

Final MBR-Network Workshop

**“Salient outcomes of the European R&D
projects on MBR technology”**

Presentation handouts

31 March – 1 April, Berlin 2009 (Germany)



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36. MBR STANDARDISATION IN EUROPE: MARKET INTEREST, TECHNICAL POTENTIAL AND INITIATION OF FORMAL ACTIONS

*W. De Wilde, A. Tazi-Pain, M. Richard, B. Lesjean,
G. de Gueldre*

MBR standardisation in Europe: market interest, technical potential and initiation of formal actions

Wouter De Wilde, Annie Tazi-Pain, Mireille Richard, Boris Lesjean
Greet De Gueldre



Goal and methodology

- ▶ Goal investigation
 - Assess the market interests/expectations and the technical potential for standardisation of MBR technology in Europe
 - MBR filtration modules
 - Membrane characterisation methods for membrane acceptance and membrane monitoring
- ▶ Methodology
 - Extensive questionnaire sent to the chief players of the European MBR industry (80 companies and institutions)
- ▶ Focus on submerged filtration systems in municipal applications

Results – Respondents profile

- ▶ 45 responses out of 80 (participation rate 56%)
- ▶ Module suppliers, MBR constructors, MBR operators, research institutes and academic experts equally represented (> 50%, operators 44%)
- ▶ Two leading module suppliers + principal outsiders of the European market
- ▶ High capacity plants (> 10.000 p.e.) also represented
- ▶ 10 European and 4 non-European countries

➔ Representative panel

Results - MBR filtration module standardisation (1)

Market interests and expectations

- ▶ Interest in guidelines/standards on interchangeable filtration modules
 - End-users: right time now
 - Module suppliers: too early now, would hamper technological innovation
 - Will increase application of the technology and growth of market
- ▶ Potential advantages/opportunities and disadvantages/threats identified

Results – MBR filtration module standardisation (2)

	For end-users	For module suppliers
Main advantages/ Opportunities	Reduction of dependency one supplier Price decrease Increased trust and acceptance Standardisation in tendering Comparability Training operators	Growth of market Standardisation in design and construction: cost savings Introduction times ↓ SME compete fairly
Main disadvantages/ threats	Overdimensioning civil constructions Extra costs peripherals Process/plant reliability More complex legal/guarantee matters	Higher competition Lower profit margins Limitations for Innovative module producers Innovation

Results – MBR filtration module standardisation (3)

Technical potential

- ▶ Analysis and comparison of technical aspects of 4 HF and 5 FS commercially available MBR filtration modules
- ▶ > 30 technical factors potentially hamper standardisation
 - 4 factors: high to extreme high potential
 - Relate to module geometry and dimensions
 - 16 factors: moderate to high potential
 - Immature products
 - Required adaptation works to peripherals
 - 16 factors: low to moderate potential
 - Common knowledge or practice
- ▶ Flat sheet versus hollow fibre
 - 2 separate groups
 - Standardisation equally complicated

Results - Membrane characterisation methods (1)

Market interests and expectations

- ▶ Interest in standardisation now
 - End-users: harmonisation of membrane acceptance tests at module delivery and during plant commissioning positive for growth
 - Module suppliers and constructors: divided
- ▶ Main advantages
 - Improved comparability in selecting membranes
 - More trust/transparency/knowledge in MBR technology
 - Easier operation and cost optimization
- ▶ Main disadvantage
 - Difficulty to find the right methods for all membranes

Results – Membrane characterisation methods (2)

Technical potential

- ▶ Parameters identified for which common definitions and measuring protocols can help harmonisation
 - « membrane life time », « sustainable flux », « peak flux » ...
- ▶ Guidelines and protocols to check product quality and performance at module delivery and at plant commissioning
 - Normalised permeability in clean water and in sludge
 - Integrity test
 - Maximum flux & critical flux
 - Capacity test
- ▶ Operating conditions (biology and filtration systems)
- ▶ Membrane fouling, integrity and ageing

Results – Membrane characterisation methods (2)

	Monitoring methods		
	Membrane fouling	Membrane integrity	Membrane ageing
Main procedures used	TMP Permeability	Visual control Chemical / biological parameters.	TMP Permeability
(Additional) requirements/ considerations in a standardisation process	Prediction of duration to maintain flux level at specified conditions Monitoring biological parameters	Turbidity Pressure decay test Integrity indicators	Membrane surface investigation Threshold values for evolution of normalized flux after chemical cleaning Turbidity/Visual control

Conclusions - Recommendations by the industry (1)

- ▶ Conclusions summarised in a white paper (downloadable)
- ▶ Draft results discussed with 35 representatives of MBR industry in an international WS (Nov 2006) with CEN as co-organiser
- ▶ White paper accepted as reference document to initiate standardisation
 - 75 %: standardisation needed for the modules
 - 85%: standardisation needed for the characterisation methods
 - 40% only within a few years

Conclusions - Recommendations by the industry (2)

- ▶ CEN workshop decided to initiate a standardisation process
- ▶ CEN workshop agreement (CWA)
 - Submerged systems
 - FS versus HF
 - Scope
 - Common terms and definitions
 - Acceptance and monitoring tests
 - Guidelines

Acknowledgements

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
AMEDEUS is part of the MBR-NETWORK Cluster



More info: www.mbr-network.eu

37. MAJOR ITEMS AND OUTCOMES OF THE CEN WORKSHOP AGREEMENT N° 34 ON SUBMERGED MEMBRANE BIOREACTOR (MBR) TECHNOLOGY

F.-B. Frechen

CEN Workshop Agreement (CWA) on Submerged Membrane Bioreactor (MBR)

Technology:

**CWA 15897
(20.11.2008)**

Final MBR-Network Workshop

31 March – 1 April, Berlin, Germany

Franz-Bernd Frechen, University of Kassel/Germany

Chair, CEN/WS/34 "Submerged Membrane Bioreactor (MBR) Technology"

Chair, DWA-Committee "Membrane Bioreactor Systems"

Vice Chair, IWA Specialist Group "Membrane Technology"

Department of Sanitary & Environmental Engineering (DESEE)
Head: Univ.-Prof. Dr.-Ing. F.-B. Frechen

**U N I K A S S E L
V E R S I T Ä T**

The geography of CEN

- Member
- Affiliate



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Dept. of Sanitary & Environmental Engineering (DESEE)
Head: Univ.-Prof. Dr.-Ing. F.-B. Frechen

**U N I K A S S E L
V E R S I T Ä T**

- ➔ Produced in Technical Committees with national delegations:
 - ↪ European Standard – EN
 - ↪ Technical Specification - CEN/TS
 - ↪ Technical Report - CEN/TR
 - ↪ CEN Guides

- ➔ Produced in Workshops with interested parties:
 - ↪ CEN Workshop Agreements - (CWAs)



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Dept. of Sanitary & Environmental Engineering (DESEE)
Head: Univ.-Prof. Dr.-Ing. F.-B. Frechen

U N I K A S S E L
V E R S I T Ä T

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What is a CWA (CEN Workshop Agreement)?

- ➔ The CEN Workshop is a **flexible** working platform **open** to the participation of any company or organisation, inside or outside Europe, for **rapid** elaboration of consensus documents
- ➔ The results are purely voluntary in application
- ➔ Are valid for 3 years, after which there is a choice:
 - ↪ withdrawal or
 - ↪ prolongation for a further period (with or without amendments) or
 - ↪ conversion to a more binding/normative text.

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Head: Univ.-Prof. Dr.-Ing. F.-B. Frechen

U N I K A S S E L
V E R S I T Ä T

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- ➔ Foreword
- ➔ Introduction
- 1. Scope
- 2. Normative references
- 3. Terms and definitions
- 4. General system-requirements
- 5. Material characteristics
- 6. Configuration
- 7. Design and operation parameters
- 8. Acceptance, commissioning and monitoring tests
- 9. Information and documentation
- 10. Interchangeability



Foreword

- ➔ Stakeholders attending the AMEDEUS Workshop on 24th November 2006 confirmed the standardisation potential and needs of the membrane technology in Europe and especially to develop **guidelines** or standards on **interchangeable** filtration modules from both sides of the market.
- ➔ **End users** have a focus on **costs** and **guaranties**.
- ➔ Most market players expect that interchangeable modules will increase the willingness of decision makers to **invest in MBR technology**.



- ➔ Only plants exceeding approximately 1,000 m³/d are covered.
- ➔ It appeared not possible to have interchangeable modules without considering a **complete system**.
- ➔ Thus, guidelines will deal with the **membrane tank and its ancillaries** rather than **modules alone**. This is the key to having one text for both flat sheet and hollow fiber modules.

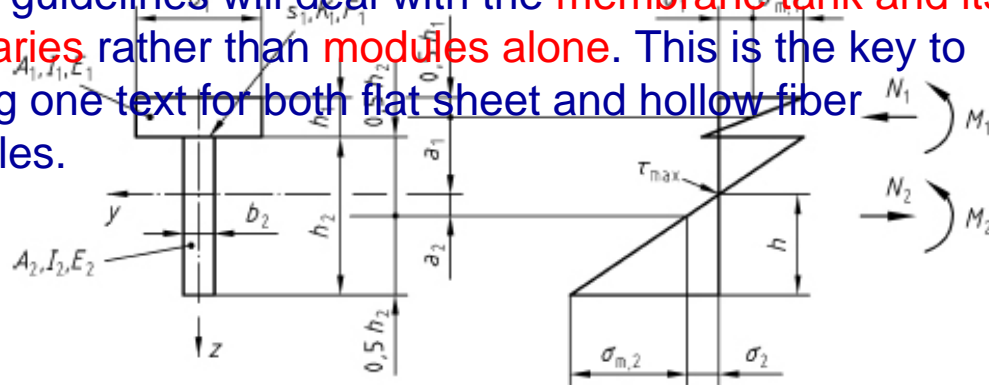


Bild 5 — Querschnitte aus nachgiebig miteinander verbundenen Querschnittsteilen



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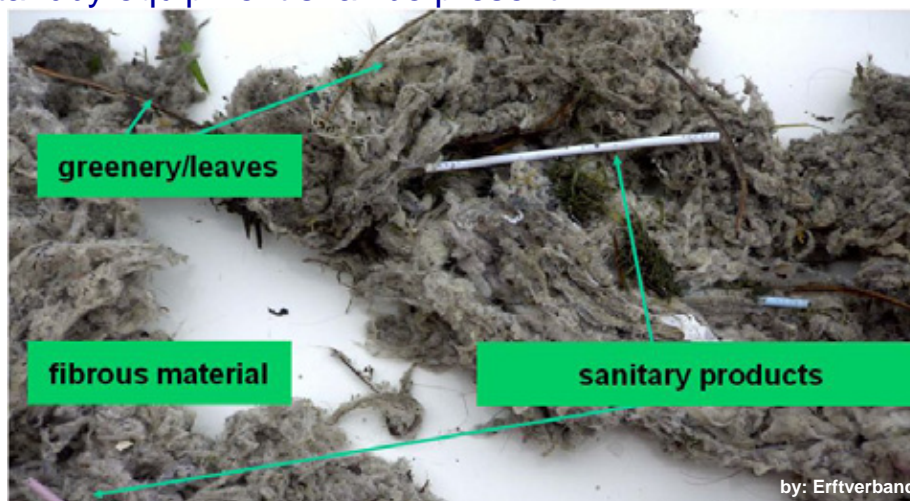
U N I K A S S E L
 V E R S I T Ä T

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4 General system requirements

4.2 Pre-treatment and internal sieving

- ✦ Advanced mechanical pre-treatment (AMP) is needed.
 - Besides gap width, also gap geometry, structural shape and flow direction of sieves have to be regarded.
- ✦ **No leakage or bypass** of untreated wastewater is acceptable. Standby equipment shall be present.

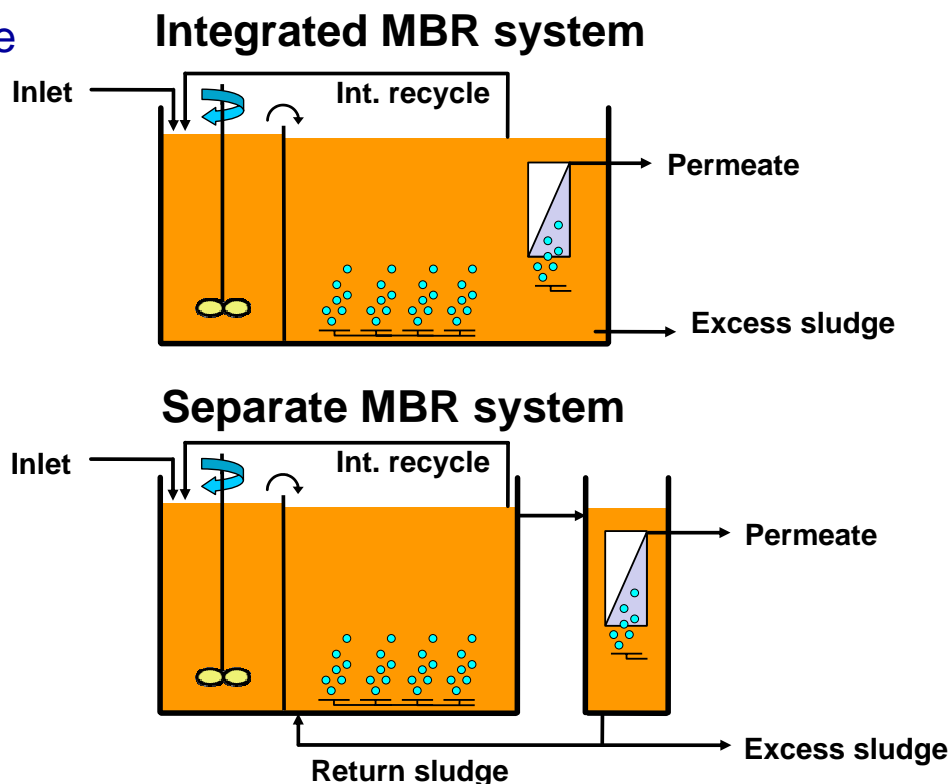


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4.4 Membrane filtration system



4.4 Membrane filtration system: pro integrated system

- ↪ The **cost** of civil works for an integrated system can be lower.
- ↪ When utilizing separate membrane tanks, it is necessary to incorporate pumps to either feed or return. Integrated tanks will eliminate this need if sufficient mixing is provided to eliminate MLSS gradients.



4.4 Membrane filtration system: pro separate system

- ↪ Separate membrane tanks allow for **in-situ maintenance** and cleaning of the membranes as a separate membrane tank can be drained while the biological system and remaining membrane tanks still operate. Where membranes are installed directly into the aeration tanks, membrane removal is required for servicing.
- ↪ In a separate MBR system, it is possible to **adjust the MLSS** concentration in the biological tank(s) and in the membrane tank(s) independently in a wide range, which may be of importance when
 - upgrading plants utilizing existing tank volumes,
 - seasonal varying loading,
 - expected increase of biological load etc.
- ↪ Choosing a separate MBR system makes it possible to introduce **internal sieving** (see 4.2).
- ↪ When utilising a separate MBR system, a high **flexibility** concerning tank volumes in operation can be applied.



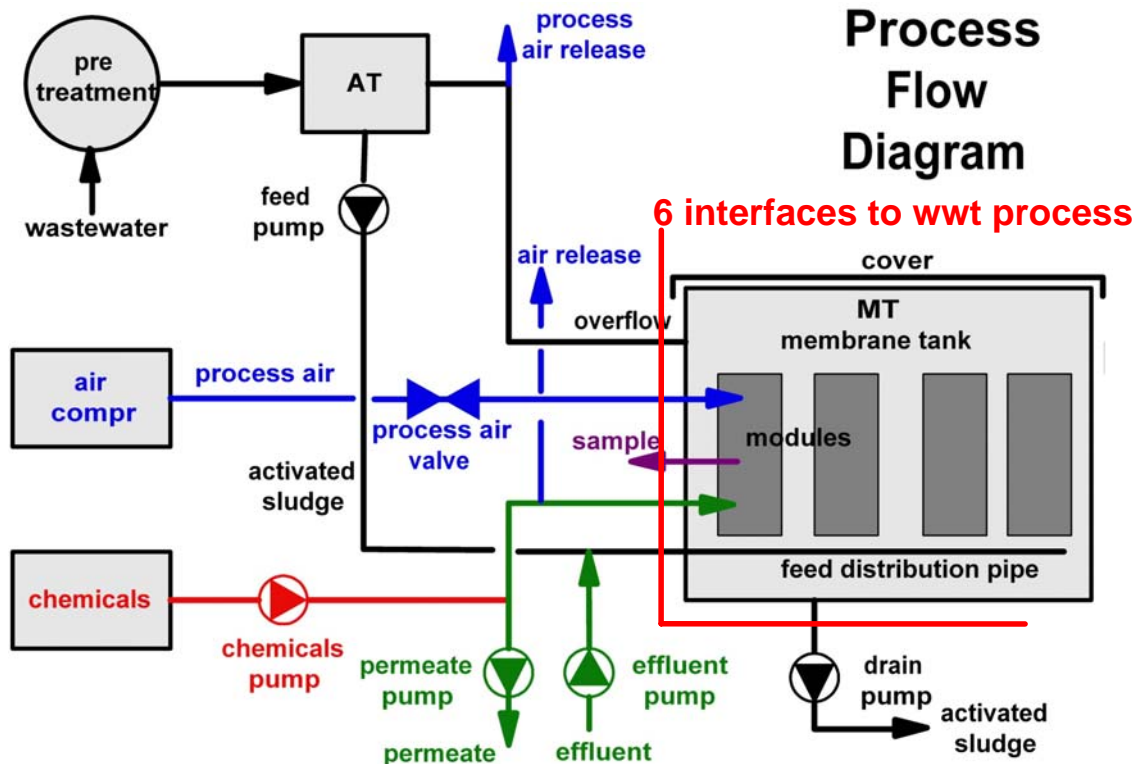
10 Interchangeability

10.1 Principle

- ↪ It is important when replacing membrane modules or complete systems (including membrane tanks) that for a period of time, the two systems shall operate perfectly together.
- ↪ This requires interchangeability to be a consideration in all stages of the design of a MBR.
- ↪ Generally, separate systems seem more appropriate with respect to interchangeability. Thus, the chapter mainly focuses on separate systems.



10.3 Interchangeability – process flow diagram

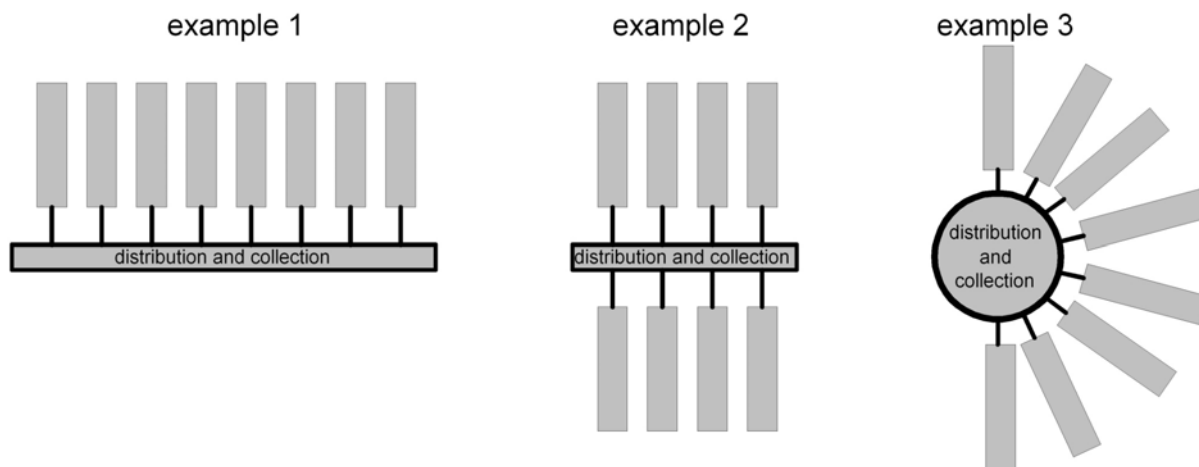


10.4 Interchangeability – scope of supply

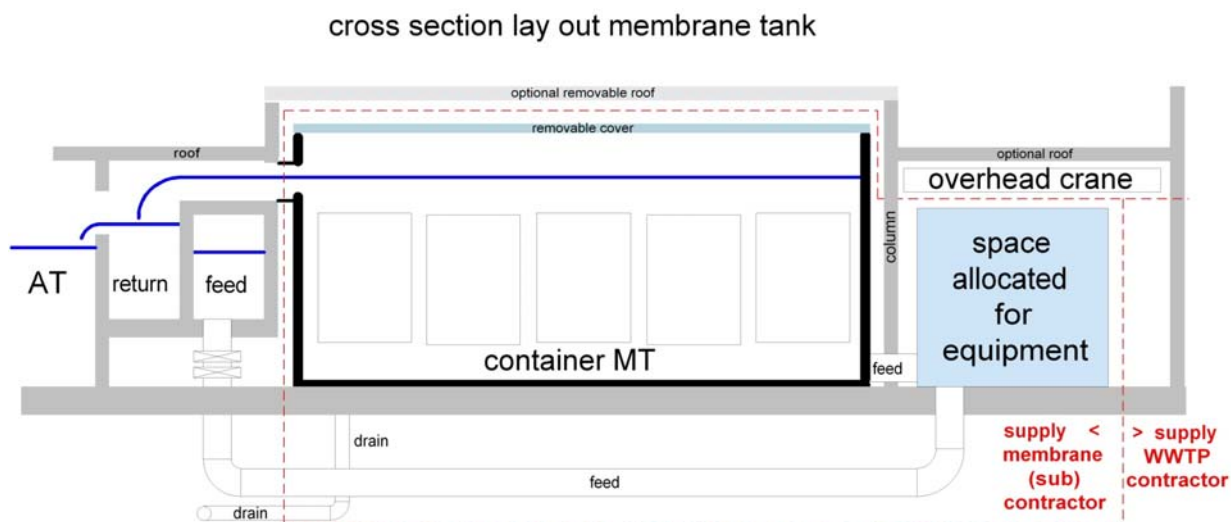
Item	Supplied as part of	
	WWTP	Membrane system
Pre treatment	X	
Air scouring blowers	X	
Air control valve		X
Drain pump	X	
Drain valve		X
Effluent pump	X	
Effluent valve		X
Chemical circulation pump, storage tank	X	
Chemical dosing pump		X
Permeate / backpulse pump, headers and valves		X
Feed pump		X
Storage waste chemicals (after cleaning)	X	
Membrane filtration tanks		X
Process control system membranes		X
Process control system WWTP	X	



➔ Layout



➔ Tank – example tank in container

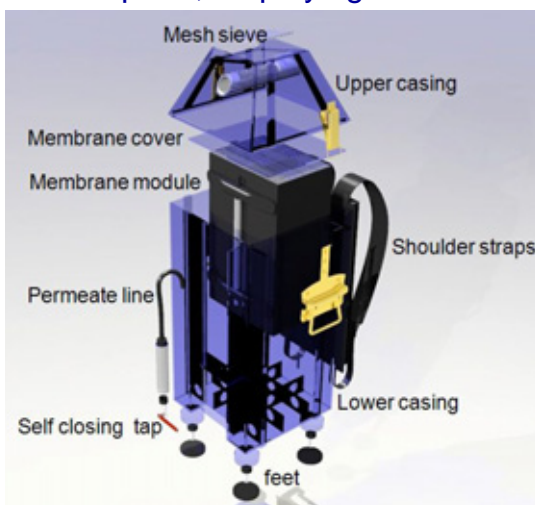


- ➔ Moderating a workshop is sometimes difficult
- ➔ If no one is fully satisfied with the result, then it is most likely that the document agreed upon is a **good compromise**
- ➔ Those who did not contribute should not moan afterwards



Thanks for your kind attention

No presentation on membranes without a note on the „**Water Backpack**“, a device for **water treatment in cases of disasters for small groups** of affected people, who do not receive first aid so far – no energy, nor chemicals, no moving parts, employing membranes – see our website (see below).



More information and the slides of this presentation (in a few days) can be retrieved from www.uni-kassel.de/fb14/siwawi



38. AN AERATION ENERGY MODEL FOR AN IMMERSED MEMBRANE BIOREACTOR

*B. Verrecht, G. Gugliemi, J.W. Mulder, C. Brepols,
S. Judd*

An aeration energy model for an immersed MBR

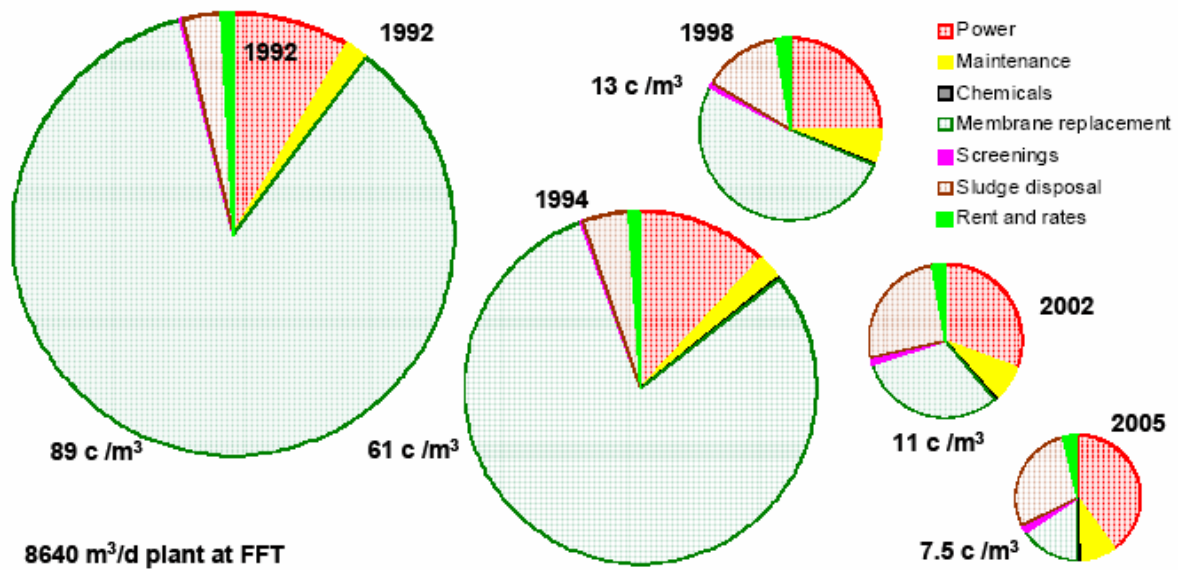
Simon Judd and Bart Verrecht, *Cranfield University*
Giuseppe Guglielmi, *Trento University*
Christoph Brepols, *Erftverband*
Jan-Willem Mulder, *Water Authority of Hollandse Delta*



Outline

- ▶ MBR energy demand
- ▶ Aeration model
 - Key assumptions
 - Pilot testing
- ▶ Benchmarking against full scale FS - HF
- ▶ Model predictions
 - Influence of HRT
 - Difference between modules
 - Sensitivity analysis
- ▶ Conclusions

O&M costs through the ages, Kubota (Kennedy and Churchouse, 2005)

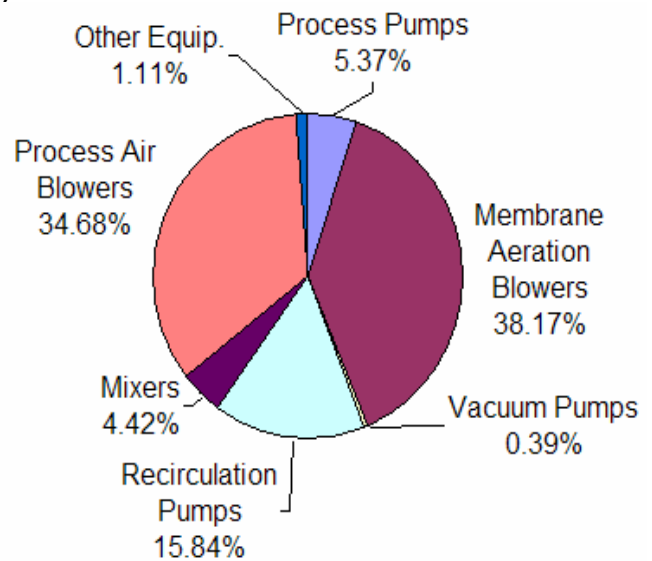


MBR energy demand

Relates mainly to aeration (60-70%).

Aeration for membrane & bio tanks:

- ▶ Biotank
 - Provides DO to biomass
 - Suspends flocs
- ▶ Membrane tank
 - Scours membrane by providing shear
 - Agitates membrane (for HF fibres)



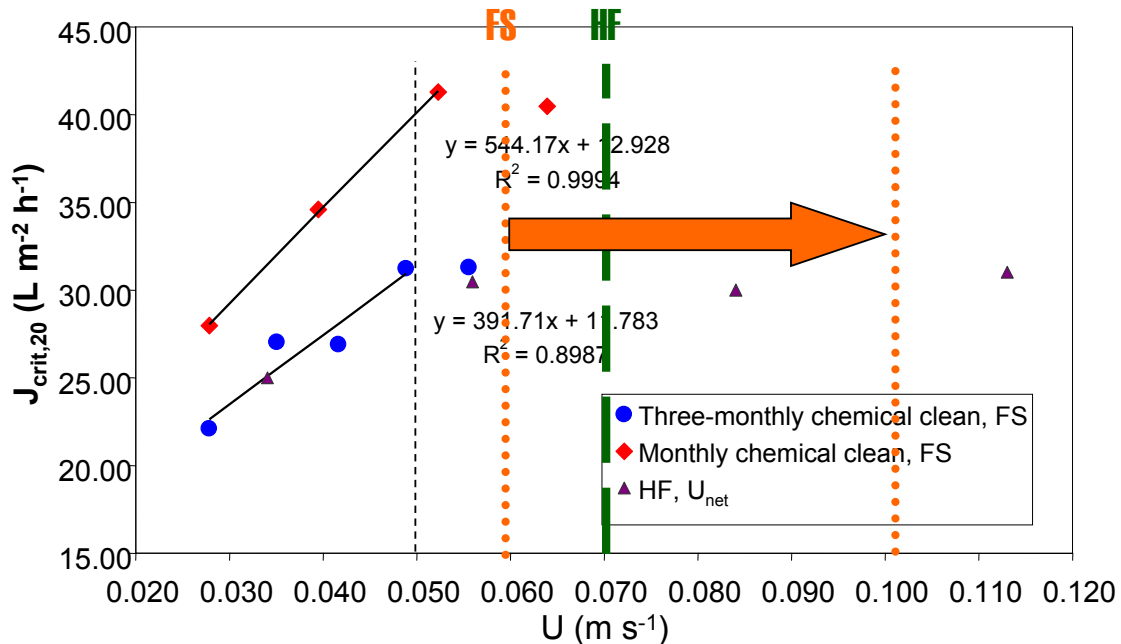
Membrane aeration

- ▶ Key identified parameters are:
 - Specific aeration demand with respect to membrane area (SAD_m , $Nm^3/(h.m^2)$)
 - Specific aeration demand with respect to permeate production (SAD_p , $m^3/m^3 = SAD_m/flux$) - proportional to specific energy demand (E_A , kWh/m^3) and
 - Aeration intensity (U , m/s) – **the *in-module* air upflow velocity**

Three big assumptions:

- ▶ scour intensity correlates roughly with shear and thus U
- ▶ flux increases linearly with shear
- ▶ threshold value exists beyond which no further improvement in flux occurs

Pilot plant FS & HF sustainable flux



Values of U , J and SAD – large-scale plant

- ▶ Values for key operating parameters can be taken from plants operating under most optimum sustained conditions
- ▶ Values of U less variable than those of SAD

Parameter	FS1	FS2	FS3	FS4	FS 4	HF 1	HF 2	Ave	SD
	F, sd	D, sd	F, dd	F, dd	D, dd	D	F		%
L , m	0.95	0.95	1.9	3.04	2.2	2.09	2.09		
δ , m	0.007	0.007	0.007	0.0065	0.007				
φ , m ² /m ³						300	300		
d , m						0.0019	0.0019		
SAD_m	0.75	0.88	0.27	0.42	0.21	0.25	0.43	0.45	60%
U, m/s	0.057	0.066	0.041	0.109	0.037	0.051	0.087	0.064	36%
Aeration	100%	100%	100%	100%	100%	50%	50%		
J , l/(m ² .h)	25	31	25	26	26	30	24	24	33%
SAD_p	30	28	11	16	8	8	18	20	52%

F Full; D Demonstration; sd single deck; dd double deck; δ channel thickness; d fibre diameter

The model

- ▶ The model is based on a number of adjustable parameters for tuning which arise from:
 - An empirical expression relating flux J to membrane aeration, where relates linearly to U up to threshold value:
 - $J = mU + J_o$ at $J < J_{max}$
 - $J = J_{max}$ at $U > U_{max}$
 - A biokinetic model (Ekama et al, 1984) to provide figures for COD and ammonia removal
 - The classical expression for blower energy demand
- ▶ Other key assumptions
 - Flux identified from full-scale data is sustainable
 - Dissolved oxygen created by membrane aeration is available for biodegradation
 - Constant values and/or consistent simple interrelationships for such pivotal parameters α -factor, OTE, etc.
 - Tuning based on m and blower efficiency

Protocol

- ▶ Set flux J .
 - ▶ From module characteristics determine A_x and aerator depth y
 - ▶ Determine SAD_m and combine with y and J to provide specific membrane aeration energy demand, selecting most conservative value of ζ and m to match with SAD_p .
 - ▶ From air flow rate and physical characteristics determine mass flow of oxygen provided by membrane aeration
 - ▶ From feedwater and effluent quality and flow, determine biological parameters/oxygen requirement for biodegradation from biokinetic model
 - ▶ Thus: **Estimation of biology aeration**
 - = total mass flow of DO required minus
 - mass flow of DO provided by membrane aeration
- incorporating factors such as:
- % oxygen in air
 - Oxygen transfer efficiency
- ▶ Determine specific biotank aeration energy demand.
 - ▶ **Total Aeration Energy Demand =**
- Membrane aeration energy demand + Biotank aeration energy demand**

Benchmarking

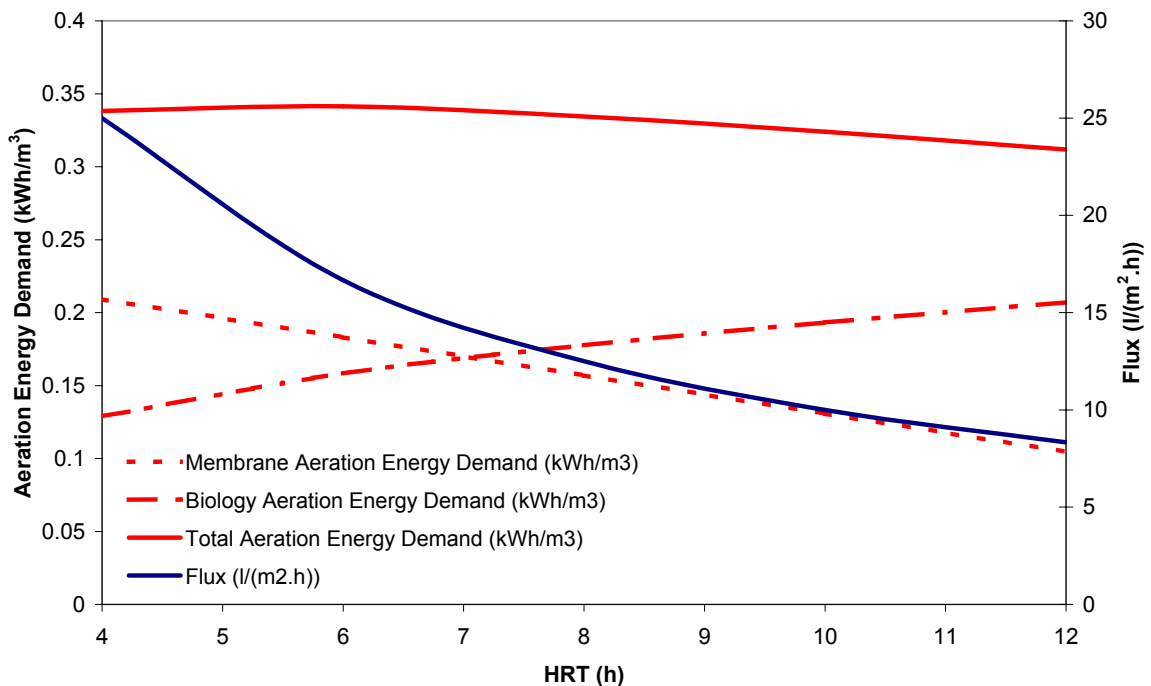
Parameter	Units	FS			HF		
		Pred.	Actual	%diff	Pred.	Actual	%diff
SAD_m	$Nm^3/(h.m^2)$	0.439	0.439	0	0.430	0.430	0
SAD_p	-	17.6	16.4	6	17.2	17.2	0
E'_A (per m^3 air)	kWh/Nm^3	0.022	0.022	0	0.013	0.013	0
E_A (per m^3 permeate)	kWh/m^3	0.390	0.365	6	0.229	0.200	15
m^*		228	-	-	264	-	-
ζ^*	%	58	-	-	54	-	-
E_A (per m^3 permeate)	kWh/m^3	0.194	0.165	18	0.028	0.035	-20
Total E	kWh/m^3	0.584	0.530	10	0.257	0.235	~9
COD	mg/l	23.4	24	3	4.8	4.8	0
Total N	mg/l	6.4	2.9-5.3	-	3.2	3-9	-
Total biotank volume	m^3	693	N/a		9,986	9,314	7
Anoxic volume	m^3	243	N/a		3,545	3,525	1
Aerobic volume	m^3	451	N/a		6,441	5,789	10
Overall HRT	h	6.8	7	-2	4.7	4.7	0

Membrane zone biotreatment zone permeate quality tank volumes

Baseline parameters

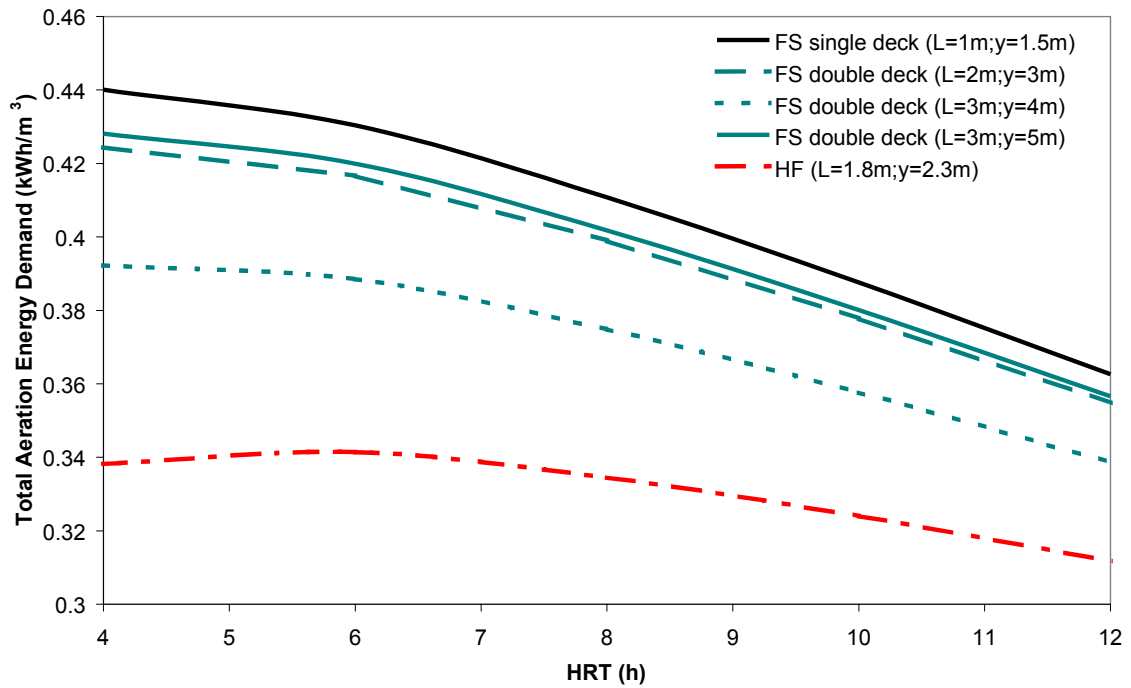
Parameter	Value	Parameter	Value
Membrane		Feedwater quality, mg l⁻¹	
Flux J , l m ⁻² h ⁻¹	25	COD _{in}	430
m	247	TKN _{in}	40
ζ , %	56	(N-NO ₃) _{in}	0
Module parameters		Operating parameters	
$A_x/A_{FS, \text{single deck}}$	0.00417	MLSS in biotank, mg l ⁻¹	8,000
A_x/A_{HF}	0.00157	SRT, d	19
Aeration		$N_{a,out}$, mg l ⁻¹	0.81
OTE _{coarse} , % m ⁻¹	2.5	Anoxic fraction f_n	0.4
OTE _{fine} , % m ⁻¹	4.5	Process temperature, °K	293
ω	0.084	Process pH	7.2
Fine bubble aerator depth y_{fine}	5	Fine bubble aerator blower efficiency ζ_f	48.7
β	0.95		
ψ (T=273K): $\psi = 1.024^{T-273}$	1.024		
<i>Membrane zone biotreatment zone feedwater quality operating parameters</i>			

Results: impact of HRT



Increased biological aeration demand at longer HRTs due to endogenous respiration countered by decrease in membrane aeration demand at lower SAD_m values required at lower fluxes incurred

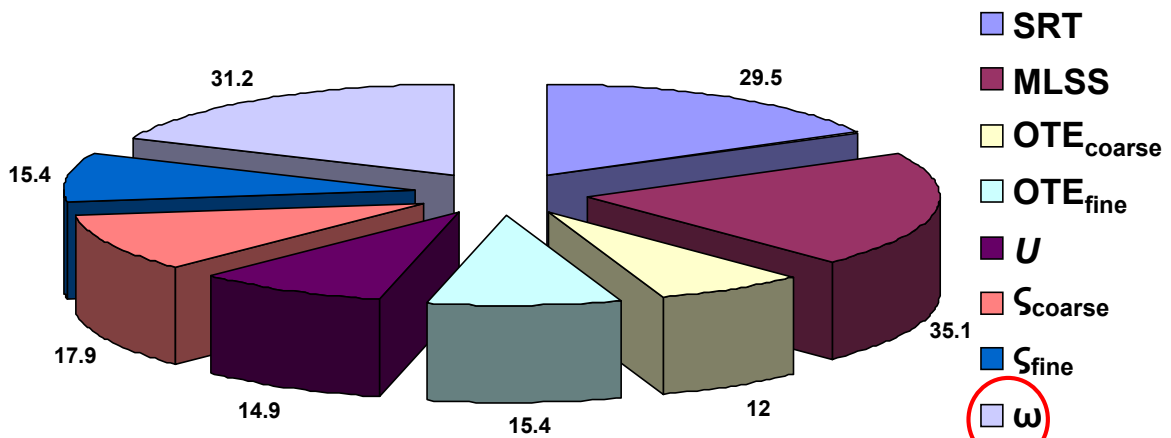
Impact of membrane configuration and HRT



Sensitivity

- ▶ % change in energy demand corresponding to a 50% change in the value of the individual parameter

- Baseline specific aeration energy demand = 0.391 kWh/m³



Exponent in alpha factor relationship with MLSS: $\alpha = e^{-\omega X}$

Summary

- ▶ A model has been created which calculates aeration energy demand based on the most optimum set of assumptions
- ▶ Key assumption is validity of in-module aeration velocity U , values for which vary little across optimised plant
- ▶ Benchmarked against two large-scale plant for which sustained operation under optimum conditions was attained, the model predicts:
 - changes in HRT have little impact on aeration demand
 - a double-deck plant has only slightly lower specific energy demand than a single-deck plant
- ▶ Output was most sensitive to assumptions regarding OTE and change in MLSS concentration

Acknowledgements

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

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Duration: 01/01/06 - 31/12/09

EUROMBRA and MBR-TRAIN are part of the MBR-NETWORK Cluster

More info: www.mbr-network.eu and www.mbr-train.org



MARIE CURIE ACTIONS

39. POTENTIAL FOR MBR APPLICATIONS FOR WASTEWATER TREATMENT IN THE MIDDLE EAST AND NORTH AFRICAN REGION

M. J. Bino, S. N. Al-Beiruti, M. Wade



Potential for MBR Applications for Wastewater Treatment in the Middle East and North African Region

Murad J. Bino, Shihab N. Al-Beiruti and Matthew Wade

Presentation for the Final MBR Workshop
Wasser Berlin



Puratreat S&T objectives

Puratreat is about new energy efficient approach to the operation of MBRs for decentralized wastewater treatment

- To study the performance of three types of membrane technologies working under different operating conditions of low solids retention times and specially adapted to the requirements of MENA countries
- To study the characteristics of the microbial community present in the reactor for the different experimental conditions investigated
- To propose the most suitable technology for the application of decentralized MBR wastewater systems and its optimum operating conditions
- *To study the feasibility of decentralized wastewater treatment plants based on MBR technologies in the MENA countries*



Investigated membrane types (flat sheet types)



- Kubota
- Martin Systems AG
- Wiese Water Systems



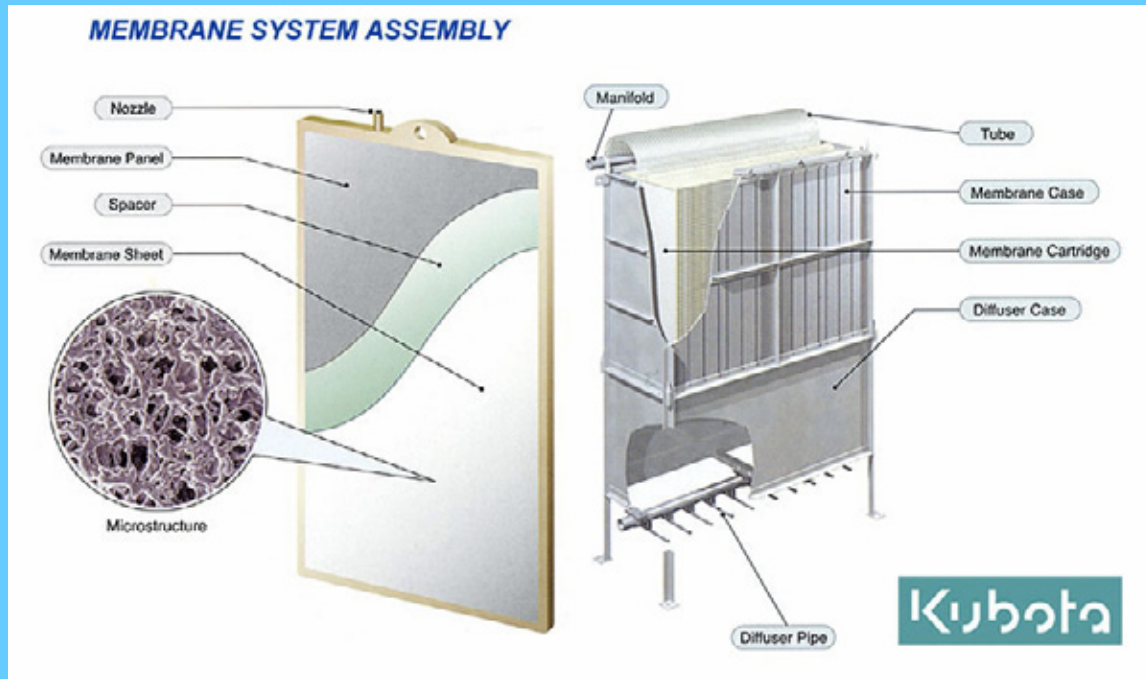
Kubota membrane



The investigated full size Kubota membrane panels were double-sided, 0.5 m wide, 1.0 m deep and 0.006 m thick with a gap between membrane panels of 0.006 m. Permeate is removed from each membrane panel via a tube connection located on the top.



Kubota flat sheet membranes



www.puratreat.com

5



Matrin Systems MBR



The investigated Martin Systems MBR contained one membrane module, with 6.5 m² of membrane area. Each module contained parallel plate membranes, with a 6 mm space between the membranes.

www.puratreat.com

6

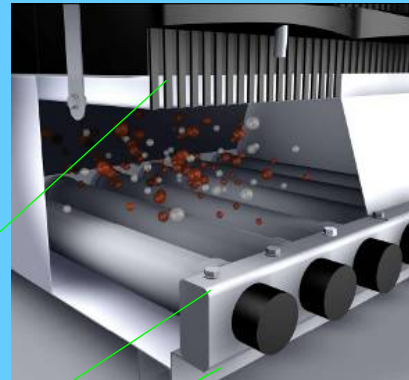
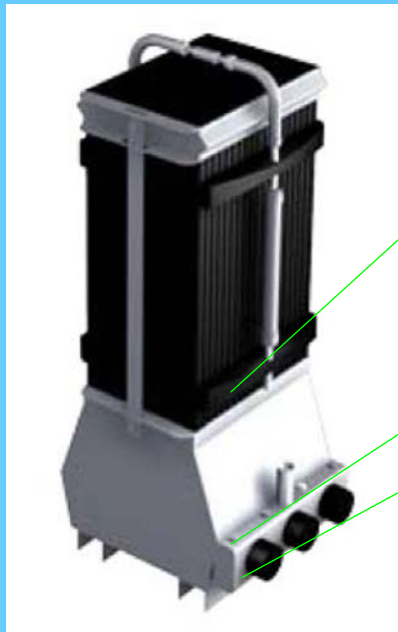


Martin Systems

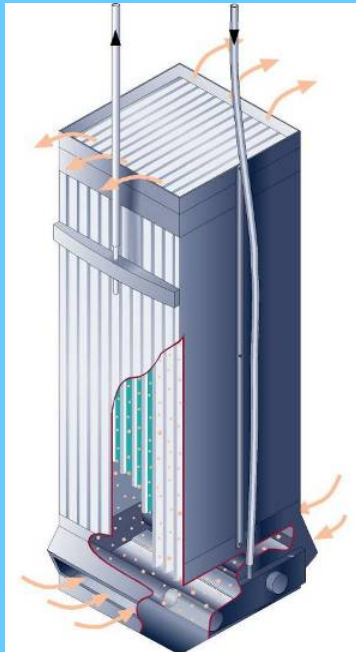


Permeate

Air



siClaro[®] FM 611,
6.25 m²



www.puratreat.com

7



Weise Water Systems MBR



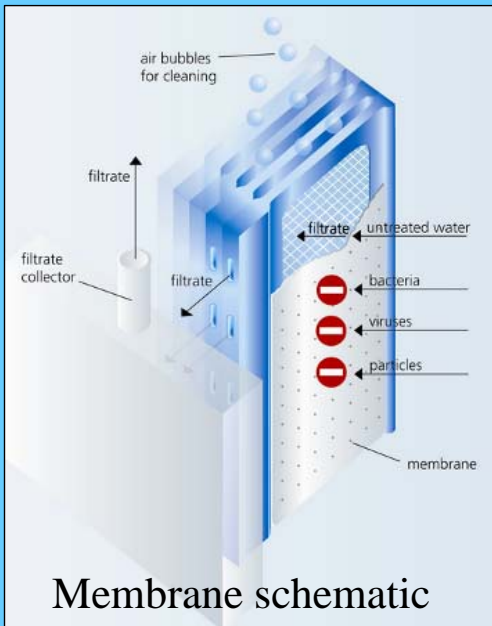
The investigated Weise Water Systems MBR set up contained two MCO3 membrane modules, each with 3.5 m³ of membrane area. Each module contains 24 parallel plates, with a 5.5 mm space between the membranes.

www.puratreat.com

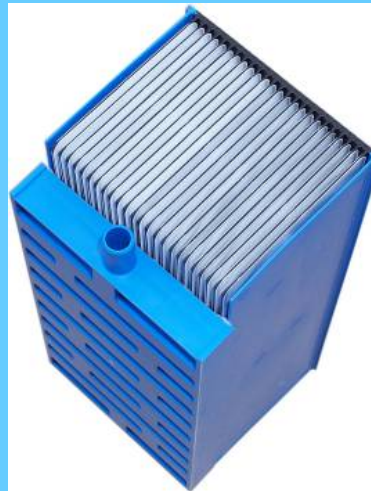
8



Weise Water MBR Systems



Membrane schematic



MicroClear
MCO3, 3.5 m²



Filter housing

www.puratreat.com



Membrane market development (MENA)



- MBR applications and market is growing rapidly since late seventies
- Large applications are dominating the MBR market and the technology is becoming more and more competitive
- Largest MBR plant will be commissioned in MENA countries

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10



Decentralized sewage treatment plants



- Reduces the freshwater input for waste transportation,
- Unlikely simultaneous operation failures of all the smaller systems
- Increases the feasibility of treated wastewater reuse as it will be done as close as possible to the treatment facilities,
- Wastewater treatment becomes more cost effective,
- Permits incremental development and investment,
- Permits the use of compact wastewater treatment technologies,
- But requires well trained personnel for O&M



Sanitation situation in the MENA region



- Urban sewer coverage is high but less in rural areas
- Public owned centralized plants are dominant
- New trend encourages PPP and decentralization
- Wastewater quality is high in BOD and is saline
- Decentralization means treating liquid wastes close to the sources of its generation, and as close as possible to sites of its reuse.



Sanitation needs in MENA

- Puratreat investigated the state of sanitation in peri urban areas of the MPC
- Investigated investment capacity in peri urban areas of the MENA region
- Proposed Jordan as case for implementing a peri urban municipal wastewater treatment plant based on MBR



Samoa WWTP details

Flow data	WW flows, volumes
Total daily flow, 500 PE @ 0.135 m ³ /day	67.5 m ³ /day
Averages raw sewage inflow	2.813 m ³ /hr
Max flow in 6 hrs at 40% total	4.5 m ³ /hr
Sludge volume at 5% daily flow	3.375 m ³ /day
Flow balancing PE tanks, m ³	10 m ³



Samoa WWTP



Component	Details
Site preparation	Roads and fencing
Flow balancing PE tanks, 10 m ³	2 PE circular 5 m ³ each
MBR treatment and ancillaries	2 MBRs modules
Prefabricated housing- MBR treatment	Containerized 5x3x3 m
Prefabricated housing- air compressors	Containerized 3x3x3 m
Treated water collection tank	100 m ³ circular concrete
Sludge storage tank	25 m ³ circular concrete



Targeted effluent quality



Unrestricted irrigation water quality

Parameters	Description
< 5 mg/L	BOD
<2 mg/L	Total suspended solids
<1 mg/L	Ammonia N (plant nutrient)
<2.2 c/100 ml	Total coliforms
<1 /L	Parasites
<0.1 mg/L	Total phosphorus (plant nutrient)
<3 mg/L	Total nitrogen
<0.2 mg/L	NTU Turbidity



Samoa MBR WWTP



Benefit/cost study



The following formula was used to estimate the present value of costs and benefits of the MBR

$$P = \frac{A (1 + i)^n - 1}{i (1 + i)^n}$$

where

P: Present value of money

A: An end – of – period payment (cash inflow or outflow at the end of the year)

i: Discount rate

n: Number of discounted periods (life span of the project assumed 20 years)



Estimated Costs of MBR WWTP (US\$)



- A) Construction and installation costs (total of 88,000) distributed as below:
- 1) Site preparation (roads and fencing): 10,000;
 - 2) Flow balancing PE tanks, 10 m³ (2PE circular each 5 m³): 2,000;
 - 3) MBR treatment and ancillaries (2MBRs rows, + aeration + lab space): 35,000;
 - 4) Housing of MBR and tanks 5x3x3 m: 15,000;
 - 5) Housing of utilities 3x3x3 m: 10,000;



Estimated Costs continued



- 6) Sludge storage tank (25 m³ concrete circular): 6,000;
 - 7) Plant commissioning and training: 10,000;
- B) O&M costs
- Yearly operation and maintenance costs: 10,000;
 - MBR replacement in the 10th year: 10,000.



Estimated Benefits of MBR WWTP (US\$)



The following benefits of use of treated wastewater for irrigation were considered for this study:

- 1) Initial sewer connection fees (paid by beneficiaries in the first year): 25,000;
- 2) Sale of treated wastewater @0.5/m³: 12,000 per year;
- 3) Sewer use fees: 8,500 per year;
- 4) Sludge sale @2/m³: 2,500;

Total yearly benefits: 23,000 per year over 20 years.

Other community benefits such as growing agro products, marketing and jobs created by the project are not included in the estimation of the benefit-cost analysis.



Benefit/cost ratio



A) Present value of costs:

- 1) A total of 88,000 will be invested directly at the start of the project;
- 2) Present value of operation and maintenance of US\$12,000 per year for 20 years (assuming discount rate of 8%) will be:115,000
- 3) Present value for replacing the MBR in the 10th year will be:4,500

Total present costs of MBR WWTP will be about 207,500.



Present value of benefits



- 1) Direct benefits from sewer connection fees
25,000 (present value)
- 2) Present value of yearly benefits (assuming
discount rate of 8% over 20 years) are 220,500

Total present value of benefits:

US\$245,500. Thus the B/C is 1.18

For each US\$ invested in the construction and operation of WWTP 1.18 US\$ will be generated over 20 years



Acknowledgement



The study reported in this presentation was performed within the FP7 European Specific Targeted Research project PURATREAT, contract No. 015449. INWRDAM and its Puratreat partners acknowledge the financial support provided by the European Commission in support of this study.

40. POTENTIAL AND IMPLEMENTATION OF FULL-SCALE DUAL (HYBRID) MBR-CAS CONCEPTS IN NEWLY ACCESSED COUNTRIES

*D. Bixio, L. Maes, W. De Wilde, J. Deurinck, C.
Thoeye, G. De Gueldre*

Potential and implementation of full-scale dual (hybrid) MBR-CAS concepts in newly accessed EU countries

D. Bixio, L. Maes, W. De Wilde, J. Deurinck, C. Thoeye, G. De Guedre



Content

- ▶ Introduction
- ▶ **Part I:** Inception stage:
 - Status of wastewater treatment in newly accessed EU countries
- ▶ **Part II:** Strategic screening stage:
 - Preliminary cost comparison in different legislative settings
- ▶ **Part III:** Tailor-made scenario analysis stage:
 - Case study
- ▶ Conclusion

Introduction

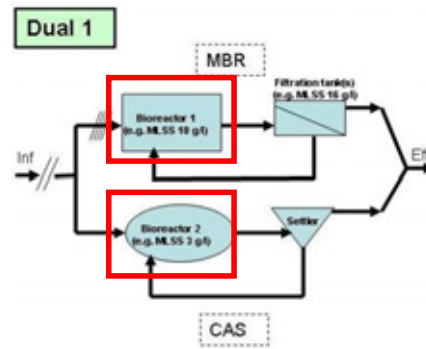
Dual technology

- ▶ Combination of CAS and MBR technology
 - Mitigate high costs
 - Advantages:
 - > Less membrane area required
 - > Reuse existing infrastructure
 - Renovations

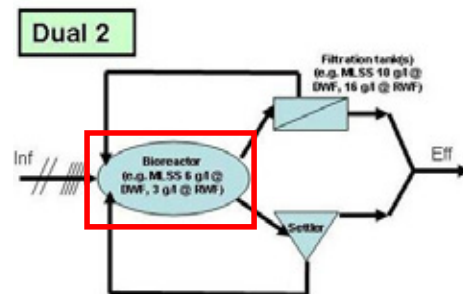
Dual technology

► Flow schemes

- Dual 1



- Dual 2® (patent application WO 2007/065956 A1)

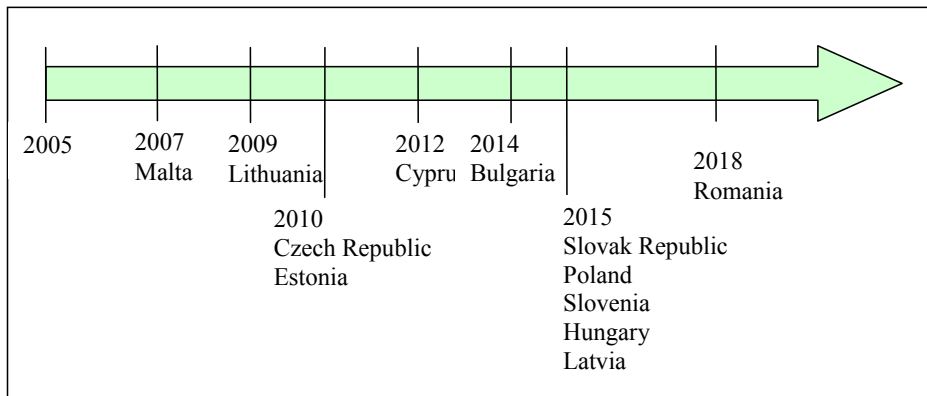


Part I: Inception stage

- Literature review on the status and implementation of typical wastewater treatment infrastructure in Accession countries and new member states.

Country profiles

► Compliance to the UWWTD



► Priority

- Sensitive areas
- Larger agglomerations

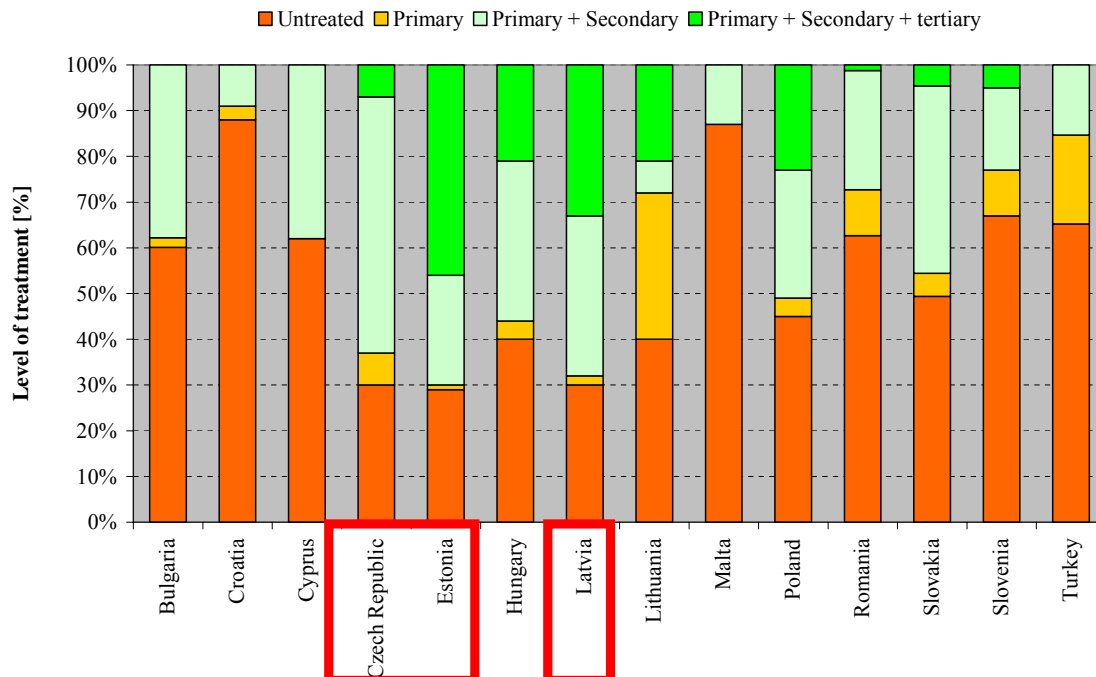
Country profiles

► Level of compliance to UWWTD



Country profiles

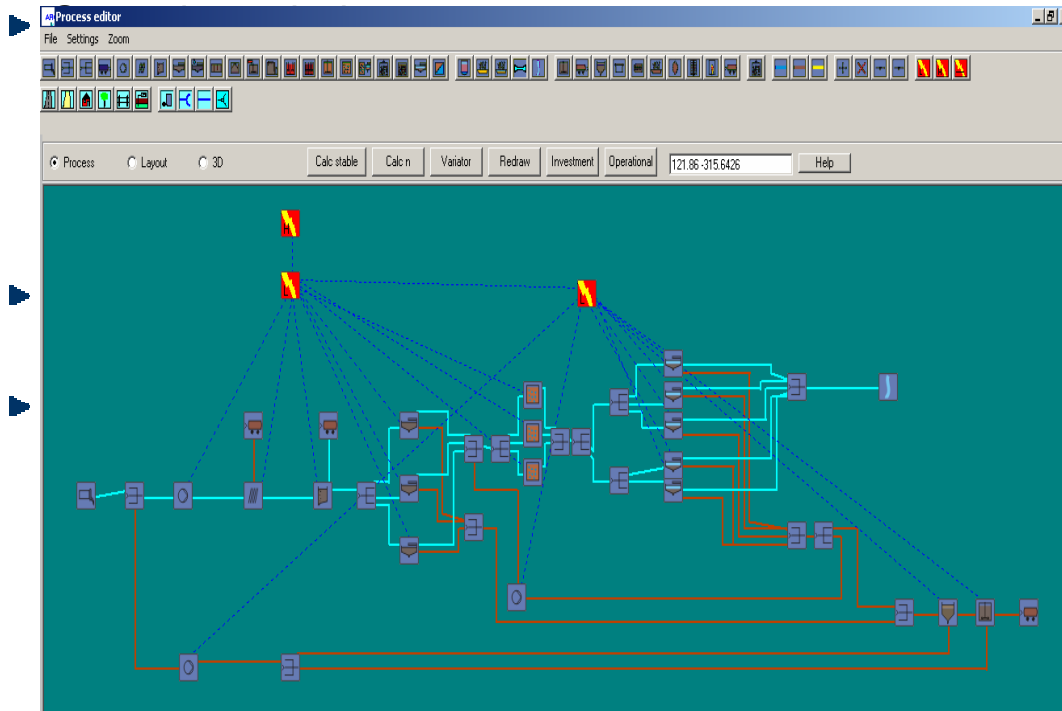
► Level of compliance to UWWTD



Part II: Strategic screening stage

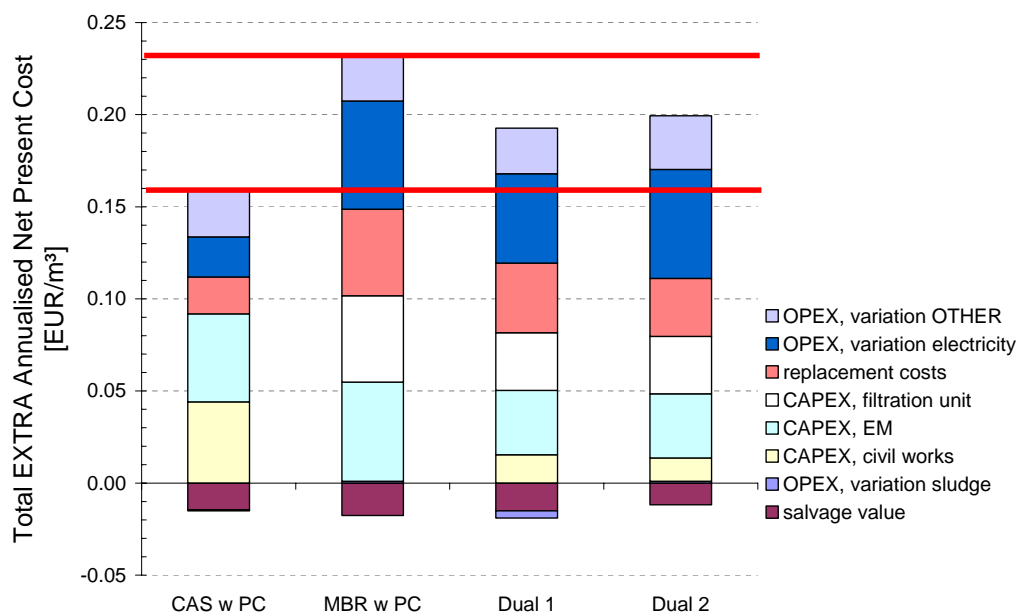
► Preliminary cost comparison of renovation scenarios in different legislative settings (Bulgaria versus Cyprus)

Method



Cost comparison: Bulgaria

► Bulgaria



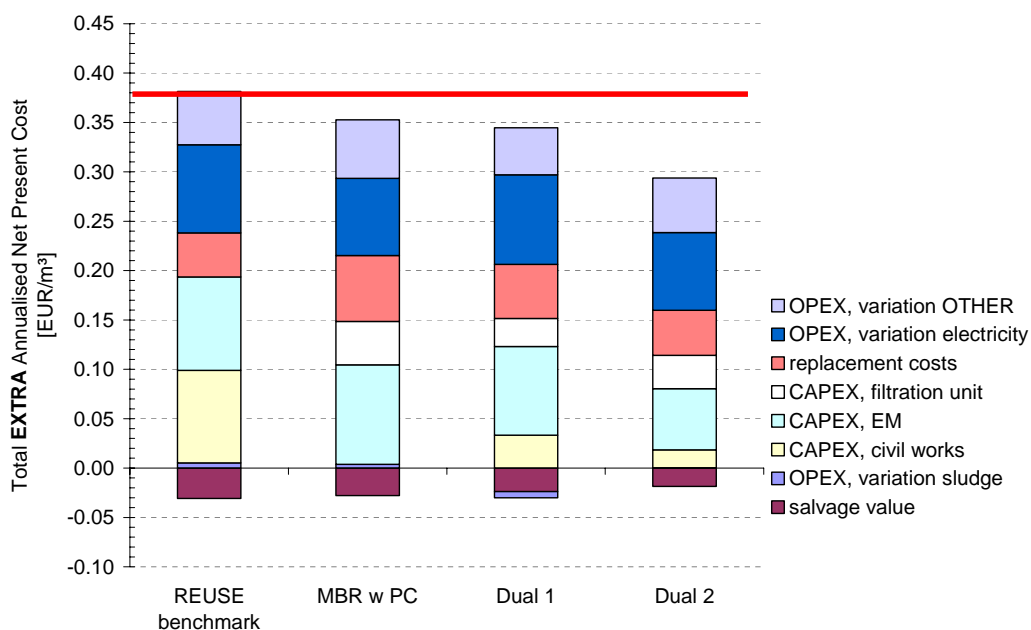
Cost comparison: Bulgaria

► Dual 1/Dual 2:

- 20/25 % more expensive than basecase
- 25/20 % more cost-efficient than MBR

Cost comparison: Cyprus

► Cyprus



Cost comparison: Cyprus

- ▶ Dual1/Dual2:
 - More feasible than classic MBR refurbishment
 - More feasible than reuse benchmark

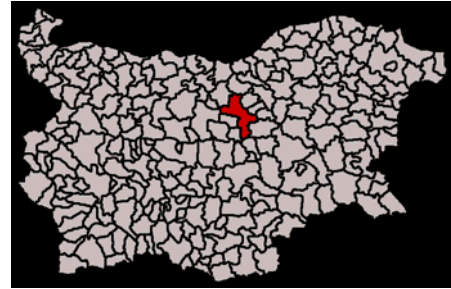
Part III: Tailor-made scenario analysis stage

- ▶ Cost comparison of different scenarios for the renovation of a specific plant. The aim is to achieve a detailed technical plan in a specific context.

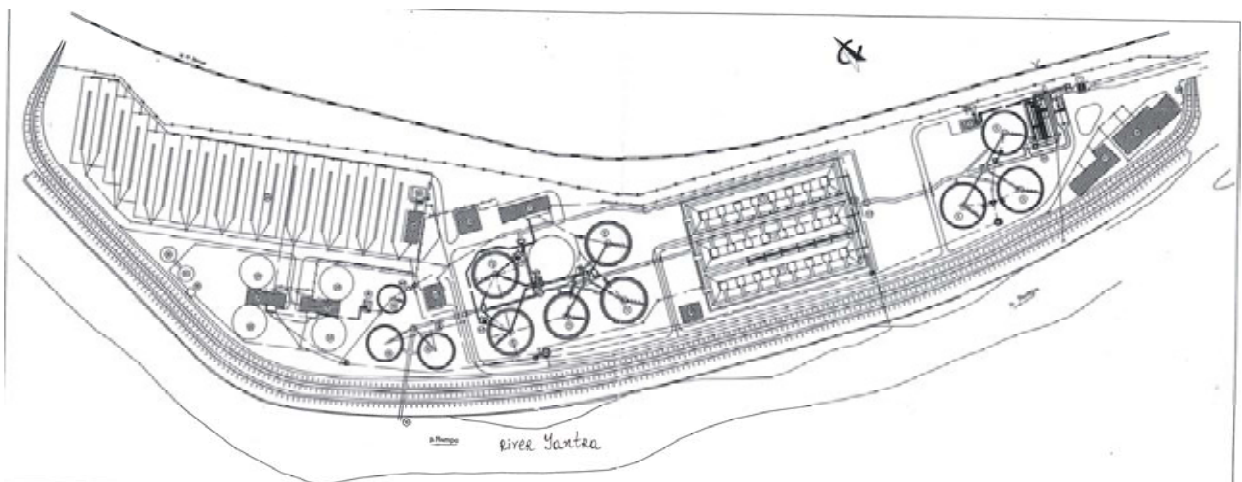
Location

▶ WWTP Veliko Tarnovo, Bulgaria

- Construction: 70ies
- Overloaded
 - Biologically
 - Hydraulically
- Actual Design population: 92,000
- Renovation Design population: **120,000** **10 x**
- Maximal flow after renovation: 60,000 m³ day⁻¹
- Discharge point: River Yantra (sensitive)



Location

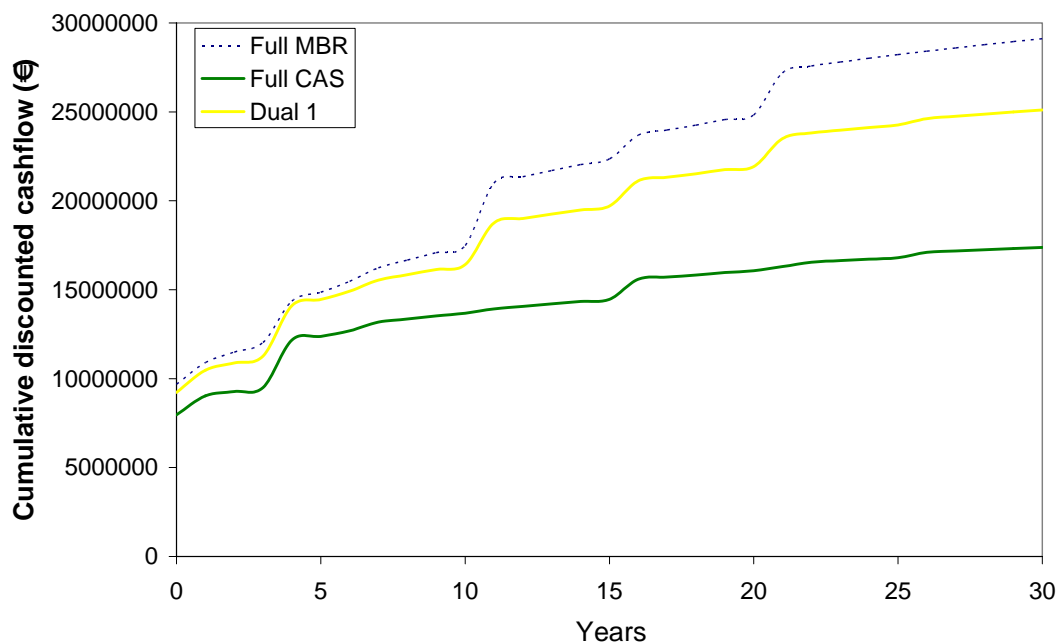


Cost comparison

- Investment over 30 years:
 - Depreciation times:
 - Civil costs: 30 years
 - EM costs: 15 years
 - Membranes: 10 years
 - $I_{\text{year } x} = I * 1/(1+0.046)^x$
 - Included:
 - New constructions
 - Renovation reused infrastructure
 - Electricity cost

Cost comparison

- Investment over 30 years: $I_{\text{year } x} = I * 1/(1+0.046)^x$



Conclusion

- ▶ Dual scenario not competitive in Veliko Tarnovo
- ▶ General advantages of a refurbishment with Dual technology:
 - Reuse of the existing aeration basins
 - Potential for reuse
 - ➔ Not applicable in Veliko Tarnovo
- ▶ Matter of scale

General conclusion

General conclusion

- ▶ Dual technology less expensive than Full MBR
- ▶ Advantages:
 - Reuse of existing infrastructure
 - Less membrane area required
- ▶ Membrane cost and replacement, highest cost impact
- ▶ Under specific circumstances:
 - Smaller scale
 - Reuse of water
 - Stringent effluent norms

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
AMEDEUS is part of the MBR-NETWORK Cluster



More info: www.mbr-network.eu

Back-up

► Assumptions scenario-analysis D56

- 20 year project life
- 6 % discount rate
- Civil: 30 years, EM: 15 years
- Extra manpower: Pessimistic, Baseline, Optimistic
 - MBR: 40%, 20%, 20%
 - Dual 1,2: 20%, 10%, 10%
- Oxygen transfer coarse bubble aeration: 25%

Back-up

	Units	CAS	MBR		
			Pessimistic	Baseline	Optimistic
Influent load	g p.e./d	BOD ₅ = 60, COD = 135, SS = 90, TN =12, TP = 2			
Design-average water temp.	T°C	16-22 (Cyprus); 12-18 (Bulgaria, Black Sea coastal areas)			
MLSS	g/L	3.5-4.0-4.5	8	11	14
α -factor	-	0.70	0.45	0.55	0.65
Membrane lifetime	Years	-	7	11	13.5
Energy use for filtration	kWh/m ³	-	0.60	0.45	0.25

41. ECONOMIC ASPECTS OF LARGE SCALE MEMBRANE BIOREACTORS

C. Brepols, H. Schäfer, N. Engelhardt

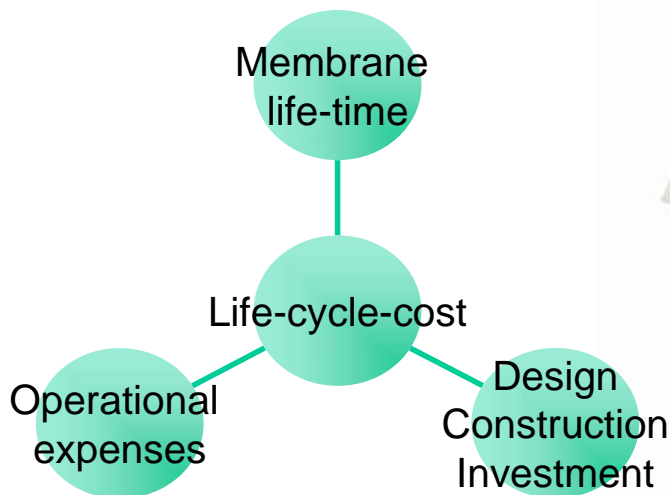
Economic Aspects of Large Scale Membrane Bioreactors



Christoph Brepols, Heinrich Schäfer, Norbert Engelhardt
Erftverband, Am Erftverband 6, 50126 Bergheim / Erft, Germany
christoph.brepols@erftverband.de

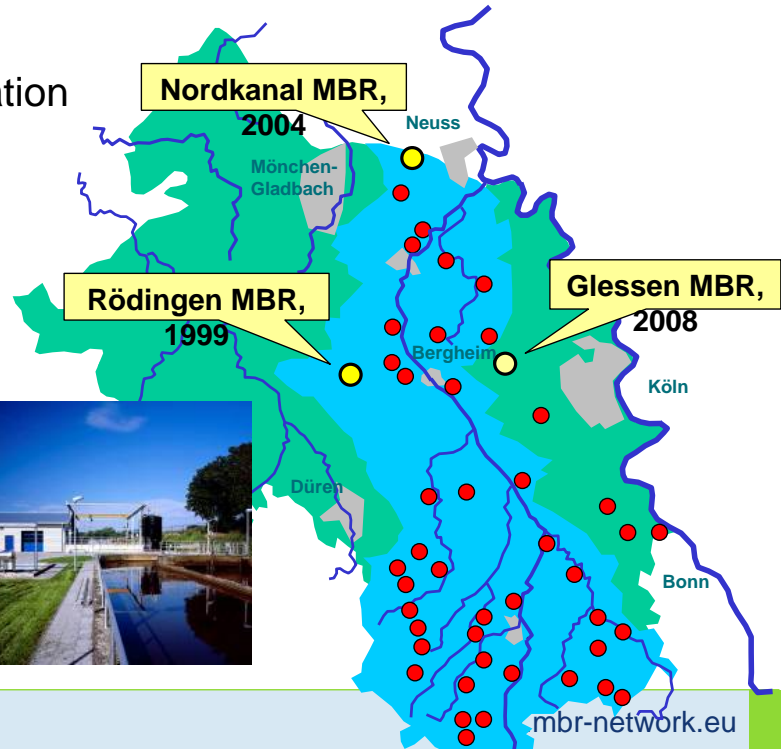


Key Economic Issues



Outline

- ▶ Investment
- ▶ Operation
- ▶ Life-cycle-cost calculation
- ▶ Conclusions



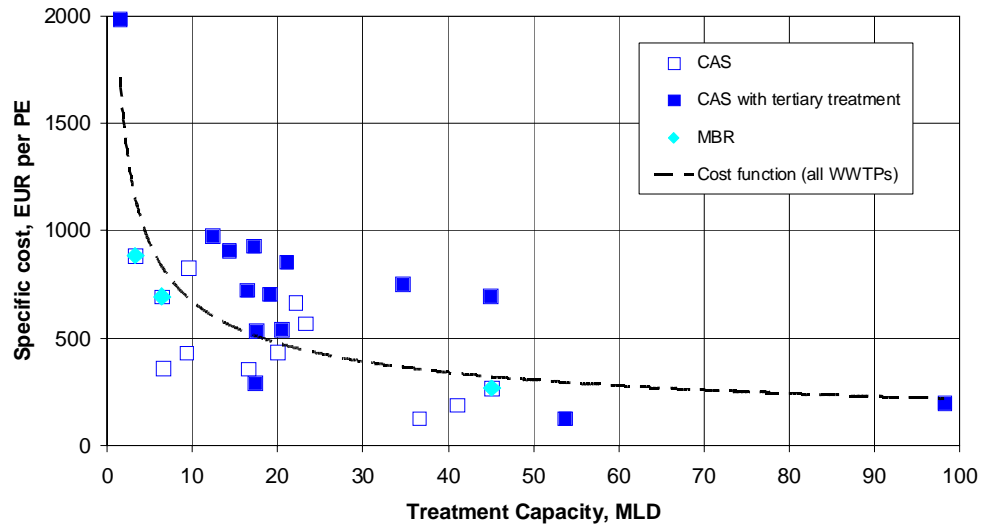
MBR Plants 1999 to 2008



	Rödingen, 3,000 PE	Glessen, 9,000 PE	Nordkanal, 80,000 PE
Commissioned	1999	2008	2004
Dry-/ rain weather inflow	300 / 3200 m ³ /d	2000 / 6500 m ³ /d	12000 / 45000 m ³ /d
Bioreactor	400 m ³ + 80 m ³ (filtration tanks)	1,600 m ³ + 320 m ³ (filtration tanks)	9,300 m ³
Membrane	5,280 m ² hollow fibre modules, separate filtration units	12,100 m ² hollow fibre modules, separate filtration units	84,480 m ² hollow fibre modules, integrated filtration
Effluent requirements	COD < 30 mg/L NH ₄ -N < 4 mg/L P _{tot} < 1.5 mg/L	COD < 30 mg/L NH ₄ -N < 1.5 mg/L P _{bt} < 0.6 mg/L	COD < 90 mg/L NH ₄ -N < 10 mg/L P _{tot} < 1.5 mg/L

Investment Cost MBR vs. CAS

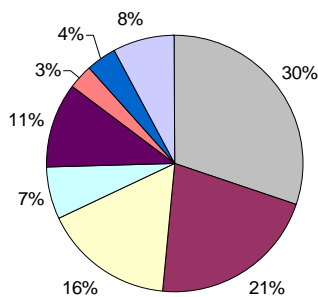
Investment cost, new and retrofitted WWTPs
1989 - 2008, cost index 2000



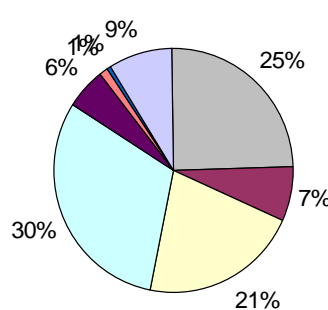
Investment cost structure	Construction	Mechanical equipment	Electrical equipment	Membranes
CAS	63%	28%	9%	-
MBR	46%	31%	13%	10%

Types of Operational Cost

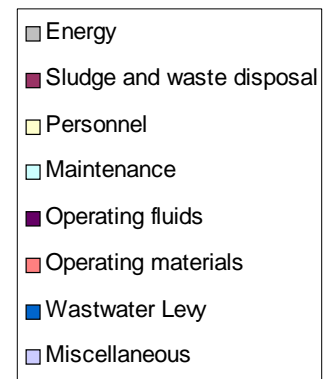
- Cost categories at Nordkanal and Rödingen MBR, actual values of 2004 - 2008



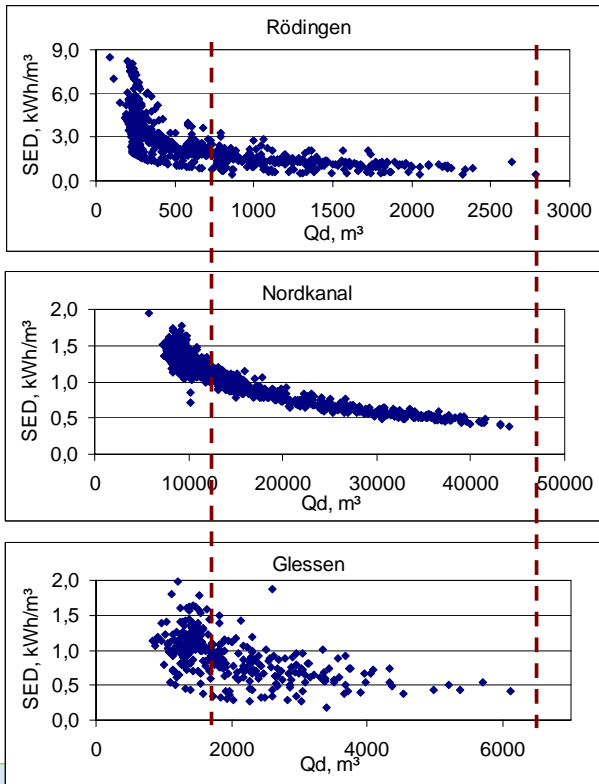
Nordkanal MBR



Rödingen MBR



Specific energy demand

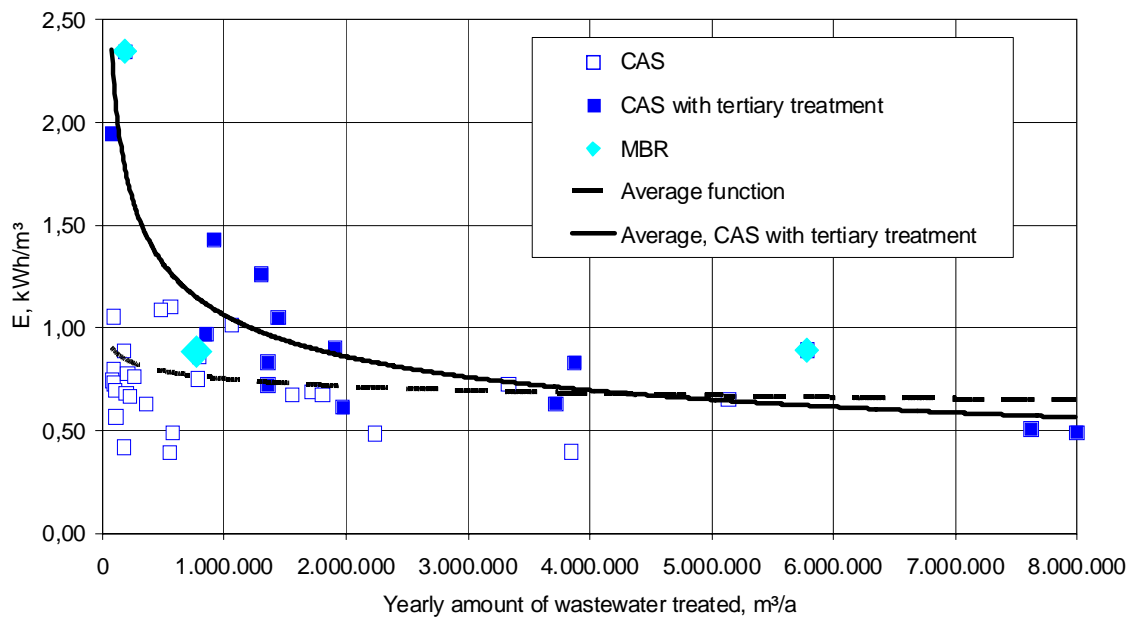


- ▶ Constant cross-flow aeration leads to low energy efficiency
- ▶ Multilane design
- ▶ Control strategies for operating at low inflow

7

Energy consumption of CAS and MBR

Average specific energy consumption



8

Prolonging membrane life-time

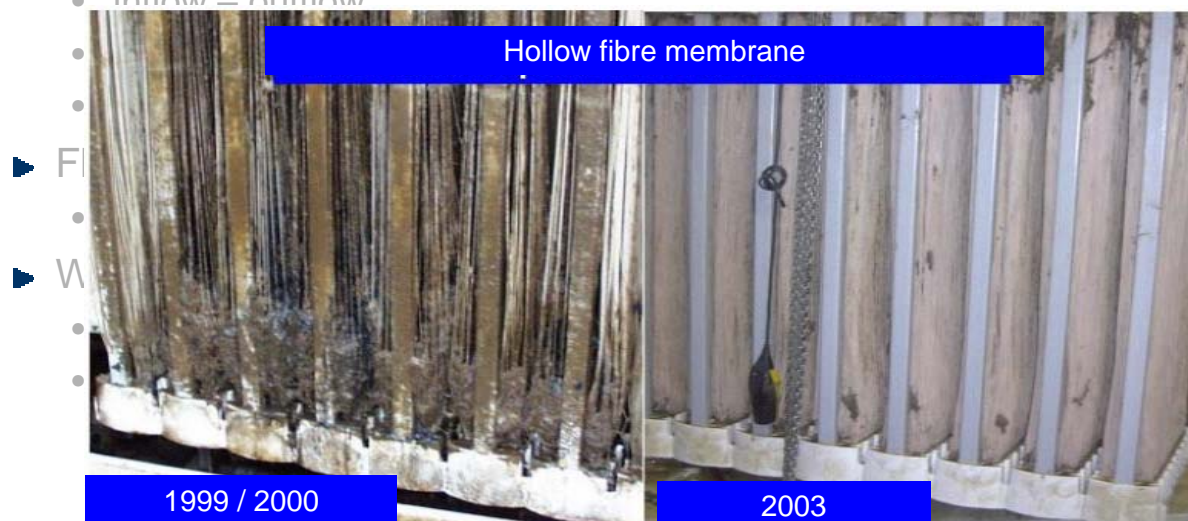
- ▶ Sufficient mechanical pre-treatment
 - prevent clogging and mechanical rupture of membranes
- ▶ Design and operation of membrane compartments
 - inflow – outflow
 - MLSS concentration
 - moderate design flux
- ▶ Flexible and appropriate cleaning concept
 - adapted to seasonal variations and ageing equipment
- ▶ Well trained personnel
 - monitoring and controlling of operating conditions
 - preventive maintenance

Prolonging membrane life-time

- ▶ Sufficient mechanical pre-treatment
 - prevent clogging and mechanical rupture of membranes

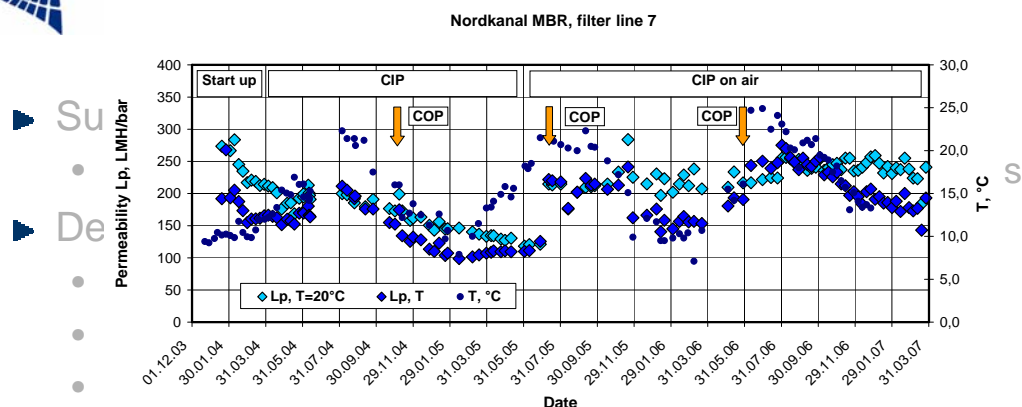
- ▶ Design and operation of membrane compartments

- inflow – outflow



Prolonging membrane life-time

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Prolonging membrane life-time

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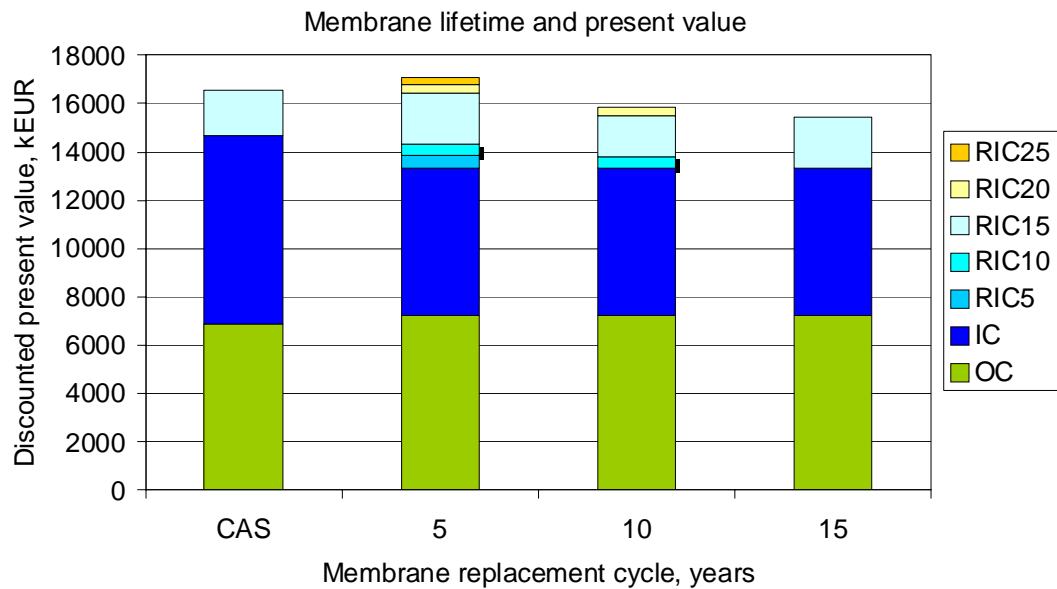
Cost Comparison MBR vs. CAS

- ▶ Example of a WWTP with a capacity of 10 000 PE
 - Comparable effluent quality for MBR and CAS
 - High phosphorous removal and hygienic effluent required
 - Tertiary treatment and disinfection at CAS

	CAS	MBR
Investment Cost	7 800 000.00 €	6 100 000.00 €
Civil construction	4 900 000.00 €	2 800 000.00 €
Mechanical equipment	2 200 000.00 €	1 900 000.00 €
Electric equipment	700 000.00 €	800 000.00 €
Membrane		600 000.00 €
CAPEX (per PE)	780.00 €	610.00 €

Life-Cycle-Cost

► Influence of membrane lifetime



Conclusions

- Effluent quality and low footprint make MBRs competitive
- Trade-offs between investment and operation cost
- Proper design and maintenance is rewarded with long membrane lifetime
- Effort to overcome technical challenges in MBR technology

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 - 30/09/08
EUROMBRA is part of the MBR-NETWORK Cluster



More info: www.mbr-network.eu

42. THE EUROPEAN MBR MARKET: SPECIFICITIES AND FUTURE TRENDS

E. Huisjes, K. Colombel, B. Lesjean

The European MBR market: Specificities and future trends

Final MBR-Network Workshop
Berlin, 31 March – 1 April 2009

E. Huisjes, K. Colombel, Boris Lesjean
Berlin Centre of Competence for Water, Germany

boris.lesjean@kompetenz-wasser.de



Perthes-en-Gâtinais: the 3rd municipal MBR in Europe

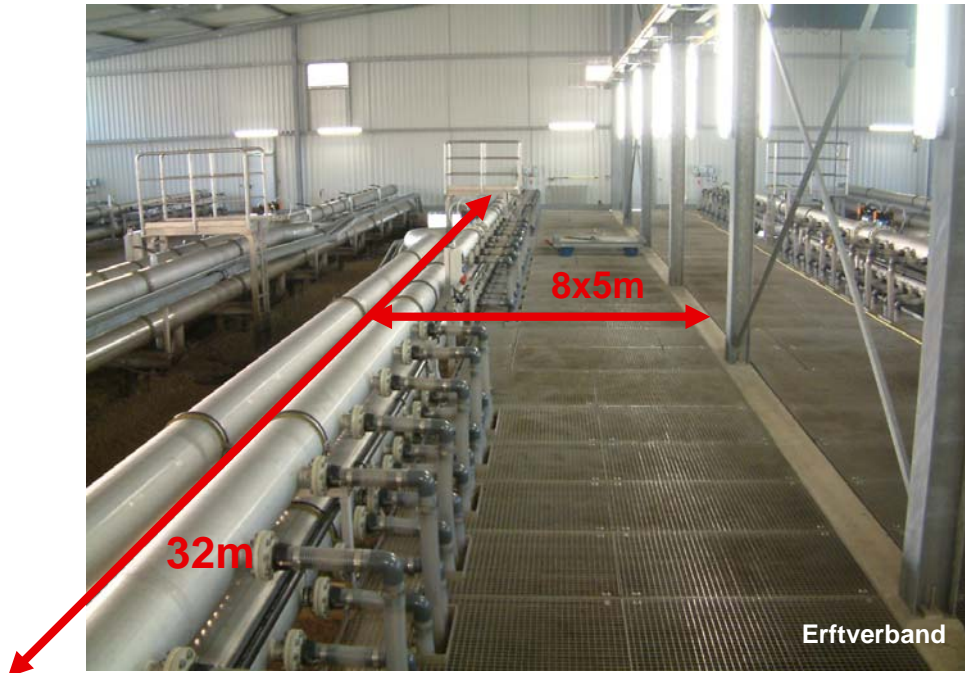
1999: 4,500 p.e., 1.5MLD



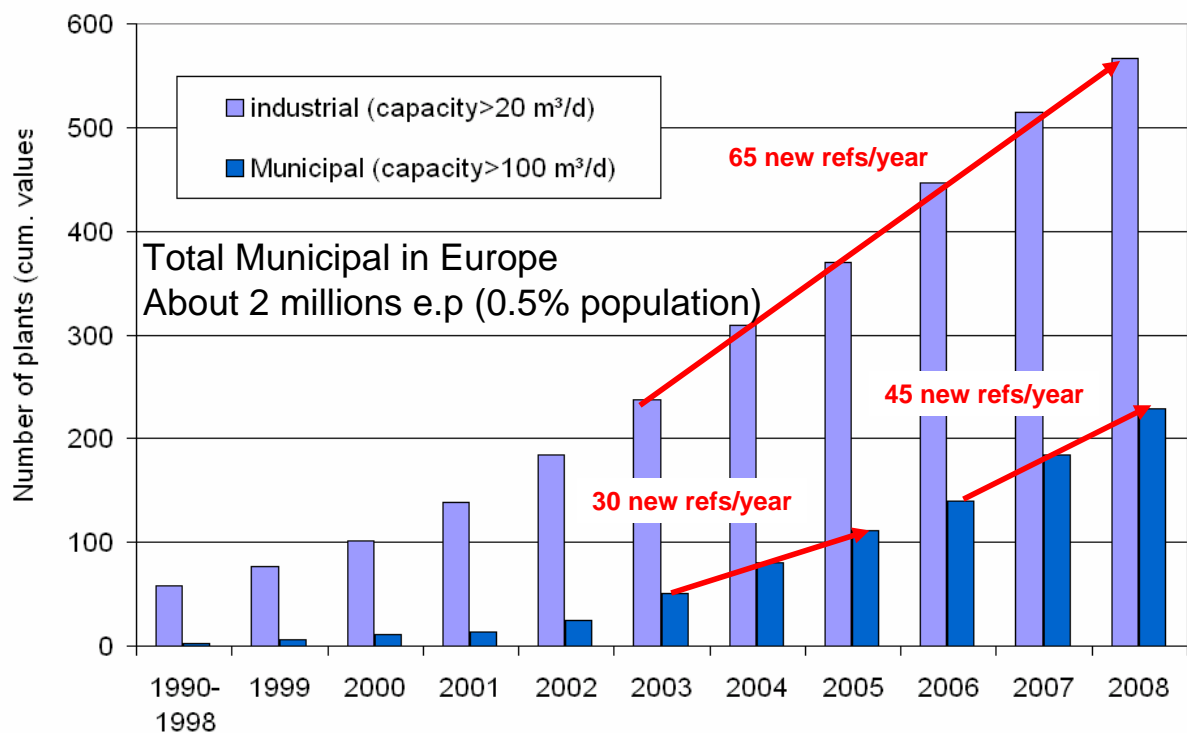
Veolia Water Systems

Nordkanal: the largest MBR plant

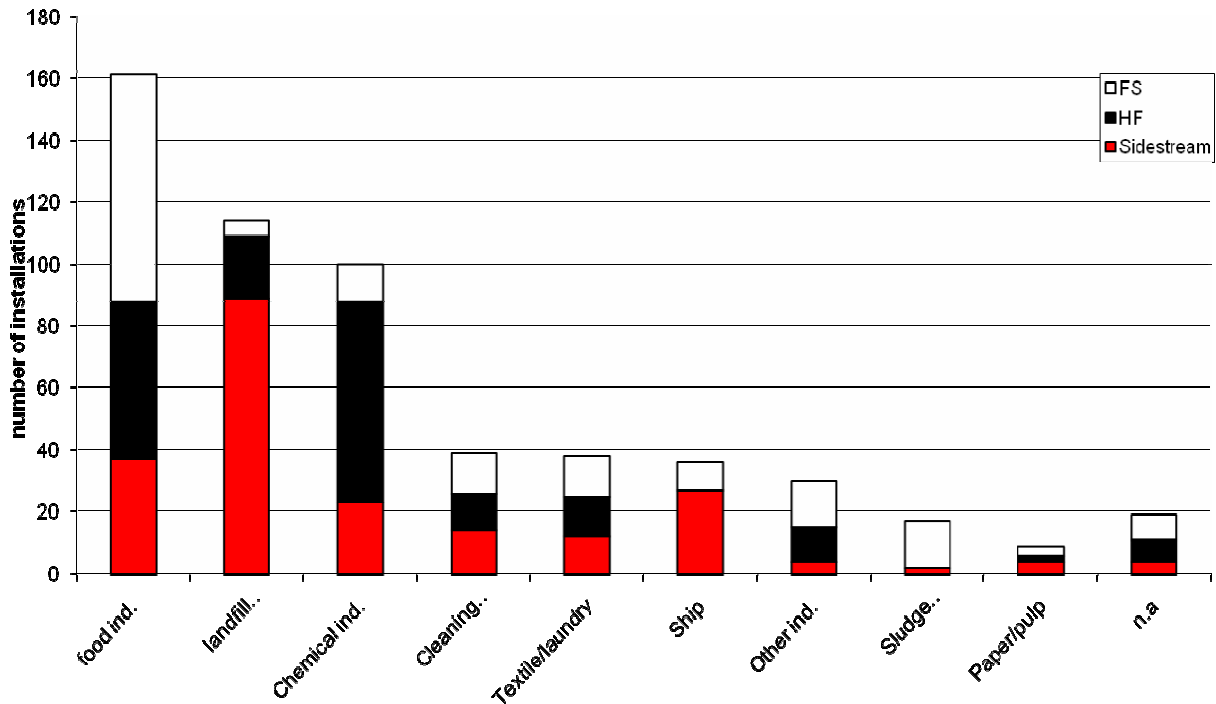
2004: 80,000 p.e., 40MLD



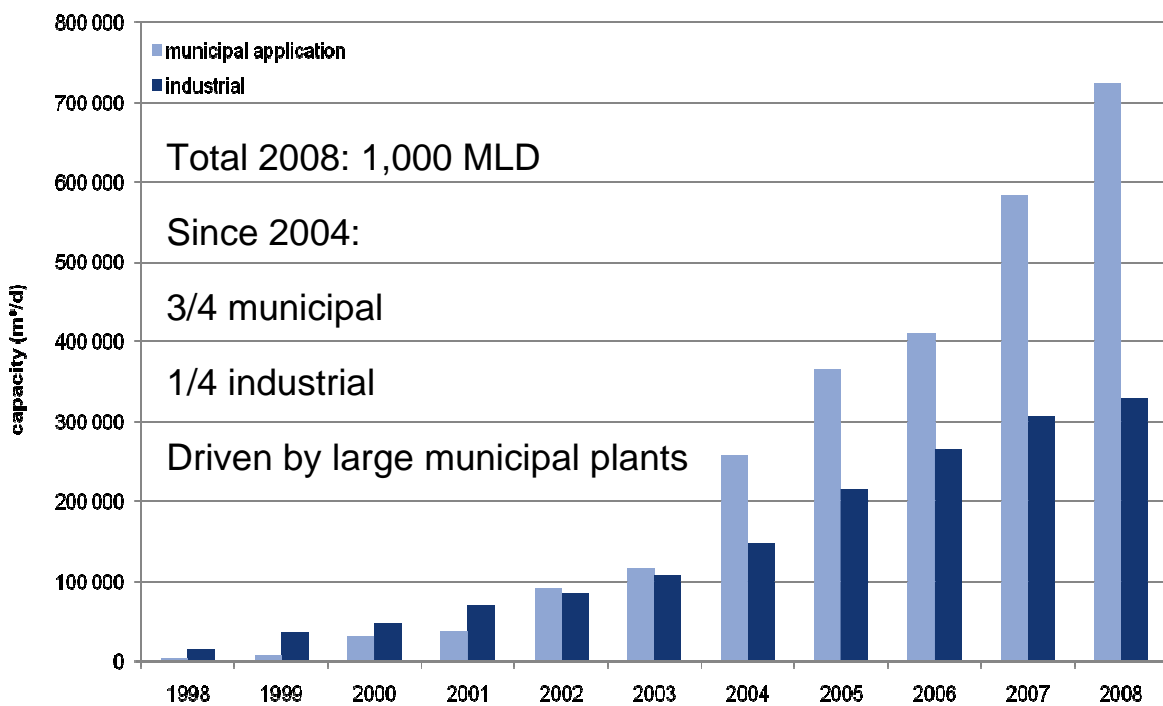
Global European MBR market



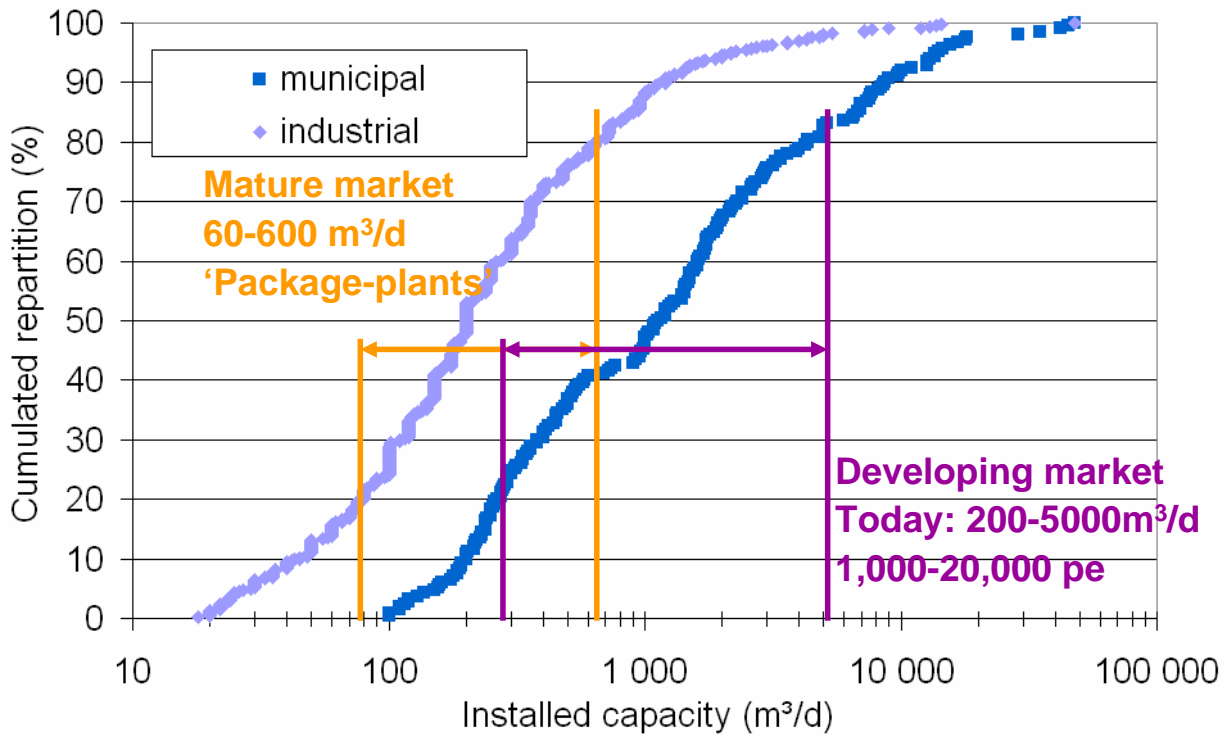
Industrial application domains



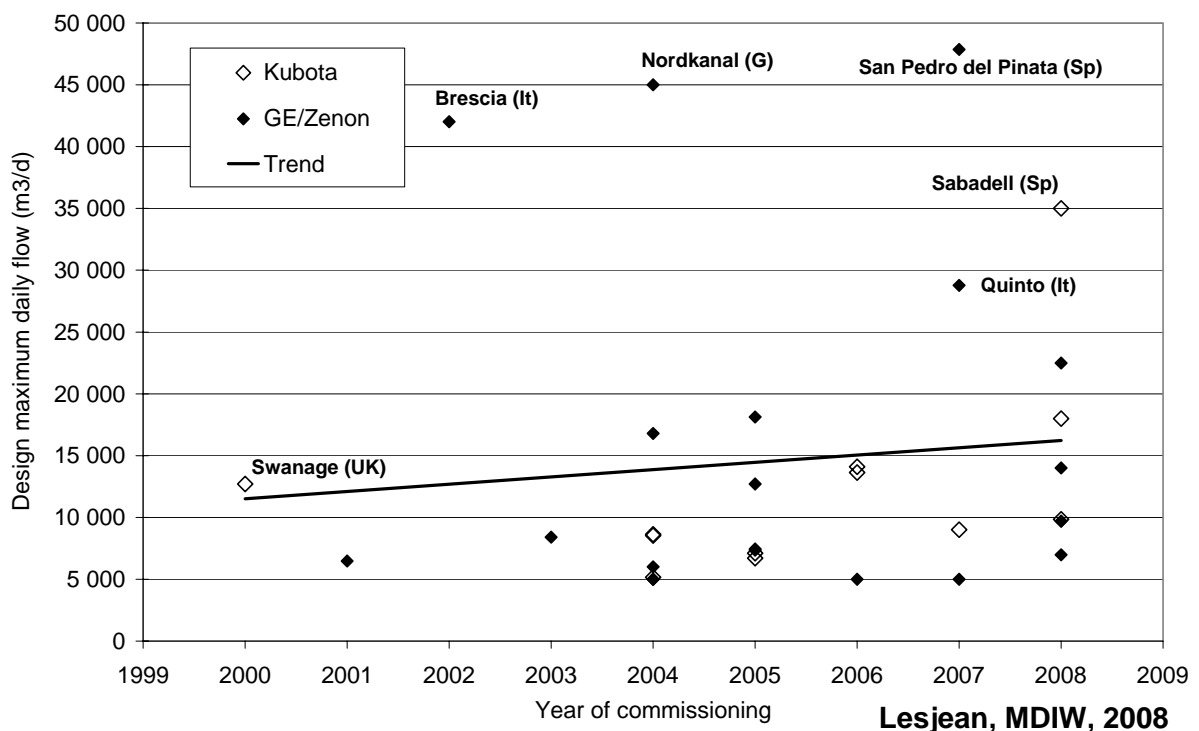
Installed capacity in Europe



Capacity repartition of MBR in Europe (up to 2008)



37 very large MBR in Europe (> 5 MLD, 2008)



Domestic MBRs: BUSSE Concept



Capacity	1-4 p.e.	5-8 p.e.	10-32 p.e.	36-50 p.e.	Total Units	Total Cap.
Installed units (2005)	185	60	15	6	266	2000
Installed units (2007)	233	80	19	12	344	2800

www.mbr-network.eu

Statistics on municipal MBR retrofitting in Europe

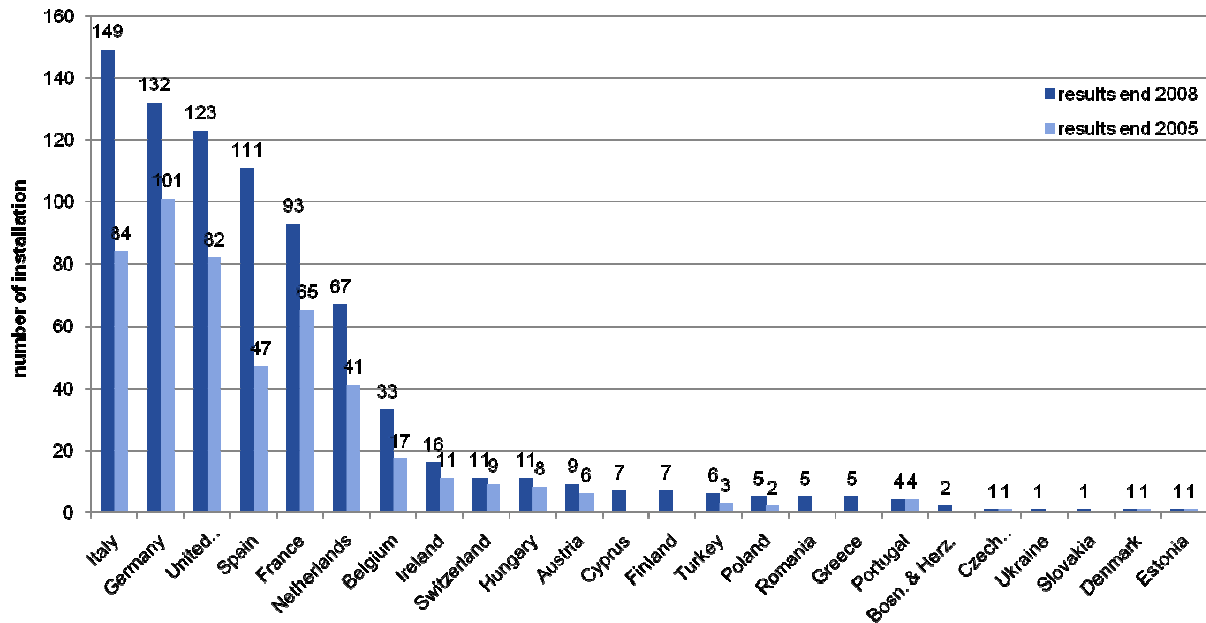
- ▶ About 1/3 of constructed municipal MBR units (50% hybrid)
 - All size considered (2006): 29 retrofits of 98 plants (De Wever et al., 2008)
- ▶ Independant of size range
 - For MBRs > 5MLD (2008): 12 retrofits of 32 plants (Lesjean et al., 2008)

	Total	100% new	Retrofitting	(of which hybrid)
GE/Zenon	20	14	6	4
Kubota	12	6	6	2
Total	32	20	12	6

- ▶ To date: no **new** plant constructed on hybrid configuration ...

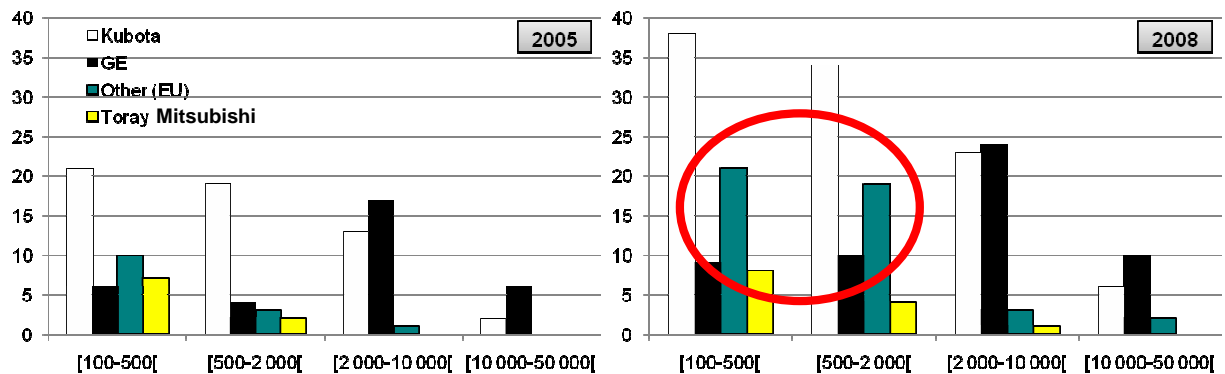
www.mbr-network.eu

Key markets in Europe



European New-Comers ?

Distribution of MBR plants per capacity (m3/d) and supplier – All applications



- A3 Water Solutions
- Berghof
- Huber
- Koch-Puron
- Martin Systems

- Microdyn Nadir
- Norit – X-Flow
- Novasep
- SFCU
- Weisse WS
- Wehrle Umwelt

Conclusion

- ▶ MBR technology **is** now a Best Available Technology
 - Economically viable for industrial wastewater treatment
 - Relevant option for municipal wastewater treatment
 - Plant upgrade / retrofit
 - Advanced treatment / water reuse
 - Compactness
- ▶ > 100 new plants per year (+ 200 MLD/y)
- ▶ MBR market driven by large municipal plants
- ▶ New markets in Europe
 - Mediterranean countries
- ▶ European New Comers and European expertise

Acknowledgement

AMEDEUS and EUROMBRA are research projects supported by the European Commission under the Sixth Framework Programme (Priority “Global Change and Ecosystems”)



Contract No. 018328 – AMEDEUS
Contract No. 018480 – EUROMBRA
Duration: 01/10/05 – 31/05/09



They constitute the MBR-NETWORK Cluster
More info: www.mbr-network.eu