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.

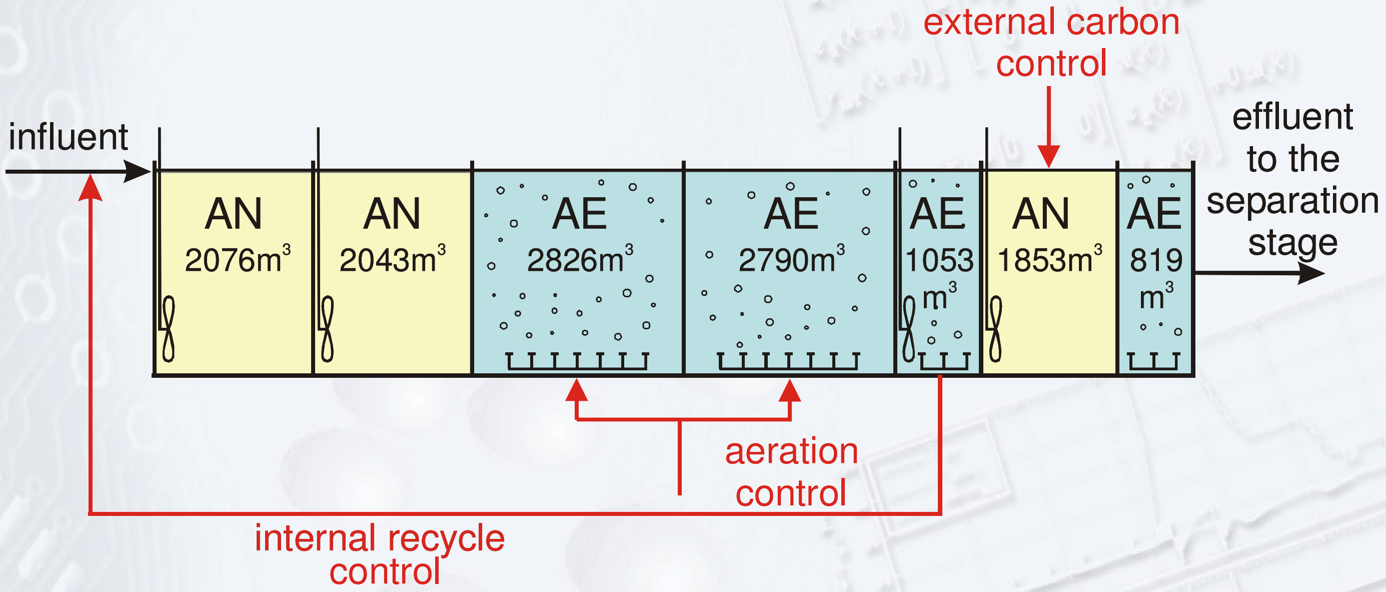
Optimisation of nitrification and denitrification processes using on-line nitrogen measurements.

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


influent

AN 2076m^3

AN 2043m^3

AE 2826m^3

AE 2790m^3

AE 1053 m^3

AN 1853m^3

AE 819 m^3

external carbon control

effluent to the separation stage

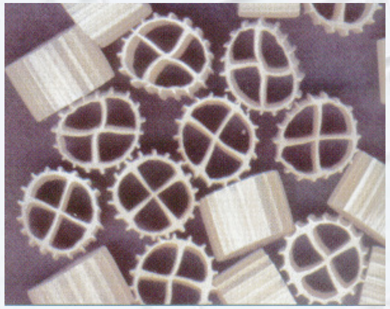
aeration control

internal recycle control

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

$$AC = \frac{E_{price}}{T_p} \int_{t=0}^{t=T_p} \frac{Q_{air}(t) \cdot head \cdot \rho_{H2O}}{86.4 \cdot 10^7 \cdot \eta_{pump}} dt,$$

- external carbon dosage costs

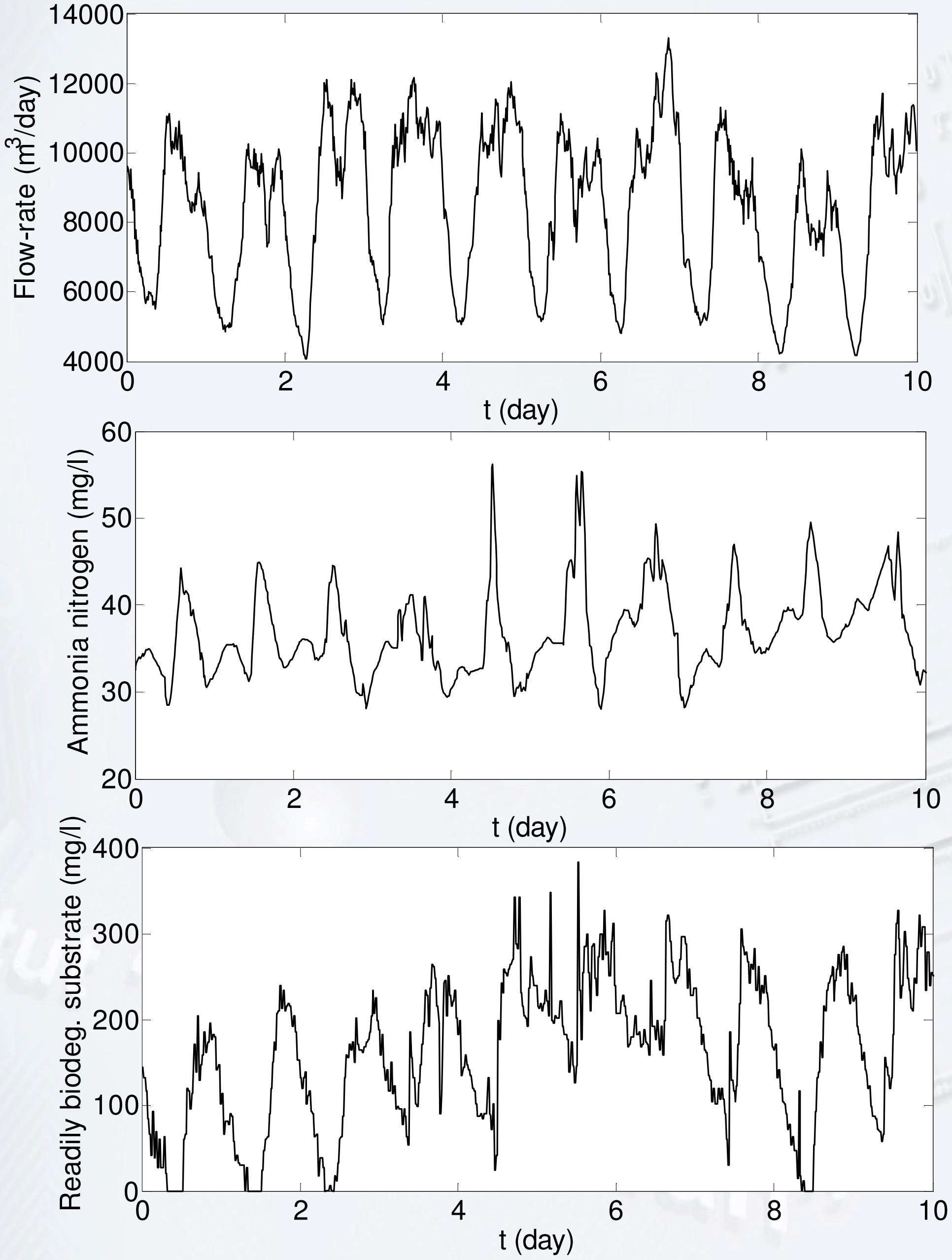
$$CC = \frac{C_{price} \cdot COD_S}{1000 \cdot T_p} \int_{t=0}^{t=T_p} Q_{carb}(t) dt,$$

- effluent quality (soluble TN, COD, NH_4-N and S_S)

Comparison with basic control:

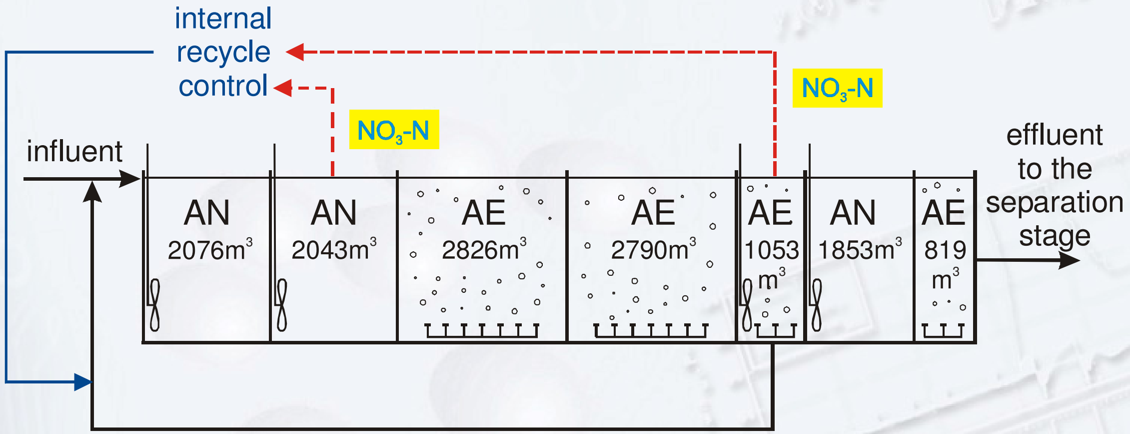
constant internal recycle flow
constant carbon dosing
oxygen control with constant set-point

Influent data: real plant measurements



Control strategies

Internal recyle control:

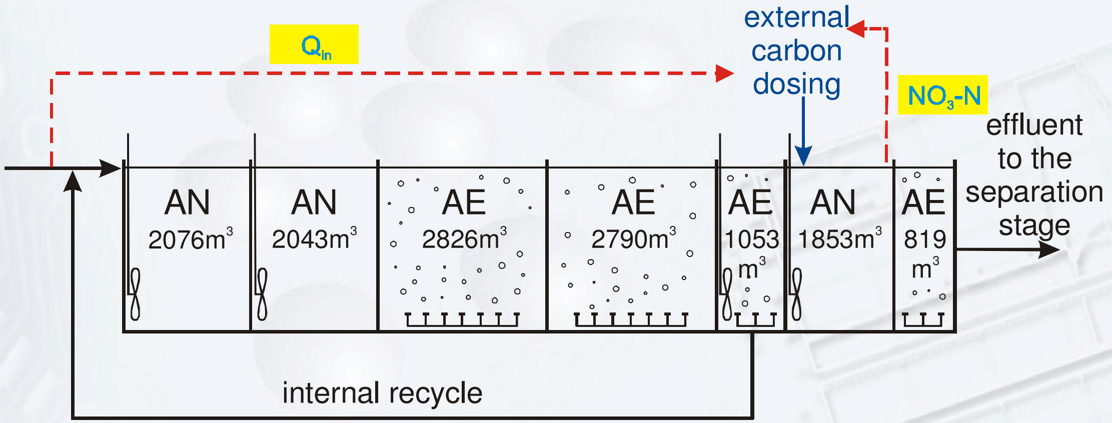


Not useful in our case because of limited maximal internal recycle flow (max. $2Q_{in}$)

External carbon dosage control:

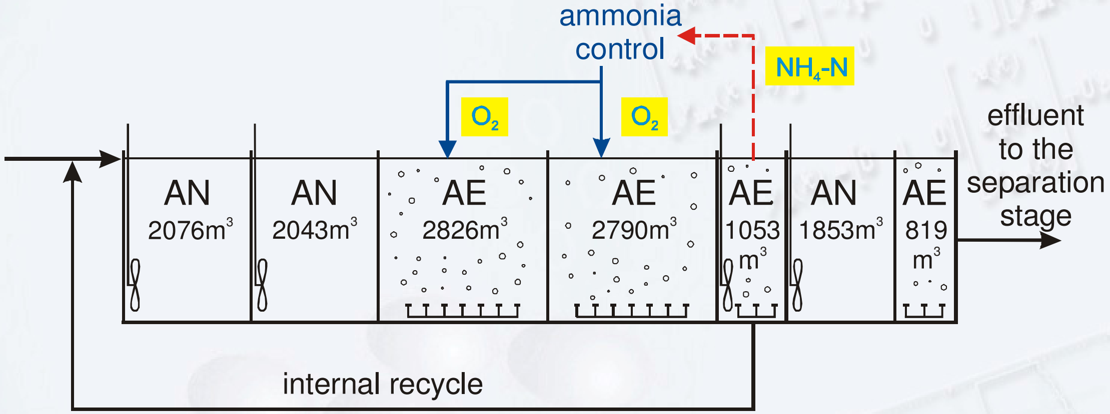
(a) Feedforward control based on influent flow

(b) PI control with NO_3-N in the 6th reactor as controlled variable

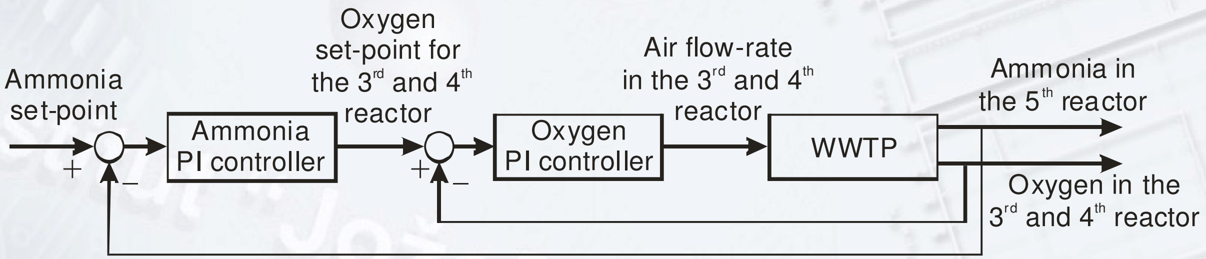


Aeration (ammonia) control:

Controlling NH_4-N in the 5th reactor by adjusting the oxygen setpoint in aerobic reactors

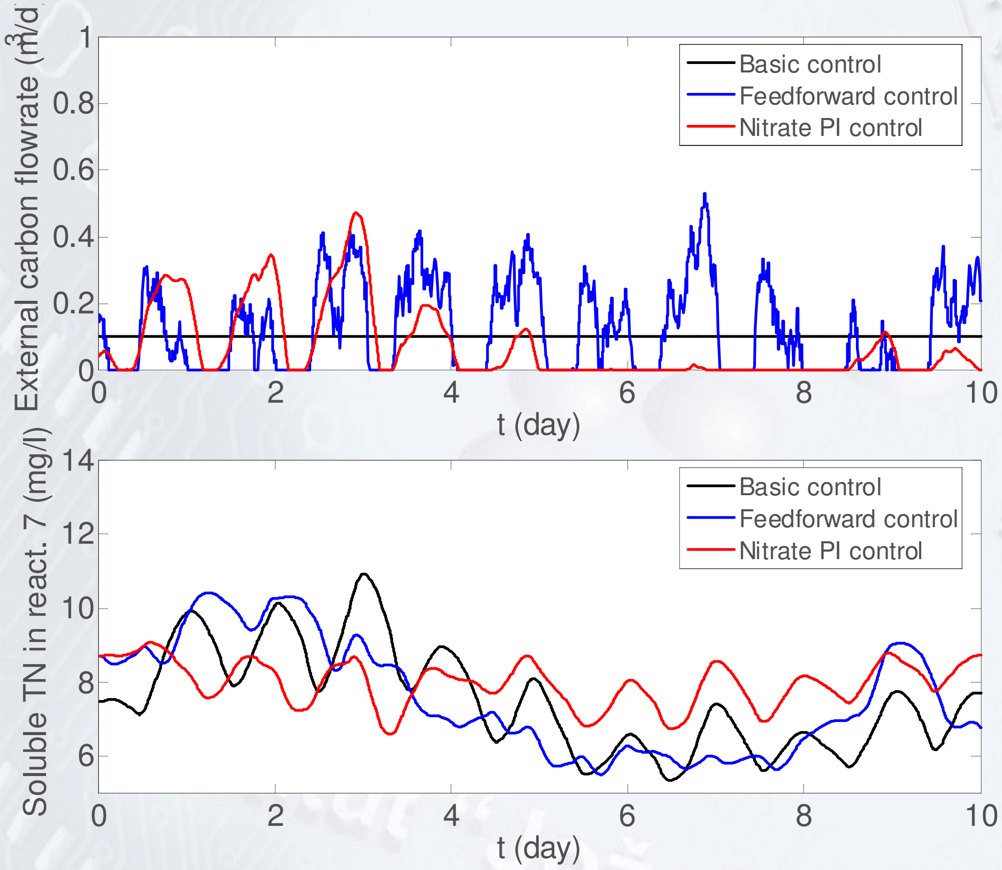


Cascade ammonia PI controller:

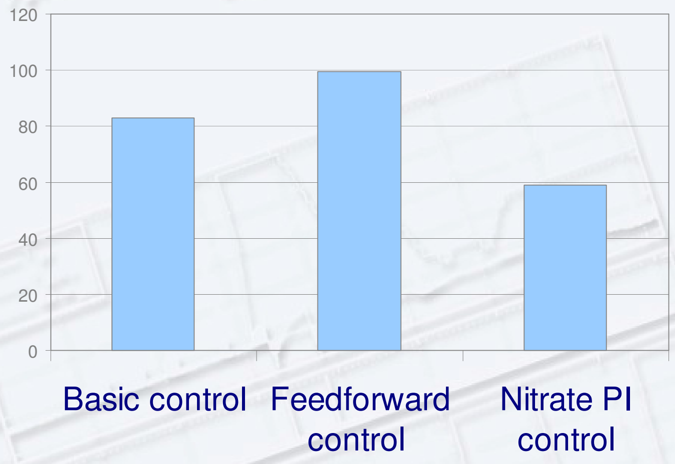


Evaluation of control algorithms

External carbon dosage control

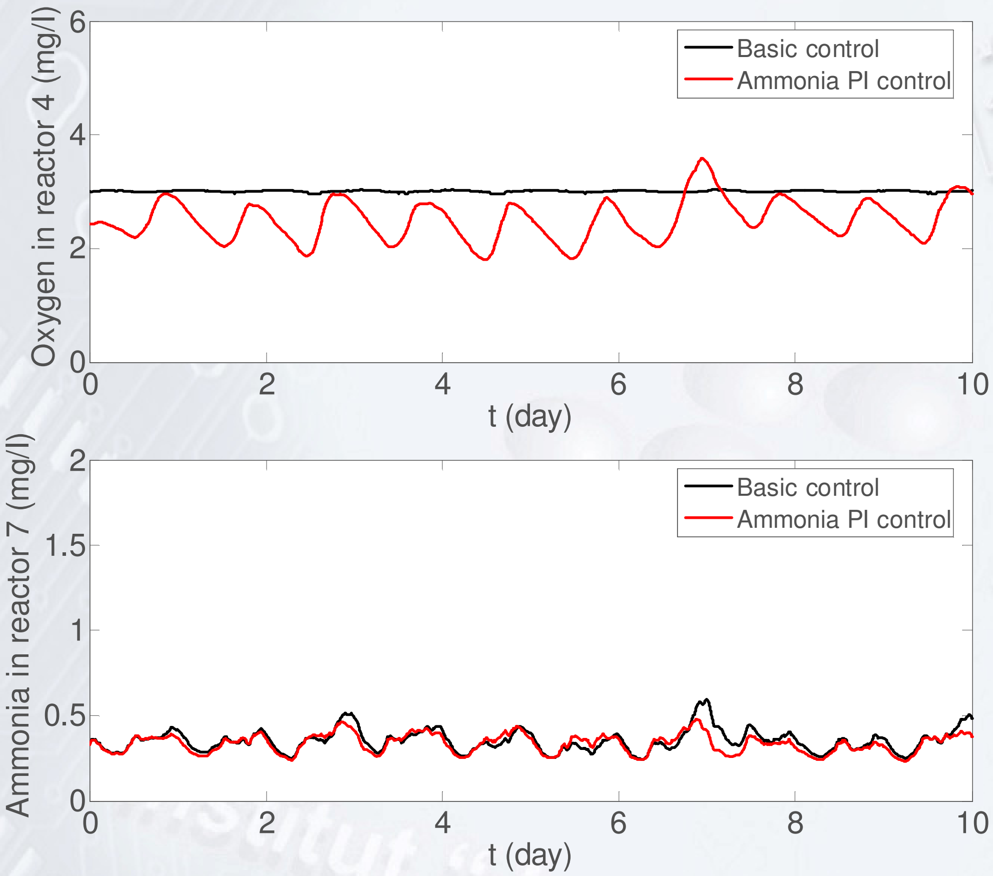


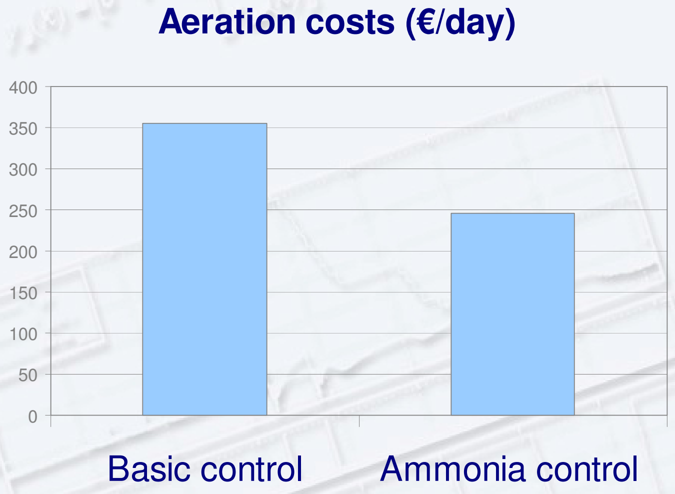
Carbon costs (€/day)



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

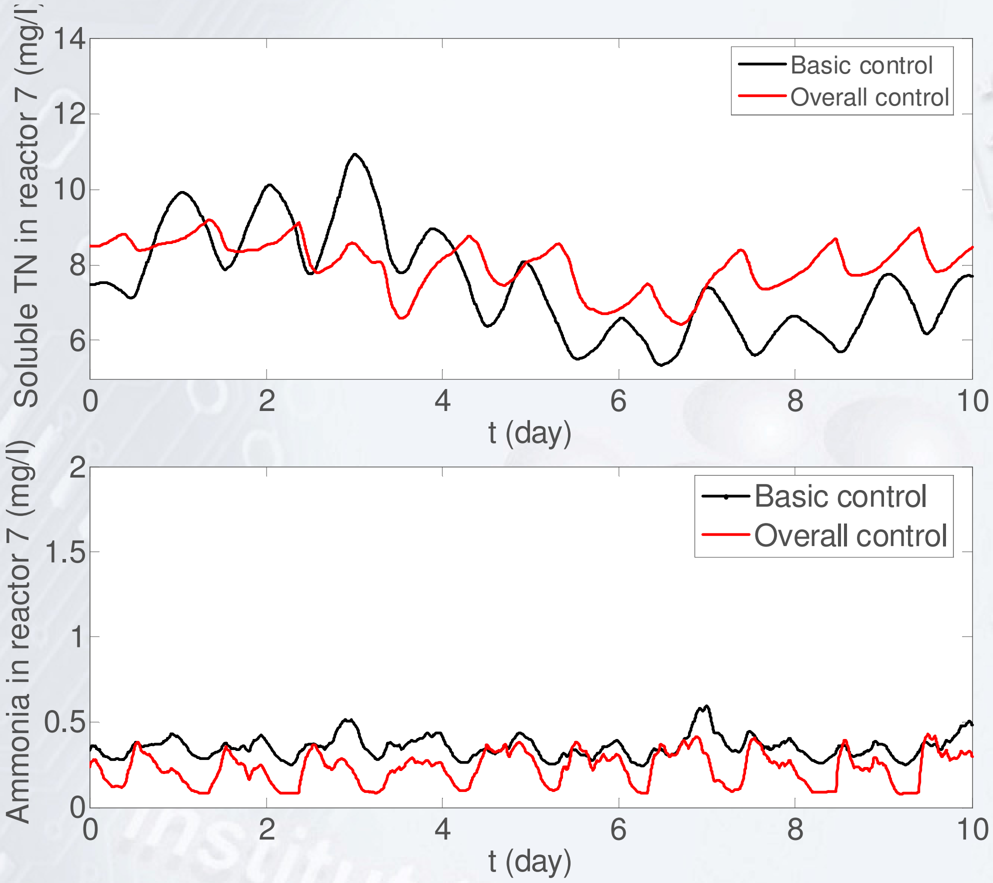
Ammonia control

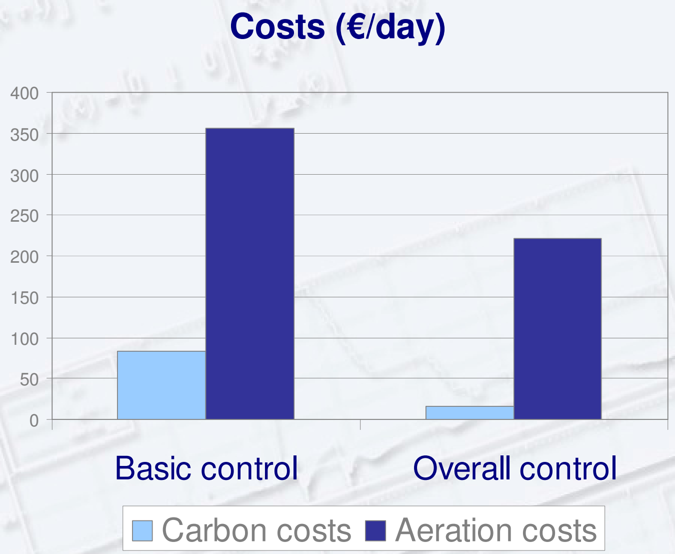




Considerable reduction of aeration costs (around 30%)

Overall control

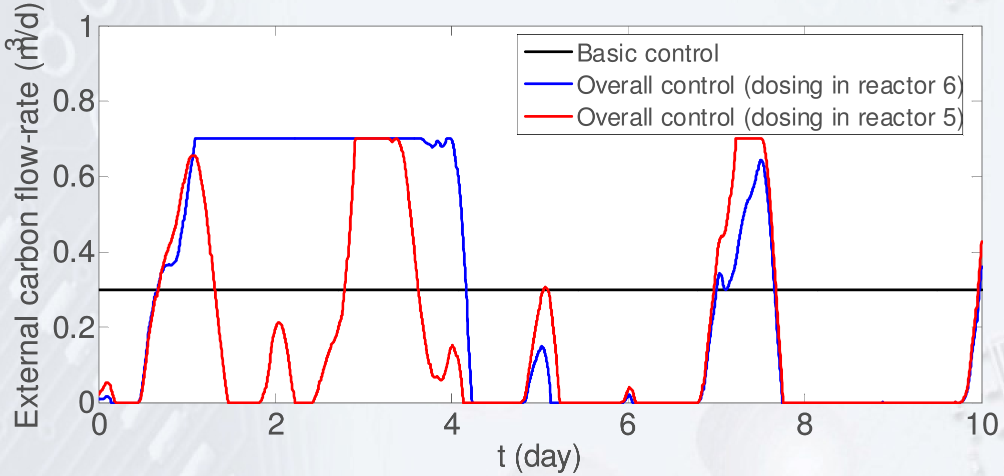


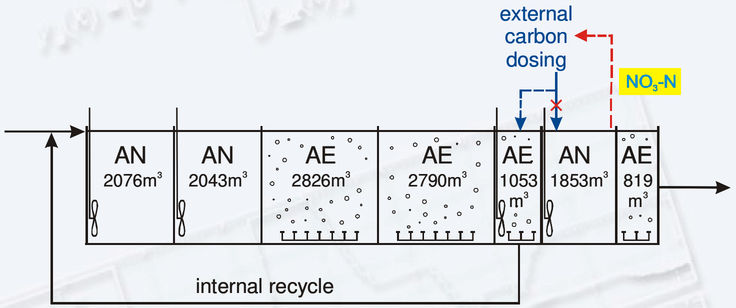


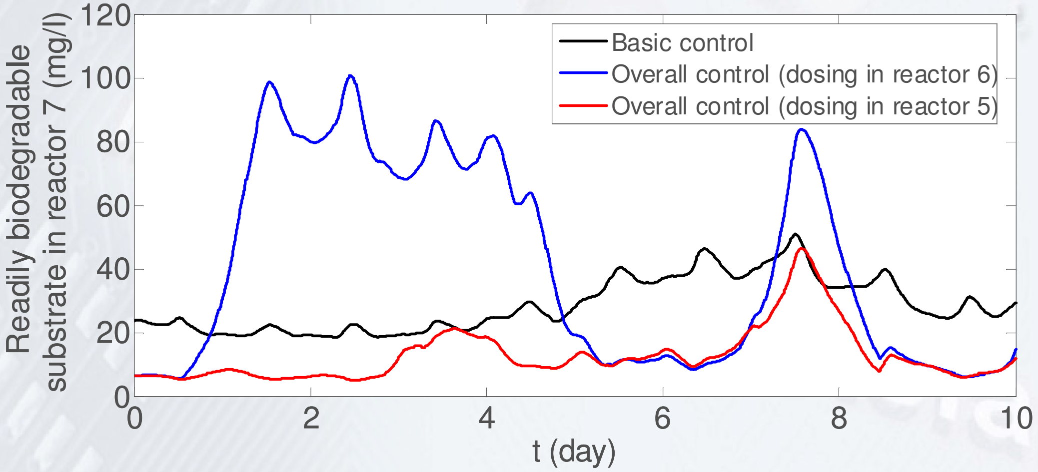
Similar effluent quality with considerable reduction (around 40%) of external carbon dosage costs and aeration costs with overall control

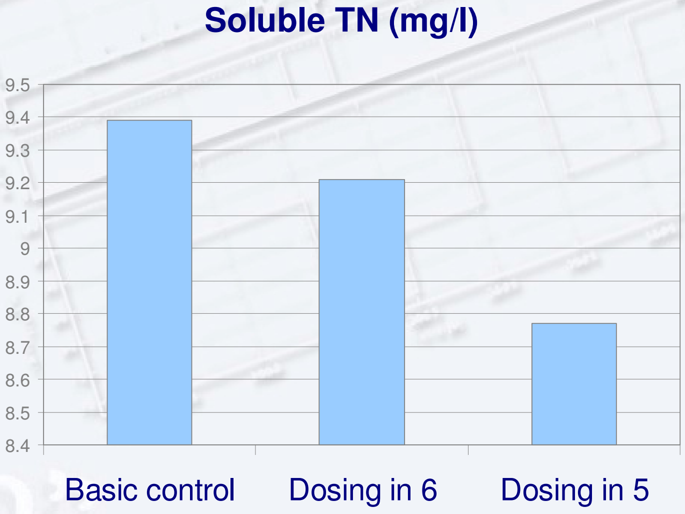
Evaluation of control strategies at low temperatures (10^{o}C, previous analyses at 15^{o}C)

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









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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.