Possibilities to enhance the management of wastewaters

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Global Drivers

Several drivers exist for making water treatment systems as optimized as possible

- Nature protection and necessity for carbon neutral processes
- Rising energy prises
- Shortage of clean freshwater for drinking and agricultural uses
- Need to gain improved security despite of increased dynamics in climate and therefore WWTP influent streams

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Trends resulting thereoff

Photo: Hannu Poutiainen

- Biogas units
- Carbon neutral wastewater treatment (CO_2, N_2O)
- Energy optimisation of processes
- Looking at the ”big picture” (IWSM; LCA)
- Smart data usage (models, control)
- Clean for use, recycling

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Biogas

Due to energy price rise processes have been developed and improved, including use of models in optimisation

- Thermophilic vs mesophilic
- Several stages
- Improved automation and control
- Possible extra organic material addition
- May be separate organisations (includes marketing for use)

Biogas process options

- Traditional
- Continuosly stirred tank reactor
- Upflow anaerobic sludge blanket reactor (UASB)
- Extended granular sludge blanket (EGSB) reactor

- Co-digestion with suitable and available (high energy) organic materials

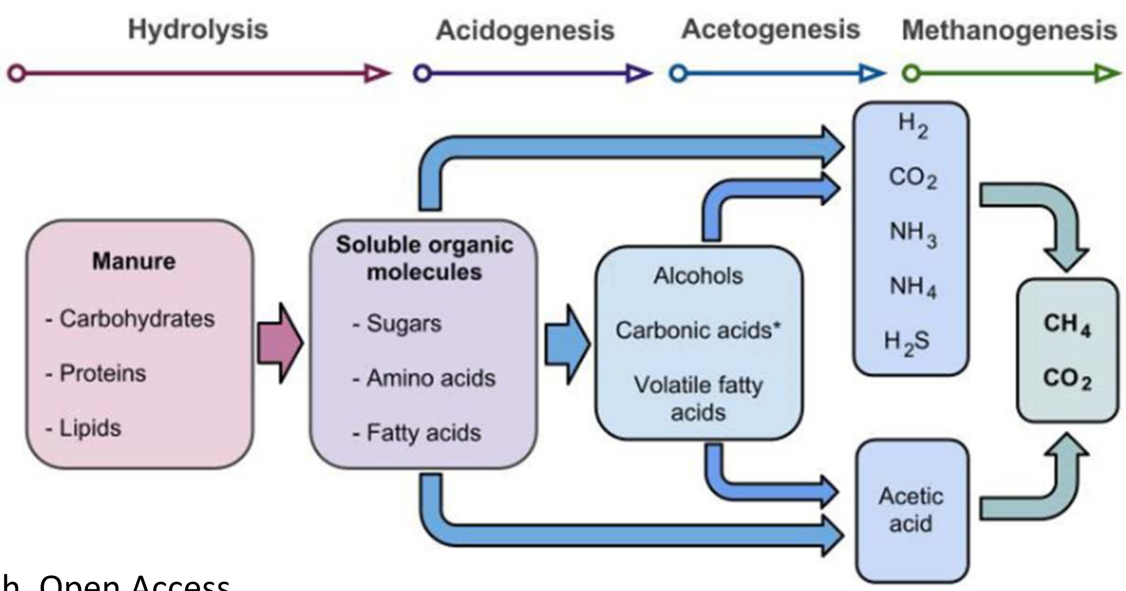
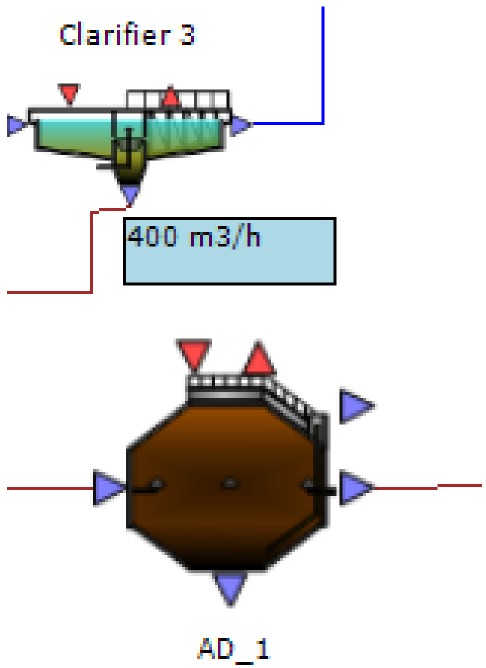


Figure: InTech, Open Access

Biogas process options continued

TPAD (Temparature Phased Anaerobic Digestion)



- Thermophilic first reactor in which hydrolysis stage is taking place.
- Mesophilic second reactor (methanogenesis i.e. biogas produced).

- Methanogenesis separated into own (lower temperature) reactor). Sometimes even hydrolysis done separately

- Since 2008 Biogas process has been integrated into wastewater treatment models.

Carbon neutral wastewater treatment

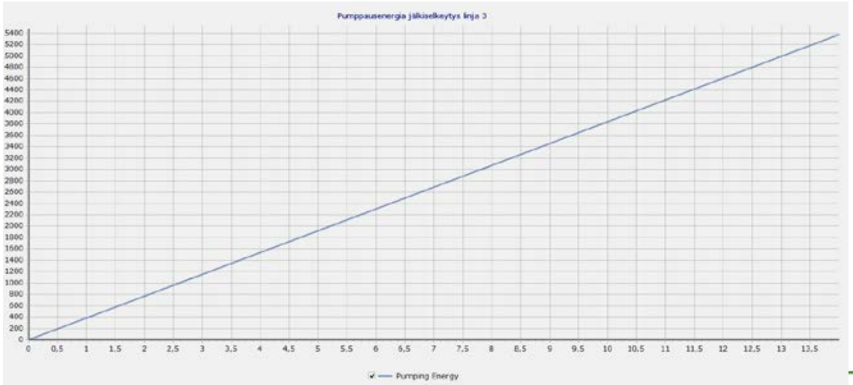
- Use of WWTP produced biogas for energy/heat may lead to positive carbon balance.
- HOWEVER if process is suboptimal Nitrous Oxide (N_2O) may be produced, which is a very strong greenhouse gas). This situation may arise especially if aeration is lowered to save energy. Nowadays N_2O can be measured by sensors, and the process optimised in this respect as well.

Recommendation; DHI TechTalk #11 https://www.youtube.com/watch?v=ns0qdH4DlfM&feature=youtu.be

Energy optimisation of processes

- New model versions have integrated energy usage information of individual model components (pumps, weirs, aerators, etc.) – these can be used for calculating and optimising total process energy usage.

- This is especially valuable when different options are being considered for process extension/renovation.



Group: Energy			
F_Energy_Flow...	0,04	kWh/m3	0,04
Group: Settling			
v0	474	m/d	474
v00	250	m/d	250
r_P	0,00286	m3/g	0,00286
f_ns	0,00228	-	0,00228
X_Lim	900	g/m3	900
X_T	3000	g/m3	3000

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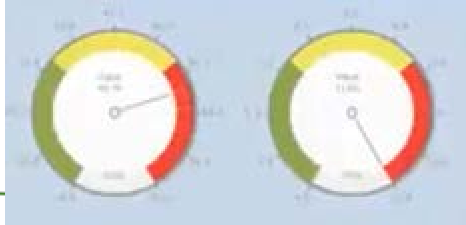
Identifying process violations

- This is part of standardised WWTP modelling protocol BSM1/BSM2 which is available at http://apps.ensic.inpl-nancy.fr/benchmarkWWTP/. The use is to both compare models build in different modelling environments AND to use the models to study different control strategies for WWTP:s (under different load situations)

  - Modern software now has process violation calculations included



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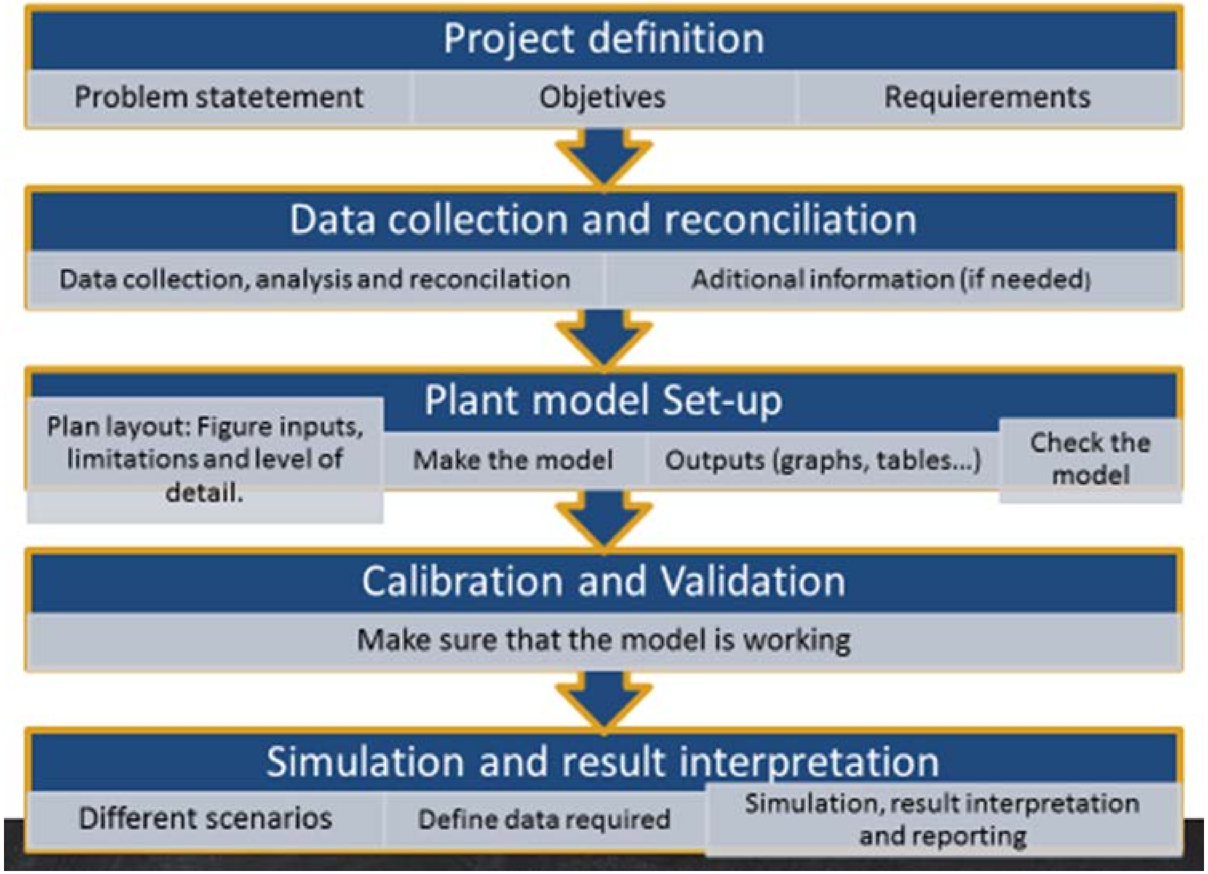
	End Value	1	36,891937
	Number of Upper bound Violations	1	0
	Percentage of Time in Violation of Upper bound	1	0
.out_2.TKN	**AbsSquared**	**1**	
	Minimum	1	32,225785
	Maximum	1	32,240868
	Mean	1	32,230936
	End Value	1	32,225785
	Number of Upper bound Violations	1	1
	Percentage of Time in Violation of Upper bound	1	100
.out_2.TSS	**AbsSquared**	**1**	

Looking at the Big Picture

Modelling project quality process



From separate models to Integrated parts of the whole

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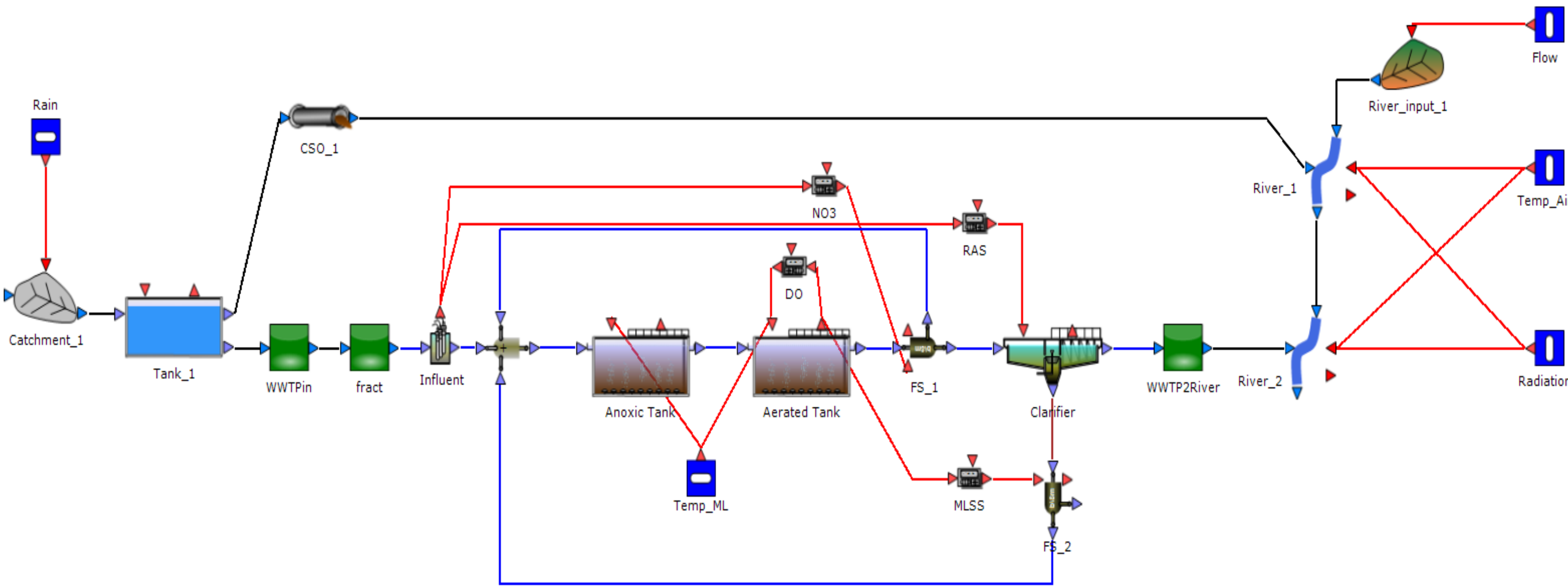
Separated models vs IUWS management

- Previously (with low computer power one cause) different systems were modelled (and developed!) separately with closed system boundaries. Now in big urban areas and development projects IUWS and IWRM are used

INTEGRATED URBAN WATER SYSTEMS MANAGEMENT IUWSM	INTEDRATED WATER RESOURCES MANAGEMENT IWRM

IUWS-M



Category: Parameters		
Group: Catchment		
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TotalArea	2	km2
Group: DWF		
Inhabitants	**3000**	
Q_Industry	**100**	m3/d
WastewaterPerIE	0,19	m3/d
f_tourist_pollution	1,1	
f_tourist_water	1	
f_we_pollution	0,5	

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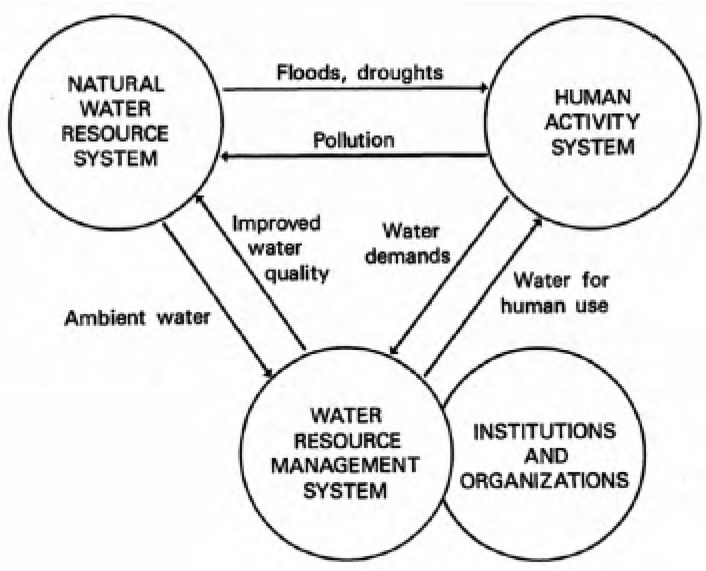
IWRM



- *Integrated water systems management* accounts for natural and man made water systems
- *Integrated water resources management* adds to this a social and political aspect

Source: Lukenga: Water Resources Management

Life Cycle Assessment (LCA) of WWTPs

- Life cycle assessment (LCA) is an appropriate methodology for assessing the sustainability of a wastewater treatment plant design.
- Normally low energy use leads to low environmental impact and better sustainability, also construction materials and operational life time of system has effect.
- Novel approach is additionally to compare in specific cases Net Environmental Benefit (NEB) of design options by including terms that describe effluent quality.

Regular activated sludge control methods

WWTP process adjustment relies on few parameters

- Air feed and feed profile
- Internal recycle and settled sludge recycle
- Extra (partly microbially generated) sludge wastage.

AIM: Minimum aeration to reach Nitrogen reduction targets. Too high aeration may lead to air in denitrification (leading to N_2O and inhibition of PAO.) Normal target is 1-2 mg N/l

Aeration can be adjusted by ammonium measurement (low at end of aeration.) If at entrance also load change can be seen and aeration adjusted proactively.

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Regular activated sludge control methods
Continued

- Too low nitrate circulation does not bring enough NO_3 to denitrification.
- Too high nitrate circulation may bring oxygen to anoxic part and flush COD to aerobic parts, which are both detrimental.
- Although circulation pumping uses energy, this is minor as elevation is low.
- Particulate COD is normally attached to sludge flocs and present in both anoxic and aerated zones.
- Part of soluble COD reacts in anaerobic zone in denitrification while rest continues forward. Nitrate should be available in whole anoxic area through sufficient circulation.

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Regular activated sludge control methods
Continued

- If additional carbon source is added (low C municipal wastes or high N conc. In wastestream) the amount should be minimum needed as addition increases:
  - Total need of chemicals in process
  - Sludge production
  - Aeration energy

For exact adjustment Nitrate sensors at influent and end of aerobic sector. With one sensor at end reactions to long term (seasonal) changes manually

Return sludge and waste sludge adjustment

- Effects are seen slowly and manual adjustment based on long term averages is considered adequate
- SRT should be short without sacrificing nitrification at high loads
- Long SRT aids nitrification as MLSS increases and therefore amount of nitrate used in cell metabolism.
- For Enhanced Biological phosphorus removal ideal SRT is 5-12 days. SRT has no effect on COD reduction
- Short SRT may give better sludge settleability.
- Short SRT increases WAS amount and thus cost if no biogas process exists.
- Normal adjustment is manual based on changing growthrate of nitrification bacteria in reaction to different (seasonal) temparatures.

Sludge Bed Height in settling tank

- Sludge Blanket Height measurement has been developed but optimum height is not clear.
- High Sludge blanket increases sludge density at bottom of settler and lowers thus volume of WAS
- SBH varies dynamically based on inluent flow (and nitrogen)
- ASM model family has several settler models but this is bottleneck in WWTP modeling regarding exactness.
- One possibility would be to use emperical models at this stage. Also Neural Networks have been suggested.

Smart adjustment

Or just regular with more sensors?

- Aeration in sectors, and to each sector DO sensor
- Some NH_4 sensors
- Do not aerate too much in initial aerated sectors, BUT so that ammonium is still minimised at exit. Ammonium oxidation and COD redution takes place also in last section.
- Sensors in (data from) mid sectors can be used to adjust aeration in both preceeding and final sectors.
- Redox (ORP) and pH sensors are cheap and control based on these signals are interesting for small WWTPs.
- Neural network based nonlinear models still hold promise in certain situations but have not become to wide use.

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