



Membrane Bioreactors for Industrial Applications



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1. Introduction (Saudi Vision 2030 and Toray)
2. Flat Sheet MBR Membrane module
3. History of MBR
4. Case Studies in Industrial Applications
5. Consideration for Industrial Applications in future

1. Introduction



**Signing of Shareholders' Agreement on February 19, 2014 in Tokyo
in the presence of
Saudi Arabia's King Salman bin Abdulaziz Al Saud
and
Japanese Prime Minister Shinzo Abe**

Toray's Activities toward Saudi Vision 2030

1. Local Production



Toray Membrane Middle East LLC (TMME) in Dammam, started production of RO Membrane Elements in June 2015

3. Saudization



RO Membrane Elements made in Saudi Arabia,
made by Saudi Arabian

2. Exporting of High Quality Products



Exporting High Quality RO Membrane Elements to MENA Region

4. Supplying Water in Saudi Arabia



Many of desalination plants in Saudi Arabia started water production by using TMME RO Membrane Elements.

Toray Group Business Overview

As a Japanese leading chemical company founded in 1926, Toray group has been globally expanding variety of businesses, including Environmental Engineering.

- Founded: **April, 1926, Shiga, Japan**
- Operation: **23 countries** (sales offices & production plants)
- Employee: **42,584** (as of March, 2013)
- Net Sales: **1,589 billion JPY** (Fiscal Year Ended Mar 31, 2013)



**Fibers, Textiles
& Apparel**

**Plastics &
Chemicals**

65%

*Foundation
Business*

IT-Related Products

**Carbon Fibers Composite
Materials**

19%

*Strategically Expanding
Business*

Environment Engineering

< Water Treatment Division >

Life Science, Others

16%

*Strategically Developing
Business*

Membrane Design Concepts

- Advanced PVDF Membrane for a good operation of MBR

Requirements

1. Chemical and physical durability
2. High water permeability and high permeate quality
3. Prevention from clogging

Design Concepts

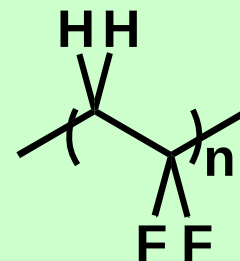


1. Material

- *PVDF (poly (vinylidene fluoride))*
 - > good chemical resistance and high mechanical strength

2. Pore

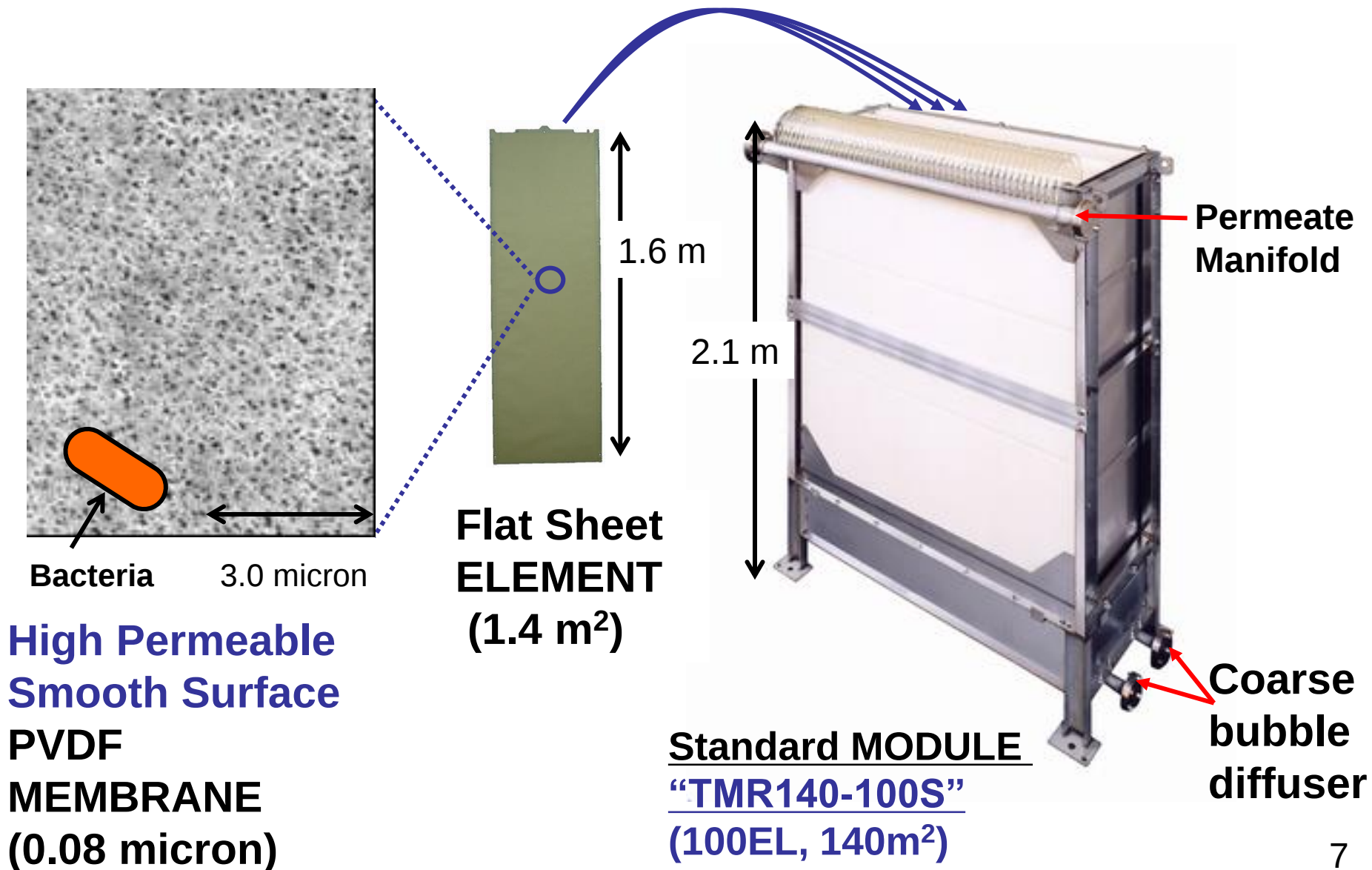
- *Numerous number*
 - > high filterability
- *Small size and narrow distribution*
 - > prevent from pore clogging



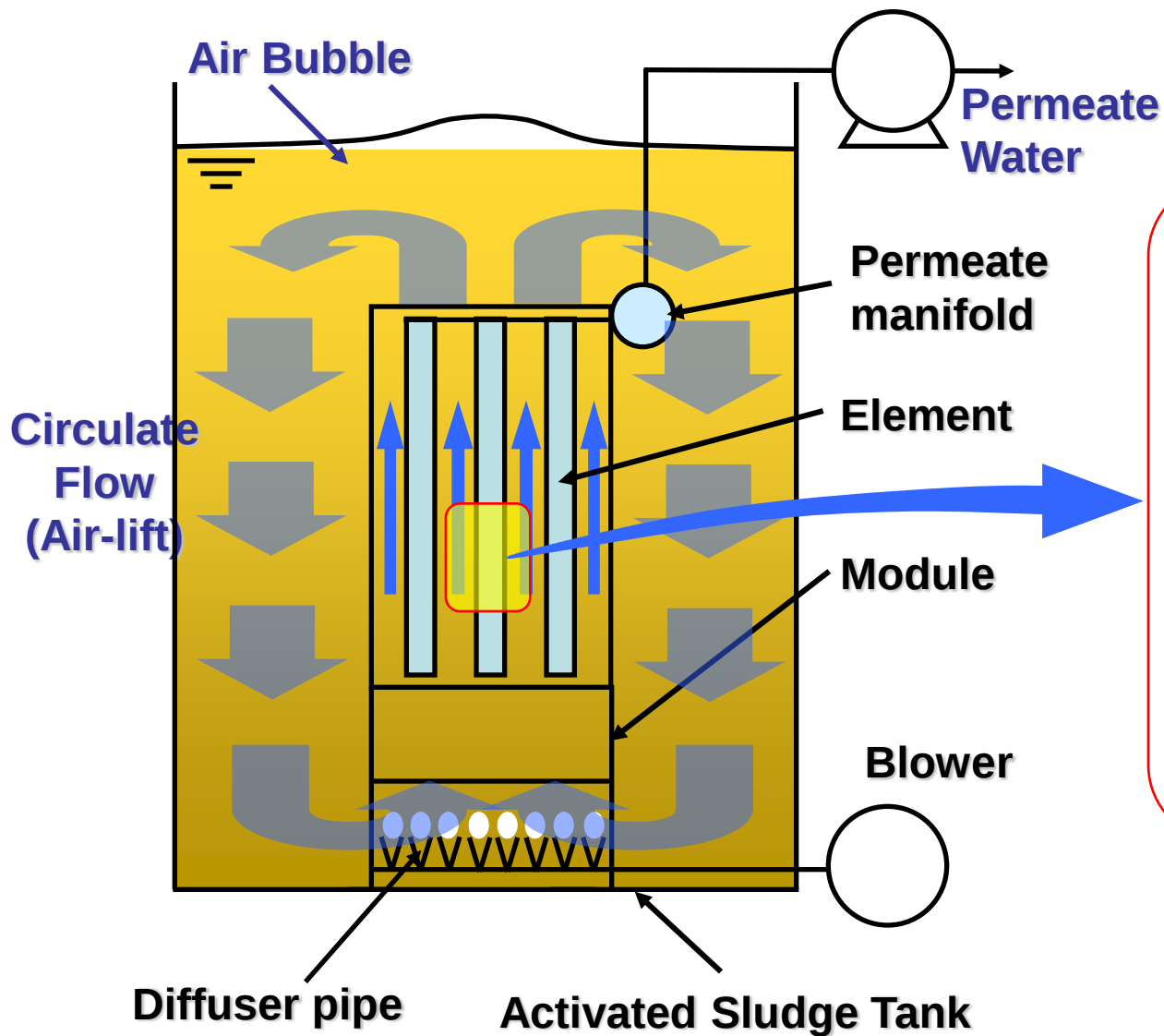
3. Surface morphology

- *Smooth surface*
 - > prevent from the sludge accumulation onto the membrane surface

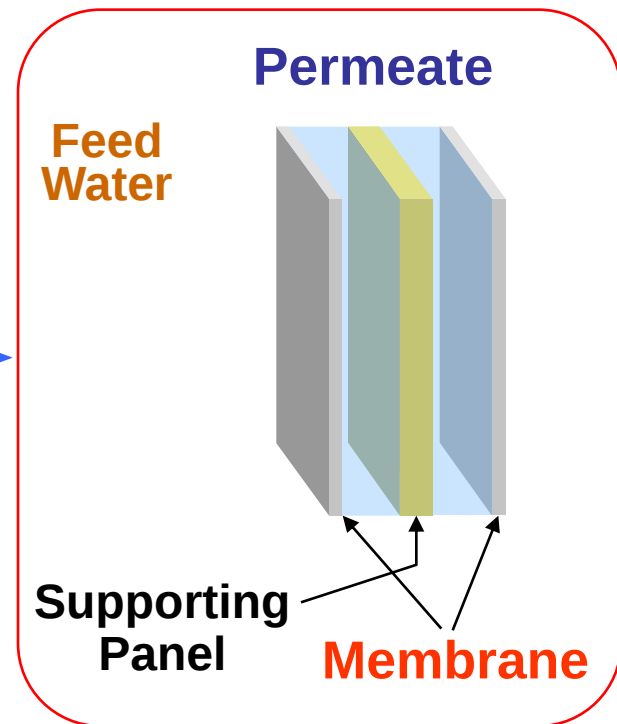
Toray's Submerged Membrane Module "MEMBRAY"



How submerged membrane module works



Filtration Image



- Air Bubble
- Activated Sludge

- AQUA RENAISSANCE '90
 - 1986-1990, Japan
 - 20 private companies and AIST National Labs.
 - MBR, Anaerobic reactor, Membranes evaluation
- Sewage Applications
 - 1995-2000: R&D in Europe
 - 1995 First sewage application in Japan
- MBR Boom
 - 2005-2010: Europe
 - 2005-2010: Middle East
 - 2010- : China
- Lessons Learned
 - Sewage: Limited new installation (Energy consumption / Cost / Treated Water Quality)
 - Successful Industrial Applications

Recent Findings

Category	Sub-category	Elementary attribute	CAS Sub-category or Elementary attribute score	Category score	MBR Sub-category or Elementary attribute score	Category score
TECHNICAL ASPECTS	Reliability Flexibility / Modularity Complexity		1.67 (GREEN)	1.54 (GREEN)	1.67 (GREEN)	1.41 (GREEN)
			1.75 (GREEN)		1.75 (GREEN)	
			1.20 (YELLOW)		0.80 (YELLOW)	
ADMINISTRATIVE ASPECTS - NORMATIVE CONSTRAINTS		Complexity of the authorization/administrative process	2.00 (GREEN)	2.00 (GREEN)	2.00 (GREEN)	2.00 (GREEN)
SOCIAL ASPECTS		Economic Impact	2.00 (GREEN)	0.67 (YELLOW)	1.00 (YELLOW)	1.00 (YELLOW)
		Effluent quality	0.00 (RED)		1.00 (YELLOW)	
		Odour emissions	0.00 (RED)		0.00 (RED)	
		Skyline modification	0.00 (RED)		1.00 (YELLOW)	
		Soil consumption	0.00 (RED)		1.00 (YELLOW)	
		Others	2.00 (GREEN)		2.00 (GREEN)	
ECONOMIC ASPECTS		Total cost under the most favourable conditions	2.00 (GREEN)	2.00 (GREEN)	0.00 (RED)	0.50 (RED)
		Total cost under the worst conditions	2.00 (GREEN)		1.00 (YELLOW)	
ENVIRONMENTAL ASPECTS		Global warming potential	2.00 (GREEN)	1.67 (GREEN)	2.00 (GREEN)	1.67 (GREEN)
		Acidification potential	2.00 (GREEN)		2.00 (GREEN)	
		Eutrophication, fresh water	2.00 (GREEN)		0.00 (RED)	
		Eutrophication, marine	1.00 (YELLOW)		2.00 (GREEN)	
		Eutrophication, terrestrial	2.00 (GREEN)		2.00 (GREEN)	
		Photochemical oxidant formation potential	1.00 (YELLOW)		2.00 (GREEN)	
Final score			1.58		1.32	

Table 2. Results of the techno-economic-environmental assessment of the CAS and MBR plants: scores are obtained by attributing the same weight (1) to all categories. Scores range from 0 (worst ranking) to 2 (best ranking) (Bertanza et al, 2017)

➤ Food

- Cake
- Ice Cream
- Olive Oil
- Milk Processing
- Dairy
- Protein
- Potato
- Vinegar

➤ Meat Processing

- Beef
- Chicken
- Fish
- Squid

➤ Beverage

- Juice
- Cola

➤ Chemical

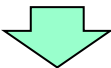
- Chemical factory (PTA, DMSO, etc)
- Cosmetic
- Dyeing, Textile
- Electronics
- Liquid Crystal
- Paper Mill
- Petrochemical
- Pharmaceutical
- Photo Film

➤ Others

- Automotive
- Landfill Leachate
- Laundry
- Marine

Applications Consideration

	SS	Oil	Inorganic Ion	Toxic Substances	Salinity	High BOD	Nutrient balance
Food	Seed, Coat	Cake, Dairy	Ca				
Meat Processing	Bone, Pelage, Fish scale,	Fish oil become solidified					
Beverage	Coat						
Alcohol Drinks	Chaff						
Chemical	Fiber, polymer, dispersed material, polyvinyl - alcohol	Mineral Oil	Si, Mn, Ca	Disinfecti on agent			
Marine	Toilet Paper			HCHO			



To be removed by Pretreatment



**Special attention required.
(Tolerance limit, separate treatment, anaerobic treatment, etc.)**



To be added

Guidelines on MBR Operation

Substance		Guideline on biological treatment	Guideline on membrane module
Oil	Biodegradable		<50mg/L at MBR inlet
	Non-Biodegradable	<~10mg/L	Trace (zero)
Alkali , Acid		5<pH<9, No rapid pH change	
Salts		<1% No rapid conc. change	Cl >100mg/L: SS316L is recommended for anti-corrosion
Organic solvent, Toxic Substances	Biodegradable	Acclimated	
	Non-Biodegradable	Within the range not toxic to microorganisms.	Within the range not harmful to materials (ABS, EPDM rubber, membrane, SS)
Inorganic Ion (Ca, Si, Mn etc)			
Anti-foam	Alcohol based		
	Silicone based		Prohibited
Coagulant	Al, Fe		
	Cationic high-polymer coagulant		Inject and agitate well prior to MBR tank

4. Industrial Applications

4-1 Chemical Factory

4-2 Liquid Crystal Factory

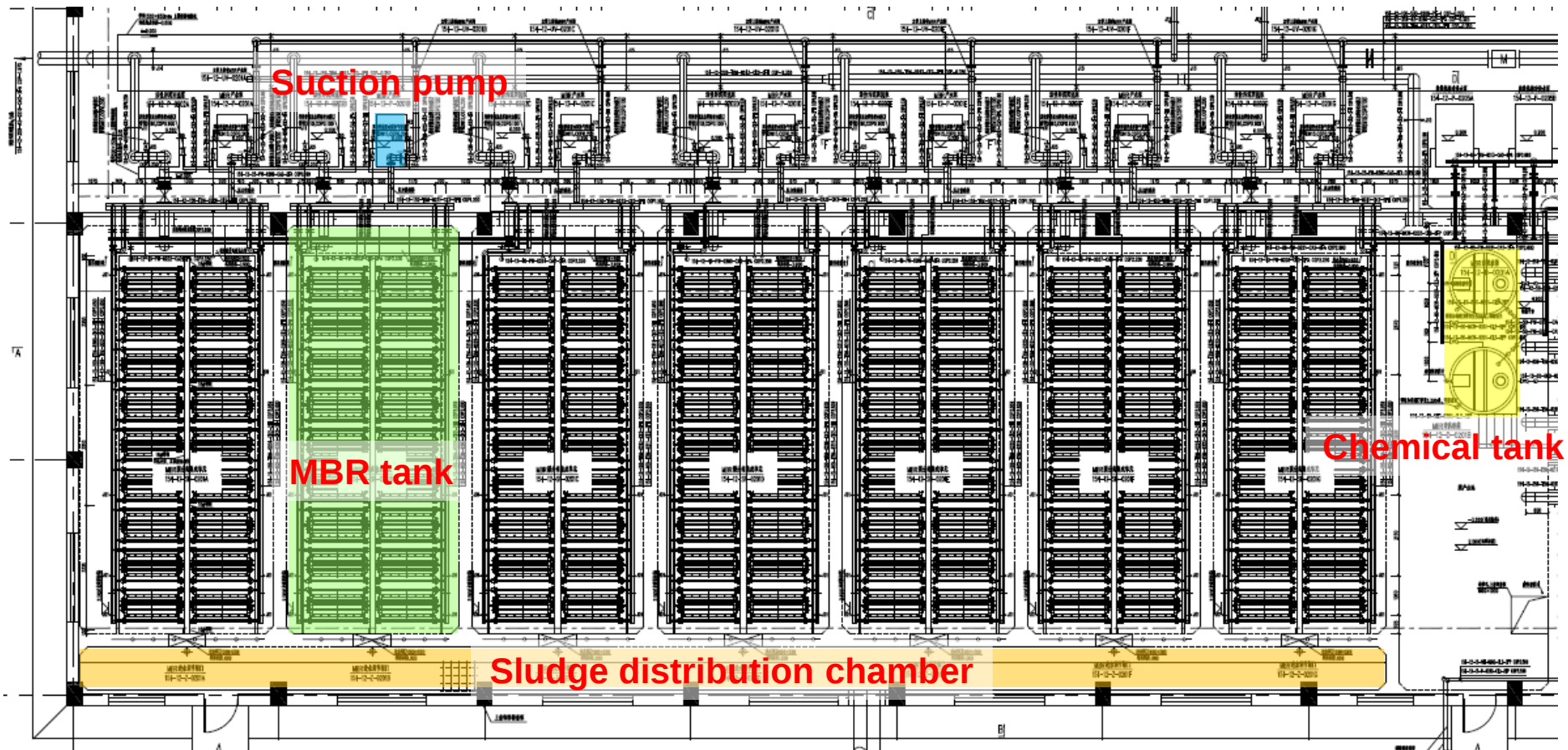
4-3 Food Processing Factory

4-4 Edible Oil Factory

4-1 Chemical Factory in China

Place of Installation:	Northern China
Application:	MBR Coal Chemical Factory WW
Design Capacity:	9840 m³/day (“N-1 design” adopted)
Installed Modules:	126 x TMR140-200D
In operation since:	June 2013
Remark:	Pilot test was conducted to assess the applicability of MBR

4-1 Chemical Factory in China - Layout



4-1 Chemical Factory in China - MBR Tank



- MBR tanks (7 tanks) in a building: protection from cold weather

- Pump room



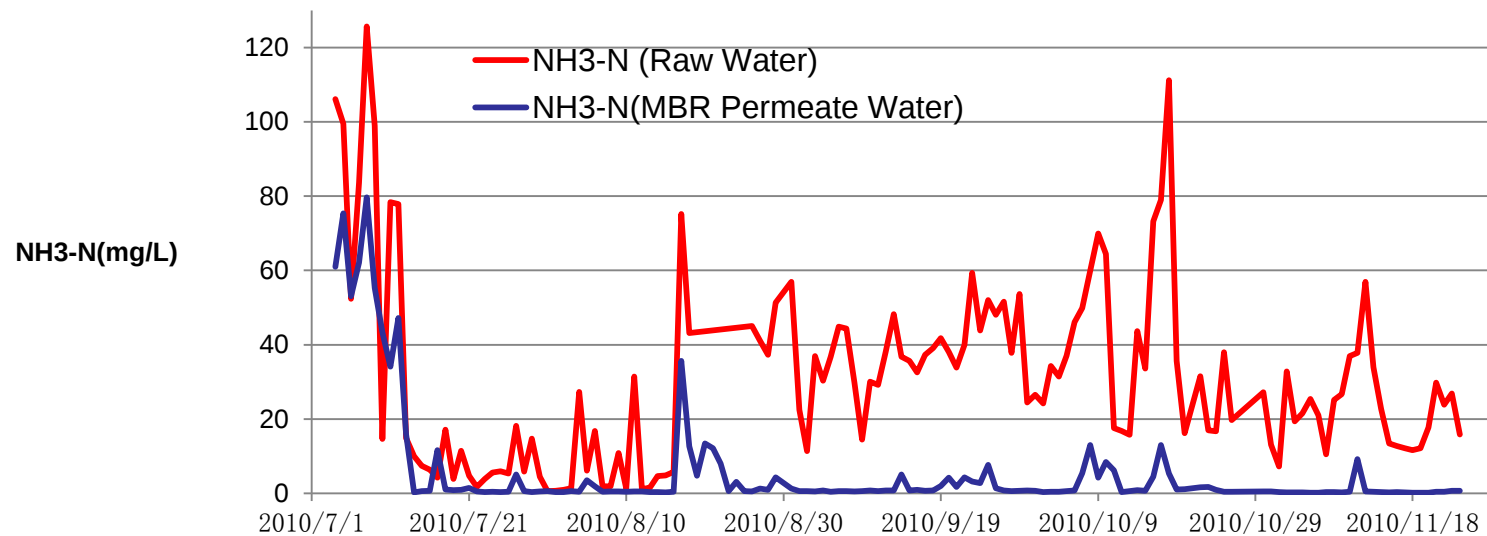
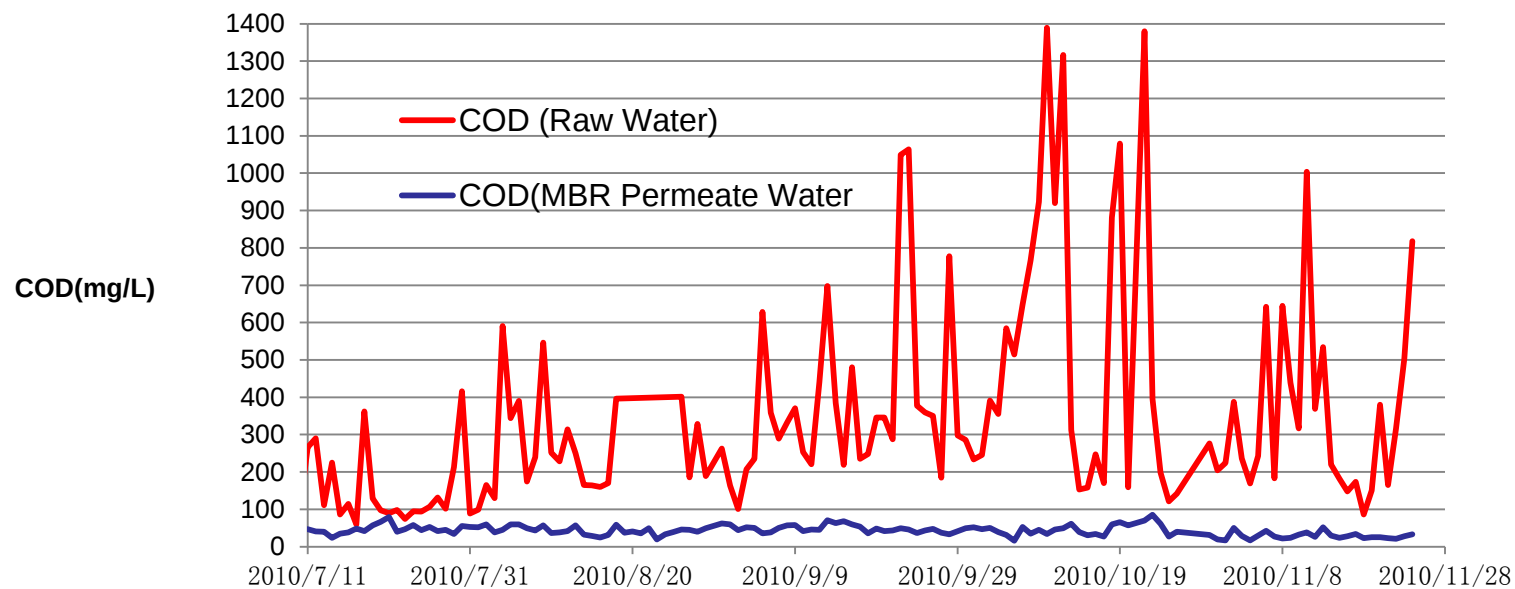
4-1 Chemical Factory in China - MBR Tank



- Combined permeate header (upper & lower)
- Auto diffuser cleaning & guide rail system installed



4-1 Chemical Factory in China - COD and NH3-N



5 months pilot study

	1 st month (July)	5 th month (November)
Treated Water COD	46 mg/L	29 mg/L
Treated Water NH ₄ ⁺ -N	20 mg/L	< 1 mg/L

Activated Sludge was well acclimatized in 5 months.

Place of Installation: China

Application: MBR Liquid Crystal Factory WW

Design Capacity: 11000 m³/day
(Phase I 6500 / II 4500)

Installed Modules: 100 x TMR140-200W
(Phase I 60 / II 40)

In operation since: November 2008 (I)
March 2012 (II)

4-2 Liquid Crystal Factory

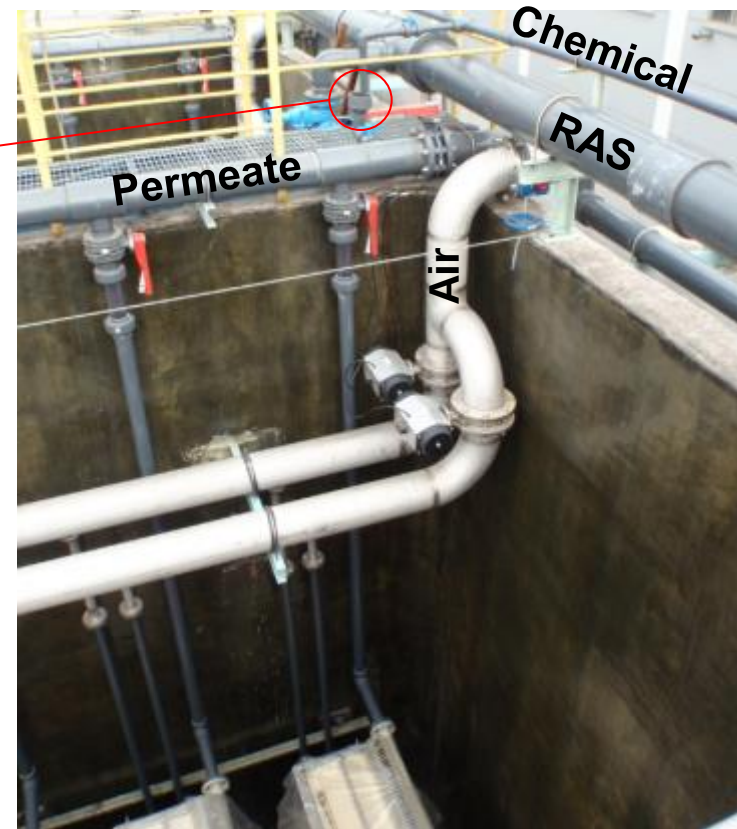


- Chemical pre-treatment (coagulation/precipitation/neutralization)
- High salinity WW – SS316L membrane module equipped with plastic manifold & diffuser

4-2 Liquid Crystal Factory – MBR Tank



End of air header



- 10 trains of 10 x TMR140-200W
- Common air diffuser cleaning
- Separated chemical piping for injection height control

- COD in Raw Water: 1,750 to 2,296 mg/L
- COD in MBR Treated Water: < 90 mg/L

4-3 Food Processing Factory

Place of Installation:	Peru
Application:	MBR Food Processing WW
Design Capacity:	850 m³/day
Installed Modules:	18 x TMR140-100S
In operation since:	October 2011
Remark:	Wastewater from livestock and seafood processing factory and restaurant

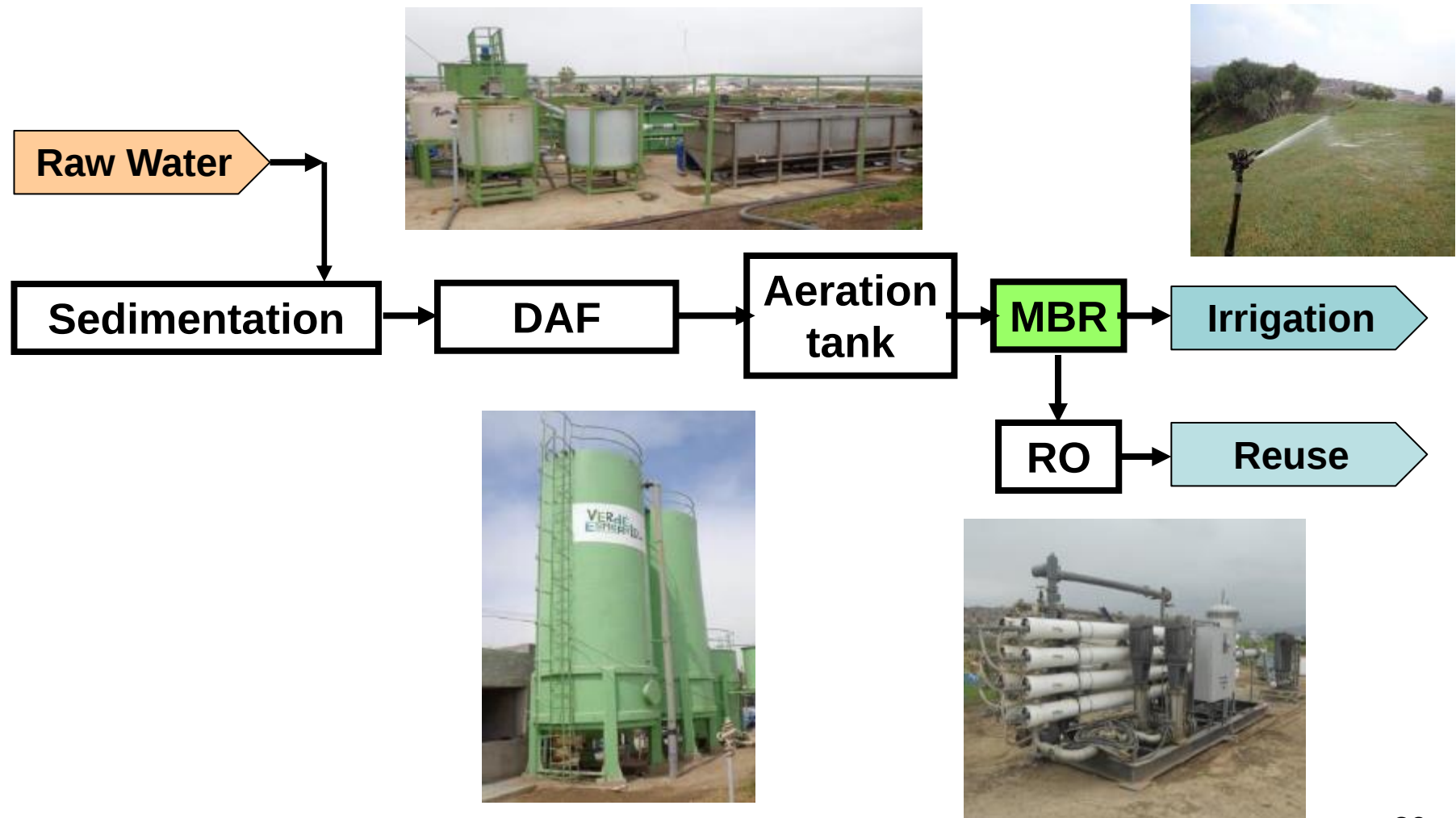
4-3 Food Processing Factory



MBR tanks



4-3 Food Processing Factory – Process Flow Scheme



4-3 Food Processing Factory – MBR Tank



Treated water tank

- 3 MBR tanks
- Gravity filtration
- Common air diffuser cleaning



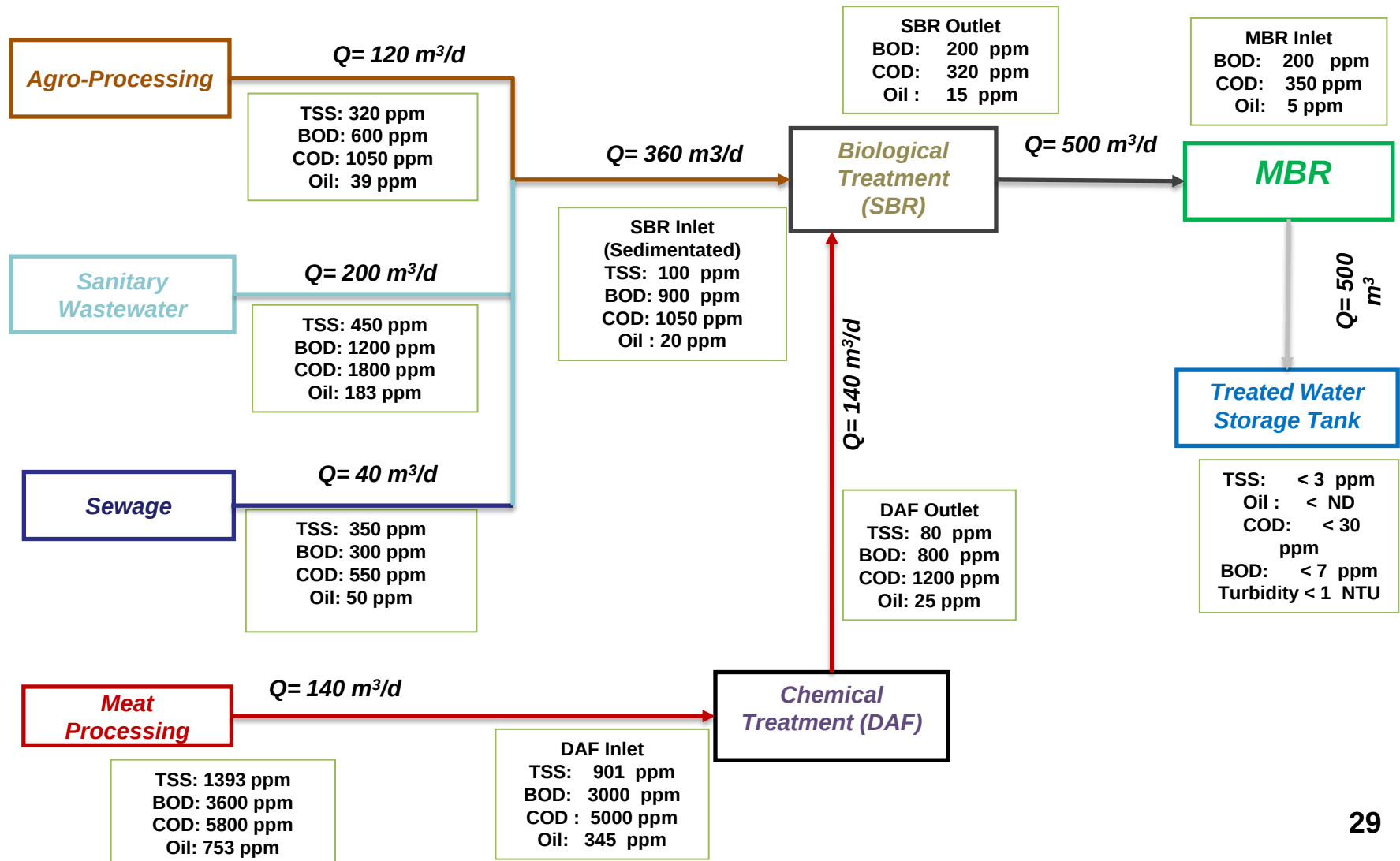
4-3 Food Processing Factory – MBR Treated water for Irrigation



- MBR permeate: Irrigation of neighboring wildlife refuge



4-3 Food Processing Factory – Overall Flow Scheme



4-4 Edible Oil Factory

Place of Installation:	Singapore
Application:	Edible Oil Production Wastewater
Design Capacity:	170 m³/day
Installed Module:	8 x TMR090-100S
In operation since:	July, 2014
Remarks:	Treated water for Cooling Water (Mixed with NEWater)

4-4 Edible Oil Factory Plant Overview



- **Process Flow: DAF → MBR → UV**
 - Mix with NEWater, and use for cooling tower

4-4 Edible Oil Factory

- Pretreatment (DAF) and Post treatment (UV)



DAF



UV

4-4 Edible Oil Factory – MBR Tank



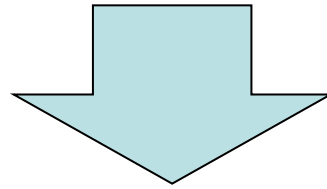
4-4 Edible Oil Factory - Flux Enhancer



MPE50: Nalco's Flux Enhancer

5. MBR's Key Advantage

- Good Water Quality
- Applicable to hard degradable substrate by retention of microorganisms and diversified microbial ecosystem in MBR



- NO downstream coagulation / sedimentation?
- NO Activated Carbon?

5. MBR Key Advantages

- **Very good treated water quality by a long SRT and existence of highly acclimatized microorganisms to treat hard-degradable components in the wastewater.**

Only MBR can do this.

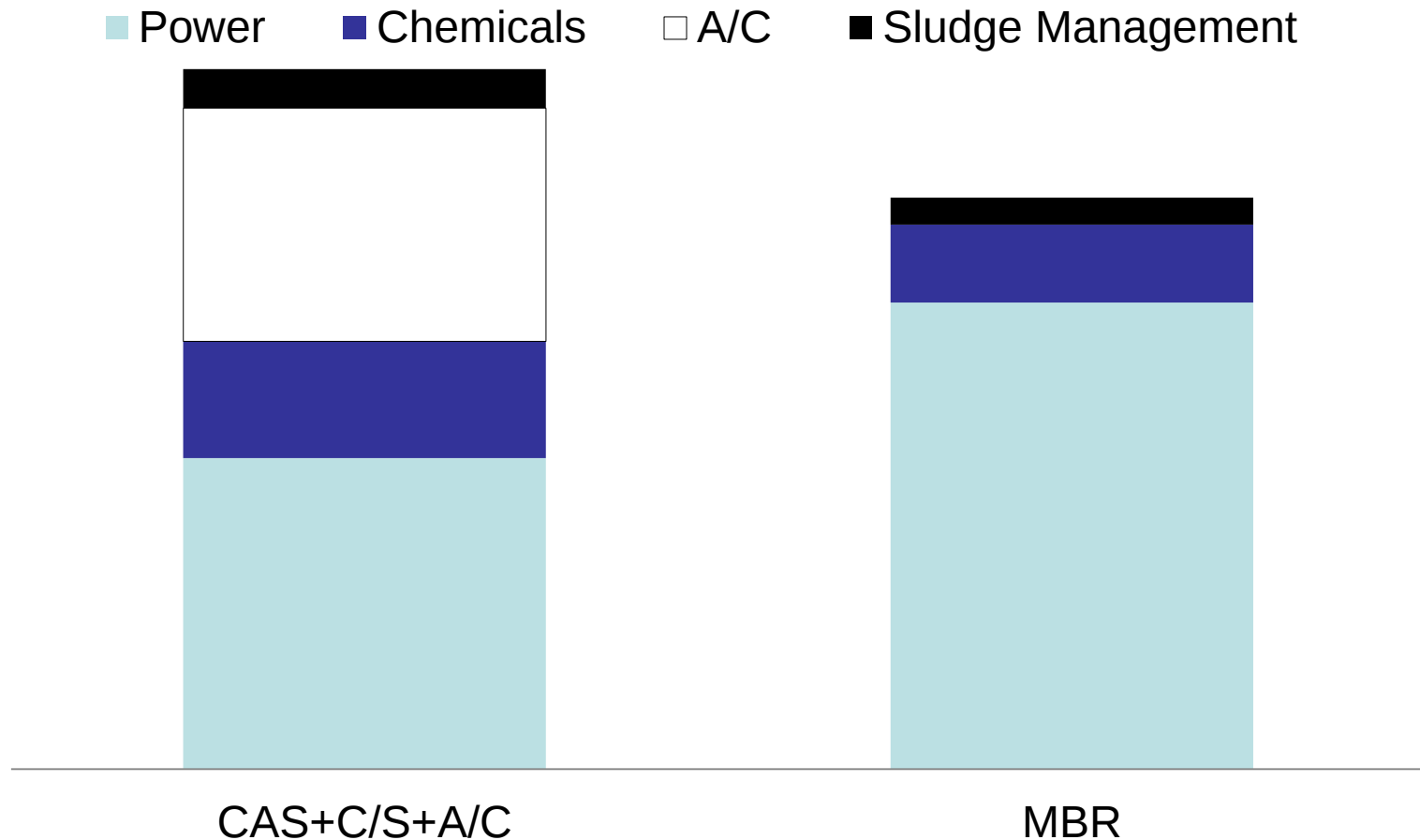
$$D > \mu$$

D: Dilution Rate ($\text{m}^3/\text{m}^3/\text{Day}$)

μ : Specific Growth Rate (g/g/Day)

- **Less excess sludge production due to a long SRT.**

Wastewater Treatment Cost Breakdown (Conceptual)



- Microorganisms which treat hard degradable substrate have very low specific growth rate and yield.
- Substrate inhibition
- Treatability study of each stream and determination of buffer tank size.

Great Potential of MBR for Industrial Application

- Cost Saving
- Less Water Consumption by Reuse: MBR+RO

Sharing MBR Experience with You

- Good Engineering for Collection System
- Consideration on Turn Down / Shut Down
- Pilot Study



Thank you very much.

www.toraywater.com