UNIVERSITEIT GENT

BIOMATH

Department of Applied Mathematics, Biometrics and Process Control

Putting control into practice : An industrial case study in wastewater treatment

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Wastewater Treatment

- Largest industry in terms of treated mass of material
- End-of-pipe solution to environmental problems
- Increasing (EU) demands that are enforced
- Biological process
  - "cheap" technology (7.10^9 BEF/yr in Flanders)
  - adapt to any type of wastewater
  - slow process
  - wide range of time constants (minutes - days)
  - nonlinear process
  - time-varying process

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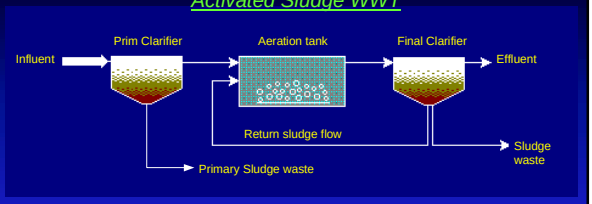
Wastewater Treatment

Activated Sludge WWT



- Different unit operations
  - Bioreactor (wastewater contacted with biomass)
  - Settler (separating cleaned water from biomass)

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Control in WWT

- State-of-the-art: Sensors
  - MANUAL (in the WWTP's lab: 1/d)
  - flow
  - level
  - dissolved oxygen (aeration is highest operating cost)
  - nutrients, biomass concentration & activity
- State-of-the-art: Control
  - MANUAL (frequency of manipulation: 1/d)
  - timers
  - on-off (e.g. water levels)
  - PI-control (aeration intensity: operating costs !)

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The project

- Demand by 2 companies:

1. Consulting company (EPAS, Zwijnaarde)

specialised in process optimisation in WWT
wants to extend its consulting capacity
with - model-based analysis / optimisation
- process control technology

2. Problem provider (Janssen Pharmaceutica, Geel)

need for increased treatment capacity (+ 40 %)
does not fulfill effluent standards (tax: 20 MBEF/yr)

standard strategy: extend reactor volumes: 200 MBEF
alternative strategy: this project: 25 MBEF + ??? MBEF

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Aim of the project

Problem: No existing proof of principle that modern sensors and control systems are a valid alternative to increased reactor volumes.

Vicious circle:

Industry is not open to this technology because no full-scale proof can be presented.

No proof can be provided because industry is not willing to do the full-scale test.

Aim: Break the vicious circle

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The project: further partners

- Sensor manufacturers
  - Applitek NV (Deinze)
  - Elscolab NV (Kruibeke)
  - Kelma bvba (Niel) => Get sensors for free
- Additional research partner
  - LBE Narbonne

    was asked to join the project
    because no post-doc could be found initially

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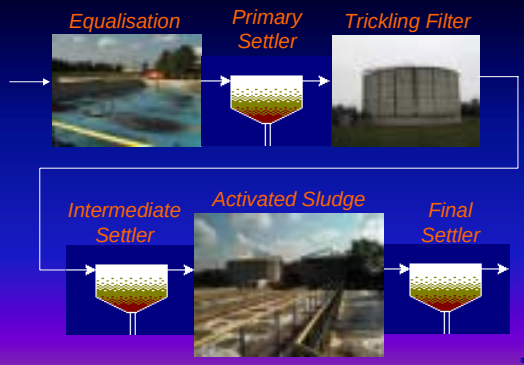
The plant under study



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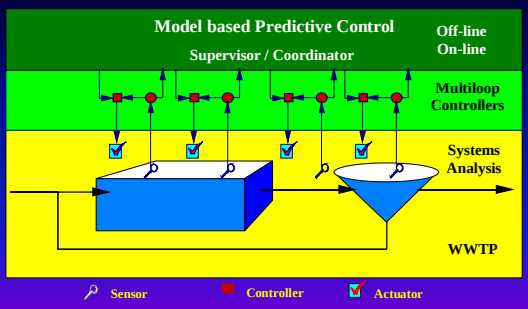
The pursued concept



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Work Packages

- Inventory of infrastructure
- Evaluation process data
- Model building
- Local controllers
  - design and tuning
  - Implementation and testing
- Fault detection/diagnosis
- Supervisory controller
  - design and optimisation
  - Implementation and testing

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Work Packages

- Inventory of infrastructure — Epas
- Evaluation process data — Epas
- Model building — Epas/Biomath
- Local controllers
  - design and tuning — Biomath/LBE
  - Implementation and testing — Janssen/Epas
- Fault detection/diagnosis — Biomath/LBE
- Supervisory controller
  - design and optimisation — Biomath
  - Implementation and testing — Janssen/Epas

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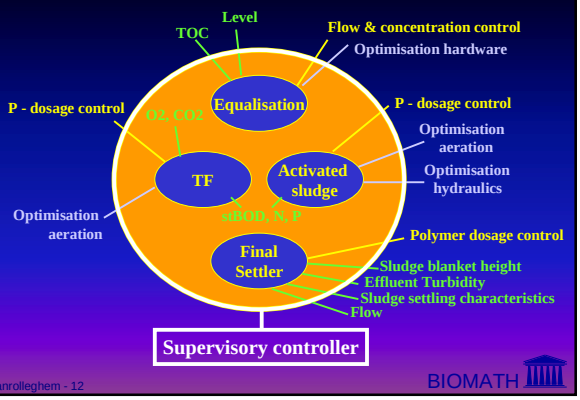
Overview of activities



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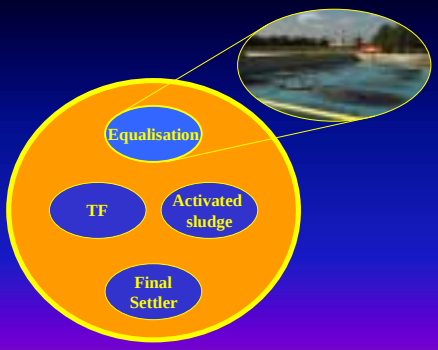
The Equalisation Controller



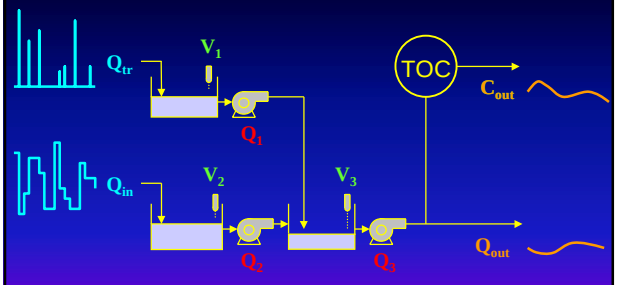
Controller objectives

- Attenuation of variations in the wastewater's
  - Concentration
  - Flow rate
- Respect physical constraints (min/max volumes)
- Adapt to varying production capacities

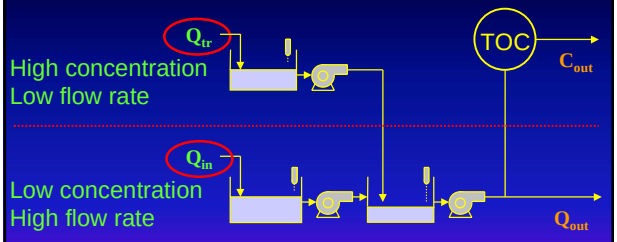
Current practice

- Timer based on/off control with fixed setpoints

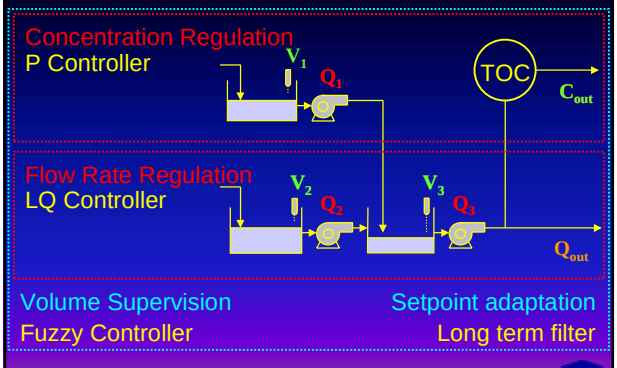
The System



Splitting the control problem



The controller: THEORY



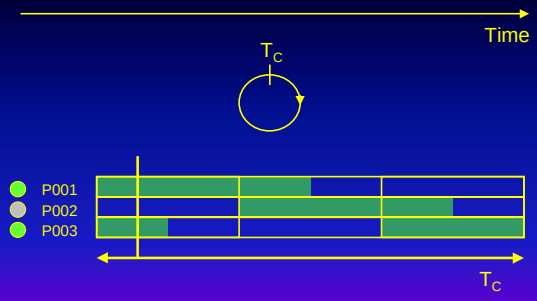
The controller: PRACTICE

- Definition of 'implementation'
  - BIOMATH : everything after the algorithm
  - END USERS : the 'wet work'
- Full scale demonstration implementation
  - No drastic modifications
  - Strict requirements

Practical Problems : 1. No frequency controlled pumps

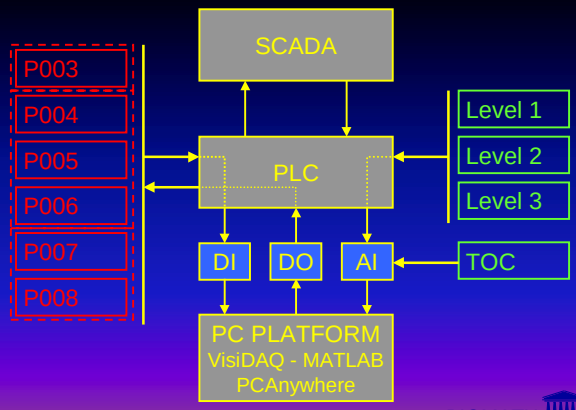
- Originally: installation of new pumps
- Reality: Flow rates have to be realised with sets of fixed flow pumps.
- Design of timer-based slave controllers. Features:
  - Variable nr of pumps per pump pit
  - Cycling over available pumps
  - Additional constraints (10 minute rule)

Example: 3 pumps of 60 m3/h; flow rate 90 m3/h



Practical Problems : 2. Software Implementation

- Originally: implementation into SCADA by Janssen subcontractor
- Reality: implementation by BIOMATH on PC platform
- Restrictions
  - No direct interaction with sensors/actuators
  - No direct interaction with SCADA system
- Additional features
  - Remote supervision (modem)
  - Additional safety requirements (life-bit, off/on tests)

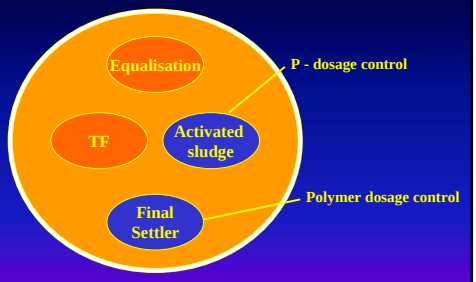


In the mean time

- Ever changing specifications
  - Constraints on volumes
  - Pumps
- Poor internal communication
- Demotivation of the operators
- Testing protocols
- Windows problems

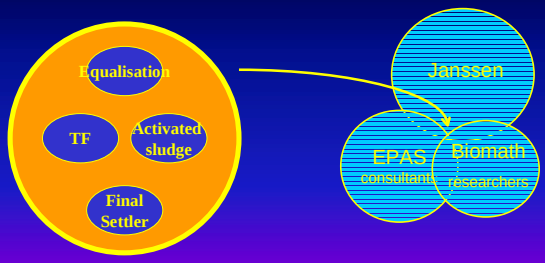
The Final Product

The project



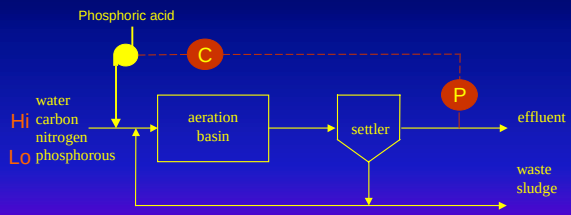
Important relationships

The project ⟷ The people



P(hosphorous) dosing

The problem defined



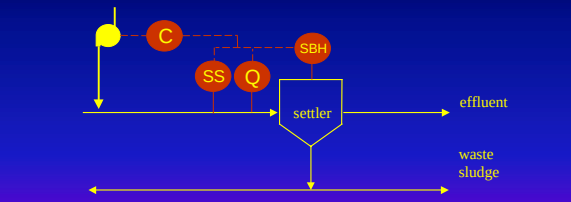
P(hosphorous) dosing

Summer 1997	The problem defined
	Pdosing bucket experiments → Challenge 1
1998	Modelling began
Summer 1998	
1999	Controller design → Challenge 2
Summer 1999	P sensor installed P sensor operational & started to build tank → Challenge 3
2000	P dosing started and stopped → Challenge 4 P dosing campaign TAKE II → Challenge 5

Polymer dosing

+ve polymer (90% of time)

-ve polymer (10% of time)



Polymer dosing

1998	The problem defined
	Modelling began → Challenge 1
Summer 1998	
	Controller designed
1999	Installation of sensors → Challenge 2
Summer 1999	New settler designed (17 MBEF)
	Settlometer operational Sludge blanket height meter operational
2000	DATA!!! → Challenge 3
	NEW SETTLER OPERATIONAL → Challenge 4

Summary

- Running time of sub-projects ~2 years
- Initial modelling completed in first year
- Controller design in 1st yr (polymer) & 2nd yr (P)
- Sensors installed and reliable in last 4 months
- Neither controller can be automated until after evaluation
- Polymer controller will not be implemented during project and P controller implementation set back another month
- Project ends in June

Challenges

- Insufficient full scale data until end of project
- Models not realistic
- Modelling still on going
- Time delays caused by poor planning
- Lack of technical personnel
- Lack of interest
- Lack of understanding

Important relationships

The people	The project
Education	The sensors
Communication	Their implementation
Levels of Involvement	Their maintenance

Work Packages

• Inventory of infrastructure	✔
• Evaluation process data	✔
• Model building	on-going
• Local controllers	equalisation ✔
– design and tuning	P ✘
– Implementation and testing	Polymer ✘
• Fault detection/diagnosis	just started
• Supervisory controller	just started
– design and optimisation	
– Implementation and testing	

The solution

Problem:

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People management

Education of people

Getting people involved

Step 1 DATA