

Science Council of Japan

Water Symposium

“Sustainable Water Resources Management in Asia”

Feb. 27, 2009

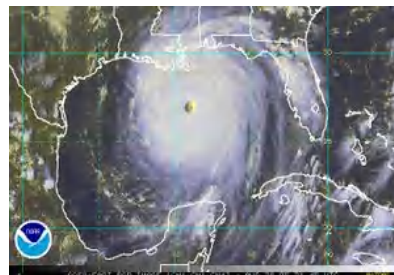
Membrane Technology against Climate Change in the 21st century

Prof. Chung-Hak Lee,

School of Chemical and Biological Engineering,
Seoul National University, KOREA

Global warming

- **Carbon dioxide and other gases:**
 - trapping solar heat in the atmosphere
 - warming the surface of the planet
- **The numerous scientists agree reality of global warming:**
 - **Glaciers are melting,**
 - plants and animals are being forced from their habitat,
 - and the number of **severe storms** and **droughts is increasing.**

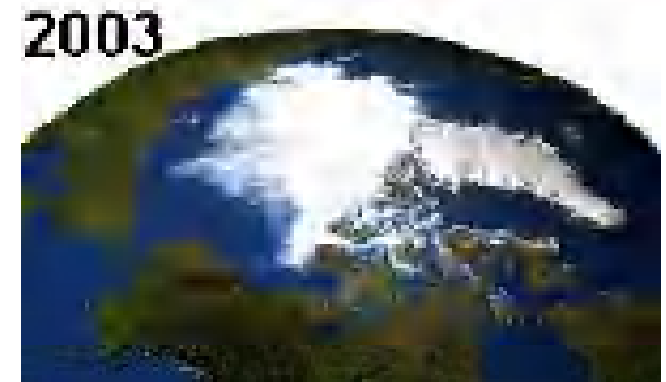


Source: USEPA

The symptoms of climate changes in the Korean Peninsula



The glacier
of the north pole



Since last 100 years,

The average temperature of the earth increased by **0.74 °C**

, whereas the average temperature of the Korean Peninsular increased by **1.5 °C**
(double)

The symptoms of climate changes in the Korean Peninsula



- The sea level around the Jeju island increased **by 22cm** since last 40 years.
- Winter has been shortened **by one month**,
summer has been extended **by 20 days** after 1920s
- Heavy rainfall : 2.8 days per year (an average year; 2.0 day) since last 10 years
- Extreme Heat caused **the death toll of 2,127** death since last 10 years
Malaria caused **2,227 deaths** in the year of 2007

The symptoms of climate changes in the Korean Peninsula

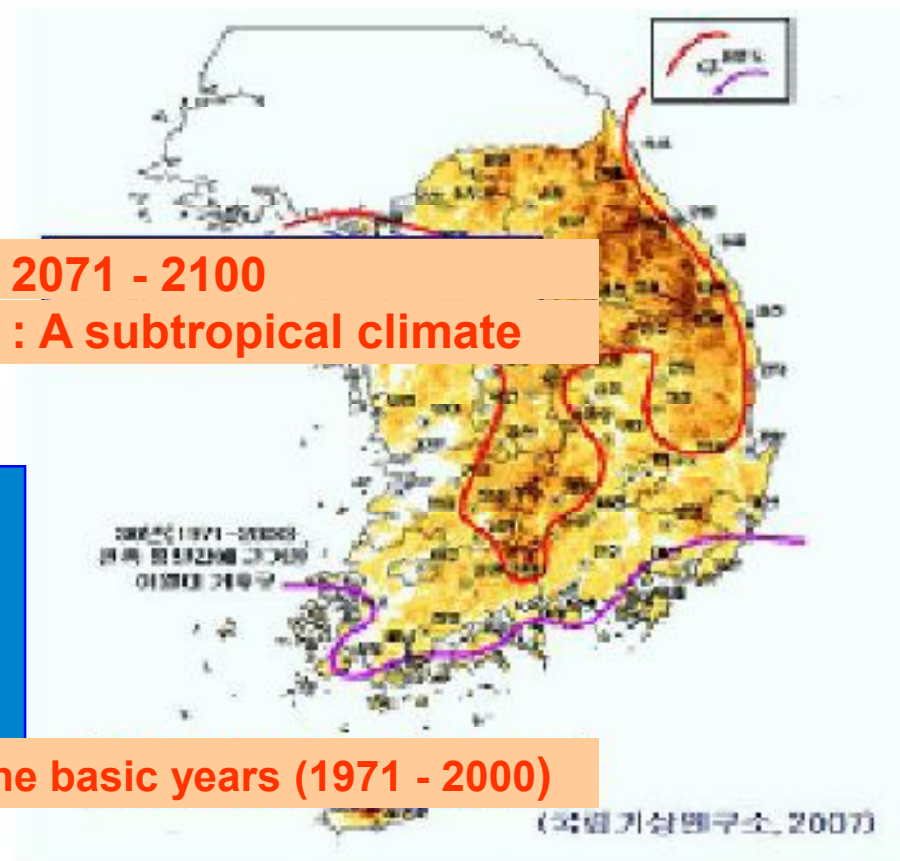
The end of 21st century (the basic years: 1971-2000)
Temperature: 4°C increase, Rainfall: 17% increase

- At the end of 21st century
A subtropical zone
will move northward

- Sea level rising (1m) in 2100
Submersion area: 2,500 km²
→ 2.6 % of Korean population
(1.25 million people)
will difficult in livelihood

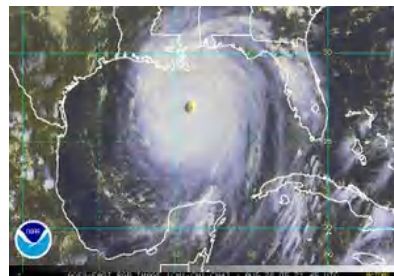
2071 - 2100
: A subtropical climate

The basic years (1971 - 2000)



Global warming

- **Carbon dioxide and other gases:**
 - trapping solar heat in the atmosphere
 - warming the surface of the planet
- **The numerous scientists agree reality of global warming:**
 - **the number of severe storms and droughts is increasing.**



Source: USEPA

National Project: Restoration of 4 Main Rivers

(*Han, Nakdong, Keum, Youngsan Rivers*)



2008

2012

National Project: Restoration of 4 Main Rivers

Objectives:

- i) Flood control,
- ii) Improvement of river water quality,
- iii) Provision for water shortage,
- iv) a relief measure for the unemployed.

Period : 2009~2012 (4 years)

Total Working Expenses : 10 billion \$

* *Annual flood damage*: 2 billion \$

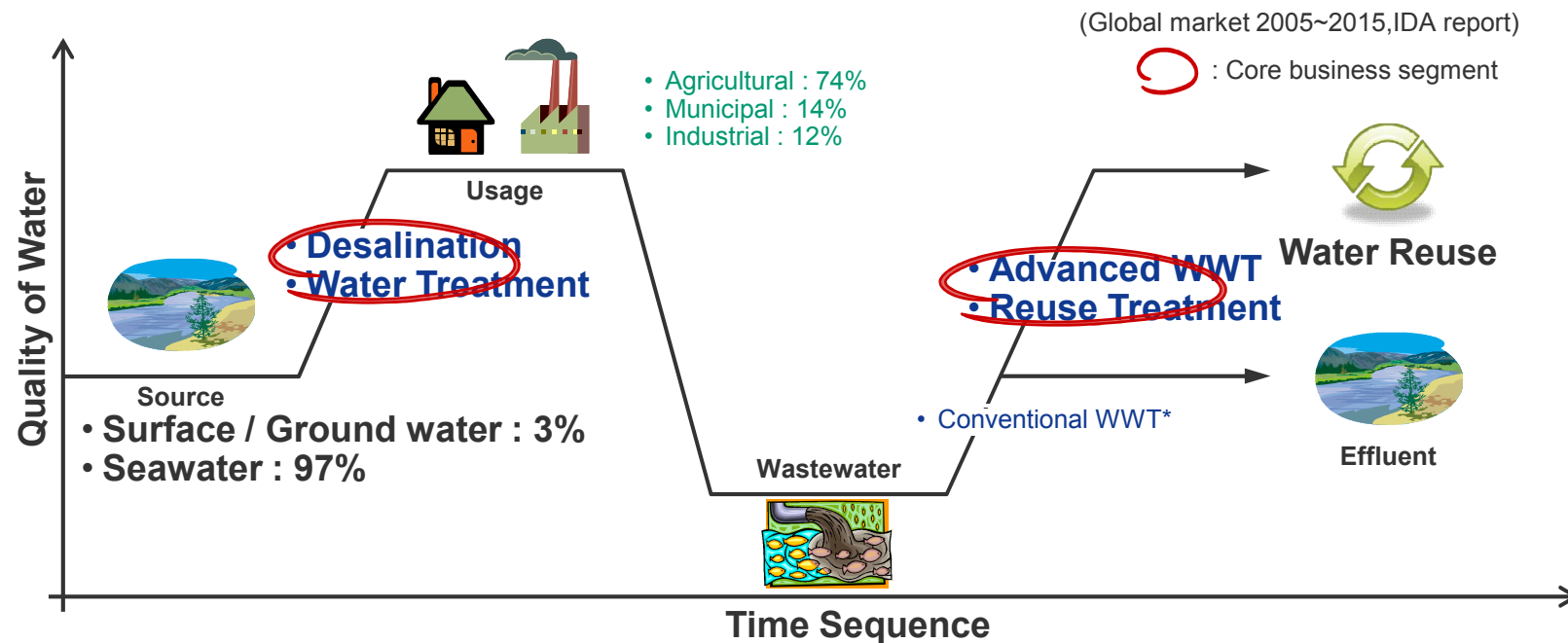


2008



2012

The life cycle of water quality

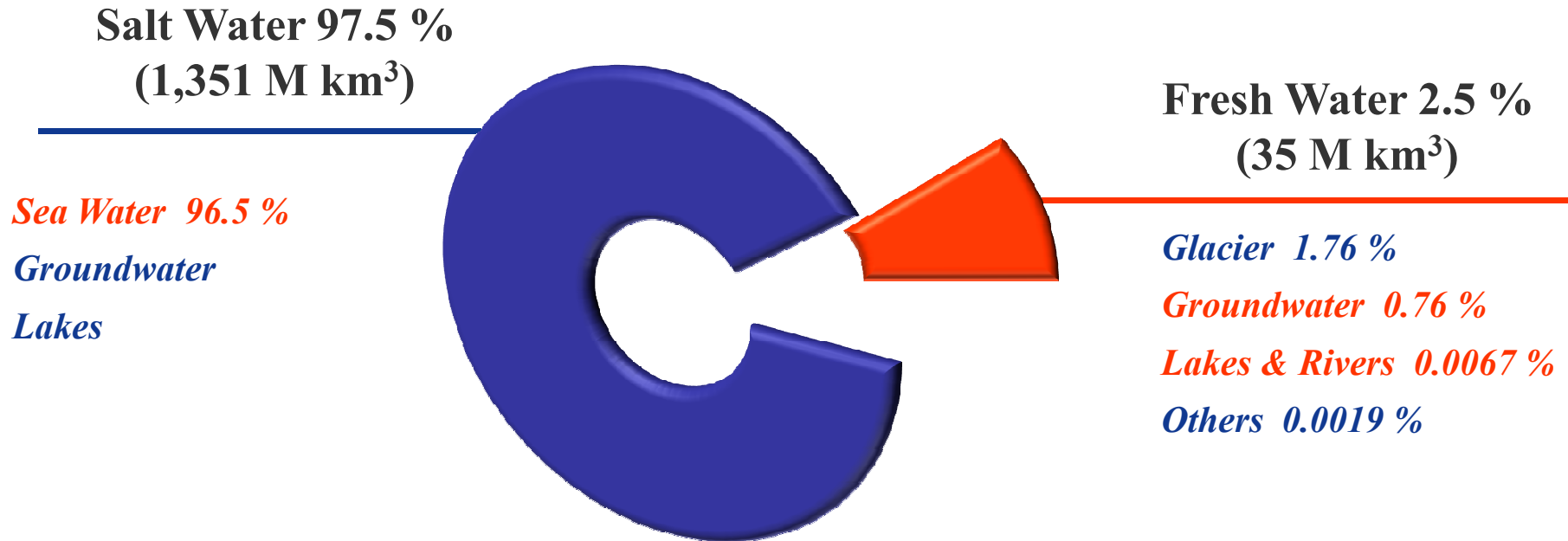


- **Advanced wastewater treatment and reuse & Seawater desalination:**
two of the most sustainable ways to create alternative water source

- **Membrane Technology** : Key for these treatment processes.

**Courtesy of Doosan heavy Industries and construction Co.*

World Water Resources

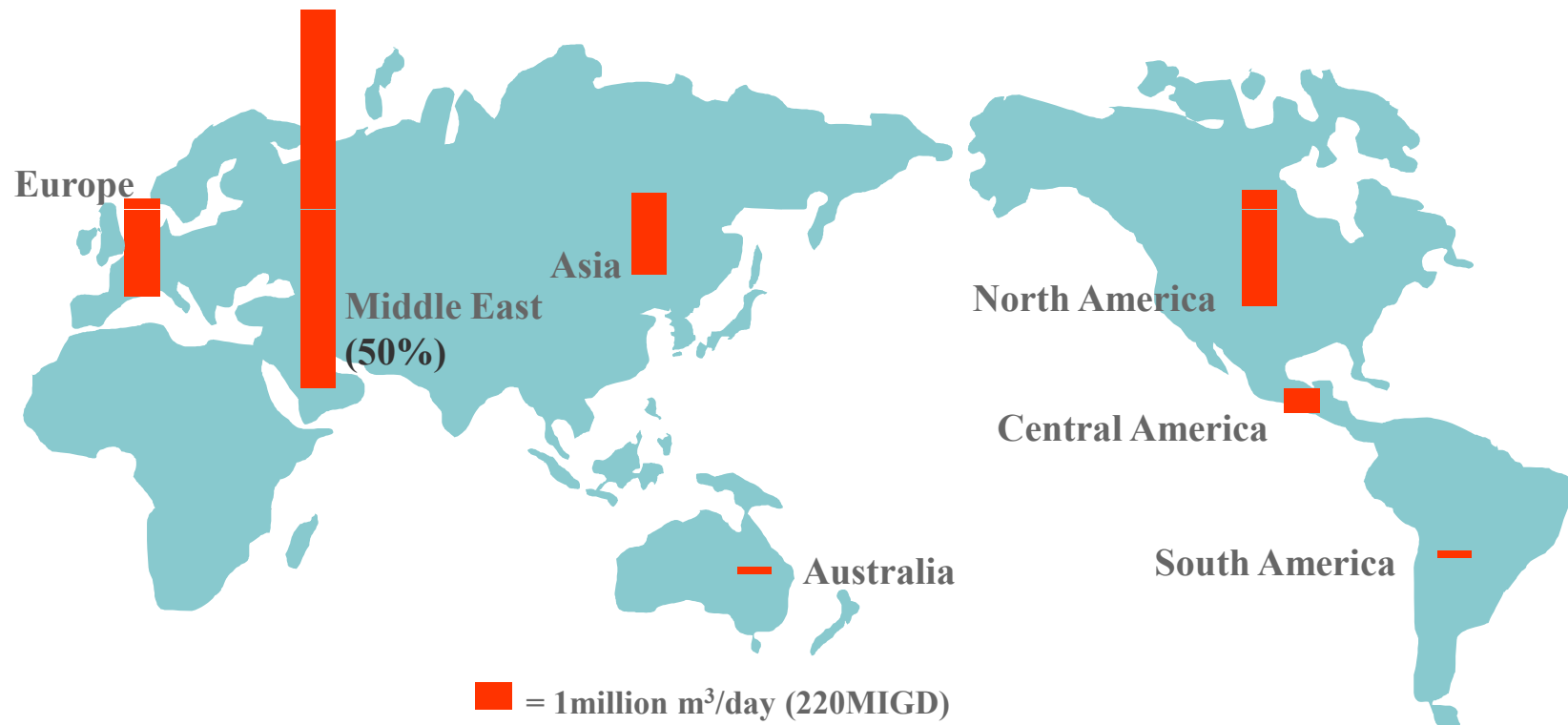


Source : Water in crisis (Gloick, P.H., 1993)

Seawater Desalination is the key to solve water shortage!!

International Market Trends

- ◆ Total capacity of world wide seawater desalination plants : > 30 million tons/day
- ◆ Total market growth rate : ~11%/year (SWRO: ~17%/year)



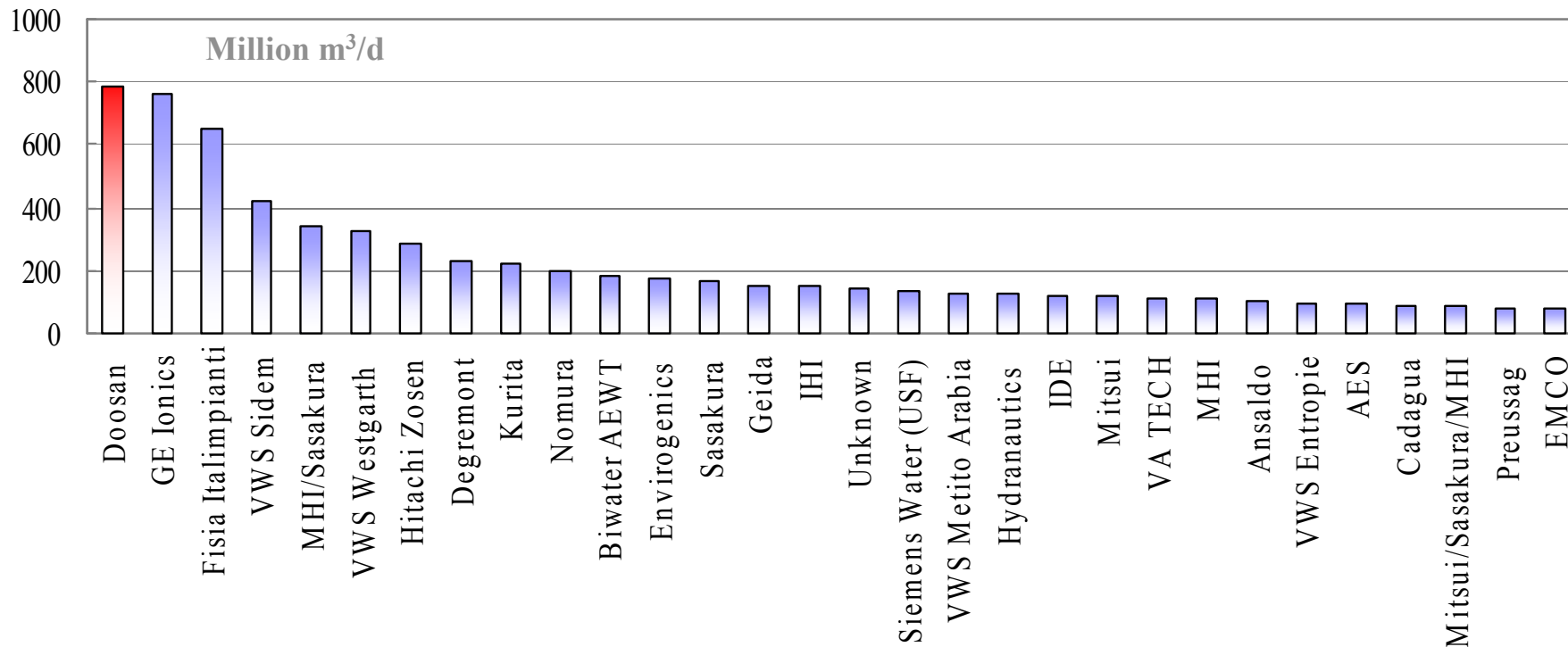
Source: Wangnick (2004)

Market Trends

Technology turning point = NOW

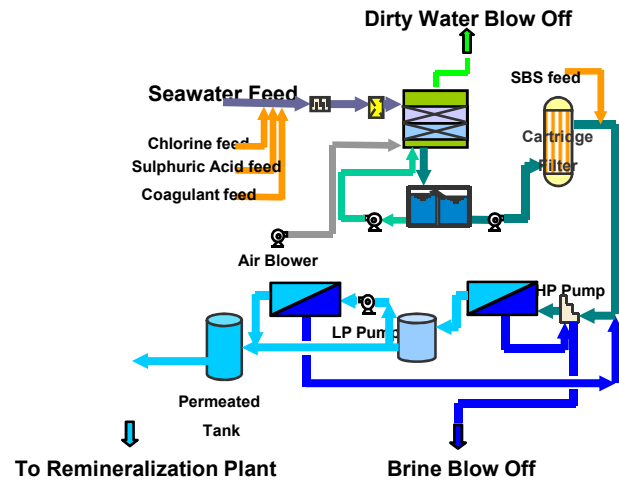
- ◆ Korean Group (**Doosan**) leads MSF (**Multi Stage Flashing**) plant technologies all around the world.
- ◆ But, market needs is being moved to membrane-based desalination.

Market possession capacity (Source: IDA 2001~2005)



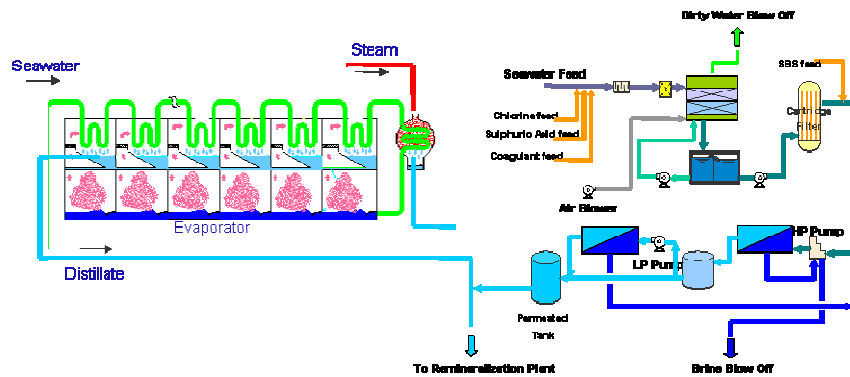
Seawater Desalination Technologies

RO (REVERSE OSMOSIS)



RO building area, UAE

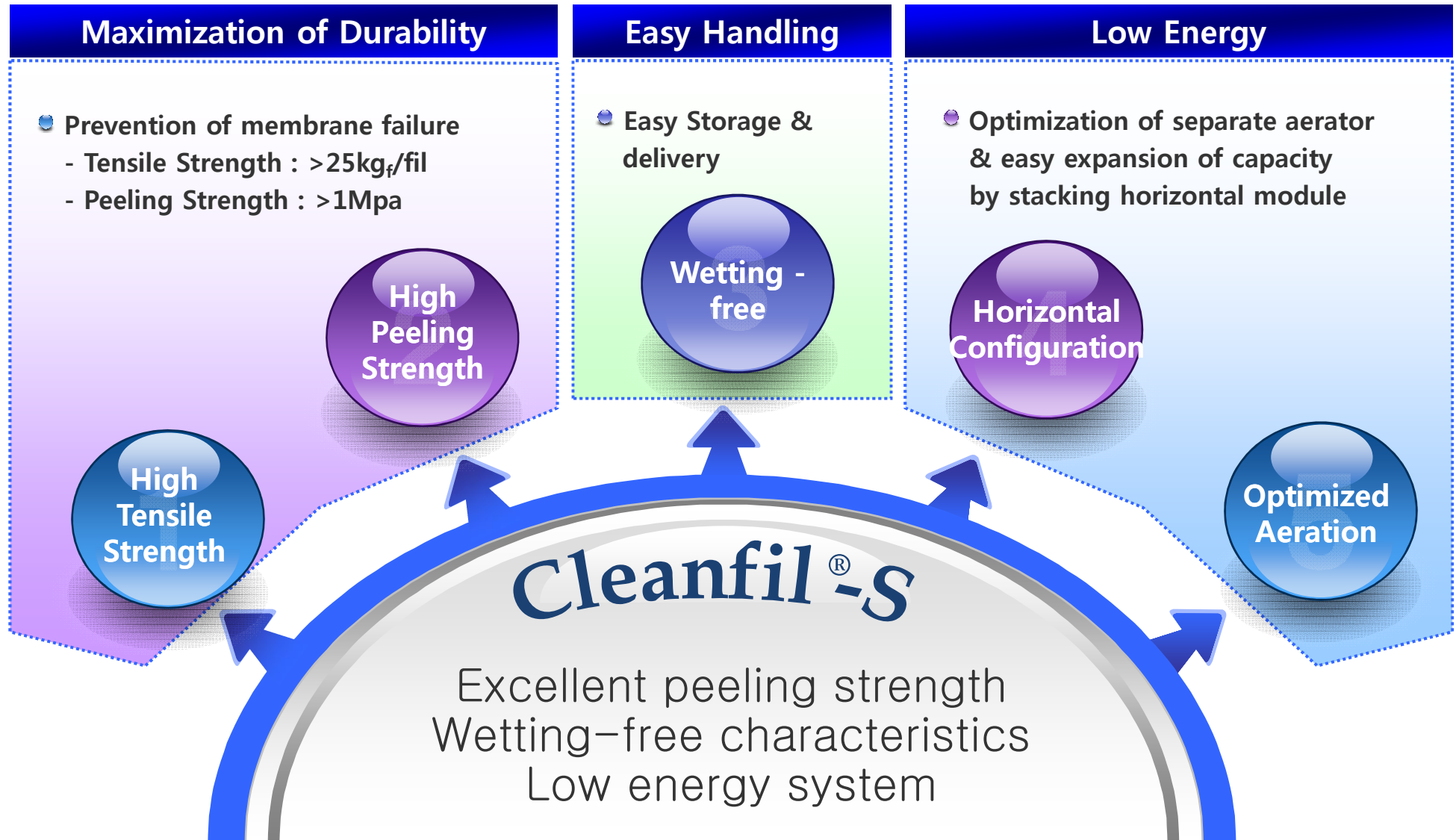
HYBRID (MSF+RO / MED+RO)



Hybrid Desalination & Power Plant, UAE

*Courtesy of Doosan heavy Industries and construction Co.

Membranes for 21st Century



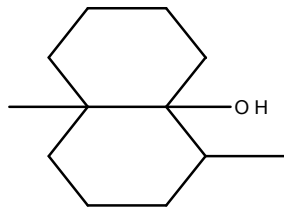
* Courtesy of KOLON Industries, Inc.

Nanofiltration Membrane for multiful purposes

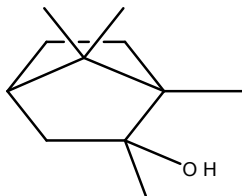
- Removal of natural organic substance & odor organics in municipal water treatment.
- Water softening
- Double pass Sea Water desalination

Odor Organics

Algal metabolites

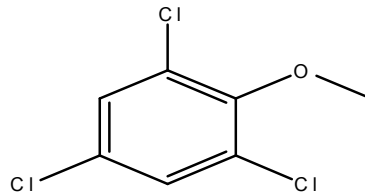


Geosmin (4ng/L)

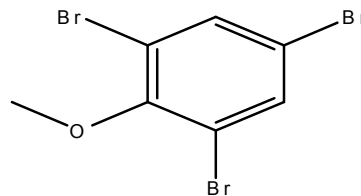


2-Methylisoborneol
(2-MIB) (9ng/L)

Halogenoanisoles

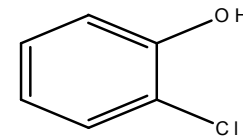


2,4,6-trichloroanisole (80pg/L)

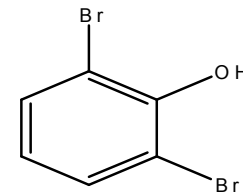


2,4,6-tribromoanisole (20pg/L)

Halogenophenols



2-chlorophenol (88ng/L)



2,6-dibromophenol (16ng/L)

* Courtesy of Woongin Chemical

SeaHERO R&D program

Supported by
Ministry of Land, Transport and Maritime Affairs (MLTM)



** Courtesy of Prof. I.S. Kim at KGIST*

SeaHERO R&D program structure

-13 main and 27 commissioned projects for 4 Core Tech.

-650 research staffs at 25 Univ., 6 Institutes, 28 Industries

CT 1: Development of core technologies for future SWRO plant

CT 2: Localization of SWRO Membrane/Pump Components and Development of Systems Integration Technologies for SWRO Desalination Plant

CT 3: Development of large-scale SWRO Desalination Plant Design and Construction Technology

CT 4: Development of Innovative O&M technology for large-scale SWRO plant

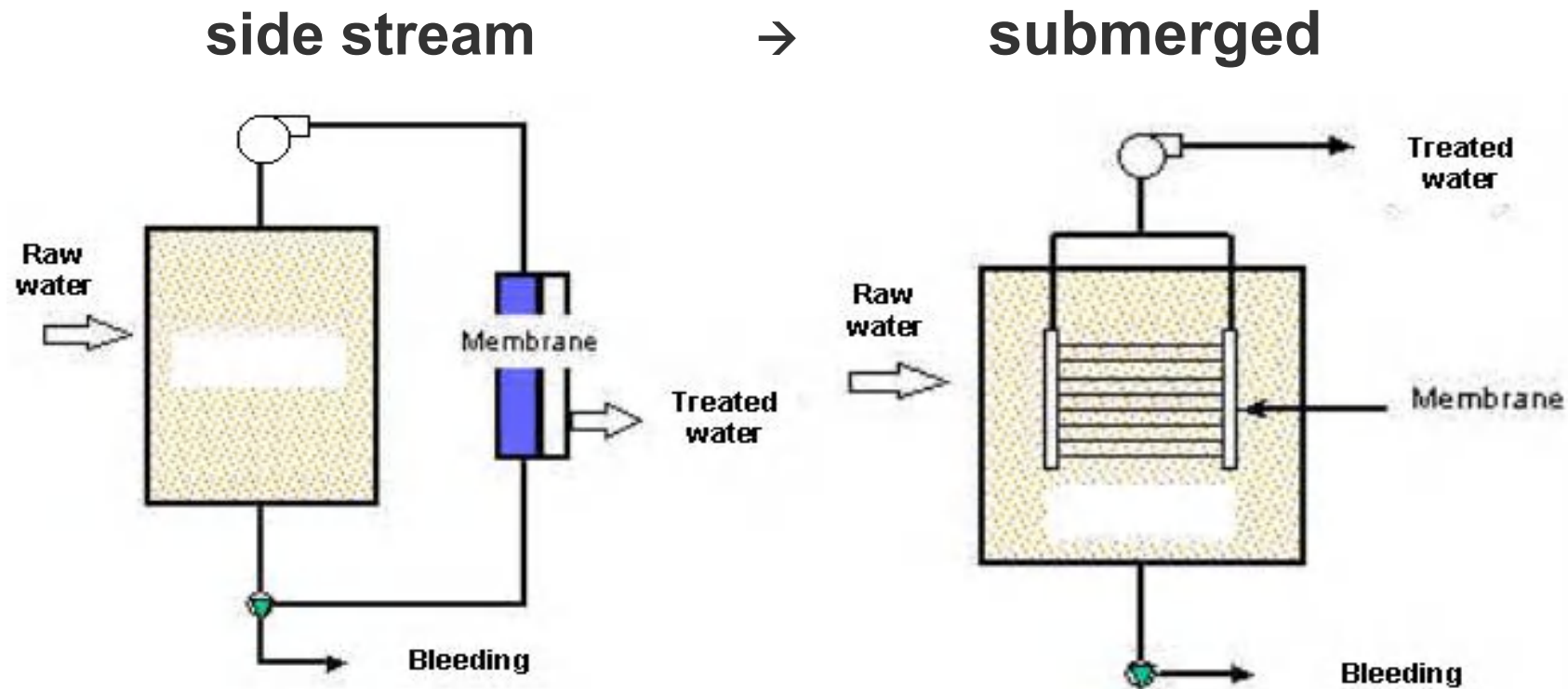
** Courtesy of Prof. I.S. Kim at KGIST*

Membrane Technology for Green Growth

- less energy & chemicals -

- 1. Membrane Operation Mode**
- 2. Less Biofouling: Microscopic Approach**
- 3. Preparation of New Functional Membranes**

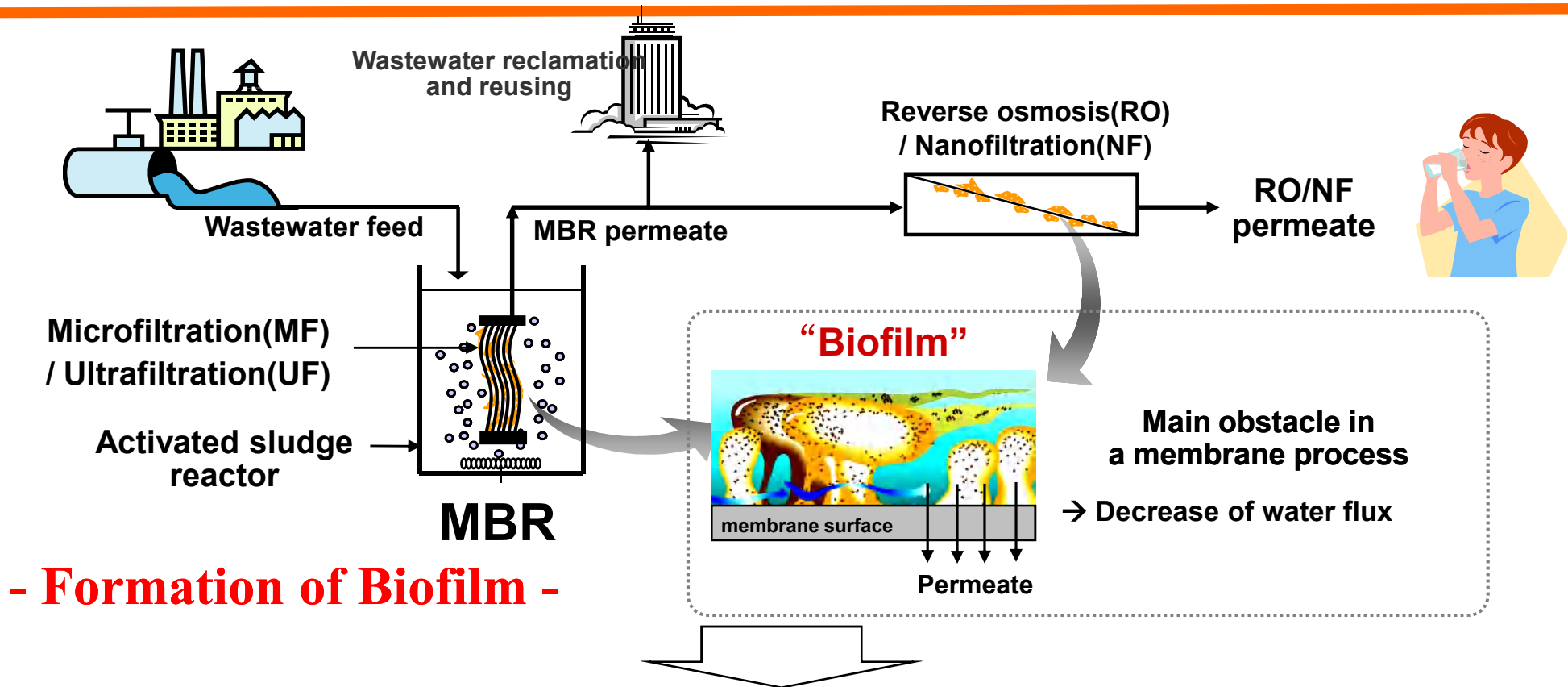
1. Turning Point of Membrane Operation Mode for less energy consumption



Kazuo Yamamoto et al. (1989), *Water Science and Technology*, 21, 43-54

Citation Number (Feb. 2009) : **233**

2. Less Biofouling : from Macroscopic to Microscopic Approach

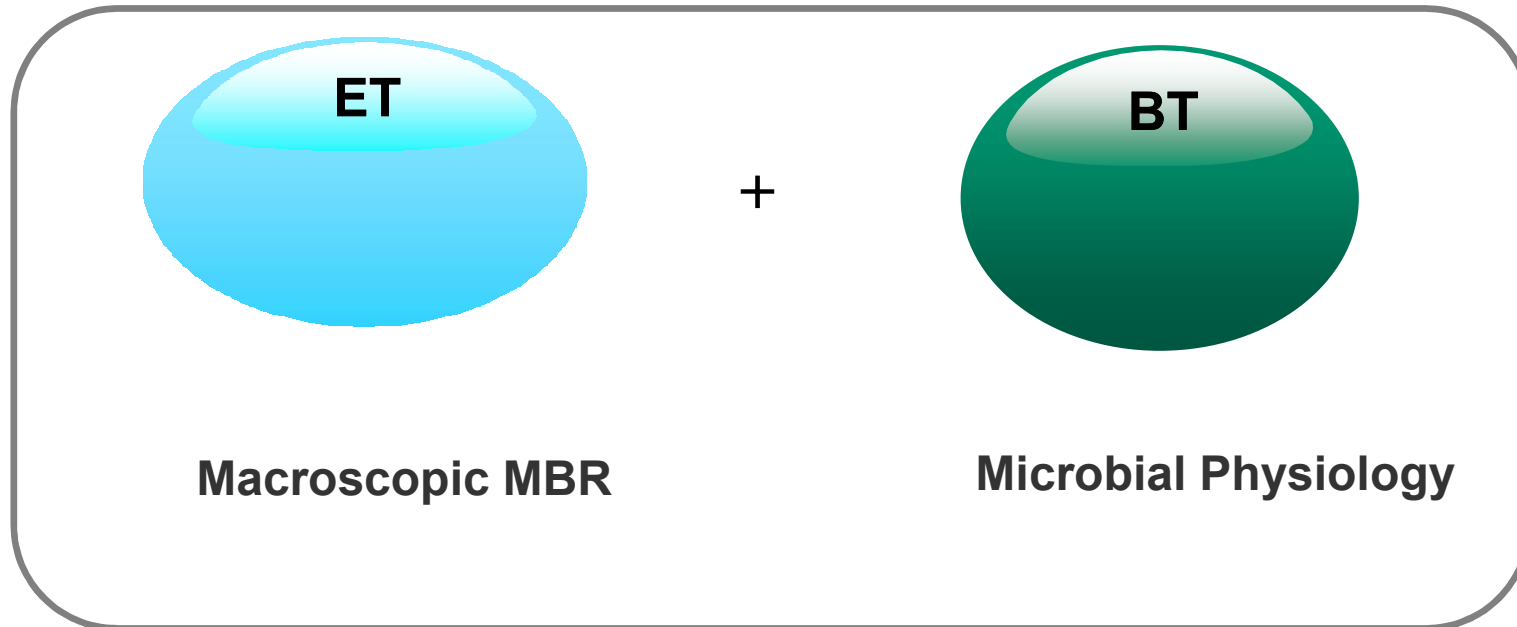


- Formation of Biofilm -

- Low water flux : 10~20 L/m²/h
- Short membrane life span : 3-5 yr
- High energy consumption : 0.3~0.6 kWh/m³

High installation
&
operating cost

2. Less Biofouling: Microscopic Approach



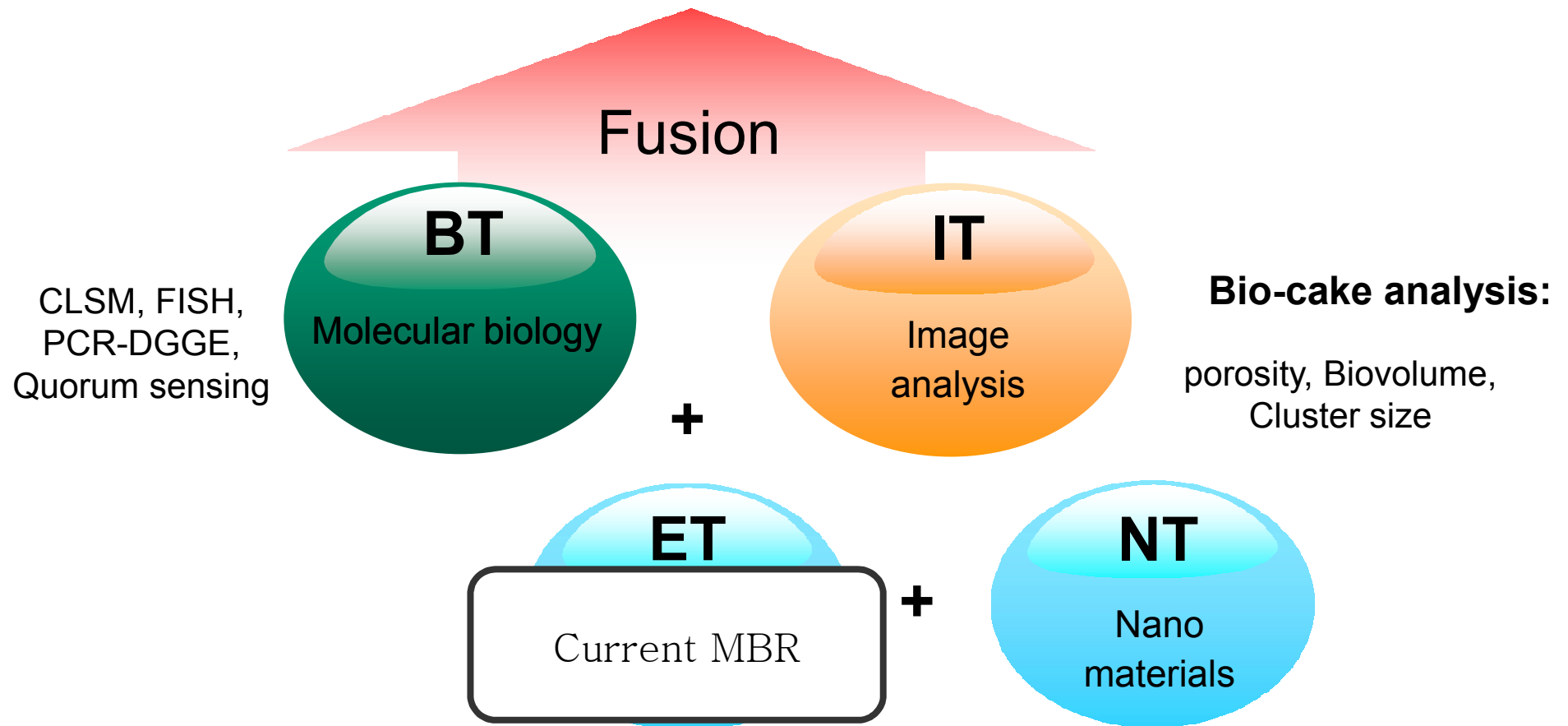
*“Effect of **physiological states of activated sludge** on membrane fouling”*

In-Soung Chang and Chung-Hak Lee, *Desalination*, Vol.120, 221-233, 1998

Citation Number (Feb. 2009) : **158**

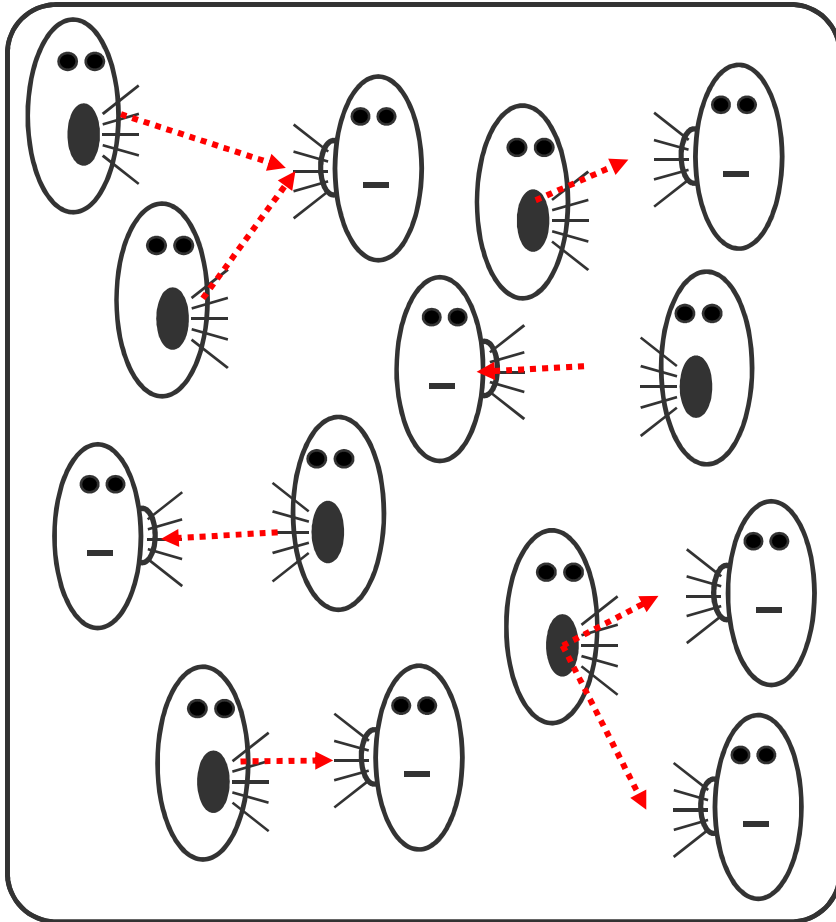
2. No Biofouling (*ultimate goal*): Quorum Sensing

MBR for Green Growth



Quorum Sensing ?

Microbial community

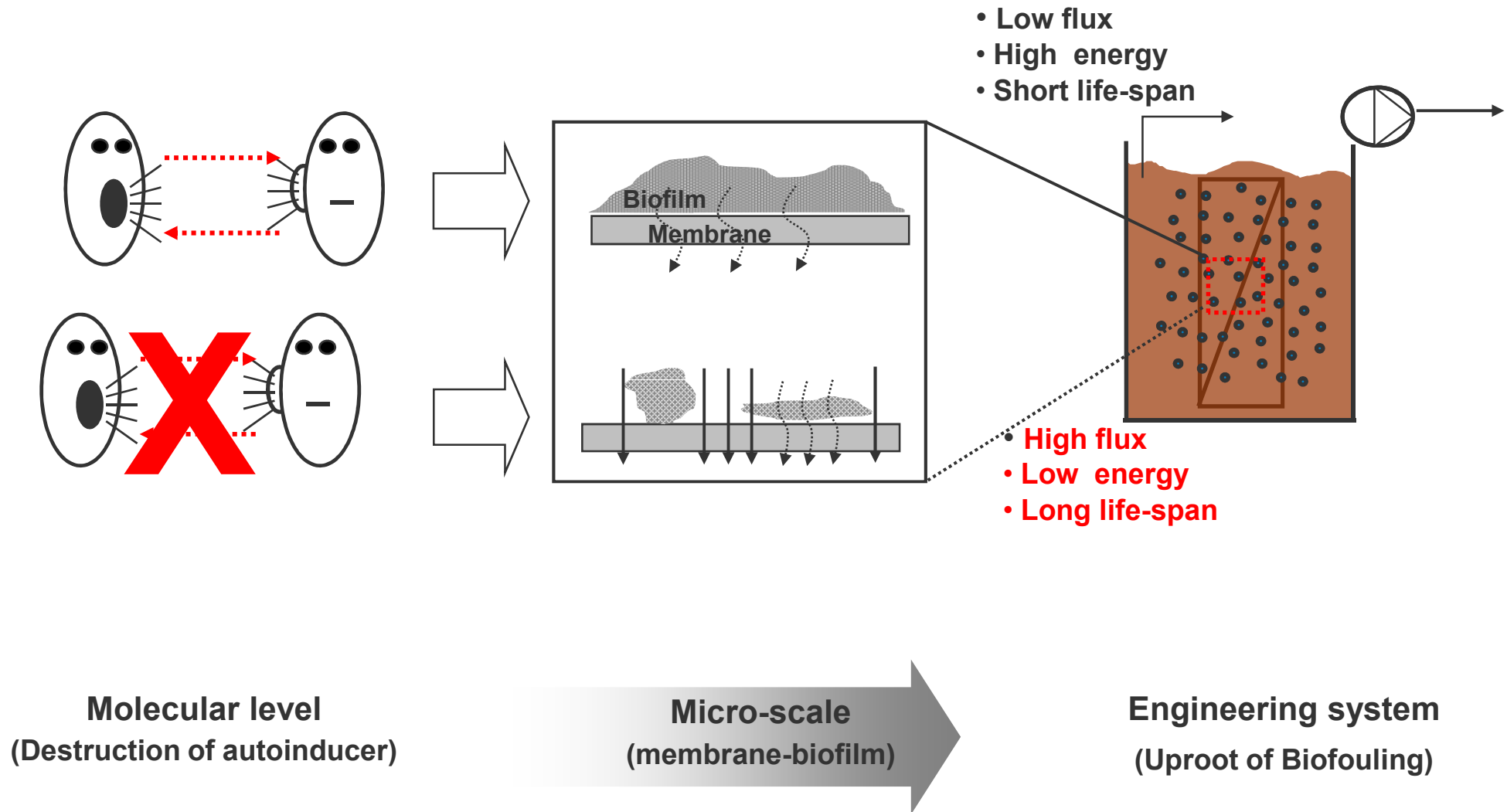


 : Signal molecules (autoinducer)

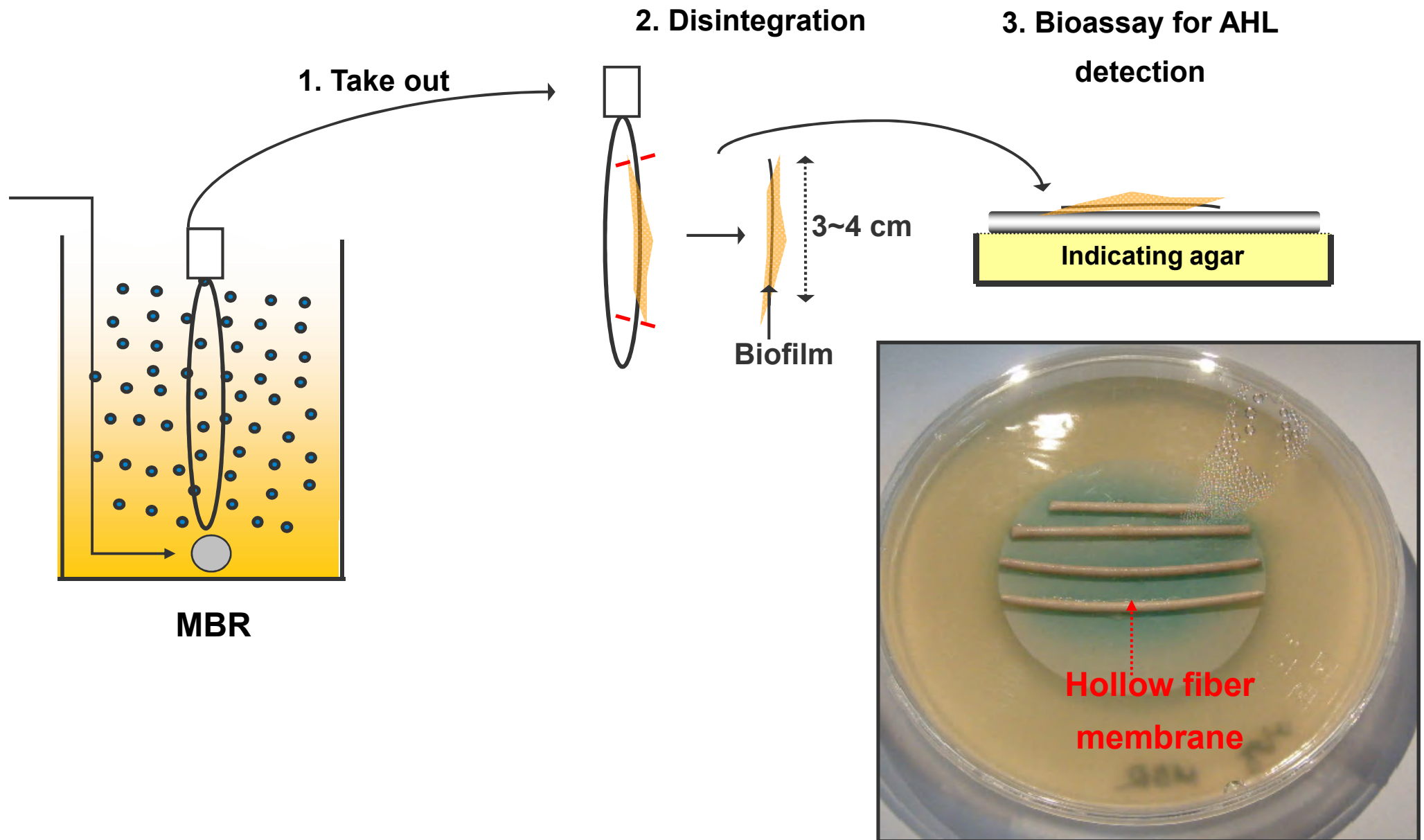
Group behavior

- Symbiosis
- Virulence
- Competence
- Conjugation
- Antibiotic production
- Motility
- Sporulation
- **Biofilm formation**

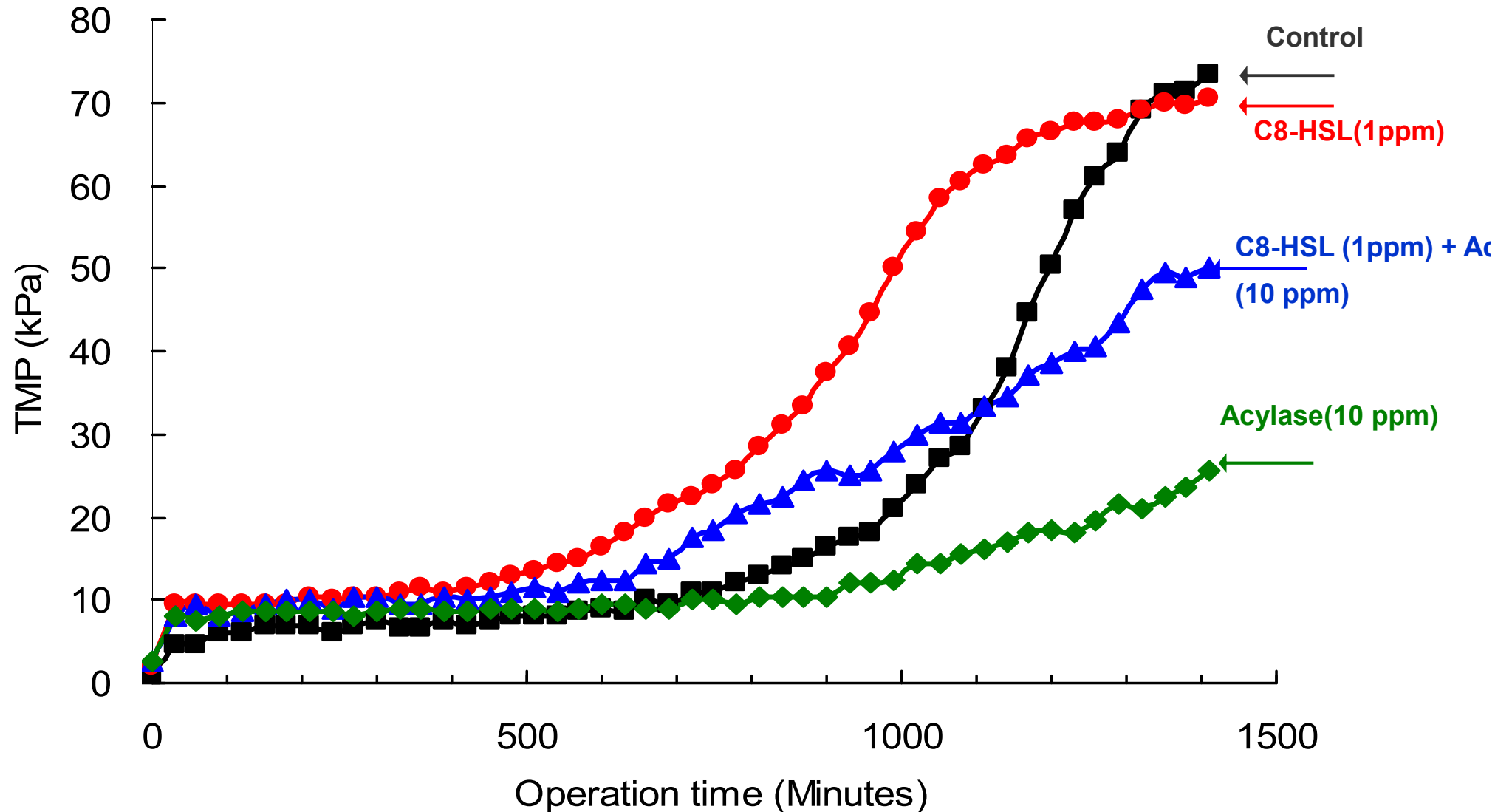
Quorum sensing based biofouling control in MBR : Concept



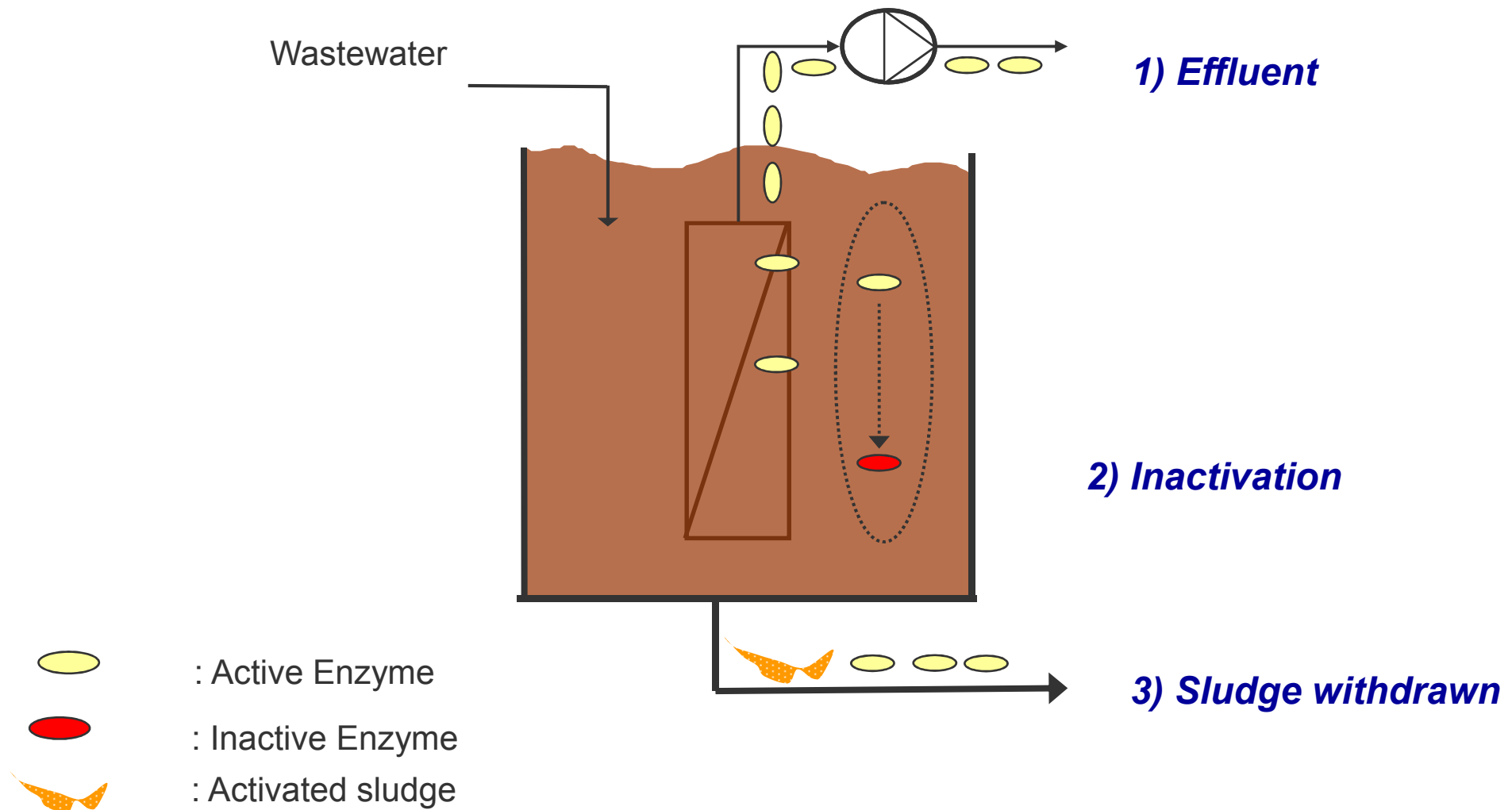
AHL QS activity in MBR : Experiment scheme



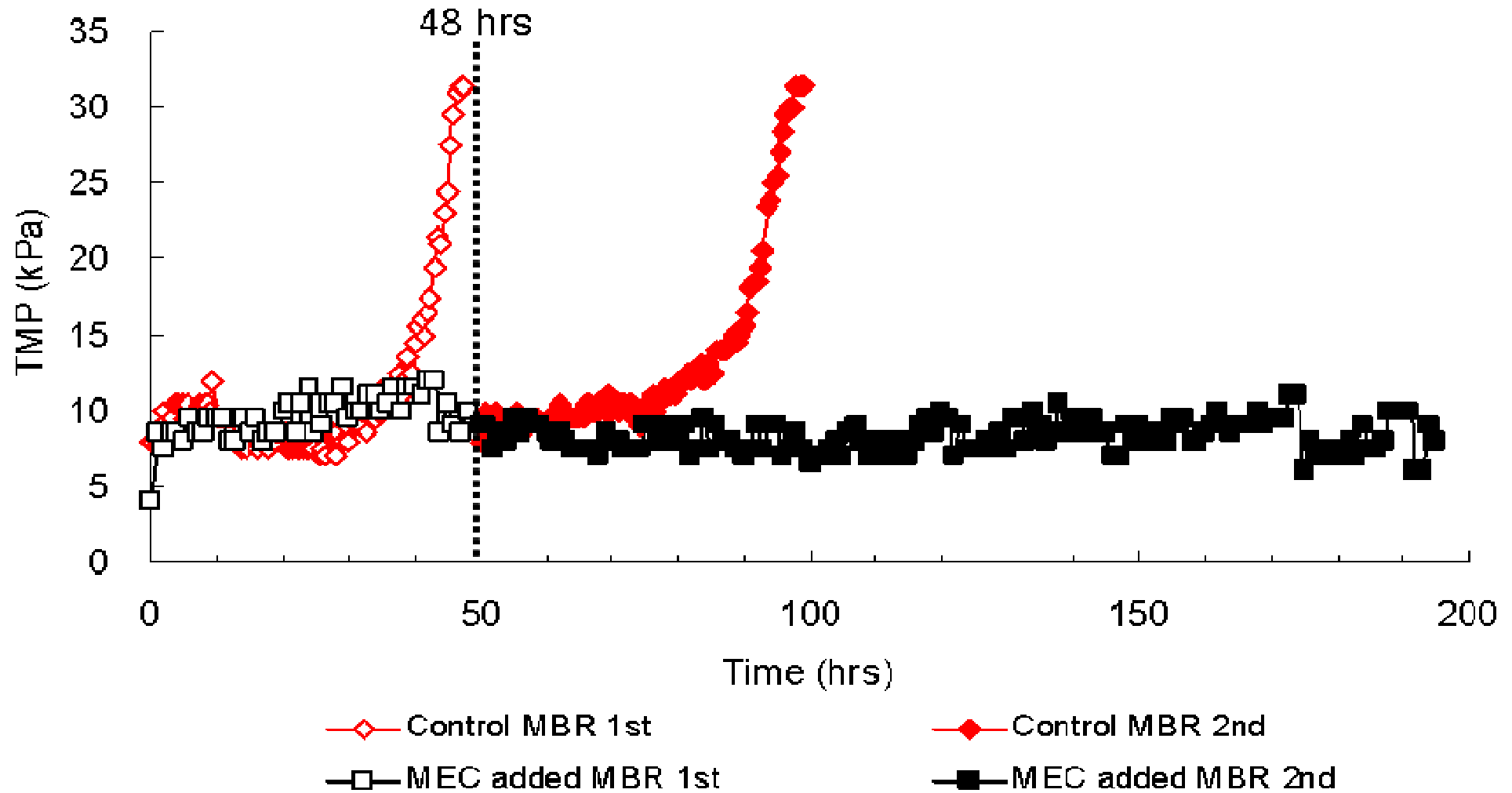
Biofouling prevention by quorum quenching



Loss of soluble acylase in continuous MBRs



Effect of MEC on MBR performance: TMP profile

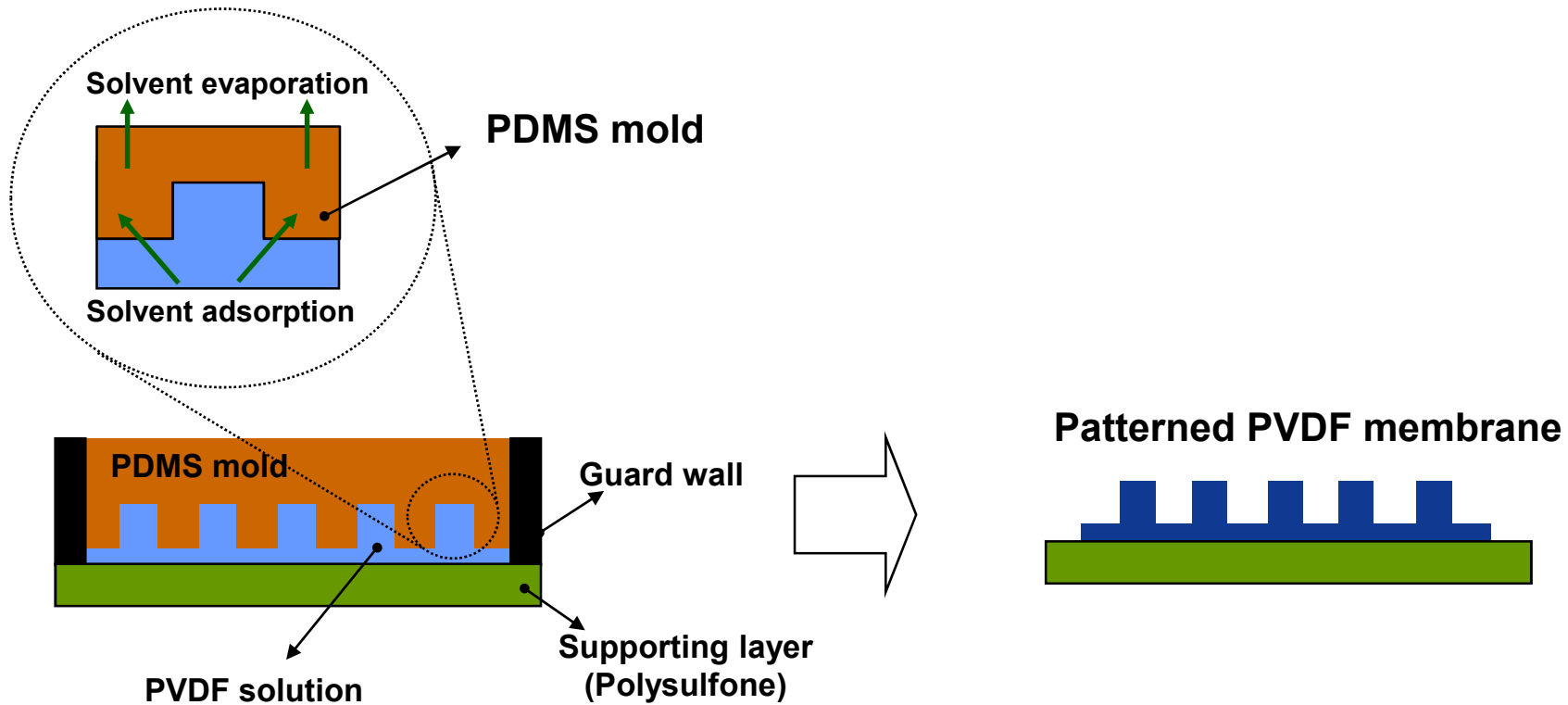
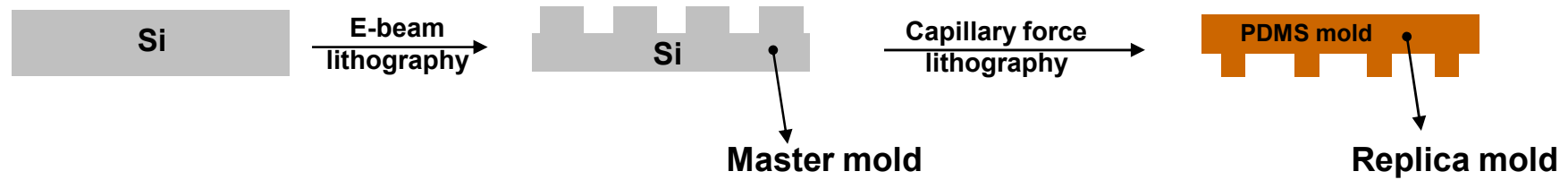


MEC: Magnetic Enzyme Carrier

3. New Functional Membranes

**Fabrication of new functional membranes
(capillary force lithography)**

Fabrication of new functional membranes (capillary force lithography)

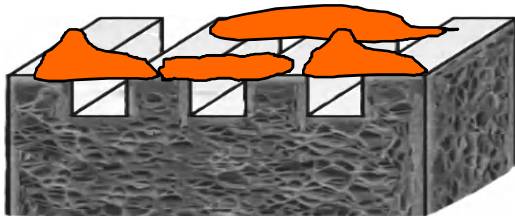


Advantages of patterned membrane

1

Sloughing

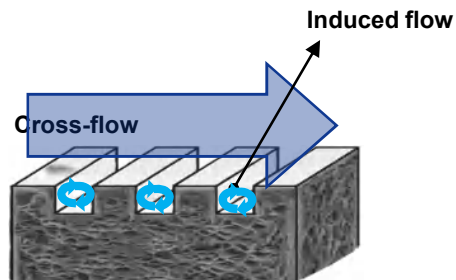
- Decrease in contact area
- Sloughing is easily induced



2

Spacer

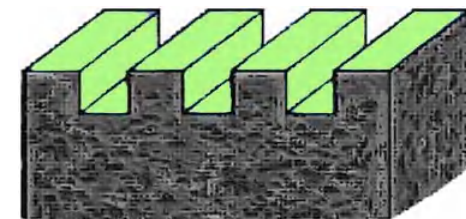
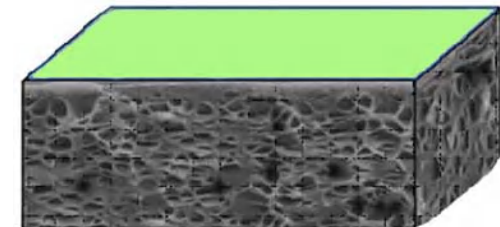
- Acting like a spacer.



3

Effective area

- Increase in surface area



Advantages of patterned membrane

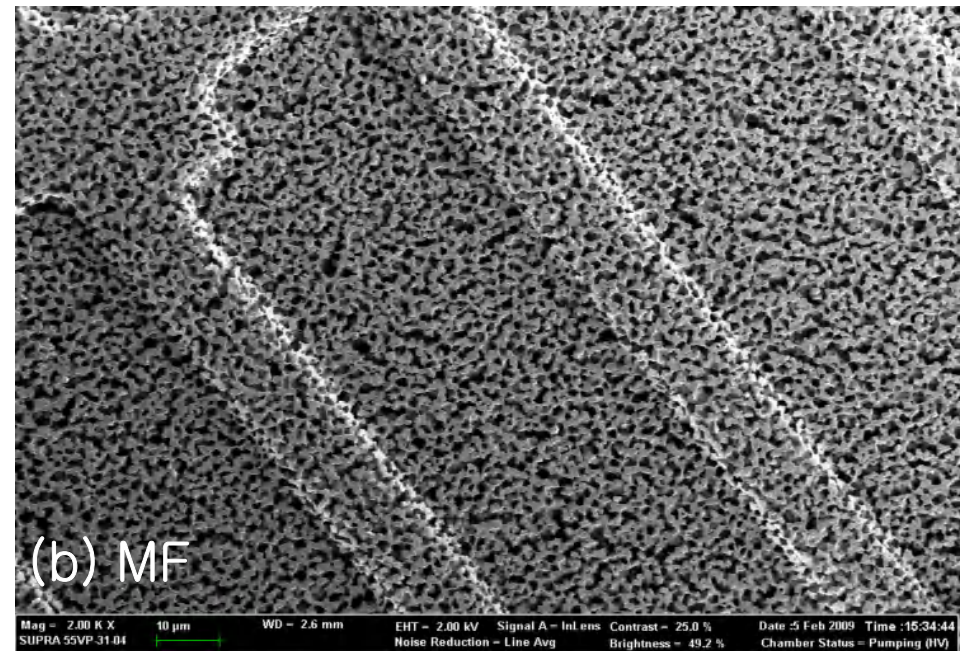
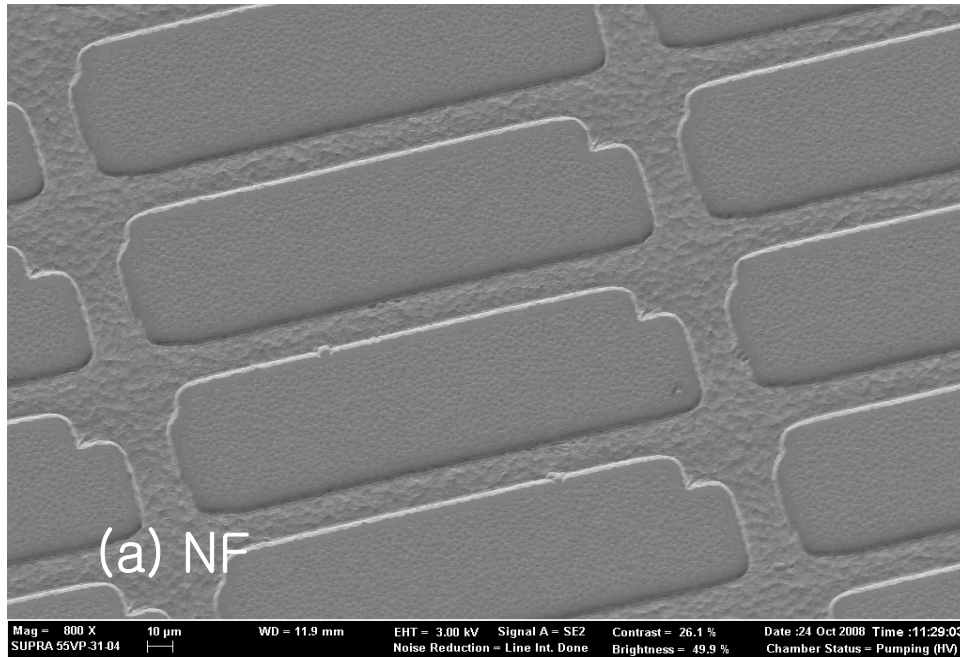


Figure. SEM images of patterned PVDF skin layer for
(a) NF, (b) MF (top view)

Regional Green Governance in Asia



EU Projects for the next generation membrane technology

- Green Lead Markets in Asia as well as in Europe



- i) **MEDINA** (Desalination,)
- ii) **EUROMBRA** (MBR, 10 countries)
- iii) **AMEDEUS** (MBR, 6 countries)
- iv) **MBR-TRAIN** (MBR, 7 countries)
- v) **PURATRET** (MBR, 10 countries)



**International
Water Association**

First Announcement and Call for Posters

Final MBR-Network Workshop

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

Organised By:



Sponsored By:



Hosted By:



Specialised
Conference



31 March – 1 April 2009
Berlin, Germany

Hosted by Trade Fair « Wasser Berlin 2009 »

Abstract submission: contact@mbr-network.eu

Deadline: 30 September 2008

Asian Green Governance with Membrane Technology

AMBITION

Asian Membrane Bioreactor Initiative
by Trilateral cooperatION

21st Membrane Tech

application

Upgrading

AMEDEUS

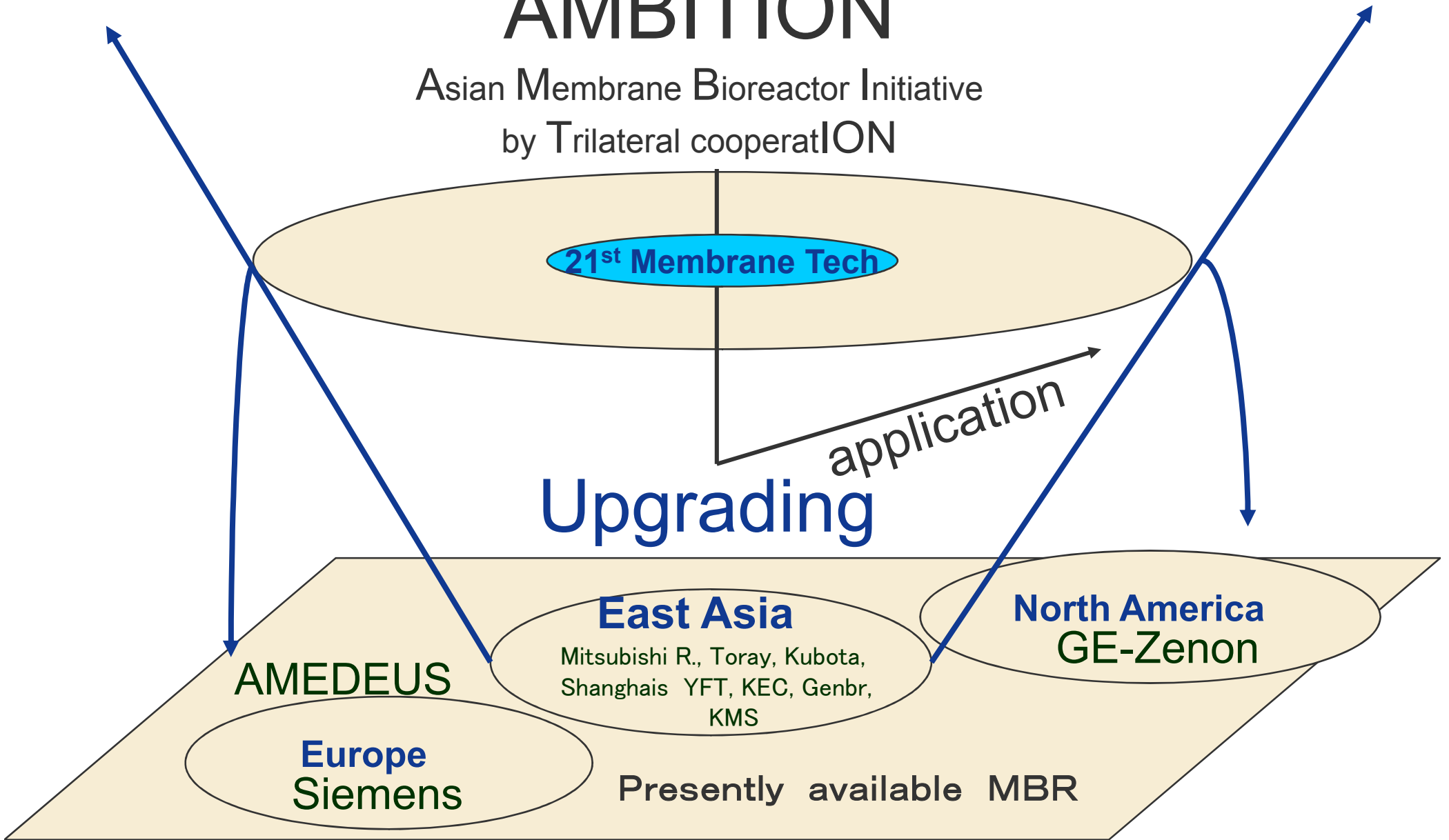
Europe
Siemens

East Asia

Mitsubishi R., Toray, Kubota,
Shanghais YFT, KEC, Genbr,
KMS

North America
GE-Zenon

Presently available MBR



Acknowledgements

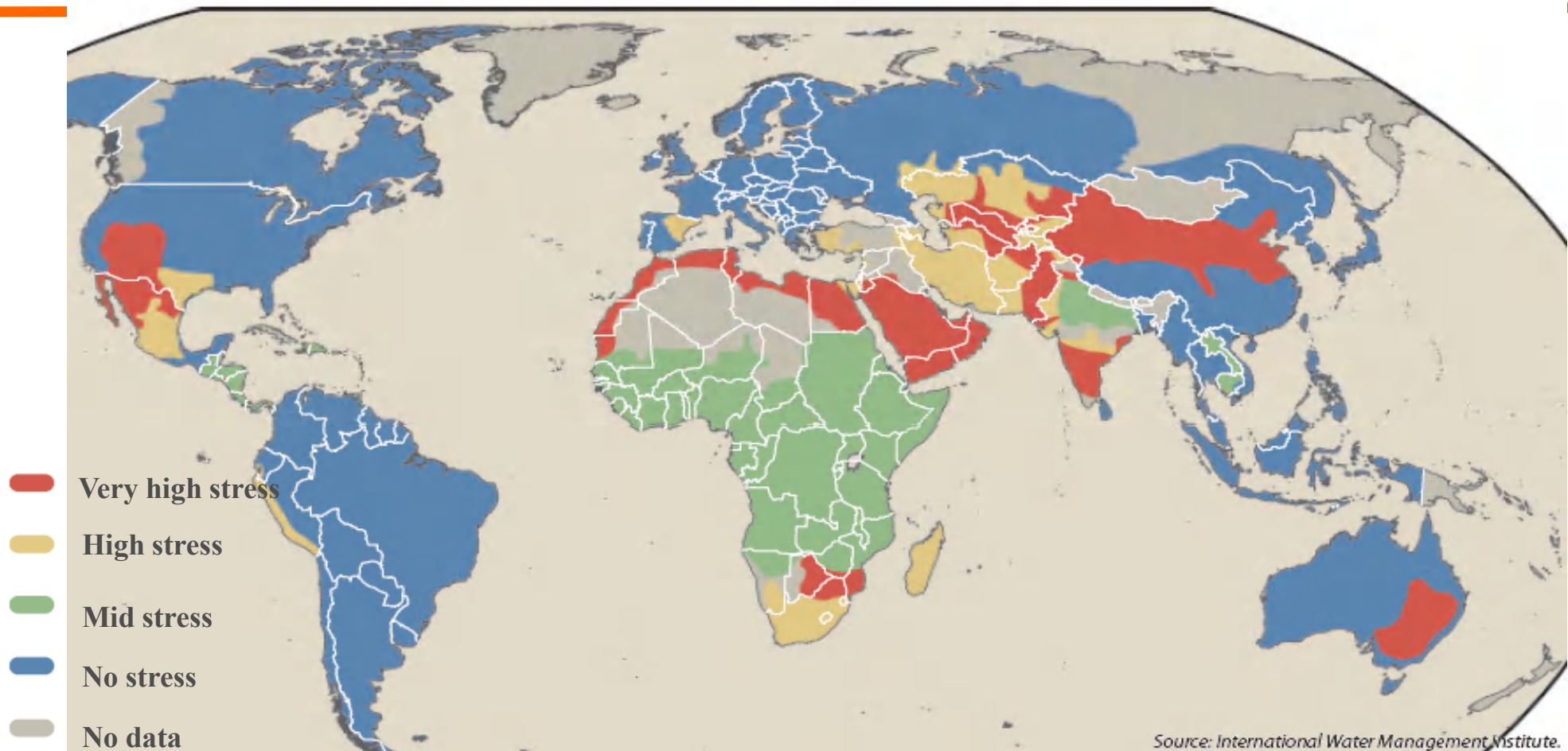
Thank You!

Prof. Chung-Hak Lee

*WATER ENVIRONMENT – MEMBRANE TECHNOLOGY Lab.
SCHOOL OF CHEMICAL AND BIOLOGICAL ENGINEERING,
SEOUL NATIONAL UNIVERSITY, Korea*

[**http://wemt.snu.ac.kr**](http://wemt.snu.ac.kr)

Global Water Shortage in 2025

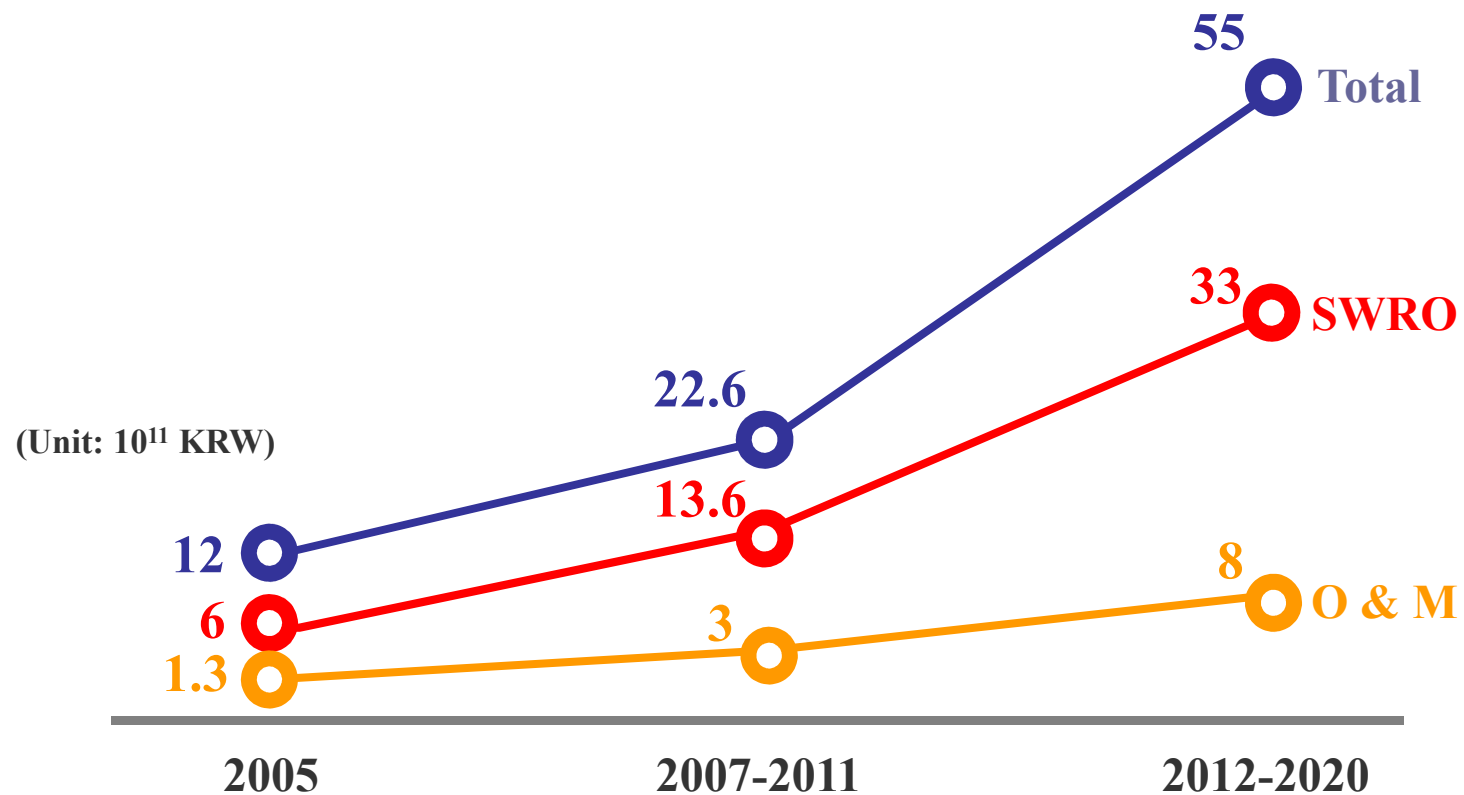


Source : International water management institute

- **Water shortage population: 1.1 billions in 2005 and 3 billions in 2025.**
- **WHO reports that 3.4 million per year are killed by waterborne diseases. (2005)**

Market Growth

- ◆ Market needs is being moved to SWRO
- ◆ SWRO market is rapidly growing.



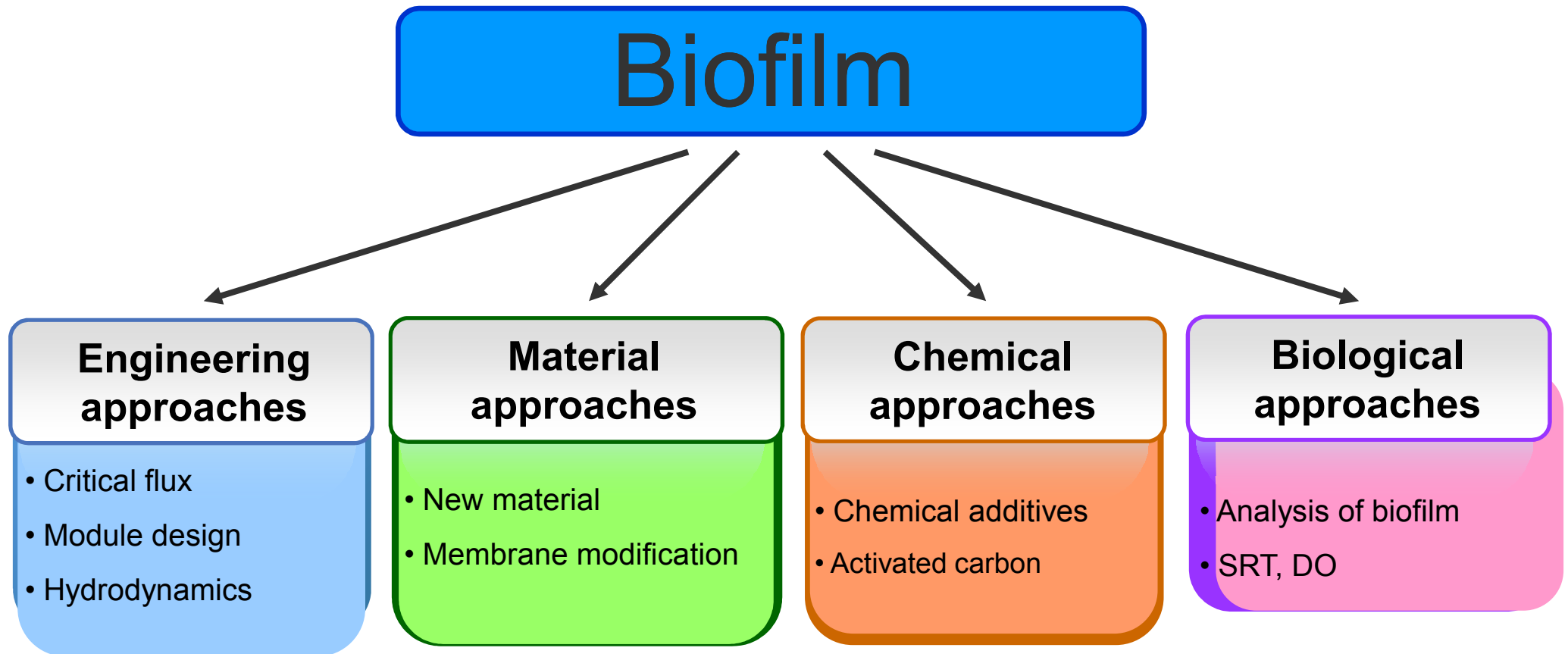
Source : GWI Desalination markets 2005~2015/ IDA 19th Inventory

Key Research Issues

- ◆ Ultra-precision seawater analysis techniques
(Ex: Removal of salt inhibition on the analysis, lowering the detection limit, etc)
- ◆ System Engineering for large-scale unit train (**8MIGD**)
(Ex: Reliability in System design and operation for the large-scale unit train, Optimization of energy recovery, Development of energy saving system, etc)
- ◆ Increase of recovery ratio (**60%**)
(Ex: Selective Removal of Ca^{2+} and Mg^{2+} ions by pretreatment, innovative SWRO system design, etc)
- ◆ Innovative SWRO membrane modules
(Ex: Higher water permeability, Higher salt rejection (99.8% → **99.9%**), Higher Boron removal(90% → **96%**), Chemical and fouling endurances, scale-up of the module (**16 inches**), etc)

* Courtesy of Prof. I.S. Kim at KGIST

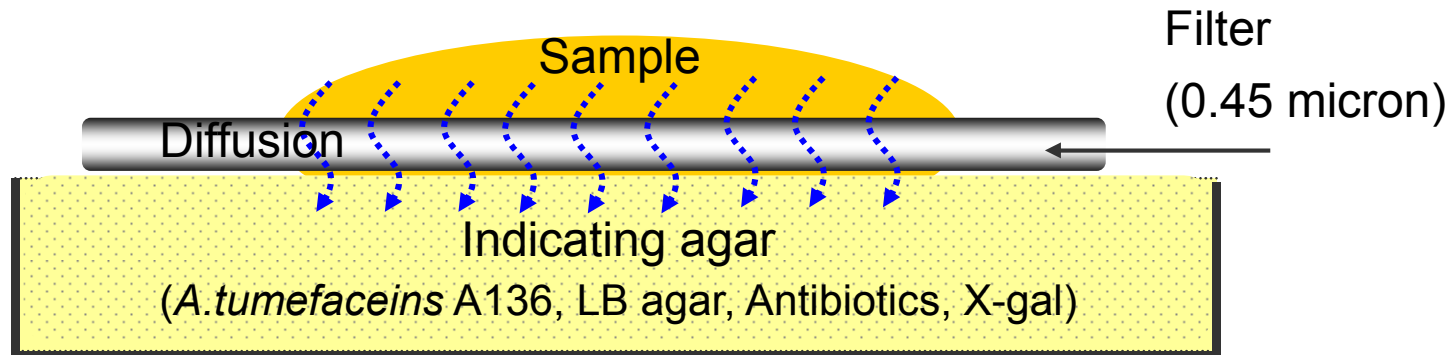
2. Less Biofouling: Microscopic Approach



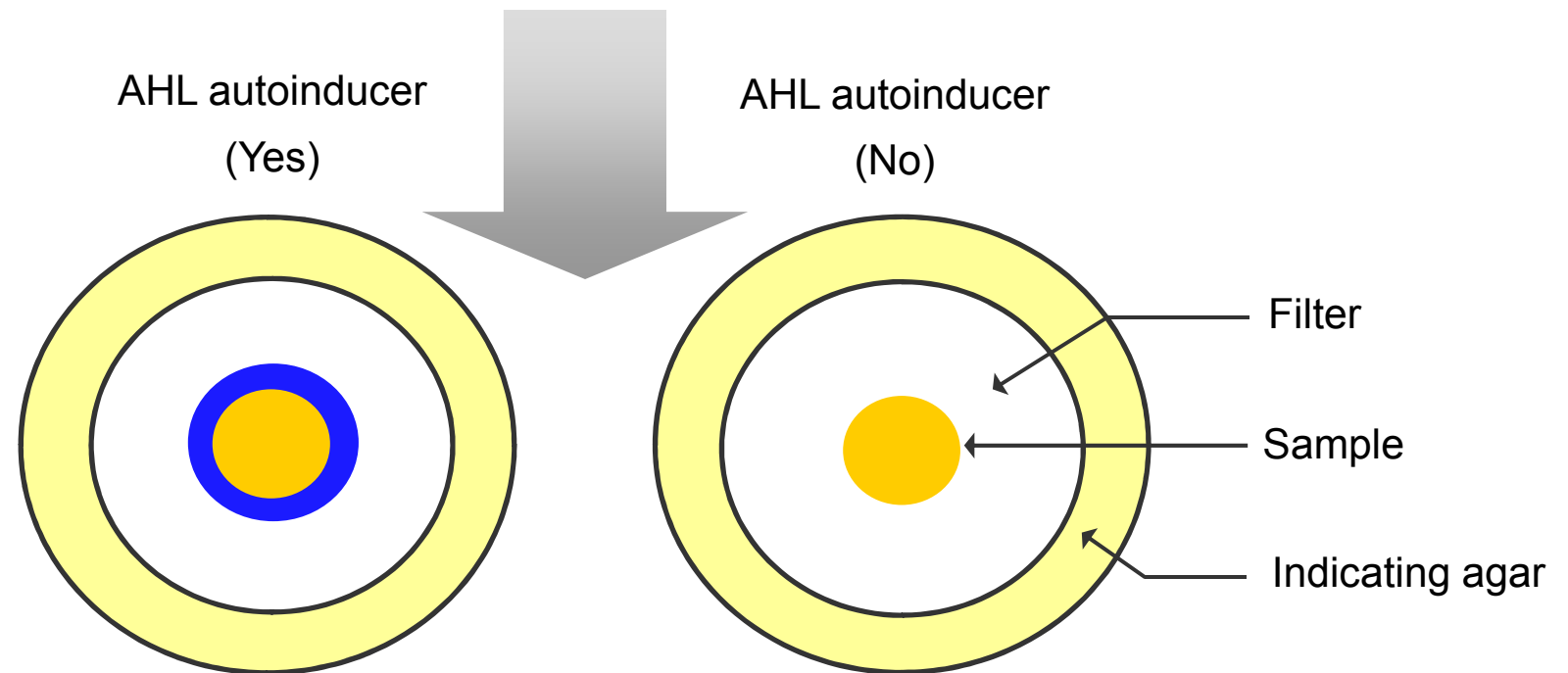
New Paradigm : How to essentially prevent biofouling by uprooting the biofilm formation ?

A. tumefaciens A135 bioassay for AHL detection

Vertical view

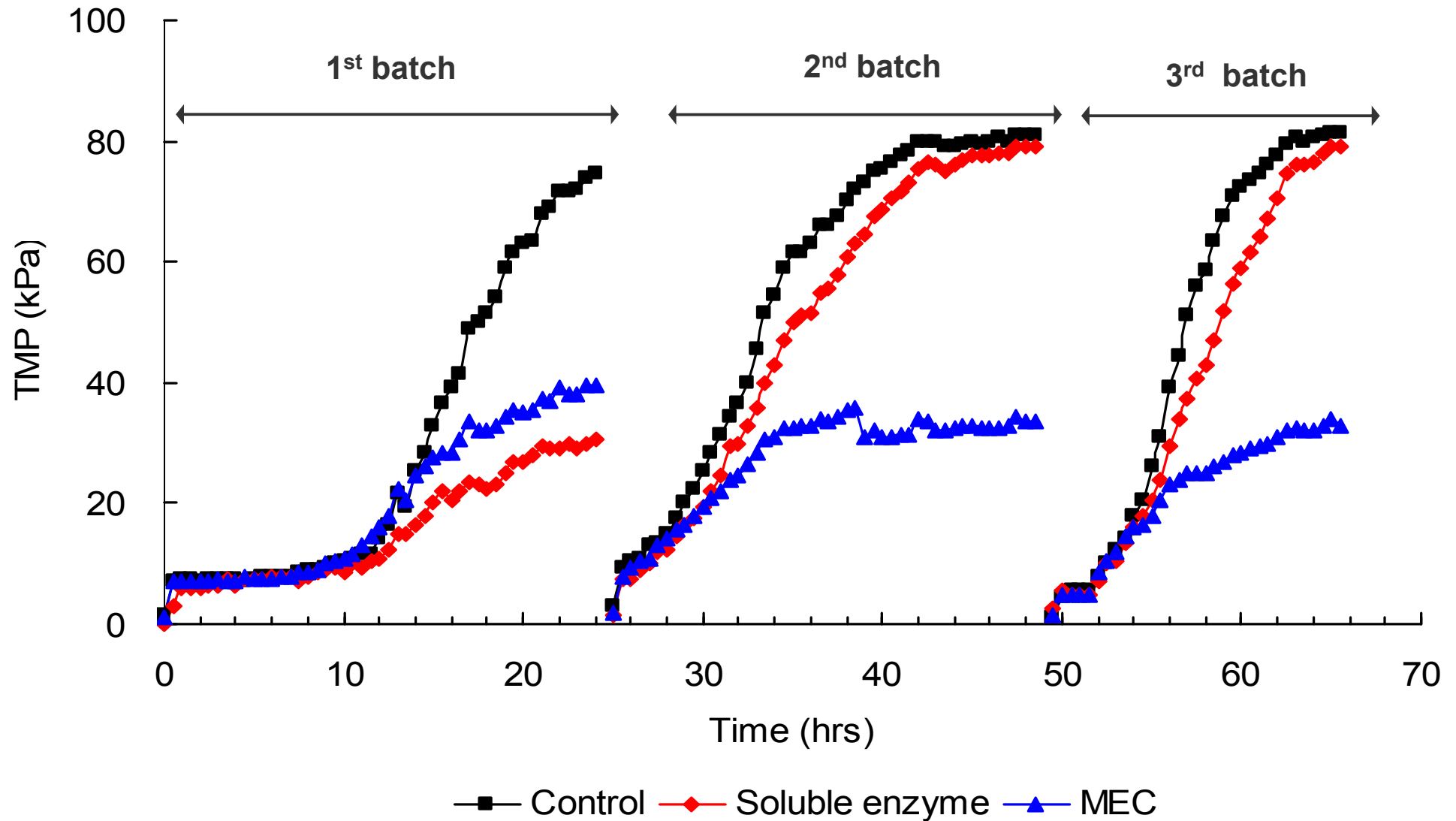


Top view

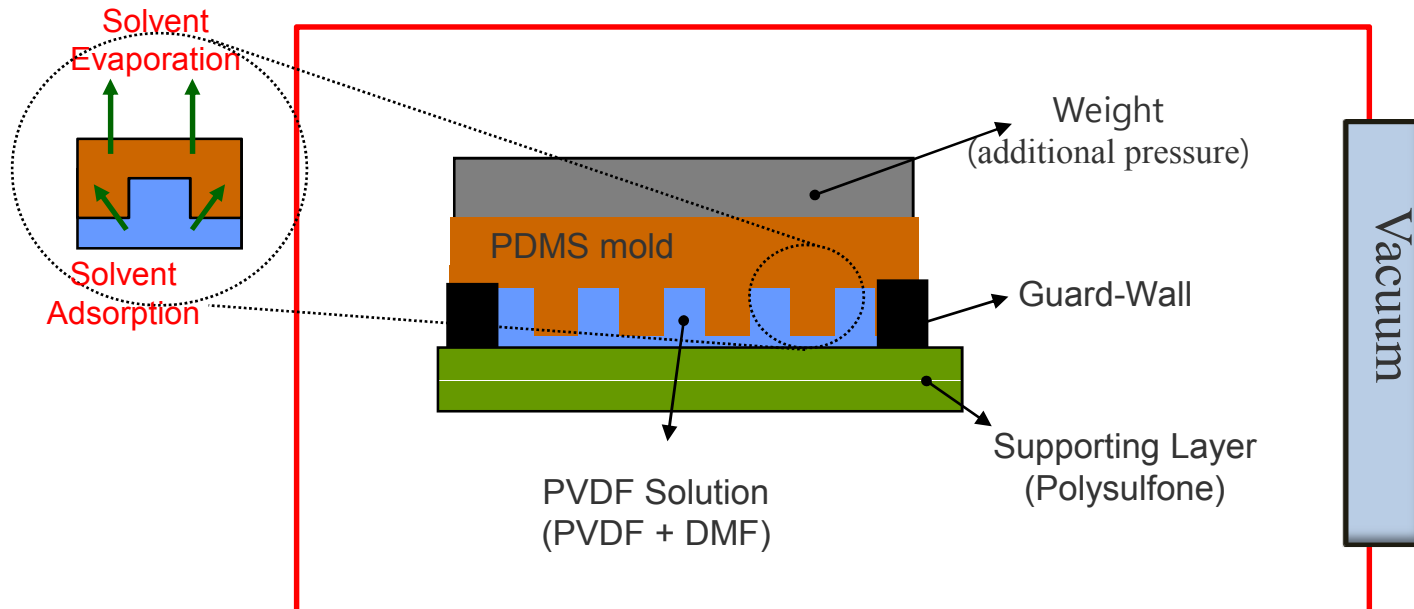


Blue color development around the sample

Magnetic Enzyme Carrier vs. Soluble Acylase



Manufacturing Process for Patterned Membranes



- Cast PVDF solution on the Supporting layer
- Cover with PDMS mold
- Additional pressure is applied
- Control the vacuum and temperature