Energy Efficient MBR Design: Rabigh Refinery, Saudi Arabia

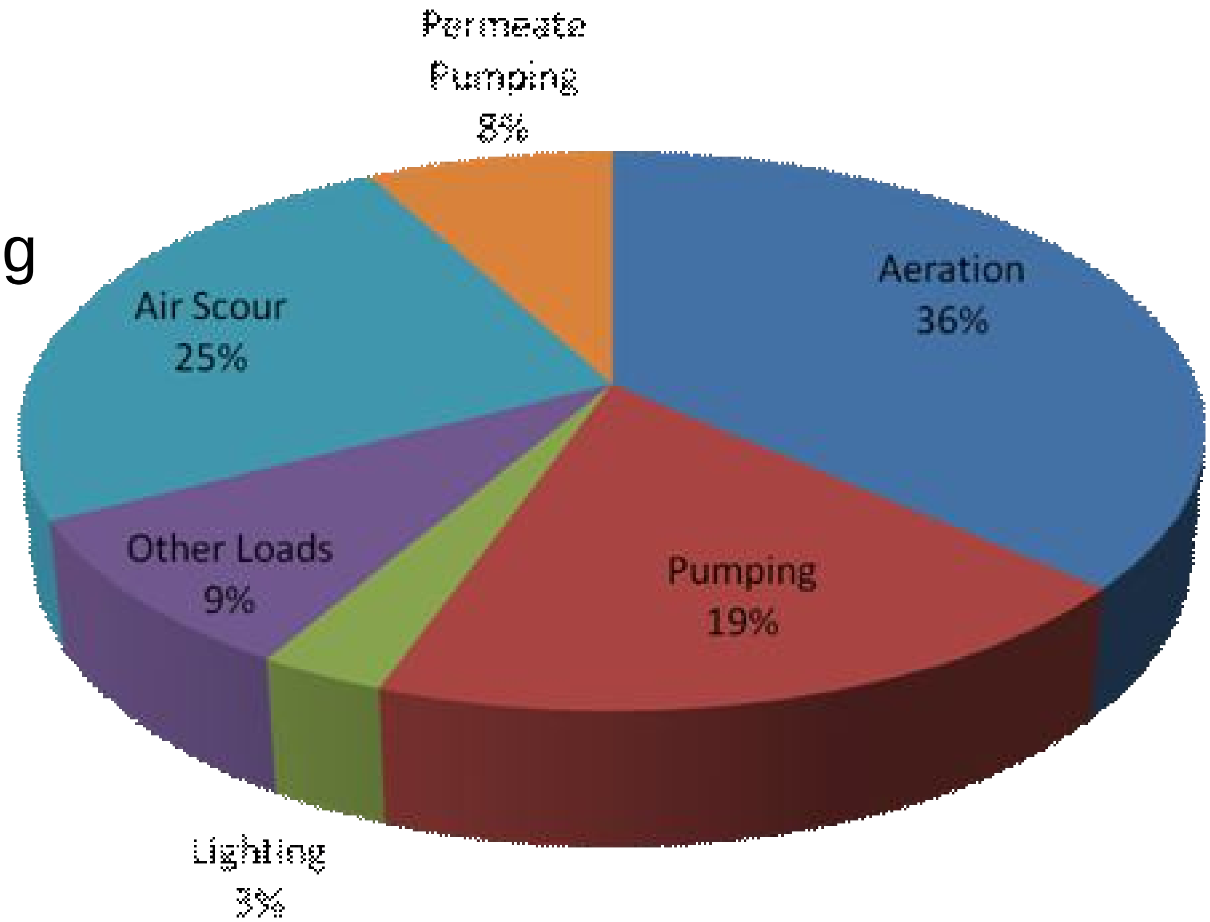
Water Arabia

Wednesday, February 2, 2011

Dr. Dirk Herold
Koch Membrane Systems

Power Consumption MBR

- Aeration
- RAS Pumping
- Air Scour
- Permeate
- Lighting
- Other



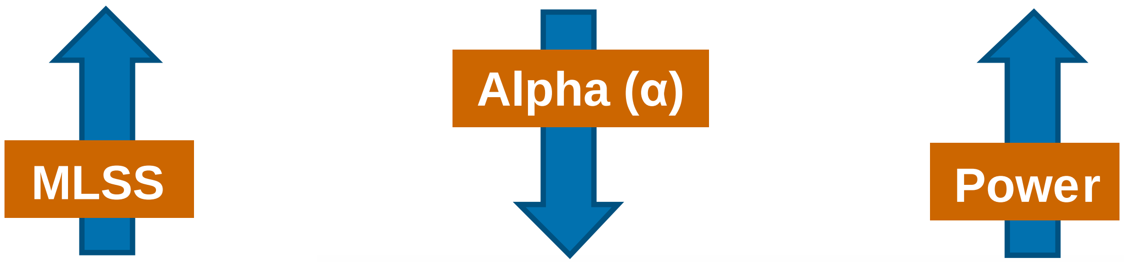
Relevant Aspects for MBR Energy Consumption

KOCH MEMBRANE SYSTEMS

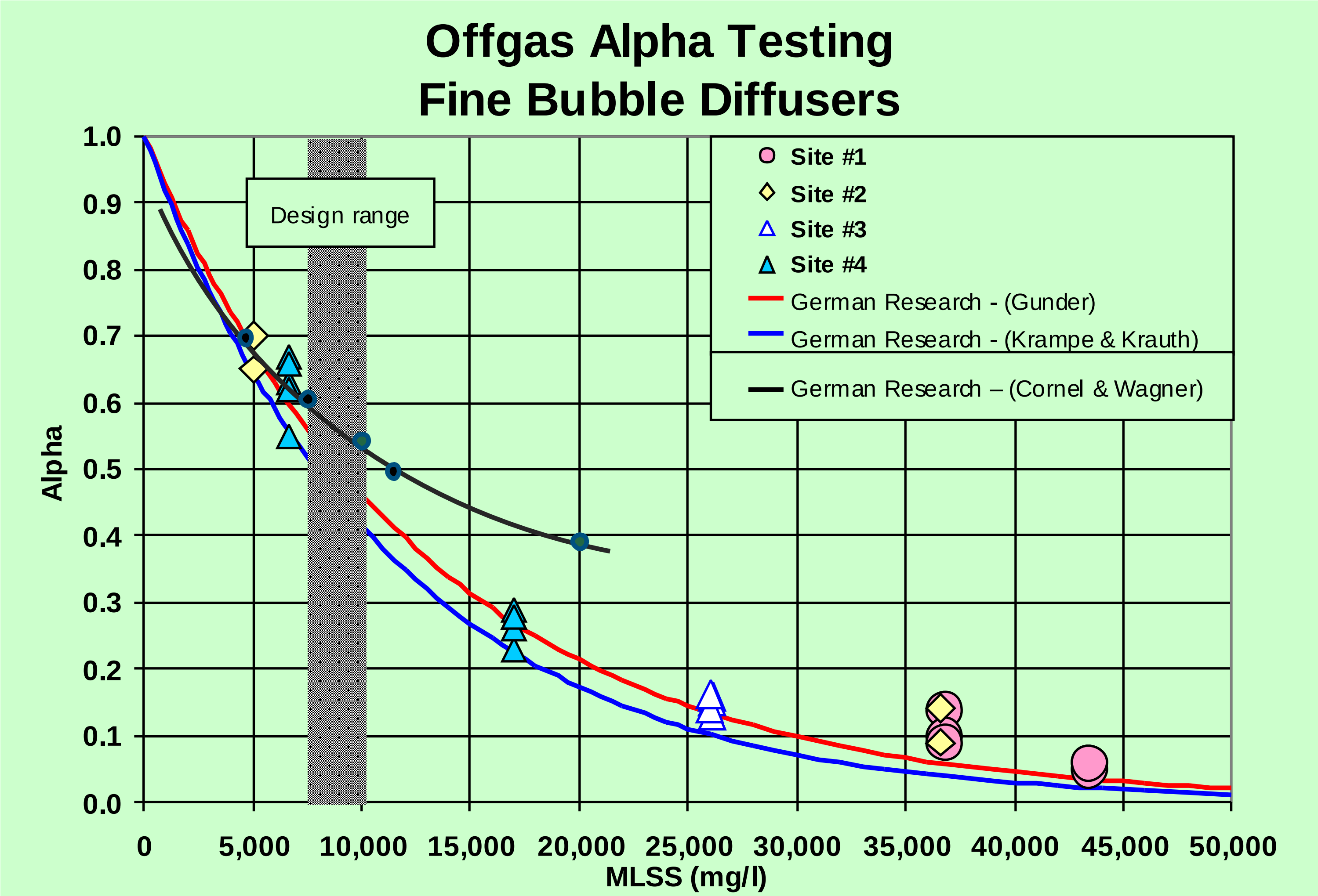
- **Maximize aeration tank alpha value**
  - ✓ Mixed liquor suspended solids (MLSS) selected based on loading/process
- **Efficient return activated sludge (RAS) pumping design**
  - ✓ Pump feed versus gravity feed
  - ✓ Variable speed control
- **Matching membrane area with design flows**
  - ✓ Reduce peak flows
  - ✓ Adequate flux rate to reduce membrane area
  - ✓ MBR membrane train layout
- **Minimize air scour requirements**
  - ✓ Module design
  - ✓ MBR membrane train layout

MBR Aeration Power Consumption

- α-factor: ratio of oxygen mass transfer coefficient (Kla) in wastewater to the same coefficient in clean water.
- Aeration power consumption elevated in MBR due to depressed alpha value associated with increased MLSS concentration of MBR process.
- α-factor indirectly proportional to power required to supply air for adequate oxygen transfer.



Alpha as a Function of MLSS



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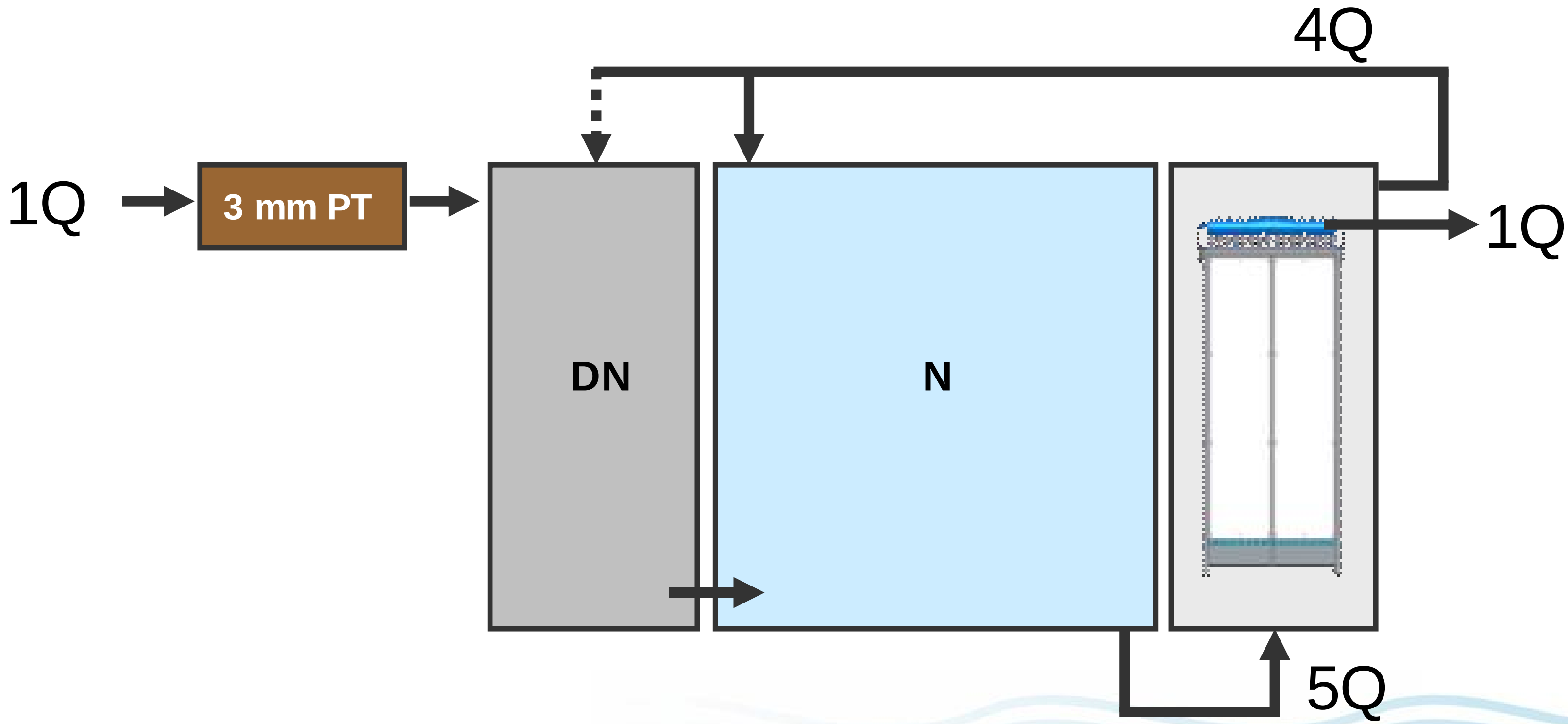
MBR RAS Pumping Power

- RAS pumping in MBR typically 4x influent flow rate.
- MBR RAS important to balance MLSS between membrane tank and bioreactor.



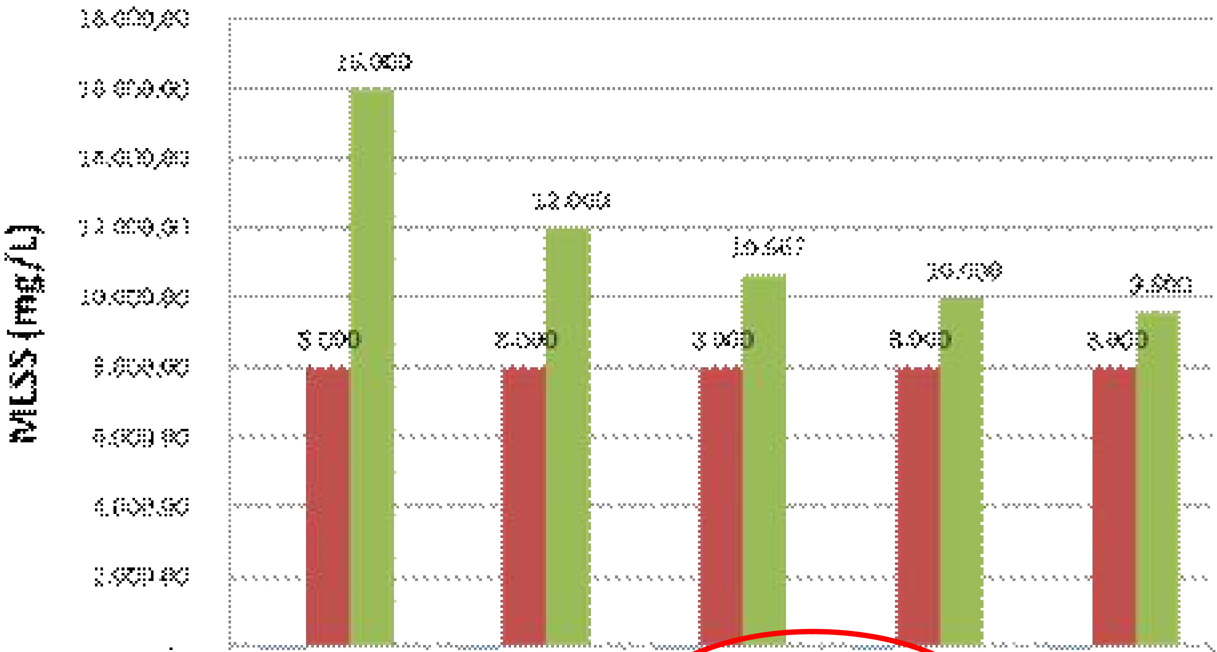
MBR RAS Gradient

$$MLSS_m = MLSS_b * (R+1)/R$$

$MLSS_m$: MLSS membrane

$MLSS_b$: MLSS bioreactor

R : Recirculation factor



	1	2	3	4	5
Recycle Rate	1.00	2.00	3.00	4.00	5.00
MLSS Bioreactor	8,000	8,000	8,000	8,000	8,000
MLSS Membrane	16,000	12,000	10,667	10,000	9,600

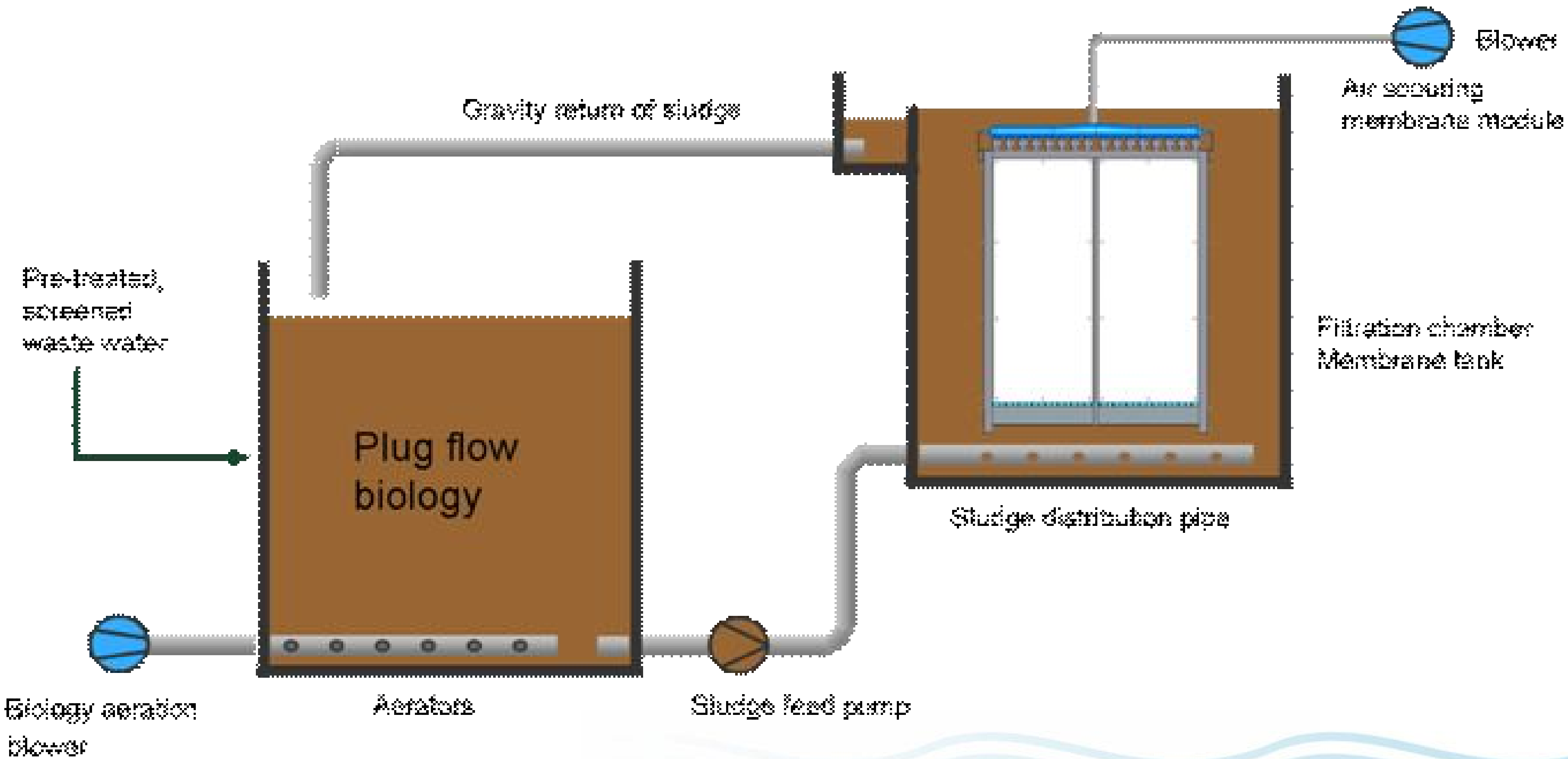
Recycle Rate

Selection of bioreactor MLSS impacts:

1. Alpha value
2. Recycle rate

Pumped Feed and Gravity Return

- Better control over MLSS distribution
- Pumping additional Q compared to gravity feed but usually at lower pumping head



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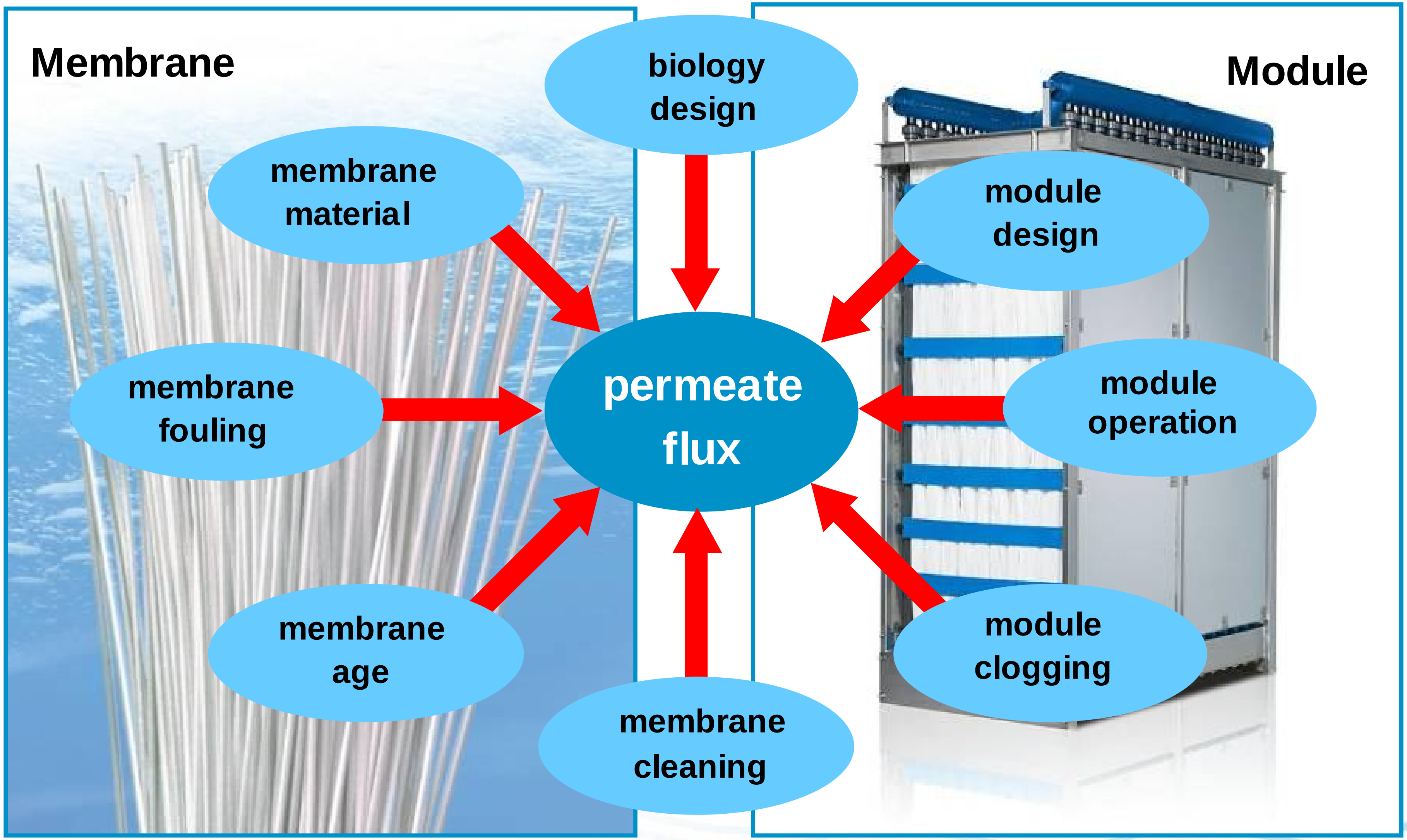
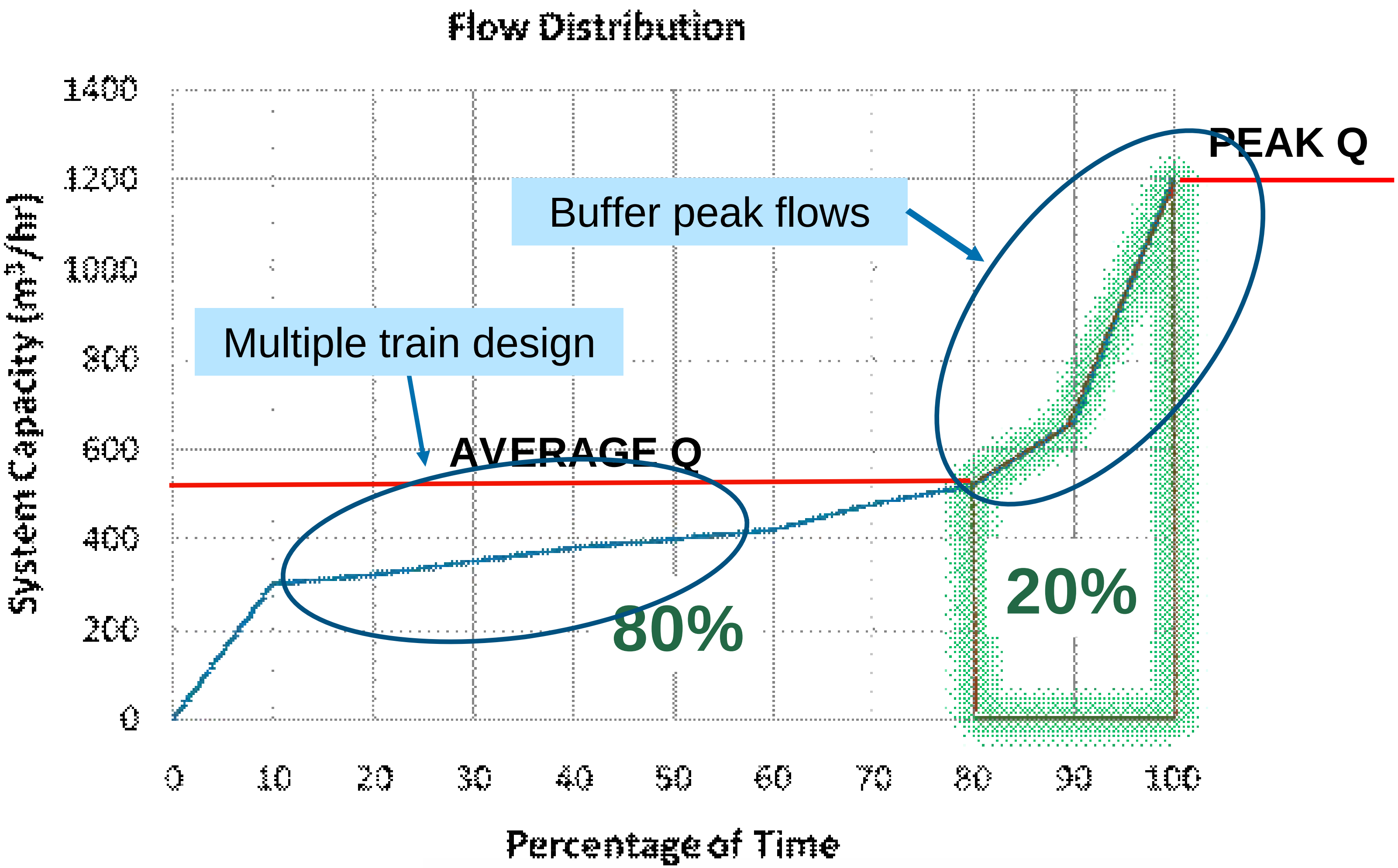
Influencing Factors on Permeate Fluxes

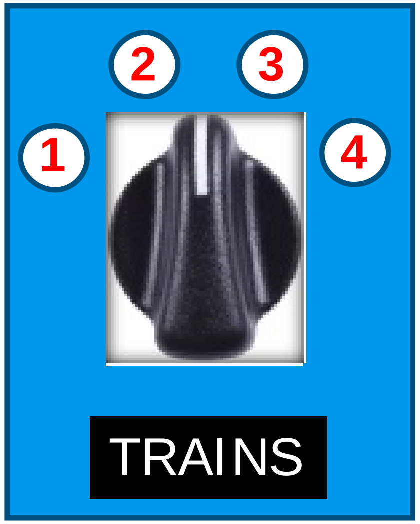


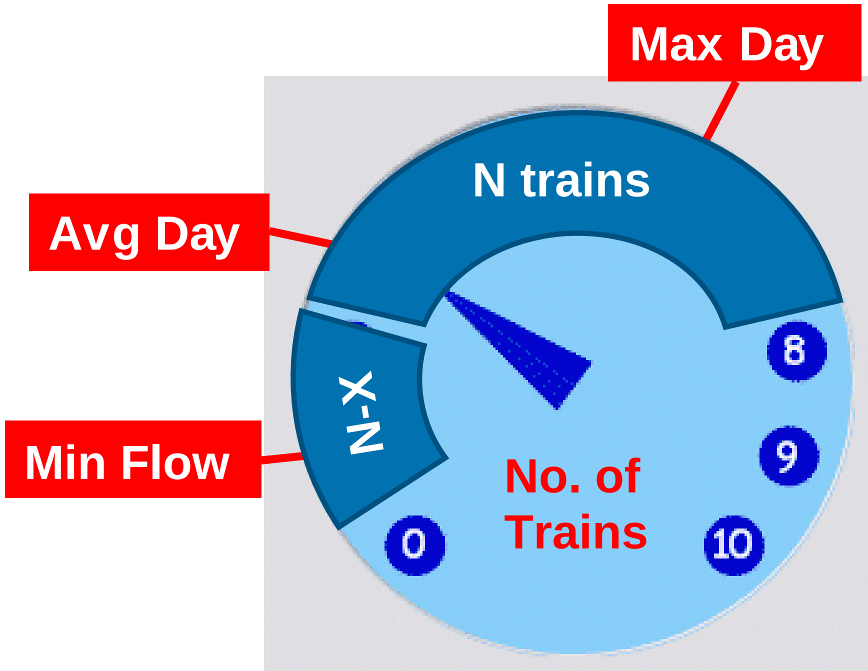
Optimizing Membrane Area



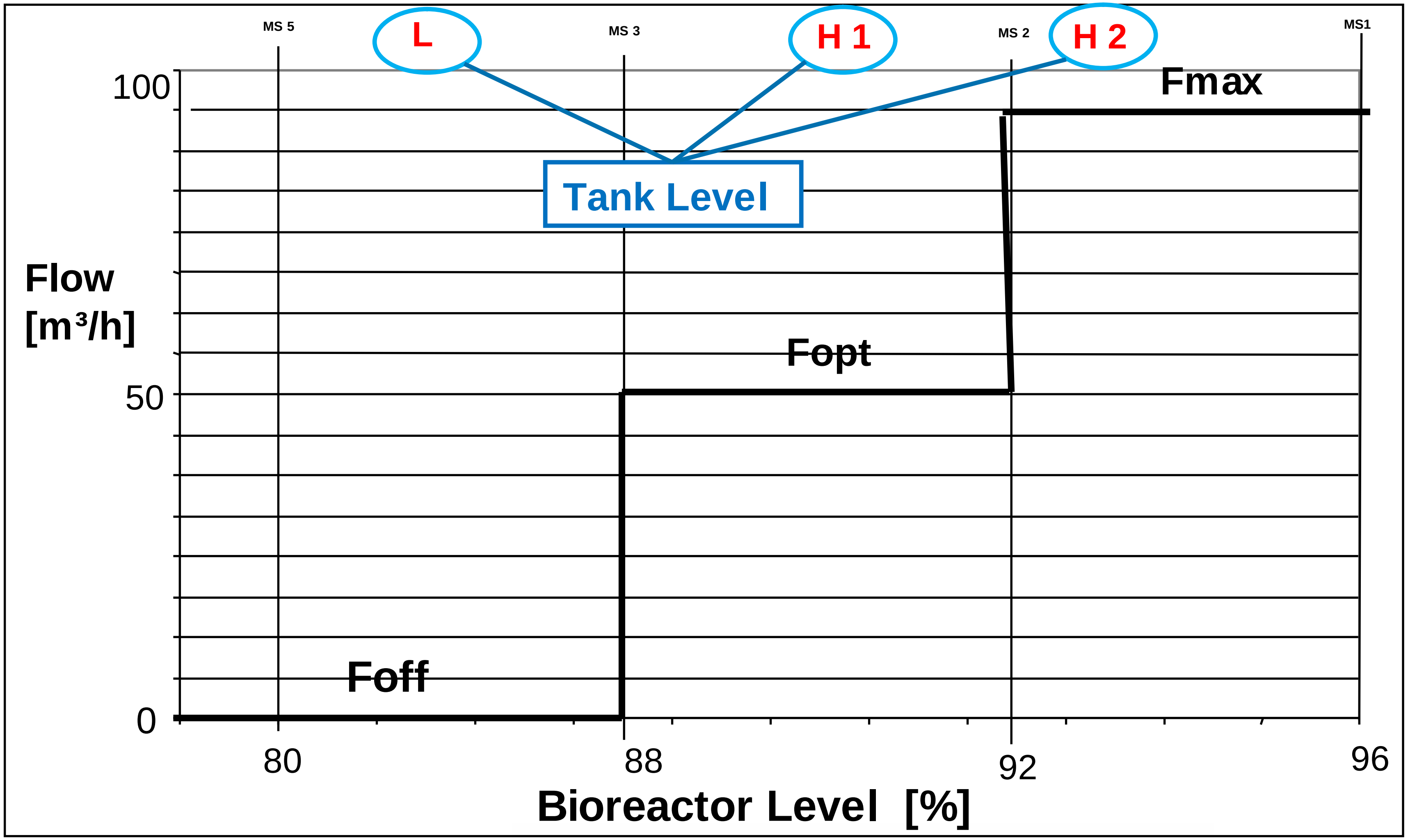
Optimizing Membrane Energy

- **How do we fine tune membrane operation to conserve energy?**
  - ✓Number of trains in operation
  - ✓Flux





Flux & Membrane Train Operation



MBR Train Design

- **Multiple train design allows**
  - ✓Energy friendly
  - ✓Redundancy
  - ✓Cyclical air supply
  - ✓Stand-by of membranes under low flow conditions

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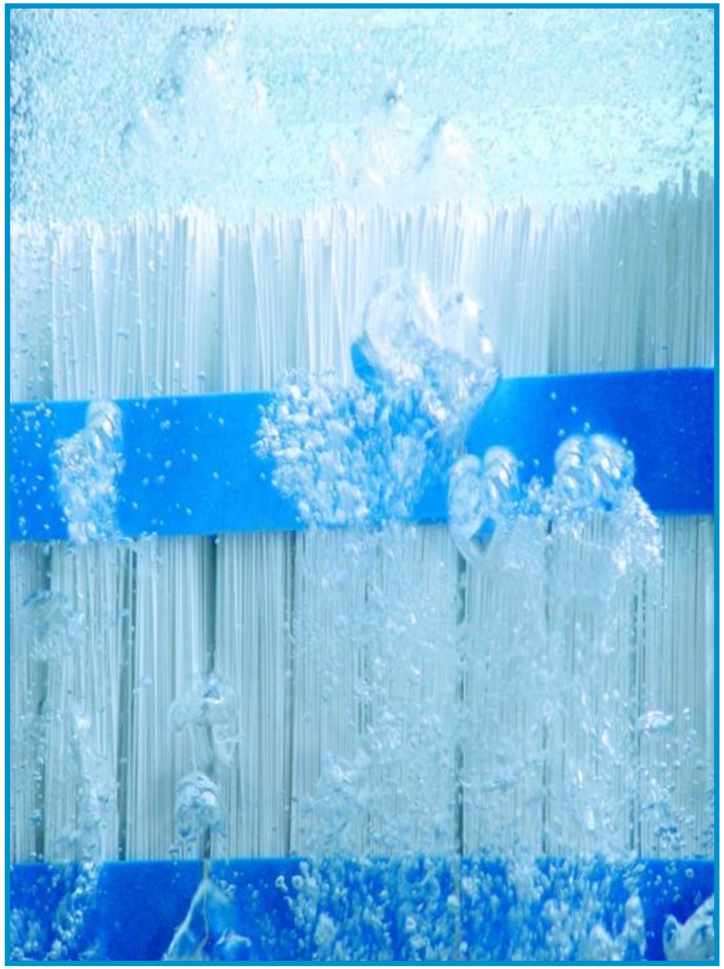
Membrane Air Scouring

- Major power consumer with regard to membrane operation
- Critical to membrane operation/permeability
- Efficient design allows intermittent air supply and variable air delivery rate without compromising membrane permeability
- Air scour systems vary with manufacturers



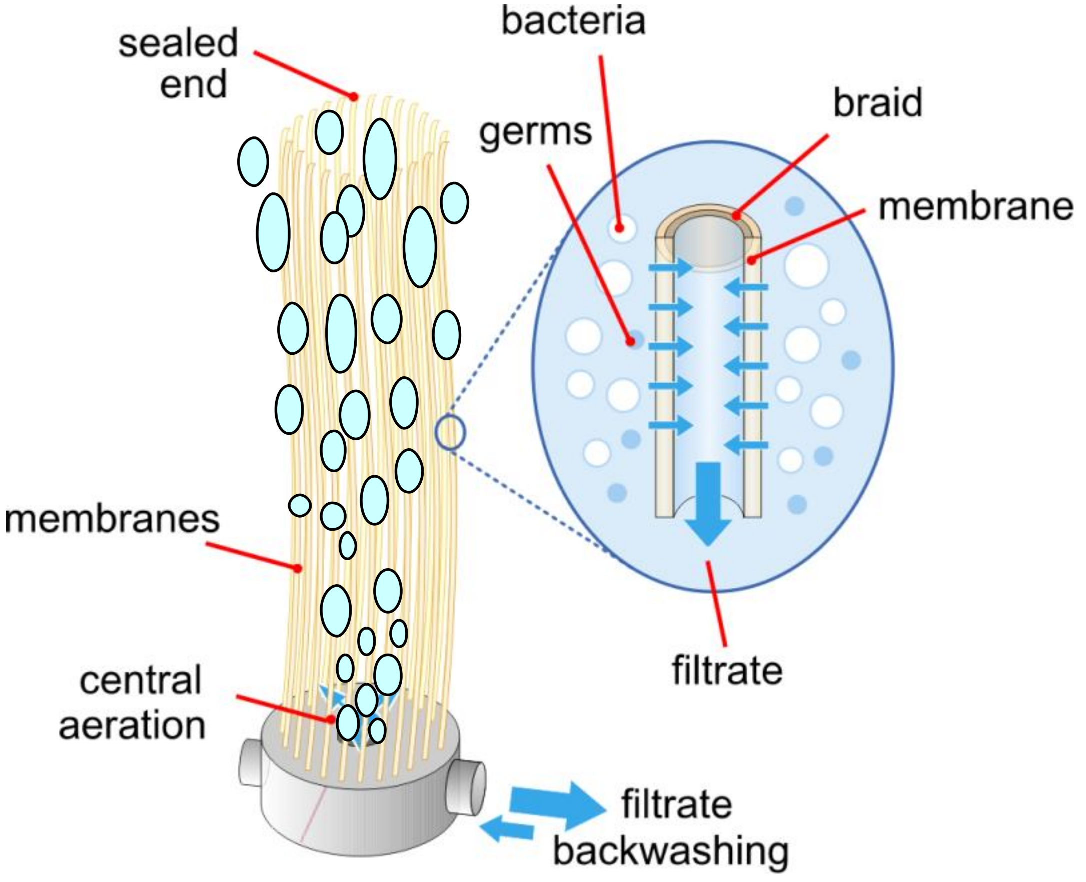
How to Optimize the Membrane Aeration?

Design aspects:

- Membrane module design
- Plant design

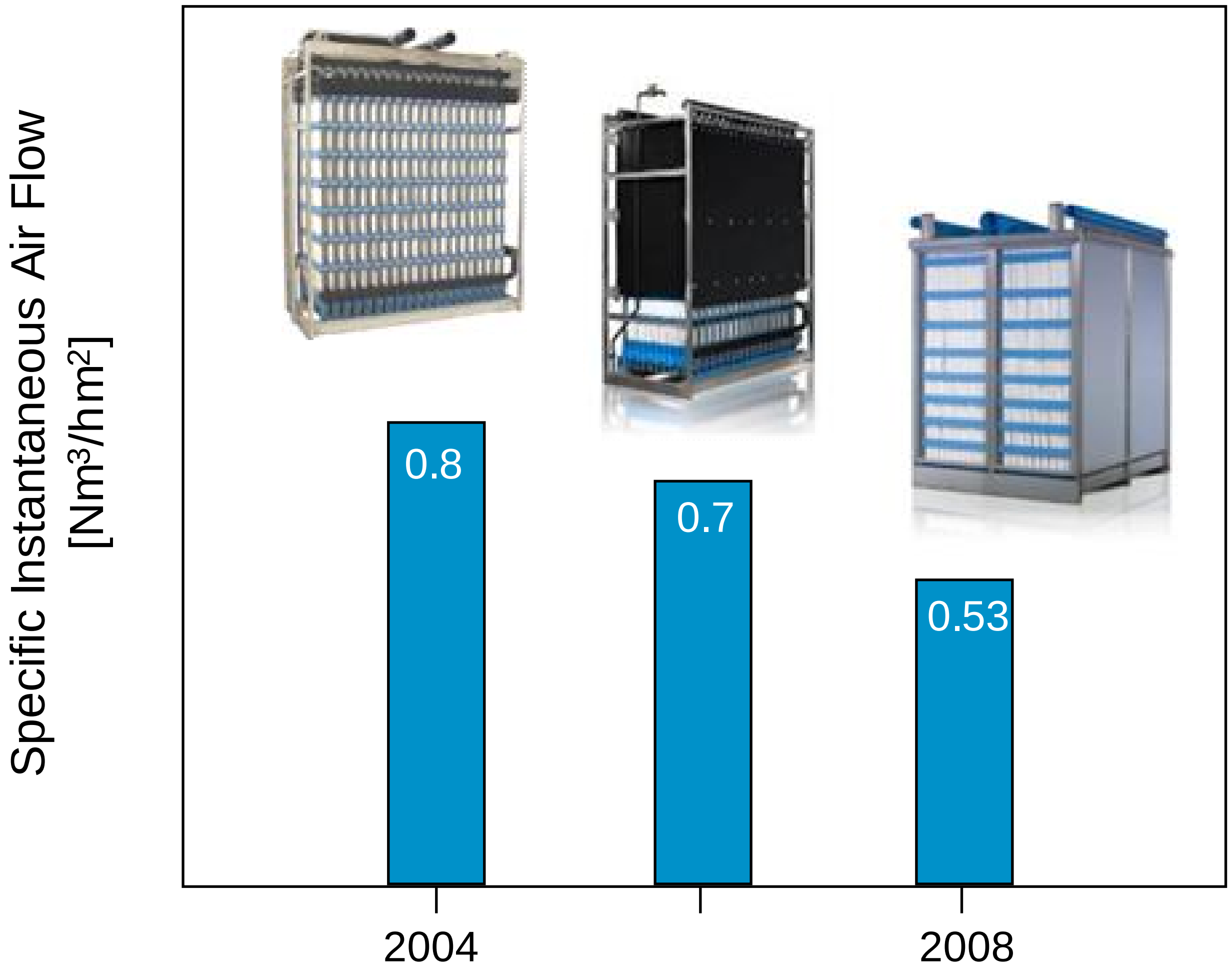
→ **Both aspects have to be optimized**

PURON® Air Scour Concept

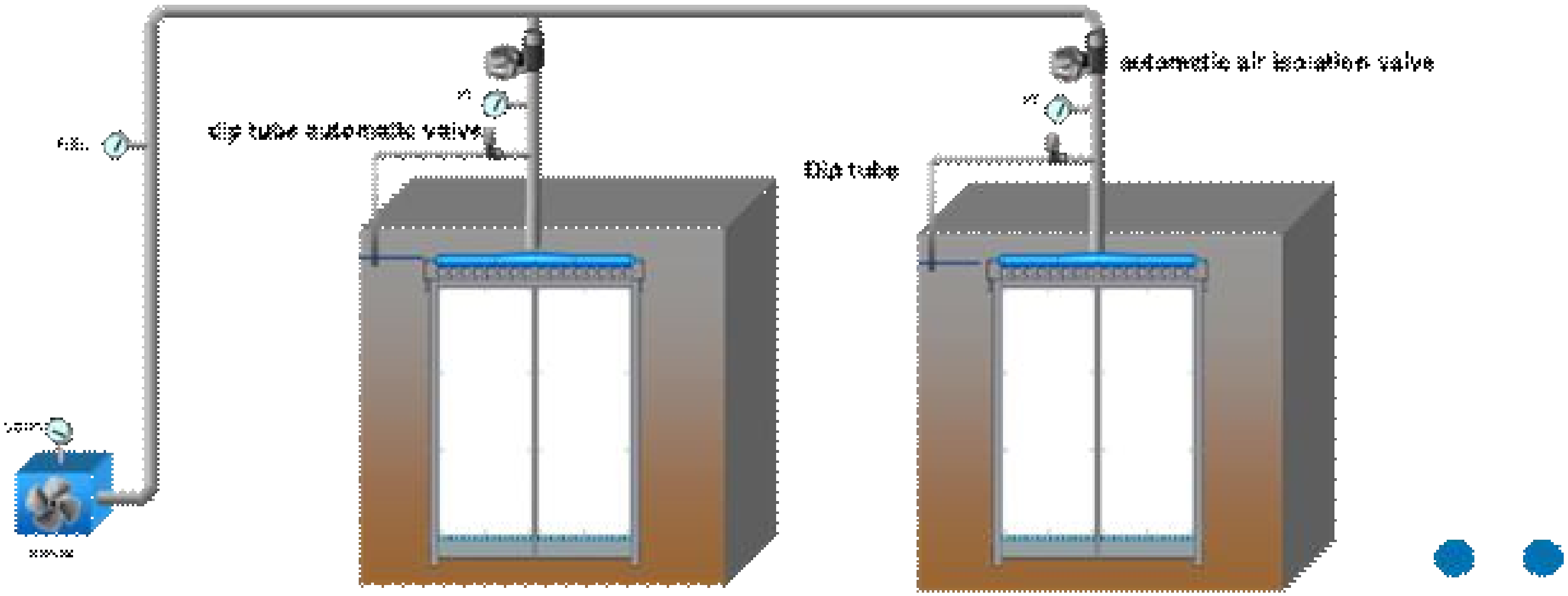


Membrane Bundle

Specific Instantaneous Air Flow

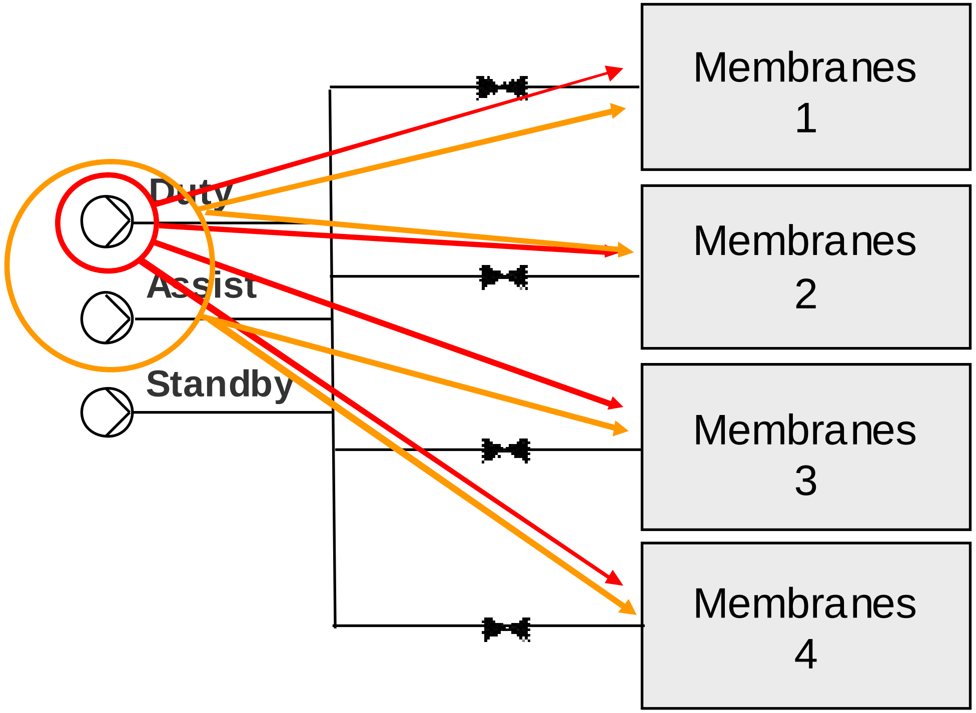


General Operation Modes
Membrane Module Aeration



2 Trains: 50 % Aeration
3 Trains: 33 % Aeration
4 Trains: 25 % Aeration
at average flow treatment

4 Train System
Alternating Membrane Aeration



- At average hydraulic capacity, only 1 blower is operated
- Air is switched alternating between the four filtration lines
- Only at peak hydraulic capacity, 2 blowers are operated parallel
- Air is switched alternating between 2 x 2 filtration lines
- Air supply is realized depending on hydraulic capacity

25 % Aeration management during average flow conditions for a 4 train membrane filtration systems

Advantages of Intermittent Air Scour

Specific aeration rate	0.53 Nm^3/m^2h
Specific aeration rate (@ 50 % aeration)	0.27 Nm^3/m^2h
Specific aeration rate (@ 25 % aeration)	0.14 Nm^3/m^2h
Aeration pressure for operation	300 mbar
Overall energy consumption	0.15 – 0.09 kWh/m^3

→ Highly energy efficient
Intermittent aeration management

Example Project (4 trains): Total Energy Consumption of Membrane Filtration

Energy consumed by:

- Sludge circulation => 0,025 kWh/m³
- Permeate & Backwash pumps => 0,046 kWh/m³
- Membrane aeration => 0,128 kWh/m³

→ **Total Membrane filtration:**
≤ 0,20 kWh/m³ treated effluent

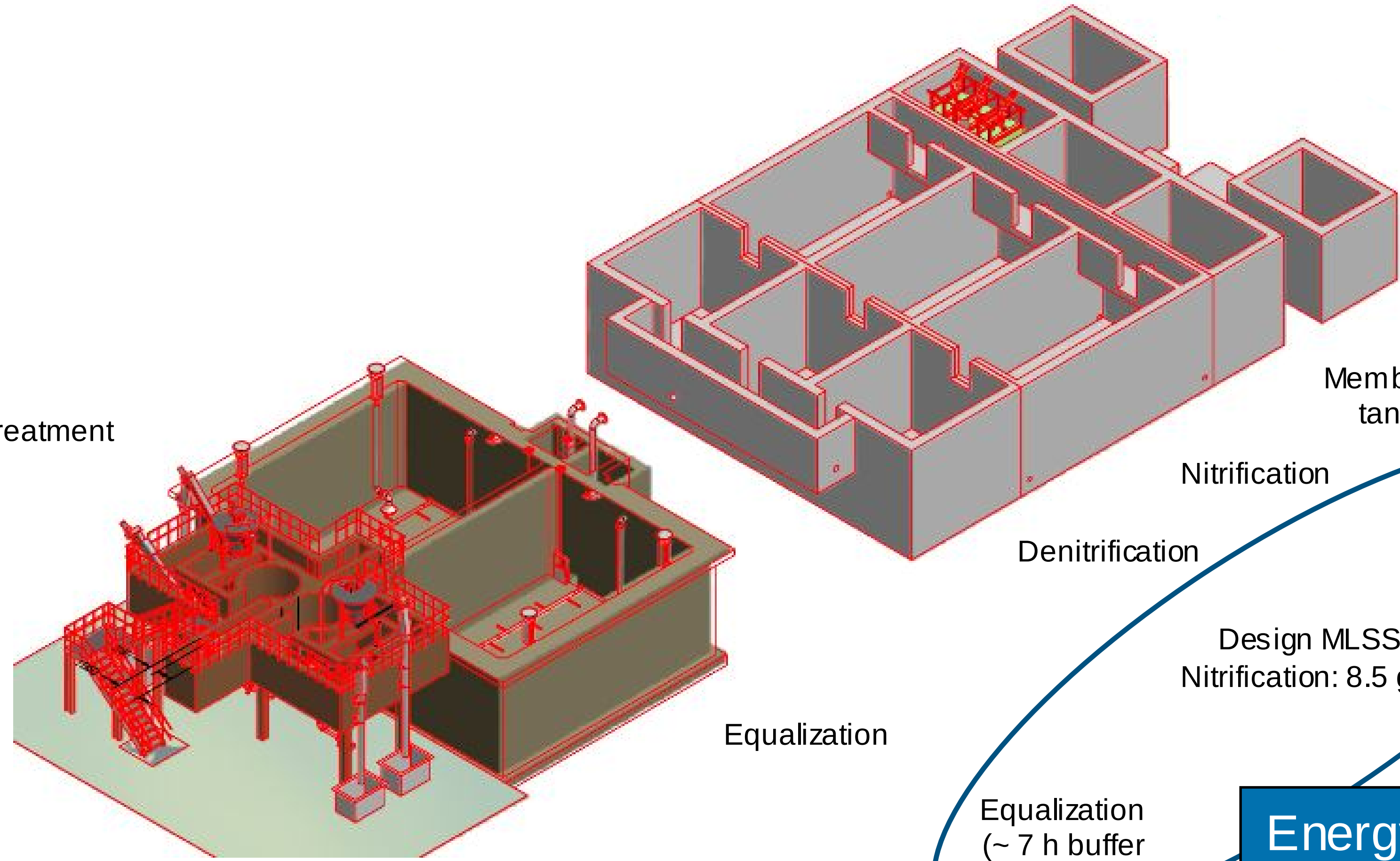
Rabigh Design Basis

Basis of Design			
Parameter	Flow	Temperature	Notes
Average Annual Flow (AAF)	1,500 m^3/day	15 °C	365 Days
Average Design Flow (ADF)	1,950 m^3/day	15 °C	365 Days with 3 Trains
Peak Day Flow (PDF) **	1,950 m^3/day	15 °C	365 Days with 3 Trains
Peak Hourly Flow (PHF) **	82 m^3/hr	15 °C	Corresponds to 1,950 m^3/day

Parameter	Influent	Effluent Limits
BOD	225 mg/L	< 10 mg/L
TSS	225 mg/L	< 5 mg/L
TKN	45 mg/L	< 3 mg/L
NH_3	25 mg/L	< 1 mg/L
NO_3	N/A	< 10 mg/L
Alkalinity	250 mg/L *	< 75 mg/L *
Maximum Wastewater Temperature	35 °C	
Elevation	30 m *	

MBR plant realized by:
Parkson ME in cooperation with Al-Busaili

Rabigh Layout



Multiple train layout

Design MLSS
Nitrification: 8.5 g/L

Equalization
(~ 7 h buffer capacity)

Energy efficiency

Rabigh Layout

Start of commissioning:
December 2010

Adaptation of biology
Increase of influent flows

Summary

- Minimize membrane area to optimize power consumption
- Effective management of solids
- Flexible membrane operation
- Effective air scour device
- Multiple trains allow intermittent air scour
- Bioreactor operation

Questions & Comments

Thank you

for your attention!