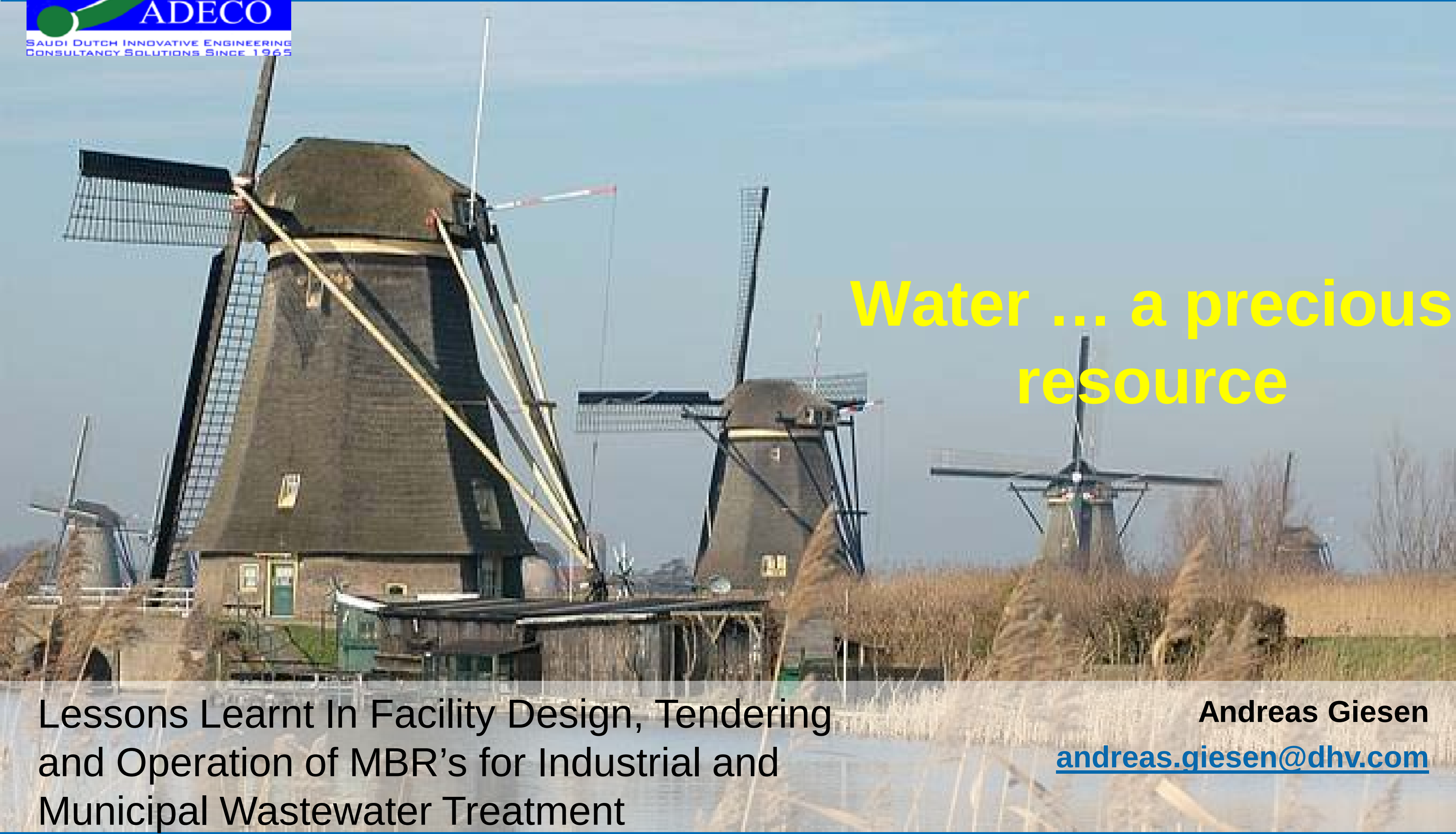
SADECO
Saudi Dutch Innovative Engineering Consultancy Solutions Since 1965

Consultancy and Engineering

DHV

Dutch from origin.....International in scope



Water … a precious resource

Lessons Learnt In Facility Design, Tendering and Operation of MBR's for Industrial and Municipal Wastewater Treatment

Andreas Giesen
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Gateway to solutions

Consultancy and Engineering

Lessons Learnt

Carrousel® MBR, Sonac

Turn-key project

Consultancy and Engineering

135.000 pe
Largest in Europe
(1998)

Item	Influent	Effluent	Efficiency
	mg/l	mg/l	%
COD	5.000 – 10.000	< 65	> 99
BOD	3.000 – 7.000	< 5	> 99
TKN	900 – 1.350	< 5	> 99
NH4 - N	> 80 % of TKN	< 1	> 99
TN		< 10	> 99
TSS	200 - 500	< 1	> 99

12 – 13 g MLSS/l

Design flux 42 l/(m^2.h) at T > 25 ^{o}C

start-up: 1998 (Membrane lifetime > 5 years)

MBR at Vos Logistics

Turn-key project

Consultancy and Engineering

Retrofit of SBR

Item	Influent	Effluent	Efficiency
	mg/l	mg/l	%
COD	2.500 – 8.000	< 400	> 90
BOD	25 – 40 % of COD	< 10	> 99
FOG	200 – 300	< 1	> 99
TSS	200 – 500	0	100

25 g MLSS/l

Design flux 100 - 150 l/(m^2.h) at T > 30 ^{o}C

Cross flow intensive cleaning

start-up: 2000

MBR at Rendac

EPCM project

Largest in Europa
400.000 pe

Item	Influent	Effluent	Efficiency
	mg/l	mg/l	%
COD	4.000 – 12.000	< 100	> 98
BOD	50 – 70 % of COD	< 10	> 99
TKN	900 – 1.400	< 5	> 99
NH4 – N	> 80 % of TKN	< 1	> 99
TN		< 10	> 99
TSS	< 1.000	< 1	> 99

10 – 13 g MLSS/l

Design flux 30 - 35 l/(m^2.h) at T > 25 ^oC

MC in air (developed in Beverwijk)

start-up: 2002

MBR at Ben Gurion Airport

full water reuse, phased construction (3→5 MLD)


Covered effluent reservoir

First municipal in Israel

Covered MBR in "air wing"


Item	Influent	Target	Currently[1]
	mg/l	mg/l	mg/l
COD	1.250	< 70	
BOD	650	< 5	1
TKN	75		0.1
TN		< 10	
TP	17	< 0.2	
Turb.			1 NTU

Phased construction: 3 → 5 MLD

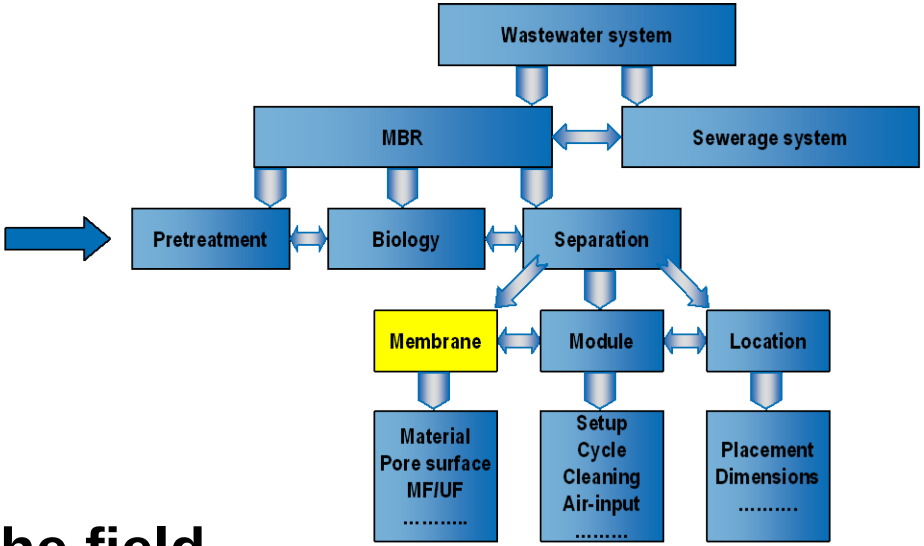
Submerged hollow-fiber

Start-up: early 2008

1) First 3 months of plant operation under full load

MBR: few years ago

- only affordable for higher concentrated waste
- **focus on membrane flux and membrane sales**
- **insufficient know-how on**
  - **fundamentals**
  - **field optimisation**



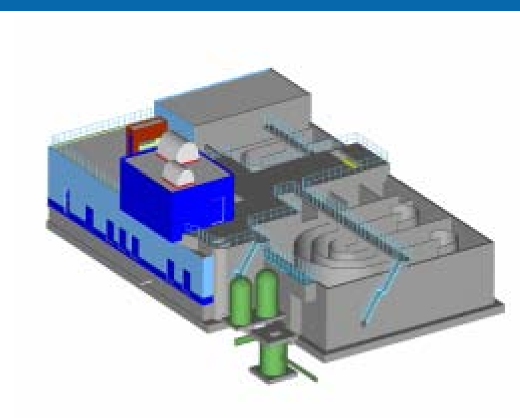
- **many negative experience in the field**
- **no sound engineering standards for large scale application**

Dutch MBR programme

Three phase approach

PILOT RESEARCH	DEMONSTRATION INSTALLATION	FULL SCALE INSTALLATIONS
INTEGRATION membranes and microbiology	technical STANDARDISATION of MBR-installation	Competition on the MARKET

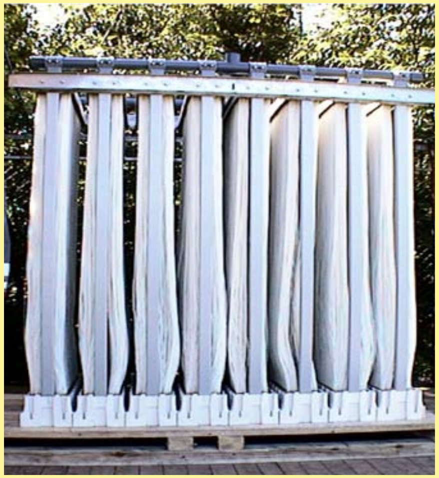
01/2000 — 01/2010



MBR research Beverwijk

4,5 year hands-on operation

Mitsubishi



Zenon

Huber

X-Flow

Kubota

Toray

Memfis

Koch/Puron

Results of pilot

- extensive hands-on experience with most membrane types
  - clear picture on performance, operability aspects and pitfalls
  - determination of “safe” and optimised design and process conditions
- initiation of many technology improvements → opex reduction
  - improved cleaning strategies
  - improved membrane aeration
  - improved control systems
  - improved pre-treatment concepts
  - improved membrane module configurations
- significant contributions to worldwide MBR knowhow (M-cleaning and importance biology)

MBR Varsseveld

Dutch first municipal MBR

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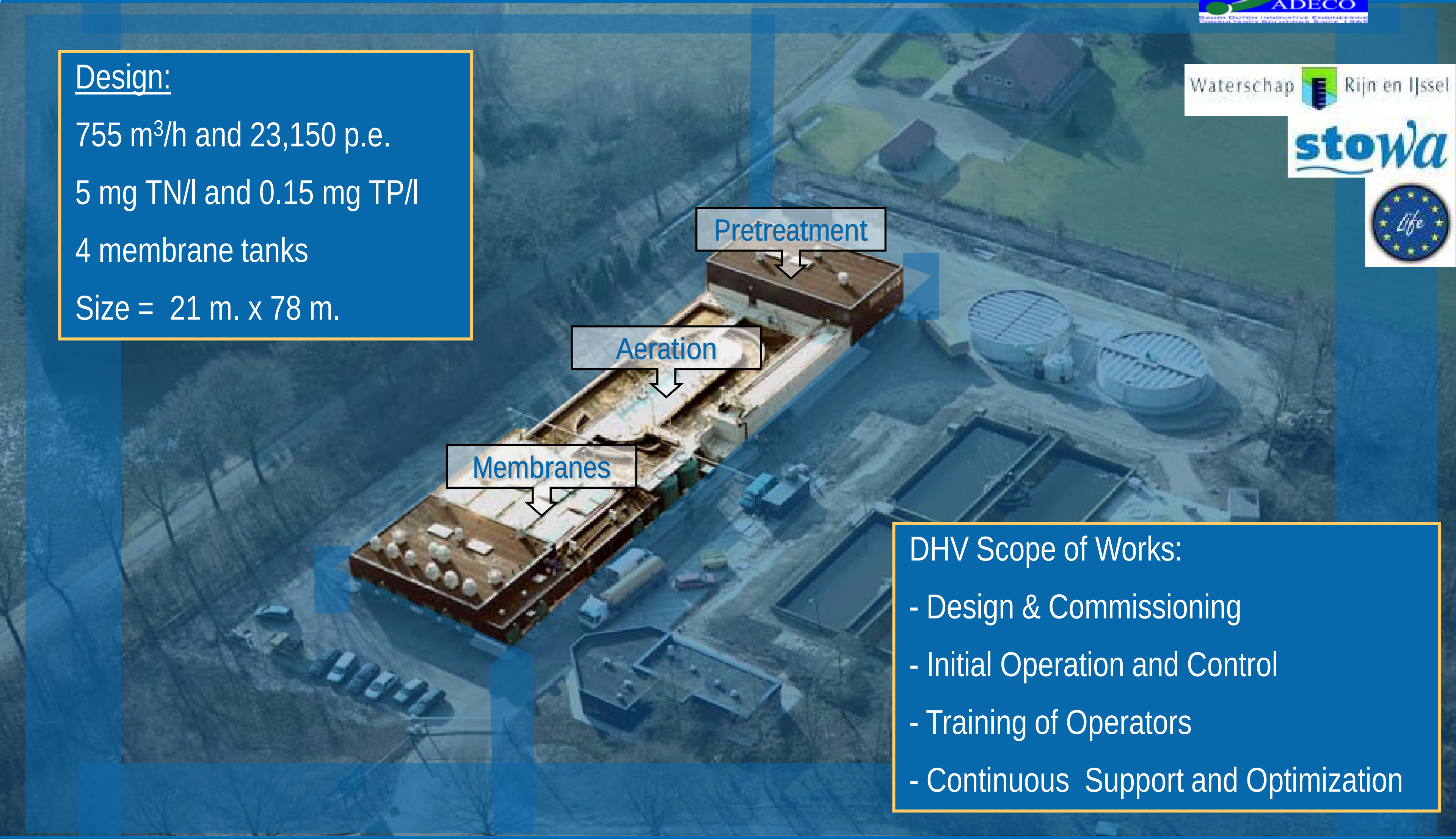


Design:

755 m^3/h and 23,150 p.e.

5 mg TN/l and 0.15 mg TP/l

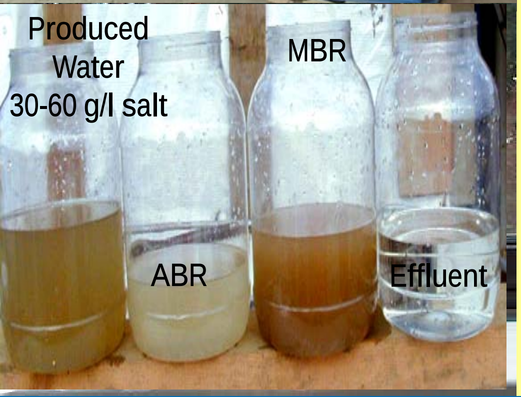
4 membrane tanks

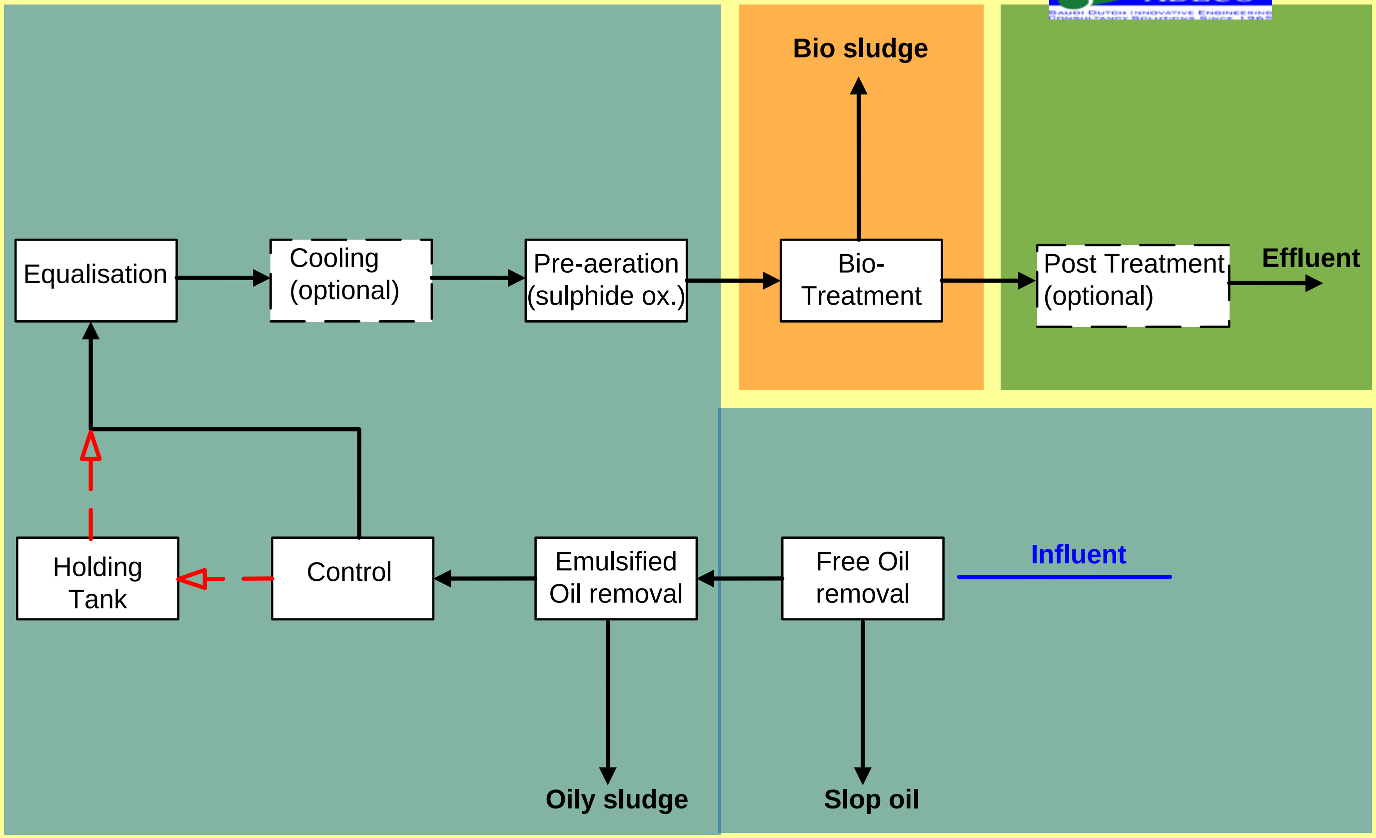
Size = 21 m. x 78 m.

DHV Scope of Works:

- Design & Commissioning
- Initial Operation and Control
- Training of Operators
- Continuous Support and Optimization

MBR going for tougher challenges
high oil content in refineries and produced water



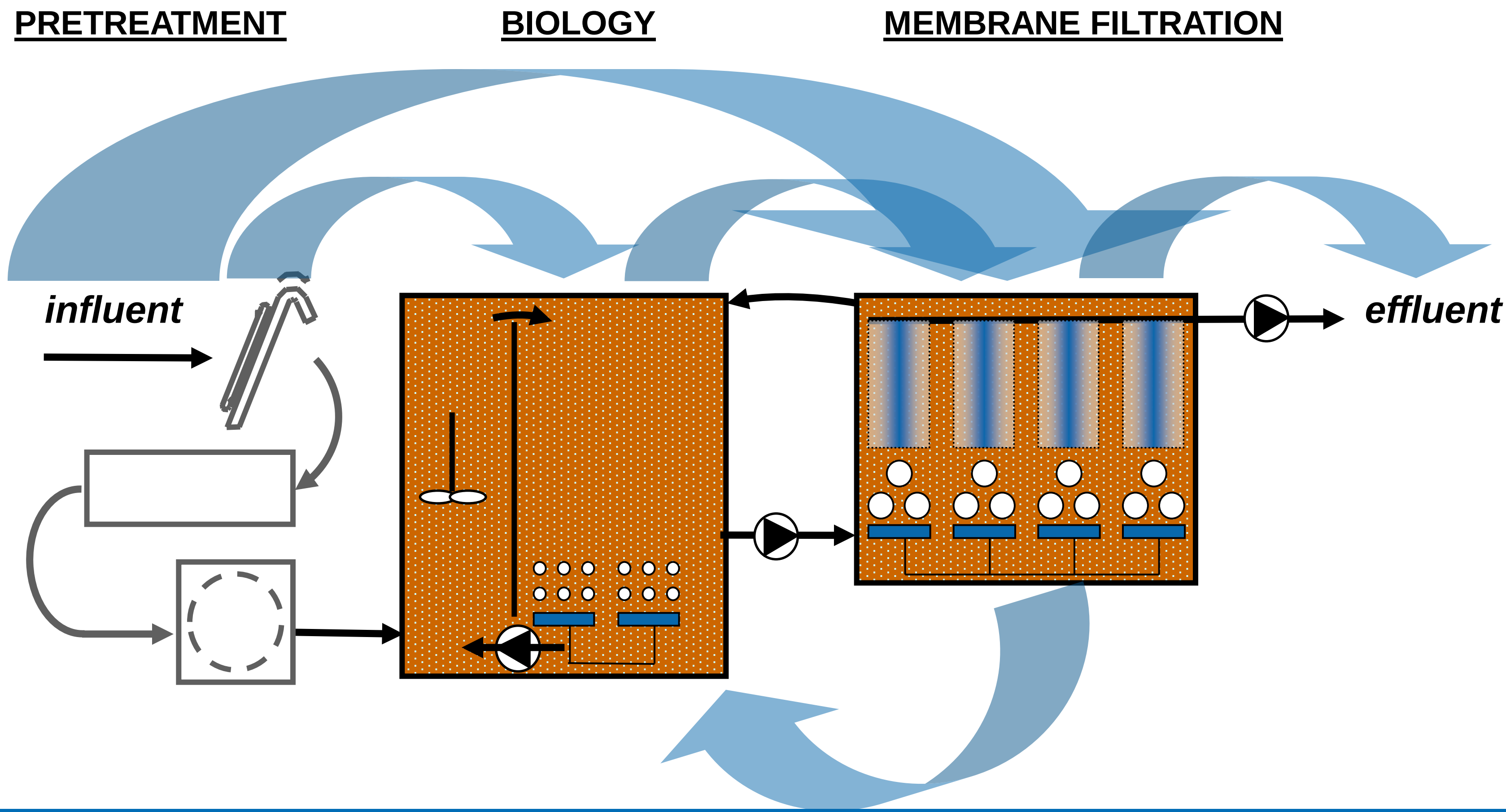


Lesson Learnt

- We have learnt many lessons and will probably experience more wise lessons
- Many lessons seem to be obvious, logical or one-liners, but are indeed based on a lesson
- There are too many lessons to cover in this presentation

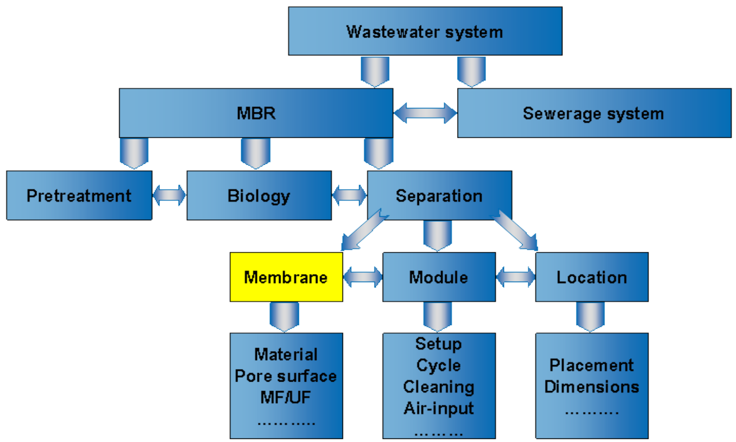
Lessons Learnt

A MBR is more than only a membrane



"Dutch" contribution

FROM



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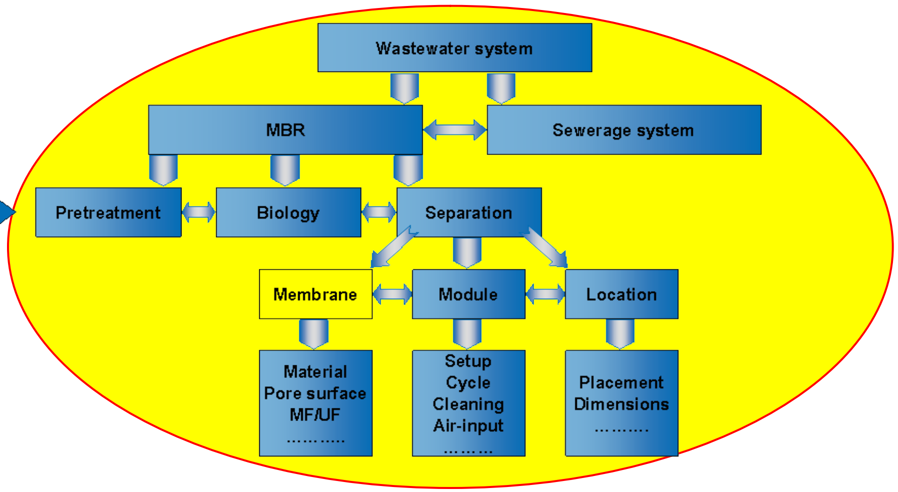


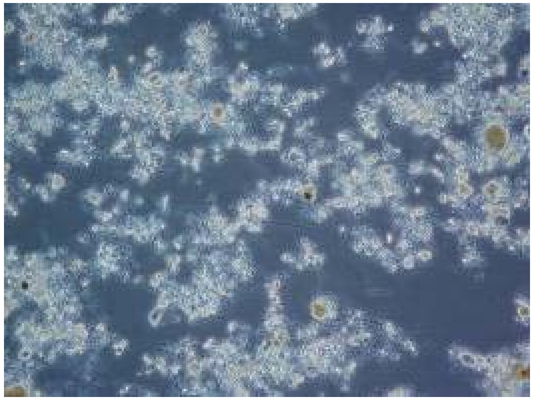
Lessons Learnt

Not the membrane, but the biology is the critical factor

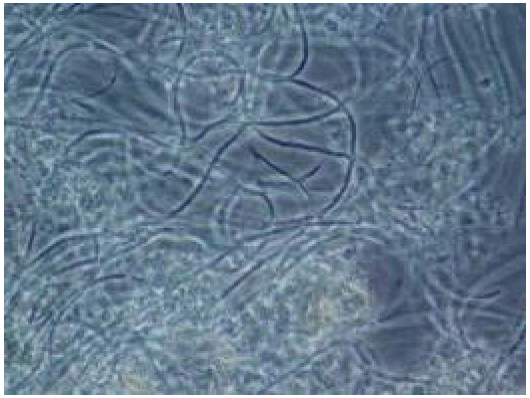
- Biosludge characteristics depends on biotreater design & operation
- It is the biology that gives the pollutants removal

MBR Biosludge Morphology

EPS
Poor allround performance
SVI = 200 – 300ml/g

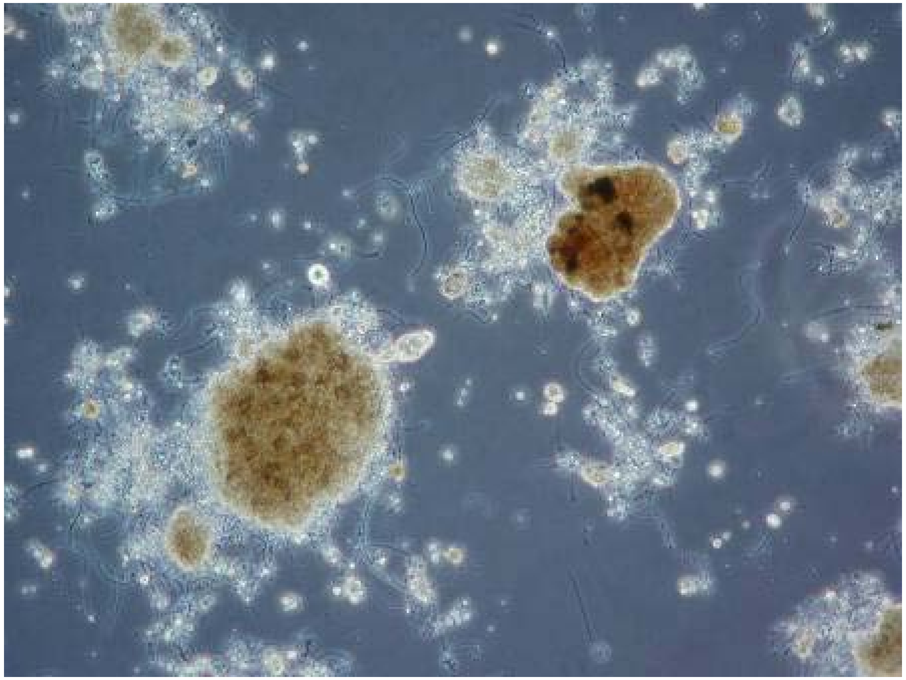


Fine sludge+EPS
Stress
Ok performance
SVI = 100-150ml/g



EPS
Filamentous
Bad performance
SVI = >300ml/g

MBR Biosludge Morphology



Useful tool:
BioWatch

Sludge bound EPS
+
Big flocs
=
Much Water Phase

=

Excellent
Performance
SVI < 100 ml/g

Lessons Learnt

Perfect biosludge characteristics results in low energy consumption and in low membrane fouling

MBR Varsseveld

Energy consumption

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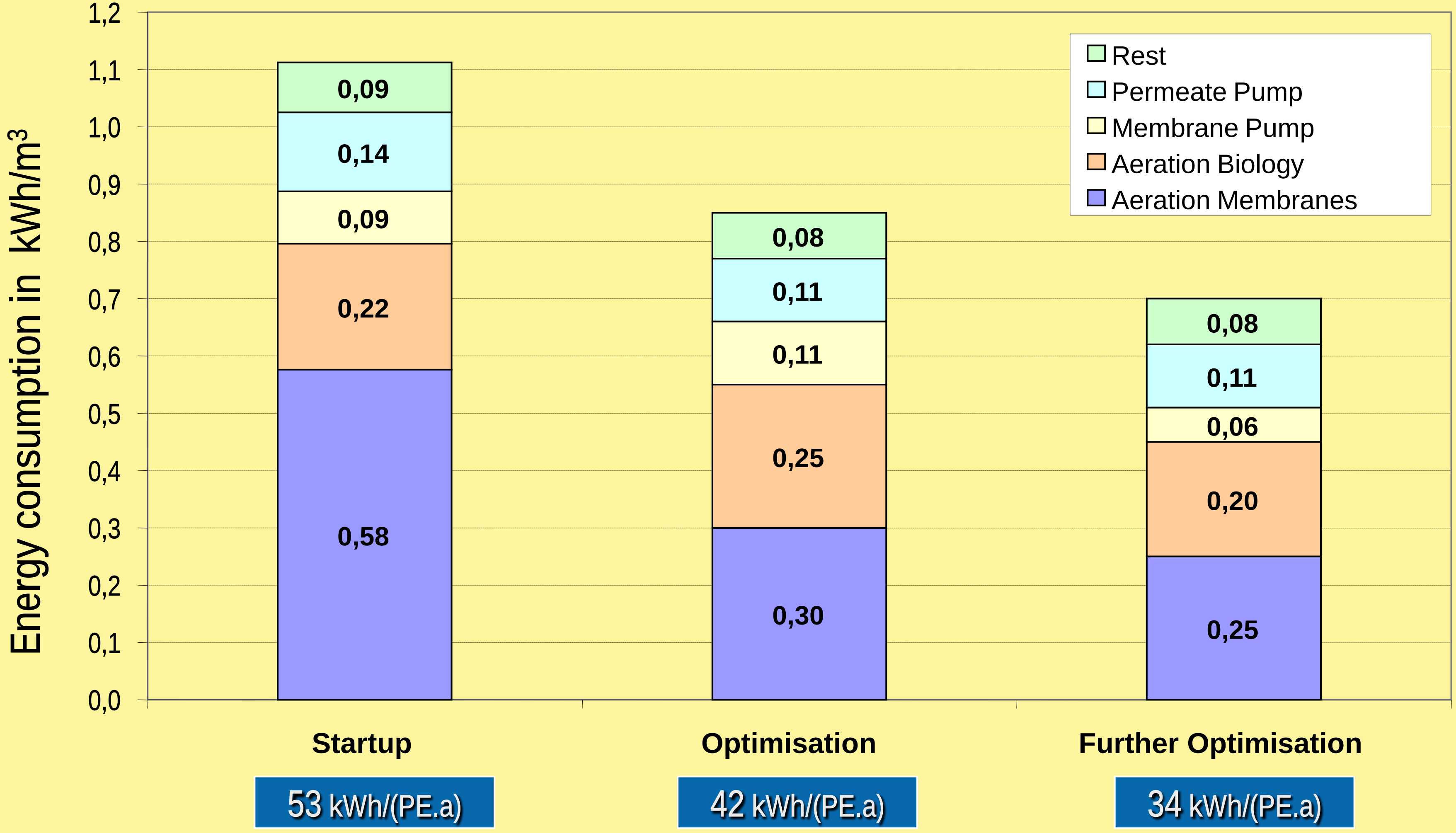

Lessons Learnt

It is difficult not to get a good COD-conversation

It requires expertise to obtain good nutrient removal

MBR Varsseveld

Biological performance

Consultancy and Engineering

Parameter	Influent	Effluent	Efficiency
	mg/l	mg/l	%
COD	824	23	97
Total N	58	3.5	94
Total P	16.3	0.15	99
Suspended solids		0	100
Turbidity		<< 0,1 NTU	
Bacteria and viruses		swimming water	

Consultancy and Engineering

MBR at Rendac

EPCM project

Largest in Europa
400.000 pe

Item	Influent	Effluent	Efficiency
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10 – 13 g MLSS/l

Design flux 30 - 35 l/(m^2.h) at T > 25 ^oC

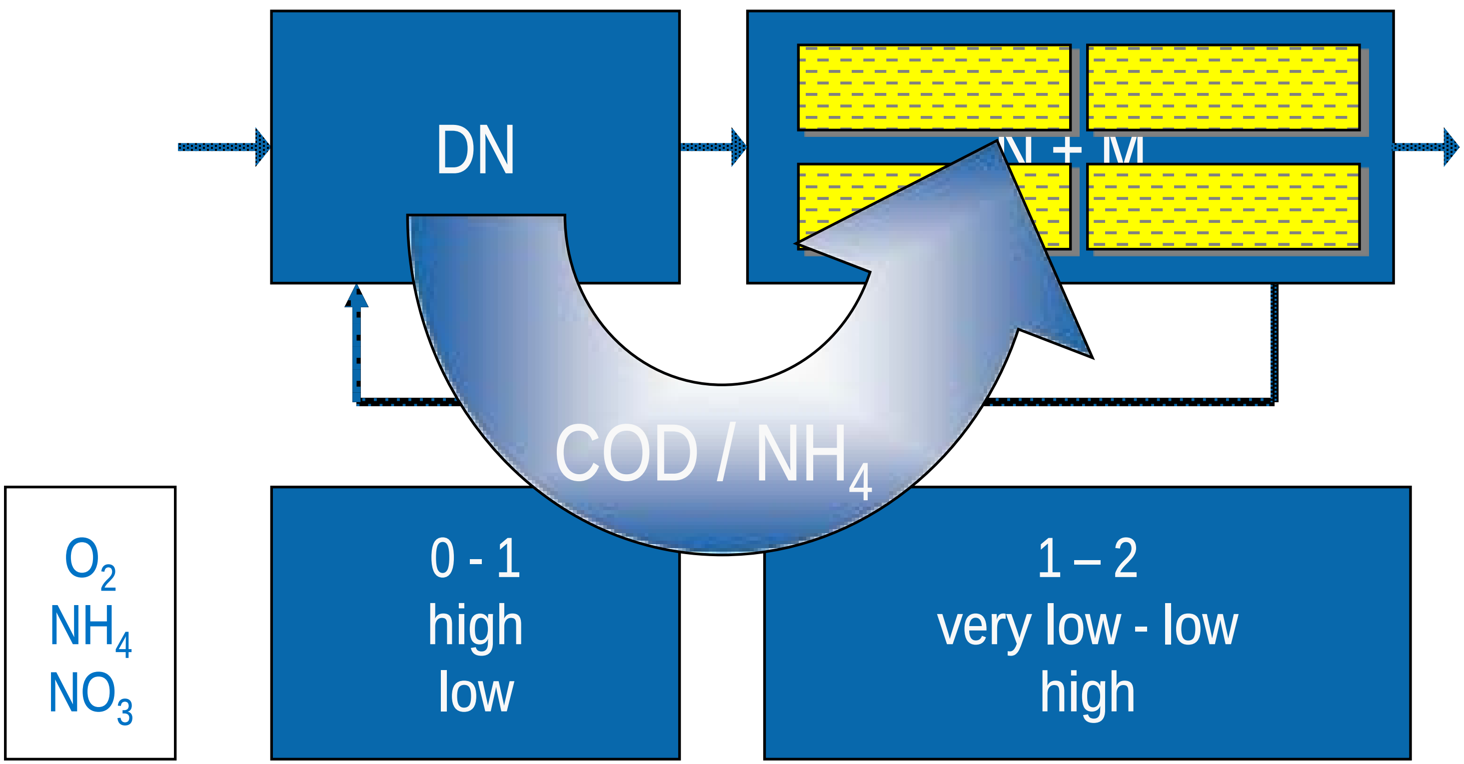
MC in air (developed in Beverwijk)

start-up: 2002

Consultancy and Engineering

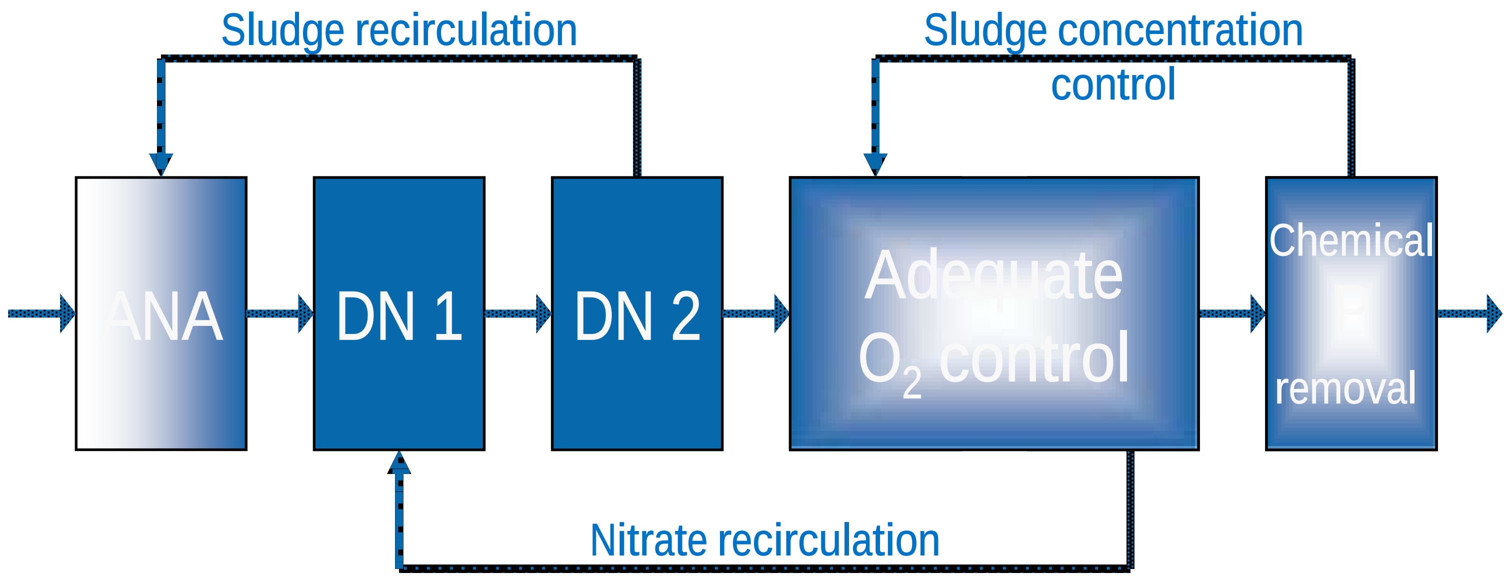
Lessons Learnt

Most membranes are good, it's the plant design and operation that makes them to perform well



Consultancy and Engineering

A better design



	ANA	DN 1	DN 2			
O_2	0	0	0	2	0.5	4 - 8
NH_4	high	high	high	low	lower	0
NO_3	low	high	0	lower	low	low

Lessons Learnt

All membranes foul, proper pretreatment design and operation is essential

Lessons Learnt

Do not focus on how rough you can clean fouled membranes, better focus on how gentle

- Pre-requisites
  - No macro-pollution
  - Good sludge quality
  - Perfect process and cleaning control
  - Low TMP
  - Good mix between relaxation, MC and IC (membrane type dependent)
- Results
  - High fluxes
  - Low chemical consumption
  - Stable permeability at low T and RWF

Lessons Learnt

Integrity membranes can be at stake with all ….

- Plate membranes in Dutch municipal MBR
  - Membrane layer detaches from support within several months after start-up → all membranes replaced
  - Leakage permeate lines/connectors
- Hollow Fiber membranes in Dutch municipal MBR
  - New more effective air cross-flow control strategy → breakage permeate pipe connectors
- Have early warning (e.g. turbidity meter)

Lessons Learnt

For all submerged membranes, air cross-flow is critical to prevent fouling and sludge thickening

- Cross-flow failure → plate membranes clogged within tens of minutes
- Prevent power and air failures

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Lessons Learnt

There is not a “best” membrane for a certain application

	Hollow Fiber	Plates	Tubular
Flux	+/-	+/-	+
Energy consumption	+/-	+/-	+
Membrane costs	+	+/-	-
Sludge concentration	+/-	+	-
Pretreatment requirements	+/-	+	+/-

But there is certainly a best design for the membrane in that particular application

Plates or Hollow-Fibers?

World distribution (> 20 m^3/d)

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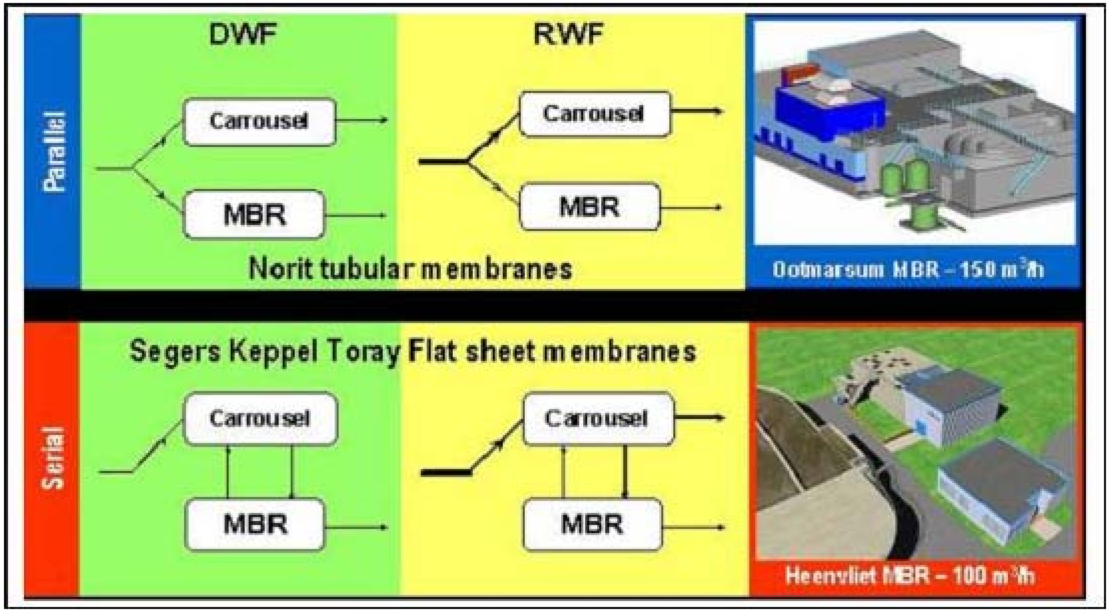
Region	# MBR plants (-)		Total	Capacity MBR plants (m^3/day)		Totaal
	Plate Membranes	*Hollow-Fiber Membranes*		*Plate Membranes*	*Hollow-Fiber Membranes*	
North America	98	198	**296**	123.452	368.980	**492.432**
Asia	241	45	**286**	159.509	108.132	**267.641**
Europe	113	56	**169**	164.357	259.175	**423.532**
Australia	18	5	**23**	13.919	30.931	**44.850**
Africa	12	3	**15**	1.082	28.239	**29.321**
South America	3	5	**8**	703	3.370	**4.073**
Total	**485**	**312**	**797**	**463.022**	**798.827**	**1.261.849**

Source: Pinnekamp. 2007

Lessons Learnt

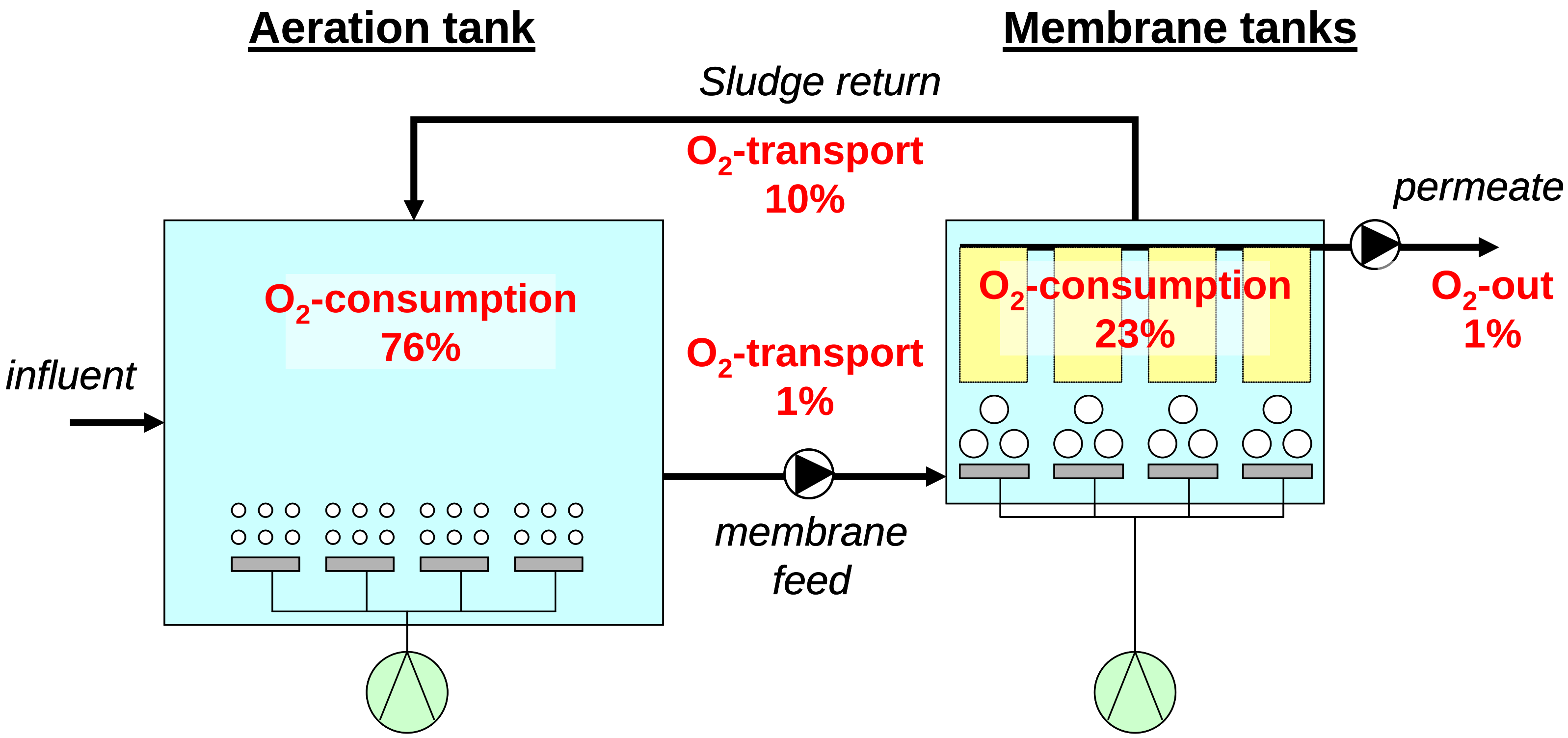
Reduce the maximum membrane capacity as far as possible

- Smart selection of average and maximum flux
- Peak-shaving using existing tanks/clarifiers
- Hybrids



Lessons Learnt

The air cross-flow is the largest energy consumer, optimization essential for acceptable running costs



Air flow	22%		Air flow	78%
O_2-uptake	67%		O_2-uptake	33%

Lessons Learnt

The air cross-flow is the largest energy consumer, optimization essential for acceptable running costs

- Ensure good biosludge characteristics
- Switch-off membrane lines to operate remaining lines close to optimum flux
- Reduce air flow at higher temperature
- Intermittent operation
- Optimize the critical flux
- Optimize air flow during stand-by mode

Lessons Learnt

In a good designed MBR, it is not the membrane that causes the operational problems.

Lessons Learnt

Expect higher scum productions in MBR's

- Higher hydrophobility by accumulation of hydrophobic compounds
- High air input (membrane cross-flow)
- Higher DS

Lessons Learnt

A MBR is often not the preferred technology if treatment objectives can be met with conventional activated sludge systems or new breakthroughs like the Nereda aerobic granule technology

- MBR versus CAS
  - Energy (optimized systems!)
    - CAS without filter: 50-100% higher
    - CAS with filter: 0- 20%
  - Investments: higher
  - Operating costs: 10-20% higher
    WE Price Level, sludge disposal = approx. 40% OPEX

→ Use only if "perfect" effluent quality is essential (e.g. as building block to water reuse)

MBR and CAS

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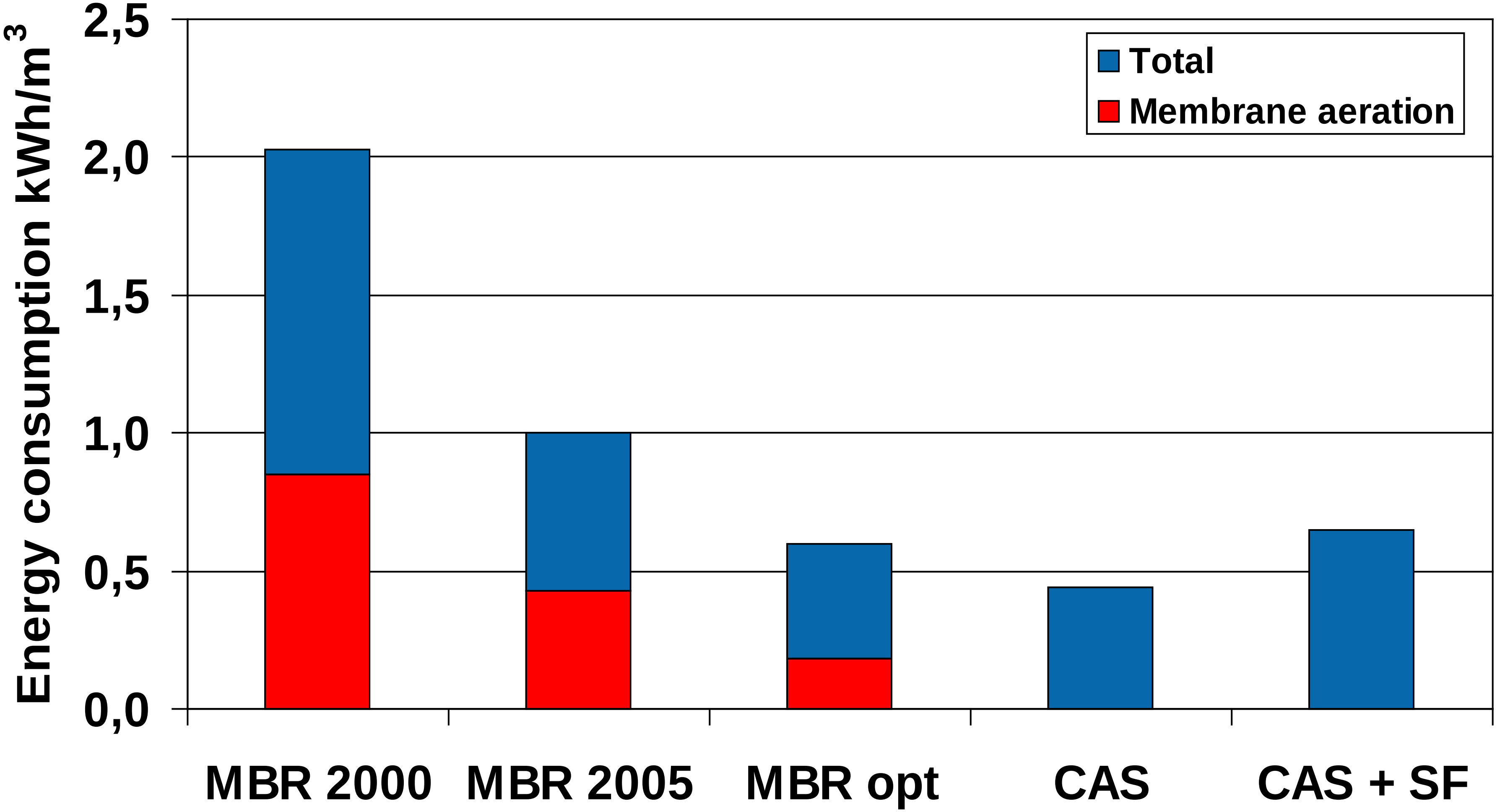


Lessons Learnt

To get a well-performing MBR against acceptable plant-life-time costs a smart tender strategy is often essential

Why a tender strategy ?

- MBR is not a commodity, but tailor-made engineered solution
- Technology is still quickly developing: no standards, no global "know-how sharing"
- Life-cycle-cost depends strongly on
  - Design & Membrane selection
  - Construction details & Appropriate operation
- Sub-optimal design → high costs and/or low performance

Tender strategy aim:

- Get a plant that works well and shows low running costs
- At reasonable investment

Ensure "working well"

Get a guarantee
Design & Construct
Design, Build & Operate

→ Limited effect

- ❑ water characteristics never well defined
- ❑ limited liability (and endless for the enduser?)
- ❑ does not protect against know-how gaps contractor
- ❑ contractor blames the operation (not DBO)

Include pilot validation ?

- ❑ difficult to fully mimic actual plant
- ❑ representative wastewater
- ❑ limited inputs for process stability
- ❑ limits project competition and makes competition field very/too transparent

→ Essential for industrial wastewater, but focus on

- "transferability" of data
- pilot setup
- experience the wastewater "problems"

The key to success

Ensure appropriate integrated know-how on:

- Biology
- Membranes
- Hands-on operation

How?

- Contractor/Designer/Consultant with proven track-record and experienced team (that will work on your project) → not much parties
- Increase role experienced consultant
  - verify / optimize design
  - “green light” critical details & operation procedures
  - coach during plant start-up & plant optimization

Ensure “reasonable investments”

Use market & competition

- DB(O)
- Designers/consultants

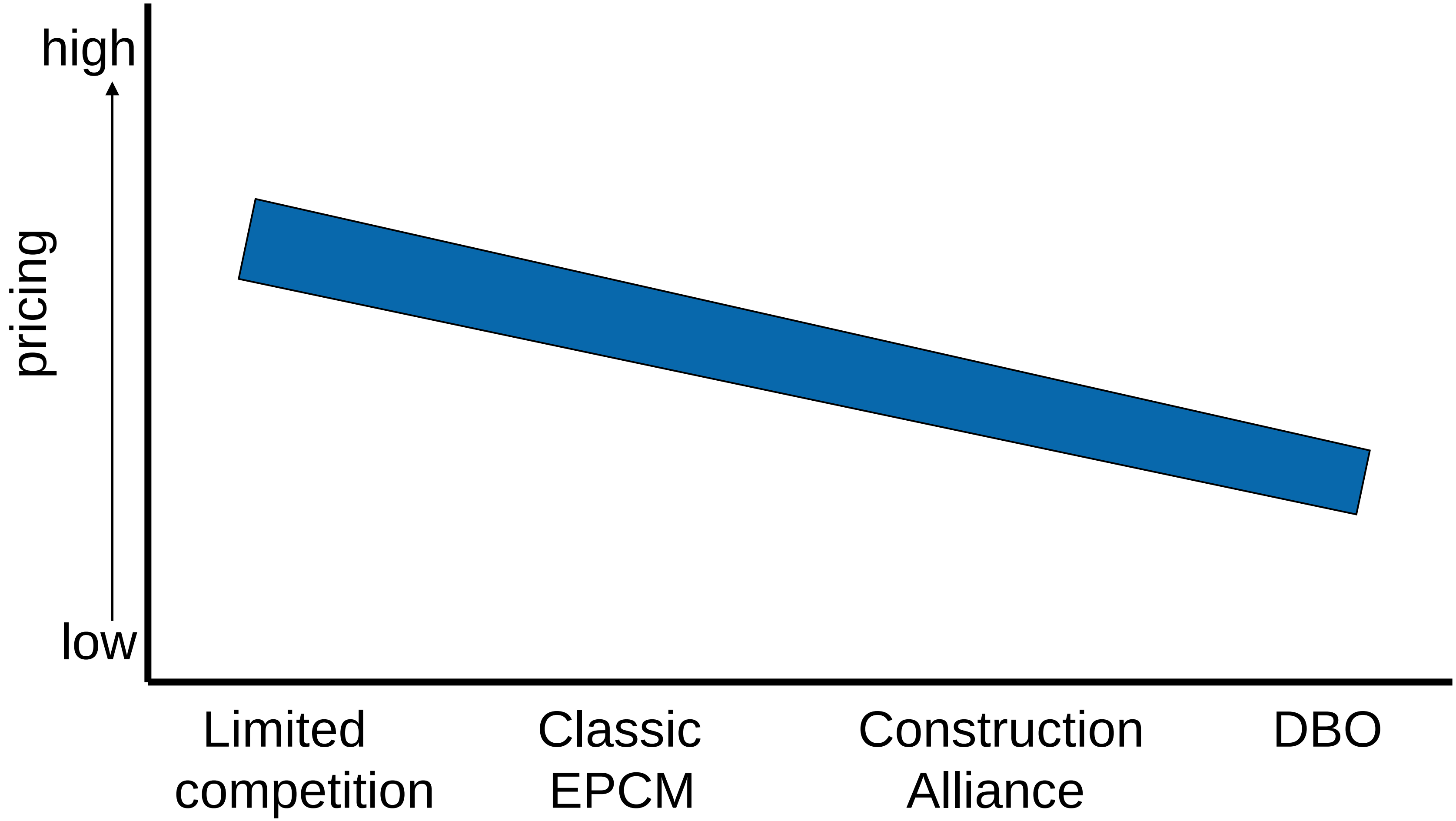
Limited experienced parties

- Construction contractors → many

Focus competition in project phase with highest volume → construction

- EPCM with experienced designer
- Increased role experienced consultant
  - verify / optimize design
  - “green light” critical details & operation procedures
  - coach during plant start-up & plant optimization
- Construction Alliance
  - Alliance is Client – Designer
  - Synergy: Classic EPMC and DB

Pricing contract models



Membrane interchangeability

Make the plant independent from the selected membranes during construction phase

- Increase competition
- Rapid improvements

Options:

1. Flexible/Generic membrane box
   - Housing / control adapted to various membranes
   - Active or Latent changeability
2. Plug&Play Concept (Membrane Tank = "Disposable")
   - Maximum flexibility
   - Complex control interactions
   - Changeability can be expensive

Nautilus™ MBR
DHV's universal Membrane Housing

Consultancy and Engineering

Generic (Exchangable)
Membrane Housing for e.g.:
HUBER / KUBOTA / KOCH
MITSUBISHI / TORAY / ZENON

Nautilus™ membrane bioreactor technology

Membrane independence
Cost reduction
Flexibility

Nautilus™ MBR ASF
Leachate and digester wastewater

Nautilus™ membrane bioreactor technology

Item	Influent	Effluent	Efficiency
	mg/l	mg/l	%
COD	4.000 – 8.000	800	> 90
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NH4 - N	80 % of TKN	< 1	> 99
TN		< 30	> 98
TSS	< 200	< 1	> 99

10 – 12 g MLSS/l

MC in air (developed in Beverwijk)

start-up with membrane X (2002), 20 m3/h

extended with membrane Y (2005), 40 m3/h

replace first set of membranes by membrane Y (2006)

Conclusion

- MBR is a mature and reliable technology, but not yet a commodity and still shows fast evolution
- Especially of interest for water reuse
- MBR requires extensive know-how on design & operation of biology, membranes and interactions
- Many lessons were learnt in design and tendering (and one will continue to do so)

  → make optimal use of existing know-how
- Use international Best-in-Class MBR know-how

Conclusion

Consultancy and Engineering



- MBR is a mature and reliable technology, but not yet a commodity and still shows fast evolution
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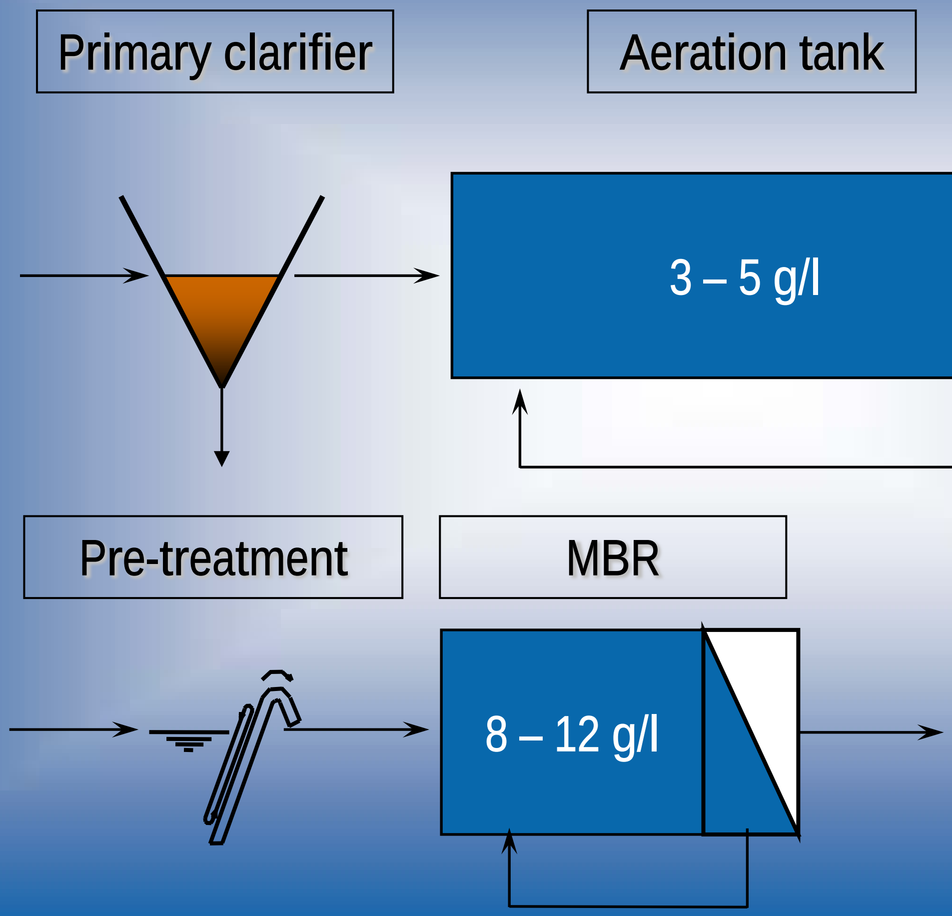
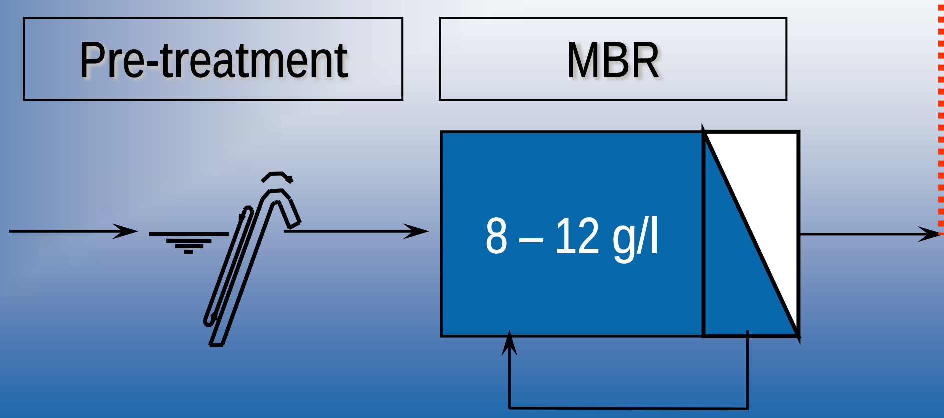
MBR technology



EFFLUENT QUALITY

SPACE SAVINGS

MBR technology



- Cooling water
- Boiler feed water
- Process water
- Wash water
- Drinking water
- Etc. Etc. Etc.

EFFLUENT QUALITY

SPACE SAVINGS

MBR as enabler for integrated and sustainable urban developments

Consultancy and Engineering

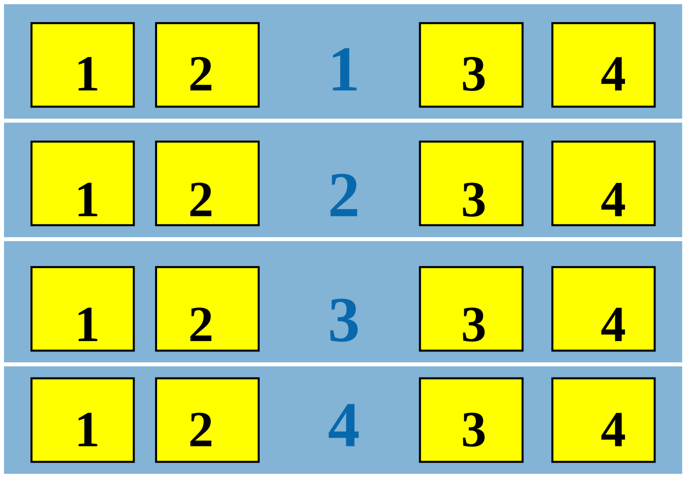
MBR Varsseveld

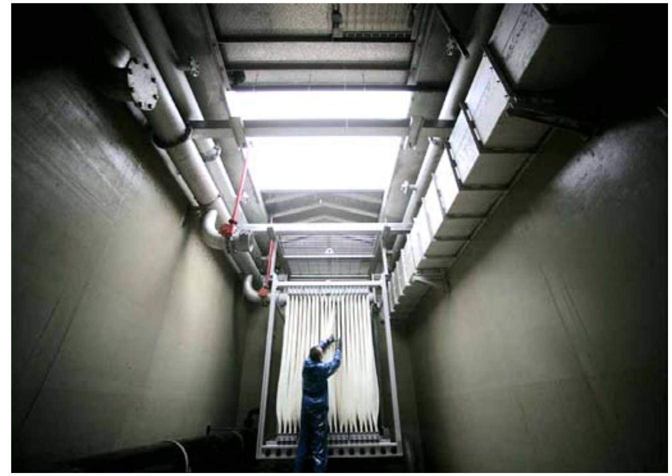
Design and load

Parameter		Design	Influent	
			Average	Min. – Max.
Flow	m³/h	755		
	m³/d	5,000	4,225	2,100 – 15,600
COD	kg/d	3,000	3,340	990 – 14,900
Total Nitrogen	kg/d	280	228	70 – 820
Total Phosphorous	kg/d	50	66	20 – 330
Energy	kWh/m³	1.0	0.85	0.8 – 1.2

MBR and energy

MBR Varsseveld



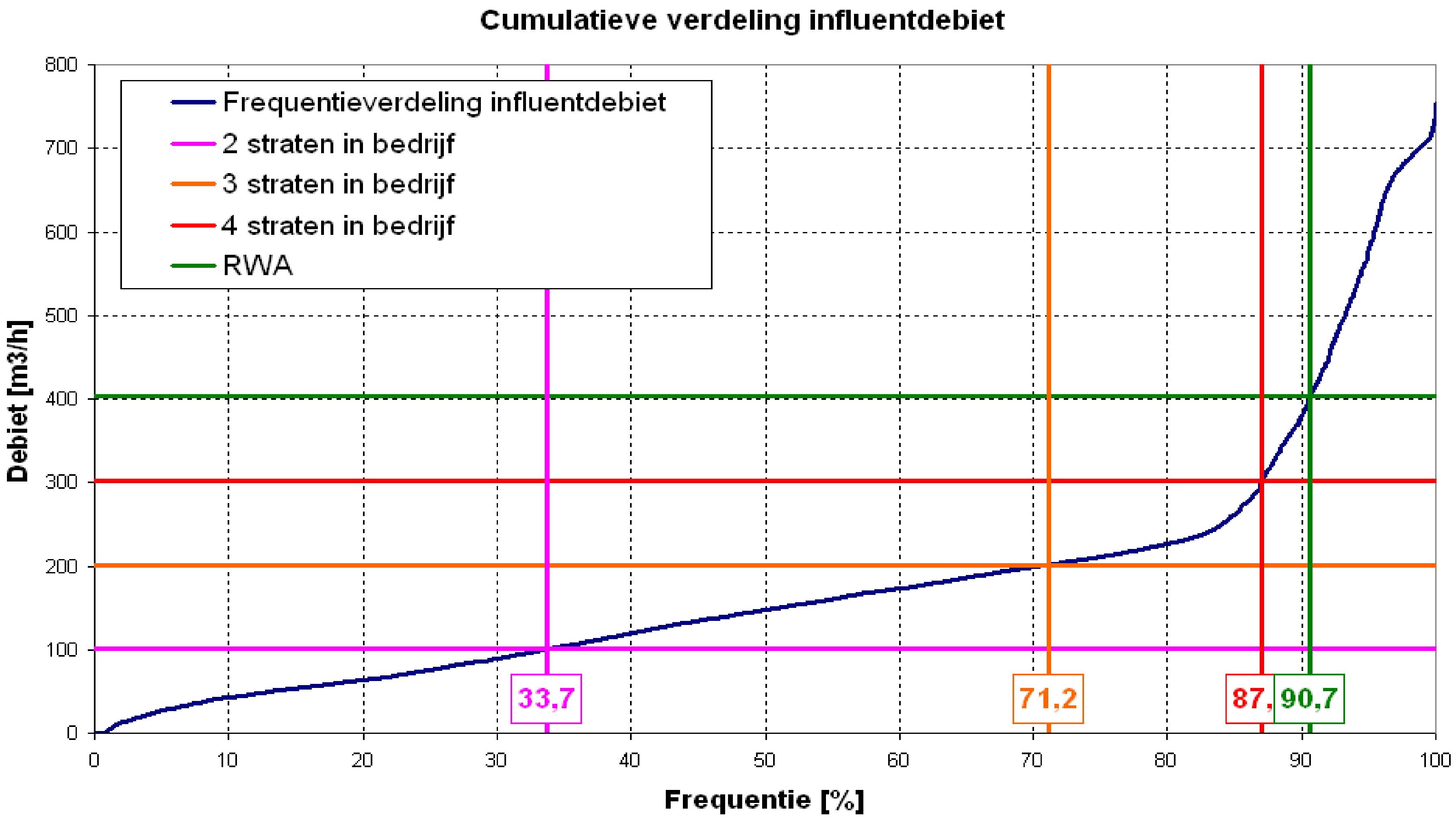


Case	Nett Flux l/(m².h)	Period h	Flow per tank m³/h
Minimum	10	-	50
Optimal	15 - 25	-	75 - 125
Design	37,5	72	190
Maximum	50	8	250

MBR and energy

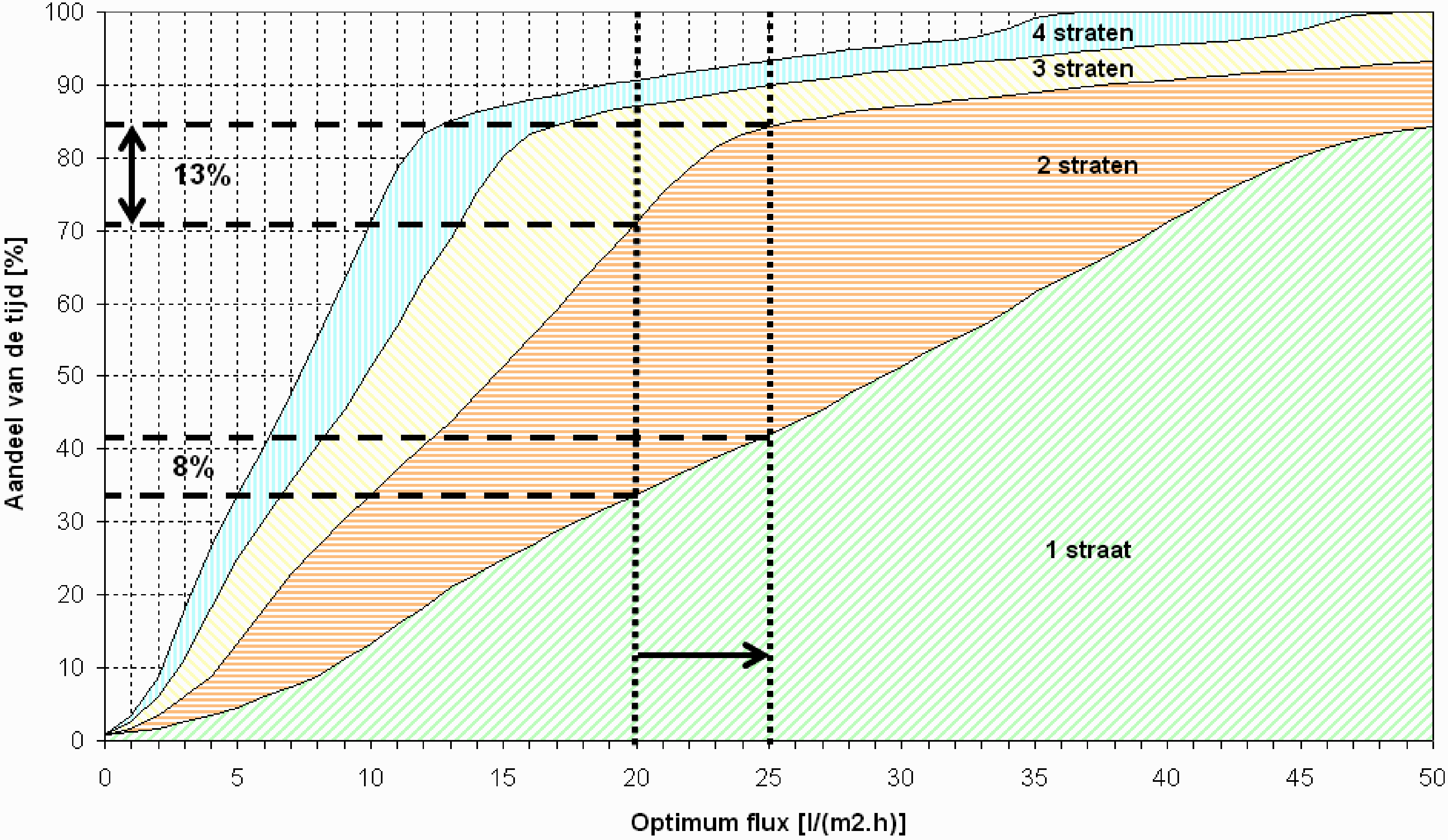
Optimumflux of 20 l/(m².h)

Consultancy and Engineering



Energy saving by increased optimum flux

Consultancy and Engineering



MBR at Rendac

EPCM project

Consultancy and Engineering

Largest in Europa
400.000 pe
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10 – 13 g MLSS/l

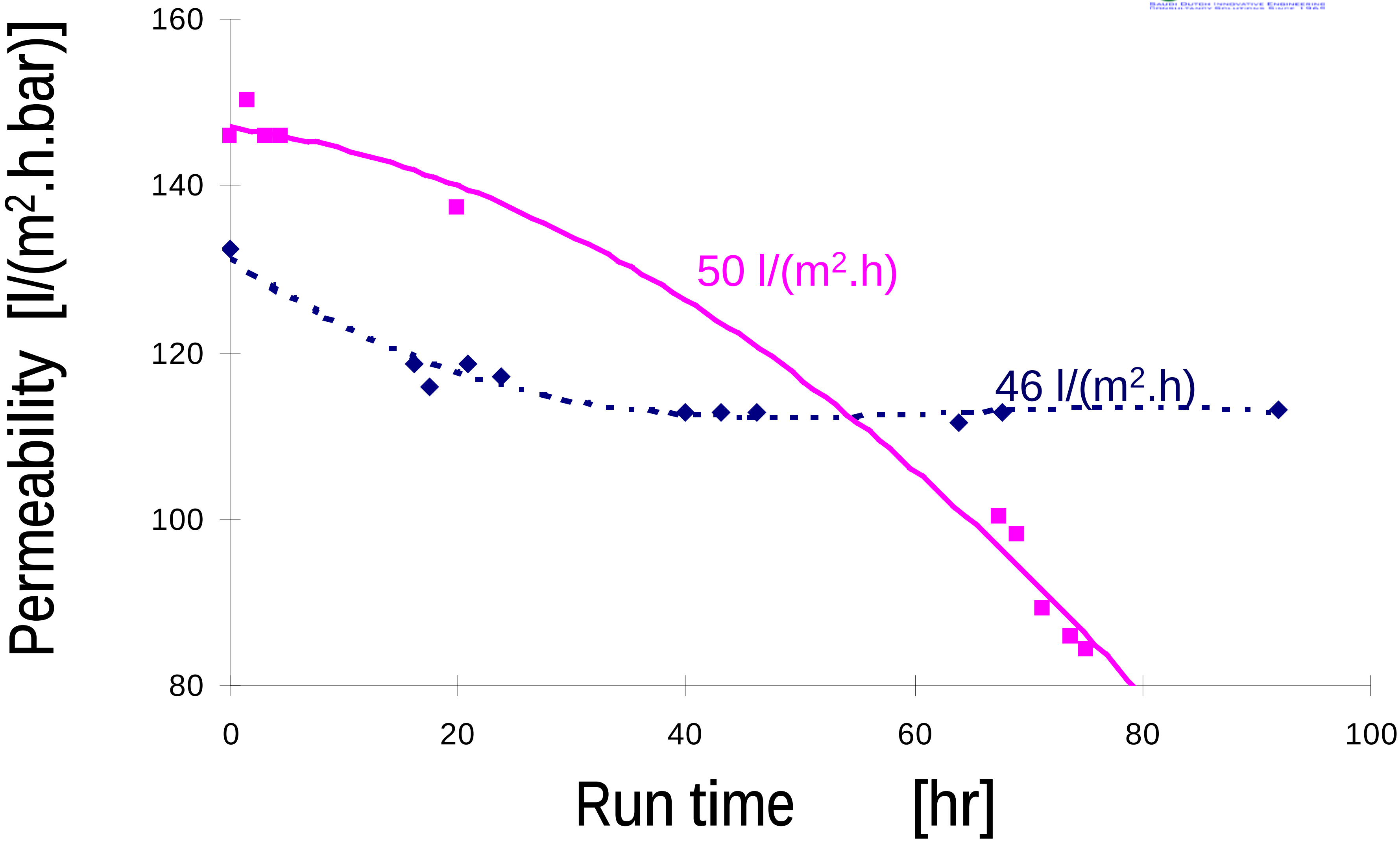
Design flux 30 - 35 l/(m^2.h) at T > 25 ^{o}C

MC in air (developed in Beverwijk)

start-up: 2002

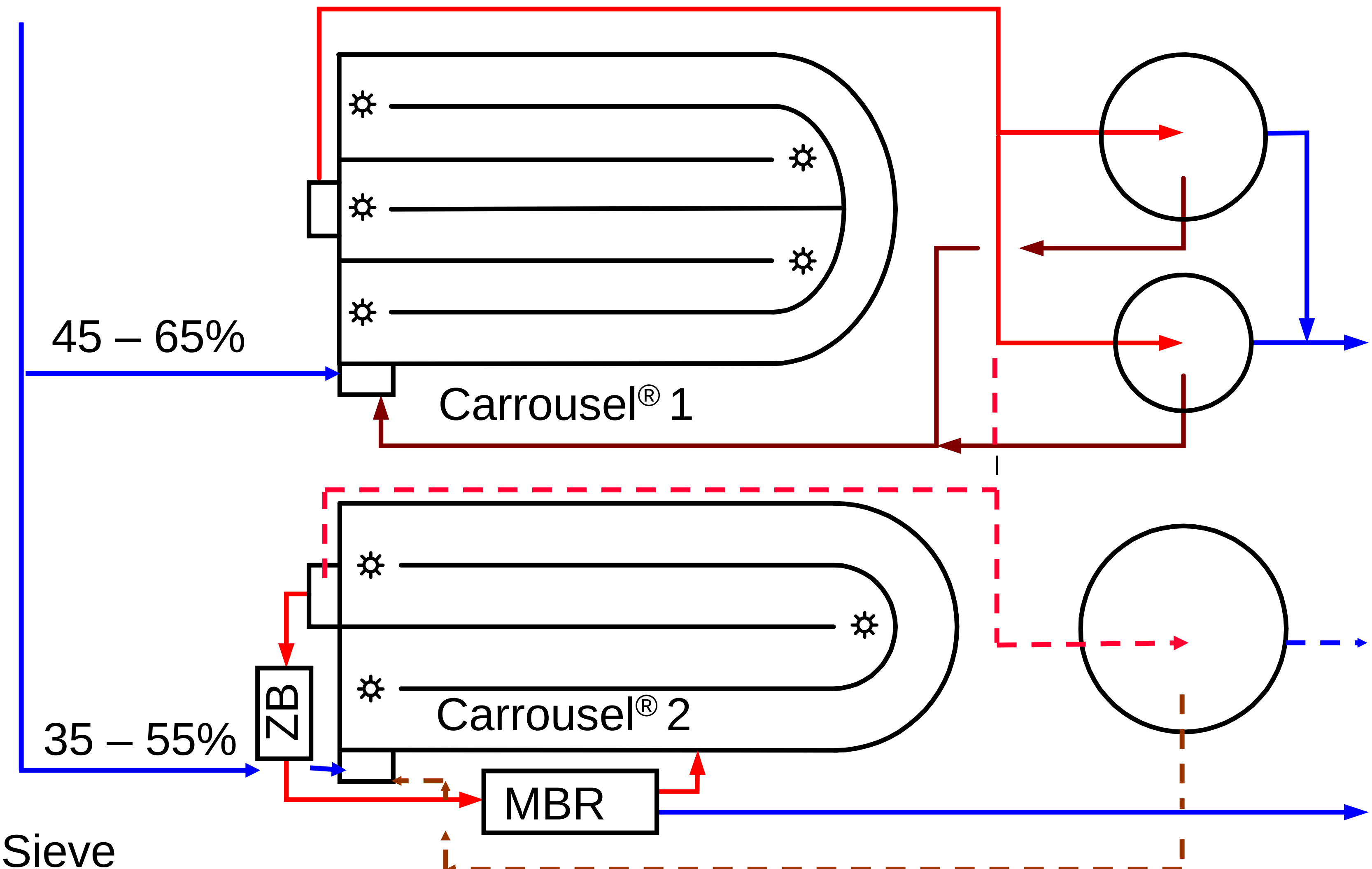
Permeability critical

Consultancy and Engineering



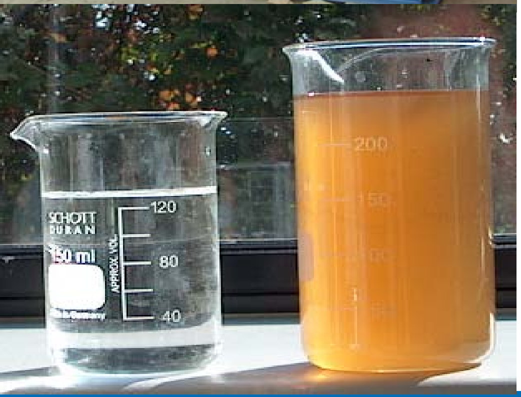
PFD MBR-Carrousel® (Hybrid)

Consultancy and Engineering



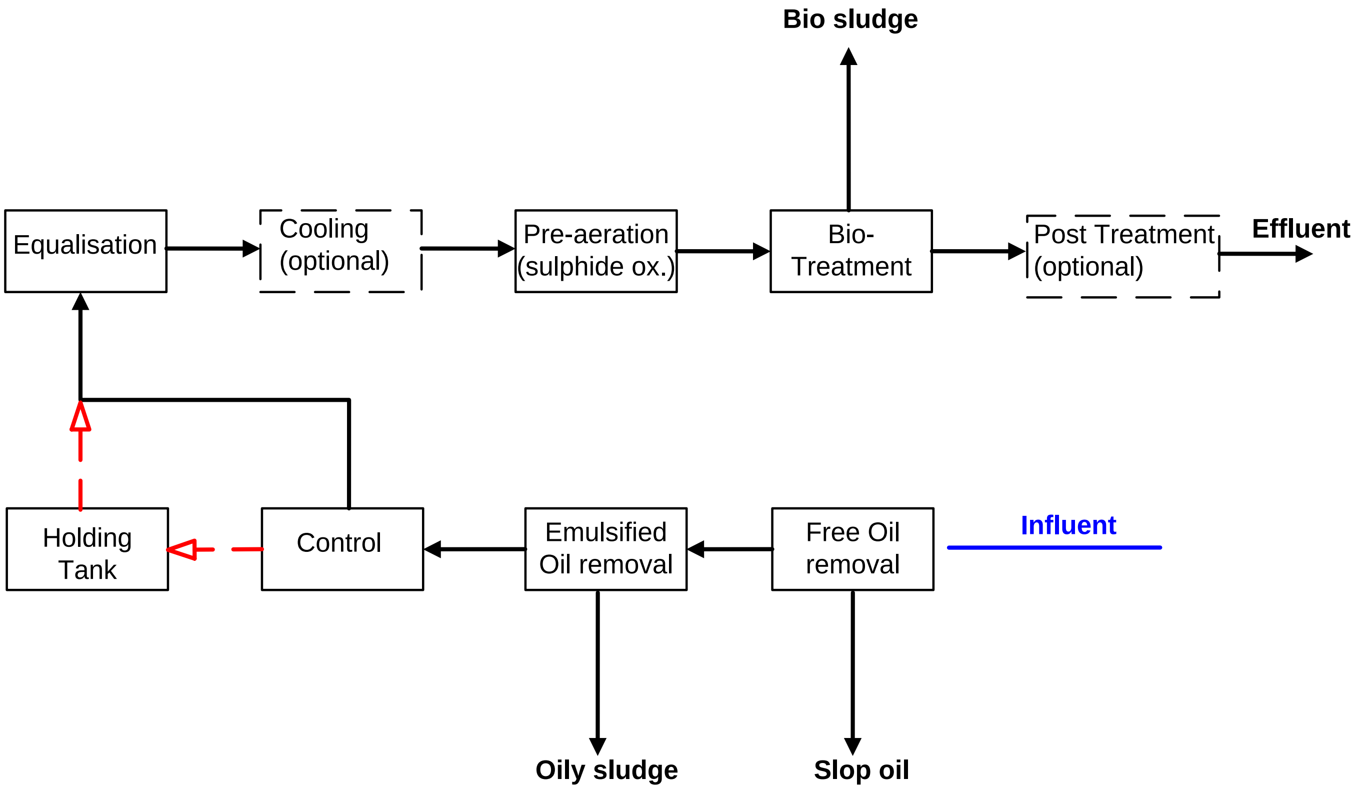
ZB = Sieve

MBR for produced water (Azerbaijan)



Highly Saline (30 – 60 g/l)

Extensive pretreatment required



Results

- COD removal >95% Feasible
  - Very high influent COD (average 25.000 ppm) prohibit meeting effluent demand
- Substantial Biomass growth:
  - ABR reduces surplus sludge
- Cleaning Feasible:
  - Repeated Recovery to permeability >100 l/(m^2.h.bar)
- Net Flux 5 – 8 l/(m^2.h)

Visual result

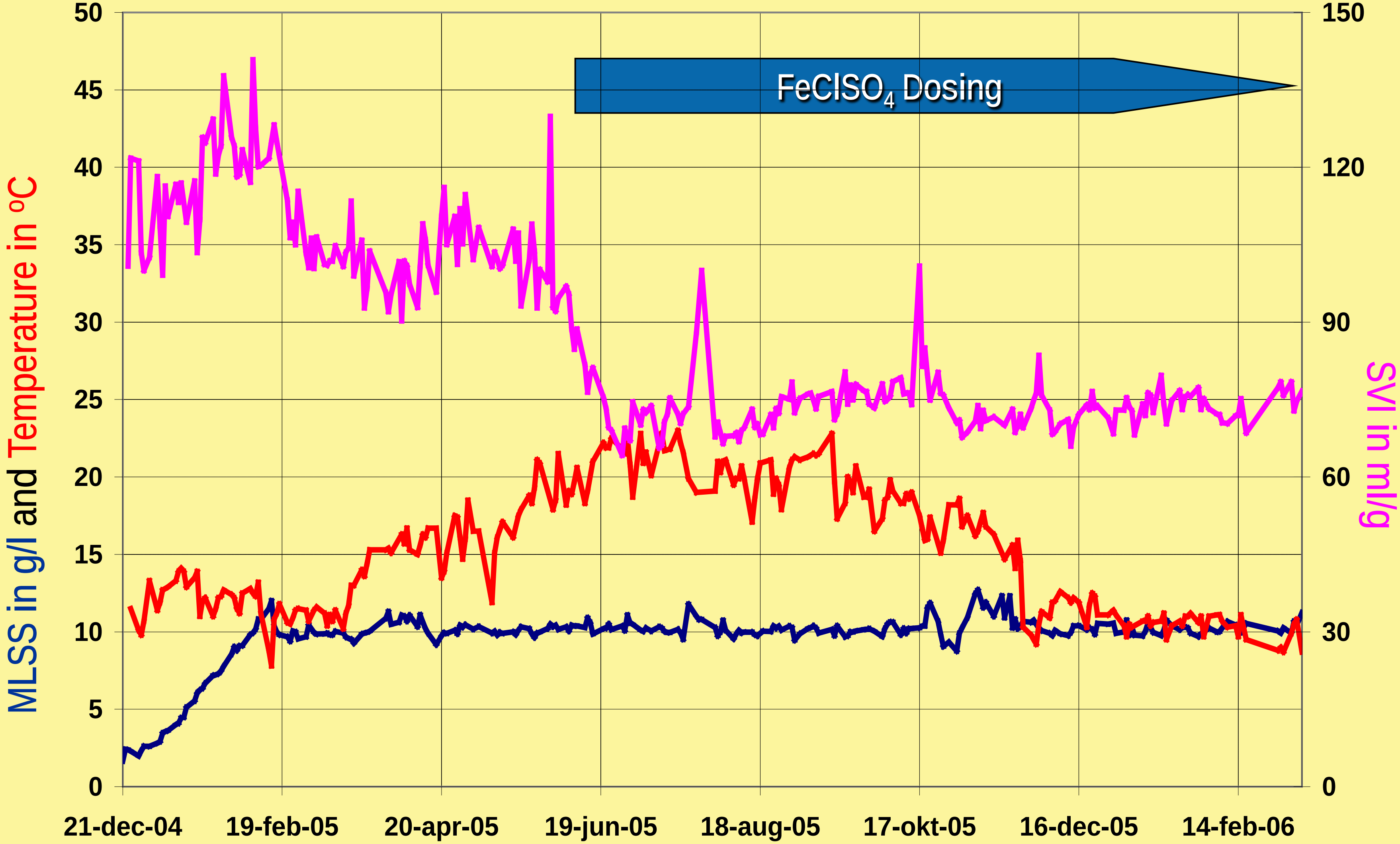
Consultancy and Engineering

Produced water ABR MBR Effluent

MBR Varsseveld

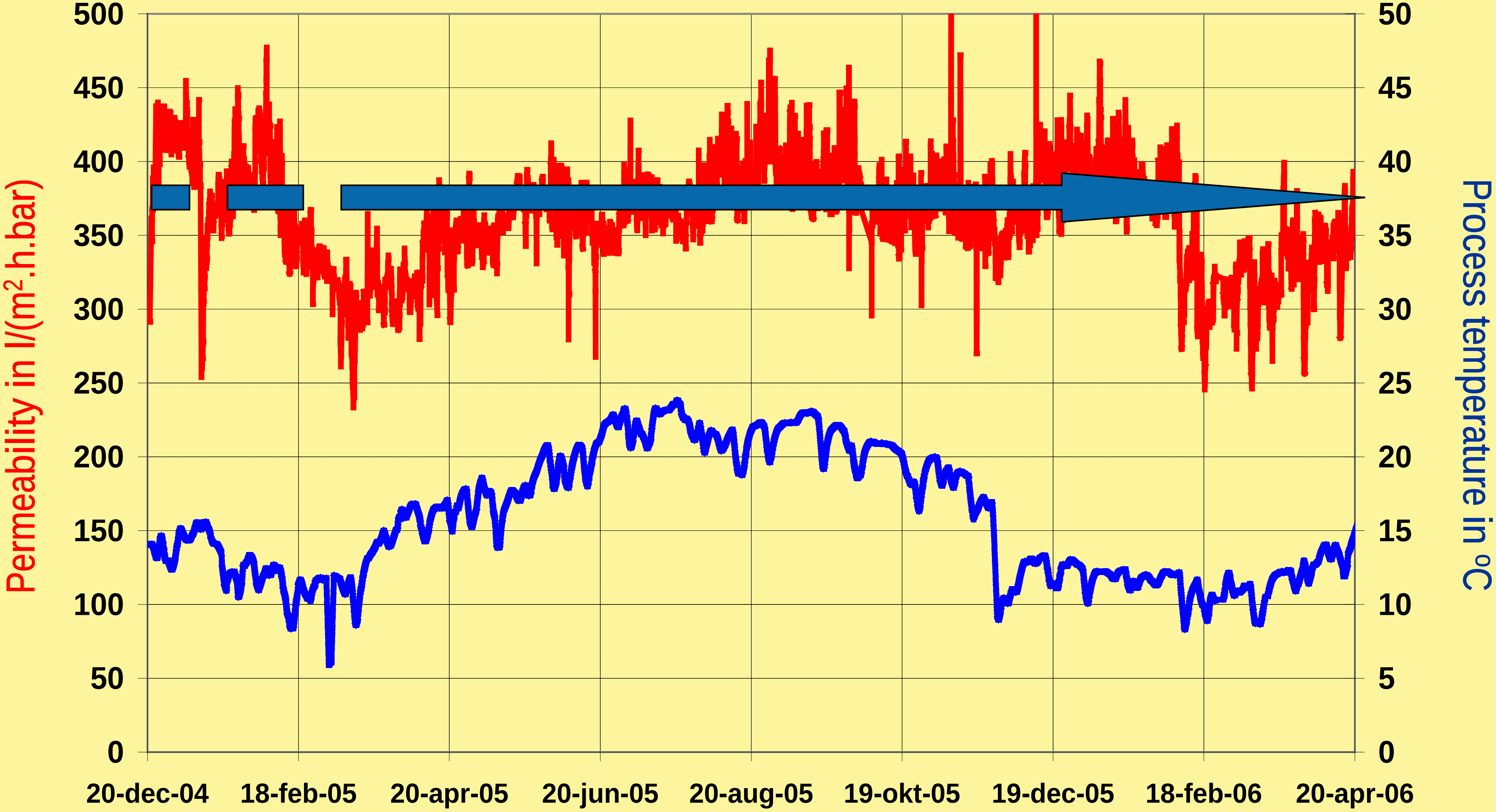
Process conditions

Consultancy and Engineering

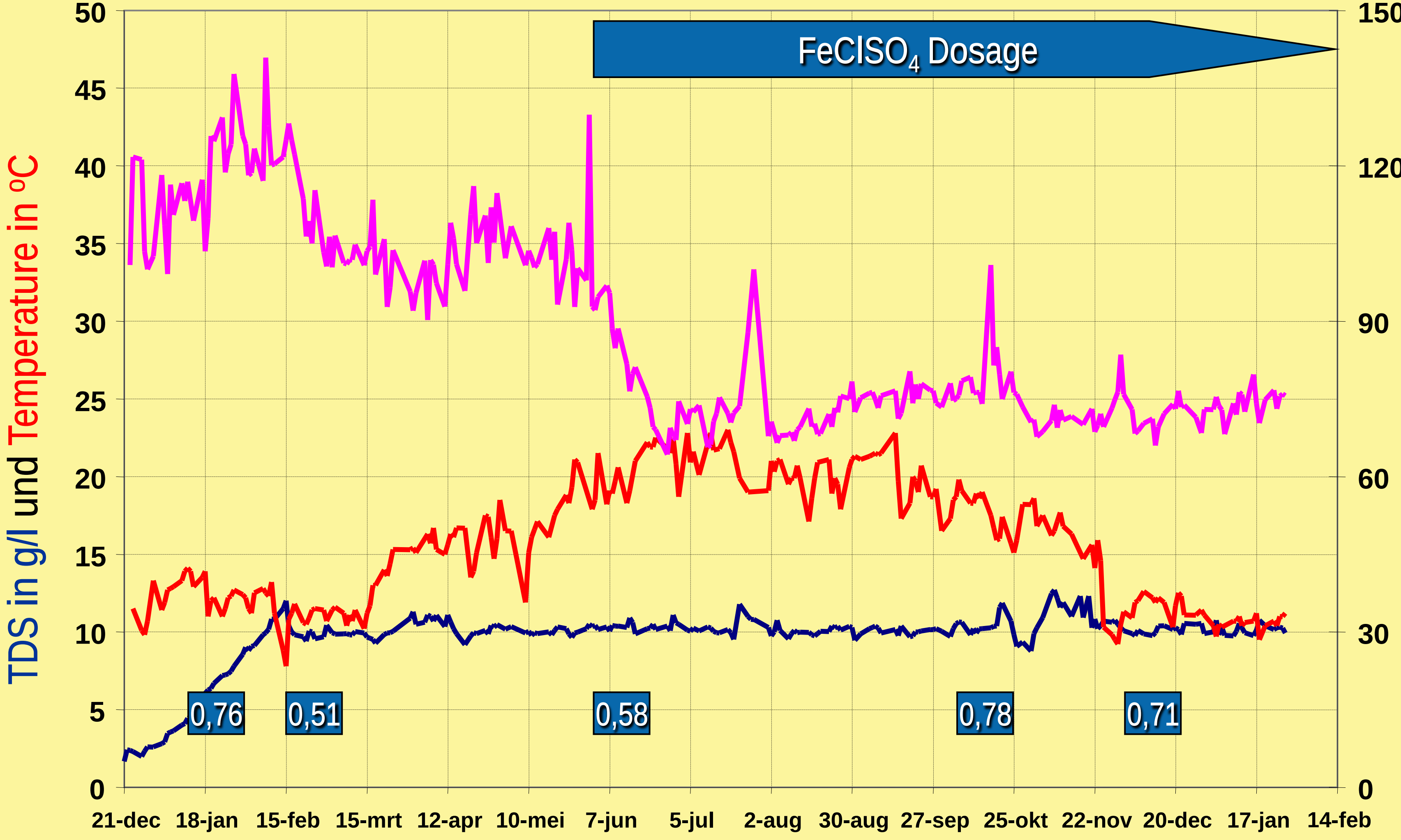


MBR Varsseveld

Control Membrane fouling



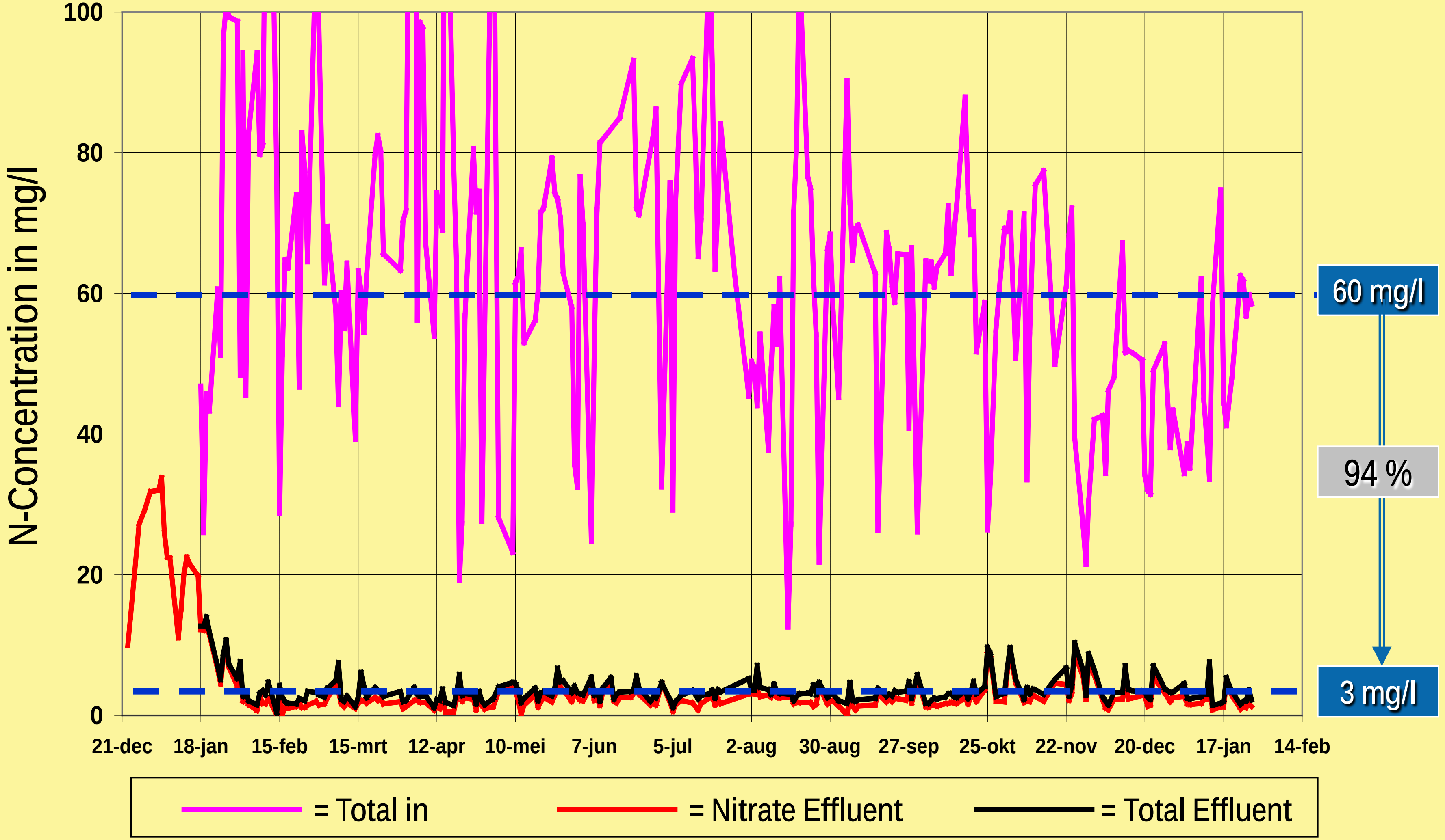
MBR Varsseveld



Gateway to solutions

MBR Varsseveld

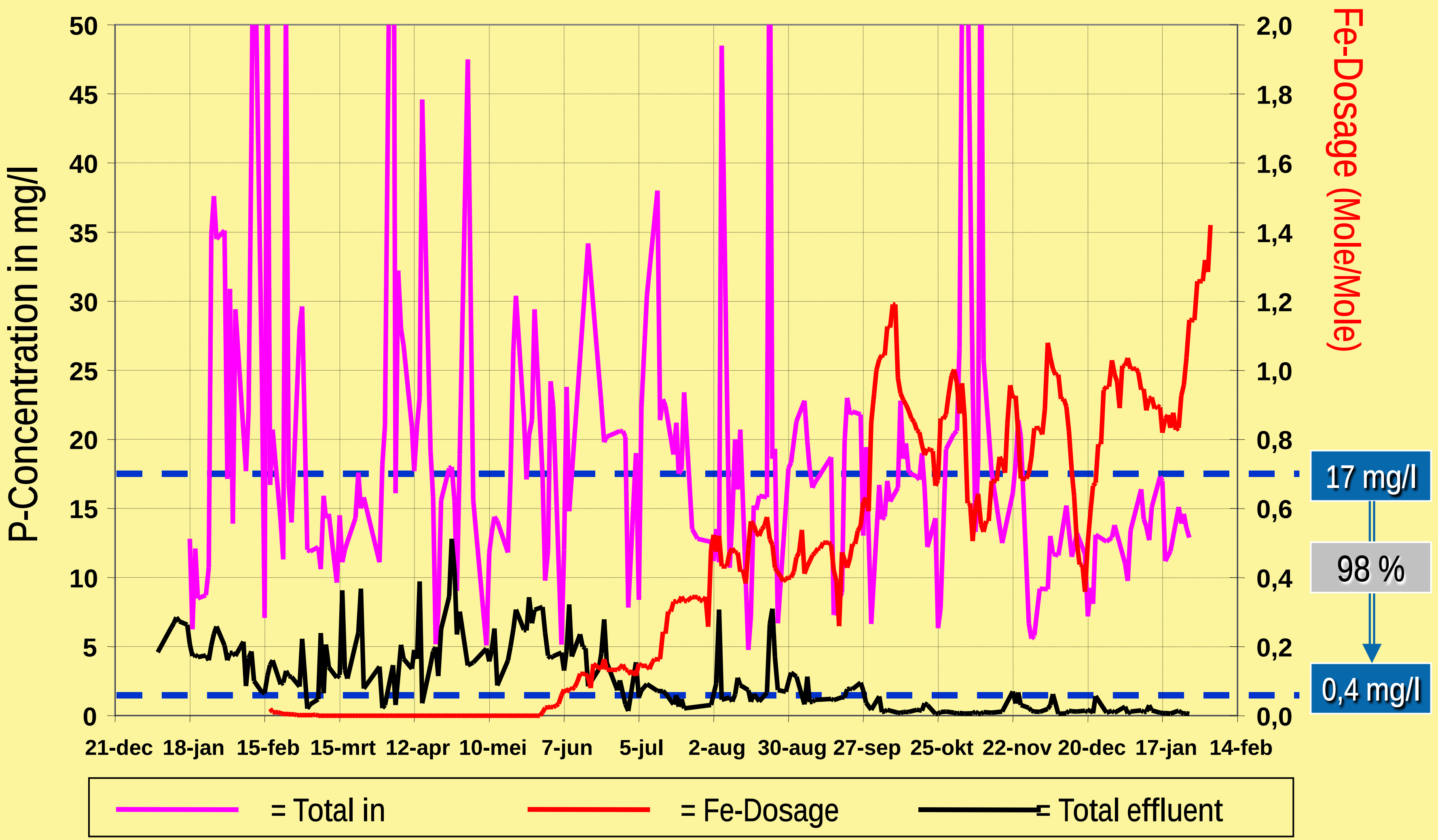
N-Removal



MBR Varsseveld

P-Removal

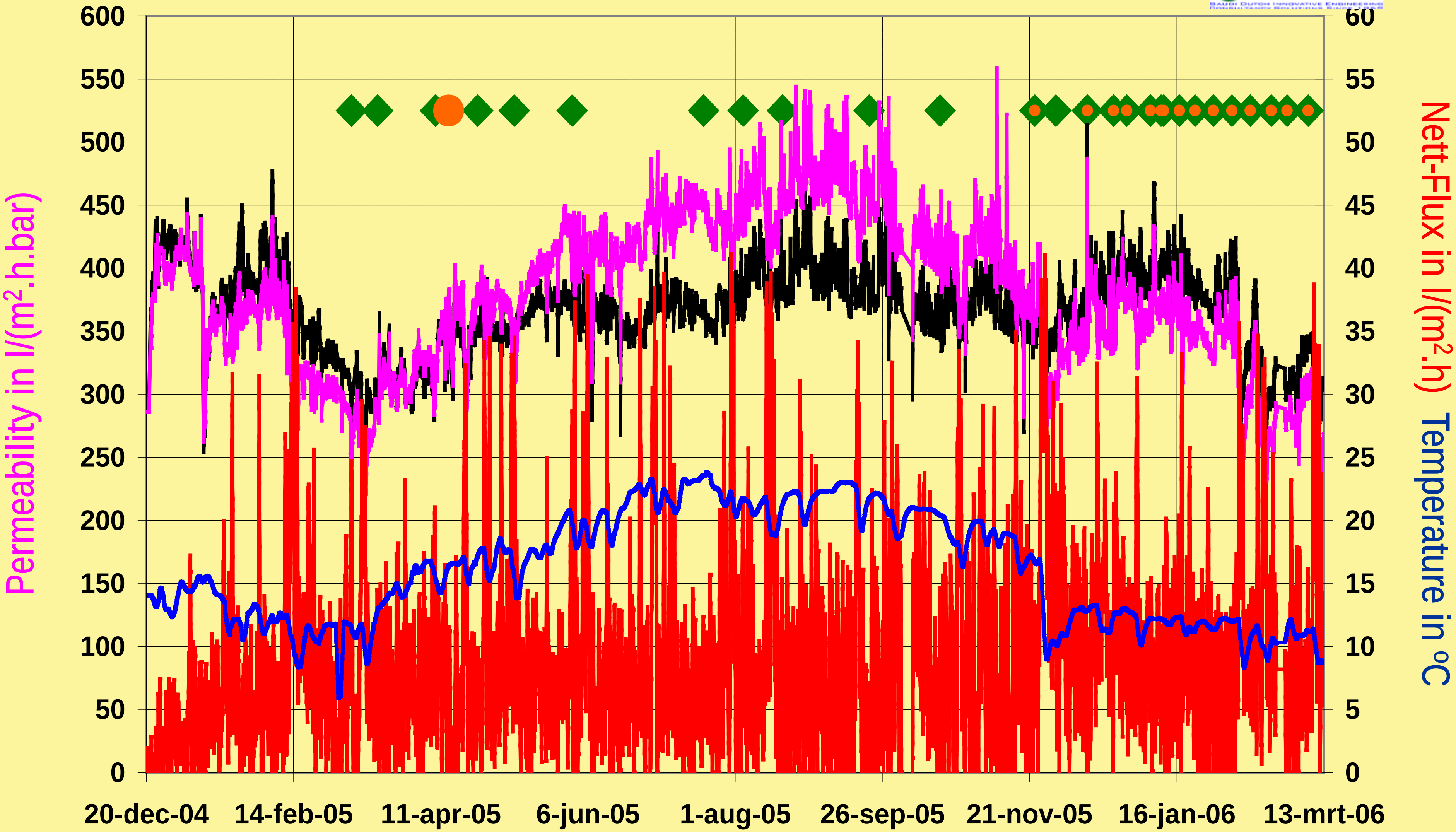
Consultancy and Engineering



MBR Varsseveld

Membrane performance

Consultancy and Engineering



Thank you