Use of control to improve nutrient removal

Perspectives (LCA and fault-tolerant control)

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Neptune workshop: Technical Solutions for Nutrient and Micropollutants Removal in WWTPs
Université Laval, Québec, March 25-26, 2010

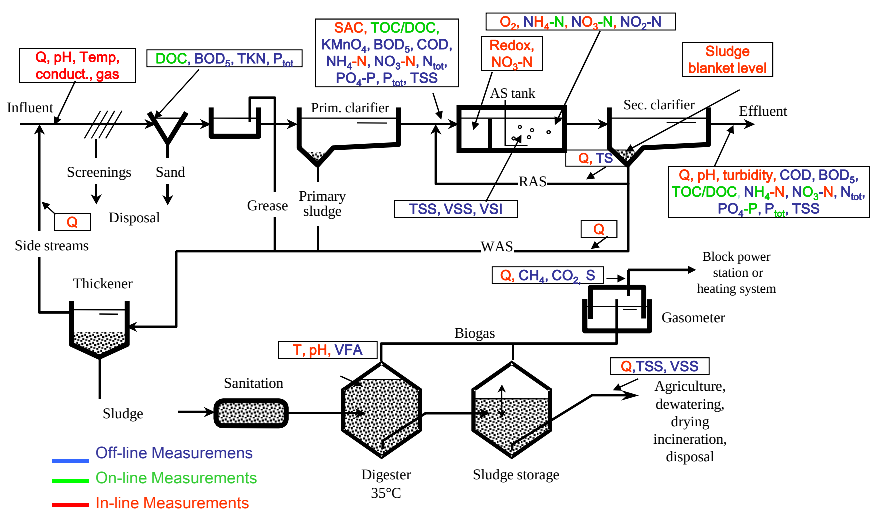
Overview

1. Introduction
2. LCA to evaluate control strategies
3. Fault-detection
4. Conclusions

1. Introduction

✓ Sensors are installed in WWTPs for monitoring and control purposes

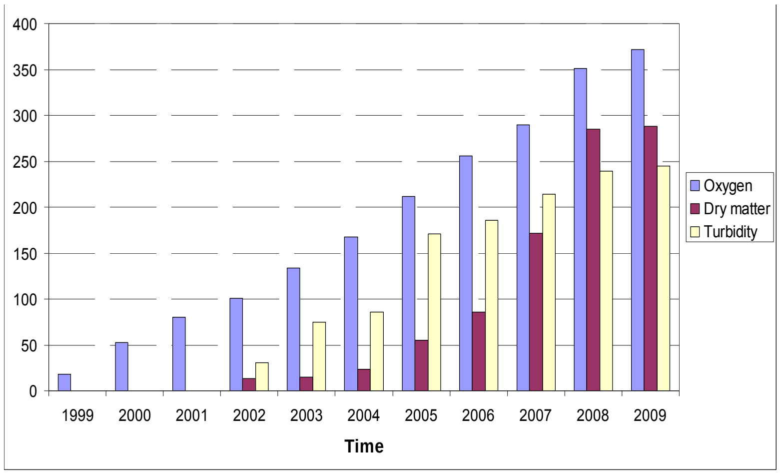
1. Introduction



Source: Hansruedi Siegrist

1. Introduction

Evolution of number of oxygen, dry matter and turbidity sensors at Aquafin plants (about 220 plants) *Source: Aquafin*



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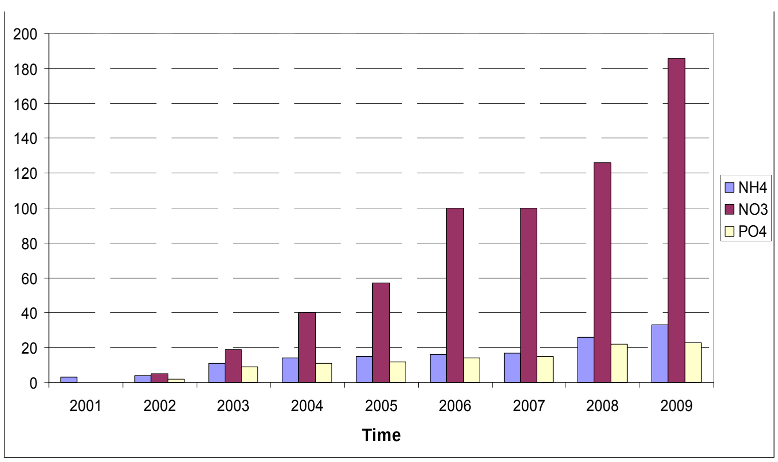
1. Introduction

Evolution of the number of nutrient sensors at Aquafin plants (about 220 plants) *Source: Aquafin*



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1. Introduction

- ✓ Driving force: Water Policies
  - ✓ Sustainable development → need for tools to estimate GHG emissions and perform Life Cycle Analysis (LCA)
  - ✓ Increasing demands on treatment efficiency (new technologies/optimization and control)

    Draw-back with control: equipment failures (sensors and actuators) can cause severe effluent limit violations → Fault-tolerant control

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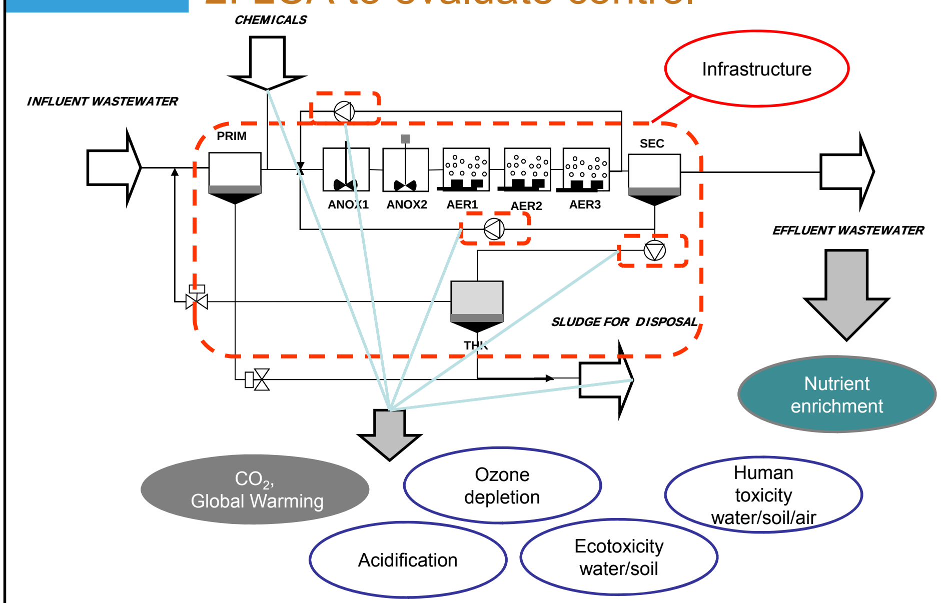
2. LCA to evaluate control



2. LCA to evaluate control

- Variables and impact factors

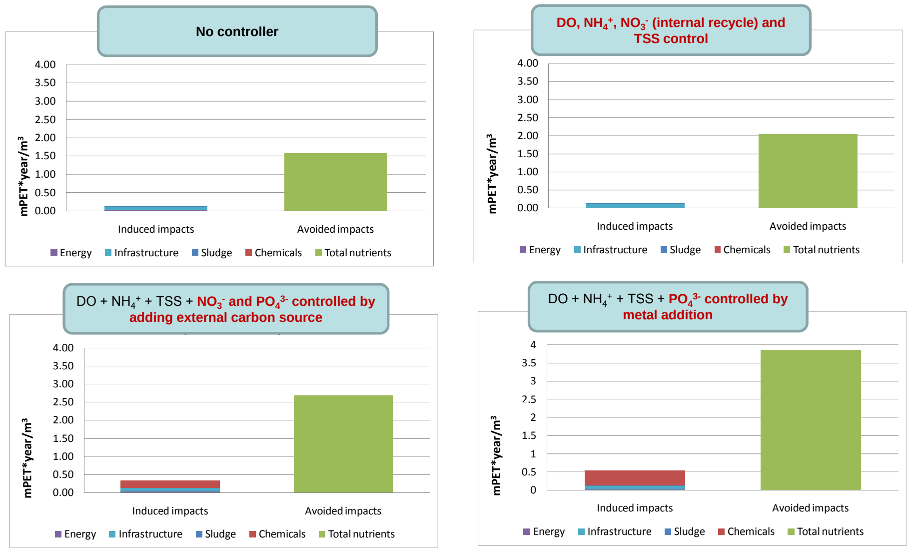
Variables (var)	Impact factors (mPET*year/unit) WF=1
Nitrogen (kg N)	37.23
Phosphorus (kg P)	269.2
Electricity consumption (kWh)	0.12324
Sludge production (kg sludge, 63% water)	0.1
Infrastructure (m^3 influent treated)	0.127
External carbon source (acetate)	3.8781
Metal ($FeCl_3$, 40%)	2.6110

- Functional unit (1m^3 of treated wastewater)
- Calculation

$$NIP_{(var)} = \frac{Value_{(var)} \text{ x } IF}{m^3 \text{ treated WW}} \qquad \left[mPET * year / m^3 \right]$$

- Presentation of the results
  - Avoided impact: Influent – effluent nutrient impact
  - Induced impact: Effluent nutrient + Electricity + Sludge + Infr + chemicals

2. LCA to evaluate control

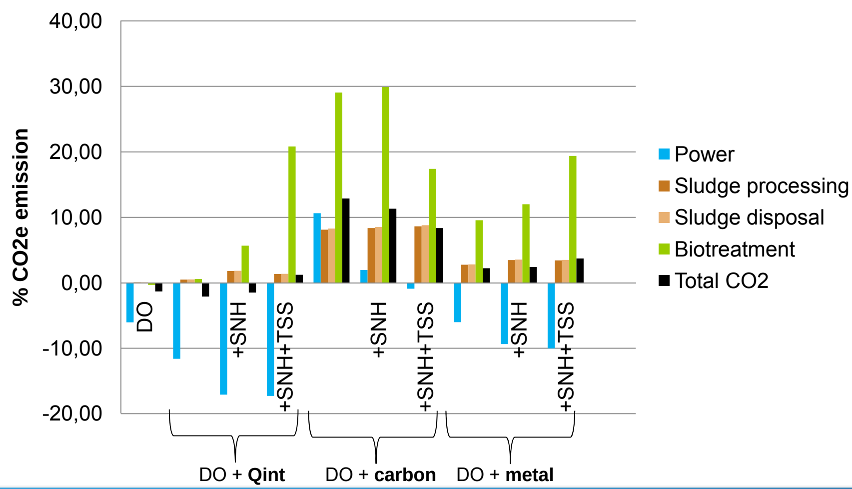


Reference: No treatment (impact of 4mPET·year/m3)

2. LCA to evaluate control

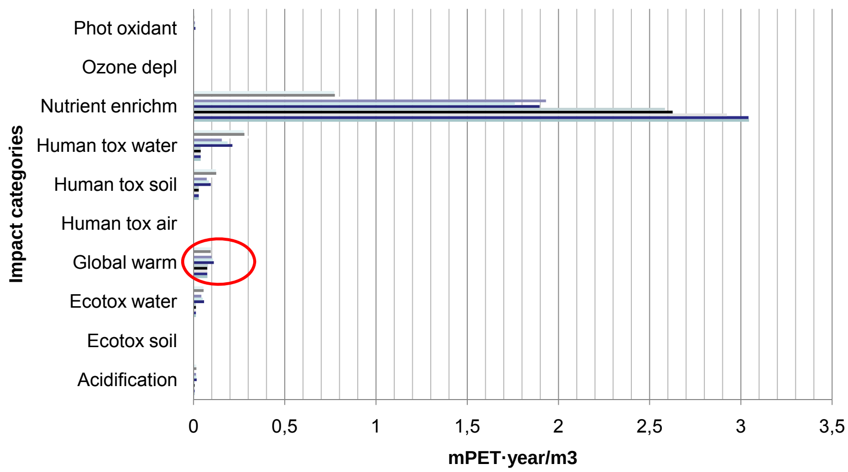
- CO_2 emissions compared to open-loop

(estimations using Monteith *et al.*, 2005 and Bridle *et al.*, 2008)



2. LCA to evaluate control

- LCA impact categories



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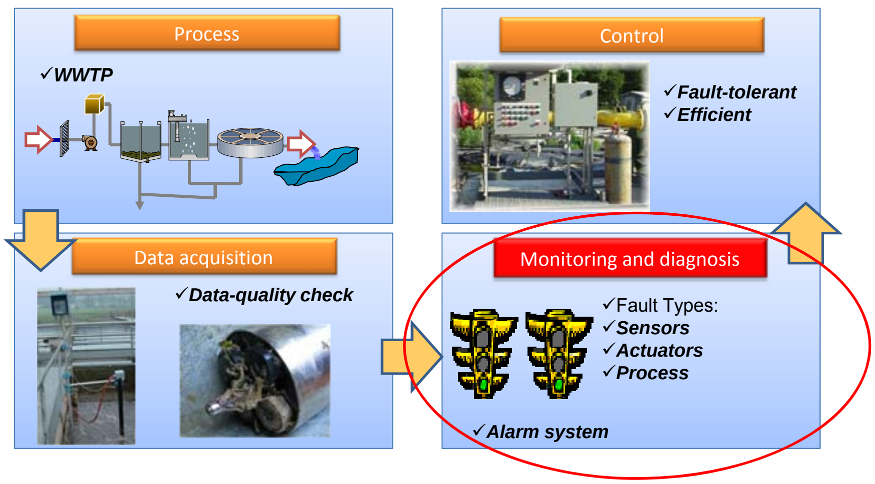
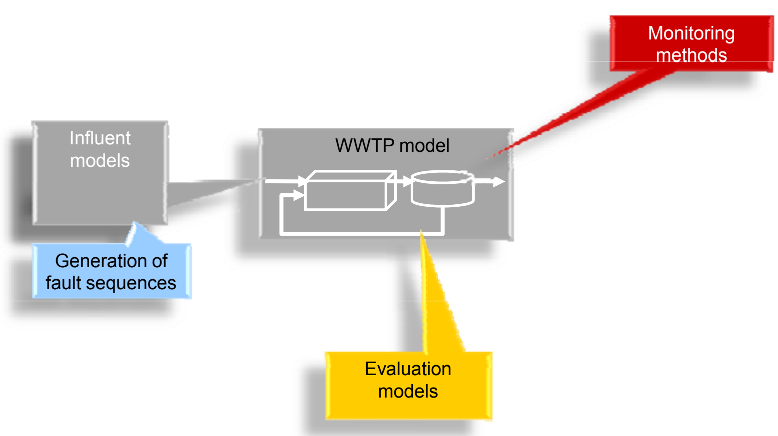
3. Fault-detection

- Fault-tolerant control



3. Fault-detection

- Goal: Compare performance of fault-detection methods



3. Fault-detection

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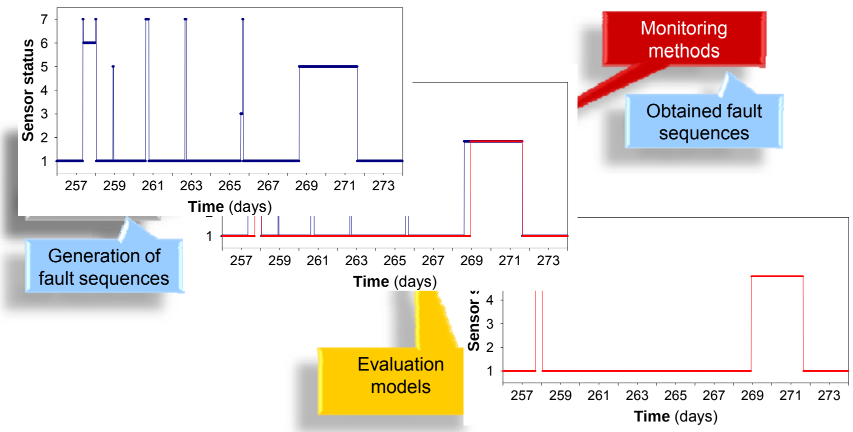
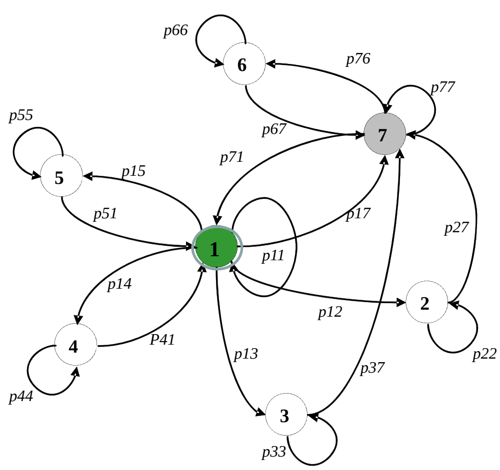


3. Fault-detection

- Sequences of faults using Markov Chains

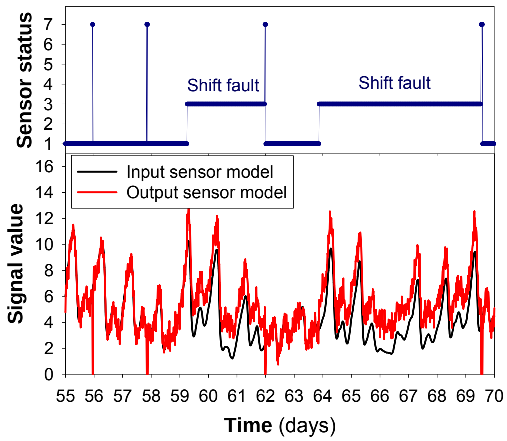
Sensor status:

1. Correct functioning
2. Excessive drift
3. Shift
4. Fixed value
5. Complete failure
6. Error gain
7. Calibration



3. Fault-detection

- Fault models (phenomenology)



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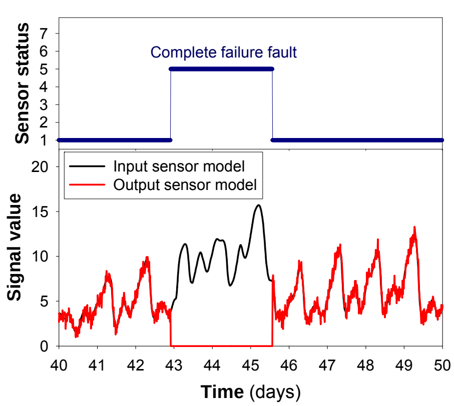
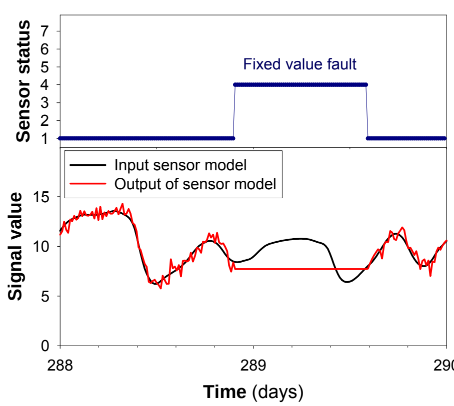
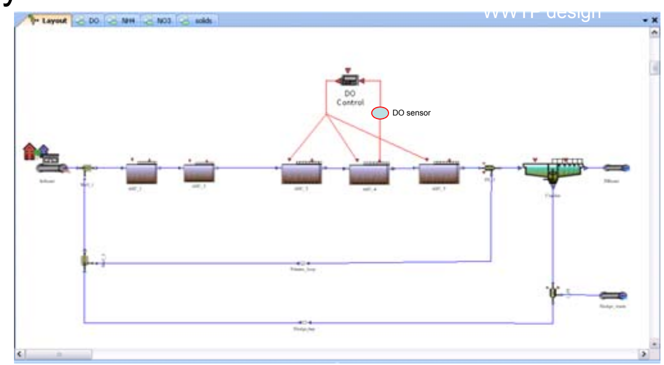




3. Fault-detection

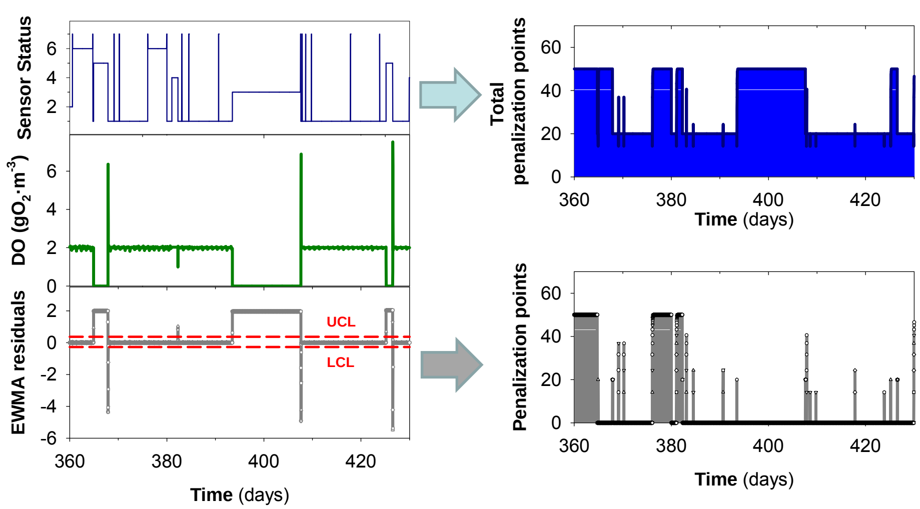
- Case-study:



- Methods:
  - Shewhart (DO)
  - EWMA (DO)
  - Residuals on EWMA (DO, $k_L a$)

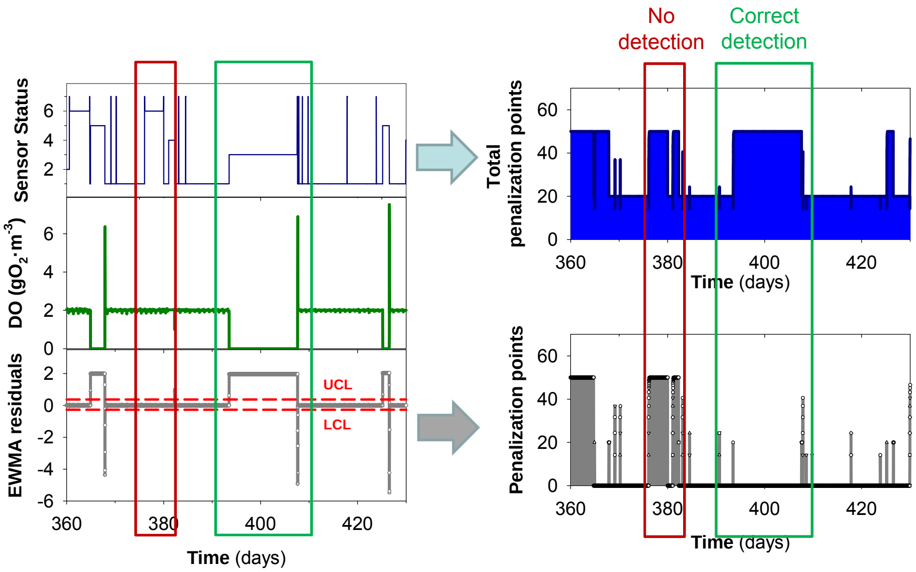
3. Fault-detection

$$y = P_{sat} \times \left(1 - e^{(-t/tau)}\right)$$



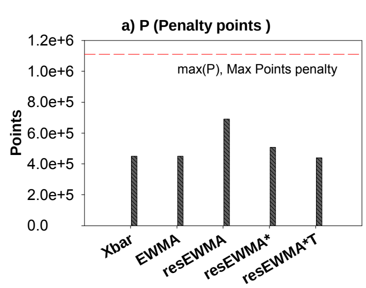
3. Fault-detection

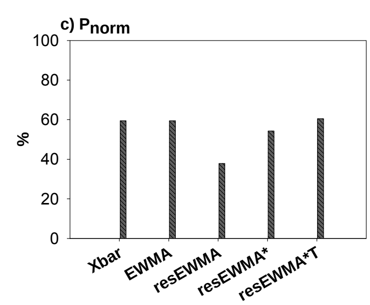
$Pnorm = 1- (P/max(P))$



3. Fault-detection

- Methods tested are at 60% of maximum fault-detection performance





- Increase of costs when faults are included in the DO sensor (Aeration energy increased by 32%)

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4. Conclusions

- The implementation of control leads to an increase of the avoided impact and a decrease in the induced impact
- The most environmentally friendly strategies are:
  - Metal addition: effluent phosphorous ↓
  - Carbon addition: effluent nitrate ↓ but GHG ↑
- In LCA nutrient removal gets more attention than global warming
- Fault-tolerant control is necessary since equipment failures can cause severe effluent limit violations
- Fault-detection methods tested so far are at 60% of maximum performance. Further research is warranted.

Acknowledgements

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