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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 V – Novel European MBR technologies

24. ASSESSMENT PRINCIPLES FOR MEMBRANE AND MEMBRANE MODULE DEVELOPMENT: A CASE STUDY

S. Buetehorn, J. Kochan, C.N. Koh, T. Wintgens, D. Volmering, K. Vossenkaul, T. Melin

Assessment Principles for Membrane and Membrane Module Development: A Case Study

Final MBR-Network Workshop

"Salient Outcomes of the European R&D Projects on MBR Technology"
Berlin, Germany, March 31 to April 01, 2009

S. Buetehorn, J. Kochan, C.N. Koh, T. Wintgens, T. Melin
RWTH Aachen University

D. Volmering, K. Vossenkaul
Koch Membrane Systems GmbH (KMS)

Outline

- Introduction
  - Research objectives
- Materials and methods
  - Characteristics of the model fluid
- Results and discussion
  - Membrane characterisation
  - Cake layer formation and removal
  - Computational Fluid Dynamics (CFD)
- Conclusions

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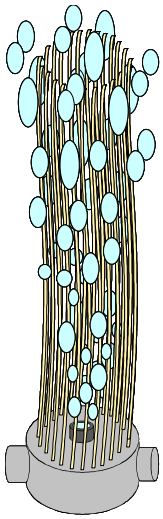
Research objectives

- Membrane characterisation
  - Impact of production conditions on membrane properties
  - Impact of membrane pore size distribution on long-term activated sludge filtration
  - Long-term stability of membrane coating (**MBR-Train**)
- Cake layer formation and removal
  - Cross-flow and submerged filtration tests
  - Impact of fibre movement and packing density
  - Cake growth and permeability distribution studies
- Computational Fluid Dynamics
  - Modelling of hollow-fibre membrane bundles
  - Phase distribution studies



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Characteristics of the model fluid

BINDZIL® (eka Akzo Nobel)

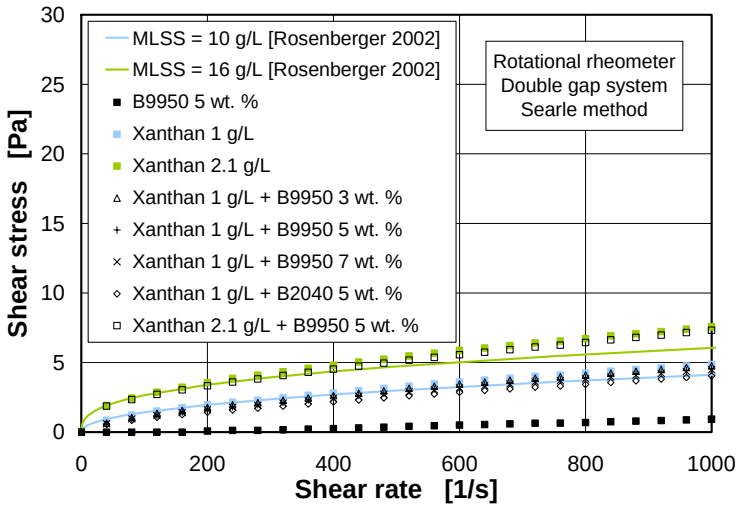
- Alkaline aqueous dispersion of colloidal silica (SiO_2)
- Amorphous spheres, slightly negative surface charge

B9950:

- d_{part} = 20 … 100 nm
- pH (stock) = 9.0

B2040:

- d_{part} = 7 … 25 nm
- pH (stock) = 10.0



Outline

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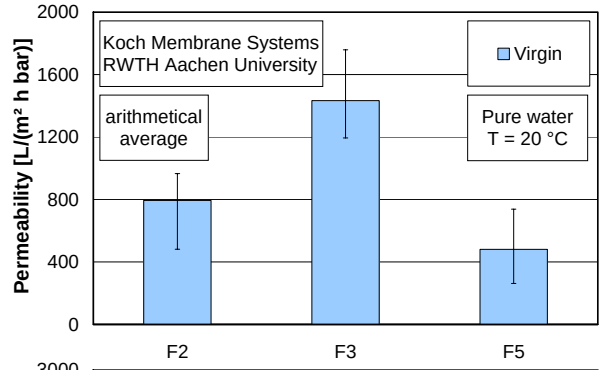
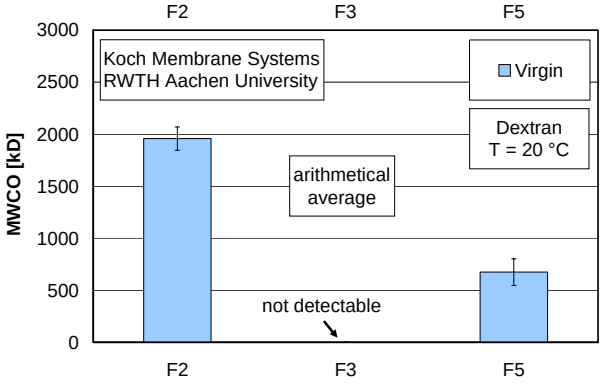
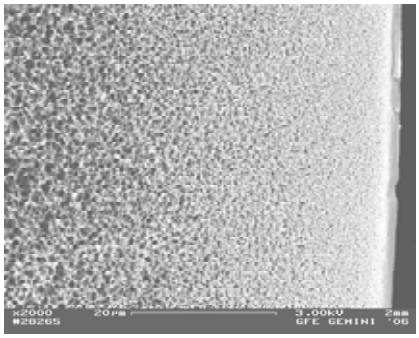
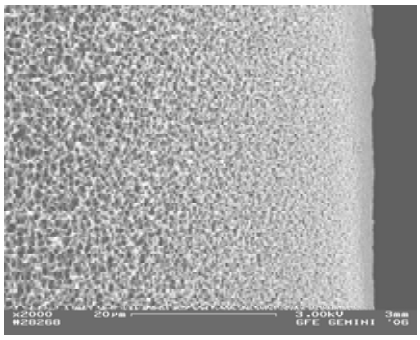
Membrane characterisation







F2



F3

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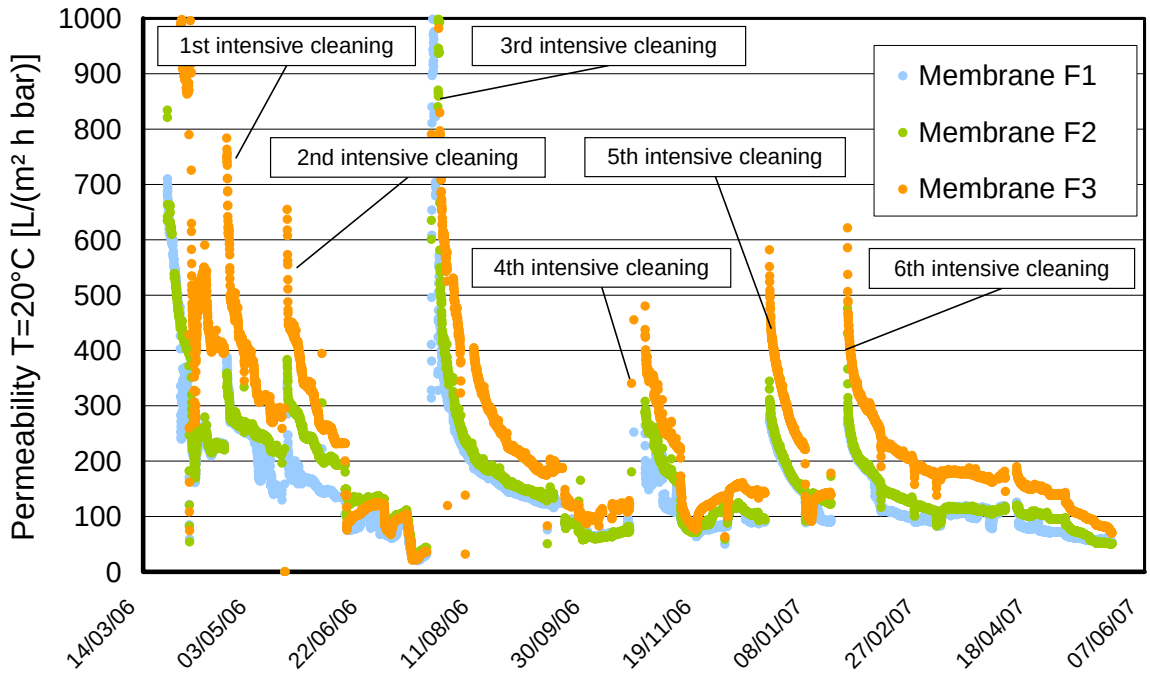
Long-term activated sludge filtration



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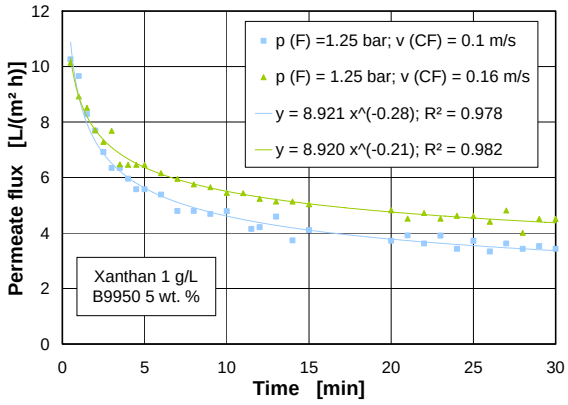
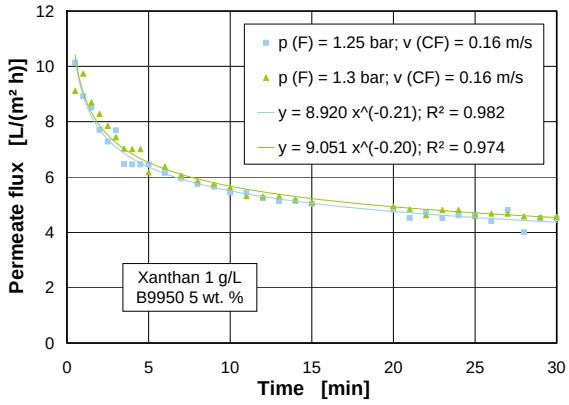
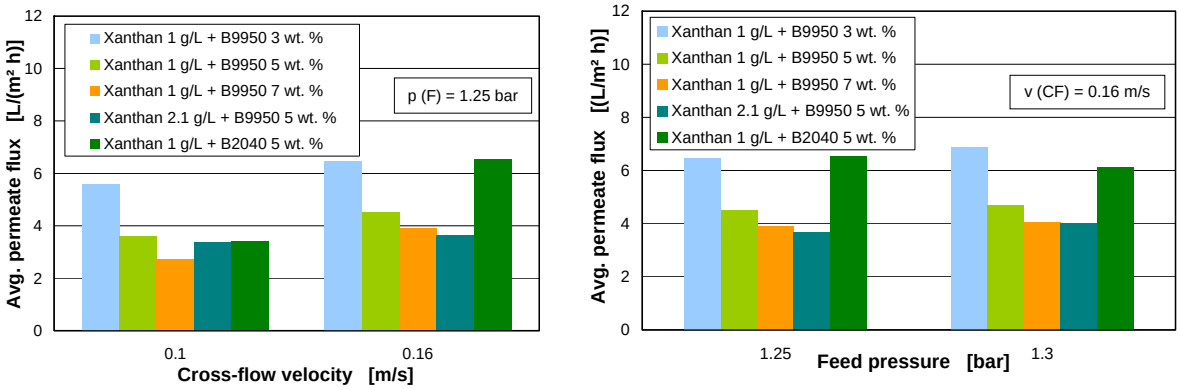
Cross-flow filtration: Operating parameters





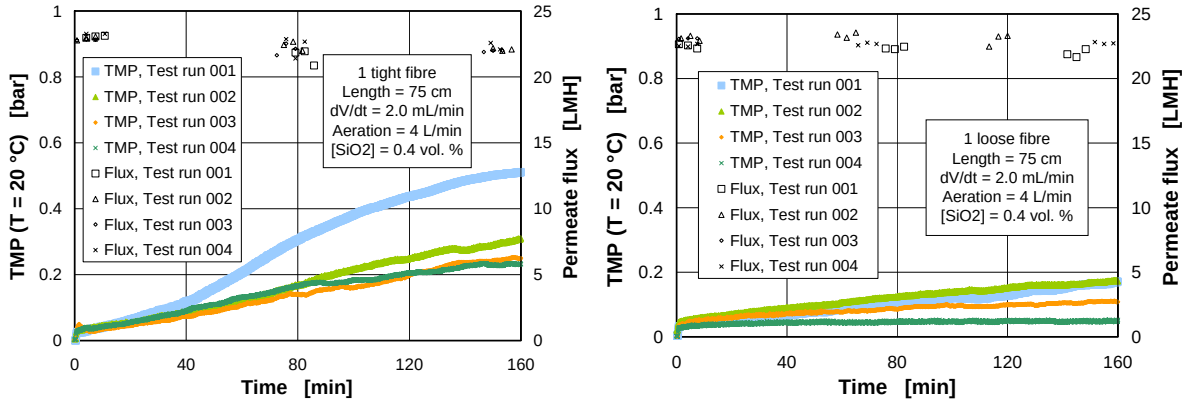
- Cross-flow velocity ↑ ⇒ Average permeate flux ↑
- TMP ↑ ⇒ Average permeate flux ↔

Cross-flow filtration: Impact of model suspension



- Solids concentration ↑ ⇒ Average permeate flux ↓
- Particle size ↑ ⇒ Average permeate flux ↓
- Dynamic viscosity ↑ ⇒ Average permeate flux ↓

Submerged mode: Impact of fibre movement



- Fibre movement ↑ ⇒ TMP ↓

Submerged mode: Fibre movement

- Direct observation with a conventional video camera:
  - Impact of fibre length, distance from the header, aeration rate, packing density and dynamic viscosity of the model suspension ...
- Subsequent image processing in MATLAB:
  - ... on the amplitude and frequency of the fibre motion.

Aeration = 4 (left) resp. 6 (centre) L/min. Right: Bundle with 4 fibres, aeration = 6 L/min.

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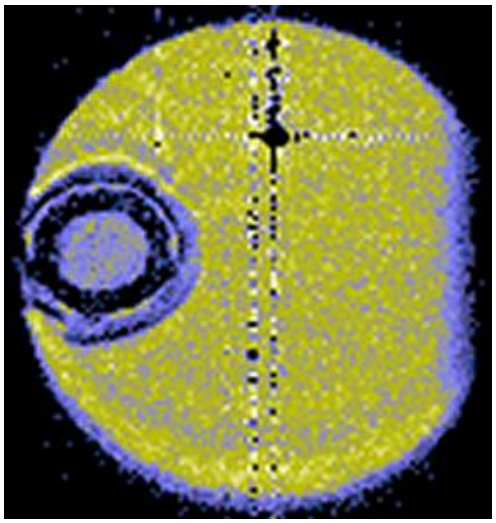
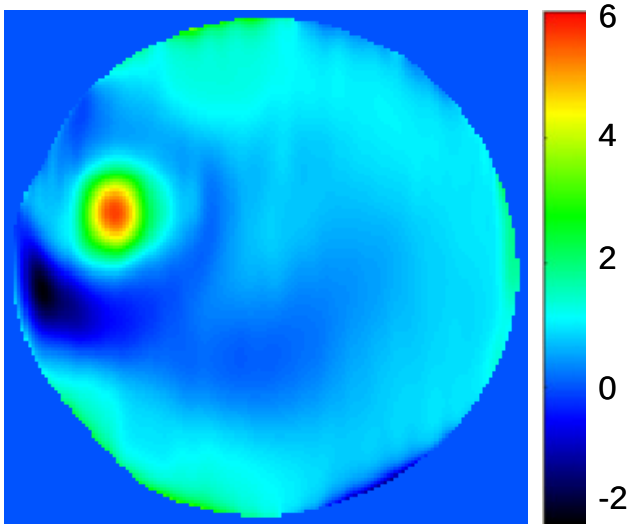
Nuclear Magnetic Resonance (NMR) imaging



Cake layer formation
(t ≈ 16 h)



Averaged vertical flow velocity
(v_{max} ≈ 5.6 mm/s)

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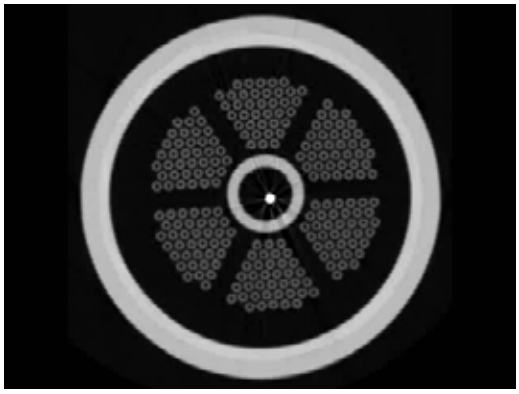
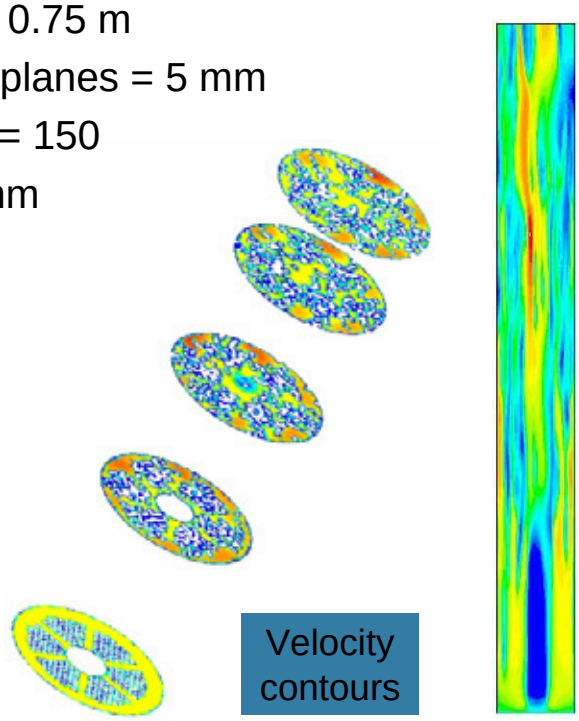
Computational Fluid Dynamics (CFD)

- Total length of scanned bundle = 0.75 m
- Distance between measurement planes = 5 mm
- Number of measurement planes = 150
- Inner diameter of the pipe = 80 mm

Instantaneous fibre displacement over the height of the bundle





Velocity contours

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Conclusions

- A lower concentration of chemical agents and a shorter residence time during the post-treatment of the membrane were leading to more open pore structures.
- Membranes with more open pore structures have shown better activated sludge filration performances.
- In cross-flow filtration at constant TMP, the long-term permeate flux is increasing with v (CF) ↑, c (solids) ↓, d (particle) ↓ as well as η ↓ and is independent of TMP variations.
- In submerged filtration at constant flux, the fouling rate is lower in case of higher aeration rates and more intensive fibre movement.
- Both the cake growth and the permeate flow at the membrane lumen were visualised with Nuclear Magnetic Resonance (NMR) imaging.
- X-Ray Computer Tomography (CT) was successfully used to represent the instantaneous displacement of hollow-fibres for CFD studies.

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Acknowledgements

- The authors would like to thank:
  - Bastian Mahr and Martin Behling, Leibniz University of Hannover, Germany
  - Daniela Tacke and Markus Kueppers, RWTH Aachen University, Germany
  - eka Akzo Nobel, Sweden/Germany
  - German Academic Exchange Service (DAAD)
  - **The Membrane Group at UNSW!!!**
- EUROMBRA is a research project supported by the European Commission under the Sixth Framework Programme (Priority “Global Change and Eco-systems”).
  - Contract number: EUROMBRA: 018480
  - Duration: 01/10/05 - 31/05/09 (extended)
  - EUROMBRA is part of the MBR-NETWORK Cluster
  - Internet: www.mbr-network.eu

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Thank you very much for your attention!

25. DEVELOPPEMENT OF NEW HOLLOW FIBER MODULES FOR MBR APPLICATION

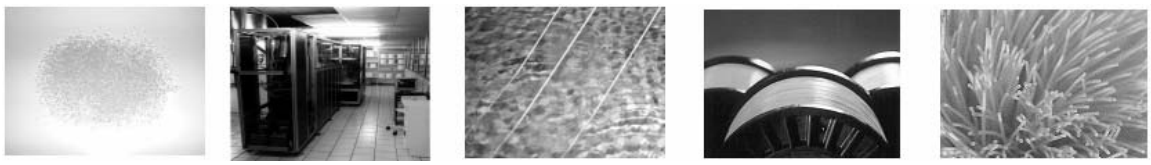
W. Bosq, F. Saux, J. M. Espenan, O. Lorain

Development of new hollow fiber modules for MBR application

W. Bosq, F.Saux, J. M. Espenan, **O. Lorain**
Polymem, Impasse de Palayre 31100 Toulouse France,
o.lorain@polymem.fr

Polymem activities overview

- Hollow fiber membranes manufacturer



- Modules manufacturer

- Water and wastewater treatment plant design and construction

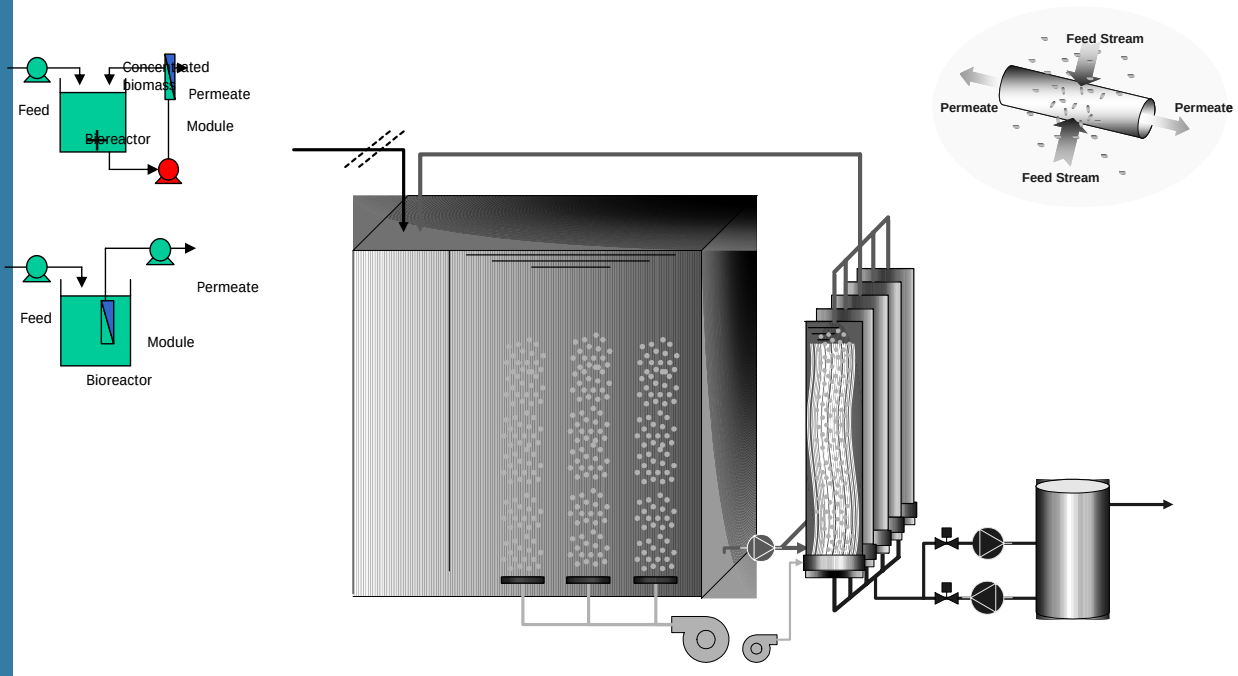
MBR-Network

Plan

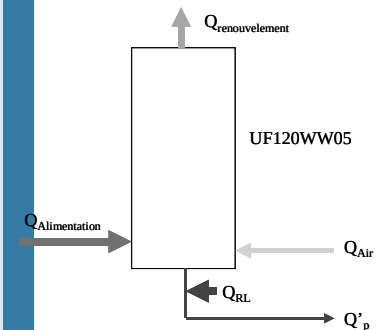
- Presentation of the design of the membrane module and the associated MBR process
- Objectives of the research activities + pilot plants overview
- Salient results of the research activities
- Conclusions and Perspectives

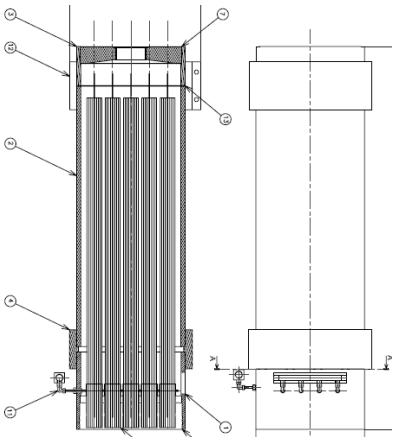
MBR-Network

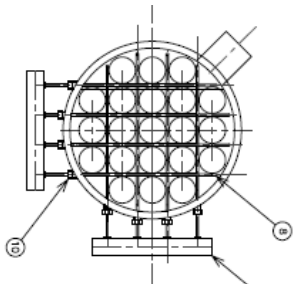
Presentation of the membrane module and the associated MBR process named Immem™



The choice of an innovative module geometry







- Membranes type = hollow fibers, PSU (pH 2-13, chlorine resistant)

- Membranes structure = homogeneous, not reinforced

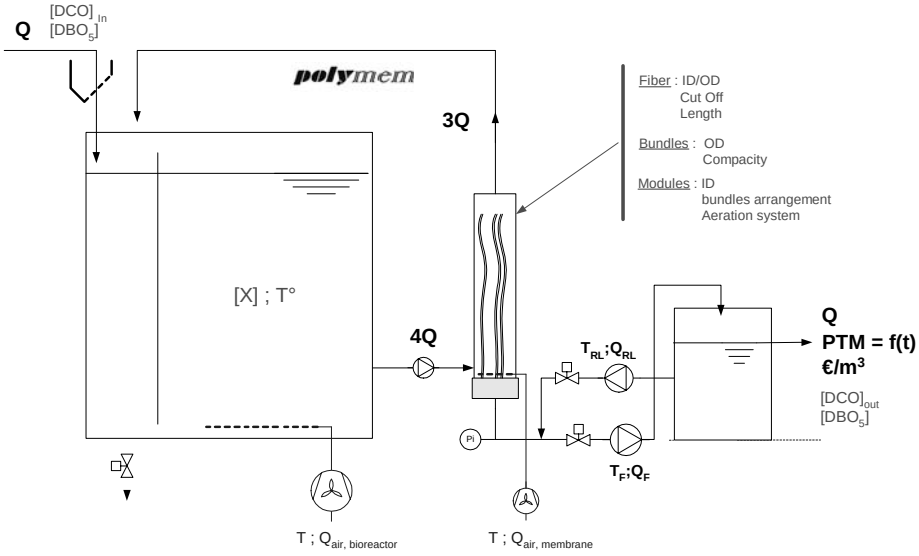
- High packing density 500, low price targeted = 50 €/m²

- Cut off : UF for easy surface cleaning and reuse perspective (RO ready), integrity was checked by Pressure Decay Test at 1 bar (3 microns breaches) to keep the membrane perfectly integer : no really needed now but would be in the perspective of reuse

Presentation of the membrane module and the associated MBR process named Immem™

- Advantages
  - Membranes in external carters
    - Easy membrane maintenance
    - Module handling
    - Safe maintenance for workers
    - High packing density 500 m²/m³, low cost of the module
  - Total independence between the bioreactor and the membrane filtration part
    - Plant retrofitting
    - Optimised and separated aeration systems for bioreactor and membrane air scouring
  - Better optimisation of the hydraulic around the membranes inside the cylindrical carter
    - Lower expected energy consumption compared to submerged cassette (SADm less than 0,25 m3/h.m²)
    - Chemical cleaning solutions and waste volumes limited at the small volume of the carters

Objectives of the research activities



? MEMBRANE parameters tested : fiber diameter OD 0.7 ; 1.4 and 2.5 mm
? MODULE parameters tested : bundles size and arrangement, module length
? PROCESS parameters tested : flux optimisation from 5 to 20 LMH and air scouring SADm from 150 to 500 l/h.m².

Our 4 pilot plants dedicated to module and Immem process development

Labège Pilot plant
equipped with a 7,5 m²
module

Twin Immem pilots equipped with 15 m² each

One full scale pilot pilot plant
equipped with modules from 50 m²
to 100 m², Salt Lake City Utah

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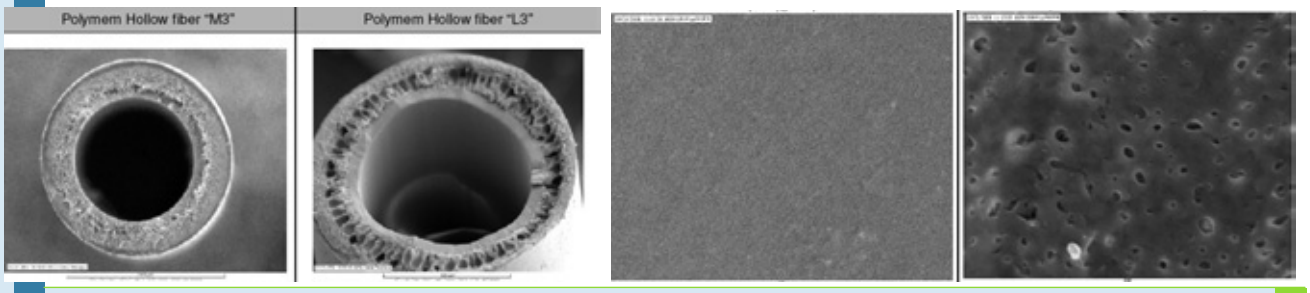
Salient results of the research activities

Membrane choice : fiber geometry 0.7 ; 1.4 or 2.5 mm?

Type of fibers tested	S 3	M 3	L 3
OD	0.72	1.4	2.5
Packing density m^2/m^3	1000	500	250
Mechanical resistance (burst strength)	1 N	3 N	10 N
Advantages	Costs, packing density	Medium	Mechanical resistance
Drawbacks	Mechanical resistance, good UF structure, no macrovoid	Medium	Low packing density, Costs, bad porous structure with macrovoid



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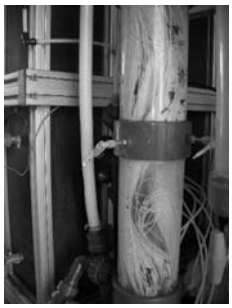
Salient results of the research activities

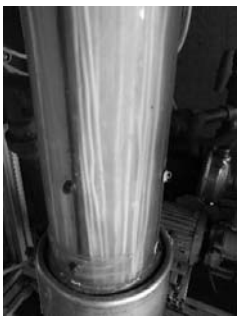
Membrane choice : fiber geometry 0.7 or 2.5 mm?

First point : cheap module 0.72 mm

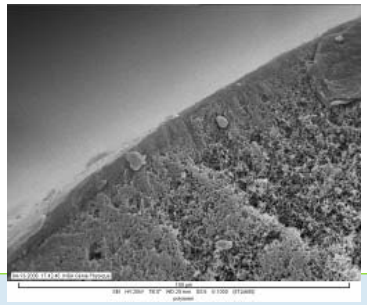
BUT Integrity issues

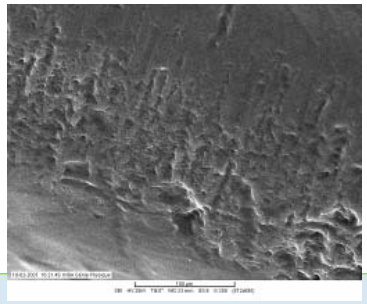


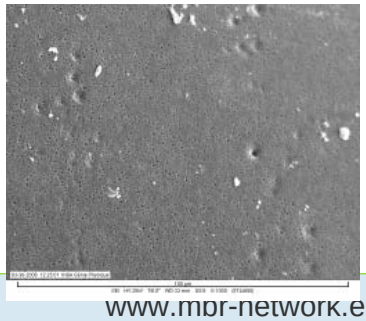
Better with Larger fiber



However even with larger fibers, surface layer erosion and particles impacts have been observed. Pictures taken on 1.4 and 2.5 mm hollow fiber.







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Salient results of the research activities

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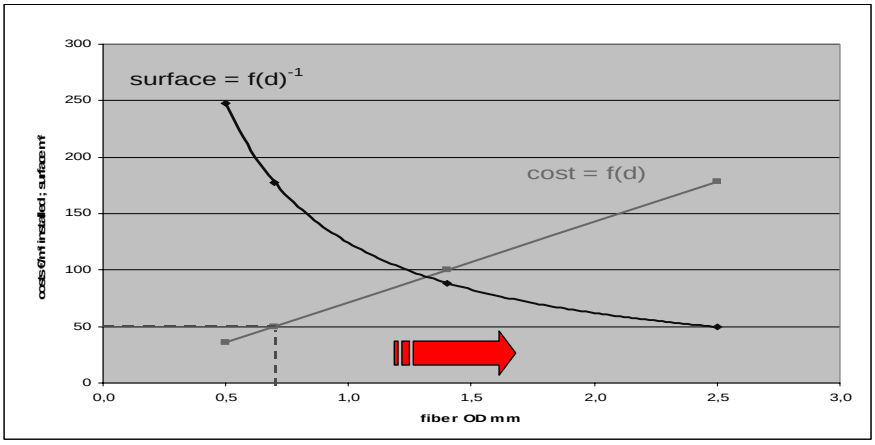

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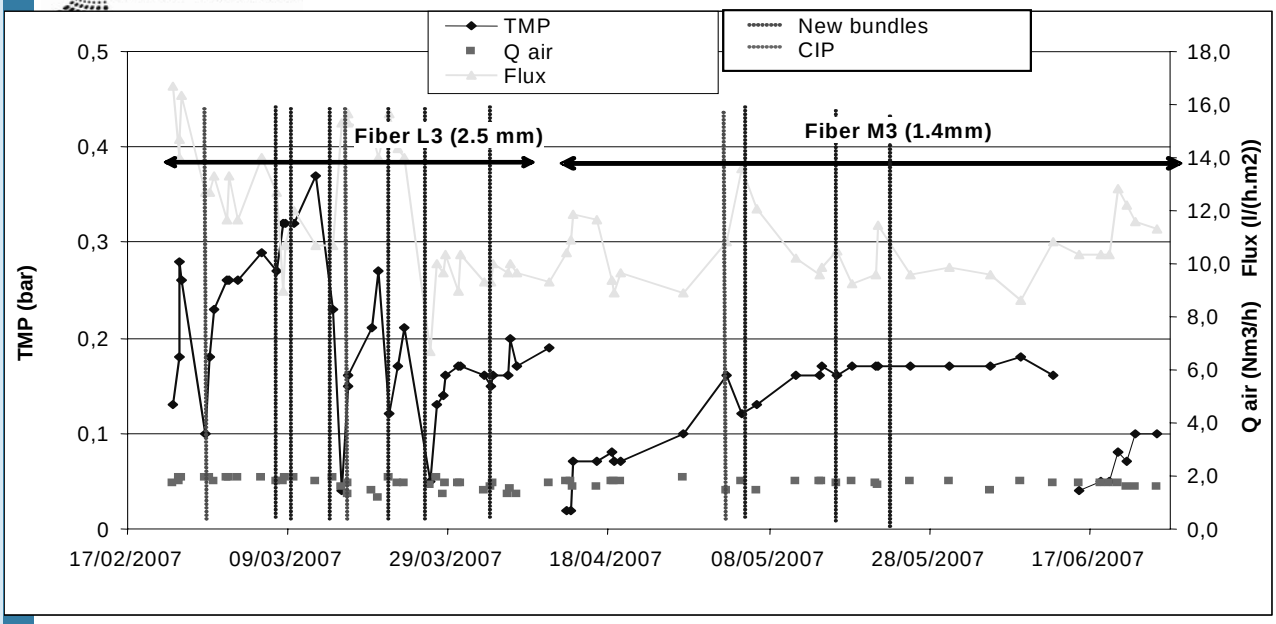
Filtration performances



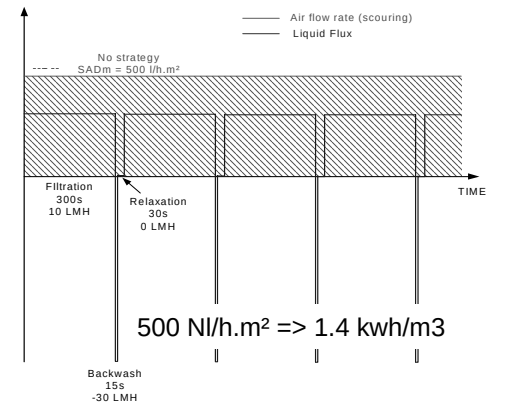
Achieved goals :

Concept demonstration : Flux optimisation at 8-10 LMH, SADm 500 l/h.m² without sequencing
CIP frequency and waste volumes = Twice per month with only 2 l/m²

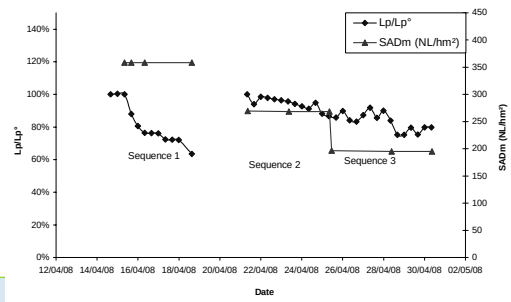
Treatment performances : Carbon and Nitrogen removal greater than 95 %
Permeate quality : Bacteria free and SDI always lower than 3, RO ready

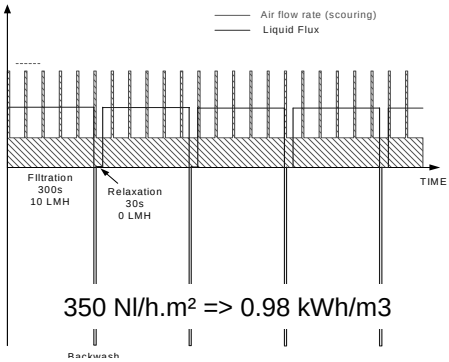
Results of research activities : aeration demand reduction

- Strategy : sequencing of air scouring (constant flux 10LMH)

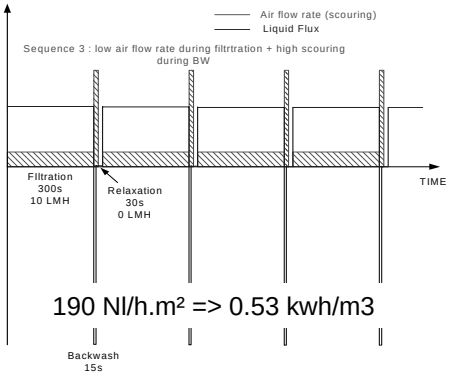


500 Nl/h.m² => 1.4 kwh/m3





350 Nl/h.m² => 0.98 kWh/m3



190 Nl/h.m² => 0.53 kwh/m3

Conclusions

- Module design validated
- Outside large cartridges concept validated
- Process validated on long term experiments
  - Removal efficiency higher than 95% for N and C
  - Flux optimised : 8-10 LMH
  - SADm less than 200 l/h.m² by aeration sequencing
  - CIP frequency 2/month, Volume for cleaning = 2 l/m²
  - High level quality of the treated water, free of bacteria and SDI always lower than 3, RO ready

Perspectives

- More robust membrane with a longer life-time for MBR
- Recommendations on pre-treatment to have the best influent quality without abrasive particles

26. DEVELOPMENT OF A NOVEL FIBRE SHEET MEMBRANE FOR MBR'S: THE FISH

M. Heijnen, R. Winkler, M. Vogg, G. Roeder, P. Berg

Development of a novel Fibre Sheet membrane for MBR: the FiSh

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Development of a novel Fibre Sheet membrane for MBR: the FiSh

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Concept of inge‘s MBR ideas

Combine advantages of Hollow Fibre and Flat Sheet Membranes:

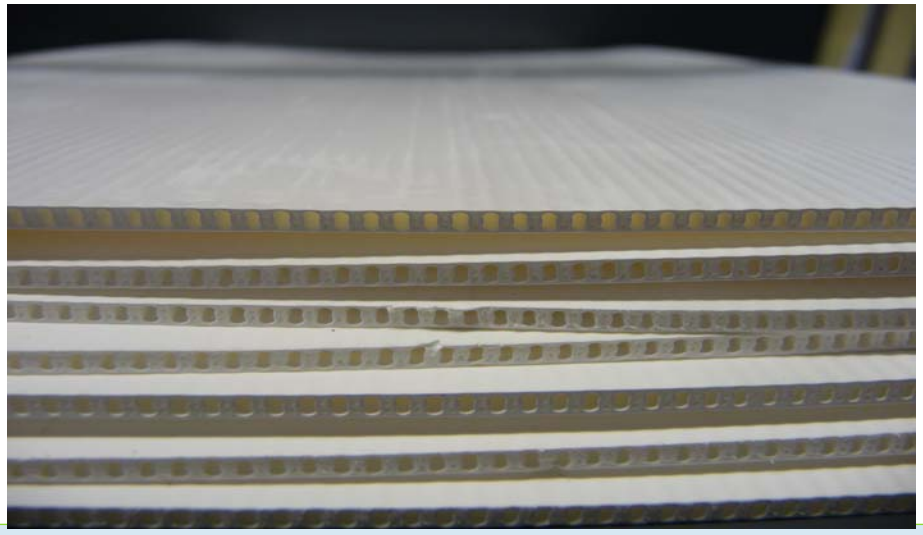
- Hollow Fibre: ie Backwashable, Packing Density
- Flat Sheet: ie Easy Module Production, no/less clogging due to fibrous material

inge solution:

(Multichannel) Fibre Sheet: **FiSh** membrane

The next generation of membranes for MBRs: Technology based on inge‘s innovative Fibre Sheet

Basic Idea: inge FiSh Membrane



Concept of inge MBR ideas

- Some Characteristics/Advantages of inge's **FiSh**:

  °Higher surface area compared to standard flat sheet

  °Highly Backwashable Membrane: one material
  Backwash (or -shock) > 150 L/m²h possible

  °Extra strength PES membrane, through carefull choice of added hydrophilising additives

  °Easy Module Fabrication

  °Limited problem with fibrous deposition

FiSh: Membrane Optimization Steps

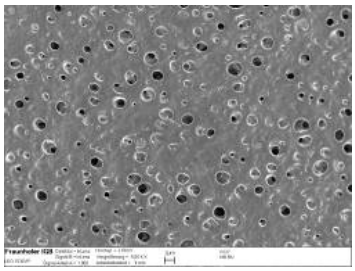
- In order to optimise membranes, many different variables need to be evaluated:

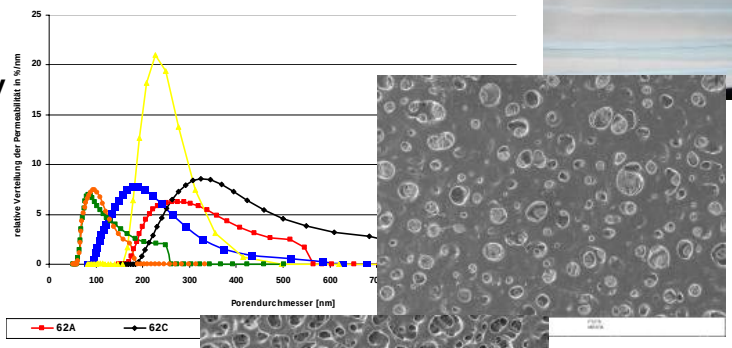
- Polymer Solution composition
- Lumen fluid composition
- Spinning parameters

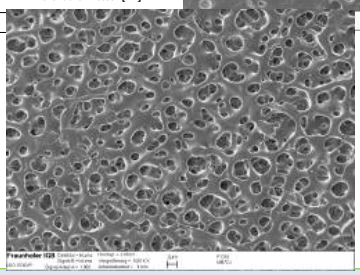
FiSh: Membrane Optimization Steps

Various wall thicknesses

Poresizes/Porosity

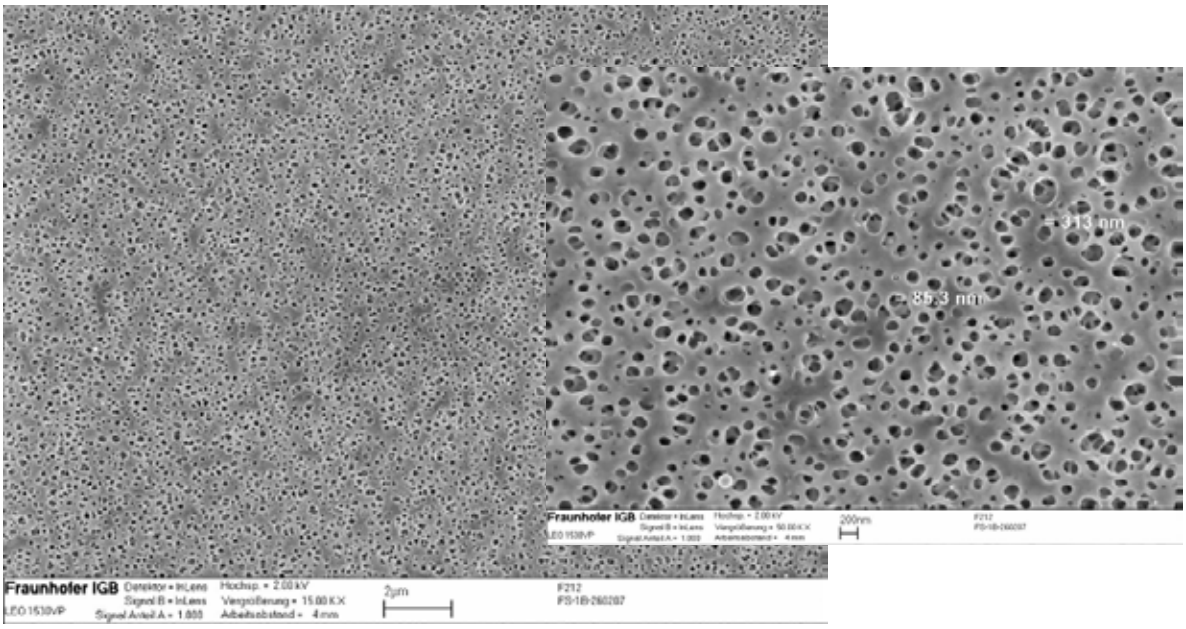






Also permeability, hydrophilicity, surface roughness, strength, etc

Selected FiSh Outside Pore structure

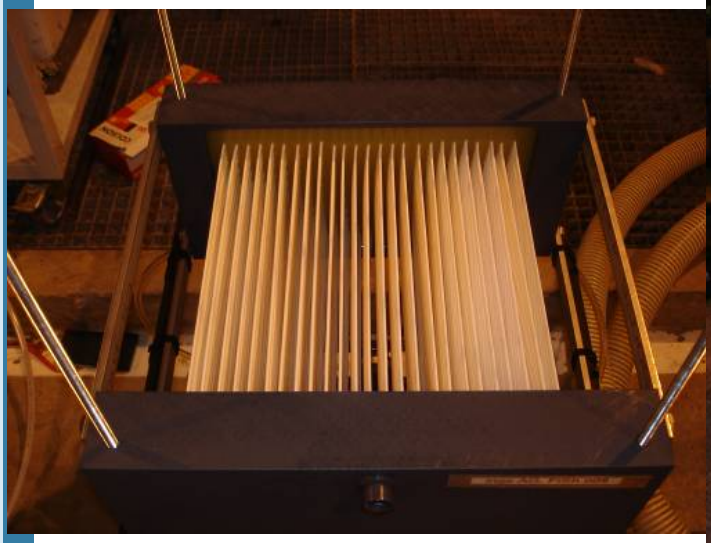


0.2 micron average

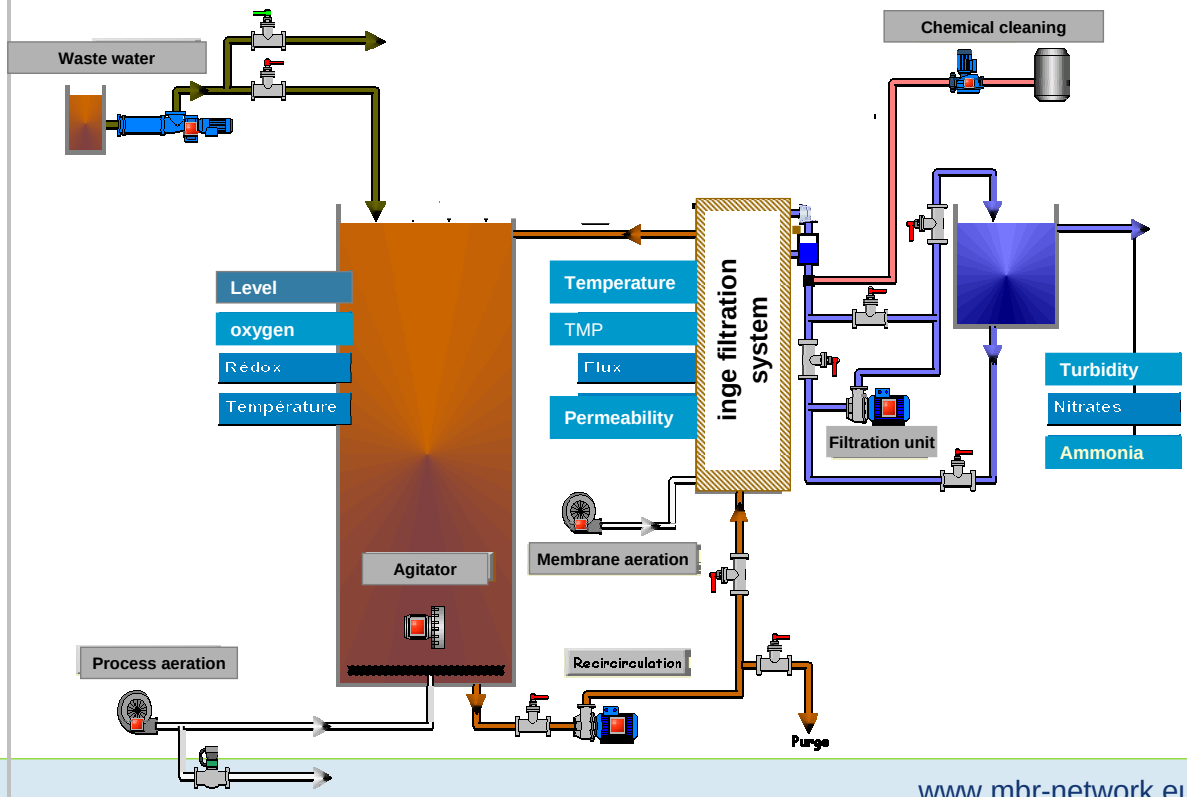
FiSh Module Stack

➔Modules: 2 configurations possible / First prototypes at inge

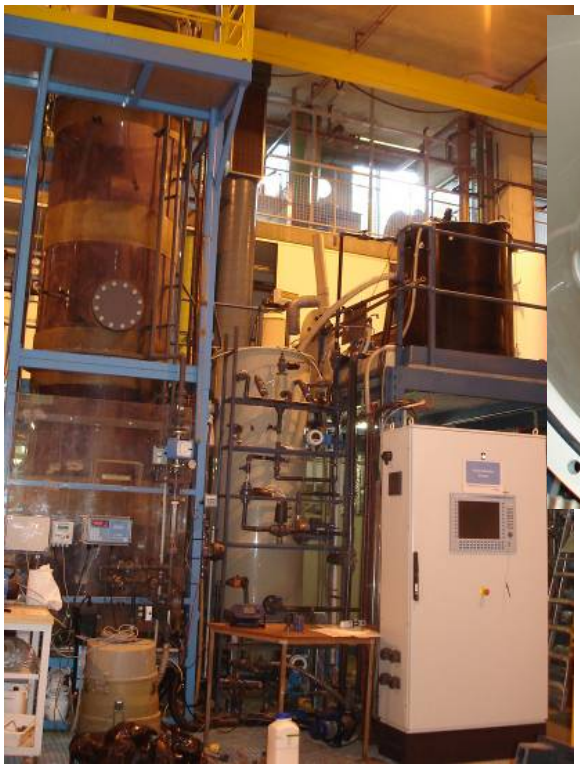
FiSh-System delivered and tested at Anjou Recherche



Pilot plant of Anjou Recherche



FiSh-System integrated in Anjou`s MBR



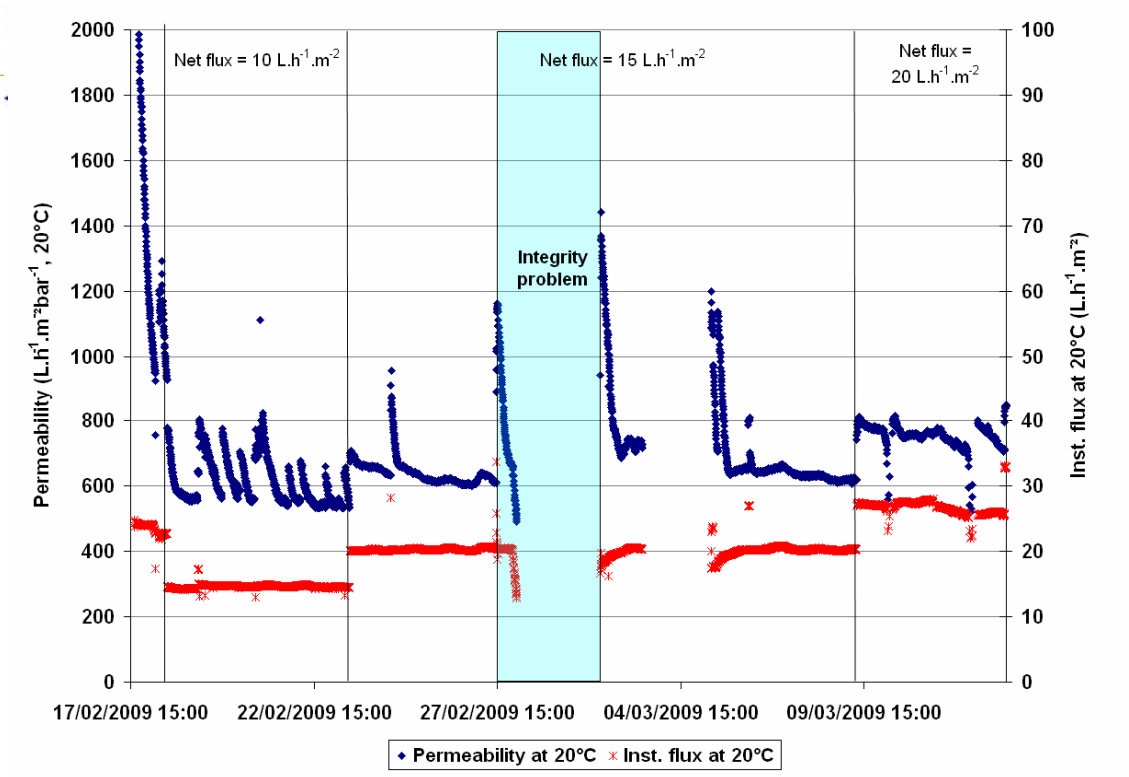
Operating Parameters of the Pilot plant of Ajou Recherche

Raw water characteristics

	Average
CODtotal (mg/l)	597±116
TSS (mg/l)	222±45
TN (mg/l)	61±7.4
TP (mg/l)	9.4±0.31

Biological operating conditions

	Average
MLSS in the biological tank (g/L)	7.5±1.0
SRT (days)	25±0.6
Volumetric loading rate (kg COD.m^{-3}.d^{-1})	1.21±0.56
F/M ratio (kgCOD.kg MLSS^{-1}.d^{-1})	0.17±0.07
HRT (h)	8.6± 1.55



- Operating conditions: 6min filtration /30s backwash; backwash flux = 2x inst. flux; SADm= 0.4 Nm^3.h^{-1}.m^{-2} (No maintenance cleaning during this period)
-17/02-27/02 (10 days): Operation with 4 modules

- 03/03- now (1 months): Operation with 3 modules

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Treated water characteristics

	Average	*Mean removal rate*
COD (mg/L)	17±1.7	97.2%
TN (mg/L)	9.8±1.15	82.2%
TP (mg/l)	4.9±0.1	44.8%

- Typical of a MBR system

Conclusion inge FiSh

- Development of a new and innovative filtration system for MBR:
  - Technology combines ADVANTAGES of
    * Flat Sheet Membranes AND
    * Hollow Fibre Membranes
- Successfully reached milestones:
  - A membrane with very good characteristics
  - A solid base for a module
  - An initial usable system design
- Further realistic potential for optimization:
  - Increasing of Flux-rates
  - Increasing of Recovery (Decreasing of BW-Time/Using Back-Shock)
  - Reducing/Elimination ? of Aeration

→ **REACH LOWER ENERGY CONSUMPTION**

Acknowledgement

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

Contract No. 018328 - AMEDEUS
Duration: 01/10/05 – 31/05/09
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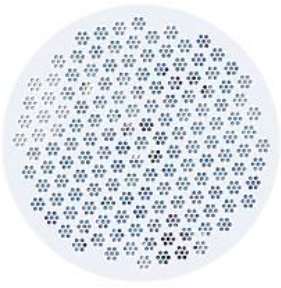
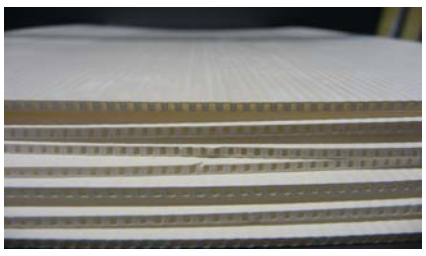
Water Berlin – Visit inge at….



Booth 526
Hall 6.2 B



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27. INNOVATIVE EUROPEAN MADE FLAT-SHEET MODULE SYSTEMS FOR MBR APPLICATION

B.Kreckel, U.Brüss, A. Grélot, A. Tazi-Pain

Innovative European flat-sheet module systems for MBR application

Ulrich Brüß, A3 Water Solutions GmbH

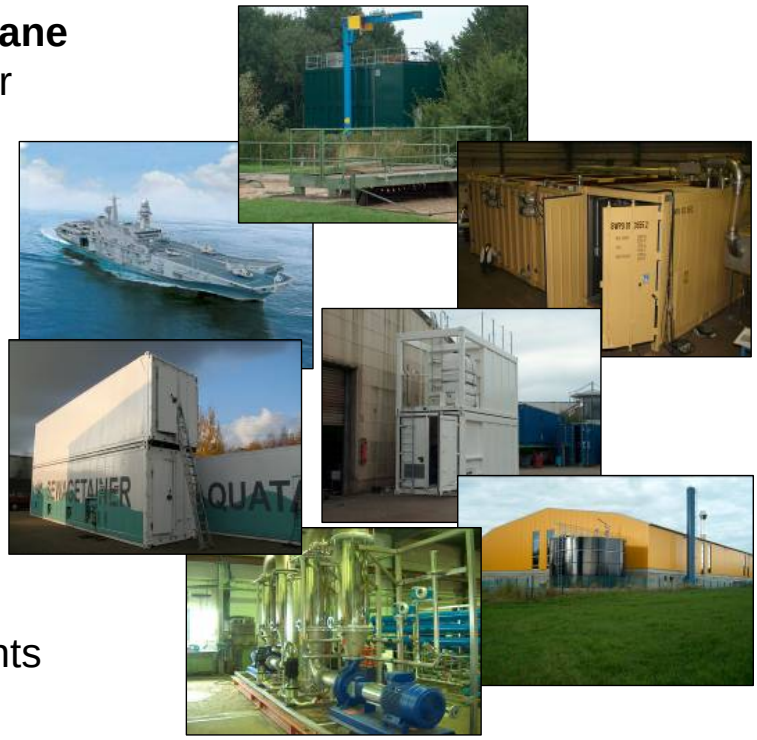
Content

- A3 company profile
- Objectives
- A3 flat sheet module system
- Module configuration
- Module performance in pilot trials
- Acknowledgement

A3 company profile

Production of **membrane filtration modules** for MBR applications

- Construction of **containerized MBR plants** for municipal and industrial applications
- Construction of **digestate treatment plants** for biogas plants



Objectives

A3 intends to **optimise existing module** technology while utilising **other types of membrane** (and other used type of material) to be **build to modules** and **testing novel configurations**, **operation methods** and **cleaning strategies**.

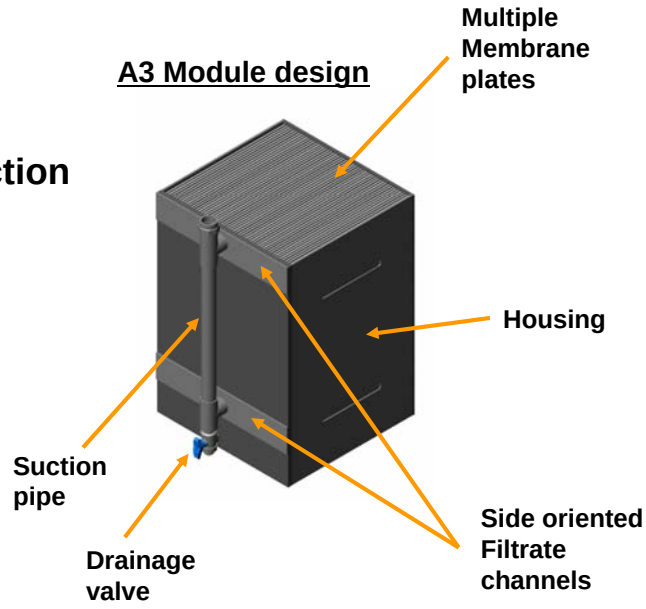
Goal: Availibility of novel MBR technology

Annex 1: „Description of Work", AMEDEUS contract

A3 flat sheet module system

- Robust **flat sheet** membranes
- **PES / PVDF Membrane** materials to guarantee high flux rates
- **Open channel design** that prevents clogging
- **No** single plate **tube connection**
- **Easy** and **compact design**
- **Flexible** membrane **area**
- **Multideck** and **Multimodule** design
- **Low** operation **costs**

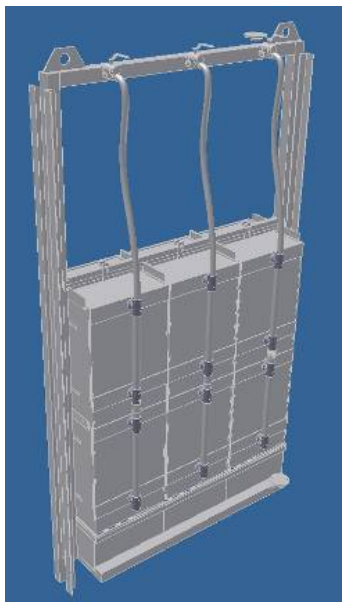
A3 Module design



Optimized multidecker and multimodule configuration

Single deck
70 m²
Air flow rate
0,68
Nm³/(h*m²)

Double deck
140 m²
Air flow rate
0,2 – 0,35
Nm³/(h*m²)



Double deck multimodule
420 m²
Air flow rate
0,2 – 0,35 Nm³/(h*m²)

Triple deck multimodule
630 m²
Air flow rate
< 0,2 Nm³/(h*m²)

Double deck Multimodule configuration with 420 m²

Optimized module configuration

Innovations and Advantages

- **Less air consumption** due to optimized upstream channel
- **Small footprint** due to compact configuration
- **Low water level** required due to compact configuration
- **Easy handling** due to one filtrate line concept and drainage line
- **Easy mounting** and **demounting**

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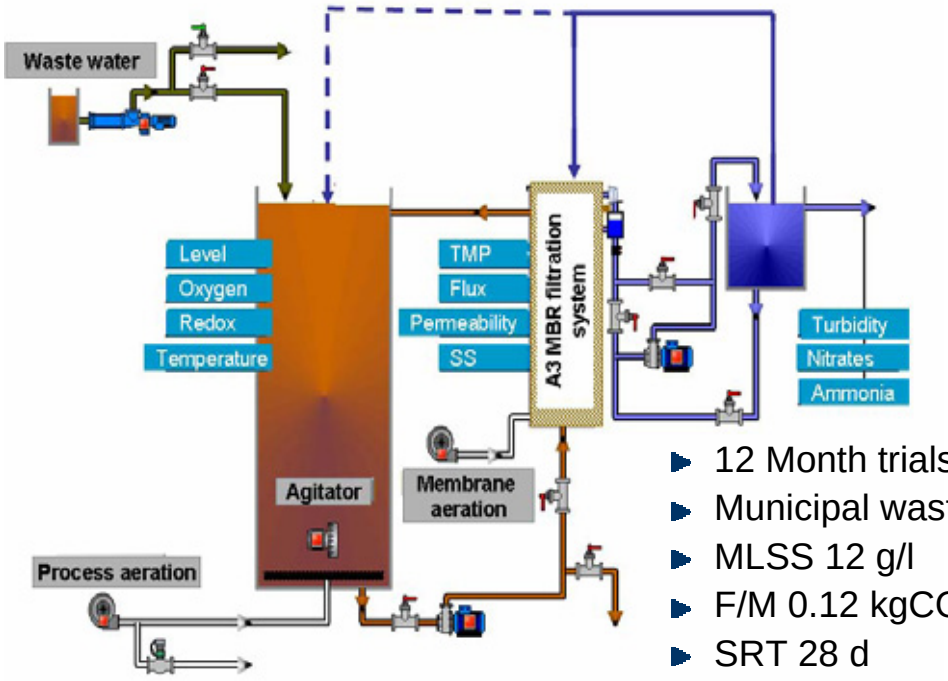
Testing platform at Anjou Recherche



- 12 Month trials
- Municipal waste water
- MLSS 12 g/l
- F/M 0.12 kgCOD/(kgMLSS*d)
- SRT 28 d
- Double Deck configuration

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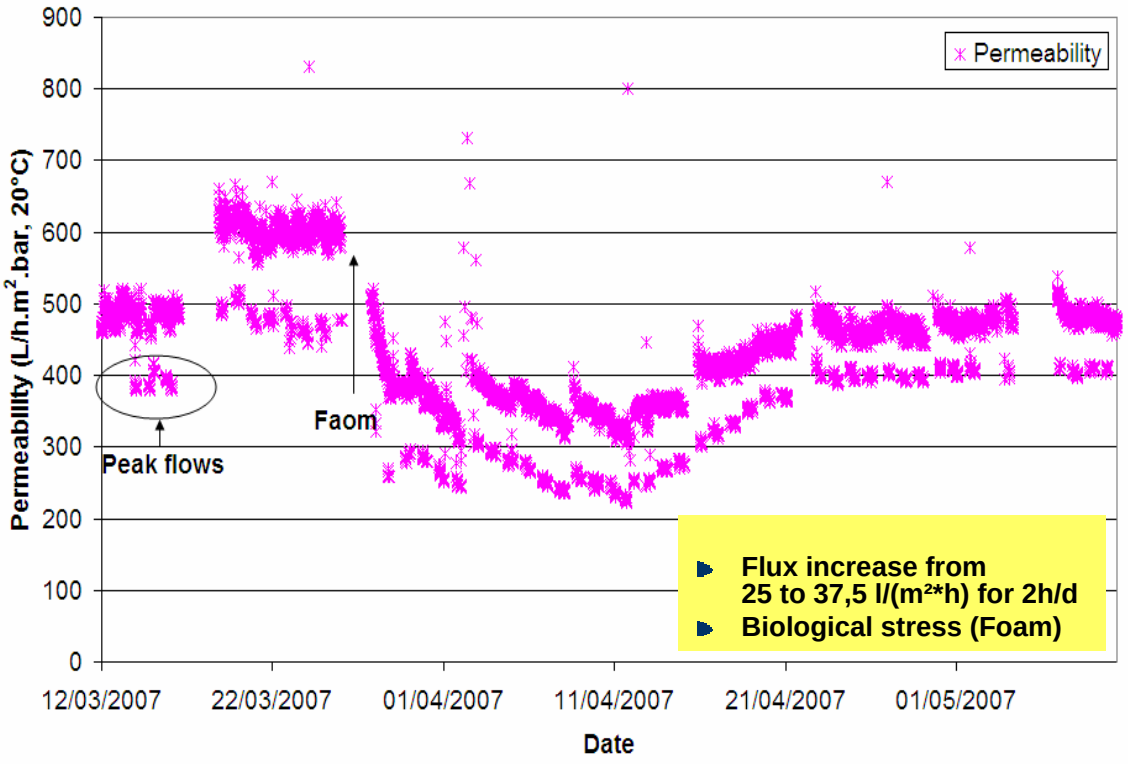
Results of pilot trials at Anjou Recherche

- Initial permeability was about 1,600 l/(m²*h*bar)
- Permeability could be stabilized at 500 to 600 l/(m²*h*bar)
- Flux was stabile at 25 L/(m²*h)
- Air flow was 0.2 Nm³/(m²*h)
- Specific aeration demand was 8 $Nm^3/m^3_{permeat}$



Results of flux and biological stress tests

- **Recovery of permeability** is possible after **biological stress**
- It is possible to apply **high flux rates** (flux stress) for a distinct time
  without permanent **loss of permeability**
- In Addition to **flux stress** events it is possible to **recover permeability** during **biological stress** periods
- System **acts flexible** to demand

Acknowledgement

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Contract No. 018328 - AMEDEUS
Duration: 01/10/05 – 31/05/09
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28. FROM CONCEPT TO INTERNATIONAL EXPORT OF EUROPEAN MBR FILTRATION SYSTEM

D. Volmering, K. Vossenkaul

EUROMBRA

MBR Network Workshop

From concept to business
of European MBR filtration system

Dirk Volmering

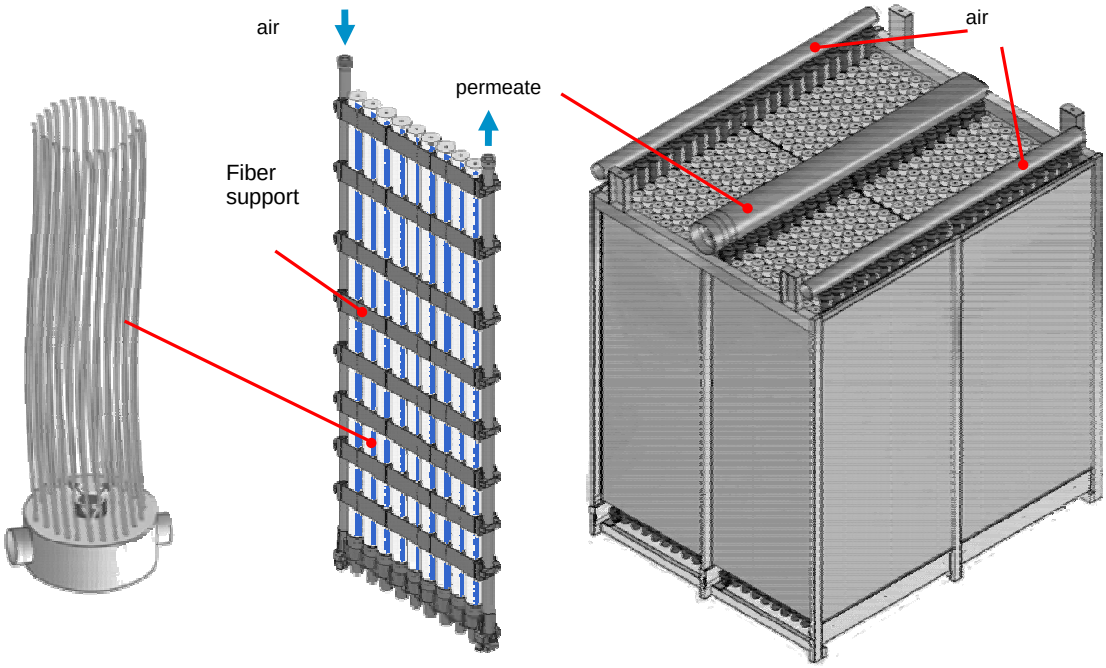
R&D process and module development

Submerged membranes

KOCH Membrane Systems
GmbH, Germany

EUROMBRA

Concept and Modular Design of PURON® module



Membrane bundle | Module row | Module

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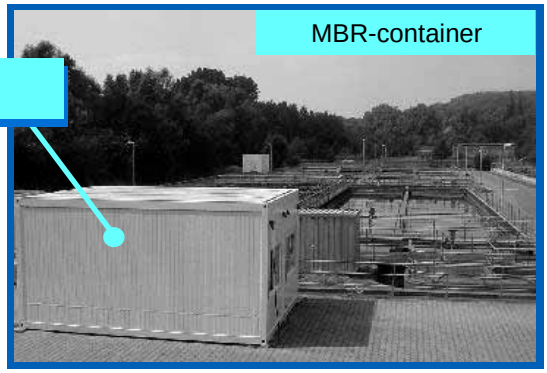
PURON – history

08-2001 proof of concept in first pilot unit at MWTP Aachen Eilendorf
- founded by NRW government (competition network water)

testfield for MBR



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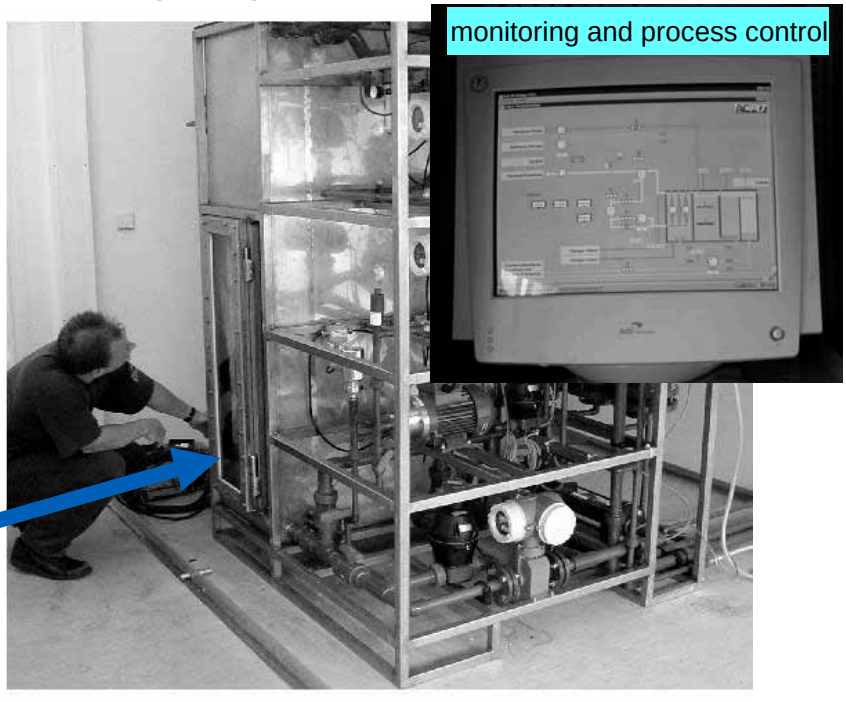
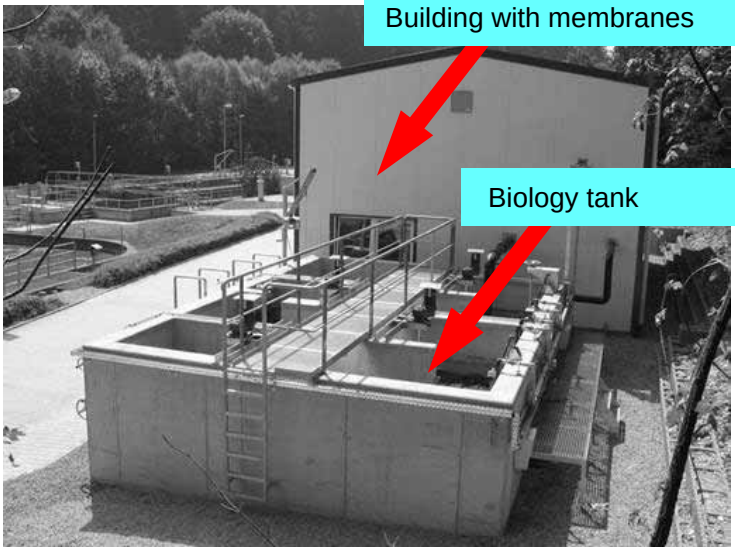
MBR-pilotplant in Eilendorf

membrane module

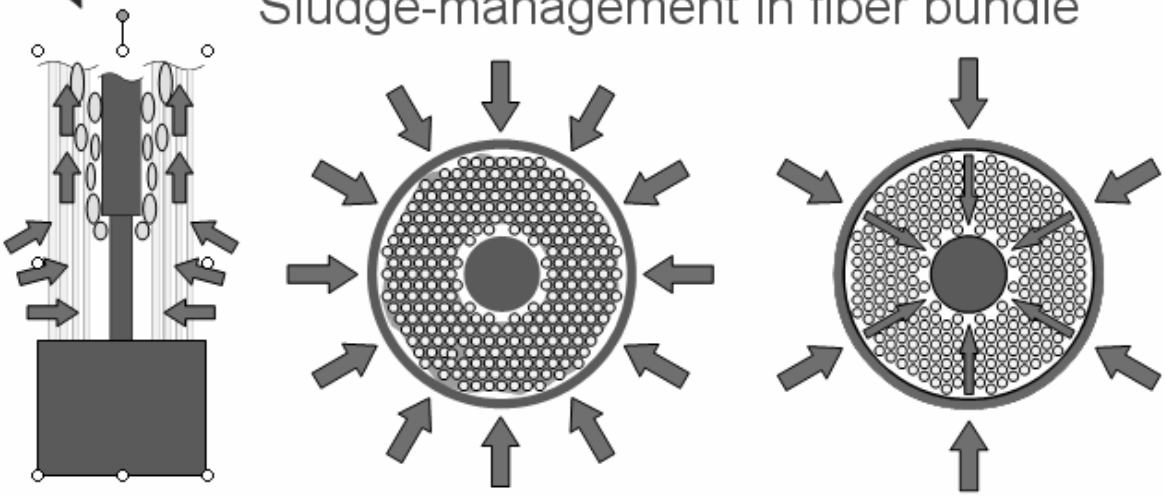


PURON reference plant Simmerath (Germany)



- commissioning March 2003 - 500 m³/d - 1000 p.e.
- two years of successful operation

Sludge-management in fiber bundle



- aeration creates horizontal sludge flow inside the bundle
- filtration lead to sludge dewatering and concentration

→ **bundle sludging during higher fluxes**

gaps in fiber bundle → **reduce sludging**

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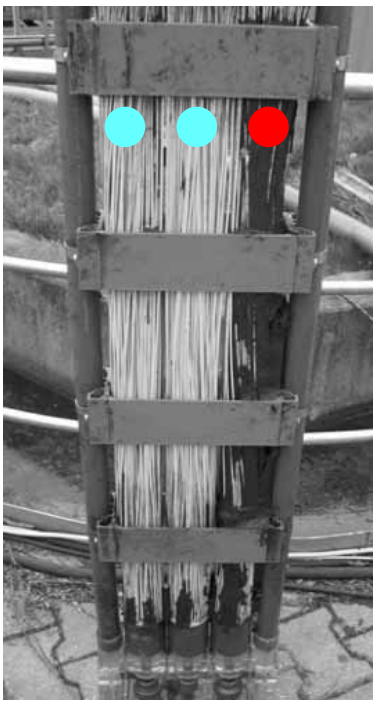
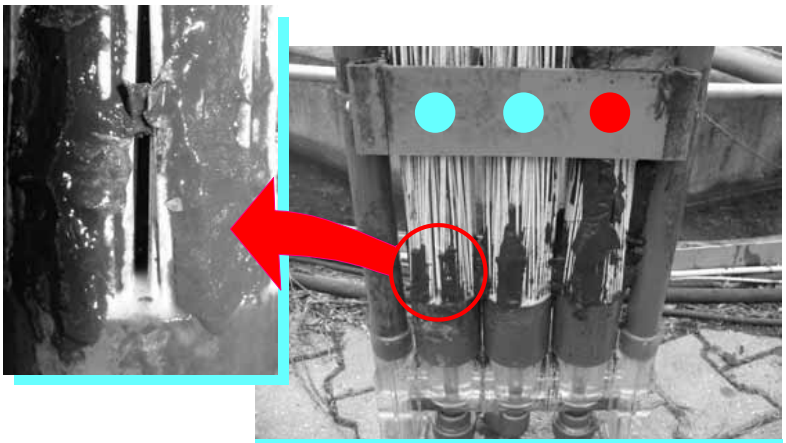
Bundles with gap design



- with gaps in fiber bundle
- without gaps in fiber bundle



permeate flux > 25 l/m²h

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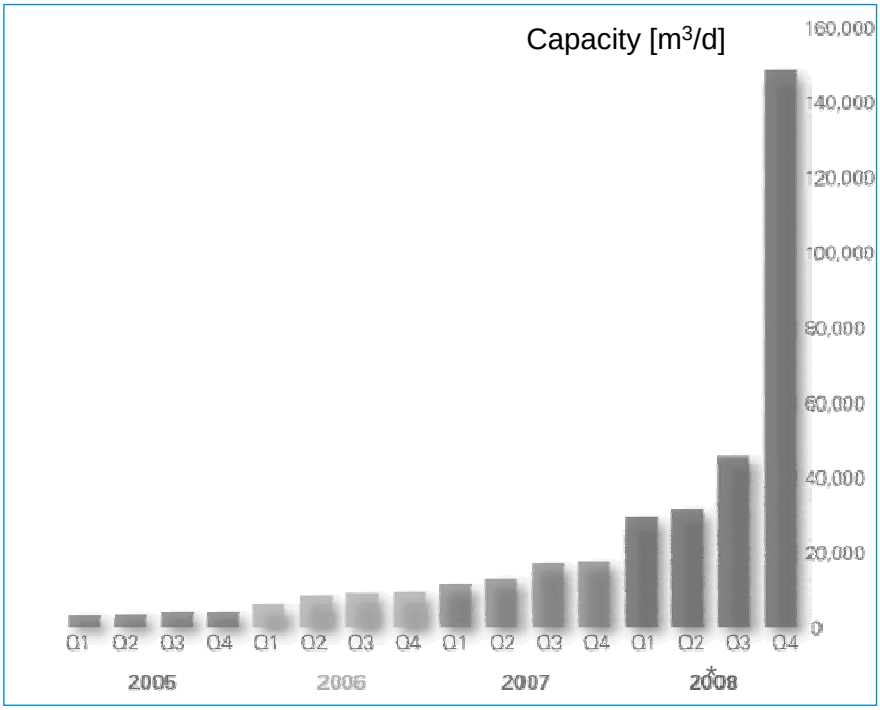
Growth of PURON® Submerged Membrane since 2005



* includes plants in design or construction phase

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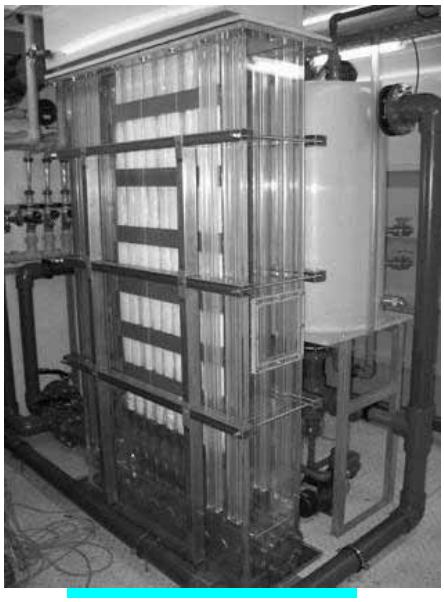
3-row pilot

features:

- 3 trains with 1 module row each
- connected to the same biology
- excellent tool for comparative tests



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MC vs. Semi RC cleaning

MC (maintenance) cleaning

- Low flow chemical backwash in sludge followed by a low flow permeate flush without chemicals
- 2 different strategies tested
  - With small amount of aeration
  - Without aeration

Semi RC (recovery) cleaning

- Changing of sludge of membrane tank with a chemical solution
- Soaking of chemicals for approx. 1 hour

Important: overall chemical demand for all cleaning strategies was the same!

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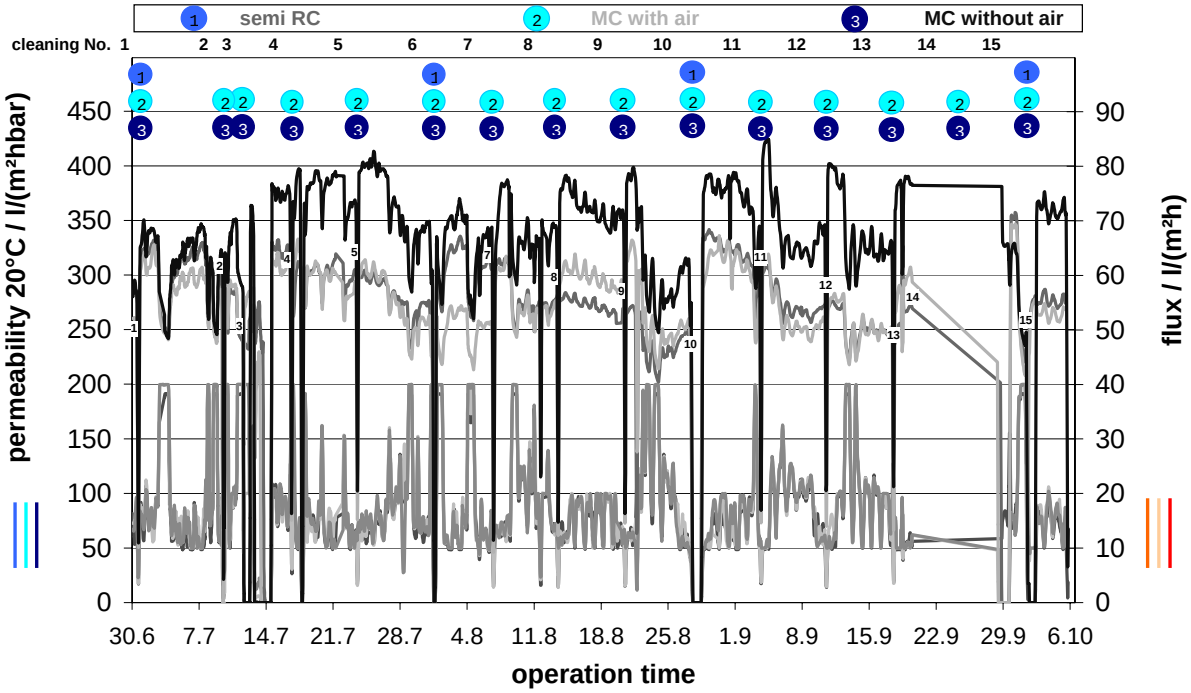
Cleaning: MC vs. Semi RC results



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Conclusions MC vs. Semi RC cleaning

- MC cleaning without air was the best strategy
- Air scouring while MC cleaning leads to low chemical concentrations at the surface of the membrane and therefore to a reduced cleaning efficiency
- If the mc cleaning with air and the semi rc cleaning would lead to a stable but lower permeability level is not yet clear

→ MC cleaning without air is recommended for the PURON System

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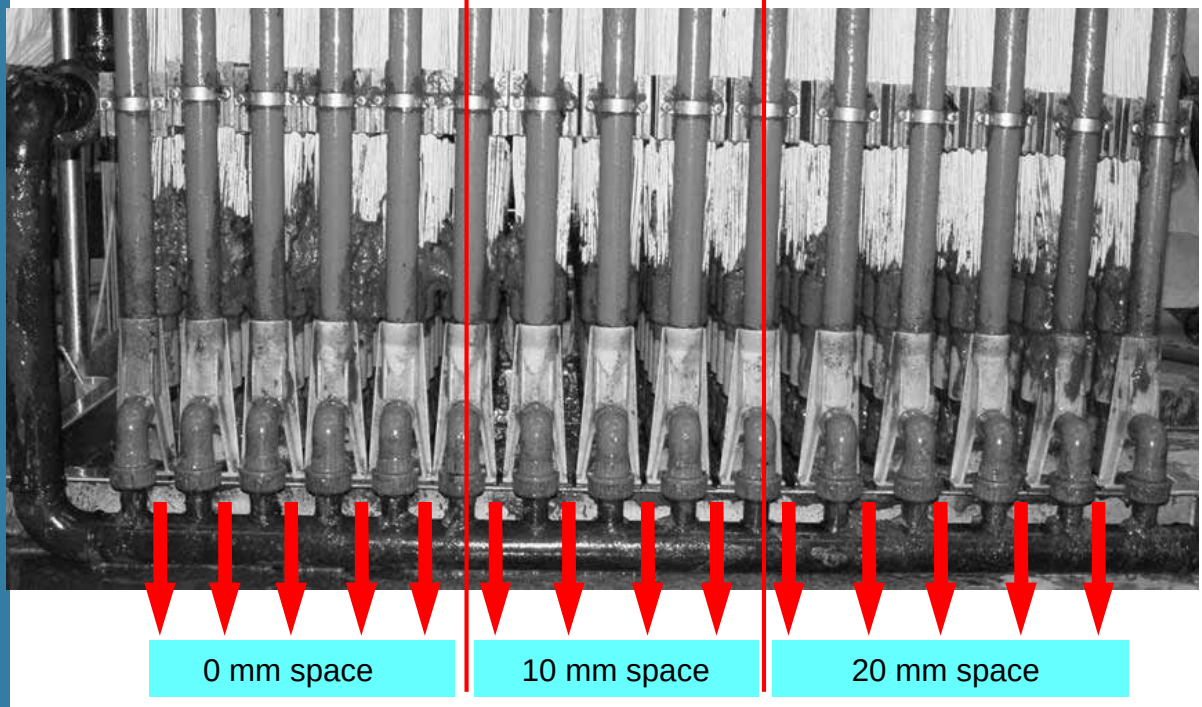
Packing density: space between rows



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Conclusions

- A row distance of 10mm was an optimum in this trial
- A row distance of 0mm leads to sludging especially in the bottom part

→ 10mm is chosen for the 2nd product generation

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Thank you for your attention!

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Contract No. 018480 - EUROMBRA
Duration: 01/10/05 – 31/05/09
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29. DEVELOPMENT OF CONTAINERISED TURN-KEY MBR PLANTS

D. Vilim, P. Hlavinek, J. Kubik, P. Hlustik

Development of containerised turn-key MBR plants.

Petr Hlavinek, BUT

Daniel Vilim, ENVI-PUR, Ltd.
Jiri Kubik, BUT
Petr Hlustik, BUT

Activities of ENVI-PUR

- waste-water treatment plants
- water processing (purification) plants
- equipments and components of WWTPs and water processing plants (oil, fat, sand separators, pumping stations, tanks, aeration systems, sliding gates,…)
- air-conditioning systems
- metal workshop

ISO and PC containerised MBR plants

- ENVI ISO-MBR 50
- ENVI ISO-MBR 100
- ENVI ISO-MBR 200
- ENVI ISO-MBR 400

- ENVI PC-MBR 50
- ENVI PC-MBR 100
- ENVI PC-MBR 200
- ENVI PC-MBR 500

Pretreatment and buffer tank

- It prevents clogging and membrane damages due to hair and other debris.
- 3 mm screen as a pretreatment for flat sheet membrane technology
- Technical solutions
  - Integrated facility (sieves and sand trap)
  - Screw drum screens
  - Rotary drum screens
- Very efficient cleaning with extra work to the operators.

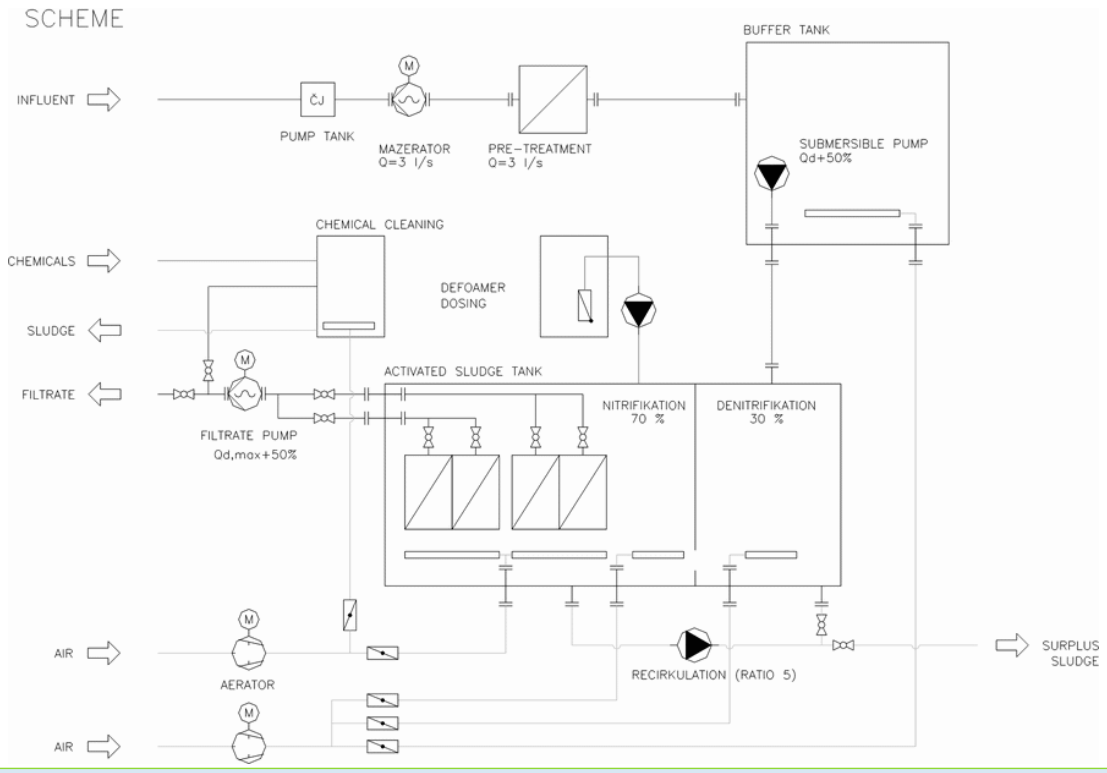
- Buffer capacity to reduce as much as possible the membrane surface installed.
- Minimize hydraulic and concentration load variations
- Mixing of the tank is recommended to prevent anaerobic zone creation

Design parameters of MBR

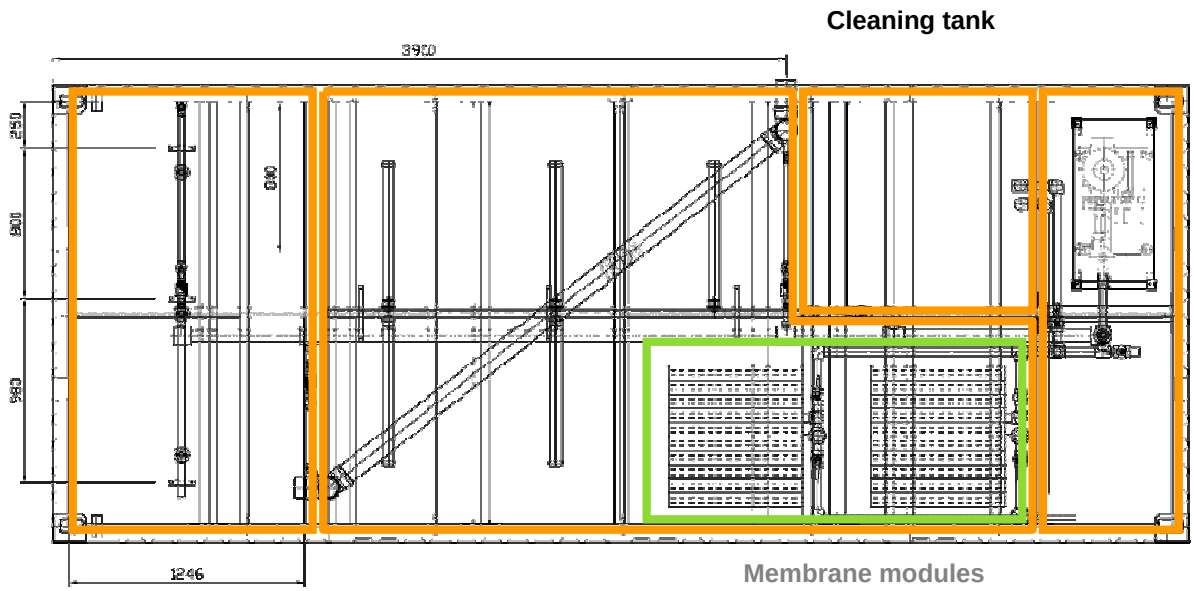
- Nitrification and denitrification tanks
  - Denitrification – 30 to 40 % of bioreactor volume
  - Nitrification – 60 to 70 % of bioreactor volume
- Same MLSS and F/M ratio for all sizes

PE	50	100	200	500	
BOD loading	3	6	12	30	[kg/day]
F/M ratio	0,06	0,06	0,06	0,06	[kg BOD/kg MLSS/d]
MLSS	10	10	10	10	[kg/m^3]
Volume of bioreactor	**5**	**10**	**20**	**50**	**[m^3]**
Design Net flux	12	11	11	11,5	[LMH]
Filtration area	40,4	88,1	176,1	421,2	[m^2]
Membrane aeration	0,7	0,7	0,7	0,7	[Nm^3/m^2.h]

Scheme of containerized MBR



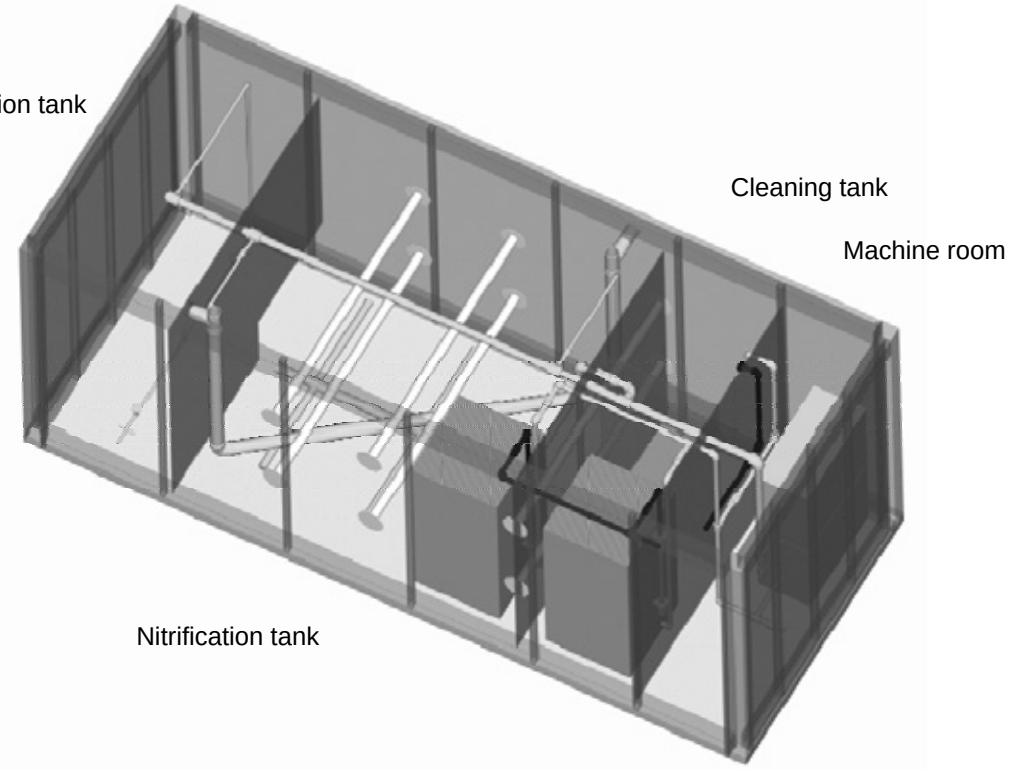
ISO container – ground plan



Container equipment

- Pumps
  - Buffer tank pump
  - Recirculation pump
  - Permeate pump
- Blowers
  - Membrane modules
  - Denitrification, nitrification, buffer tank
- Mixing
  - Mixers
  - Coarse bubble aeration
- Monitoring and control units
  - Dissolved oxygen, TMP and flow measurement, system control by floats, remote control system

3D model of standardized container



Case studies – MBR retrofitting

Prepared:

- **WWTP Lomnice 1800 PE**
- **WWTP Provodov-Šonov 1600 PE**
- **WWTP Sloup 2000 PE**

Under preparation

- **WWTP Jedovnice 7000 PE**
- **WWTP Deštné 1000 PE**
- **WWTP Podomi 1000 PE**

Pilot plants

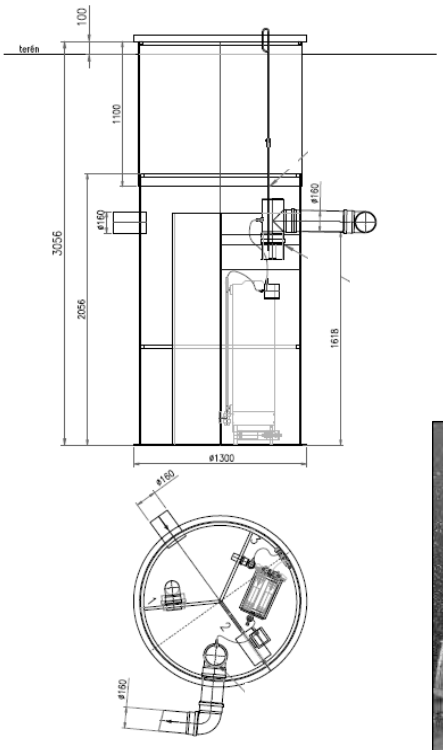
In operation:

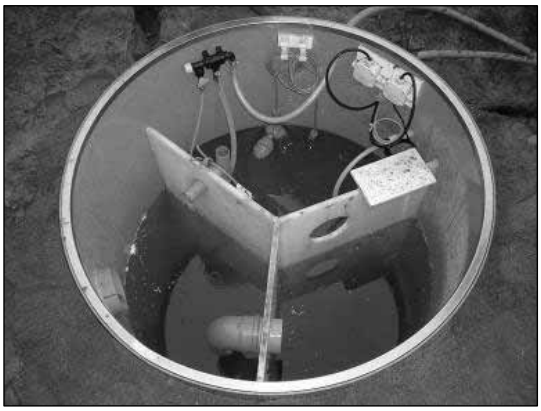
- MBR IWWTP pilot plant 9 m³/d
- Chemical industry

Domestic:

- 4 plants in operation
- Testing of different membrane suppliers and configurations

Pilot plant - Olšany





Conclusion

- Upgrading of wastewater treatment plants by mean of membrane technology is definitely feasible.
- In most of the case, some extra work and efforts would be needed:
  - An efficient pretreatment (screening in addition of the existing sand filters and grit chambers)
  - A covered activated sludge tank
  - Some buffer capacity
  - a specific membrane tank (maintenance and cleaning)
  - some extra place capacity (blowers and pumps)
- Containerized MBR WWTP is feasible with maximum capacity of 500 PE
- For more than 500 PE containers can be used for dual system or as membrane tank

Conclusion

- Containerized MBR plants are good solution for
  - Upgrading of existing CAS WWTP where higher quality of treated water is required
  - New plants where reclaimed water could be reused (irrigation, toilet flushing, car washing)
- Before the decision we need take into account:
  - Higher capital and O&M costs when we don't compare the quality of reclaimed water with CAS system
  - Problem of foam creation
- Hollow fiber modules are acceptable for applications from 400 PE
  - Higher demands on control system and operation
- The flat sheets modules are feasible for most of applications

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