IWA TG on Benchmarking of Control Strategies for WWTPs

Simulation of control strategies – dynamic modelling of sensor and actuator behaviour

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Dr Marie-Noëlle Pons
LSGC-CNRS-INPL, Nancy
France

Dr Jens Alex
ifak e.V. Magdeburg
Germany

International Water Association
IWA Task Group on "Benchmarking of Control Strategies for Wastewater Treatment Plants"
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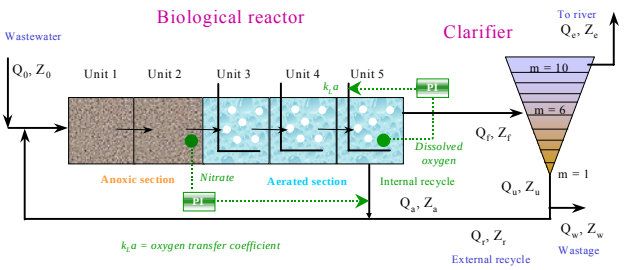
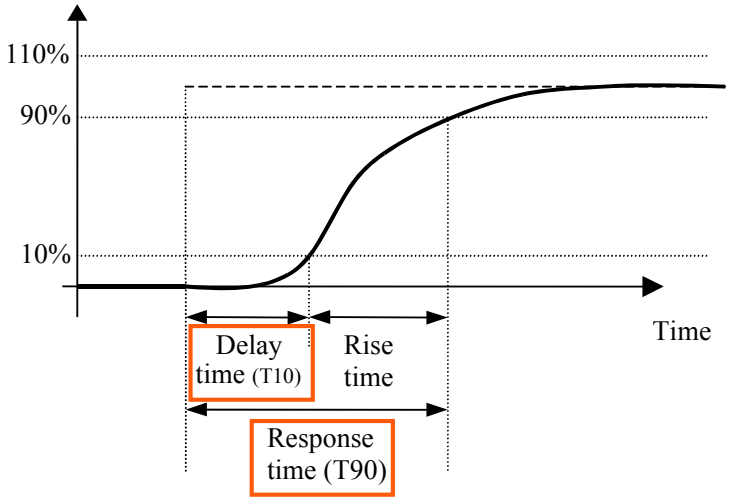
Introduction

- Sensors and actuators necessary for monitoring and control
- They are themselves complex systems and have their own dynamics



Sensors

According to ISO 2003 norm



Measuring range

Noise : random noise, standard deviation = 1, x noise level (2.5% of range)

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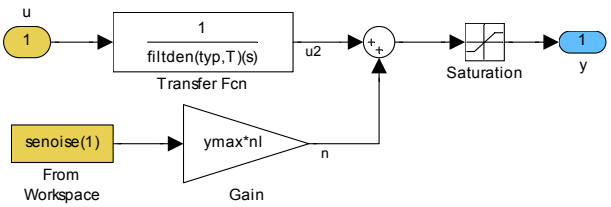
Sensor classes

Sensor classes	Response time	Measuring interval	Examples
	(T90) [min]	**(T0)** [min]	
Class A	1	0	Ion sensitive, optical without filtration
Class B_0	10	0	Gas sensitive + fast filtration
Class B_1	10	5	Photometric + fast filtration
Class C_0	20	0	Gas-sensitive + slow filtration
Class C_1	20	5	Photometric + slow filtration or sedimentation
Class D	30	30	Photometric or titrimetric for total components

Programming a simple sensor …

For Matlab/Simulink



$$\frac{d\,x_1(t)}{dt} = \frac{1}{T}u(t) - \frac{1}{T}x_1(t)$$

$$\frac{d\,u_2(t)}{dt} = \frac{1}{T}x_1(t) - \frac{1}{T}u_2(t)$$

$$y_1(t) = u_2(t) + y_{\max} nl\ n(t)$$

$$y(t) = \begin{cases} y_1(t) > y_{\max} : y_{\max} \\ y_{\min} < y_1(t) < y_{\max} : y_1(t) \\ y_1(t) < y_{\min} : y_{\min} \end{cases}$$

Recommended BSM1 sensor parameters

Measured variable	Class	Measurement Range	Measurement noise (δ)
Flow rate (m^3/d) high range	A	0-100 000 m^3/d	2500
Water level (m)	A	0-5 m	0.125
Temperature (°C)	A	5-25 °C	0.5
pH	A	5-9	0.1
S_O (mg O_2/l)	A	0-10	0.25
Sludge blanket level (m)	A	0-5	0.125
S_{NO} (mg N/l)	B0	0-20	0.5
S_{NH} (mg N/l) low range	B0	0-20	0.5
S_{NH} (mg N/l) high range	B0	0-50	1.25
S_{ALK} (mol HCO_3/m^3)	B0	0-20	0.5
Mixed-liquor suspended solids (mg/l)	A	0-10 000	250
Effluent total suspended solids (mg/l)	A	0-200	5
Total COD (mg COD/l)	D	0-1 000	25
OUR (mg/(l·d))	D	0-2 000	50

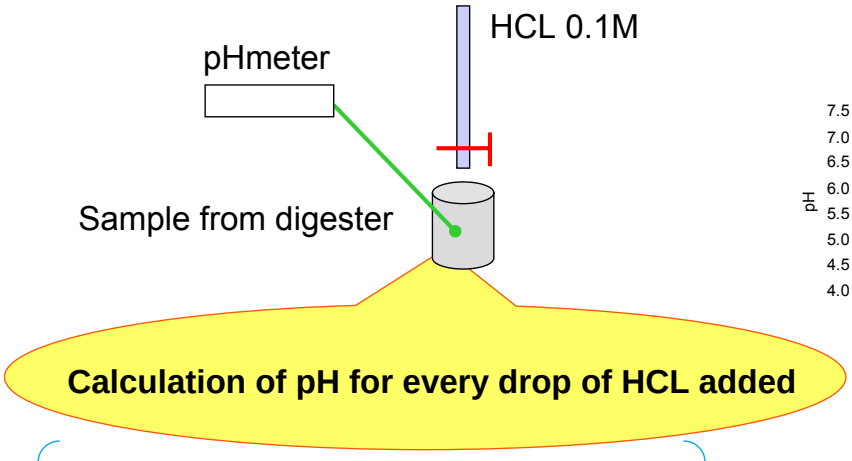
You can still program (with care) your own sensors …

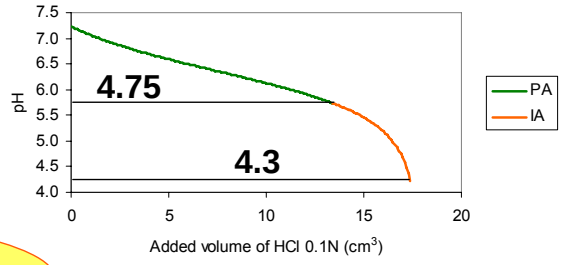
- **Purpose: test of the effect of sensor design / operation parameters**

- **Respirometer (OUR, toxicity detection) or other batch tests (nitrification potential, …)**
- **Settleability**
- **Titrimeter**

Example of a detailed simulation

Titrimetric sensor for digester monitoring (BSM2)



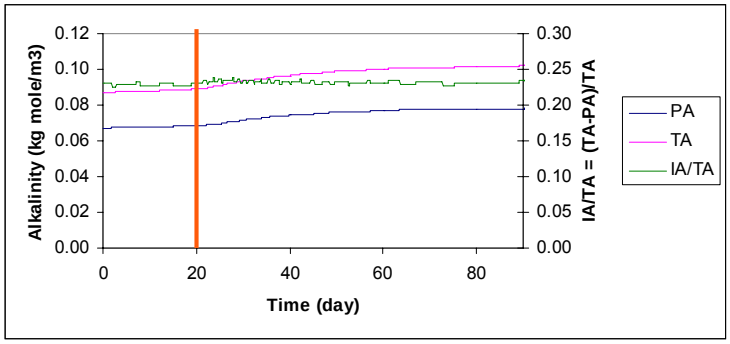


Calculation of pH for every drop of HCL added

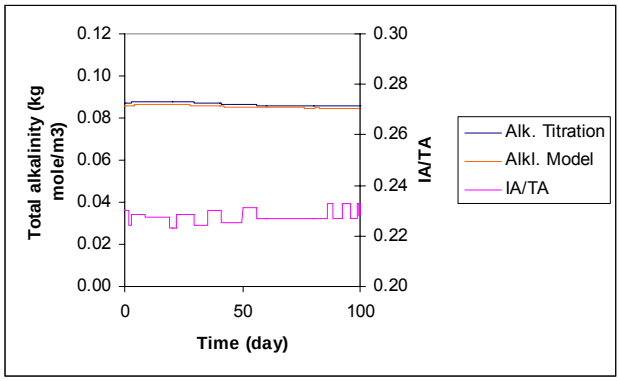
Algebraic equation (Pons et al., Talanta, 1983)
- Minimization of |Σanions - Σcations| wrt pH
- Golden Section method

Results

- Flowrate increase



- Dynamic behavior

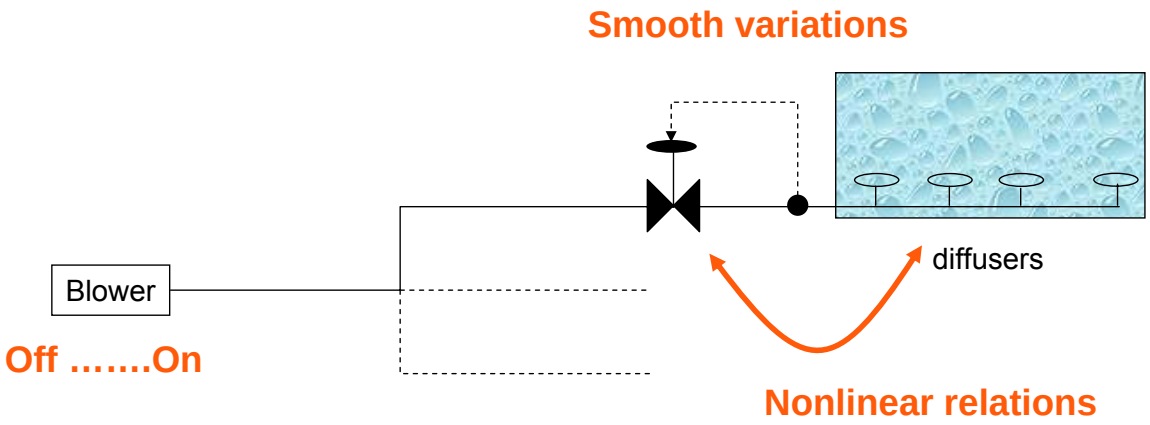


Actuators – control handles

- internal flow recirculation rate
- return sludge flow rate
- wastage flow rate
- **aeration intensity** individually
- external carbon source flow rate
- anoxic/aerobic volume
- influent distribution by use of step feed
- distribution of internal flow recirculation
- distribution of return sludge flow

1st and 2nd order systems

Aeration control could receive more attention



Conclusions

- Sensors and actuators important part of the control strategy
- Affect the control performance
- Precise description needed