between the units due to e.g. different wear & tear of the mechanical parts and non-equal distribution of suspended solids loading to the two lines in the distribution chamber. Furthermore, the two high rate clarification units are different in size.

Furthermore, there is a compensation component

- pH - pH Safe
  If the pH falls below a certain value due to excessive chemical dosage, the dosage will be reduced according to operator settings to maintain an acceptable pH level, thereby preventing the pH from dropping to a level where the chemicals become ineffective.

## RESULTS AND DISCUSSION

Before construction of the Skreia WWTP, an expected operation consumption of energy and chemicals was calculated using the mass balance and process calculations.

In reality, the actual consumptions with the standard control in PLC were happening differently, with higher consumptions of energy for WWTP and polymer for the high clarification unit and less coagulant dosage.

**Table 1.1** Energy and Chemical Consumption. Comparison of design value with operation with standard control strategy as well as with new control strategy.

| | | Energy (kWh/d) | Coagulant (l/d) | Polymer (kg/d) |
|---|---|---|---|---|
| | Design Consumption | 400 | 1320 | 4,0 |
| Feb - May 2024 | Actual With Standard Control Strategy | 500 45 % | 688 48 | 6,0 33 % |
| Sep - Oct 2024 | Actual With New Control Strategy | 281 30 51 | 506 62 26 | 4,8 20 |

% - Compared to design value (expected consumption)

% - Compared to actual value with standard control strategy

The implementation of the new control strategy has resulted in significant benefits, including enhancing the level of automation and process understanding. It has also led to a substantial **reduction in energy consumption by 51%**. The implementation of HWP has also resulted in a **reduction of coagulant dosage by 26%** and **polymer dosage by 20%**. **The effluent results of the WWTP have been compliant all the time**.
The challenges using sensors with variating reliability will be elaborated in full paper.

## CARBON FOOTPRINT SAVINGS

The solution has managed to save 50 tonnes of CO2-eq per year, thereby reducing its carbon footprint, which is equal to 40[1] electric-powered passenger vehicles driven for one year (EPA.)

## REFERENCES

Thomsen, H. R., Önnerth, T. B. (2009). Results and benefits from practical application of ICA on more than 50 wastewater systems over a period of 15 years. (2009) In: Proceedings of 10th IWA conference on Instrumentation, Control & Automation 14-17 June, Cairns, Australia.

[1] calculated using - https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator.