11th IWA conference on instrumentation control and automation – Narbonne (France)

Lessons learnt from the application of advanced controllers in the Mekolalde WWTP: good simulation practices in control

I. Irizar, S. Beltrán, G. Urchegui, G. Izko, O. Fernández and M. Maiza

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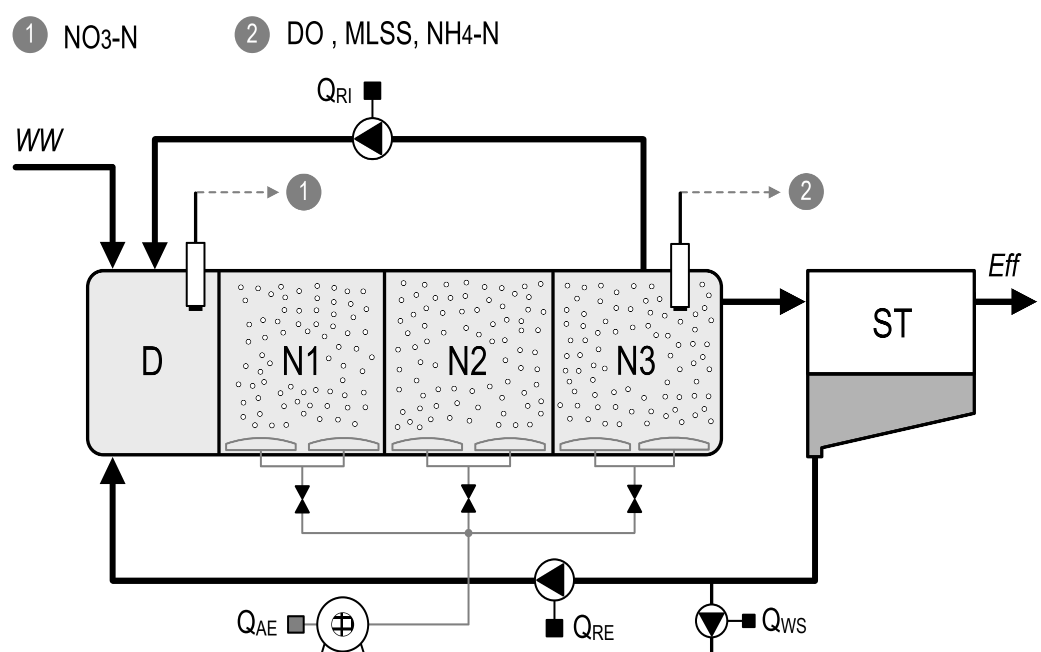
Case-study: The Mekolalde WWTP

- Located in Northern Spain
- Design capacity: 50000 PE
- Start-up in June 2008
  - Conventional operation: only low-level controllers for basic operations
  - Actuators
    - QAE
    - QRI
    - QWS
  - Advanced instrumentation
    - NH4-N @ N3 tank
    - MLSS @ N3 tank
    - NO3-N @ D tank



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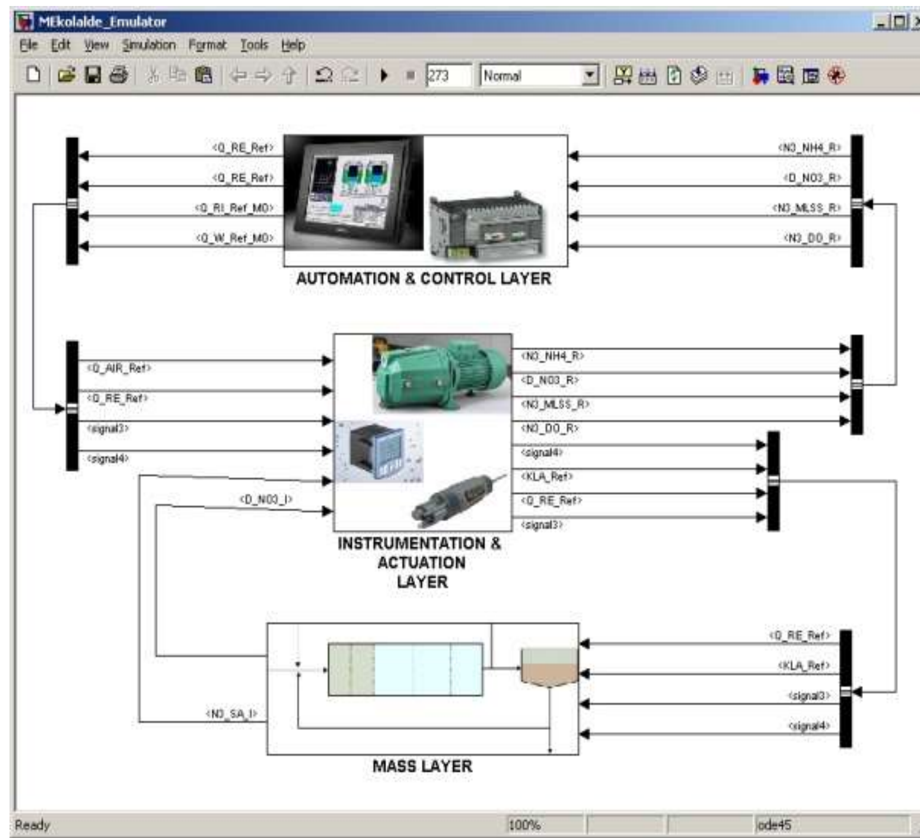
Case-study: The Mekolalde WWTP

- THE PROBLEM…
  - Since its start-up the process repeatedly evidenced unstable periods with very large fluctuations of the effluent TIN (from 5 to 30 mg N/L)
- THE OBJECTIVE…
  - To design and implement an advanced controller capable of optimizing nitrogen removal
  - To attack the problem with a practical focus: balance between time invested and quality of solution (two weeks better than three, one week better than two, …)

Plant simulator for Mekolalde: ADD-CONTROL software

- ADD-CONTROL (2009-2010): European research project aimed at producing new simulation software (Add-control software) totally oriented to ensuring a rapid and reliable development of advanced control products for WWTPs
- The **Mekolalde WWTP** was chosen to test the usefulness of Add-control software



Controller design using the plant simulator

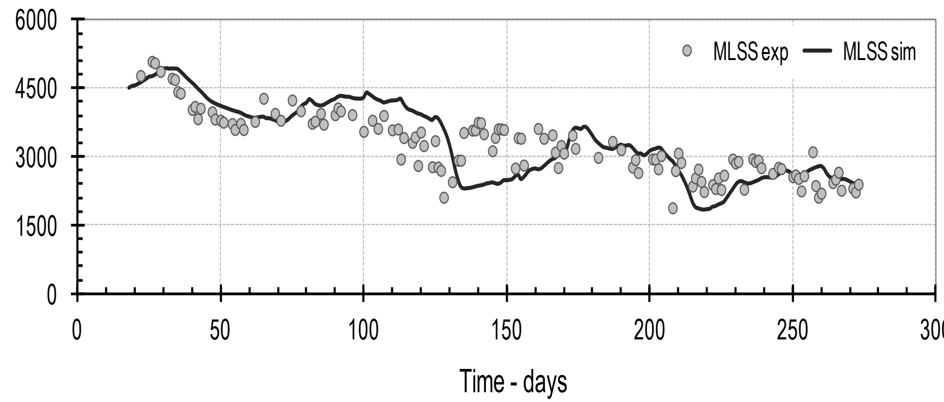
- STEP1… **CALIBRATION** of the PLANT MODEL
  - Design of control products ⇨ the plant simulator must be calibrated
  - Very often insufficient information available
  - Accurate calibration ⇨ a demanding and time-consuming task
    - When offering control products for real plants, "time" is not a minor issue
    - Calibration methodology: compromise between accuracy and time invested
    - The lower the accuracy ⇨ the larger the plant model uncertainty
      - Control specifications must not be relaxed because of the uncertainty
  - LESSON 1: "***The calibration process had to be accommodated to plant data availability, not the opposite***" (as long as the resulting uncertainty does not compromise the fulfillment of the control specifications)

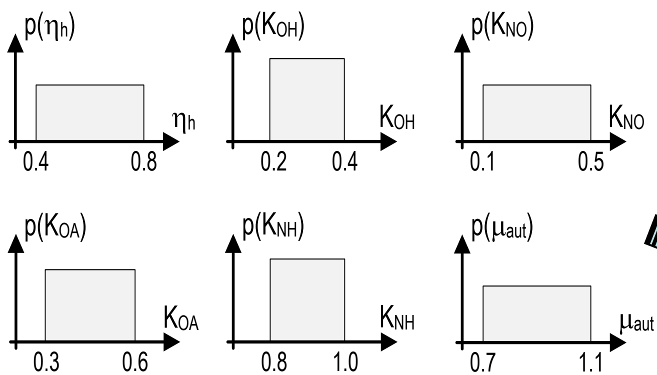
Controller design using the plant simulator

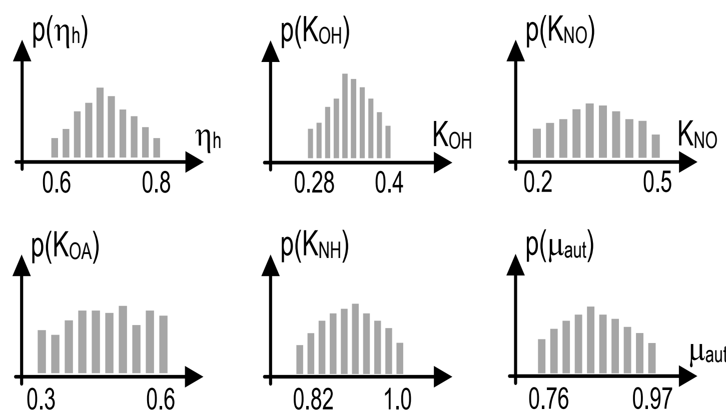
- STEP1… **CALIBRATION** of the PLANT MODEL
  - Mass balance:

    influent characterization
  - Kinetic coefficients:

    Quantifying model uncertainty







PCA + Clustering techniques

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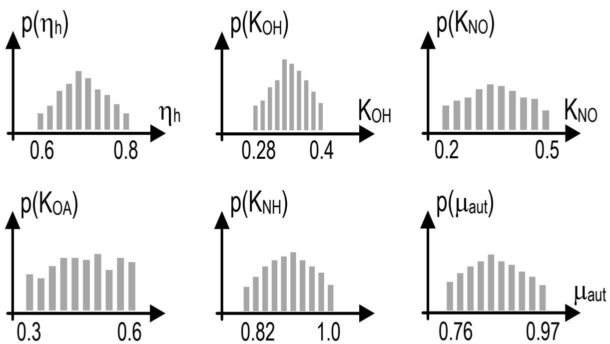
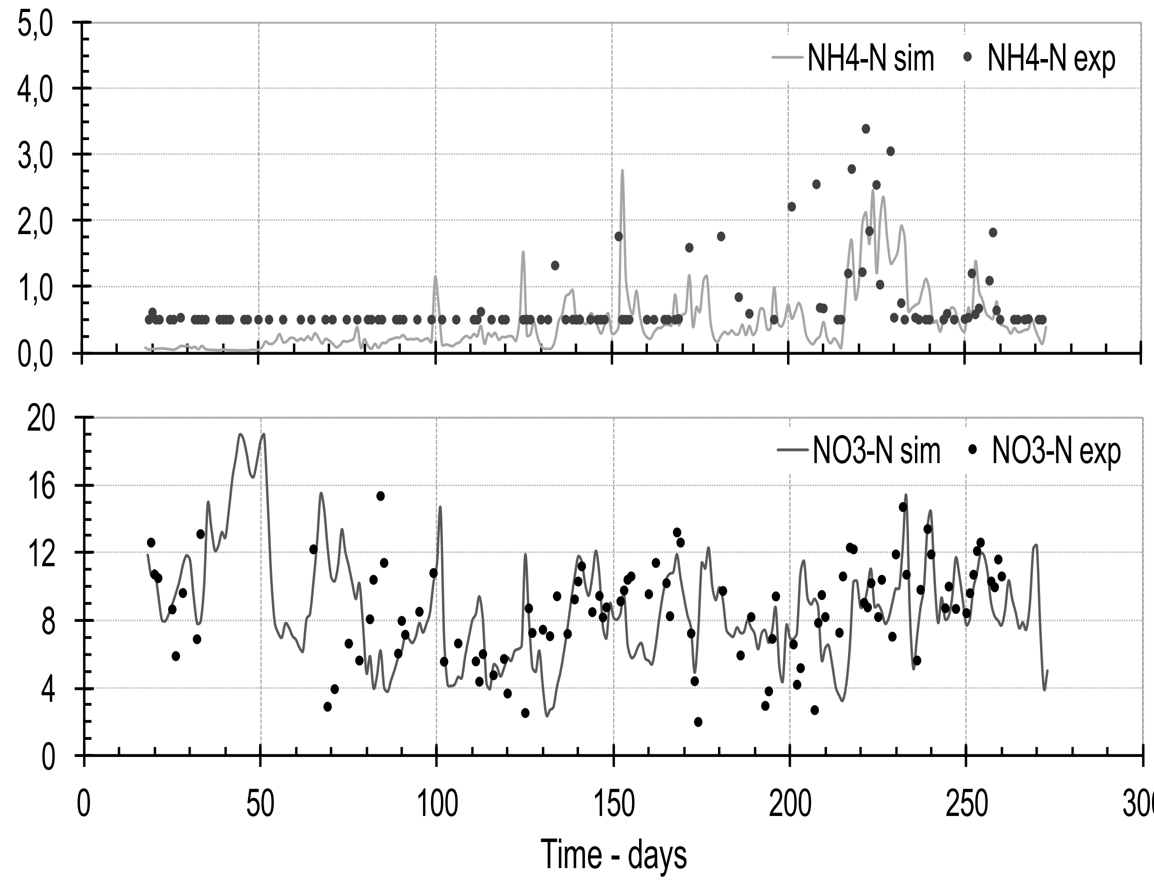
Controller design using the plant simulator

▶ STEP1… **CALIBRATION** of the PLANT MODEL





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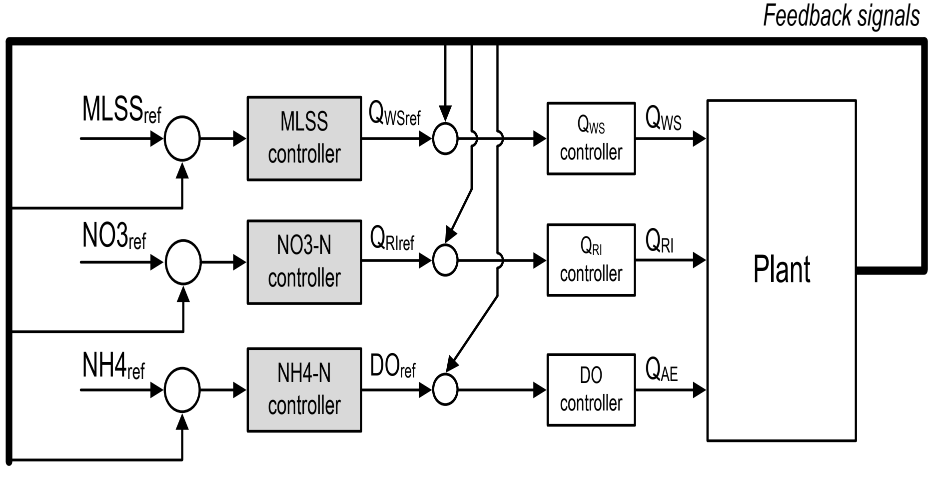
Controller design using the plant simulator

- STEP2. **Tuning the advanced controllers**
  - Controller scheme: three SISO controllers



  - LESSON 2. "***When tuning each SISO controller, the order does matter***"
    - The MLSS controller must be tuned first
    - The NH4-N controller must be tuned with the MLSS controller working
    - The NO3-N controller must be tuned with both controllers working

Controller design using the plant simulator

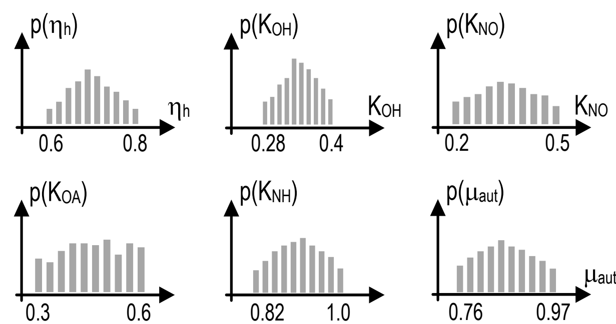
- STEP2. **Tuning the advanced controllers**
  - Specifications for the NH4-N and NO3-N control loops
    - 1st consideration, the control problem is a **regulation problem ;**no specs for tracking are required ⇨ Only specifications for disturbance rejection must be achieved
    - 2nd consideration, the energy issue (aeration and pumping energy) has a primary importance
  - LESSON 3. "***For an optimum use of the control effort (i.e., energy) these control loops must be tuned to reject only the strictly required disturbances***". In other words …
    - The range of disturbance ***frequencies that must be attenuated*** is the key specification for these two controllers
    - The control parameters were adjusted to produce the minimum bandwidth controller able to fulfill the frequency specifications for disturbance attenuation

Controller design using the plant simulator

- STEP2. **Tuning the advanced controllers**
  - Specifications for the MLSS controller
    - 1st consideration, the control problem is also a **regulation problem**
    - It is he effect of QWS on the sludge treatment that must receive primary consideration
  - LESSON 4. "***Very tough specifications for the disturbance response in the secondary treatment can cause large disturbances in the sludge treatment***" . In conclusion…
    - When designing this controller, the range of ***disturbance frequencies*** that must be attenuated is again the key specification.
    - The control parameters were adjusted to reach a reasonable trade-off between acceptable disturbance rejection in the secondary treatment and minimum impact on the sludge treatment

Controller design using the plant simulator

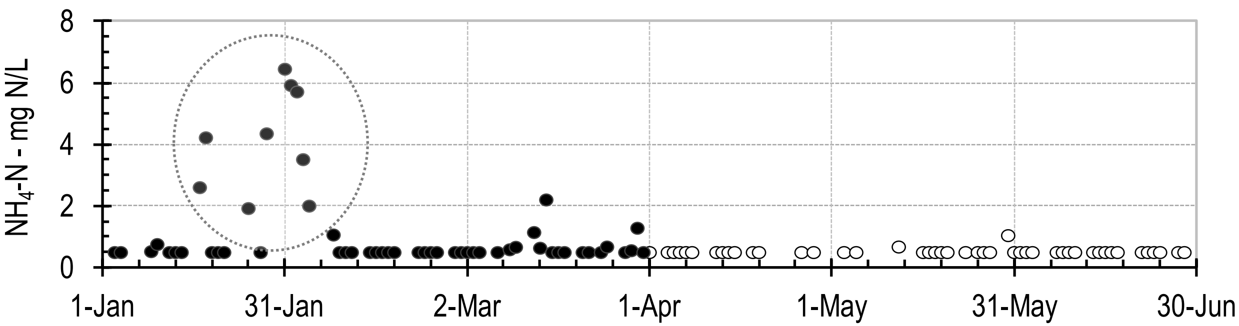
- STEP3. **Controller performance**: comparative analysis
  - Random simulations over 1000 samples taken from the uncertainty space specified after model calibration
  - Operating period: **9 months**
  - Conventional Op. VS Controlled Op.

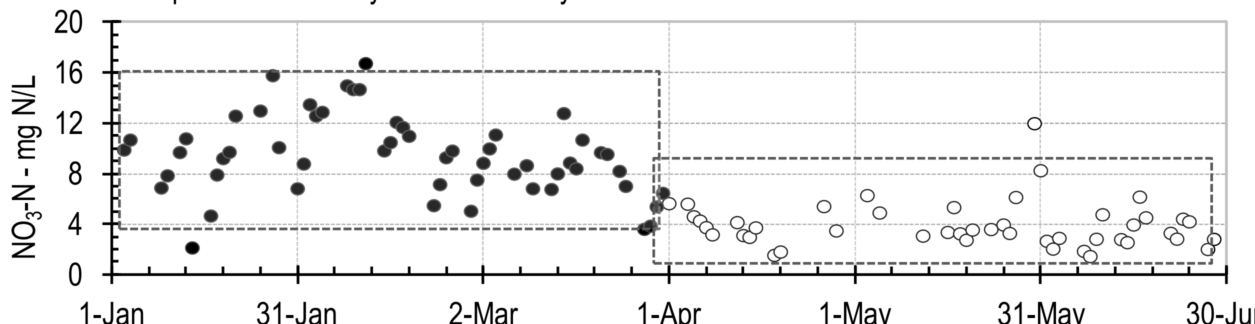


		Conventional Operation	**Controlled Operation**	**% Improvement (↑)**
NH4-N	mg/L	0.55 (0.11)	0.84 (0.14)	↓ 52%
NO3-N	mg/L	8.93 (0.26)	**5.56** (0.28)	↑ 38%
TIN	mg/L	9.48 (0.30)	6.40 (0.39)	↑ 32%
Energy costs	kW	45.3 (0.2)	41.5 (0.4)	↑ 8%

Full-scale validation

- The three controllers were implemented and put into operation at the plant in April 2011
  - On average, water quality improved almost immediately
  - Fluctuations were significantly reduced: better management of plant disturbances





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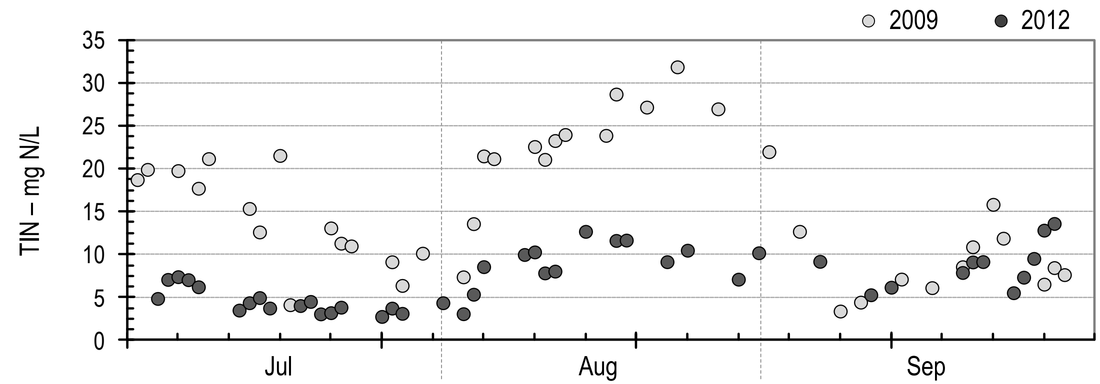
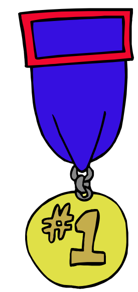
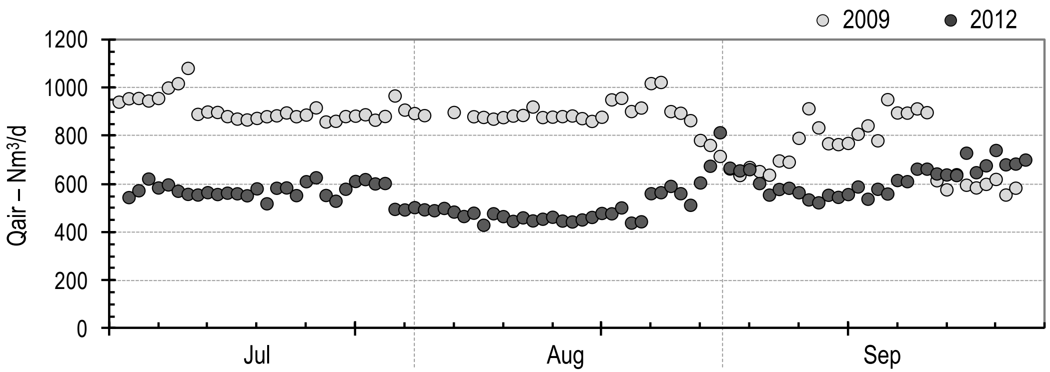
Full-scale validation

- July-Sept '09 ***VS*** July-Sept '12: daily evaluation

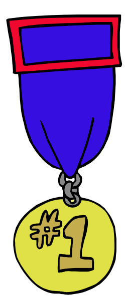


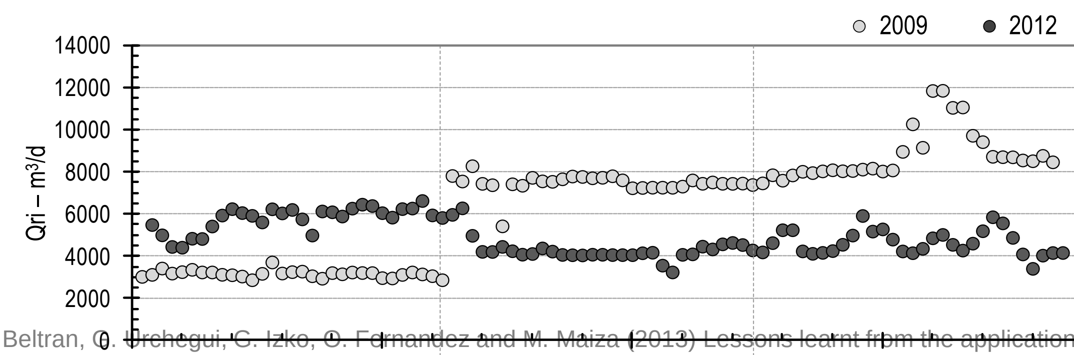


Water quality



Energy savings (-10%)





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Conclusions

- Recap of the lessons learnt:
  - The use of simulations to design control products for real plants requires the plant model to be calibrated but the process of calibrating this model must to be accommodated to plant data availability, not the opposite
  - Due to loop interactions, the order in which each individual controller has to be designed can be relevant
  - For an optimum use of the control effort the NH4 and NO3 control loops must be tuned to reject only the strictly required disturbances
  - When dealing with the control specifics for the MLSS controller, it is important to know that very tough specifications for the disturbance response in the secondary treatment will cause large disturbances in the sludge treatment
- These lessons were applied in the Mekolalde WWTP. Since then, the large fluctuations at the effluent TIN observed in the past have disappeared and the plant performance has improved .

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