The 12th Korea-US Forum on Nanotechnology

Membrane processes for Eco-Smart Waterworks Systems

October 4-6, 2015

Key Bridge Marriott Hotel, Arlington, VA, USA

Soo Hong NOH

Yonsei University /Center for Eco-smart Waterworks System, Korea

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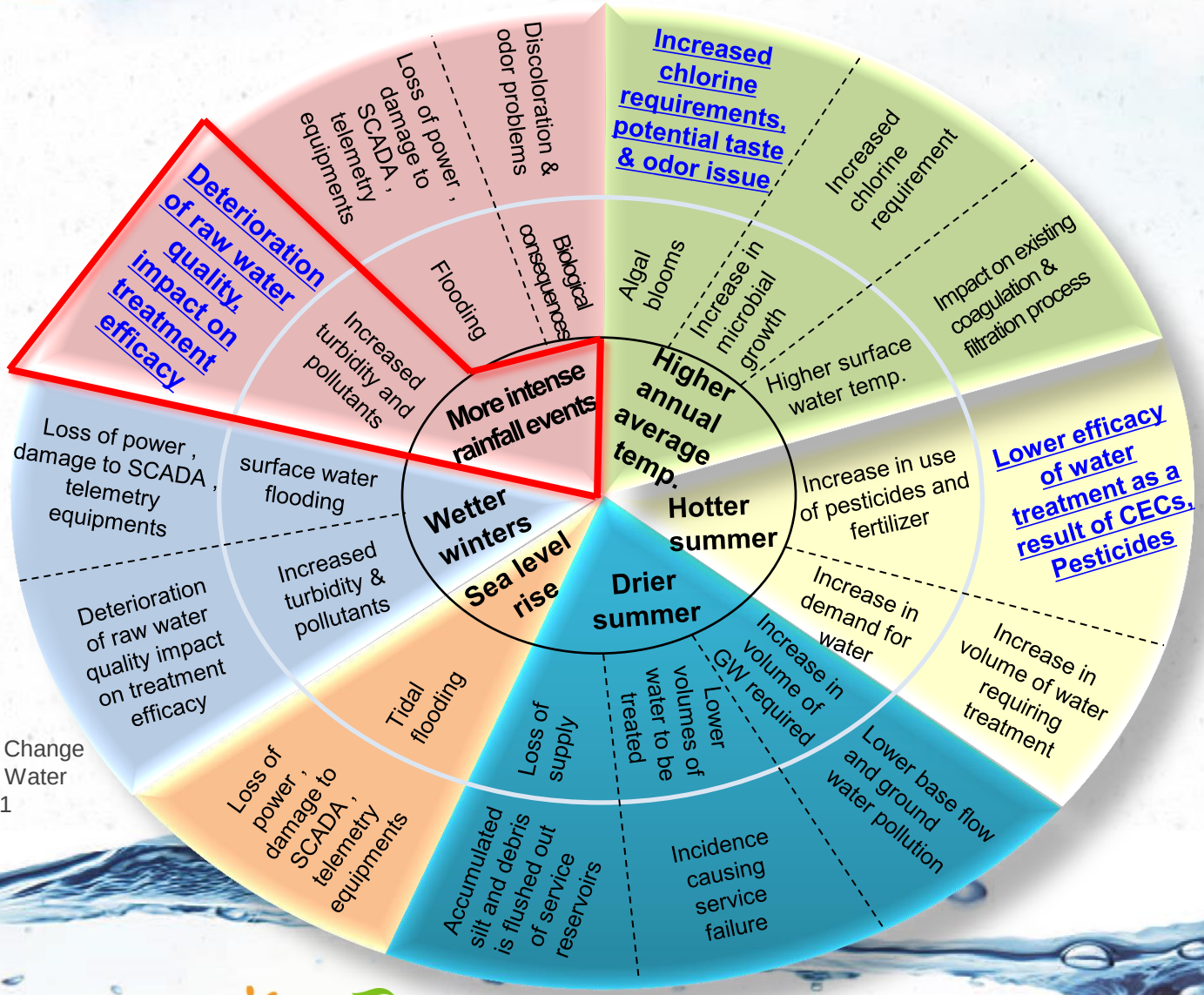

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Impact of climate change on water treatment

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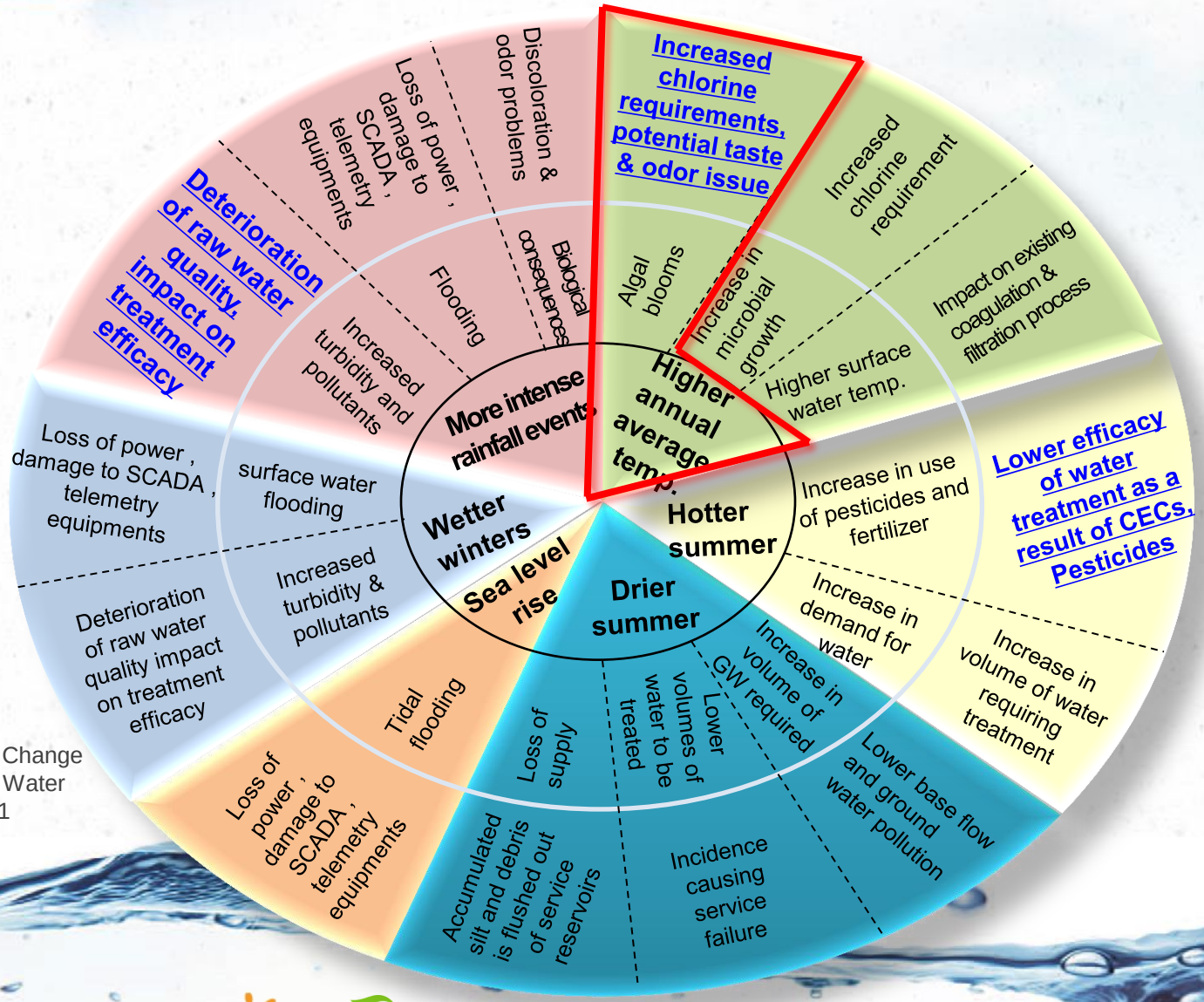

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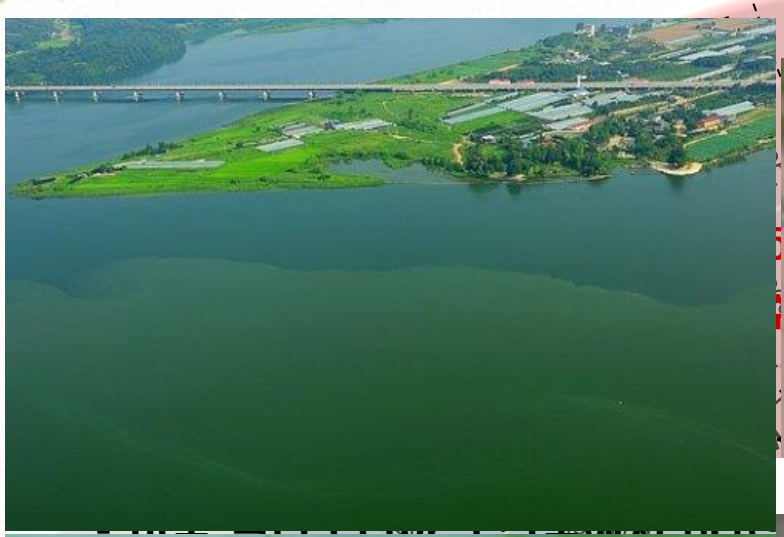
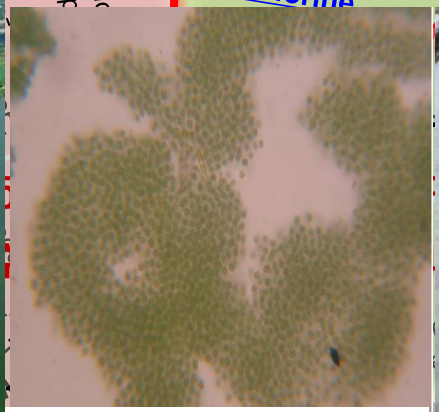
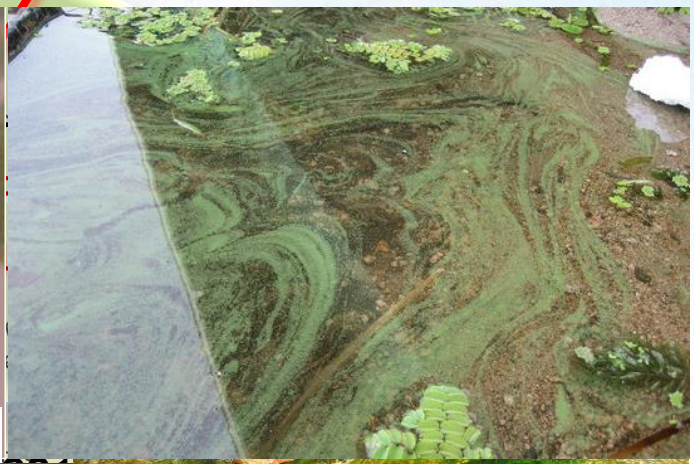
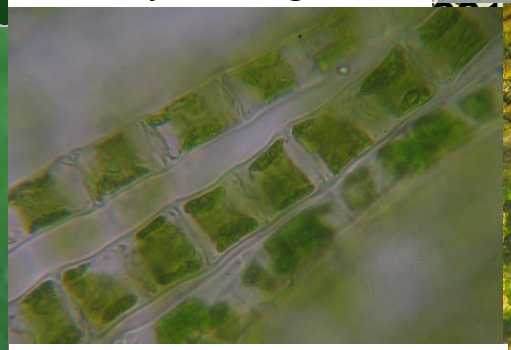


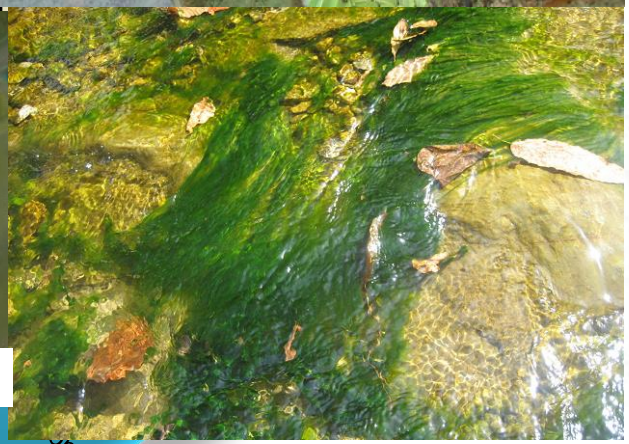


Microcystis aeruginosa



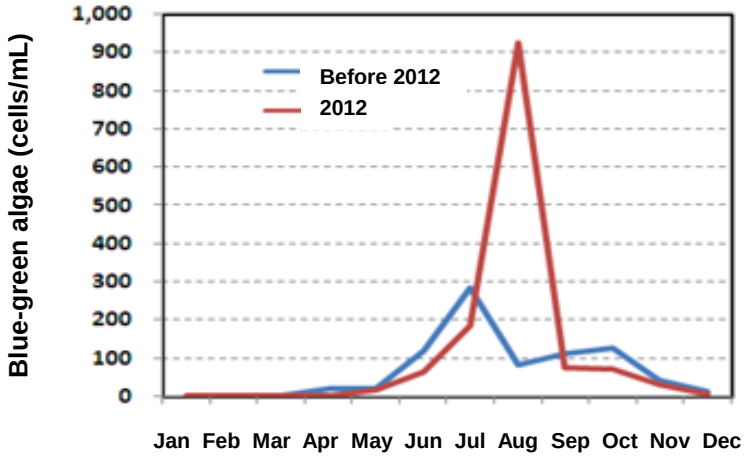


Ulothrix zonata



Impact of climate change on water treatment

Taste and odor issues by algal blooms



Ref: Waterworks Research Institute, Seoul Metropolitan Government

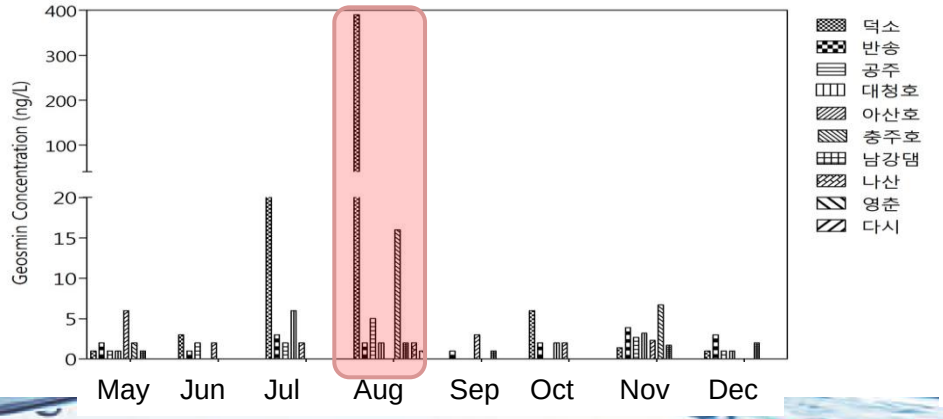
✓Conc. of Geosmin and 2-MIB in raw water in Seoul waterworks (2012. 08. 06 ~16)

→ Geosmin : 39 ~ 724 ng/L

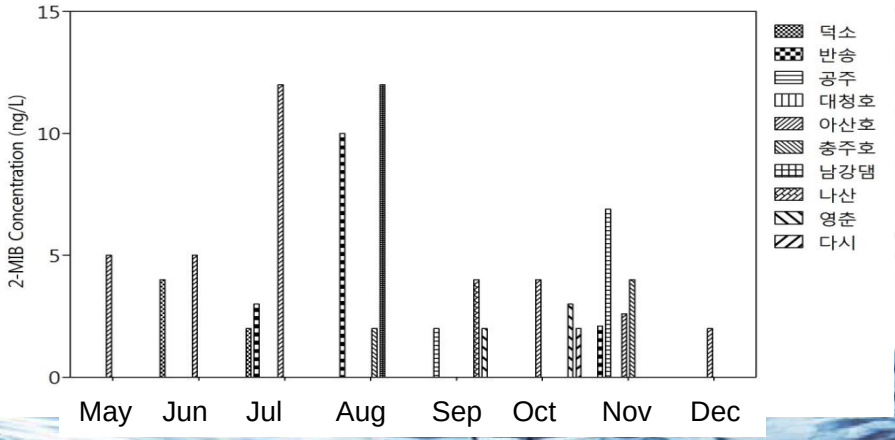
✓ Design condition for advanced water treatment process in Korea

- Parameters
  - →Geosmin 200 ng/L, 2-MIB 40 ng/L in raw water
- Design factors
  - → Post-Ozone+GAC: Ozone 2 mg/L, CT 15min, GAC EBCT >12 min
  - → Pre-Ozone+F/A: Ozone 3 mg/L, CT 10min, F/A process EBCT >12 min

Geosmin (2012)



2-MIB (2012)



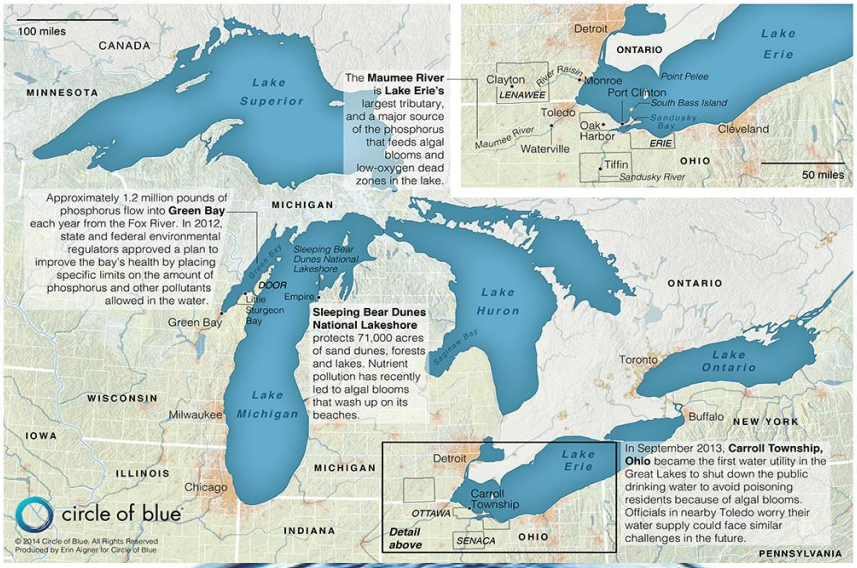
Ref: K-water

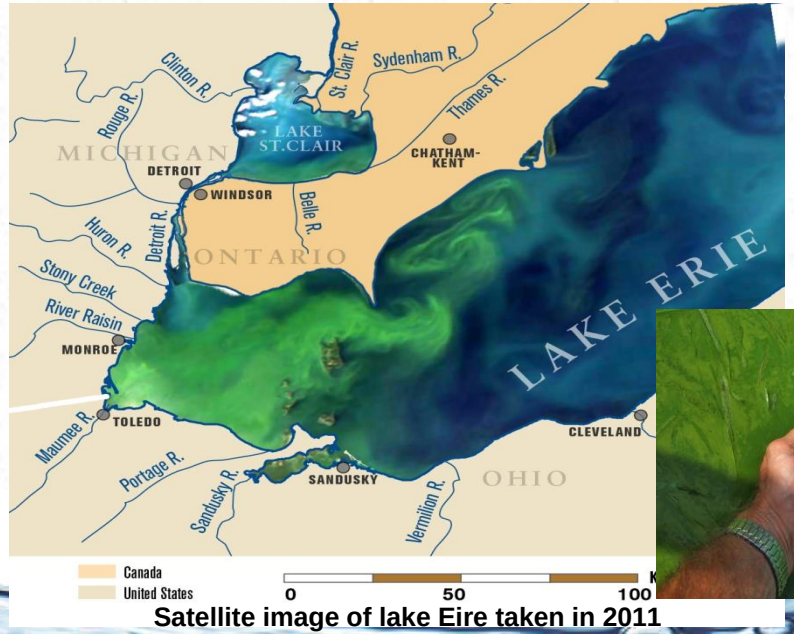
Impact of climate change on water treatment

Toxic Algae issue: Lake Erie Microcystis Outbreak (Sept. 2013, Toledo, USA)

- ✓ Toxin level: 12.76 μg/L (Max. 50 μg/L) in raw water, 3.56 μg/L in drinking water
  WHO limit 1 μg/L
- ✓ Shut down Carroll township WTP, Do not drink advisory issued → 2,288 people affected.

> $200,000/month for extra carbon treatment at Ohio public water systems due to harmful algal blooms (Ref: Raymond, Ohio EPA)

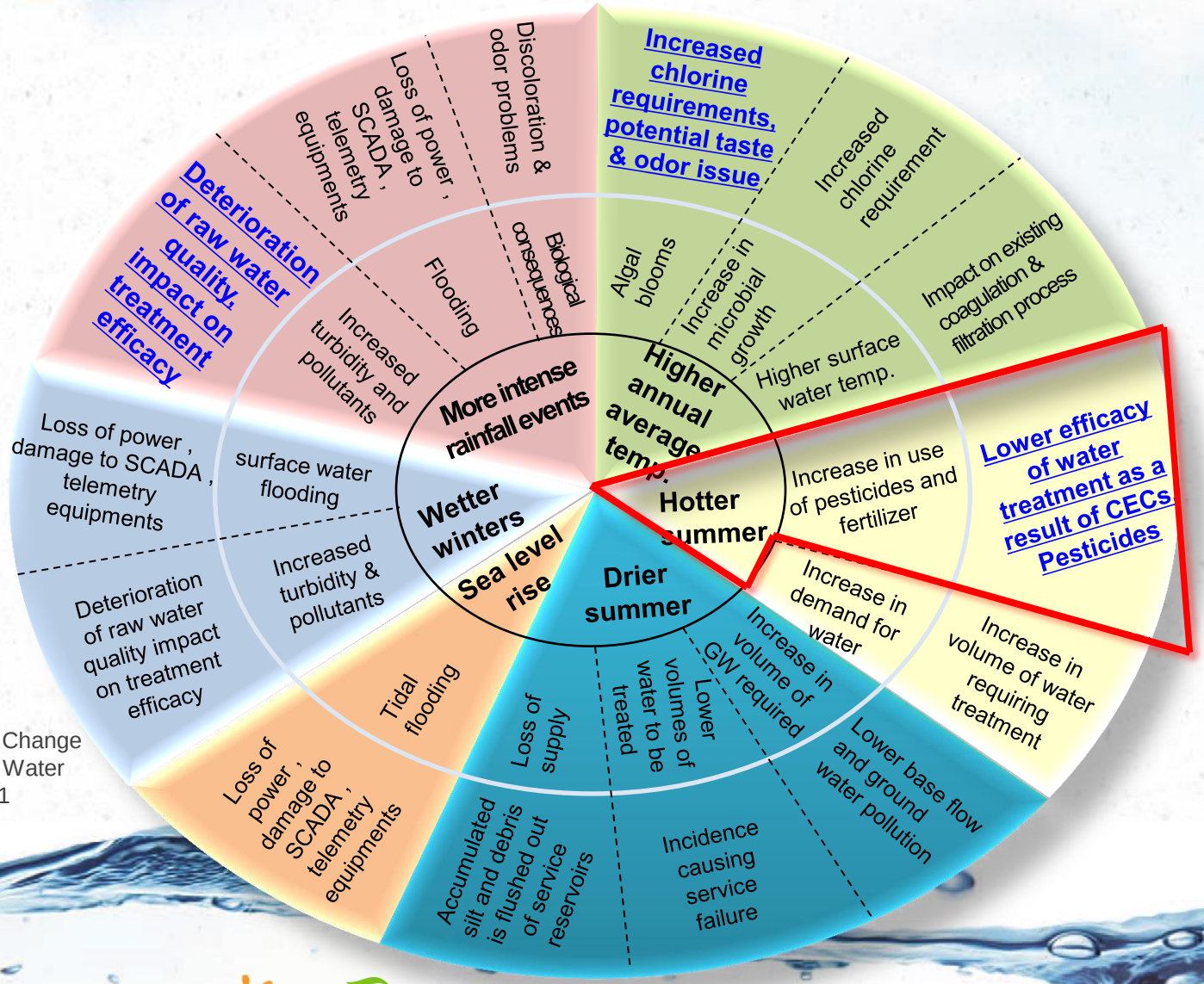




Satellite image of lake Eire taken in 2011

Source: Circle of blue

Impact of climate change on water treatment



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Impact of climate change on water treatment

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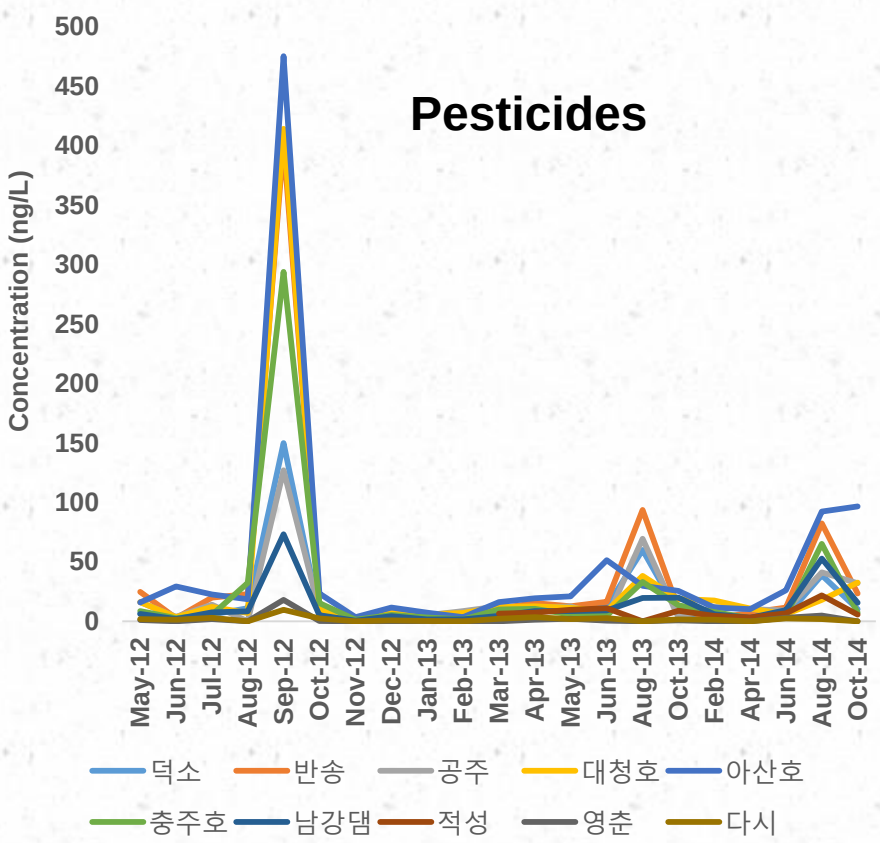
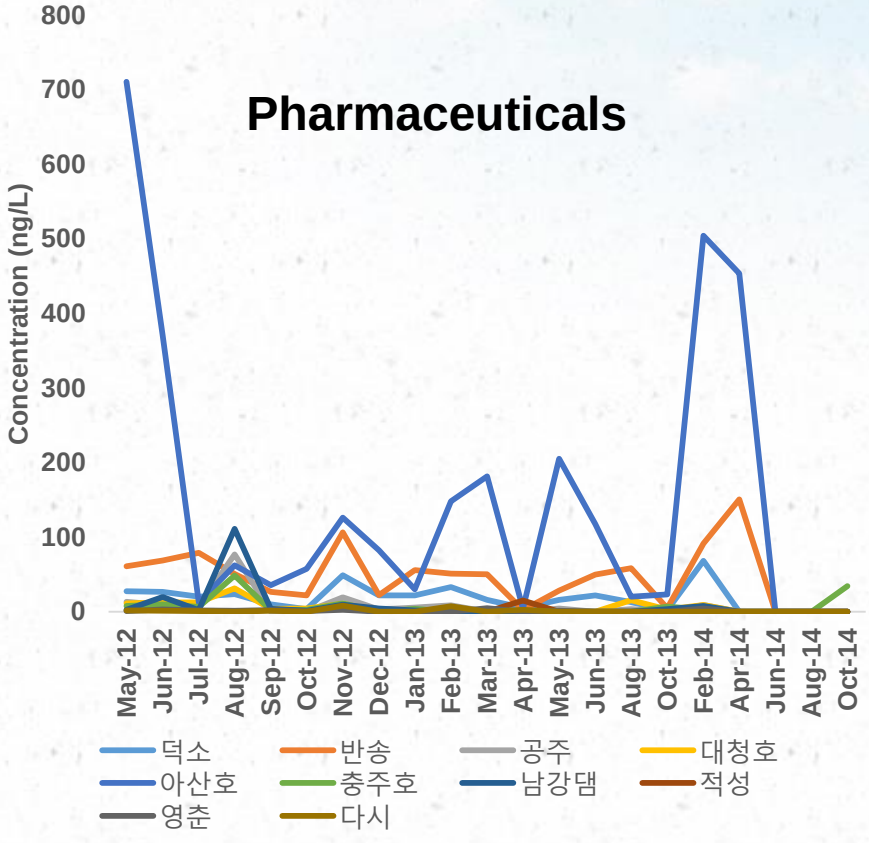
Impact of climate change on water treatment

CECs (Contaminants of Emerging Concerns) in water resources in Korea (2012-2014)





Ref: K-water


GlobalTop
SWS
Eco-Smart
Waterworks
System
II. Eco-Smart
Waterworks
systems

Eco-Smart Waterworks systems

Develop hybrid membrane system for the treatment of CECs
Establish total solution Test-beds and secure O&M technology
Promote global Top level water companies

Total Solution
Intake ▶ Water Treatment Process ▶ Tap

Membranes & Modules	Plants & Systems	Packages
World leading membrane technology	High-tech intelligent optimized water treatment system	Water treatment process optimized for export markets

TORAY 도레이케미칼 · LOTTE CHEMICAL · ECONITY · (주)퓨어엔비텍 · 경희대학교 KYUNG HEE UNIVERSITY

DAELIM · K water · GS건설 · 대우건설 Daewoo Engineering & Construction · Hanwha E&C · posco 포스코건설 · coway · posco ICT · 현대엔지니어링 · SK건설 · Soft-Tech International, Inc. · KICT 한국건설기술연구원 KOREA INSTITUTE of CONSTRUCTION TECHNOLOGY

Project overview

Project period	Budget (Phase Ⅰ)	Participation institutions
Aug. 2011 ~ April 2021 (10 years) (Phase Ⅰ: Aug. 2011~ April 2016)	$72 million (Government : $42 million Private : $30 million	51 (Academics, industrial partners)

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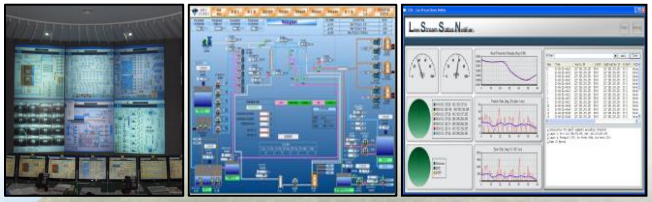
Eco-Smart Waterworks systems

Water Treatment Integrated Management Center



Water Treatment Process

- Membrane + Ozone/GAC/NF/UV-H_2O_2
- Retrofitting WTP / Water-CFD
- Best Available Technology (BAT) program
- Small scale package system

Risk Analysis and Action Program for Countermeasure of Water Pollution Accidents

Energy savings

- Optimizing pump operation

Membrane & Module

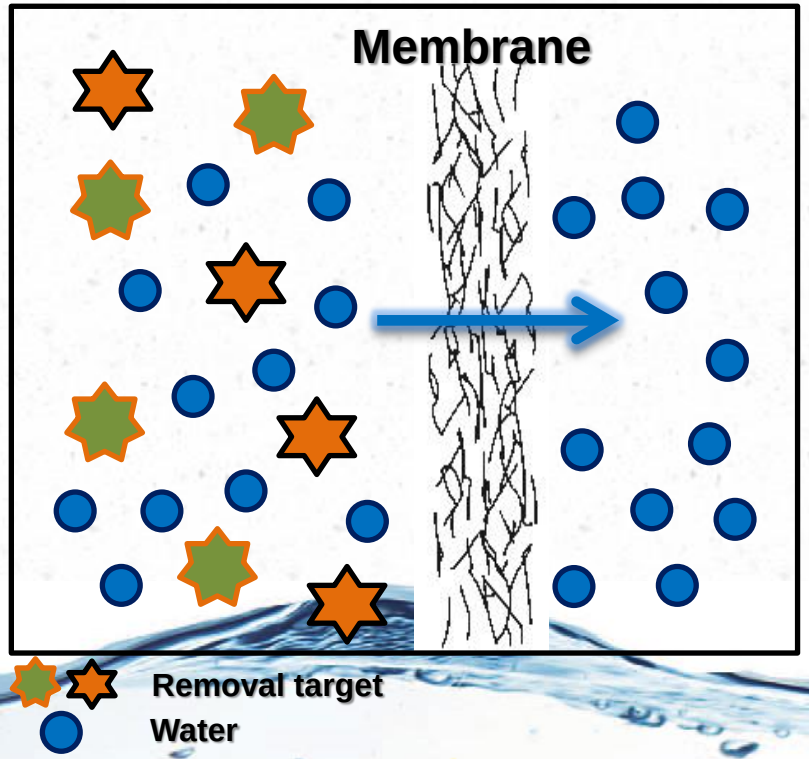
- MF & UF membrane and module
- End-free module for treating backwash water
- Nano-fiber and Graphene oxide membrane

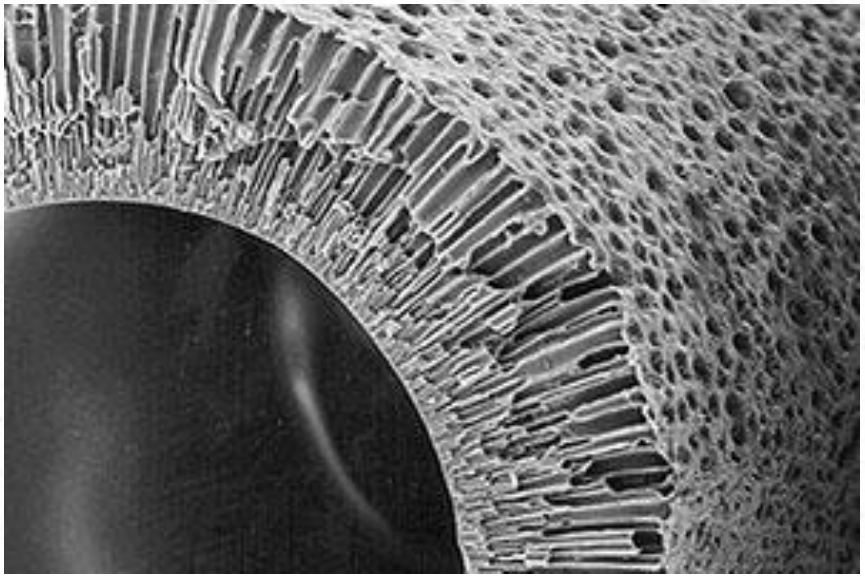
Water Pipe Network Management

- Water pipe, monitoring, operation & management
- Automatic drainage system at the end of the pipe
- Ubiquitous emergency response system using mobile tool

Membrane & Module

- **Membrane** : The phase that acts as a barrier to prevent mass movement but allows restricted and/or regulated passage of one or more species through it (Lakshminaryanaiah 1984)
- **Membrane filtration** : the separation of dissolved solute in liquid streams and for separation of gas mixture

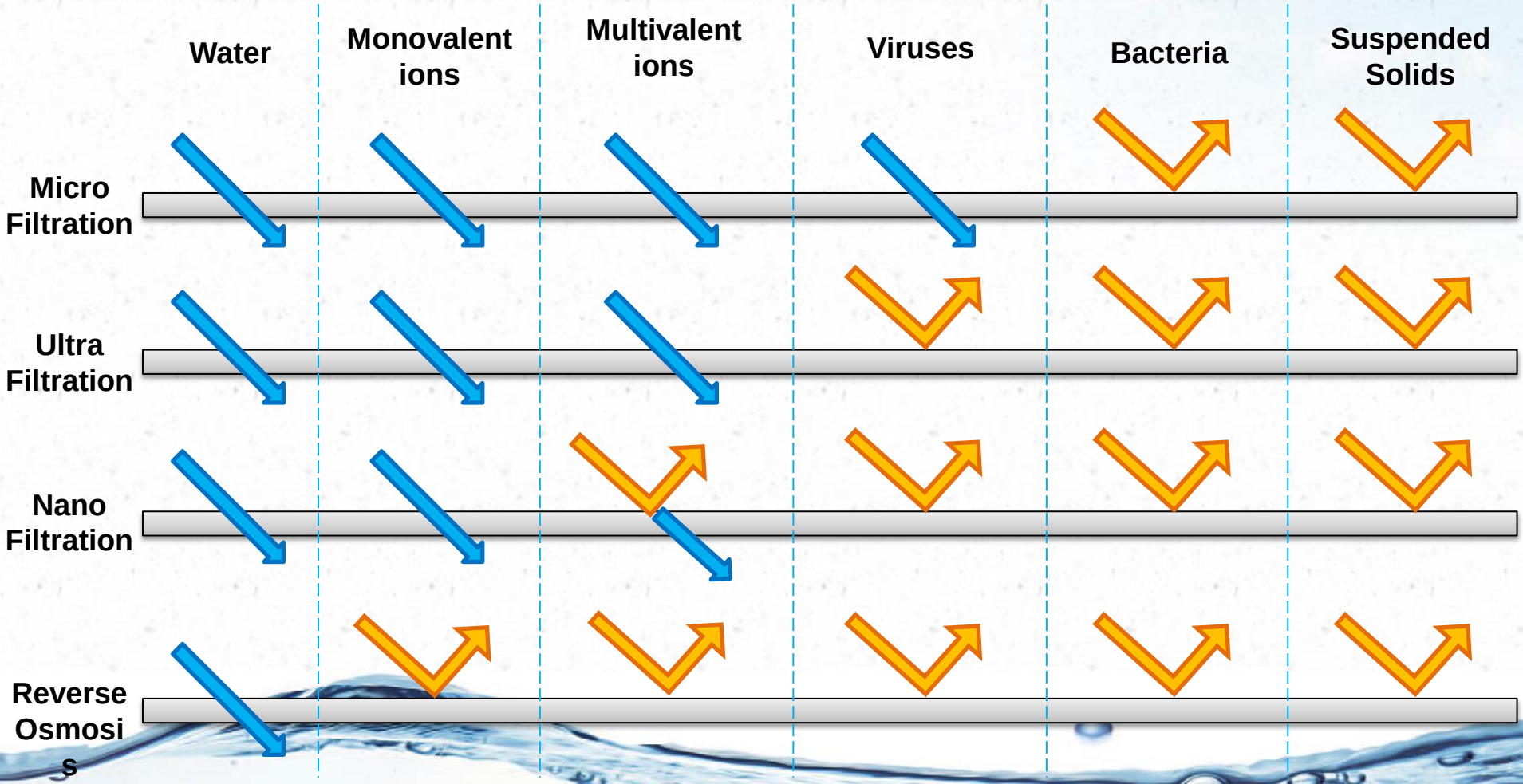




Ref. : http://www.lolopipeline.us

Membrane & Module

Classification according to the Membrane pore size



Ref. : https://reverseosmosispk.wordpress.com/97-2/

Membrane & Module

Classification according to the Membrane module type

Flat sheet

Hollow fiber

Spiral wound module

Classification according to the system

Pressurized system

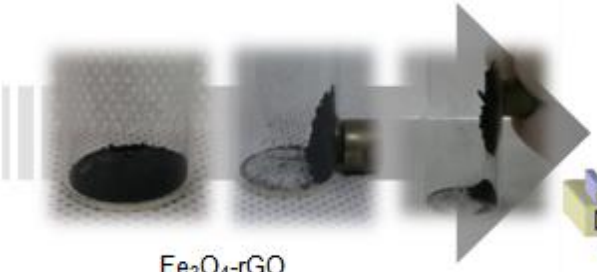
Submerged system

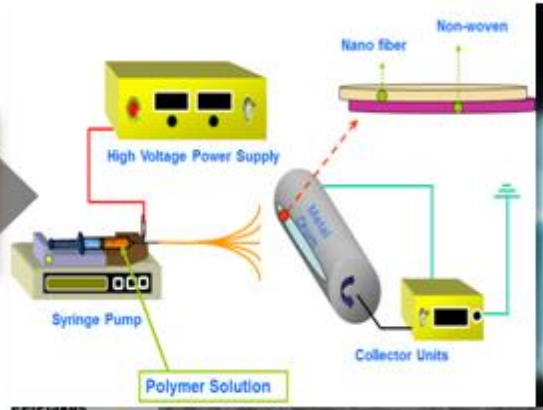
Plate : http://www.tradeindia.com/fp246705/Flat-Plate-MBR-Membrane.html
Spiral : http://www.gewater.com/products/filtration-membranes-sanitary-food-beverage.html
Hollow : http://www.internationaltradenews.com/fibron_ag/portrait/
Pressurized, Submerged : http://www.gewater.com/

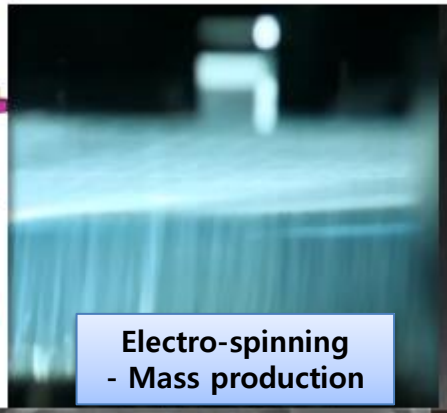
Membrane & Module

Development of next generation membrane and module for water purification

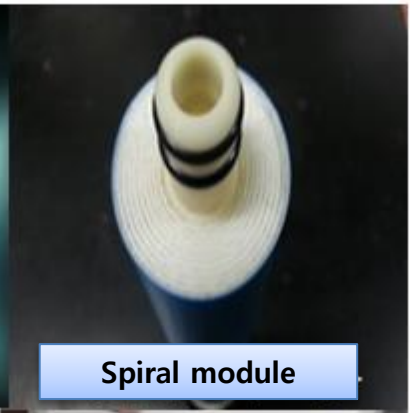
Nano-fiber/Graphene membrane and module



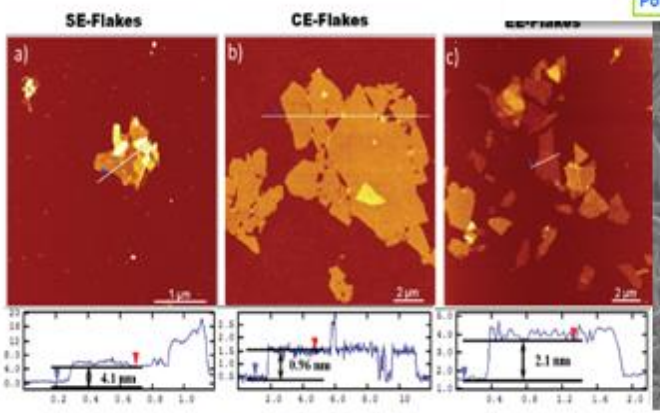




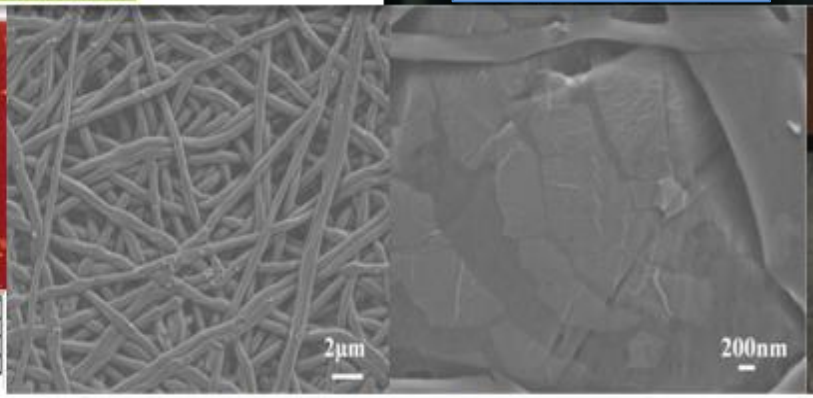
Electro-spinning
- Mass production



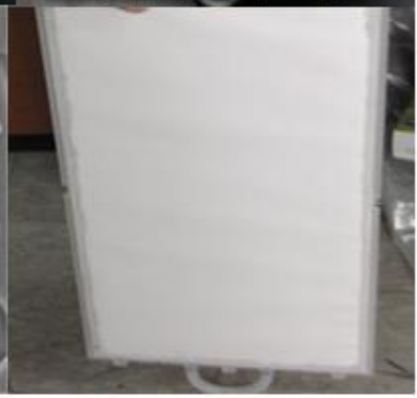
Spiral module



Graphene synthesis



SEM image: Nano-fiber, Graphene Oxide



Flat module

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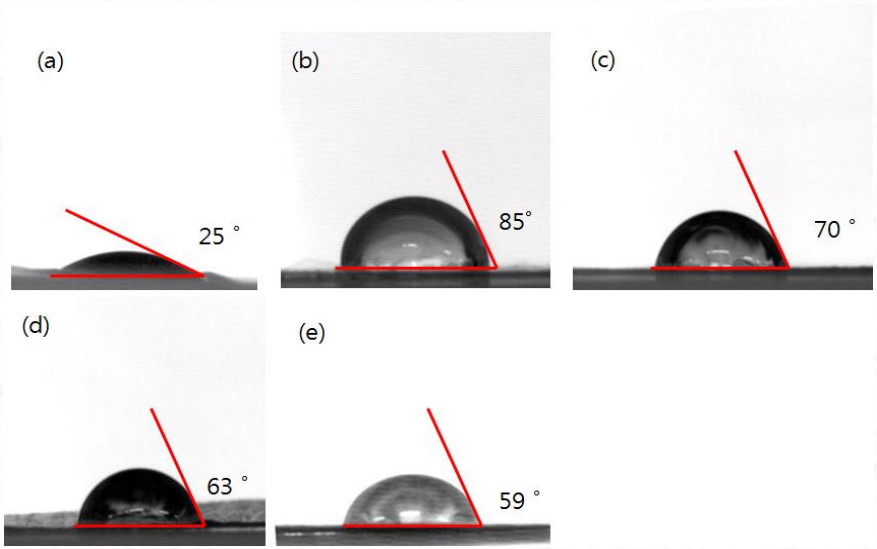
계명대학교 KEIMYUNG UNIVERSITY

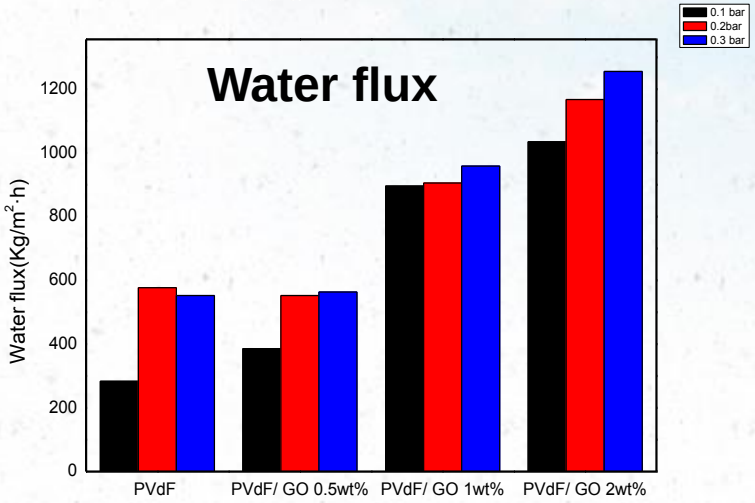
Membrane & Module

Development of next generation membrane and module for water purification

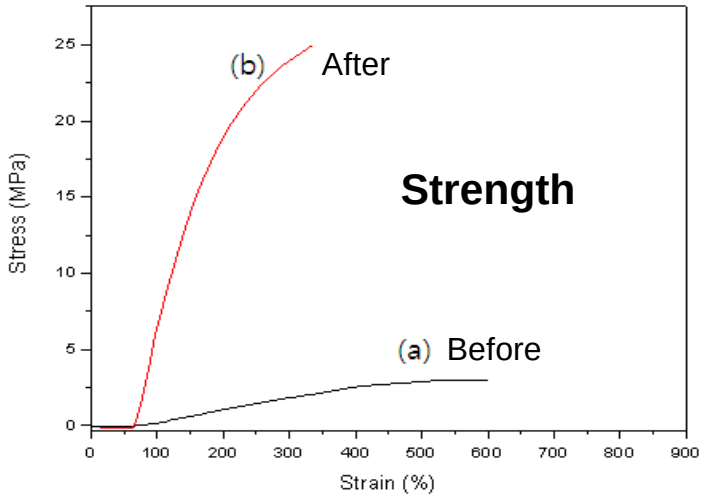
Contact angle



Contact angle measurement; (a) GO sheet (b) PVdF, (c) PVdF/GO 0.5wt% (d) PVdF/GO 1wt% (e) PVdF/GO 2wt% membrane.

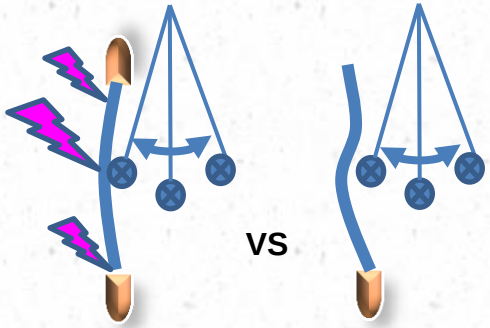


Water-flux test of PVdF and PVdF/GO 0.5wt%,1wt% ,2wt% membrane at 0.1,0.2,0.3bar and 25℃



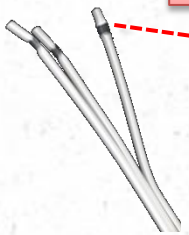
Membrane & Module

Development of membrane and module for treating highly concentrated backwash water

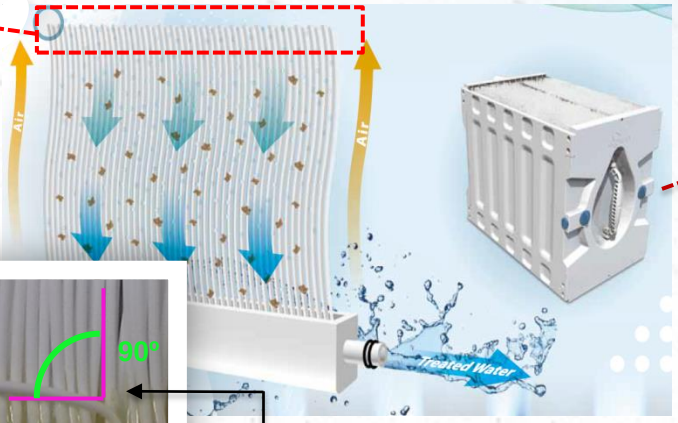


VS

End free

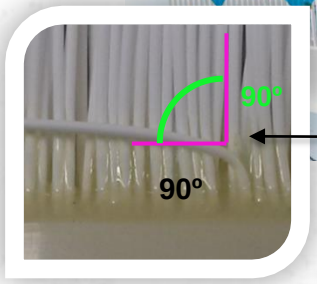


Burst pressure : 7 bar



Double layered-potting

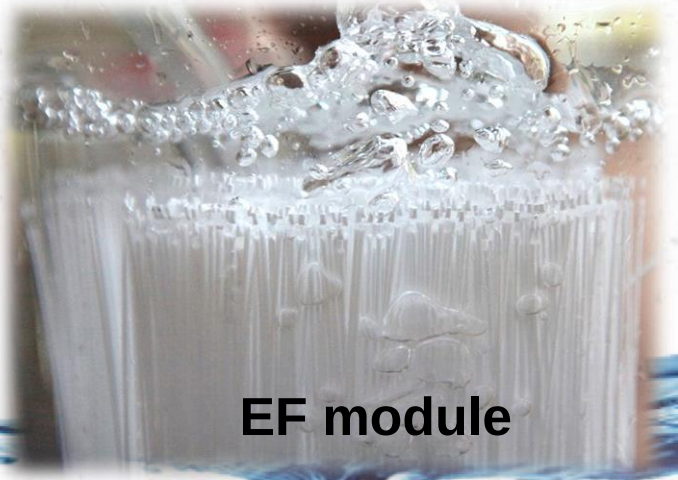
- Enhanced integrity property
- No fiber breakage



No breakage even in bending forcibly

CF- C type (old type)

CF- E type (brand-new)



EF module

Membrane & Module

Development of membrane and module for treating highly concentrated backwash water

CF module vs. New EF module (case study in MBR)

CF Series

HDPE
Double header

16.8 m^2

flux
X 0.4 m/d
X 60 EA

Foot print

400 m^3/d

Scouring air

Continuous air
SADm : 0.23
SADp : 14

0.19 Kwh/m^3

½ Reduced

¼ Reduced

NEW EF Series

PVDF
single header

21 m^2

flux
X 0.6 m/d
X 60 EA

750 m^3/d

Intermittent air
SADm : 0.09
SADp : 3.76

0.05 Kwh/m^3

Membrane-AOP hybrid water treatment process

Multi-Barrier Membrane-AOP Hybrid System for CECs Removal

Test pilot-plant (1,000 m^3/d) at Gangbuk water supply plant

Mixing → **Coagulation** → **MF** → **UV/H_2O_2** → **GAC**

- No Sedimentation Step
- Pressurized-submerged membrane combined system
  - ⇨ flexible for water quality
  - ⇨ maximize recovery rate

- Evaluation and selection for optimal process
- Optimization of each process

- Adsorption of incomplete degradation products

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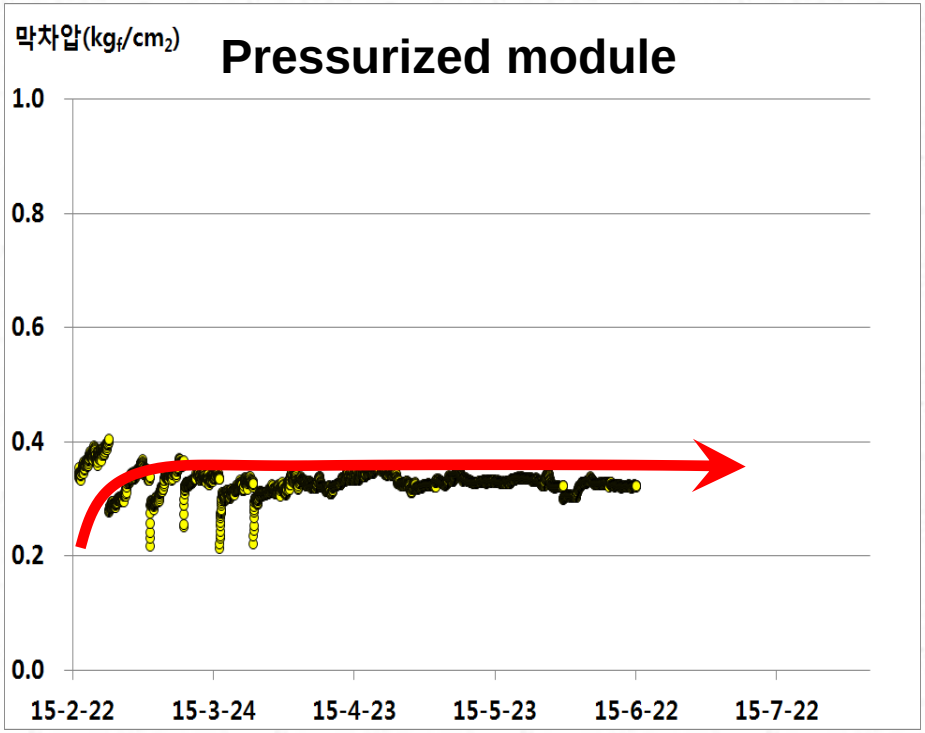
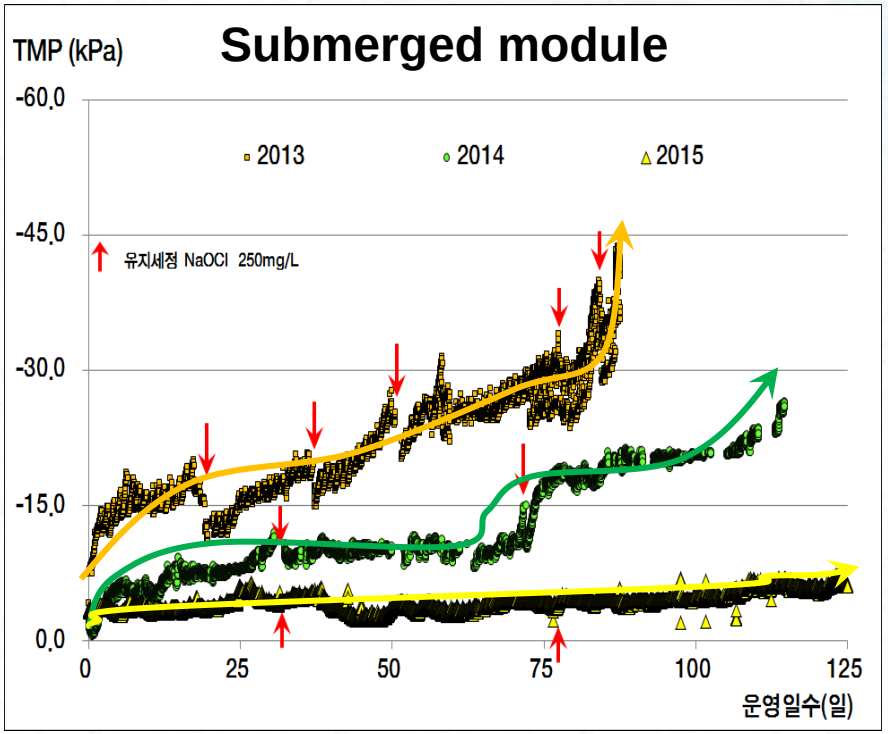
Membrane-AOP hybrid water treatment process

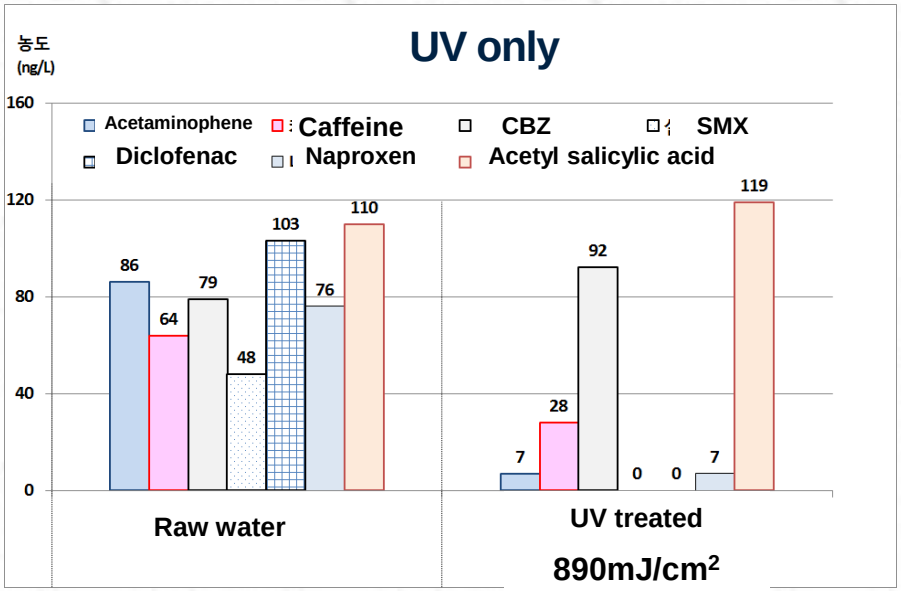
Operation of pressurized and submerged membrane systems

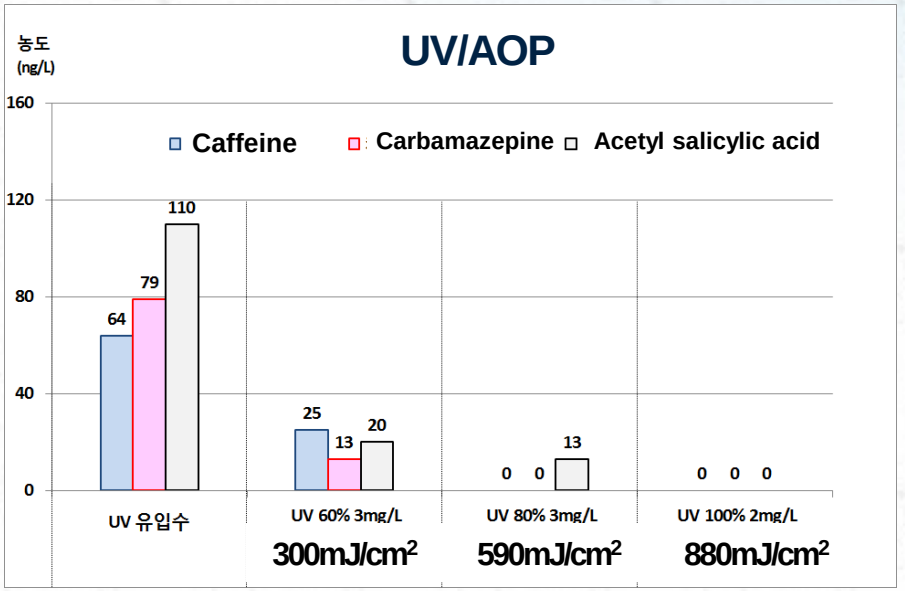




Membrane-AOP hybrid water treatment process

Removal of CECs (Contaminants of Emerging Concerns) by UV and UV/AOP processes

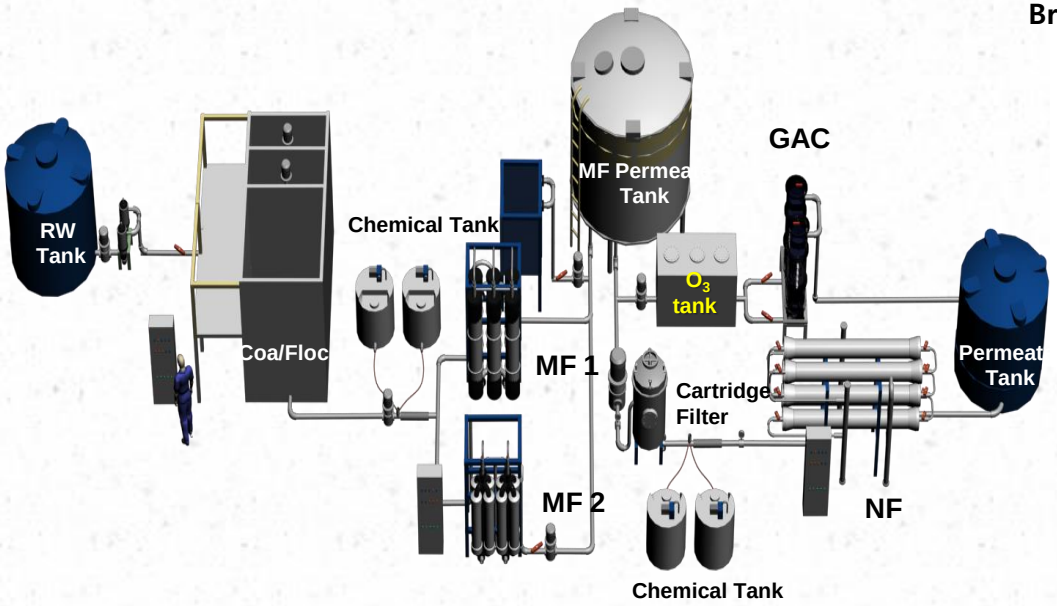


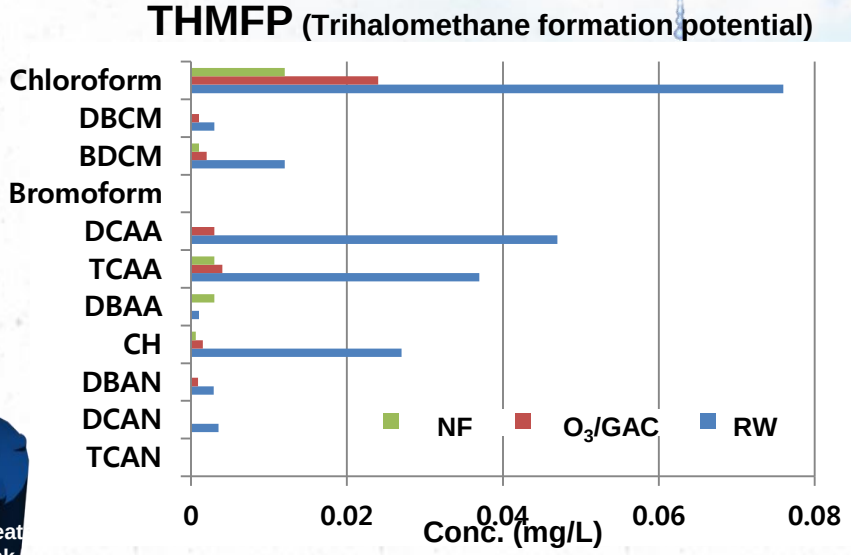


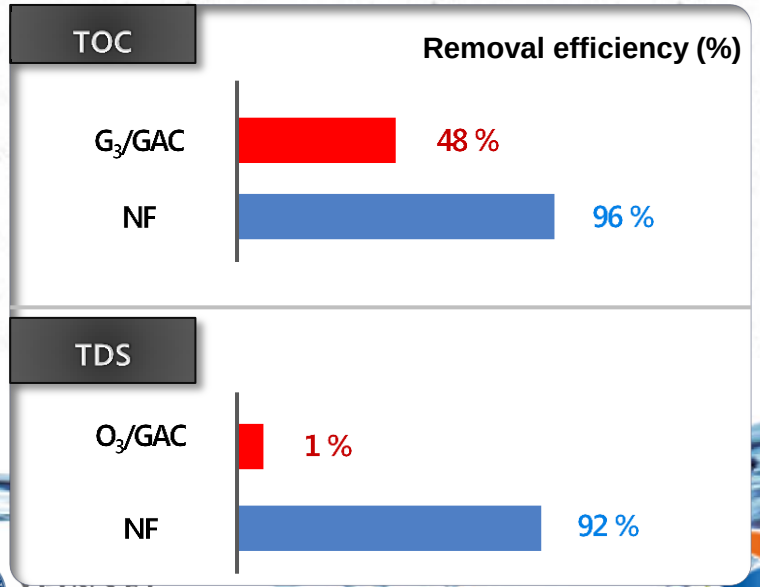
SMX: Sulfamethoxazole
CBZ: Carbamazepine

Membrane-AOP hybrid water treatment process

Removal of organic matters by NF and O_3/GAC







DBCM : Dibromochloromethane
BDCM : Bromodichloromethane
DCAA : Dichloroacetic acid
TACC : Trichloroacetic acid

DBAA : Dibromoacetic acid
CH: Chloral hydrate
DBAN : Dibromoacetyl nitrile
DCAN : Dichloroacetyl nitrile
TCAN : Trichloroacetyl nitrile


Global Top
SWS
Eco-Smart
Waterworks
System
III. Appropriate Technology for drinking water in developing countries

Appropriate technology for drinking water in developing countries

MDGs (Millennium Development Goals)

Target 7 Ensure environmental sustainability

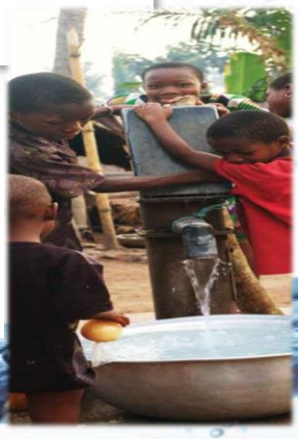
Target 7.C: Halve by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation

SDGs (Sustainable Development Goals)

Goal 6. Ensure access to water and sanitation for all

- By 2030, achieve universal and equitable access to safe and affordable drinking water for all

- By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programs, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies



- 2.6 billion people have gained access to improved drinking water sources since 1990, but 663 million people are still without.
- At least 1.8 billion people globally use a source of drinking water that is fecally contaminated.

Appropriate technology for drinking water in developing countries

Appropriate Technology

- Less than 10 USD per year per household
- 4 liter of biologically safe water per Cap.

- Easy to operate
- No electricity requirement
- No recurring costs
- Effective against bacteria
- Easy scalability
- Easy to increase operation Flux by syphon

Appropriate technology for drinking water in developing countries

Appropriate technologies for water treatment

Ceramic water filter

Lifestraw

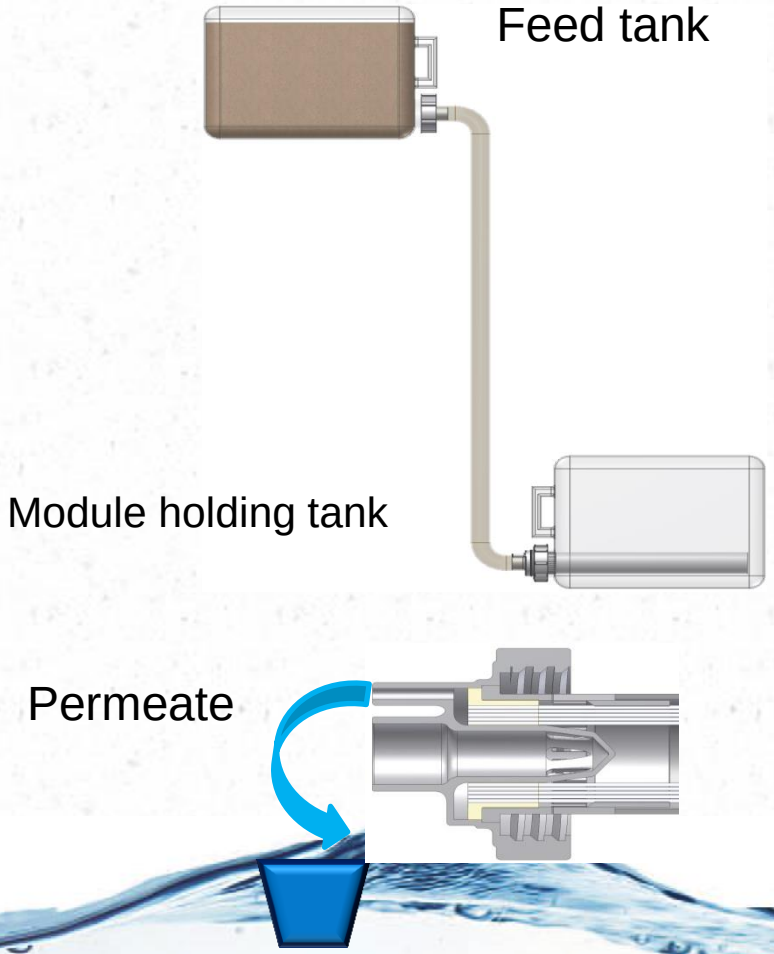
Lifesaver Bottle

GDM (Gravity Driven Membrane) system

Life Sack

Appropriate technology for drinking water in developing countries

YGDM (Yonsei Gravity Driven Membrane) system



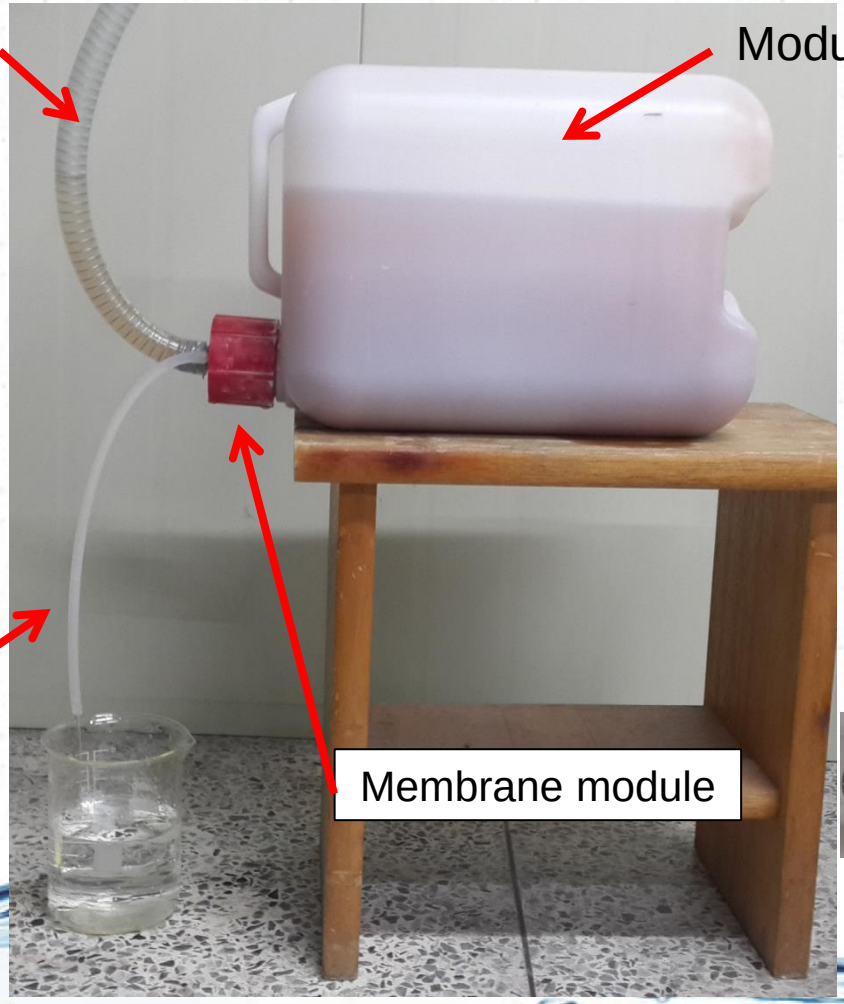
Household module

❖ **Module spec**

- Driving force : gravity
- Membrane area : 0.51 m^2
- Production : 30 L/d

Appropriate technology for drinking water in developing countries

YGDM (Yonsei Gravity Driven Membrane) system



Appropriate technology for drinking water in developing countries

YGDM (Yonsei Gravity Driven Membrane) system

YGDM in Cambodia

Feed tank

Module holding tank

Permeate

YGDM in Indonesia

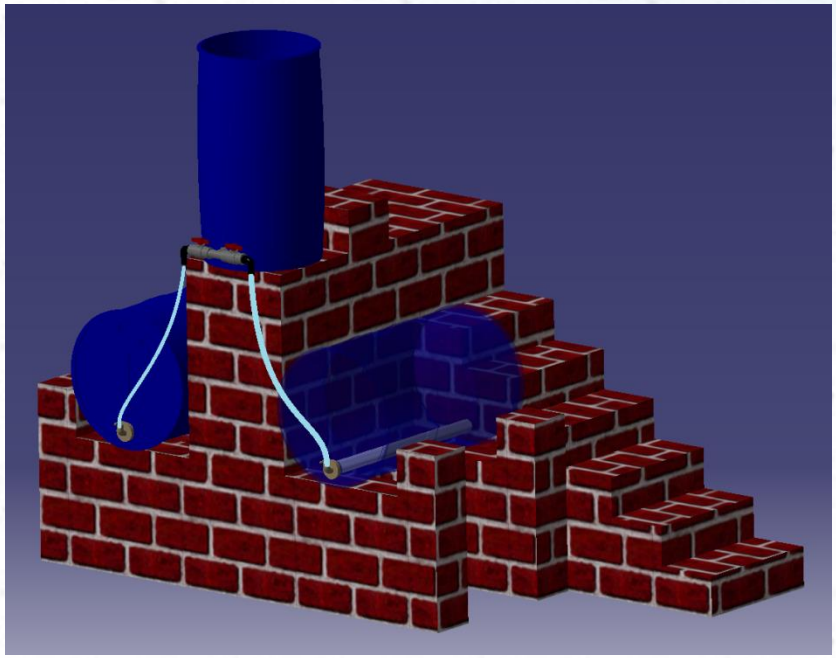
Appropriate technology for drinking water in developing countries

YGDM (Yonsei Gravity Driven Membrane) system

School type

❖ **Module spec**

- Driving force : gravity
- Membrane area : 5.2m^2
- Capacity : 130L
- **Production : 13L/hr**



Appropriate technology for drinking water in developing countries

YGDM in Tanzania

Conclusions

- Membranes are key processes for water treatment.
- Development of new membrane and module having high mechanical strength, low fouling and economic feasibility is required.
- Membranes are essential for an appropriate technology (e.g. YGDM) for drinking water in developing countries.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Thank you!