Evaluation of different nitrogen control strategies for a combined pre- and post-denitrification plant

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Presentation outline:

- Introduction
- Plant configuration
- Control strategies
- Evaluation of control algorithms by simulation
- Conclusion
Introduction

Stricter effluent requirements and the need for cost optimal plant operation.

Optimisation of nitrification and denitrification processes using on-line nitrogen measurements.

Real plant case study: Domzale-Kamnik WWTP that will be upgraded for nitrogen removal.

Challenge: to design a control system that will yield optimal plant performance with respect to both effluent quality and operating costs.

In the study we consider and evaluate different control alternatives with respect to the chosen control variables and control algorithms.
Process configuration

Effluent requirements:
TN < 10mg/l
NH4-N < 3mg/l
Simulation model:
Hybrid model in GPS-X combining standard plug-flow tank with suspended growth biomass and the biofilm model with fixed film growth on inserted media

Evaluation criteria:
- aeration energy costs
  \[ AC = \frac{E_{\text{price}}}{T_p} \int_{t=0}^{t=T_p} \frac{Q_{\text{air}}(t) \cdot \text{head} \cdot \rho_{\text{H}_2\text{O}}}{86.4 \cdot 10^7 \cdot \eta_{\text{pump}}} dt, \]
- external carbon dosage costs
  \[ CC = \frac{C_{\text{price}} \cdot \text{COD}_S}{1000 \cdot T_p} \int_{t=0}^{t=T_p} Q_{\text{carb}}(t) dt, \]
- effluent quality (soluble TN, COD, NH\textsubscript{4}\textsuperscript{-N} and S_S)

Comparison with basic control:
central internal recycle flow
central carbon dosing
oxygen control with constant set-point
Influent data: real plant measurements

- Flow-rate (m$^3$/day)
- Ammonia nitrogen (mg/l)
- Readily biodeg. substrate (mg/l)
Control strategies

Internal recycle control:

Not useful in our case because of limited maximal internal recycle flow (max. $2Q_{in}$)
External carbon dosage control:

(a) Feedforward control based on influent flow
(b) PI control with NO$_3$-N in the 6th reactor as controlled variable
Aeration (ammonia) control:

Controlling NH$_4$-N in the 5th reactor by adjusting the oxygen setpoint in aerobic reactors

Cascade ammonia PI controller:
Evaluation of control algorithms

External carbon dosage control

Reduction of TN peaks and lower carbon dosing costs with nitrate PI control
Ammonia control

Considerable reduction of aeration costs (around 30%)
Overall control

Similar effluent quality with considerable reduction (around 40%) of external carbon dosage costs and aeration costs with overall control.
Evaluation of control strategies at low temperatures (10°C, previous analyses at 15°C)

Limited nitrate removal in pre-denitrification reactors during low influent COD concentration and low temperature

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**Graphs:**
- External carbon flow-rate (m³/d)
- Soluble TN (mg/l)
- Readily biodegradable substrate in reactor 7 (mg/l)

**Table:**
- External carbon dosing
- Internal recycle
- Basic control
- Dosing in 6
- Dosing in 5
Conclusions

- Application of control schemes based on on-line nitrogen measurements is reasonable.
- Comparable effluent quality and significant energy savings (up to 40%) could be expected compared to constant setting of manipulated variables.
- Because of the process nonlinearities problems could be expected at some special operating conditions.