IWA TG on Benchmarking of Control Strategies for WWTPs

Examples
Discussion of control applications

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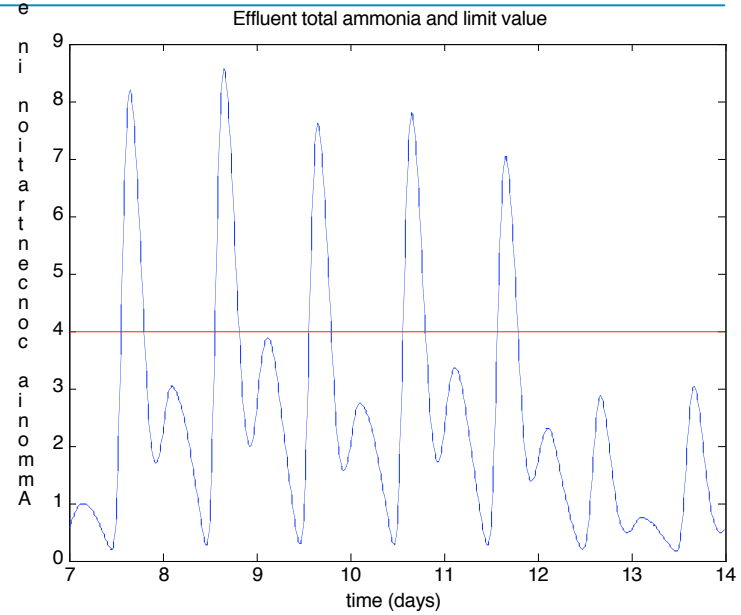
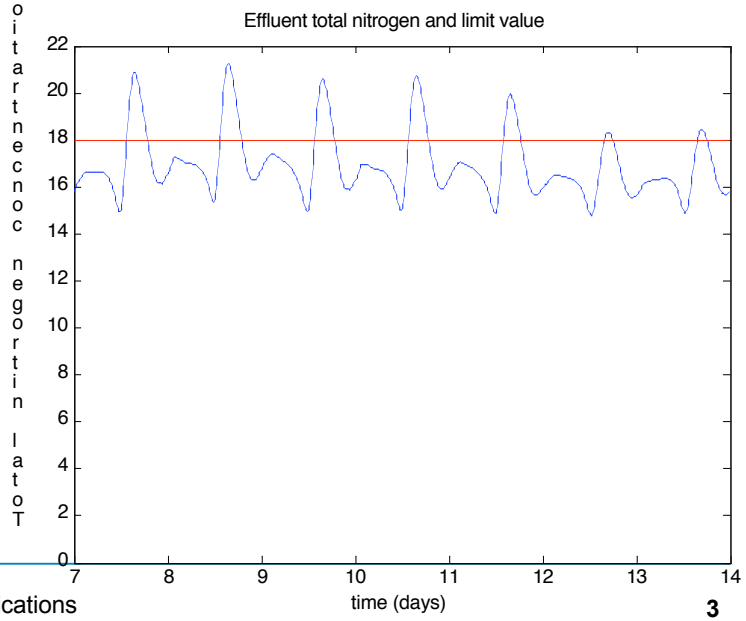
Outline

- A control challenge for BSM1
  - Description of challenge
  - Available tools
  - Issues for optimization
- Some control strategy examples
  - Standard closed loop
  - Intermittent aeration
  - Simultaneous nitrification/denitrification
- Comparison
- Discussion of results

The scenario

- Today's situation:
  - The standard closed loop
- Performance
  - Violations of ammonia
  - Violations of total N
  - Average N:17 mg/l
  - OCI: 16 368 (21 164)





The tool box

- Available sensors
  - nitrate, ammonia, DO, suspended solids, Q
- Available control handles
  - airflow individually, Q_w, Q_{rec}, Q_{ras}
  - Step feed possibilities
  - **No** carbon allowed
- Limitations
  - According to actuators

The challenge

- Design a control strategy so that
  - No violations of limits occurs at dry weather
- The best control strategy
  - Lowest operational cost index (OCI)
- The most robust control strategy
  - Minimum of violations at rain and storm

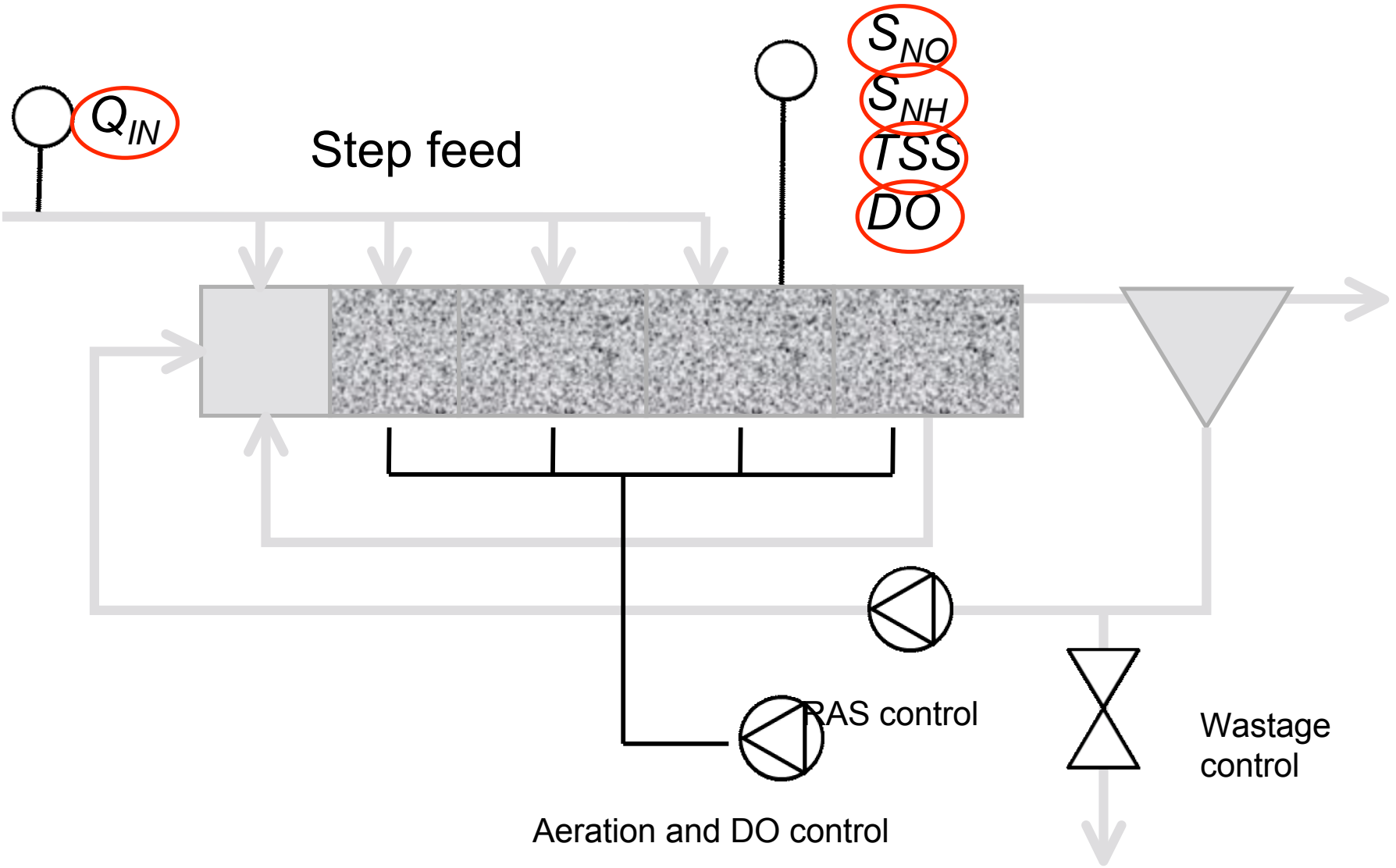
Issues for optimization

- Severe ammonia dynamics
  - Must handle peaks (peak shaving)
- Limited internal carbon source
  - Use the available carbon
- Not enough sludge in the system
  - Needs more than 4 g/l (VSS)

Example I

- Wastage control
  - Sludge concentration or
  - Sludge age control
- RAS control
  - Smoothening of the surface load
- Intermittent aeration
  - Handles dynamics well
  - Utilizes carbon efficiently
- Step feed
  - _ to first four reactors
- DO set point control
  - Minimize aeration

All control strategies from full-scale applications.

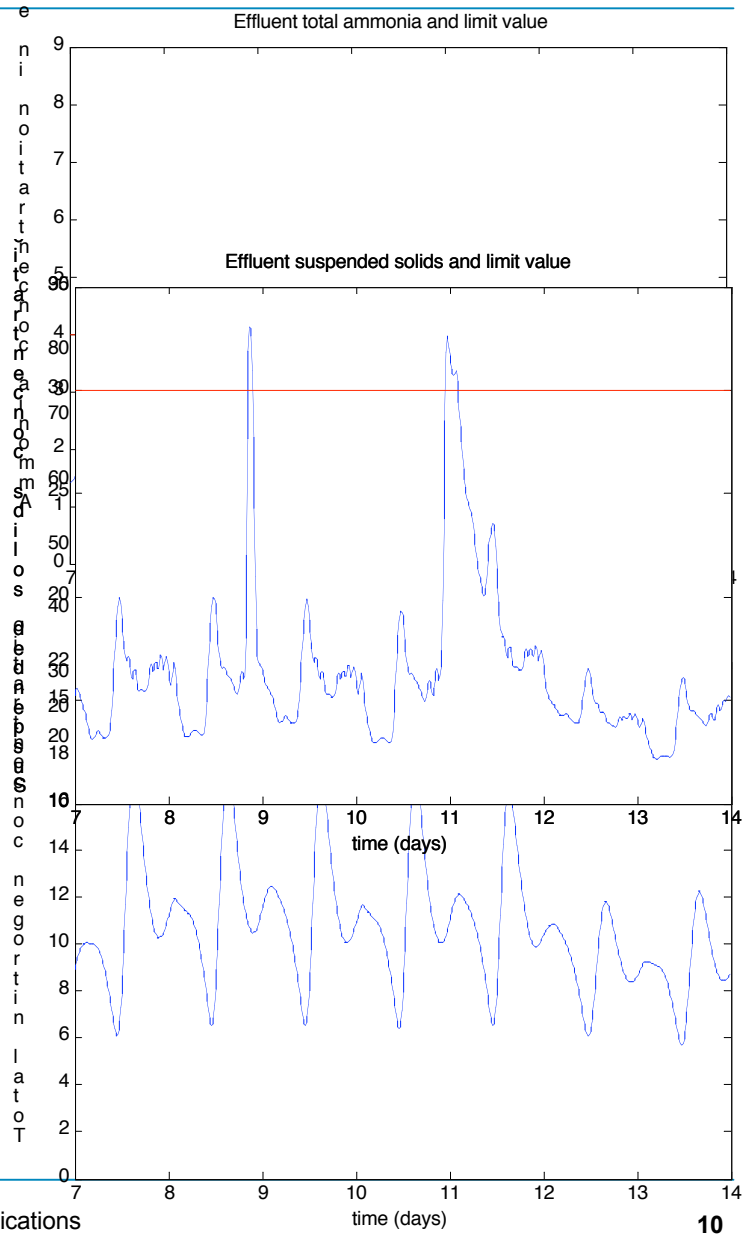

S_{NO}
S_{NH}
TSS
DO
Q_{IN}
Step feed
RAS control
Wastage control
Aeration and DO control

Example I

- Wastage control
  - $Q_w = PI\ (TSS_{sp} - TSS_{filt})$, PI control, set point = 4.5 g TSS/l
  - $TSS_{sp} = f(T, S_{NO}, S_{NH})$ simplified SA controller
- RAS control
  - $Q_{RAS} = \alpha \cdot Q_{filt} - \beta \cdot Q_{in}$ smoothening, average ratio 150%
- Intermittent aeration
  - $On/off = f\ (S_{NO}, S_{NH})$, implemented as in STAR software
- DO set point control
  - $DO_{sp} = f\ (S_{NH}, S_{NO})$, lookup table, low S_{NH} low DO etc., S_{NO} for switching off when no nitrification (winter time)

Example I

- Dry conditions
  - No violations
  - Average N: 11 mg/l
  - OCI: 14 213 (19 003)
- Rain weather
  - SS violation
  - OCI: 12 531 (17 339)
- Storm
  - Minor SS violations
  - OCI: 14 902 (19 708)



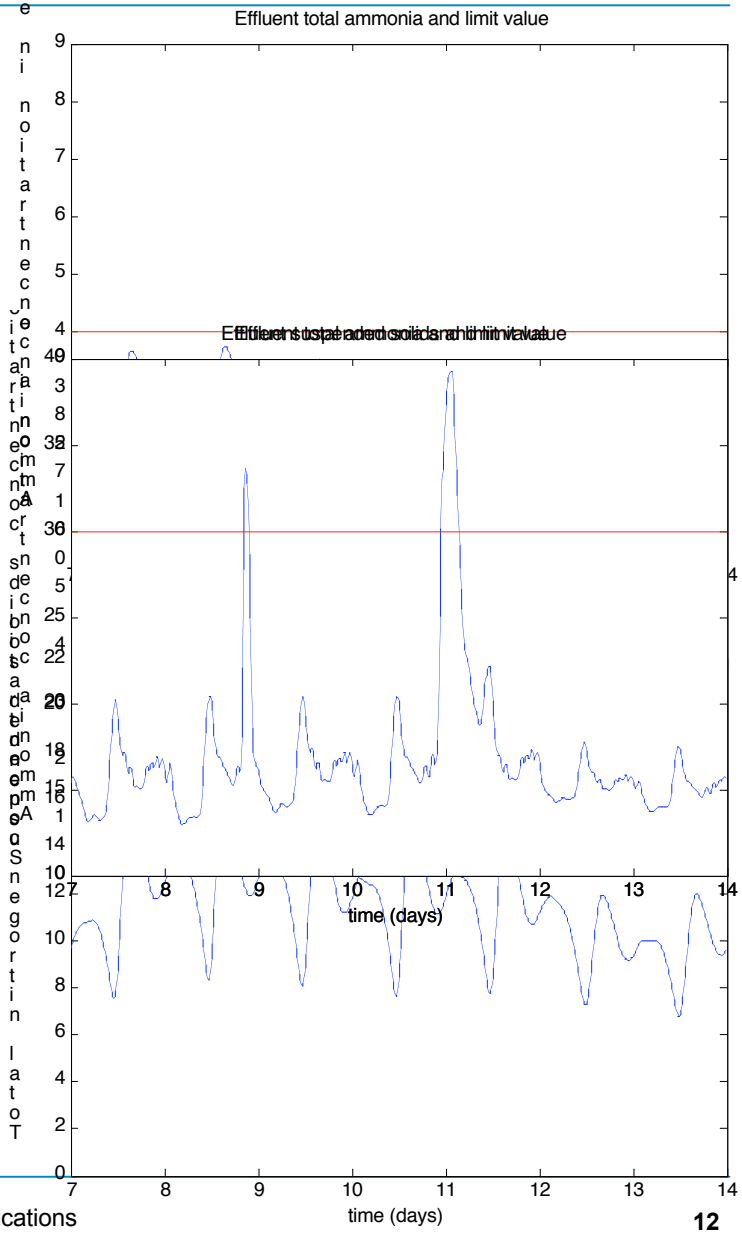
Example II

- Direct control of aeration
  - Omit the DO loop in the strategy
- Aeration control based on
  - Ammonia and nitrate
  - "Simultaneous nitrification/denitrification"
- Wastage control as Example I
- RAS control as Example I

All control strategies from full-scale applications.

Example I

- Dry conditions
  - No violations
  - Average N: 11 mg/l
  - OCI: 13 873 (18 514)
- Rain weather
  - Minor ammonia violations
  - OCI: 12 906 (17 618)
- Storm conditions
  - Minor SS violation
  - OCI: 14 616 (19 343)



Summary of performance

- Best control strategy
  - Standard strategy – OCI: 16 368
  - Intermittent aeration – OCI: 14 213 (- 13 %)
  - Simultaneous N/DN – OCI: 13 873 (- 15 %)
- Most robust strategy, rain
  - Intermittent aeration – SS violation
  - Simultaneous N/DN – minor N violations
- Most robust strategy, storm
  - Intermittent aeration – minor SS violation
  - Simultaneous N/DN – minor SS violations

WINNER: simultaneous N/DN

Discussion

Conclusions to be drawn

- Both strategies good for peak shaving
- Both strategies "cheaper" than original strategy
- Simultaneous N/DN **perhaps** "cheaper" than intermittent

Conclusions NOT to be drawn

- One strategy is generally better than the other
- Strategies can be directly applied in full-scale

Discussion

- A significant improvement
  - > 10 %, smaller improvements must be considered to uncertain
- Strategies must be checked against design rules
  - Especially clarification – less reliable model
- VSS to TSS
  - Should be accounted for
- Sludge properties
  - Risk module

Discussion

- Disturbances – process and equipment
  - Safety marginal
  - BSM1_LT
- Long term dynamics and effects
  - BSM1_LT and BSM2
- **Common sense!**