9th IWA Symposium on Systems Analysis and Integrated Assessment
14-17 June 2015, Gold Coast, Australia

Dissolved oxygen deviation control – full-scale experiments at Henriksdal wastewater treatment plant

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Keywords: Dissolved oxygen; aeration control; wastewater treatment

Summary of key findings

A dissolved oxygen deviation controller (DODC) was implemented and tested at Henriksdal wastewater treatment plant (WWTP). The controller decreases the DO set-point in the earlier aerated zones when a DO peak occurs in the last aerated zone, meaning nitrification is pushed towards the last aerated zone. The controller has been in successful operation since 2012 at Henriksdal WWTP. Simulations have shown that a saving of around 2 % in aeration energy can be reached with the controller settings used at Henriksdal WWTP, with no impact on the effluent NH_4 concentration.

Background and relevance

Due to daily load changes, there is often a daily peak in DO concentration towards the end of aerated plug-flow basins at WWTPs. The peaks occur since nitrification is complete towards the end of the basin, hence more oxygen is provided to the process than is consumed by the microorganisms, which means more energy is spent on aeration than necessary. Another drawback with DO peaks towards the end of plug-flow pre-denitrifying systems is that high DO concentrations can disturb denitrification when recirculated back to the anoxic zones.

A DODC was developed at Käppala WWTP, Stockholm, in collaboration with Uppsala University in 2007 (Thunberg *et al.*, 2009). The purpose of the DODC was to reduce aeration intensity during low loaded periods when DO peaks in the last aerated zone occurred. A new version of the DODC was implemented at Henriksdal WWTP in 2012. The control structure consisted of a NH_4 feedback controller and an extra control loop for the DODC. The control structure is presented in Figure 1.1. There are three aerated zones at Henriksdal WWTP, zone 4 to 6.

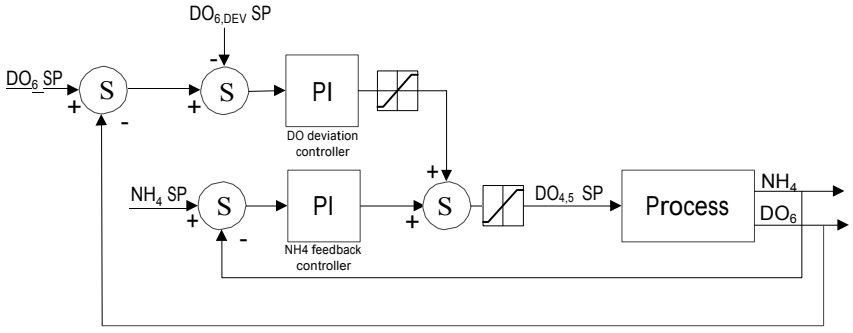

Figure 1.1. Block diagram with NH4 feedback control and DODC implemented at Henriksdal WWTP. DO4, DO5 and DO6 are the DO concentrations in zone 4, 5 and 6 in the activated sludge tanks at Henriksdal WWTP, respectively. NH4 was measured after the secondary settler.

The two controllers in Figure 1 change the DO set-point in the first two aerated zones according to (*i*) the effluent NH_4concentration (NH_4 feedback controller) and (*ii*) the deviation of the DO concentration from its set-point in the last aerobic zone (DODC). When the DO concentration is higher than the set-point in zone 6 ($DO_6SP - DO_6 < 0$), the DO_6 control error is negative and the DO set-point in zone 4 and 5 is decreased. The maximum and minimum control signal from the DODC

was 0 and -0.5 mg/l, respectively, meaning the controller could only decrease the DO set-point, never increase it. The combined control signal from the two controllers was never allowed to be lower than the minimum control signal from the NH_4 feedback controller.

Simulations with DODC were performed in a calibrated Activated Sludge model No 1 (ASM1) of Henriksdal WWTP (Åmand, 2014). The simulated periods represented two periods in spring 2011 and 2012 when DODC and NH_4 PI control was active.

Results

An example of DO deviation control in full-scale operation at Henriksdal WWTP is found in Figure 1.2. The experimental treatment line is operated with NH_4 feedback control and DODC, and the reference treatment line was operated with constant DO control. Over a weekend the effluent NH_4 concentration was decreased, which resulted in a decreased DO set-point in the treatment line with NH_4 feedback control. The DO peaks in the last aerated zone were reduced thanks to the slow NH_4 controller. The DODC decreased the DO set-point in the first two aerated zones further during periods of DO peaks. The set-point was not reduced below the lower control signal limit in the NH_4 controller which was 1.8 mg/l, which is why the DODC does not act after May 1st.

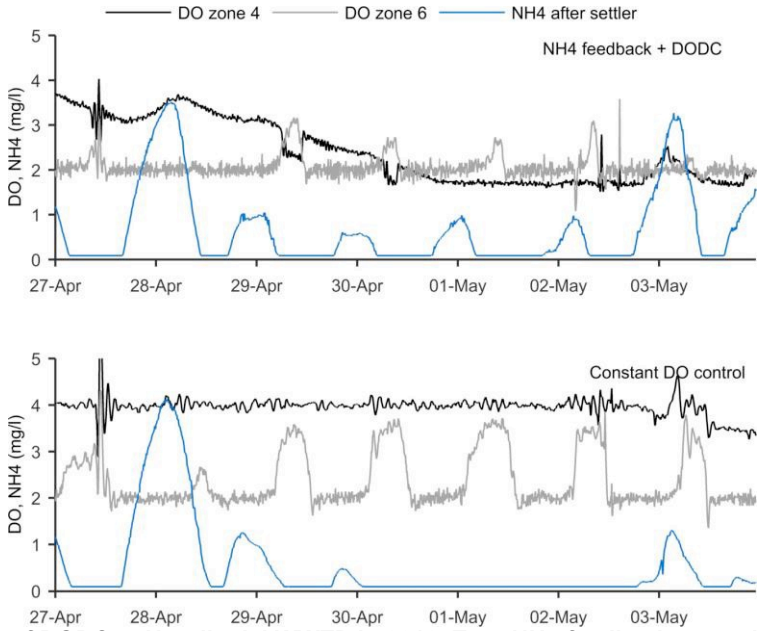

Figure 2.2. Example of DODC at Henriksdal WWTP in 2012. Top: NH4 feedback control with DODC (treatment line 4). Bottom: Constant DO control (treatment line 1). DO set-point in zone 6 is 2 mg/l.

A second example is presented in Figure. An unintended emptying of one of the digesters into the treatment plant created a large peak load when the sludge passed through the biological treatment process. Prior to this incident aeration was switched off in the last aerated zone (zone 6). The DO in zone 6 prior to August 30 is stray oxygen from the adjacent zone.

In treatment line 3 (Figure 1.3, top), aeration was switched on in zone 6 April 29 before the load from the digester reached the activated sludge process. In treatment line 4, aeration in zone 6 was switched on April 30 around noon. The effect of this can be seen on the magnitude of the NH_4 peak which was nearly twice as high in treatment line 4 as in line 3. During the peak load period the oxygen demand exceeded the aeration capacity. The DO concentrations were lower than the set-points in both treatment lines.

The DODC was active in treatment line 3, and since the DO concentration in zone 6 was higher than its set-point of 1 mg/l most part of the day the DO set-point in zone 4 and 5 was lowered. Hence, DODC helped to save energy in treatment line 3 after the NH_4 peak.

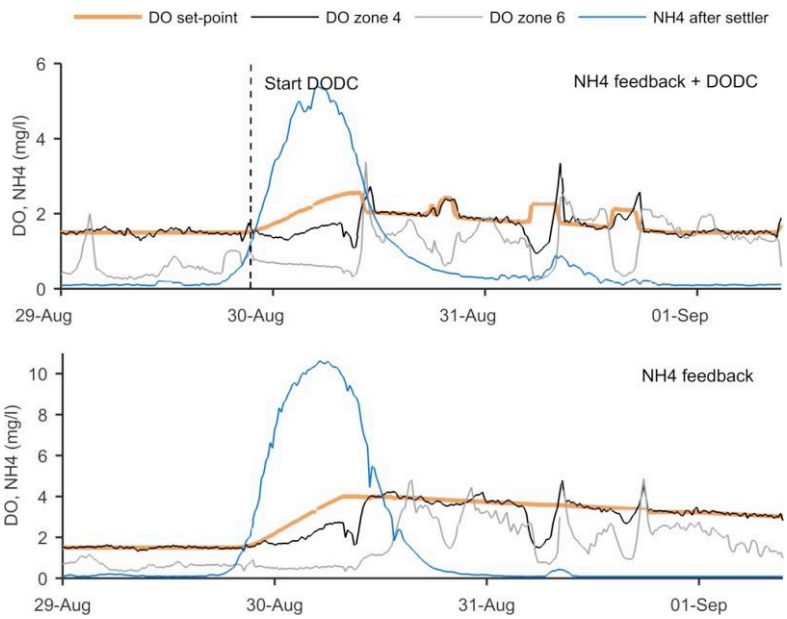

Figure 1.3. Example of DODC at Henriksdal WWTP in 2013. Top: NH4 feedback control with DODC (treatment line 3) The DO set-point in zone 4 and 5 is lowered when DO concentration in zone 6 passes its set-point (1 mg/l) on August 30. Bottom: NH4 feedback control without DODC (treatment line 4).

The simulation results are summarised in Table 1.1. The DO concentrations were reduced by around 3 % in zone 4 and 5 and by around 5 to 6 % in zone 6. The energy saving was according to the simulations around 2 %. The DODC did not have any effect on the effluent NH_4 concentration.

Table 1.1. Mean DO and effluent NH_4 concentrations in simulations with NH_4 PI control with and without DODC. The DO concentration in zone 4 and 5 are the same.

	NH_4 PI control			NH_4 PI + DODC			
	DO zone 4 (mg/l)	DO zone 6 (mg/l)	NH_4 (mg/l)	DO zone 4 (mg/l)	DO zone 6 (mg/l)	NH_4 (mg/l)	Saving Qair (%)
2011	3.16	1.23	1.30	3.06	1.16	1.30	2.2
2012	3.17	1.21	1.32	3.08	1.15	1.32	2.0

Discussion

The DODC was evaluated together with NH_4 feedback control at Henriksdal WWTP, but the controller could also be combined with constant DO control. The DODC has the effect that the incoming NH_4 load is pushed further towards the end of the process at periods of low load, since the DO set-point in the first two aerated zones is reduced. In this way, the overall aeration intensity can be reduced.

The DODC at Henriksdal WWTP is normally switched on when the last zone is aerated. Often, the second aerated zone requires more air than what can be provided by the aeration system. When the DODC decreases the DO set-point in the two first aerobic zones, it is easier for the DO controller to keep the set-point in the second aerated zone. This creates a more smooth plant performance.

References

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