MBR-Network

Final MBR-Network Workshop

"Salient outcomes of the European R&D projects on MBR technology"

Presentation handouts

31 March – 1 April, Berlin 2009 (Germany)

Hosted by KOMPETENZZENTRUM Wasser Berlin

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Session VI – Process integration and new processes

30. THE EFFECT OF ORGANIC PEAK LOADS ON MEMBRANE BIOFOULING IN A PILOT SCALE MBR TREATING MUNICIPAL WASTEWATER

Ben Zwickenpflug, Marc Boehler, Adriano Joss, Hansruedi Siegrist

EUROMBRA

The effect of organic peak loads on membrane biofouling in a pilot scale MBR treating municipal wastewater

Ben Zwickenpflug, Marc Boehler,
Adriano Joss, Hansruedi Siegrist

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EUROMBRA

Content

Content

- Objectives
- *Eurombra*-Pilot Plant
- Peak load experiments
- Results
- Conclusions

EUROMBRA

Objectives

Content

Objectives

For testing the interrelationship between peak loads and permeability, different kinds of organic substrates have been dosed, to provoke membrane fouling

- ✓ pilot scale MBR plant with state of the art modules
- ✓ municipal wastewater
- ✓ flow proportional influent
- ✓ operating conditions according to manufacturer's specifications

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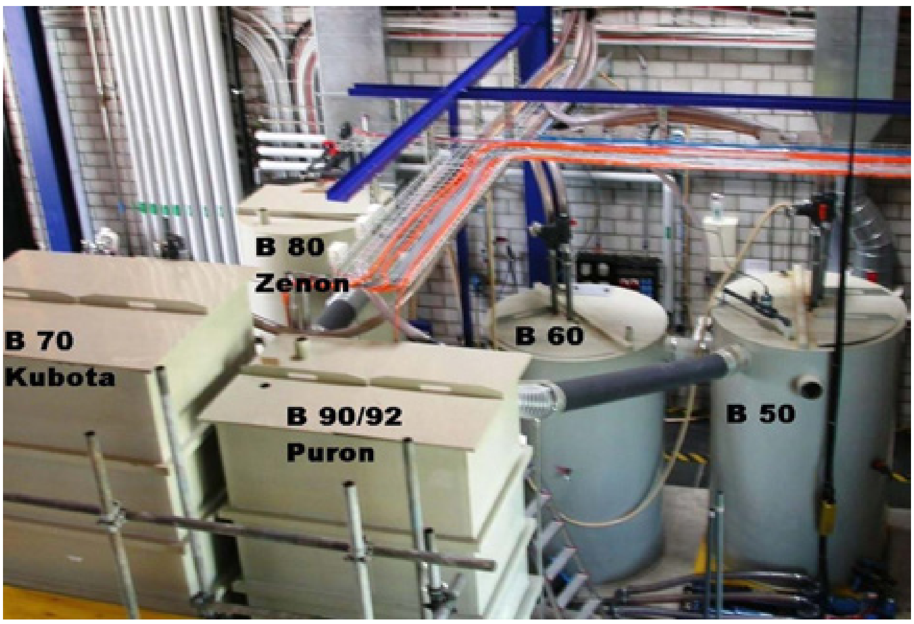
Eurombra Pilot Plant

Content

Objectives

***Eurombra*-Plant**

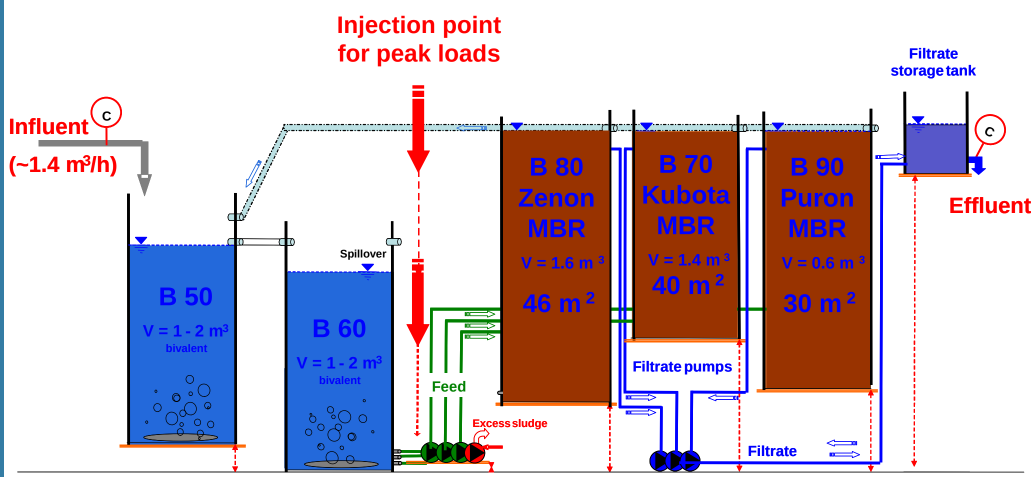


Eurombra Pilot Plant

Content

Objectives

***Eurombra*-Plant**



Installed full scale modules

Content

Objectives

***Eurombra*-Plant**

	Kubota FS50	Puron A-30-HS	Zenon ZW500A
Geometry (mm between plates or diameter)	Flat sheet (7)	Hollow fibre (2)	Hollow fibre (2)
Pore size [µm]	0.4	0.1	0.04
Membrane Area [m²]	40	30	46
Maximal gross flux [$m^3 \cdot h^{-1}$]	1.5	1.5	1.5
Aeration rate [$Nm^3 \cdot h^{-1}$]	50	15	45
Air cycling (On / Off) [s]	No	No	10 / 10
Permeate cycle: production/pause (backpulse) [s]	480 / 120 (0)	480 / 120 (30) or 300 / 60 (25)	480 / 120 (25)
Chamber volume [m³]	1.41	0.67	1.61
Chamber size (LxWxH) [m]	1.1 x 0.8 x 1.60	1.2 x 0.25 x 2.25	Ø 1.0 x 2.05

EUROMBRA

Content

Objectives

Eurombra-Plant

Experiments

Experiments

Dry weather conditions:
COD load by wastewater influent = 13.4 kg COD_{tot} / d
COD_{sol} / COD_{part} = 1

Experiment 1 and 2:

Doubling the COD_{sol} load by a daily dosing of 6 kg COD of
- sodium acetate
- or sugar

Experiment 3:

Doubling the COD_{part} load by a daily dosing of 6 kg COD of
- wheat flour

- Duration of each experiment: **7 days** in a row, with chemical cleaning and a regeneration period of 2 weeks in between the experments
- Injection of peak load solution: daily at 10:00
- Duration of dosage: **7- 12 minutes**

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EUROMBRA

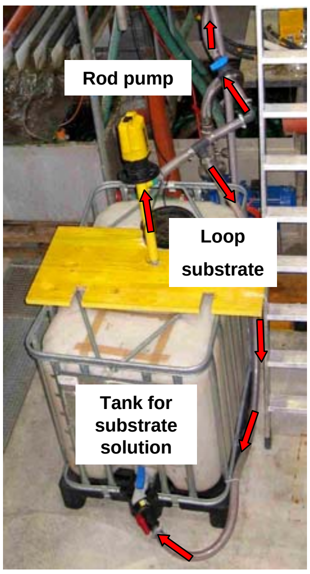
Content

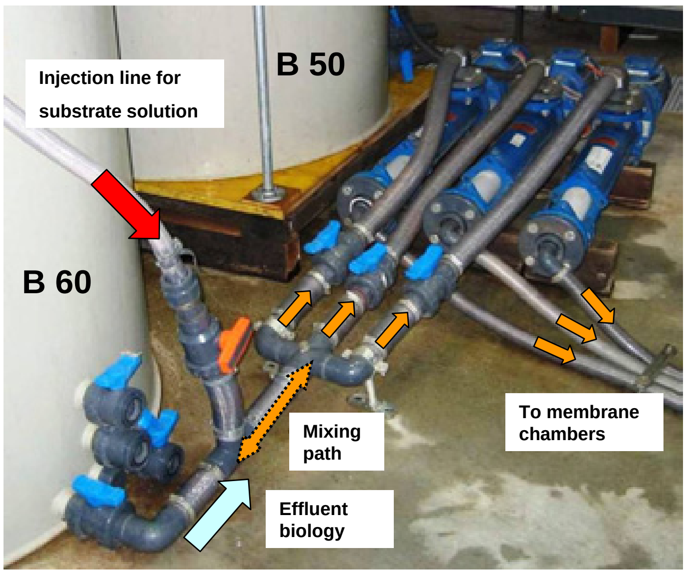
Objectives

Eurombra-Plant

Experiments

Set up





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Problems: Loss of TSS due to big foam events

Content

Objectives

Eurombra-Plant

Experiments

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COD_{sol} in sludge filtrate (paper filtered) and effluent (membrane filtered)

Content

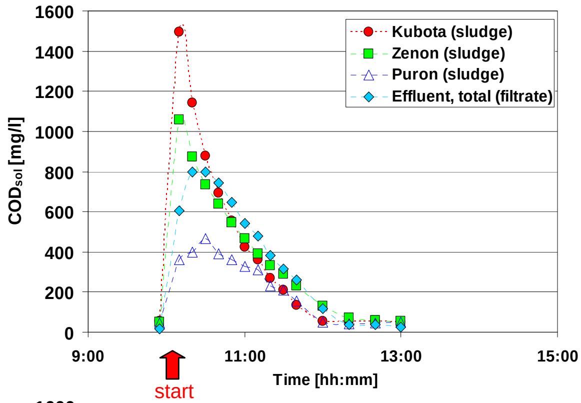
Objectives

Eurombra-Plant

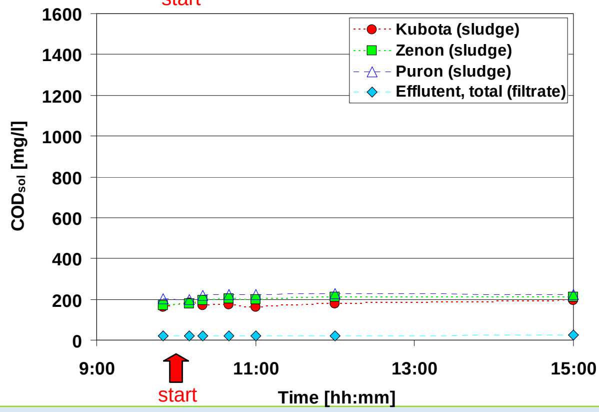
Experiments

Results

Acetate Dosage 02.12.2009 day 725



Flour Dosage 10.01.2009 day 765



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EUROMBRA

Impact of peakload experiments on membrane permeability

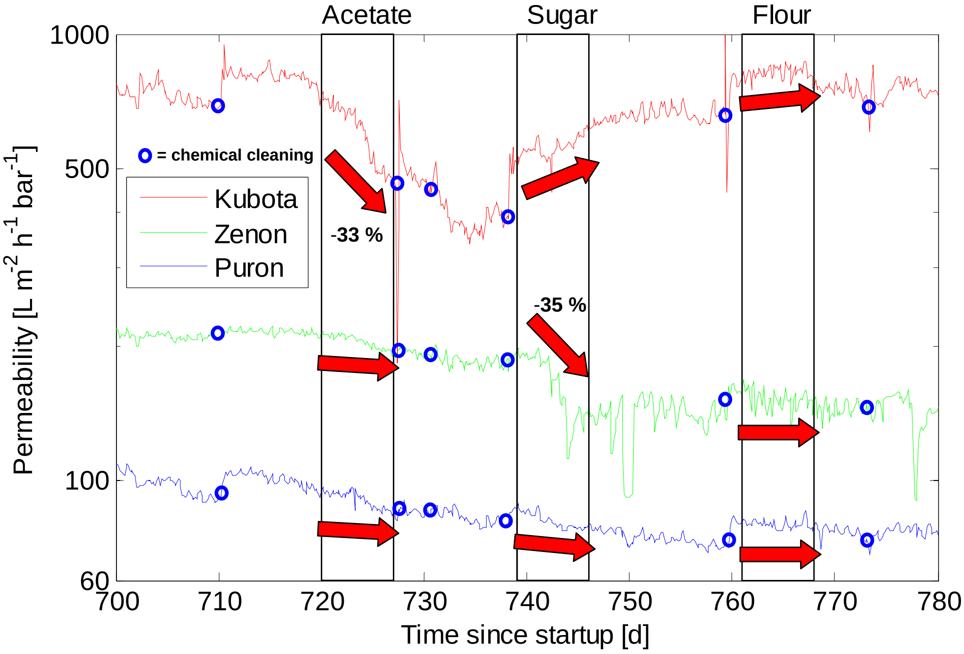
Content

Objectives

Eurombra-Plant

Experiments

Results



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Long-term Permeability

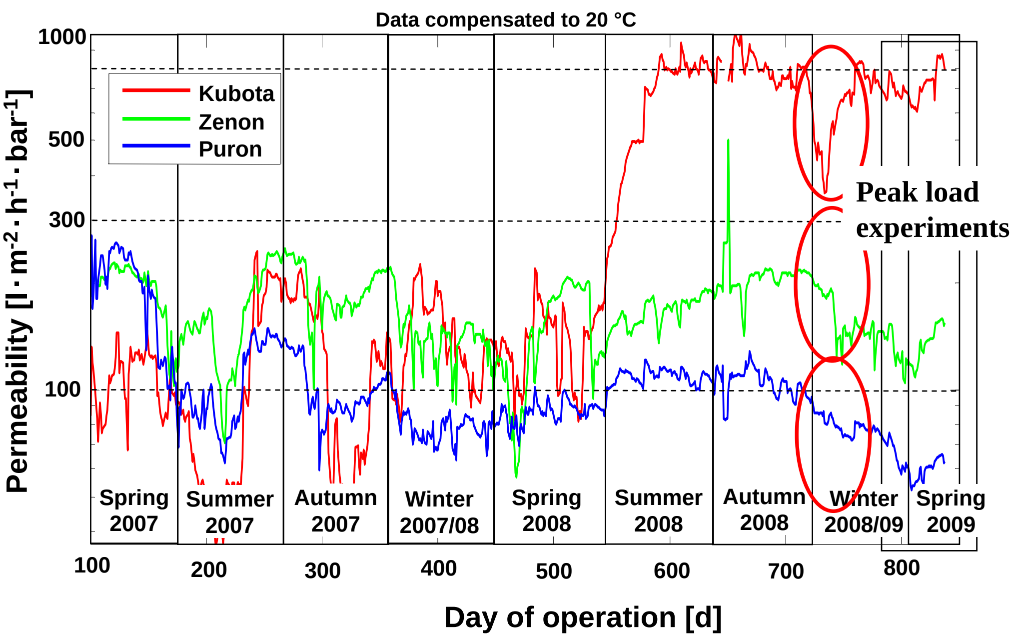
Content

Objectives

Eurombra-Plant

Experiments

Results



Spring: 01.03. – 31.05. Summer: 01.06. – 31.08.
Autumn: 01.09. – 30.11. Winter: 01.12. – 28.02.

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Conclusions

Content

Objectives

Eurombra-Plant

Experiments

Results

Conclusions

- High organic loading rates causing high F/M ratios seem to have only minor influence on membrane permeability compared to other unidentified factors, e.g. sludge characteristics or seasonal variations
- Literature findings that predicted extremely high fouling rates (decrease of permeability) could not be confirmed in our experiments
- Fouling caused by high F/M ratios seems to be mostly reversible
- Decline of permeability has been observed only for dosage of COD_{sol} not for COD_{part}

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EUROMBRA

Acknowledgement

EUROMBRA is a research project supported by the European Commission under the Sixth Framework Programme (Priority “Global Change and Ecosystems”)

Contract No. 018480 - EUROMBRA

Duration: 01/10/05 – 31/05/09

EUROMBRA is part of the MBR-NETWORK Cluster

More info: www.mbr-network.eu

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31. DECISION TREE FOR FULL-SCALE SUBMERGED MBR CONFIGURATIONS

H. De Wever, C. Brepols, B. Lesjean

EUROMBRA AMEDEUS

Decision tree for full-scale submerged MBR configurations

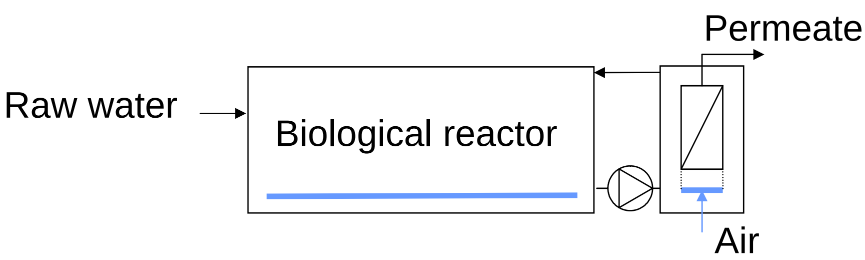
H. De Wever, VITO
C. Brepols, Erftverband
B. Lesjean, KWB

vito vision on technology   Erft Verband   KOMPETENZZENTRUM Wasser Berlin

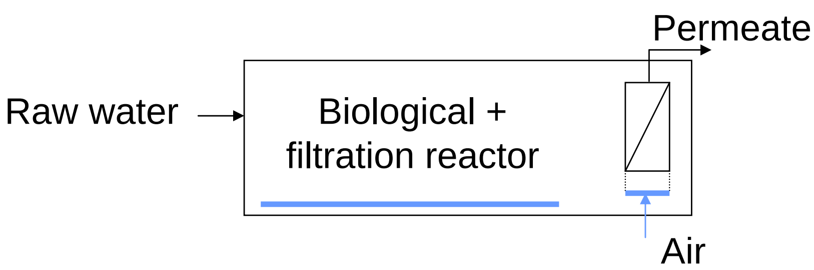
AMEDEUS

Submerged MBR configurations

- *Separate system*



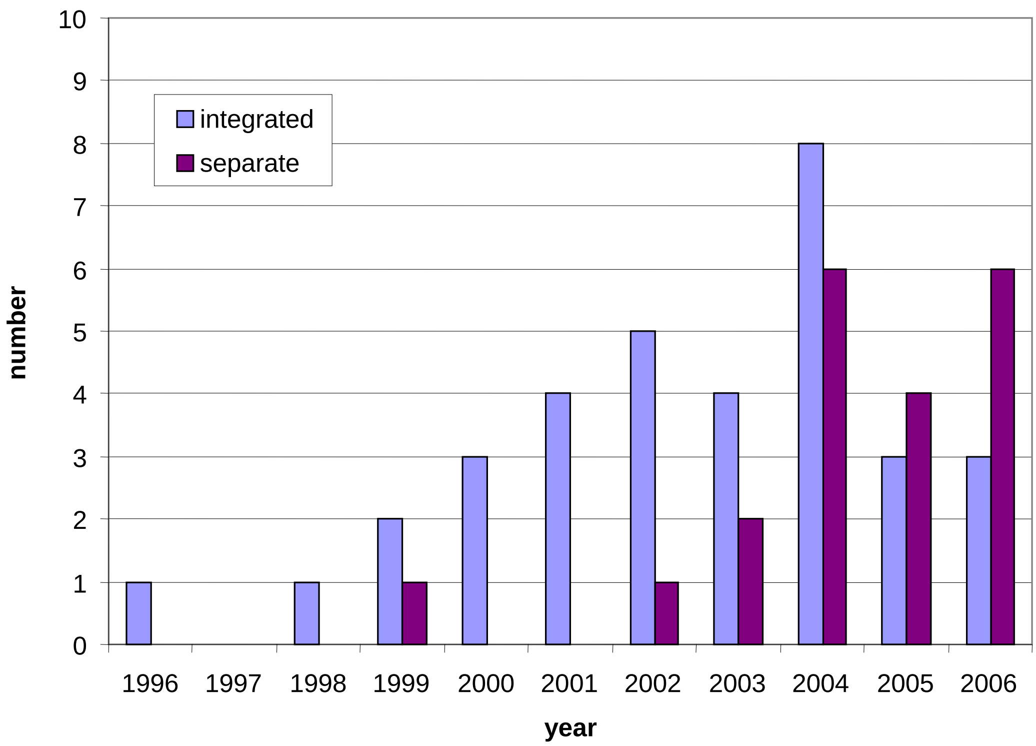
- *Integrated system*



Approach for comparison configurations

- Trends for full-scale municipal MBRs in Europe
- Comparative pilot trials
- Questionnaire for selected operators/end-users or suppliers
- Literature review
- Comparison of 2 full-scale MBRs
- Conclusions: Decision tree

Trends for full-scale municipal MBRs in Europe



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Trends for full-scale municipal MBRs in Europe

- 98 commissioned by 2006 – sufficient details found for 54
  - 34 integrated submerged (total capacity 6018 m^3/h)
  - 20 separate submerged (total capacity 6744 m^3/h)

	C removal	N removal
Integrated	19	15
Separate	3	13

	Retrofit	New
Integrated	19	14
Separate	10	10

	Flat sheet	Hollow fibre
Integrated	23	11
Separate	6	14

  - Larger plants > 200 m^3/h: preference for separate configuration

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Literature review

- Tendency towards separate configuration
  - Advantages
    - Easy access for maintenance, cleaning
    - Lower fouling – better control hydraulics, biological system
    - Different sludge distribution
    - Cascading effect: less susceptible to fluctuations in flow or load
    - Better effluent quality – advanced nutrient removal
    - Higher operational flexibility
  - Disadvantages
    - Larger footprint
    - Higher investment and operational costs

Comparison of 2 full-scale MBRs

- Kaarst-Nordkanal (integrated) <> Varsseveld (separate)
  - Both equipped with Zenon membranes
  - Operational and cost data available

  - Comparable designs
  - Nordkanal: capacity 4x higher than for Varsseveld
  - Comparable discharge consents except for total N

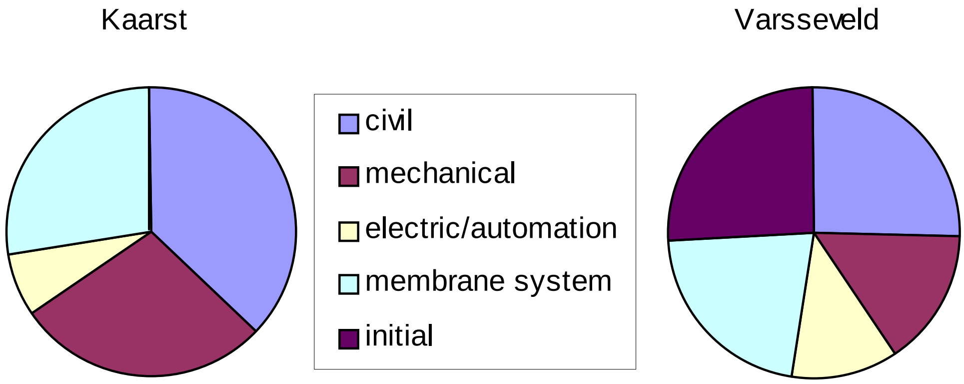
Sources: van Bentem et al. (2007), Brepols (2008)

Comparison of 2 full-scale MBRs

Parameter	**Kaarst-Nordkanal**	**Varsseveld**
Treated flow per year (m^3)	5 236 000	1 825 000
Sludge load (kg BOD/kg MLSS.d)	< 0.05	0.04
Sludge retention time (d)	25	24-35
Aeration	Intermittent (15 s off/15 s on)	Intermittent (15 s off/15 s on)
Specific aeration demand (Nm^3 air/h.m^2)	0.43	0.55
Specific aeration demand (Nm^3 air/m^3 permeate)	17	15
Physical cleaning	every 800 s backflush for 60 s	every 360 s backflush for 20 s
Chemical cleaning	maintenance clean every 1 or 2 weeks	maintenance clean every 1 or 2 weeks

Comparison of 2 full-scale MBRs

- Capital costs



270 EUR/PE

1 500 EUR/m³/d

(integrated)

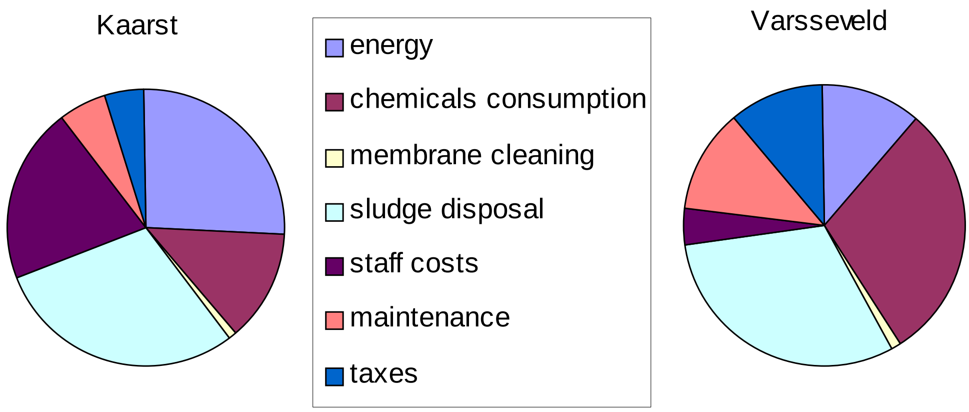
490 EUR/PE

2 250 EUR/m³/d

(separate)

Comparison of 2 full-scale MBRs

- Operational costs



17 EUR/PE

0.26 EUR/m³ treated

(integrated)

29 EUR/PE

0.36 EUR/m³ treated

(separate)

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Comparison of 2 full-scale MBRs

Energy consumption (kWh/m³)	**Kaarst-Nordkanal**	**Varsseveld**
Membrane aeration	0.23	0.34
Bioreactor aeration	0.30	0.24
Total aeration	*0.53*	*0.58*
Membrane supply pumps	0.03	0.11
Permeate pumps	0.04	0.12
Bioreactor impellers	0.05	0.04
Others	0.25 (incl. sludge dewatering)	0.05
Total specific power demand	***0.9***	***0.9***

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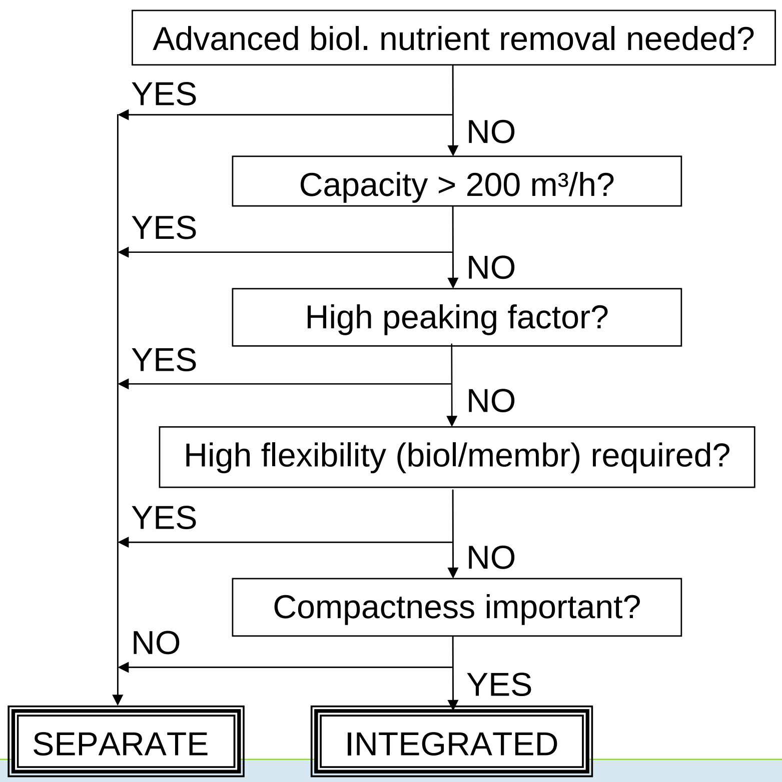
Conclusions: Decision tree



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Acknowledgement

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Contract No. 018328 - AMEDEUS
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AMEDEUS is part of the MBR-NETWORK Cluster

More info: www.mbr-network.eu

32. OPERATIONAL EXPERIENCE OF MBR DEMONSTRATION PLANT WITH POST DENITRIFICATION IN BERLIN-MARGARETENHÖHE (ENREM-PROJECT)

C. Lüdicke, J. Stüber, R. Gnirss, B. Lesjean, M. Kraume

www.bwb.de

www.kompetenz-wasser.de

MBR-Network Workshop 31.3/1.4. 2009

MBR Demonstration Plant: EBPR with Post Denitrification in Berlin-Margaretenhöhe

Regina Gnirss, Carsten Lüdicke, Berliner Wasserbetriebe

Boris Lesjean, Johan Stüber, KompetenzZentrum Wasser Berlin

Mathias Kraume, IVT TU Berlin

Structure

- Motivation
- Aim
- Process
- Results
- Energy consumption
- Conclusions

Motivation

ENREM

- Primary sedimentation
- Conventional Aeration Process:

Carbon:	COD<50 mg/L	96%	6 Large WWTP
EBPR:	TP<0,5 mg/L	96%	
Nitrogen:	TN<18 mg/L	80%	

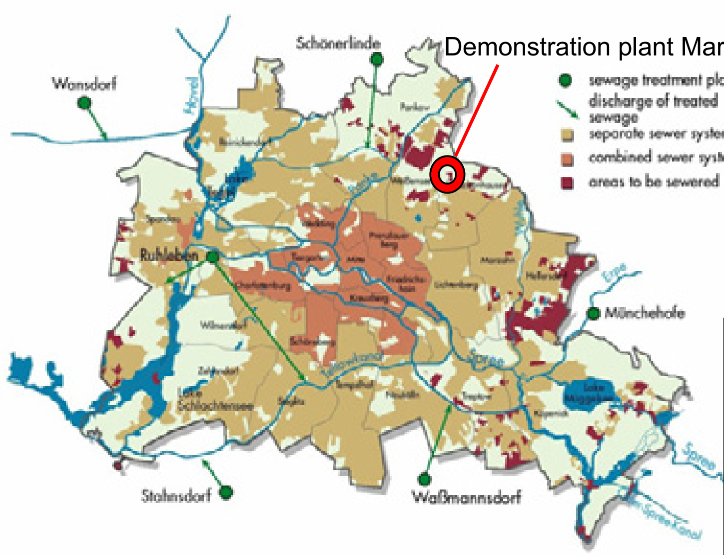
- Sedimentation
- Sludge Treatment:
  Digestion
  or Incineration

Berliner Wasserbetriebe

Motivation

ENREM

- ➔ About 33,000 inhabitants of Berlin have no sewer connection (1%)
- ➔ Only drainoff free septic tanks allowed → expensive wastewater disposal
  → risks of leaks and pollution



# of households: ~ 90

# of persons: ~ 230

Actual connection rate: ~ 100 %

approx. 20 % summer residences

Berliner Wasserbetriebe — KOMPETENZZENTRUM Wasser Berlin — VEOLIA WATER ANJOU RECHERCHE

Goals

Enhanced Nutrients Removal in Membrane Bioreactor

(Vermehrte Nährstoffelimination in Membranbelebungsreaktoren)

- ➔ Demonstration of a novel process for enhanced biological nutrients removal
- ➔ Achievement of better effluent quality than the large WWTP in Berlin
- ➔ Evaluation of the operational costs and energy consumption

- ➔ Process was developed in a 3-year research project IMF
- ➔ Patent-protected by Berliner Wasserbetriebe und Veolia Wasser

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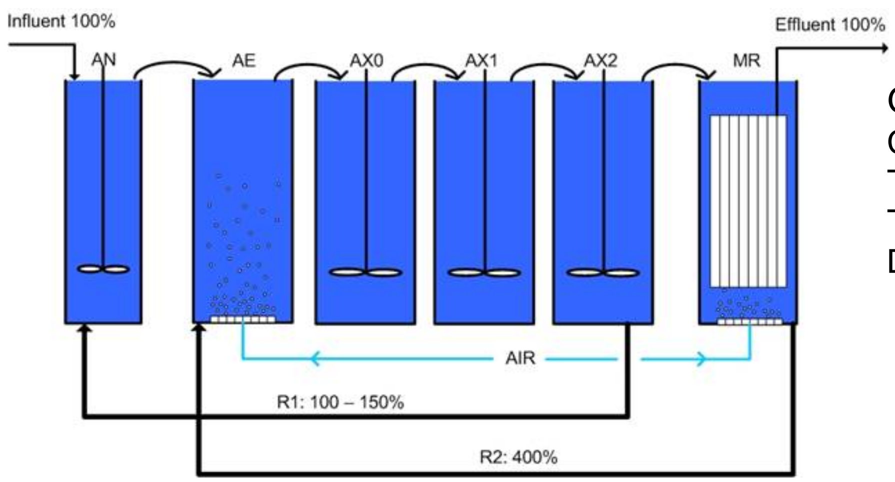
ENREM process

Combining of biological phosphorus removal and post - denitrification



Goal:
COD < 50 mg/l
TN < 10 mgN/l
TP < 0,1 mgP/l
Desinfection

Feb. 2008 Conversion AE2 – AX0

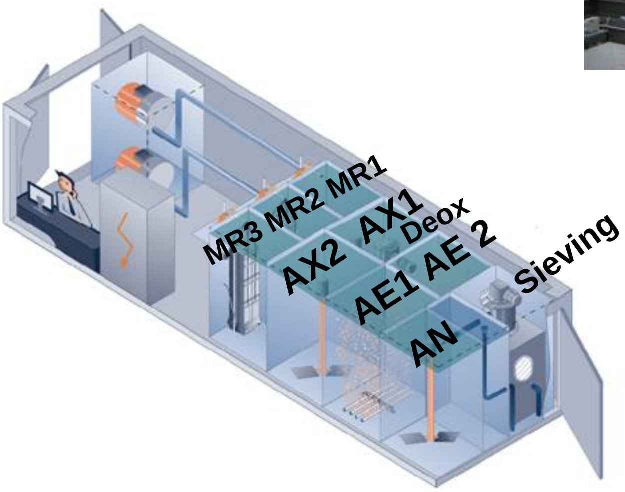
Berliner Wasserbetriebe — KOMPETENZZENTRUM Wasser Berlin — VEOLIA WATER ANJOU RECHERCHE

ENREM process

ENREM

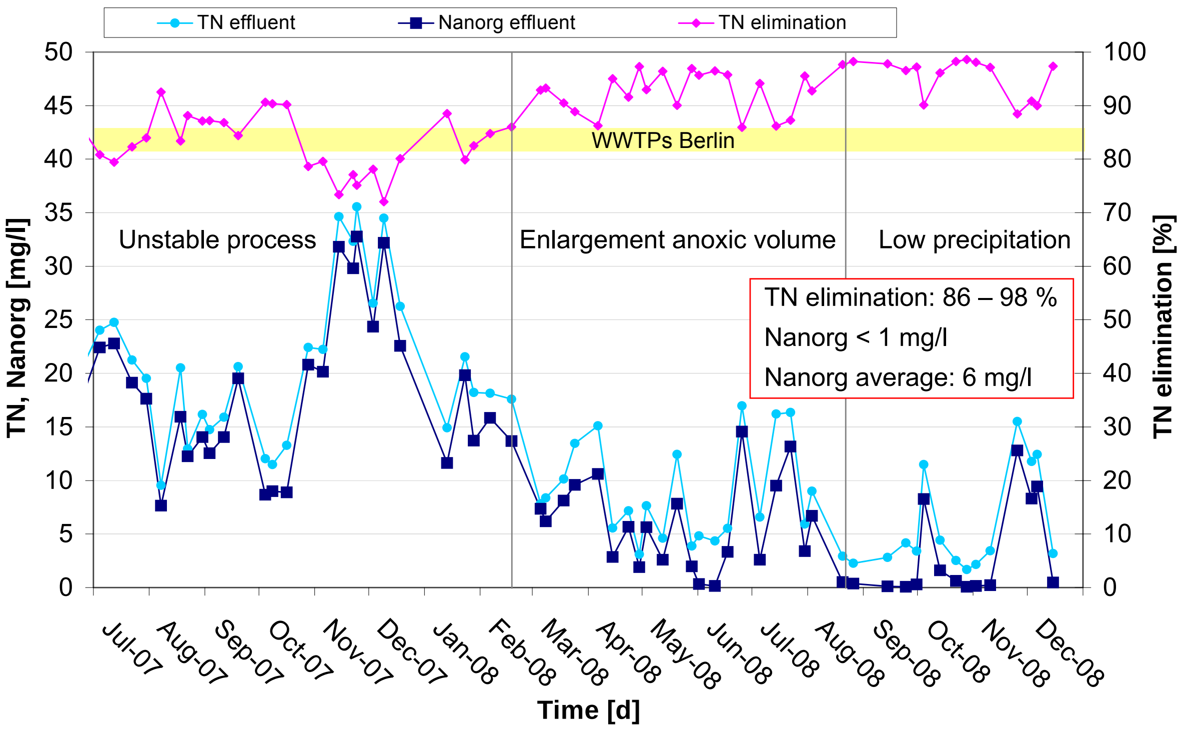
+ Containerised plant
+ Sieving within the container
+ Maintenance entry via top
+ Plant investment costs

<u>260.000 €</u>



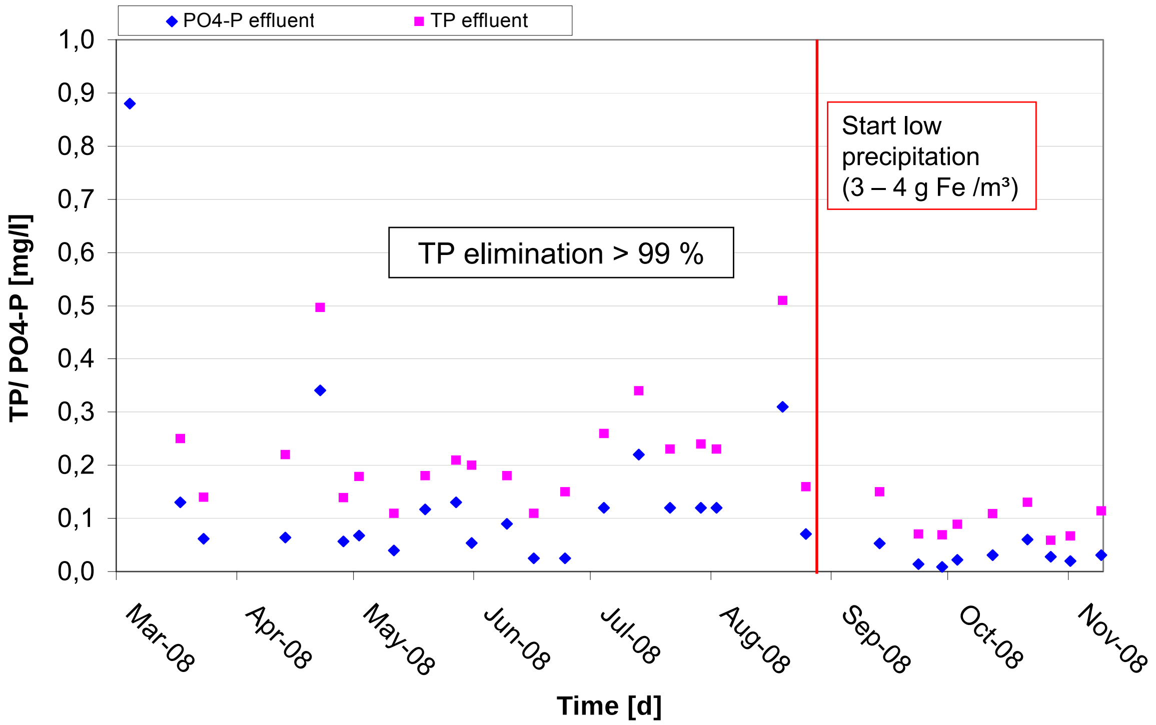
Nitrogen elimination (24h sample)

ENREM



Phosphorus elimination (24h sample)

ENREM



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Membrane cleaning

ENREM

Cleaning Objectives

- Preventive cleaning
- Low chemical concentration
- Low cleaning efforts

Module 4 (chemical soaking)	Module 5 (chemical soaking)
H_2O_2	Active Chlorine
1000 ppm / pH11	500 ppm
4 weeks	4 weeks

Cleaning strategy

- Alternating module operation
- 1 month operation / 1 month storage in chemical solution
- Cleaning with citrid acid when necessary (approx. every 3rd cleaning)

- Cleaning results satisfying:

  Permeability: 800 to 1200 L/ (m^2 * h* bar)

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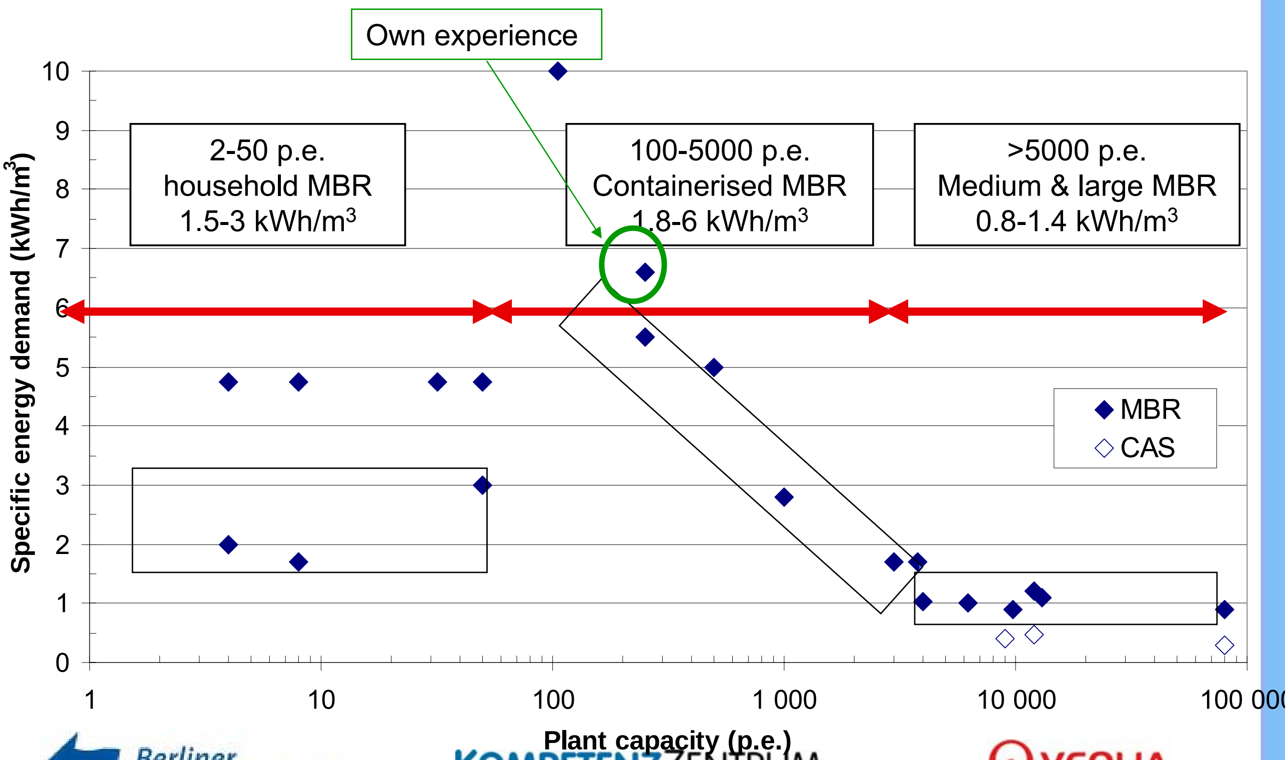
Energy consumption (literature)



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Conclusions

- Plant is running for around 3 years without heavy breakdowns
- Under design load conditions the biological ENREM process works reliably and TP between 0.05 - 1 mg/L in grap sample
- Zone conversion (AE -> AX) and minimum precipitation stabilised the process
- Over 99% P-elimination (0.05 mg/L), over 95% N-elimination (< 6 mg/L)
- Monthly maintenance membrane cleaning caused high reliability of filtration with H2O2 or chlorine detergents

Berliner Wasserbetriebe KOMPETENZZENTRUM Wasser Berlin VEOLIA WATER ANJOU RECHERCHE

Demonstration plant – view

Thank you for your attention

Acknowledgment:

This study was conducted in the frame of the demonstration project ENREM, with subventions of the European LIFE-program (LIFE 04 ENV/DE/058) and financial support from Veolia Water and Berliner Wasserbetriebe.

Backup

- Backup

Catchment area

ENREM

# of households: ~ 90

# of persons: ~ 230

Actual connection rate: ~ 100 %

approx. 20 % summer residences

Project Structure

ENREM

➔ Demonstration project:

- Duration: 2004-2007 (3.5 years)
- Budget: ca. 2.4 Mio.€ (≈ 250k€ LIFE-subventions)

Life

KOMPETENZZENTRUM Wasser Berlin – Coordination, Research

Berliner Wasserbetriebe – Investor, Operator

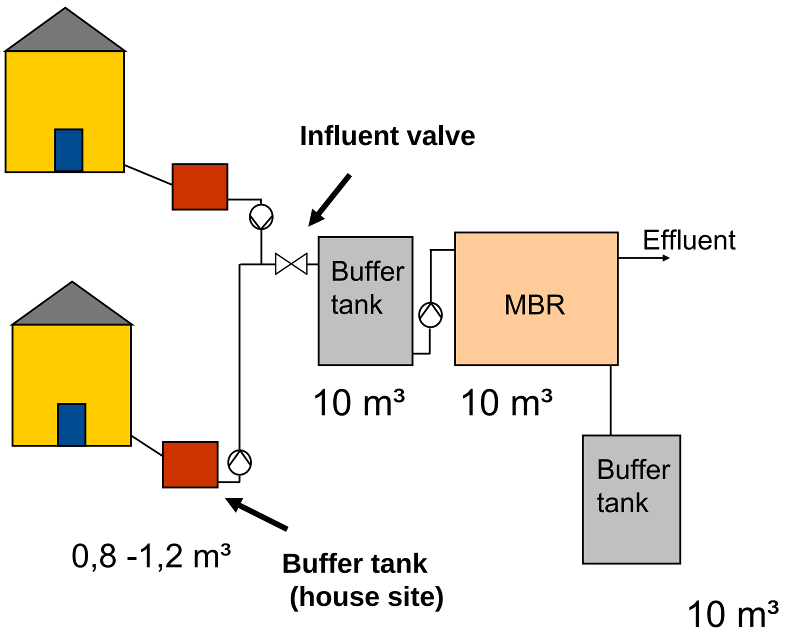
Martin Systems AG – Plant Design, Membrane

JUNG PUMPEN – Grinding pumps

VEOLIA WATER ANJOU RECHERCHE – Technical consultant

TU berlin – Prestudy

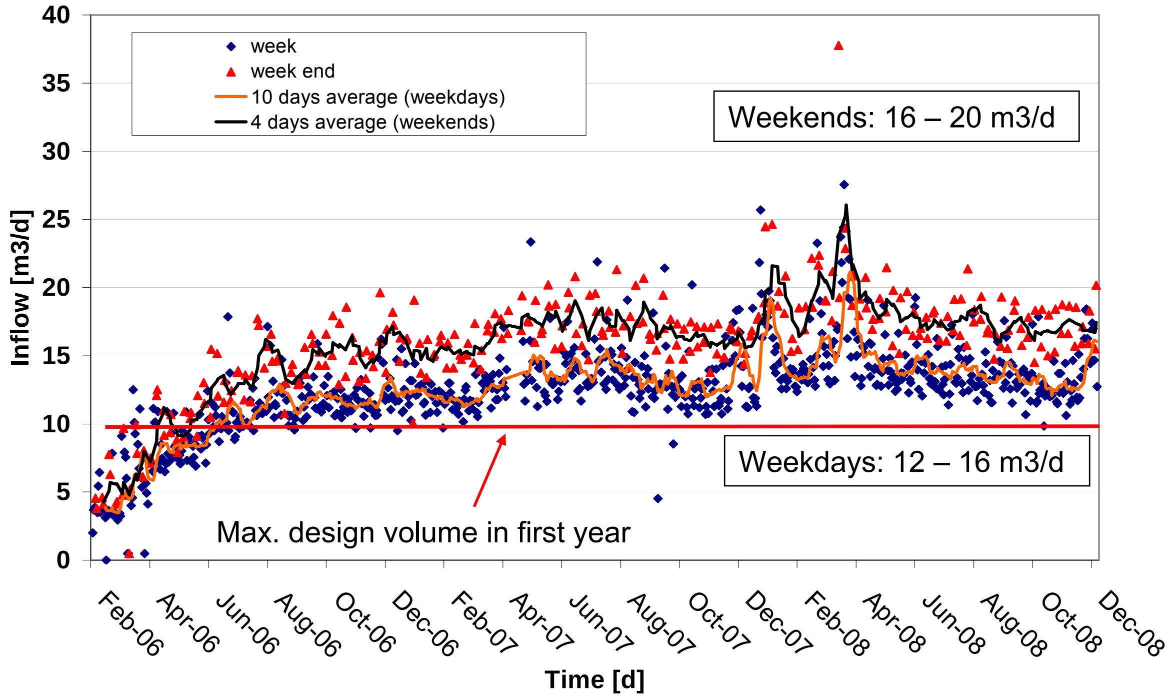
Pressure drainage and membrane filtration



Buffer tank: Homogenization of waste water inflow and concentrations

→ High reliability in running the plant

Inflow characteristics (weekdays – weekends)

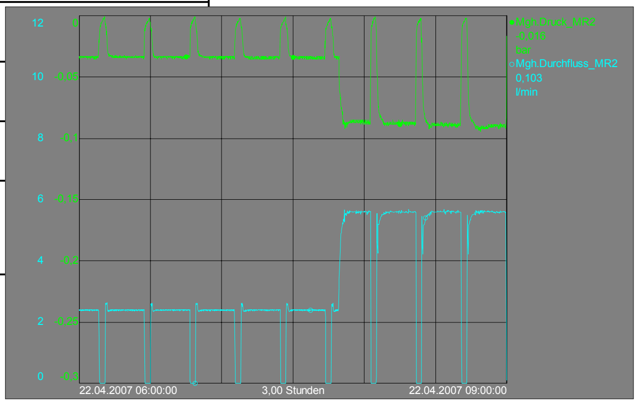


→ Extreme inflow variation (Storm water events in spring 2008)

Filtration parameter

ENREM

Type	Flat sheet
Material	Polyvinylidene fluoride (PVDF)
Pore diameter	200 nm (microfiltration)
Membrane area	31.8 m² (per line / double deck)
TMP max.	300 mbar
TMP operation	20 – 30 mbar
Operating flux	15 – 20 L/m²/h
Filtration time	999 sec
Relaxation time	143 sec No backwash



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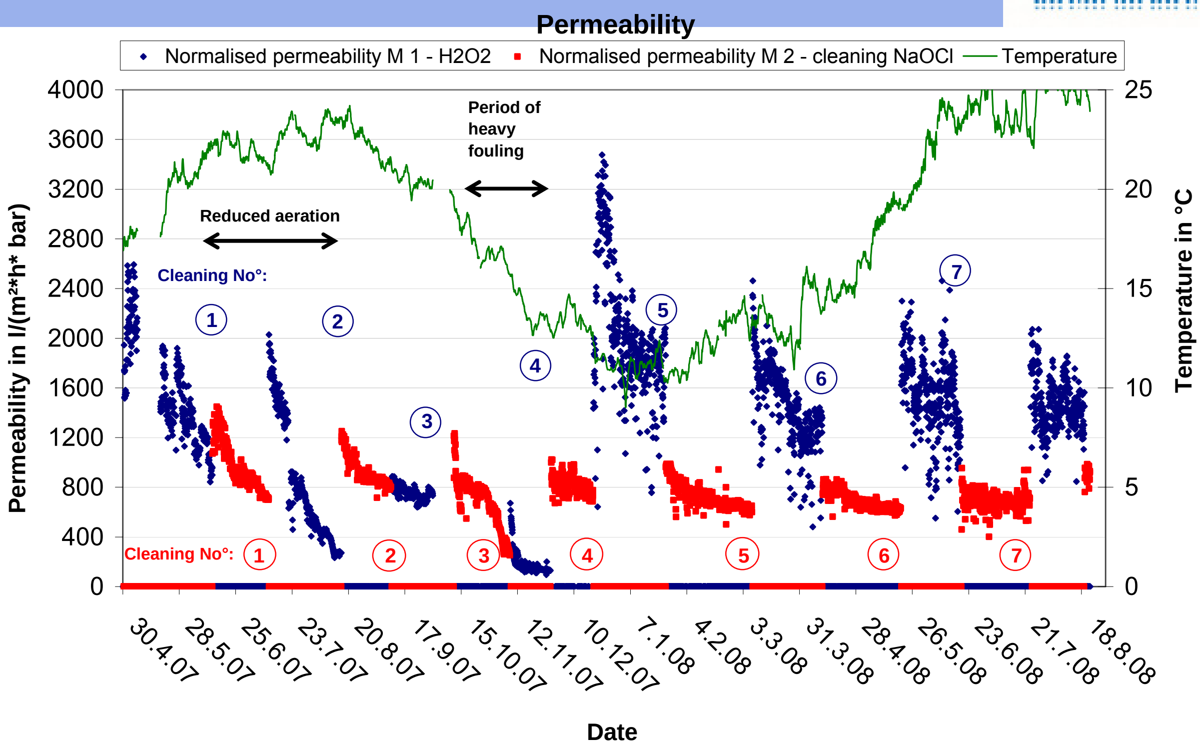
Membrane performance

ENREM



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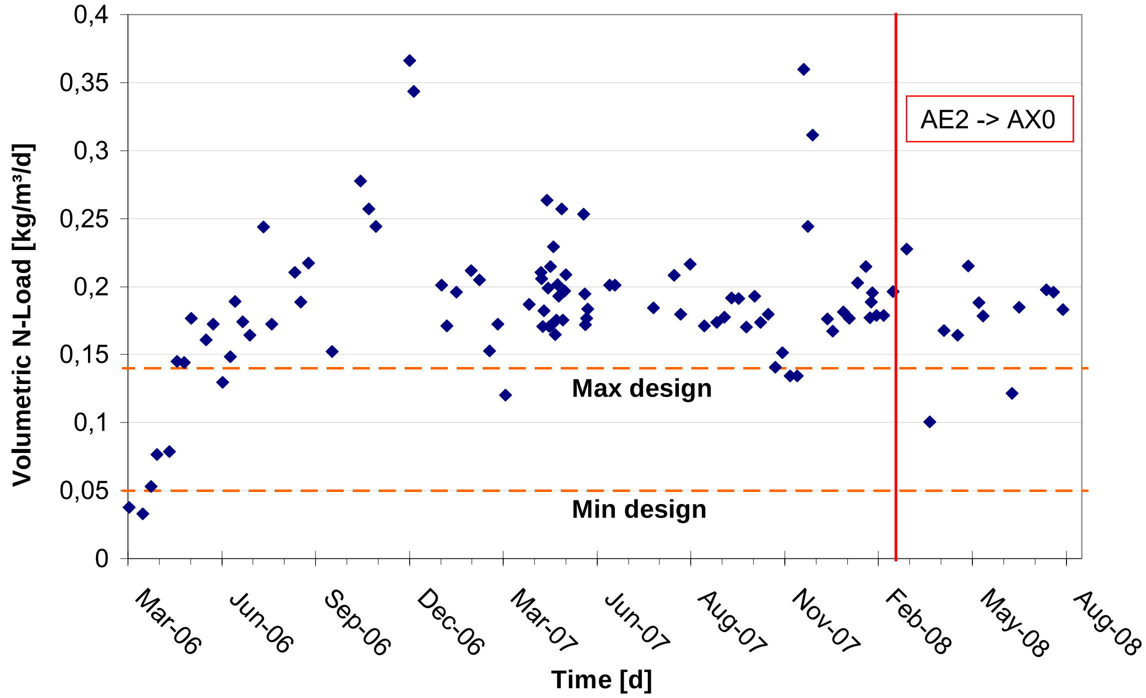
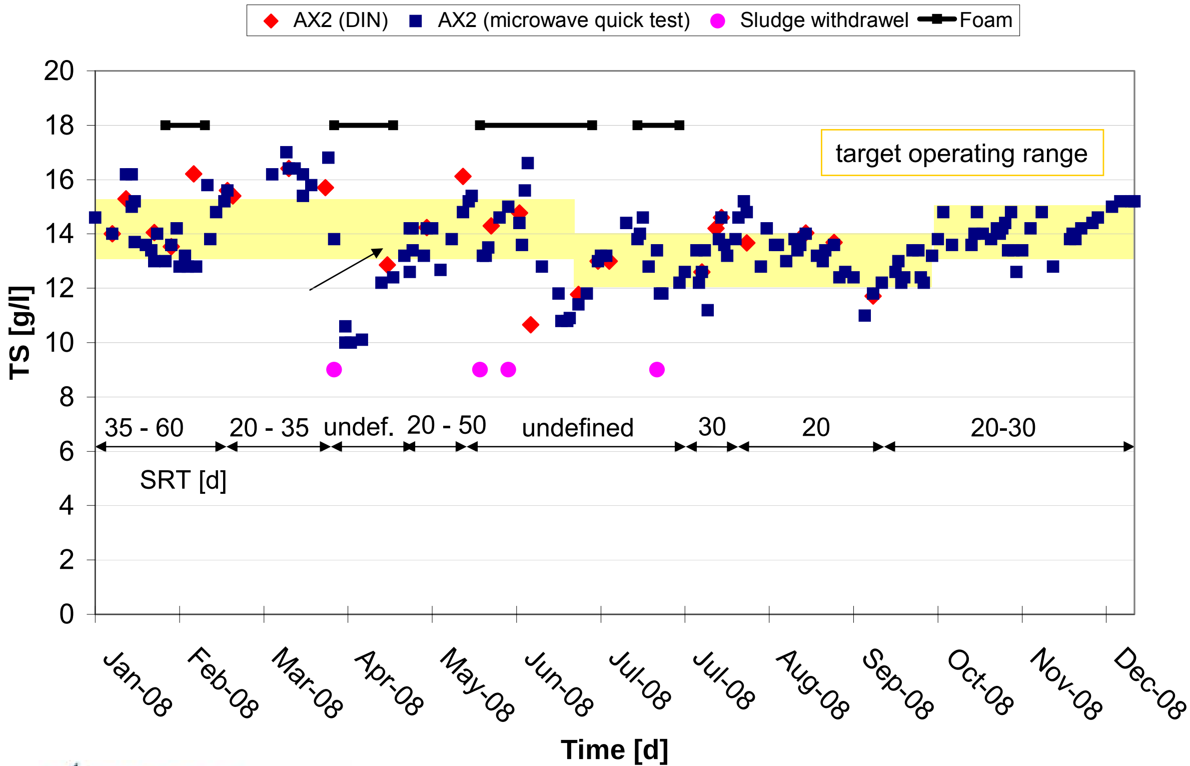
Volumetric nitrogen load



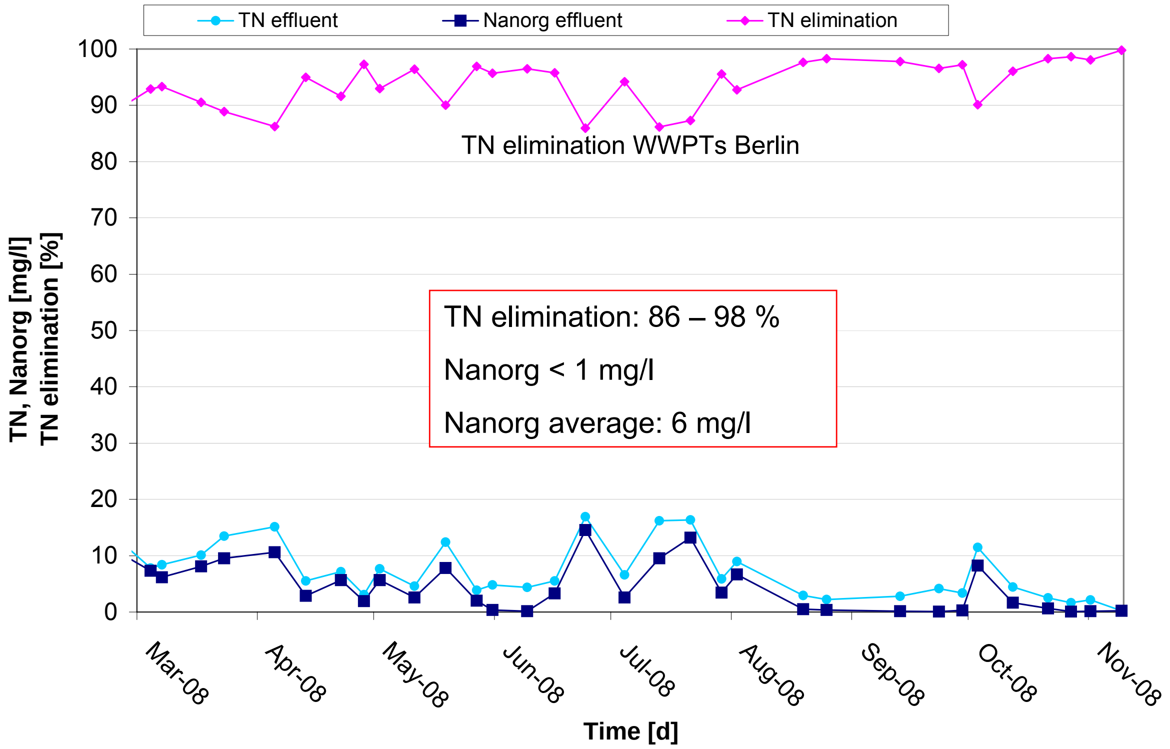
→ 20 – 50 % overload (same for phosphorus)

TS concentration



Nitrogen elimination (24h grab sample)

ENREM



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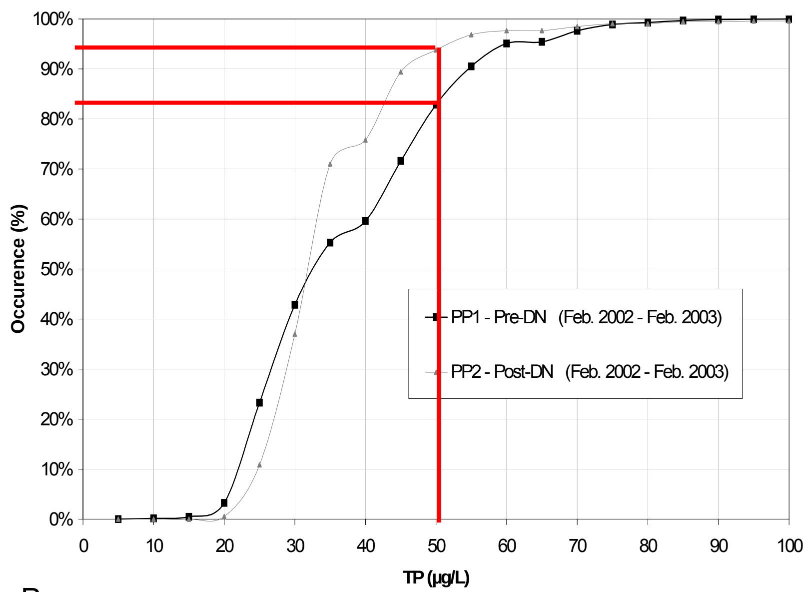
Phosphorus removal: EBPR only

ENREM



Outcomes

- Effective Bio-P in MBR from 8d up to 26d SRT
- 50µgP/L reached in > 80%
- 20µgP/L: refractory fraction
- MBR is advantageous for Bio-P process (complete retention + sludge conditioning before effluent extraction)
- But: natural precipitation in Ruhleben (Fe, Ca)

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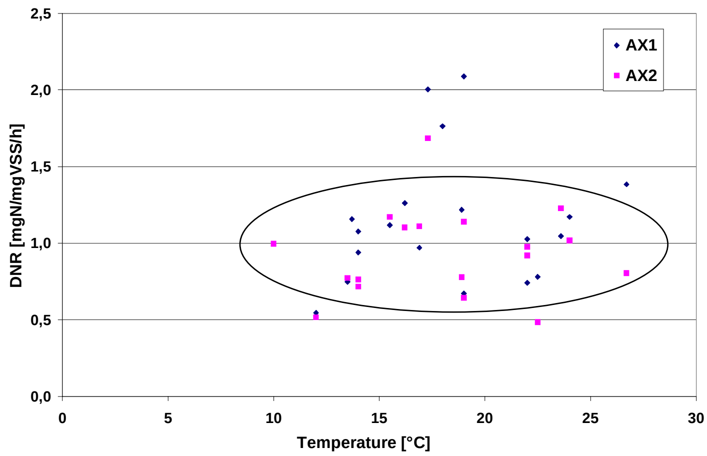
Biological reactor: Denitrification

ENREM

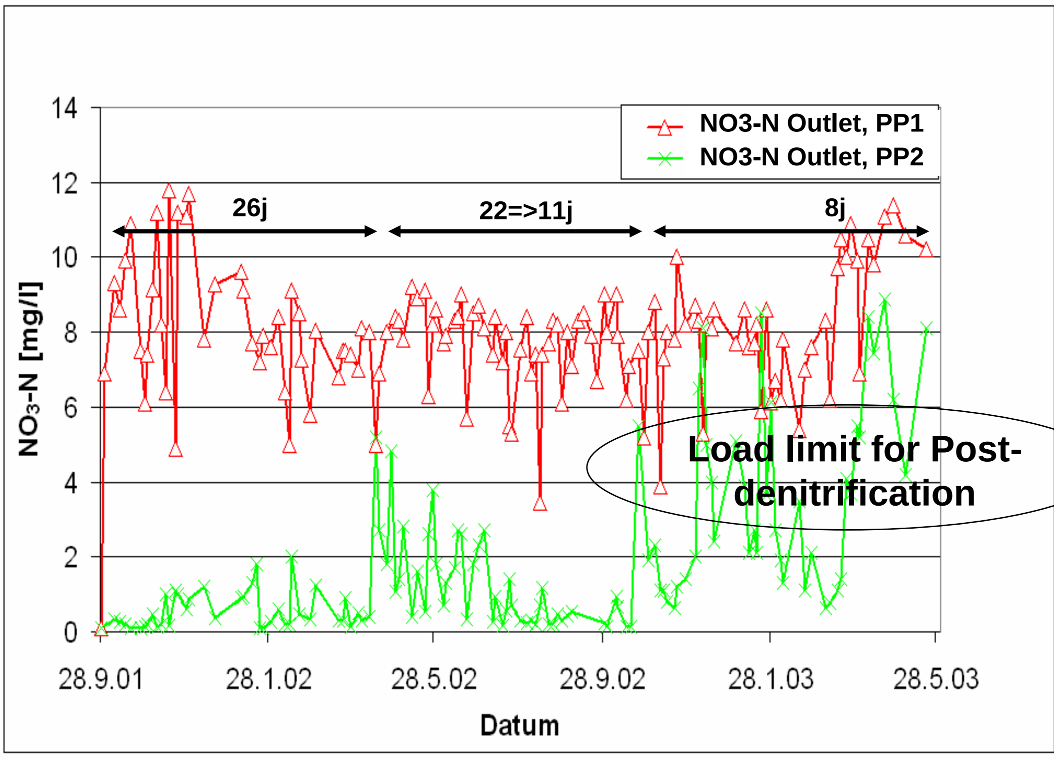
- Layout with two anoxic reactors:
  - DN-rate with 0.9 – 2.0 mgN/gVSS/h
  - DN-Rate from Pilotplants proven
  - Carbon source still unknown and under investigation
  - Nitrate removal not always sufficient due to overload of the biological step



Anoxic zone

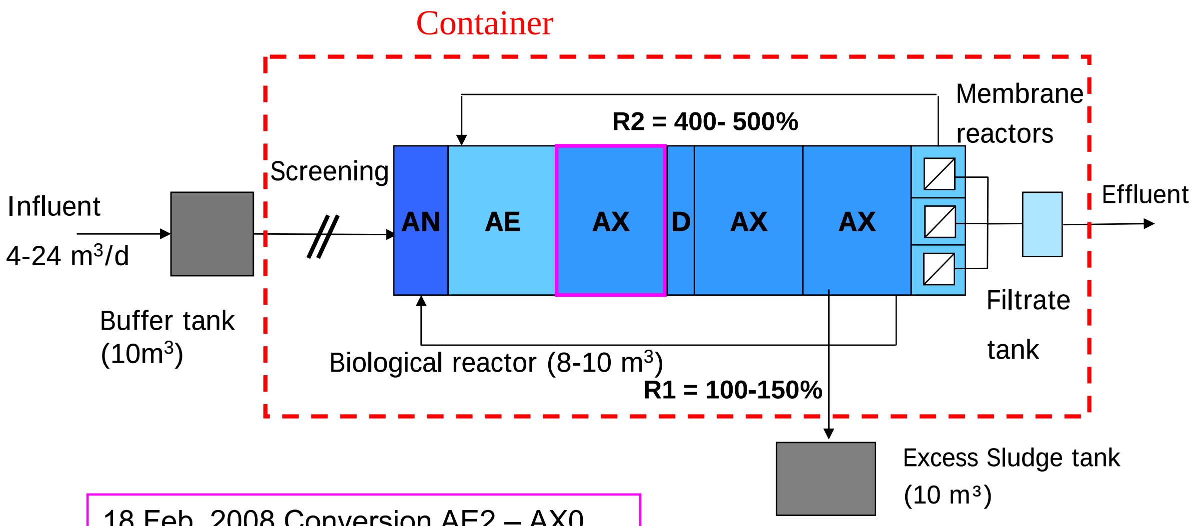
Nitrate removal (Ruhleben WWT)

ENREM



=7mg/L Ruhleben WWTP

Process overview



18 Feb. 2008 Conversion AE2 – AX0

Berliner Wasserbetriebe

KOMPETENZZENTRUM Wasser Berlin

VEOLIA WATER ANJOU RECHERCHE

33. OPERATIONAL EXPERIENCES WITH THE HYBRID MBR HEENVLIET, A SMART WAY OF RETROFITTING

J.W. Mulder

Operational experiences with the hybrid MBR Heenvliet, a smart way of retrofitting

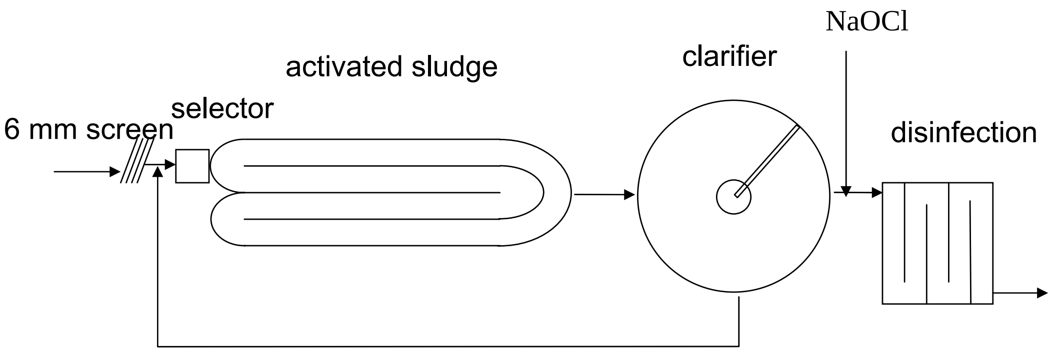
Jan Willem Mulder
Water Authority Hollandse Delta

(Final MBR-Network workshop, Berlin, 31st March 2009)

waterschap Hollandse Delta

Content

wwtp Heenvliet, old situation



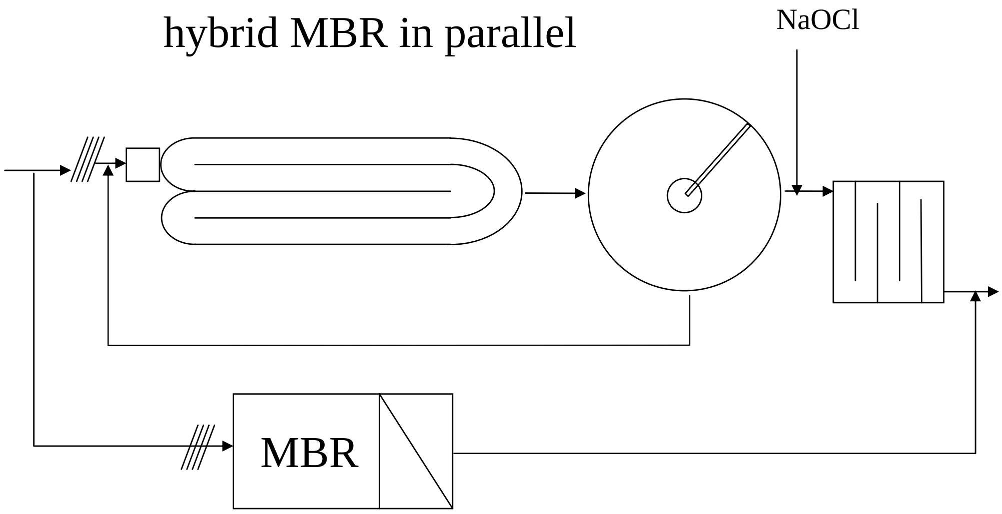
capacity: 9,000 p.e.
420 m^3/h

project objectives

- Upgrade wwtp for future growth of wastewater quantity
- Improvement effluent quality
  target for N-total: 5 / 2.2 mg/l
  target for P-total: 0.3 / 0.15 mg/l
  E-coli: < 20/ml
- Contribution to MBR development for domestic wastewater treatment
- Own experiences with new technologies
- Hybrid MBR as model for upgrading of wwtp's

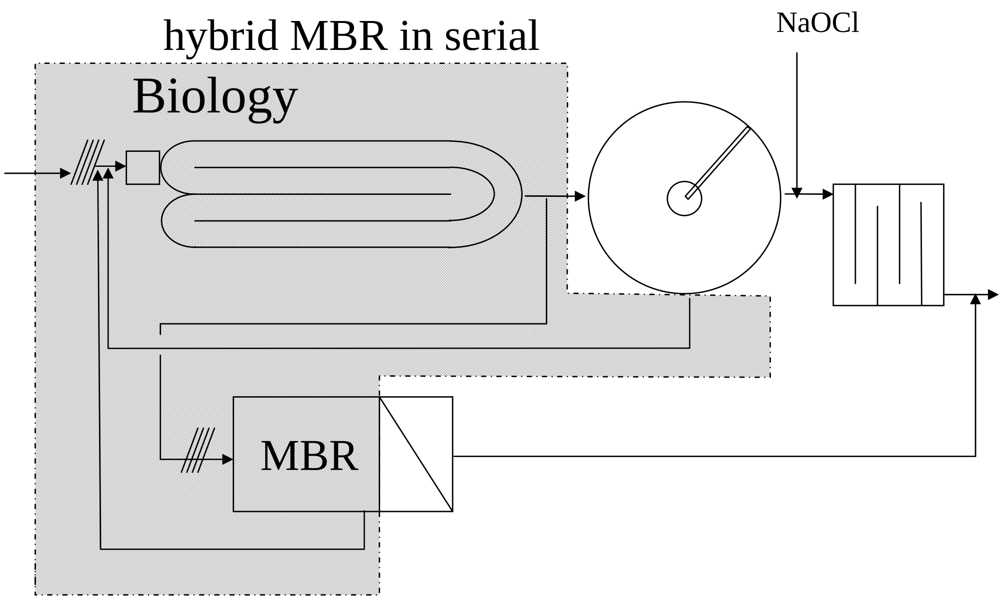
Options for wwtp upgrading 1

hybrid MBR in parallel



Options for wwtp upgrading 2

hybrid MBR in serial



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advantages option 2

- Only one biological system
- flow splitting to membranes and clarifier independant from the biological performance
- More water treated by membranes; better use of the membranes
- More water treated by membranes; better mixed effluent quality

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disadvantages option 2

- Higher average load to the membranes, what about membrane fouling?
- Sludge quality requirements for both membrane filtration and for sedimentation
- Complex proces control

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design hybrid MBR Heenvliet

- 9,000 pe ⟶ 13,000 pe
- 420 m3/h ⟶ 400 m3/h
- Max. flow to the membranes: 100 m3/h
- Toray flat sheet membranes
- material: PVDF; pore size 0.08 μm
- flux: 24.3 mlh
- 3,000 FS elements, divided over 16 modules in 2 membrane tanks
- max flow to clarifier: 300 m3/h; improvement of performance

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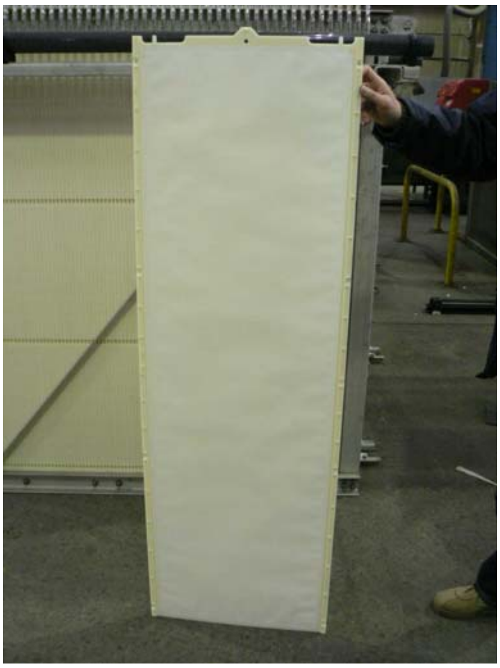

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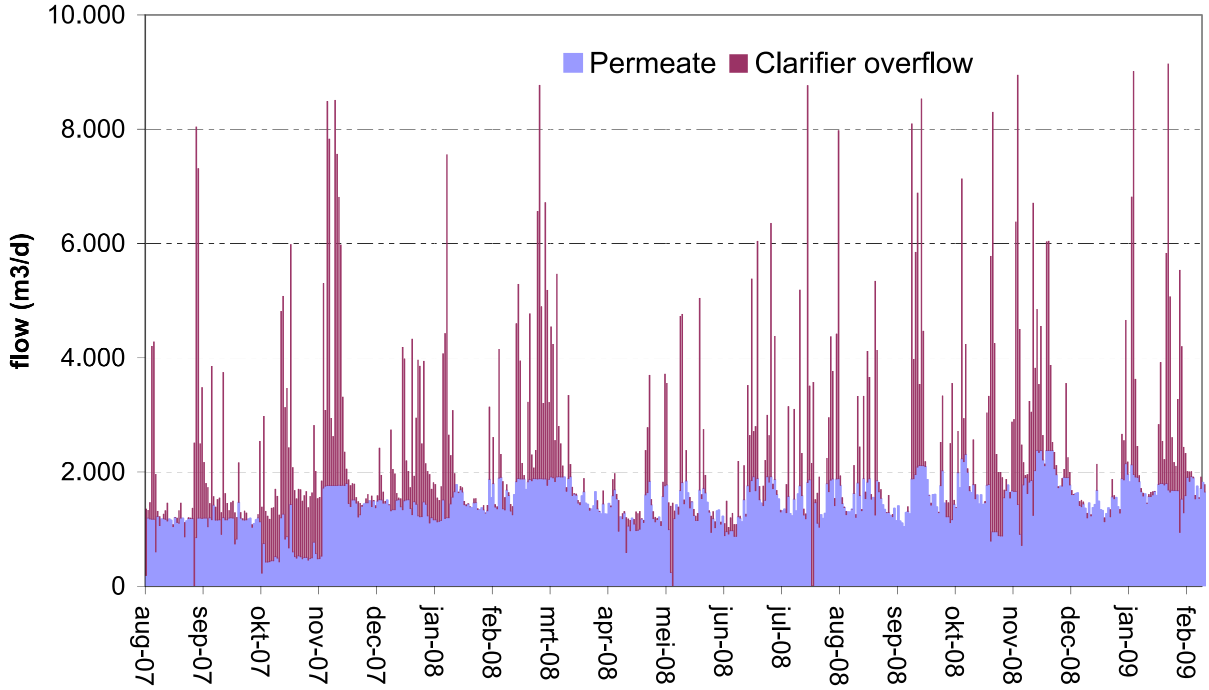
results hydraulic



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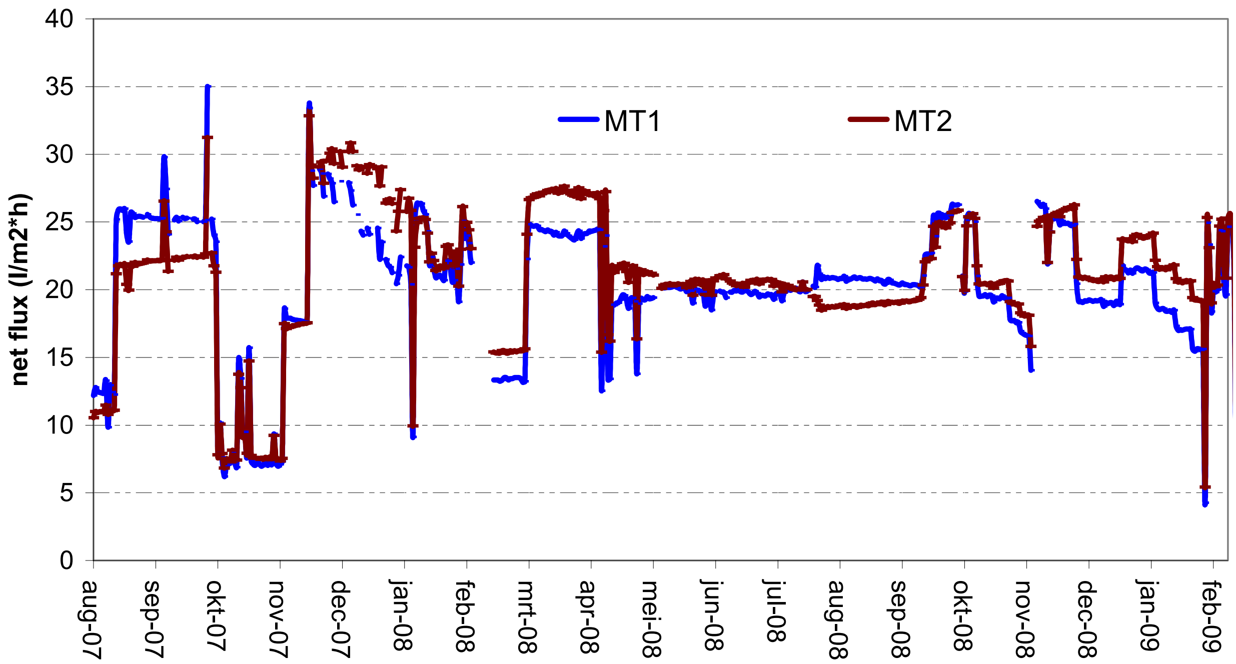
results, membrane performance



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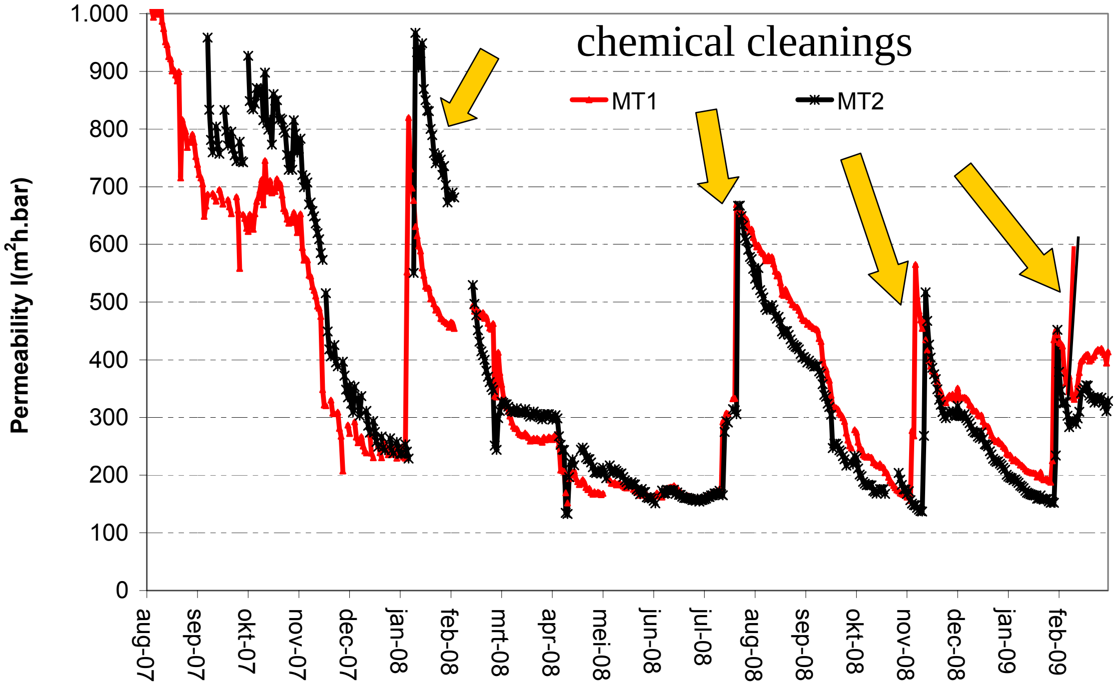
Results: permeability normalized to 15°C



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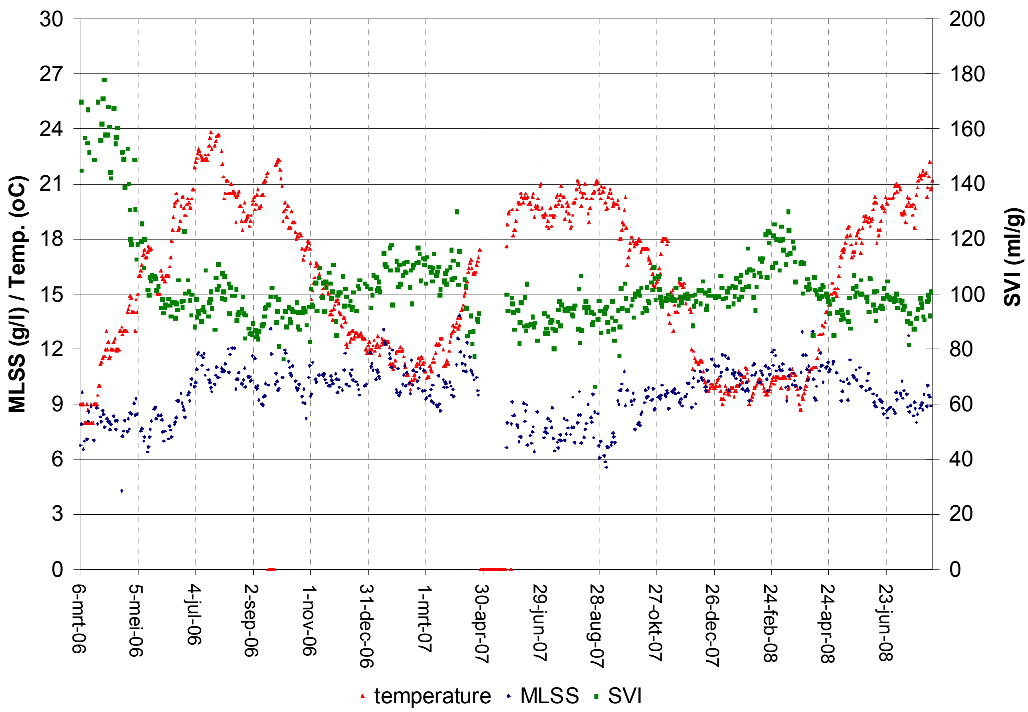
Results: sludge quality



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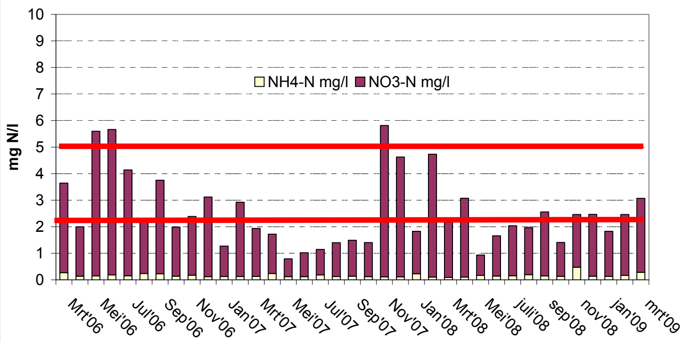
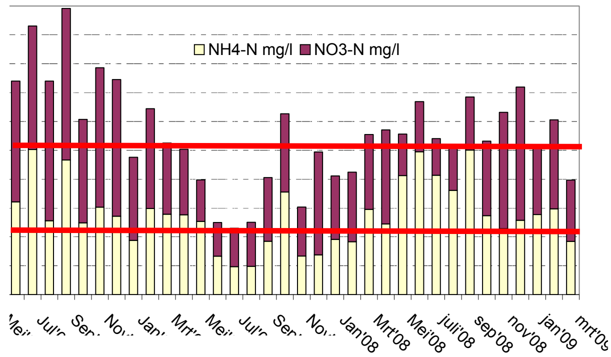
results: N removal

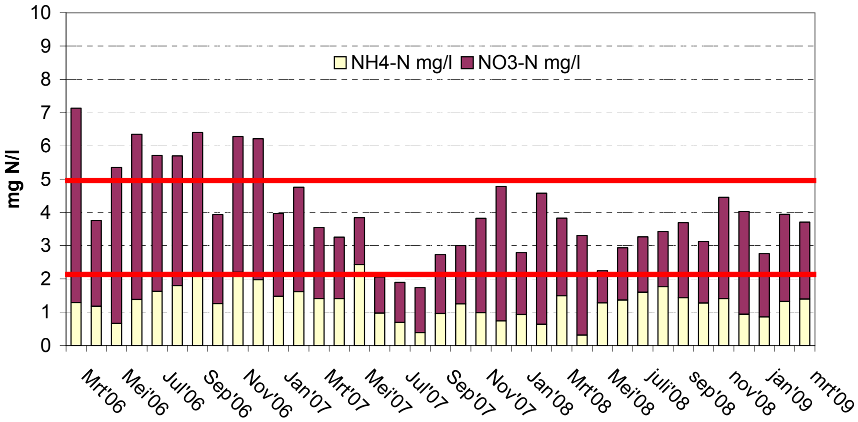
permeate



clarifier



mixed effluent



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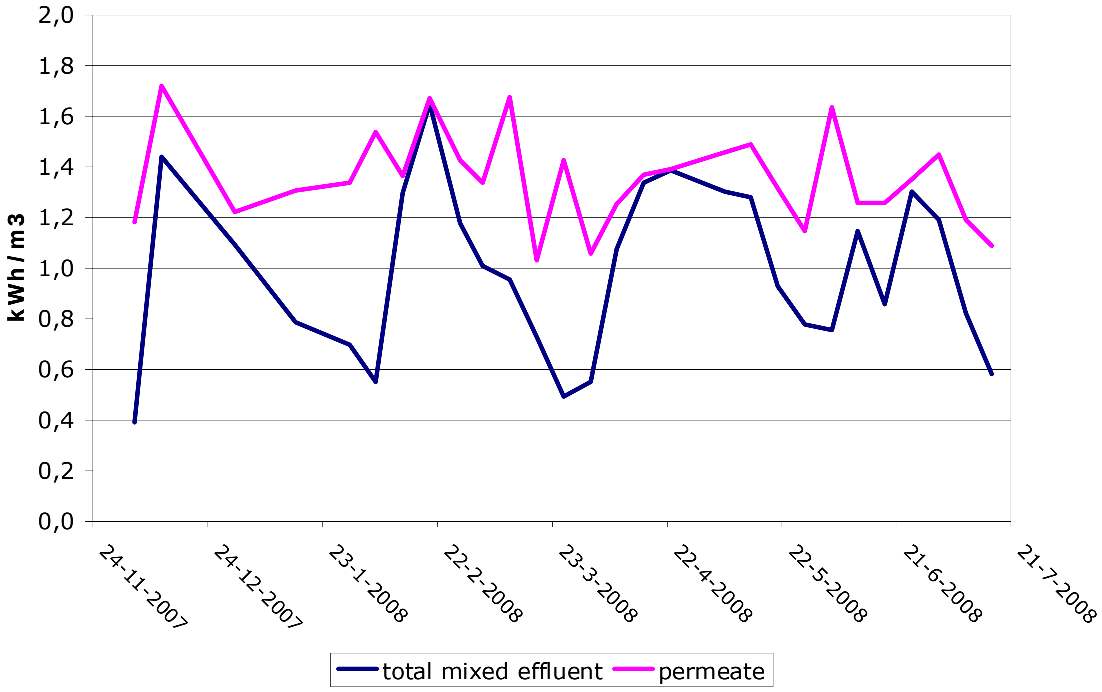
Energy consumption



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Energy: possible optimizations

- Membrane aeration
  0.45 Nm^3/m^2*h ⟶ 0.3 Nm^3/m^2*h ⟶ ??
- On/off aeration in membrane tank
- Further optimizations in the biology
- Increasing the flux

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Conclusions

- Good performance, but at relative low permeability
- Equilibrium in permeability dependant on performance
- Low frequent chemical cleaning
- The concept with one biology in two tanks need several optimizations
- Energy consumption need further optimizations

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The success of the hybrid MBR

After the Heenvliet project 2 more hybrid MBR projects in the Netherlands

- wwtp Ootmarsum
  by Water Authority 'Regge & Dinkel'
  (2007)
- wwtp 'de Drie Ambachten', Terneuzen
  Water Authority 'Zeeuws Vlaanderen' and Evides Water Company (2009)

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Acknowledgement

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EUROMBRA is part of the MBR-NETWORK Cluster

More info: www.mbr-network.eu

34. CHALLENGES AND POTENTIALS OF BIOFILM-MBR FOR MUNICIPAL WASTEWATER TREATMENT

T.O. Leiknes, J. Phattaranawik, I. Ivanovic

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Challenges and potentials of biofilm-MBR for municipal wastewater treatment.

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Outline

1. BF-MBR concept
2. Treatment performance / capacities
3. Limitations – fouling
4. Development strategies of the BF-MBR concept
5. Illustration of three alternative system designs
6. Summary and conclusions

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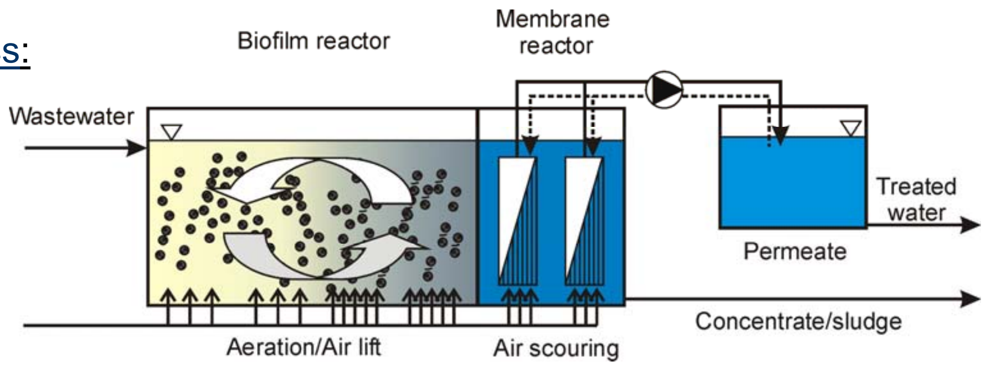
BF-MBR concept

Concept:

Biofilm process	→	**Membrane process**
SCOD		PCOD

Process:



- One-step biological degradation – biological reactor configuration
- Design membrane reactor for enhanced particle removal
- Reduce MLSS concentration in influent to membrane reactor
- Reduce foulants in membrane reactor, i.e. colloidal fraction
- Enhanced performance, i.e. fouling control in membrane reactor

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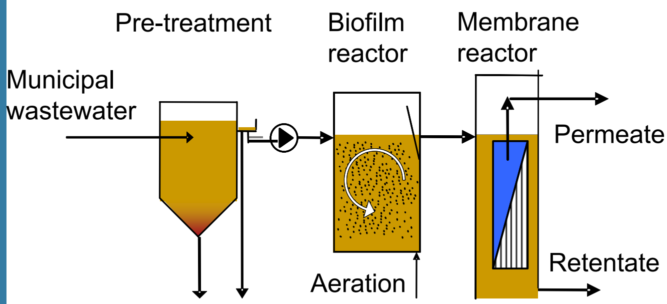
BF-MBR applied to municipal wastewater

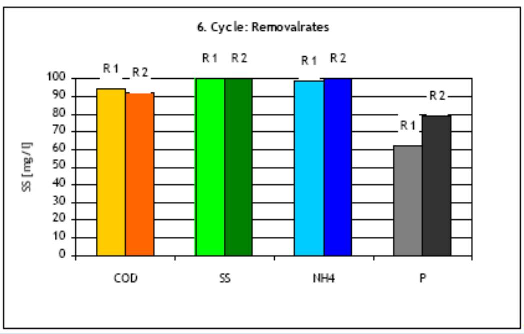
Pilot plant setup:



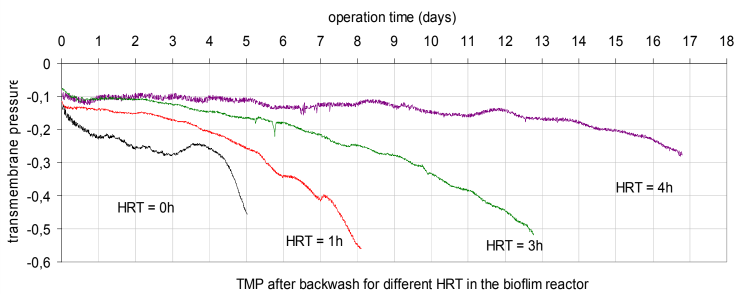
Operating conditions:

- varying organic loading rates
- varying suspended solids loads
- flux range: 35-60 LMH
- varying aeration intensities
- recoveries > 95%

Treatment efficiencies:



Membrane performance:



TMP after backwash for different HRT in the bioflim reactor

Identification of dominant foulants in BF-MBR

Biomass characteristics

EPS
- bound
- free (SMP)

• polysaccharides
• proteins

Bioflocs
- size distribution
- structure

• colloids
• filterability

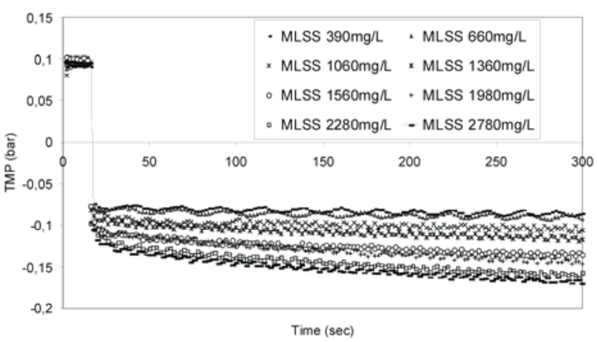
• what is significant?
• what dominates?

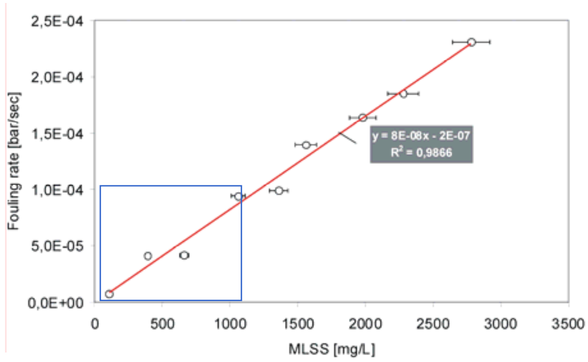
In BF-MBR results indicate that;

• suspended solids and particulates appear to dominate

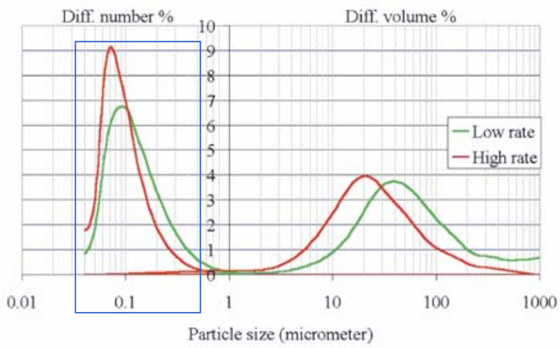
• particularly the colloidal fraction is seen to impact performance

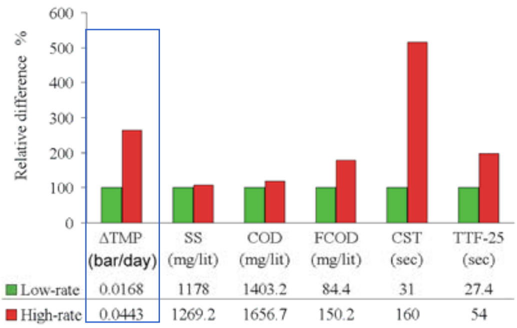
1. Suspended particles – MLSS - *range* > 1,2 µm





2. Colloidal particles – PSD number % - *range* 0,04 -1,2 µm





Advantages of BF-MBR over AS-MBR

Potentials of the BF-MBR:

- Very low suspended solid concentrations in BF-MBR
- Control of solid retention time (SRT)

Resulting in:

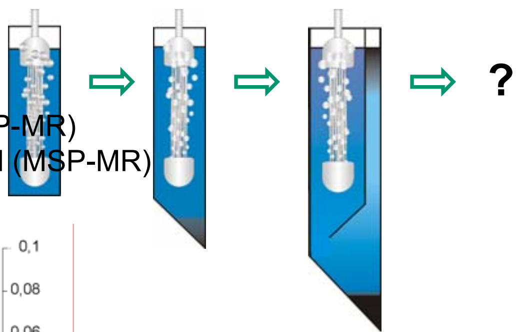
1. Enhanced fouling control by air scouring / hydrodynamics
2. Less problems with membrane clogging and plugging
3. Great flexibility for the process design: biological location and hydrodynamic arrangement etc.
4. Low viscosity: lower energy consumption for aeration
5. Higher membrane packing densities possible – more compact
6. Potentially less energy demanding

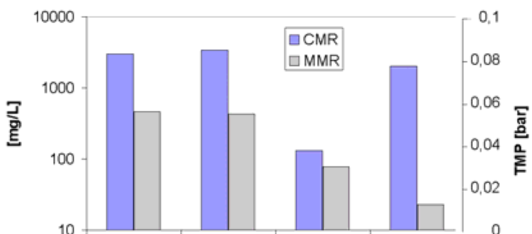
Developement strategies for BF-MBR (1)

Development of membrane module / filtration unit:

- alternative filtration unit design / operation
- integrated designs for enhanced particle removal / solids control

Completely mixed reactor (CM-MR)
CM with sludge pocket (SP-MR)
modified SP-CM (MSP-MR)





	MLSS (mg/L)	COD (mg/L)	FCOD (mg/L)	dTMP/dt (bar/cycle)
CMR	3010	3402	131	0,0769
MMR	462	432	78,4	0,0119

Example of impact on unit design / operation

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Developement strategies for BF-MBR (2)

Development of integrated process configurations:

- suspended solids management – reactor design / operating modes
- "hybrid" processes – integrating alternative reactor options
- low TSS from bioreactor to membrane unit
- keep and remove excess sludge in the bioreactor

Three BF-MBR processes investigated within Eurombra

System I. Aerated moving-bed biofilm integrated with thickener design as double-deck biofilm reactor.

System II. Aerated moving-bed biofilm integrated with floating-bed anaerobic biofilm reactor.

System III. Aerated moving-bed biofilm integrated anaerobic biofilm with bubble-driven mixing device and integrated with thickener design.

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System I - Double-deck aerobic biofilm MBR

Objective:
Aerated moving-bed biofilm integrated with thickener design

Development goals:

- Reduction of membrane clogging problem potential
- Keep and remove excess sludge in biofilm reactor
- TSS in effluent from the bioreactor : 30-80 mg/L
- Reduce / control membrane fouling
- Investigate new FS module design

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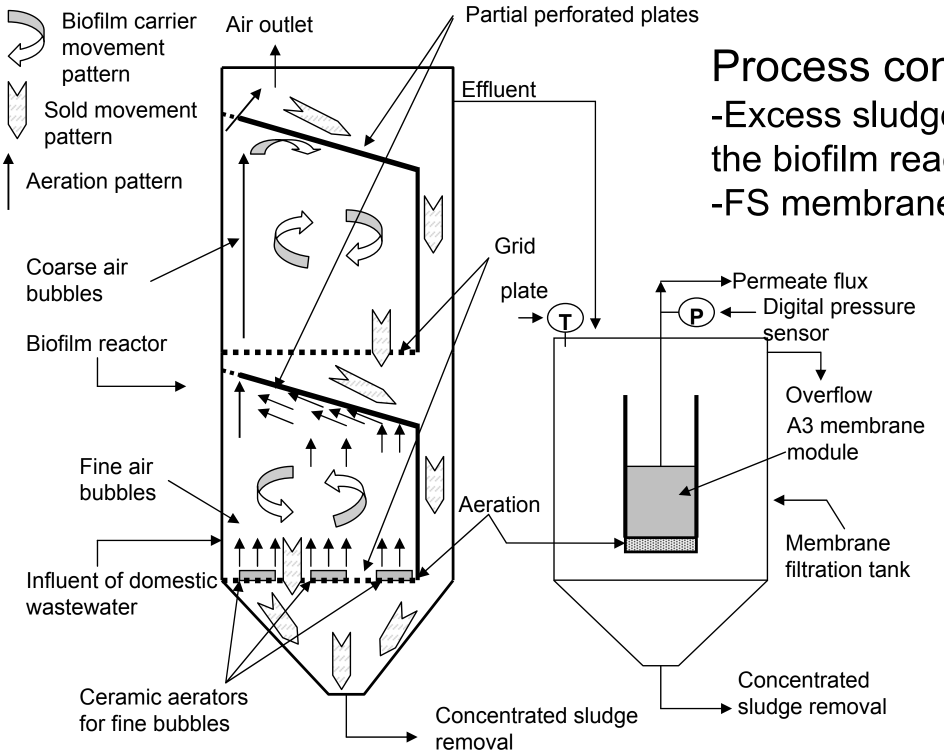


Process configuration

-Excess sludge removed from the biofilm reactor

-FS membrane module

Membrane module applied in investigation:

-FS membranes supplied by partner A3.

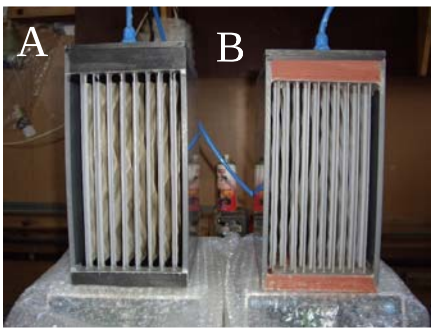
-Two modules designs compared and evaluated

- standard module for AS-MBR
- modified module for the BF-MBR

-Membrane filtration performance and clogging assessed

Potential benefit:

- Less clogging → increase membrane packing density
- Improved hydrodynamics → less energy for air scouring



A: A3 module for AS-MBR: 7 mm gaps

B: A3 module for BF-MBR: 4 mm gaps

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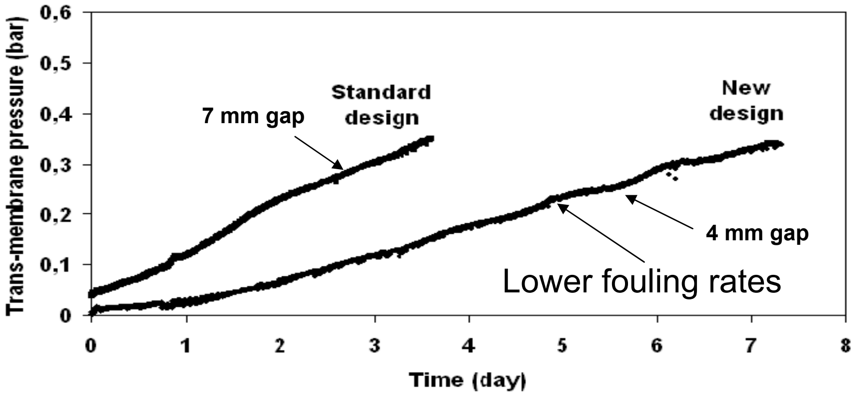
System I – results:

Comparison of the two modules:



- operating conditions; flux 18 L/m^2·h, aeration of 32 L/min
- average TSS; in influent – 44.6 mg/l, membrane tank 100-140 mg/L
- fouling (dTMP/dt); 0.086 bar/day, 0.046 bar/day new design
- superficial air velocity increased by 50%
- modified module occupied 35% less space

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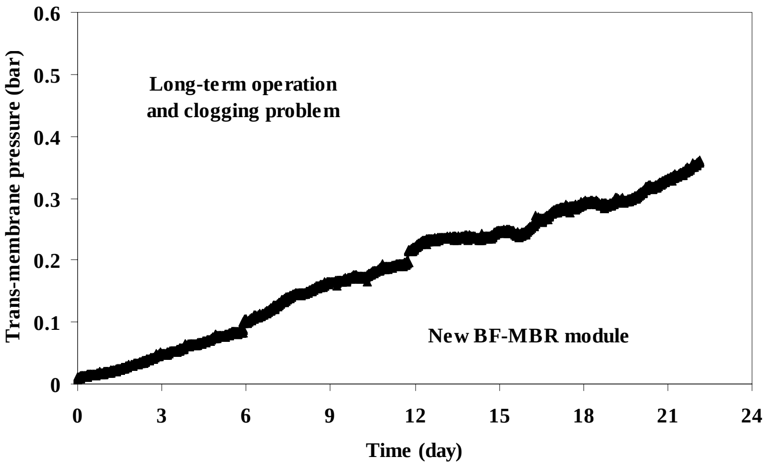
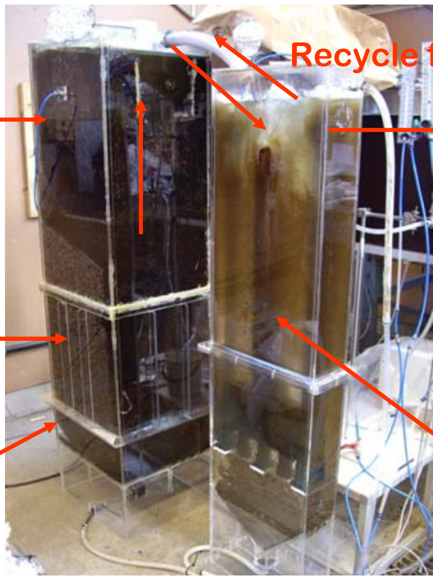
Membrane clogging test for long-term operation:



- Linear TMP development found
- No membrane clogging in the new 4 mm gap module

System II - Aerobic-anoxic biofilm MBR with energy recovery unit

Objective:
Integrated thickener design, bubble-driven mixer in anoxic zone



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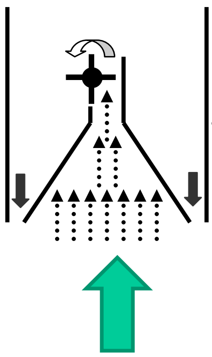
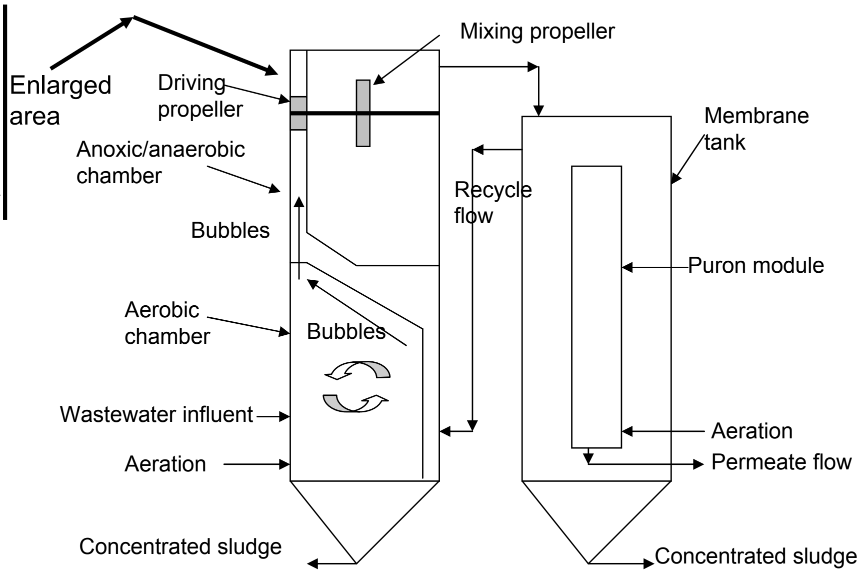
Process configuration for System II



Primary drive unit as the aeration energy recovery unit



Excess sludge removed from the biofilm reactor and membrane tank to control TSS

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Membrane module applied in investigation:

-Membrane module supplied by partner KMS, Puron.

-Membrane filtration performance and clogging assessed

- TSS in effluent from the bioreactor: 20-50 mg/L.

-Membrane clogging problem was not found for long-term test.

-The removed concentrated sludge for sludge disposal has concentration of ~ 15 g/L.

-The rotating speed of mixer ~ 55 rpm.

-Operating conditions; flux 21 L/m^2·h, aeration of 9.5 and 19 L/min

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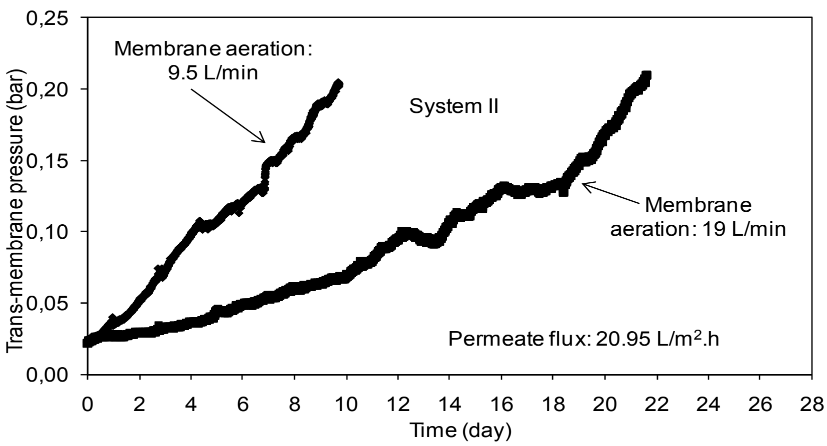
System II - results

Effect of membrane aeration intensity:



Average fouling rates

- 0.019 bar/day at aeration rate 9.5 L/min (2 cm/s superficial air velocity)
- 0.0091 bar/day at aeration rate 19 L/min (4 cm/s superficial air velocity)

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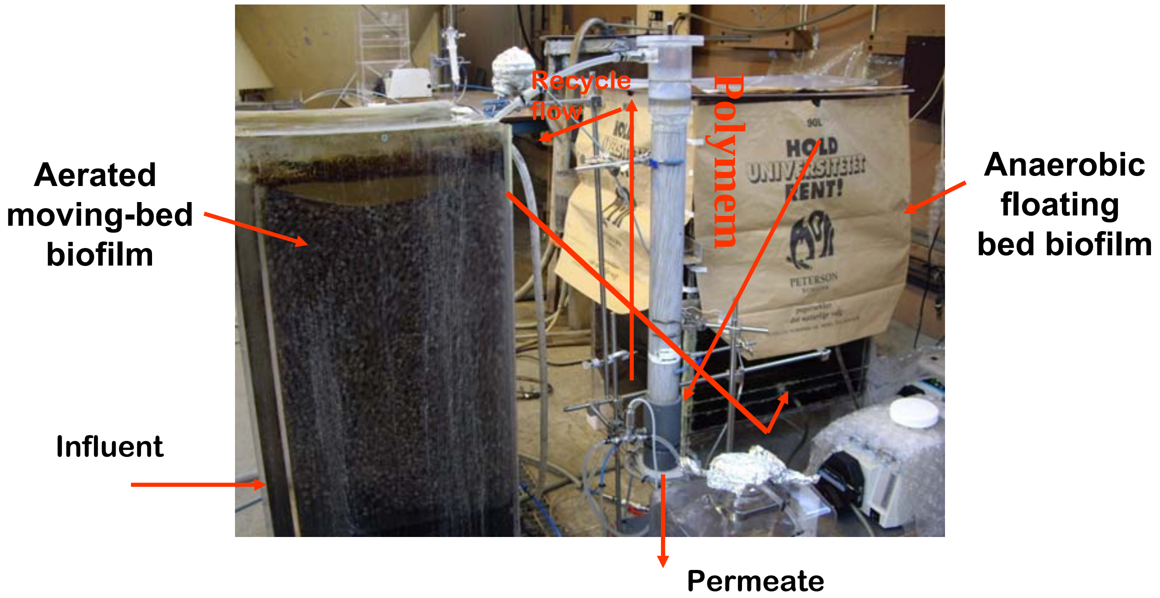
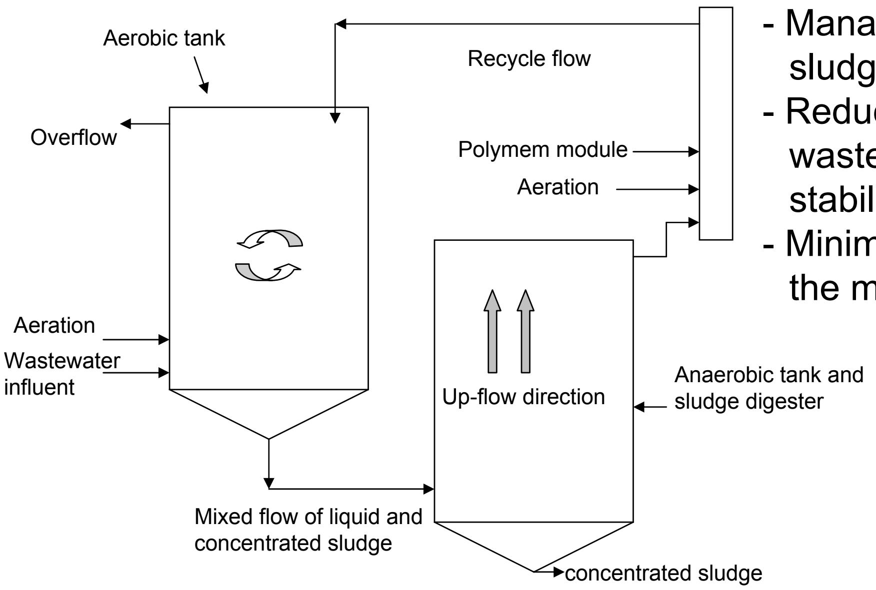
System III - Aerated moving-bed biofilm with floating-bed anaerobic biofilm

Objective:
Sludge management, anaerobic sludge stabilization



Process configuration for System III

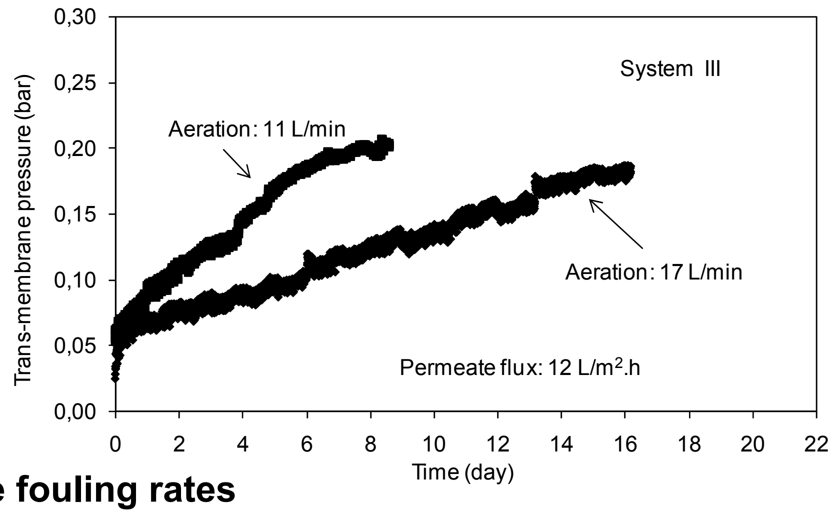


- Management of the excess sludge
- Reduction of excess sludge waste by anaerobic sludge stabilization concept.
- Minimize TSS in the flow to the membranes:

System III - results

Membrane module applied in investigation supplied by partner Polymem

Effect of membrane aeration intensity:



Average fouling rates

- 0.02 bar/day at aeration rate 11 L/min (5 cm/s superficial air velocity)
- 0.012 bar/day at aeration rate 17 L/min (8 cm/s superficial air velocity)

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Conclusions

Potentials of BF-MBR

- New and flexible process configurations possible
  - Alternative strategy for solids control and management
  - Lower suspended solids load on membrane
  - Minimal clogging/sludging problems
  - Enhanced membrane performance / less fouling
  - Lower energy requirements (overall)

Challenges of BF-MBR

- Understanding membrane fouling
- Process control and optimization
- System complexity and interdependence

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Acknowledgement

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Contract No. 018480 - EUROMBRA

Duration: 01/10/05 - 31/05/09

EUROMBRA is part of the MBR-NETWORK Cluster

More info: www.mbr-network.eu

35. ANAEROBIC MEMBRANE BIOREACTOR FOR DOMESTIC WASTEWATER TREATMENT

G. Gugliemi, D. Avesani, C. Cabassud, V. Yvenat, S. Pollet, O. Lorain, A. Schmidt, B. Pfaff, S. Pillay, K. Foxon, J. K. Bwapwa, C. Buckley

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MBR-Network
Final workshop
31st March – 1st April 2009
Berlin

Anaerobic Baffled Reactor - Membrane Combination

Sudhir Pillay, Joseph Bwapwa
, Kitty Foxon, Chris Brouckaert, **Chris Buckley**, *Diego Avesani, *Giuseppe Guglielmi, **Corinne Cabassud, Valentin Yvenat

University of KwaZulu-Natal, South Africa
*Università degli Studi di Trento, Italy
**INSA - Toulouse

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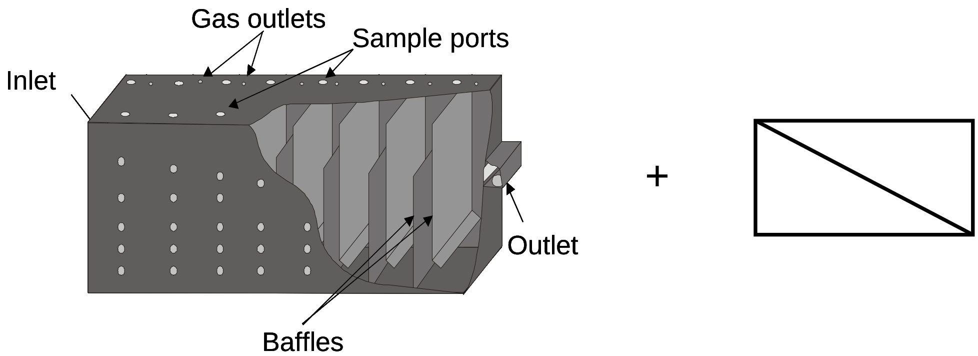
Aims

- Combine anaerobic baffled reactor with membranes
  - developing country context
  - no external energy, quiescent flow conditions
  - low per capita water consumption (50 L/d free basic water)
  - pour – flush toilets (using grey water)
  - decentralised system
  - reuse of pathogen-free water for urban agriculture
  - low biomass production and membrane operating conditions



Conditions

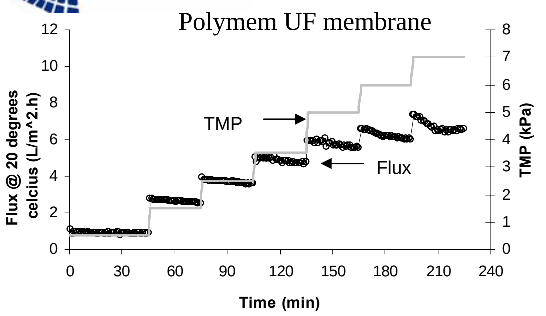
feed: solution made from pit latrine sludge

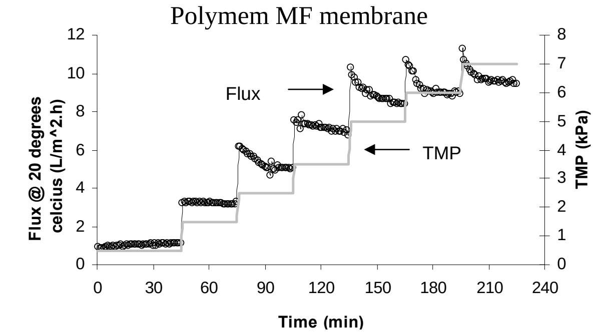
ABR: feed tank (200 L) + 4 baffled reactors (20 L each)

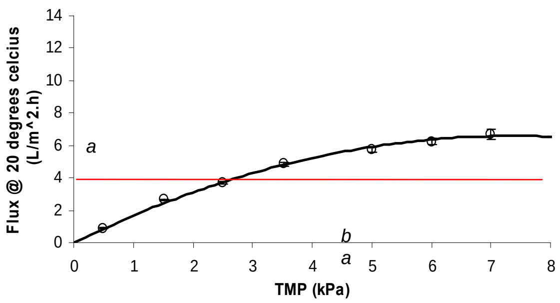
HRT: ~ 3 days

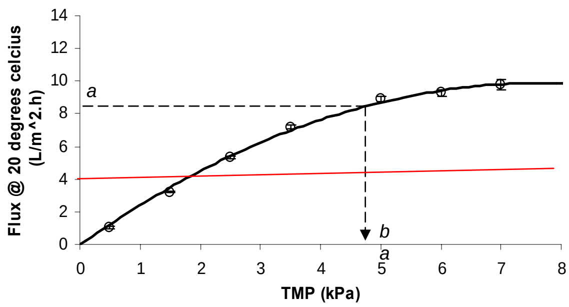
membrane: Polymem MF and UF modules

Membrane	Type	Area	Pore size	Model	Supplier
Ultrafiltration	Hollow-fibre	1 m^2	0.08 µm	UF2522 S3	Polymem, Fr.
Microfiltration	Hollow-fibre	1 m^2	0.20 µm	MF2522 S	Polymem, Fr.









Parameter	Raw Feed COD (mg/L)	Effluent COD (mg/L)	Effluent Removal (%)	MF COD (mg/L)	MF Removal (%)	UF COD (mg/L)	UF Removal (%)
$COD_{(total)}$	1 304 ± 101	234 ± 4	82	34 ± 8	86	18 ± 4	92
$COD_{(0.45\ \mu m)}$	391 ± 35	95 ± 14	76				

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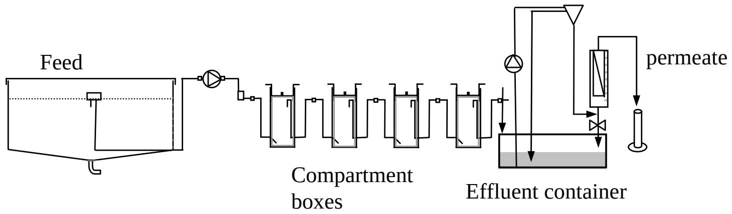
ABR-MBR Cleaning



	ABR			
	Operation (d)	**HRT (d)**	**Feed COD (mg/L)**	**Outlet COD (mg/L)**
Run 1	267	3	687	252 ★
Run 2	124	3	1 561	303
Run 3	32	2	1 036	310 ★
Run 4	28	2	1 500	334 ★
Run 5	20	3	2 000	457
Run 6	12	3	3 000	457 ★

★ TMP-Step experiments

Diapositive 5

92 Activated sludge tests not very replicable..as u can be by stdev curves...probably membrane near ned of its life. If u look at other tests where there was less membrane usage (AD sludge for example, 3 tests, achieve quite gud results, same with ABR effluent [C4 overflow if anyone asks]).
991239853; 05/12/2007

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Membrane Cleaning

Initial ("Virgin") Membrane Resistance (R_m)

↓

R_m after fouling (Fouling resistance)

↓

R_m after mechanical cleaning (tap water + distilled water rinsing)

↓

Is R_m significantly difference to Initial R_m?

↓

Decision → No → **Reversible fouling**

↓

Yes

↓

Chemical cleaning required

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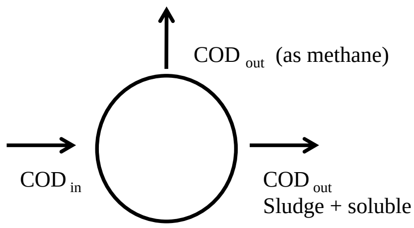
Membrane Resistance

	Stage of Filtration	MF (x 10^{12} m^{-1})	UF (x 10^{12} m^{-1})
Run 1	Initial 'Virgin' Membrane Resistance	3.62	3.62
	Pure water flux after TMP-step	3.65	3.64
	Mechanical Cleaning		
	Pure water flux before 4h filtration at 4 kPa	3.64	3.64
	Pure water flux after 4 h filtration at 4 kPa	3.66	3.67
	Mechanical Cleaning		
Run 3	Pure water flux after TMP-step	3.63	3.62
	Pure water flux after TMP-step	3.69	3.65
	Mechanical Cleaning + Chemical Cleaning (2000 ppm Chlorine for 1 h)		
Run 4	Pure water flux after TMP-step	3.60	3.60
	Pure water flux after TMP-step	3.61	3.60
	Mechanical Cleaning		
Run 6	Pure water flux after TMP-step	3.60	3.60
	Pure water flux after TMP-step	3.61	3.62

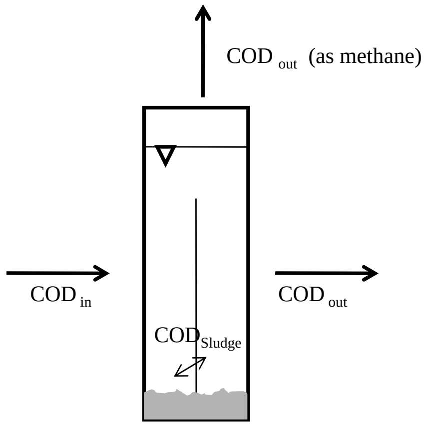
Anaerobic Sludge Production (1 of 3)

CSTR anaerobic digester



sludge production leaves the reactor with the effluent

The ABR does not operate in a steady-state mode.
It operates as a flow-through accumulation system



most of the produced sludge stays in the anaerobic compartments

Anaerobic Sludge Production (2 of 3)

The model is based on a steady-state modeling

- Kinetic part → predicts % COD removal and methane production
- Stoichiometry part → predicts the gas composition, effluent free and saline ammonia

a factor f is introduced which represents the fraction of S_{bp} and Z_{ad} that leave the reactor

From the model we know the biodegradeble particulate COD and Acidogen biomass in the effluent:

From the experimental data we know the Total COD in the effluent:

This means that we can know the unbiodegradeble particulate in the sludge

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Anaerobic Sludge Production (3 of 3)

		Average/ Median	Std Deviation	Number of observations	Min.	Max.
COD	in	688	204	202	246	1749
[mg COD/ℓ]	out	130	64	18	62	339
Alkalinity	in	256	38	190	142	369
[mgCaCO3/ℓ]	out	246	53	4	168	286
Ammonia	in	40	11	189	11	95
[mgN/ℓ]	out	51	23	10	20	90
VFA	in	33	34	4	0	79
[mgCH3COOH/ℓ]	out	nd				
pH	in	7.2		195		7.8
[Median value]	out	6.5		6	6.2	7.4

Sludge accumulation rate [kg dry solids/year]	
Model	Experimental data
52.74	60.70

The model seems able to predict the sludge despite the low numbers of experimental data and their high standard deviation

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Conclusions

- anaerobic biological system
- low TS in membrane compartment (10 to 50 mg/L)
  - anaerobic baffle reactor is a solids accumulating system
- long term operation at 400 mm water head
- simple water clean
- spend resources on membrane area not energy

Next Steps (mid 2009)

- municipality + Borda are installing a ***technical evaluation plant***
  - 84 houses
  - at a permaculture site
  - agricultural reuse (water + N + P)
  - evaluation of long-term flux + operating and maintenance requirements
- town planning objective
  - compact low-income housing

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More info: www.mbr-network.eu

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