Final MBR-Network Workshop

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

Presentation handouts

31 March – 1 April, Berlin 2009 (Germany)

Hosted by KOMPETENZZENTRUM Wasser Berlin

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44. SUBMERGED MBR TECHNOLOGY: AN UNFINISHED INTERNATIONAL ADVENTURE OF 20 YEARS

K. Yamamoto

Submerged MBR Technology:

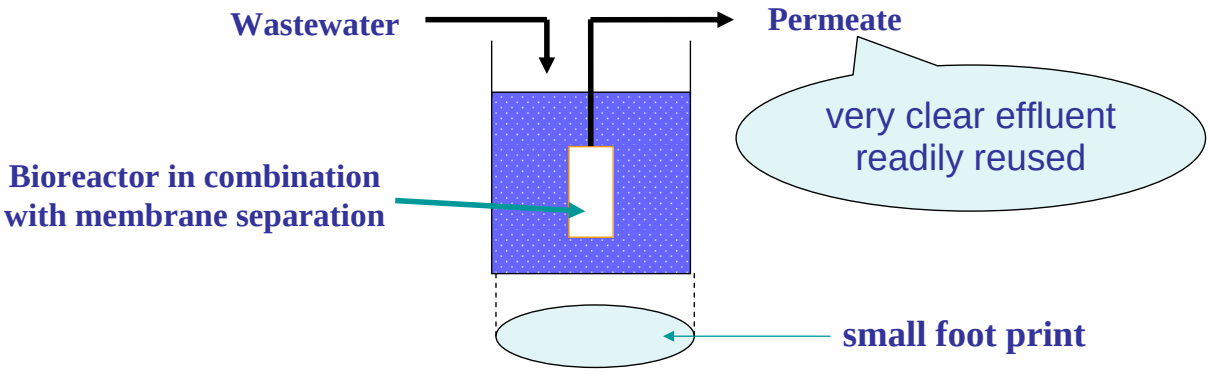
an unfinished adventure of 20 years

Kazuo Yamamoto
Environmental Science Center
The University of Tokyo

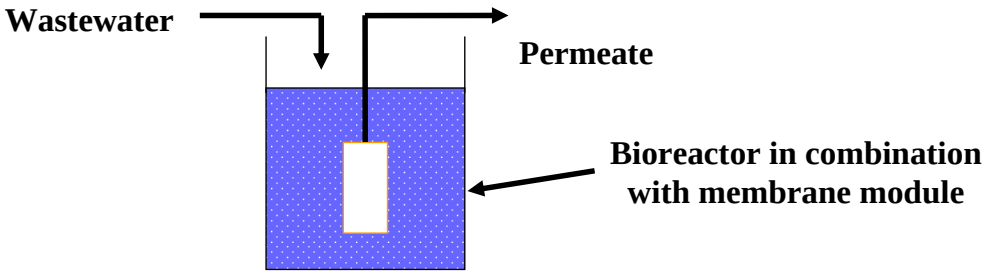
Membrane Bioreactor (MBR) is

recognized as a leading edge technology for wastewater treatment and reclamation.

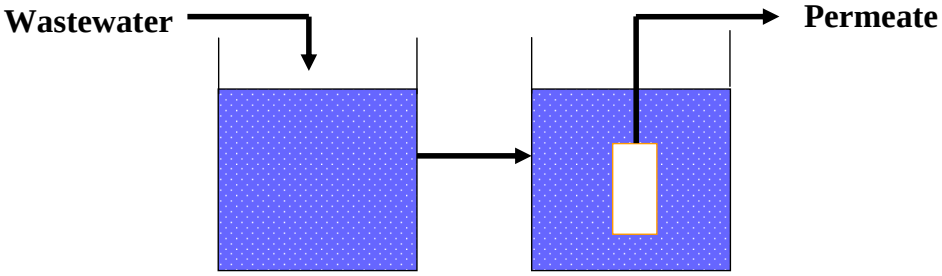
- ***Submerged MBR***



■ **submerged (integrated type)**



■ **submerged (separate type)**



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Membrane Technology

Pressure-driven processes

MF (Microfiltration)
UF (Ultrafiltration)
NF (Nanofiltration)
RO (Reverse Osmosis)

Other Membrane Processes

Dialysis
Electro dialysis
Pervaporation
Membrane distillation

MBR

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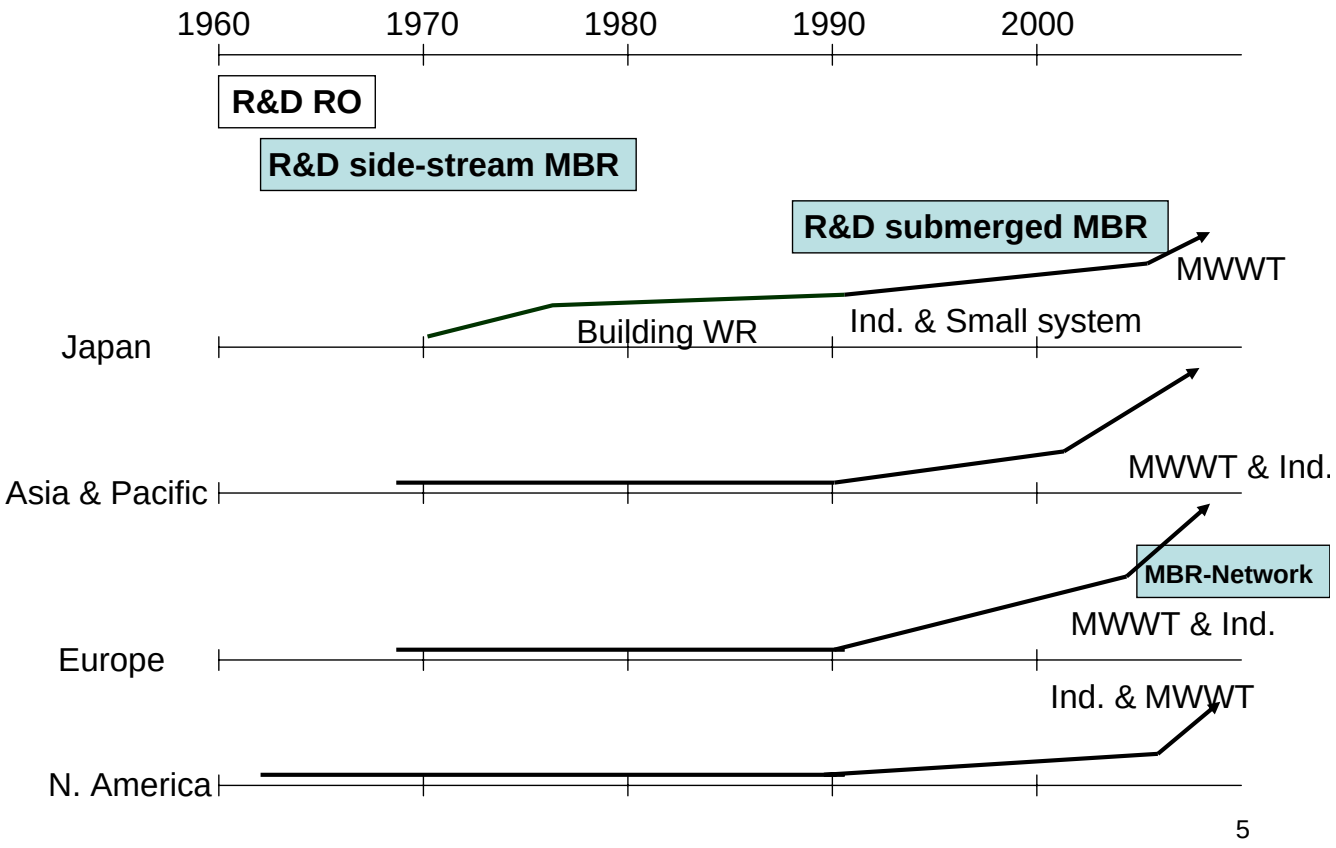

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Final MBR-Network Workshop
Recent progress in membrane research

- Better understanding of TMP jump (Prof. Tony Fane) CP effect even in MF!
- Potential of quantum leap progress to befouling control (Prof. Chung-Hak Lee) Quorum Sensing/quenching
- Many MBR-Network findings shown in this workshop for better understanding of fouling phenomena, monitoring methods and control technologies, standardization, and novel process design (BF-MBR, Hybrid MBR-CAS concepts and so on)
- *Unfinished adventures!*

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Final MBR-Network Workshop
Recent progress in membrane research

- Novel European MBR Technologies, such as
- Immen
- FiSh
- A3 Multimodule
- Puron modules (2nd generation)
- Vacuum Rotation Membrane
- Integrated BF-MBR with energy recovery
- Anaerobic Baffled Reactor – MBR combination,

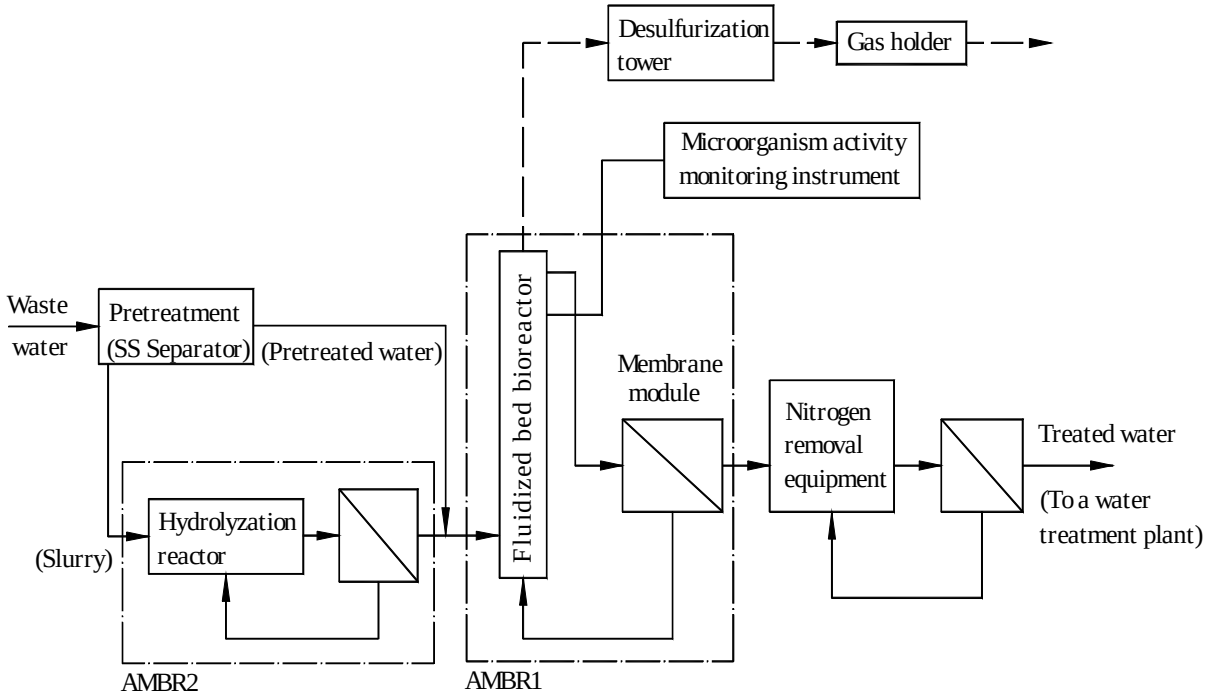
achieve a significant reduction of energy consumption.

Congratulations!

Personal adventure

- 1970's Building reuse system, (Side stream UF MBR)
- 1980's Aqua-Renaissance Project, (Side stream UF & MF and anaerobic MBR)

The "Aqua Renaissance ' 90" project
Flow Scheme of a Field Test Unit for Small-scale Sewage Treatment



(adapted from 'Fujita, Y., Ogasawara, H., Fujioka, T. (1991) Research on development of a small-scale sewage treatment plant: Bench scale investigation. *Journal of water re-use technology*, (17-3): 26-35; *In Japanese'*)

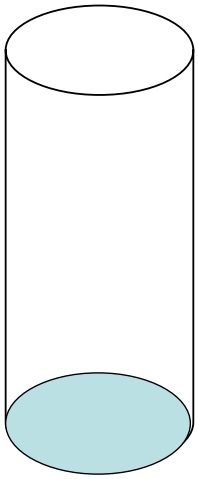
Personal adventure

- 1970's Building reuse system, (Side stream UF MBR)
- 1980's Aqua-Renaissance Project, (Side stream UF & MF and anaerobic MBR)

- 1984 Start laboratory side-stream UF & MF MBR experiments
- 1985 Start submerged MF MBR

1984 Start laboratory side-stream UF & MF MBR experiments

- Commercially available side stream modules were too big for laboratory MBR set-up.
- Commercially available dead-end filtration type modules could not be used for a MBR operation, because the surface area of membrane was too small.



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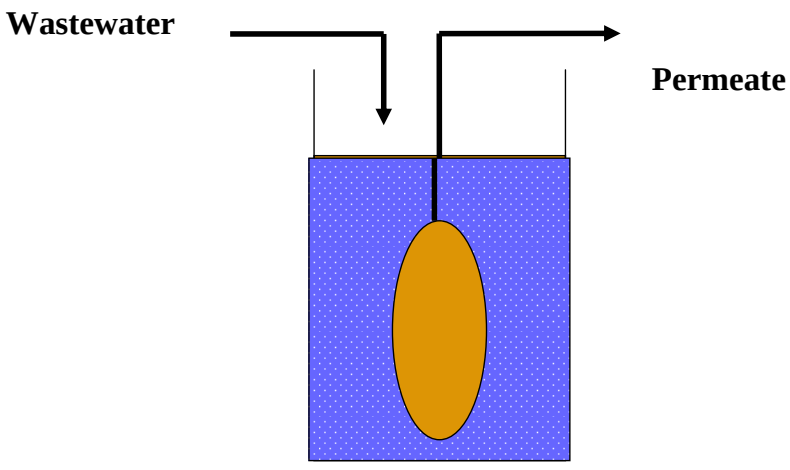
■ **trials** **Continuous filtration**



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Yamamoto,K., Hiasa,M., Mahmood,T. and Matsuo,T.(1989), Direct solid liquid separation using hollow fiber membrane in an activated sludge aeration tank, Water Science and Technology, Vol.21, No.4-5, 43-54.

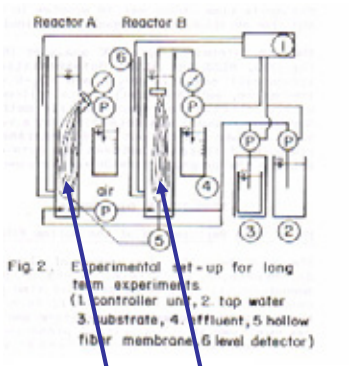


Fig 2. Experimental set-up for long term experiments (1. controller unit, 2. tap water 3. substrate, 4. effluent, 5 hollow fiber membrane, 6 level detector)

A Polyethylene hollow fiber module was directly immersed in an aeration tank

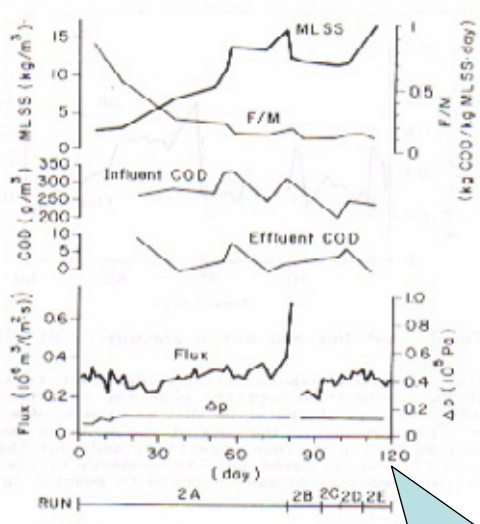


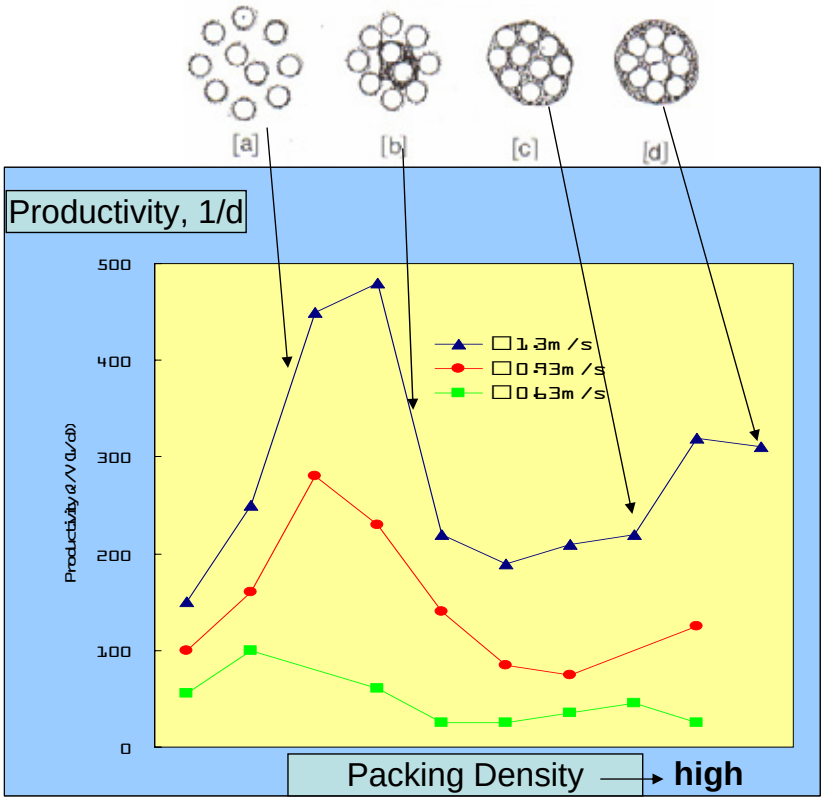
Fig. 7 Operating data in run 2

Slow process operation (Intermittent filtration, low flux, low pressure, low loading and so on) gave a stable performance without sludge wastage.

Yamamoto,K. and Win,K.M.(1991), Tannery wastewater treatment using a sequencing batch membrane reactor, Water Science and Technology, Vol.23, No.7-9,1639-1648.

However, this was just a fundamental research that had shown the concept and potential feasibility of submerged MBR. We needed to wait R&D by MBR industries to make the submerged MBR practically applied, such as
Zenon, Kubota, and Mitsubishi Rayon especially in 1990's.

Wong,Y.K., Yamamoto,K. and Ohgaki,S.(1992), Optimal fiber spacing in externally pressurized hollow fiber module for solid liquid separation, Water Science and Technology, Vol.26,No.5-6,1245-1254.



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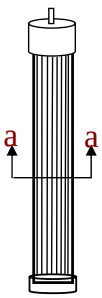
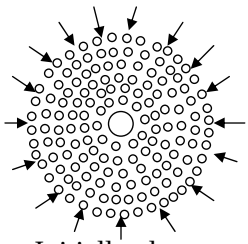
Hollow fiber with spacer

Usual hollow-fiber module

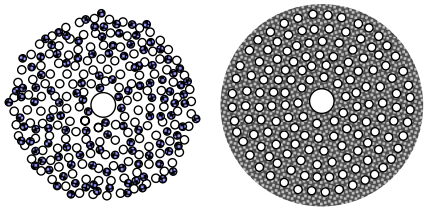


Mixed liquor in-flow

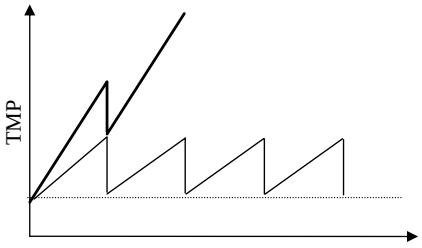


Initially clean

[Section a-a]

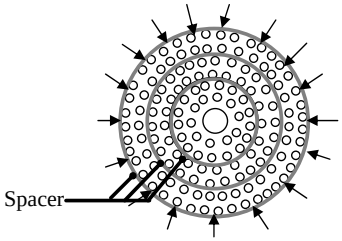


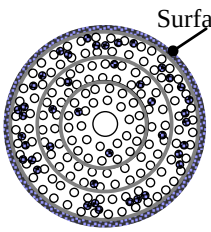
Progressive sludge intrusion



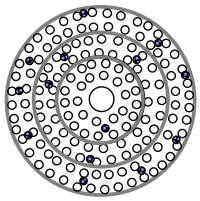
Cleaning attempts: Case-specific success

Hollow-fiber module with spacer



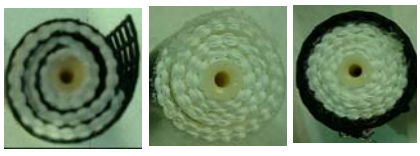


Limited intrusion



•Chemical backwash

•Air-scouring of surface



Unfinished adventure

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submerged NF-MBR

Pressure-driven processes

MF (Microfiltration)
UF (Ultrafiltration)
NF (Nanofiltration)
RO (Reverse Osmosis)

Other Membrane Processes

Dialysis
Electro dialysis
Pervaporation
Membrane distillation

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- **NF-MBR**

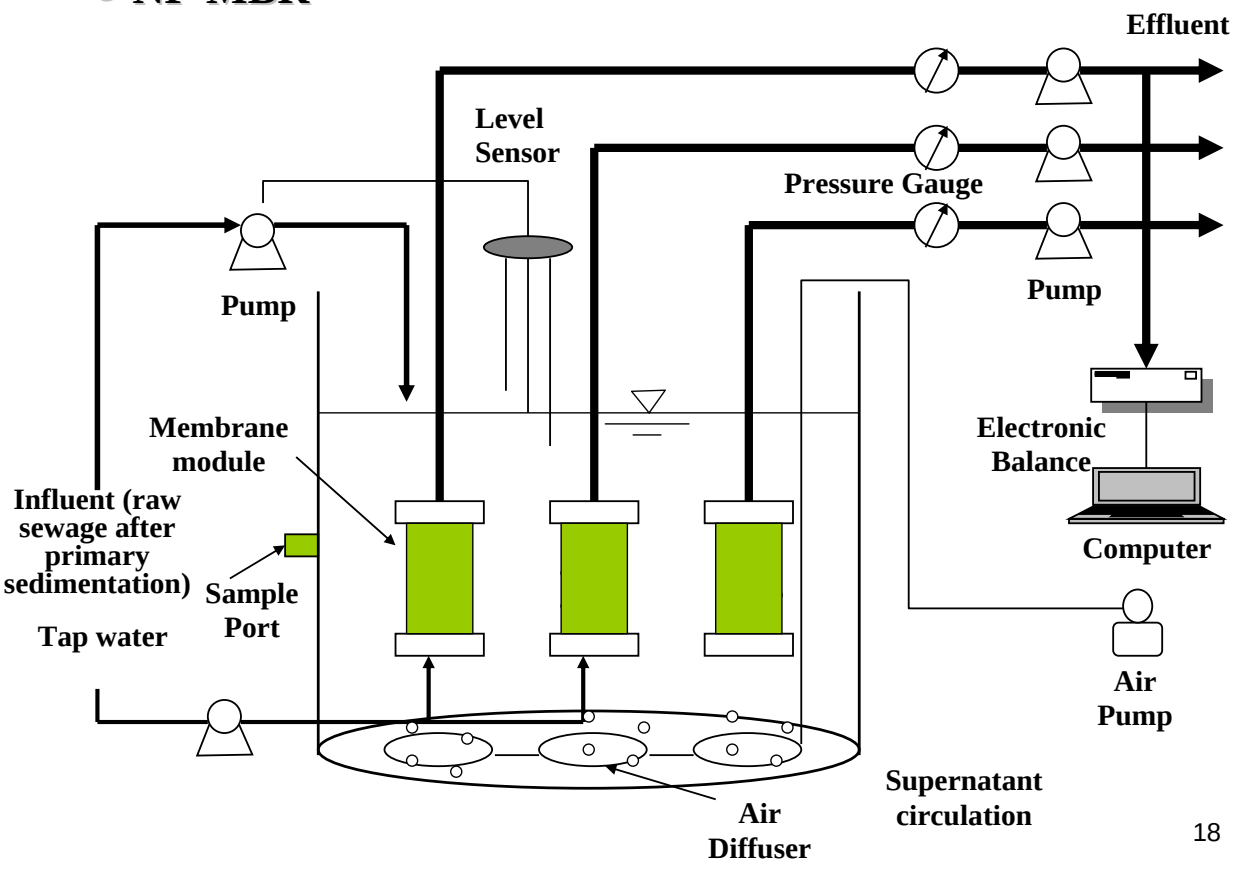

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Table 1
Properties of the cellulose acetate NF membrane module

Item	NF membrane
Membrane configuration	U-shaped hollow-fiber
Outer and inner diameter (μm)	177 and 86, respectively
Number of hollow-fiber/module	81,000
Membrane fiber length (mm)	270
Salt rejection[a] (%)	94
Pure water permeability[b] (L/m^2 h kPa)	0.0028

[a] The information on salt rejection was obtained from the membrane manufacturer (test conditions; (1) pressure-driven mode, (2) target: 500 mg/L NaCl solution, (3) operating pressure: 0.98 MPa, (4) temperature: 25 °C, (5) recovery

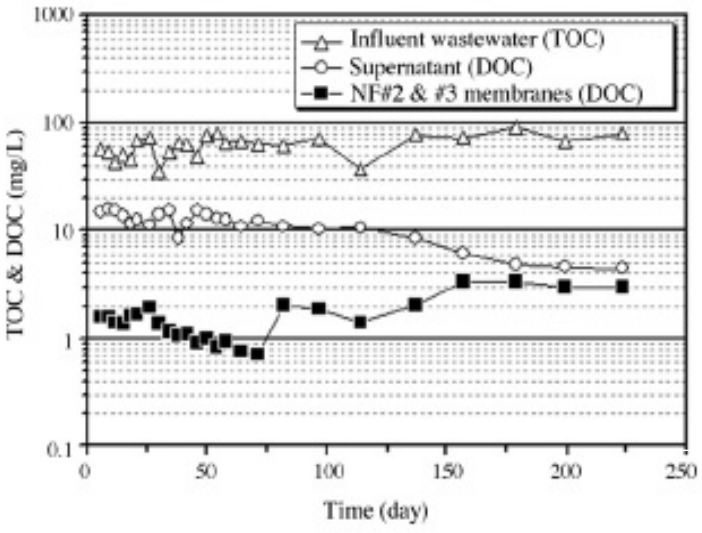

Fig. 1. Evolution of TOC and DOC concentrations in the waters from the NF MBR.

We still need nano-structure designed NF. *unfinished adventure*

(J.H.Choi et al., Separation and Purification Technology, 52(2007),470-477)

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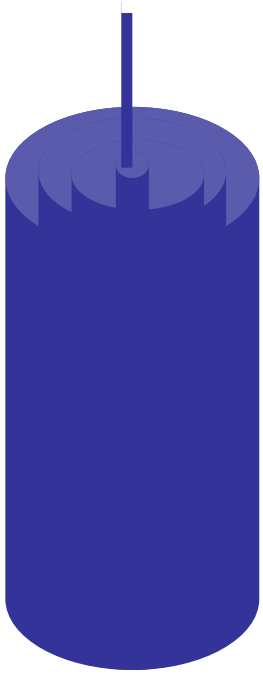
If a properly designed module is developed,



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If a properly designed module is developed,

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If a properly designed module is developed,

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If a properly designed module is developed, waste minimization will be achieved!

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Towards Next Generation of MBR

unfinished adventure

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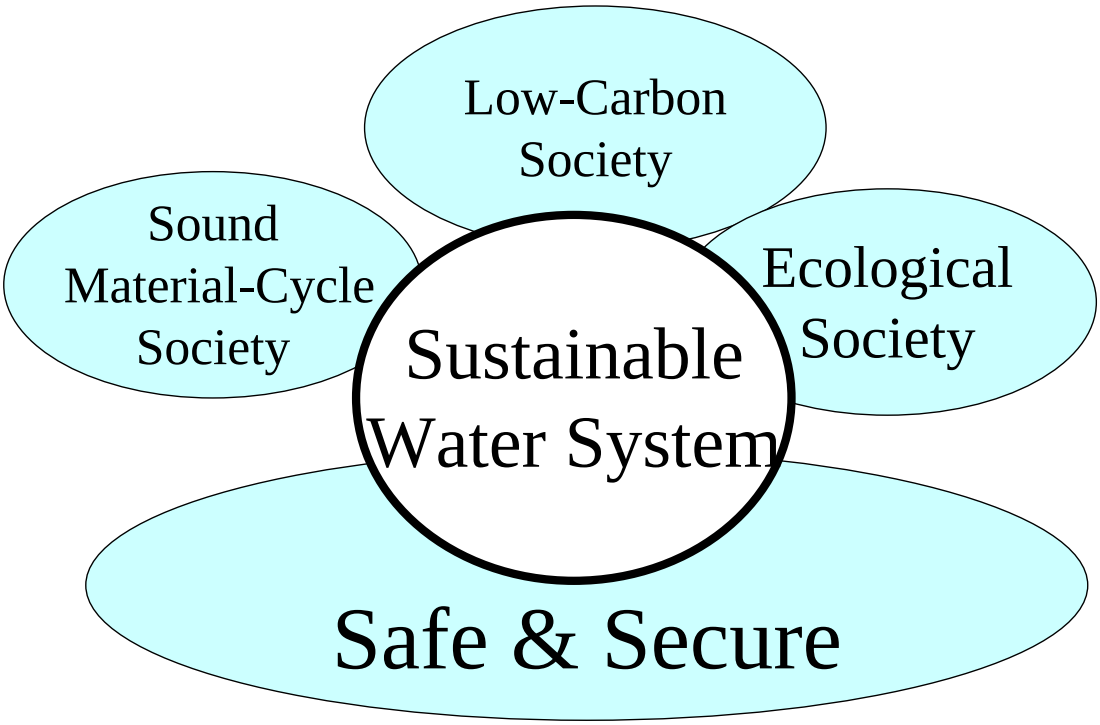
Advantages of MBR

MBR is recognized as an advanced treatment technology to get high quality effluent.

- Because of its hybrid nature

  designed microbial activity + selective physical barrier
- Considering MF, the center key of the technology is ‘complete removal of Suspended Solids (SS) ‘.
- This makes a variety of combination of technologies to get a desired level of reclaimed water quality, i.e. MBR-UV, MBR-AC, AC/MBR, MBR-RO and so on.

Sustainable Water System



Change of the concept of ‘Advanced treatment’ in the context of sustainable water system

a coupling technology of water production of required quality and material conversion from waste.

Required quality does not always mean ‘high quality’. Quality comes from necessity. **Membrane technology has potential to be an on-demand quality distributor just by separation.**

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Three types of advanced wastewater treatment

Depending on the weights for three aspects of sustainable society, i.e.

Sound material cycle society ,

Low carbon society, and

Ecological society, the following are classified

- Material productive
- Energy efficient (or productive)
- Ecological oriented

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MBR contribution to Advanced Treatment

MBR is characterized as a compact process, i.e. a reclaimed-water factory.

MBR is easily adapted to the technology

- Material productive and
- Energy efficient

However, presently available MBR technologies are still large energy eaters.

We must develop Advanced MBR - Next generation MBR -

Significant reduction of aeration requirement.

➔e.g. Compact module design & Sludge concentration control

Coupling renewable energy source

➔e.g. Add other organic wastes & combine anaerobic digestion process for methane recovery.

Urban Biomass as Renewable Energy Source

change of the concept

from 'organic wastewater treatment' to 'water/biomass production'

by developing next generation of MBR

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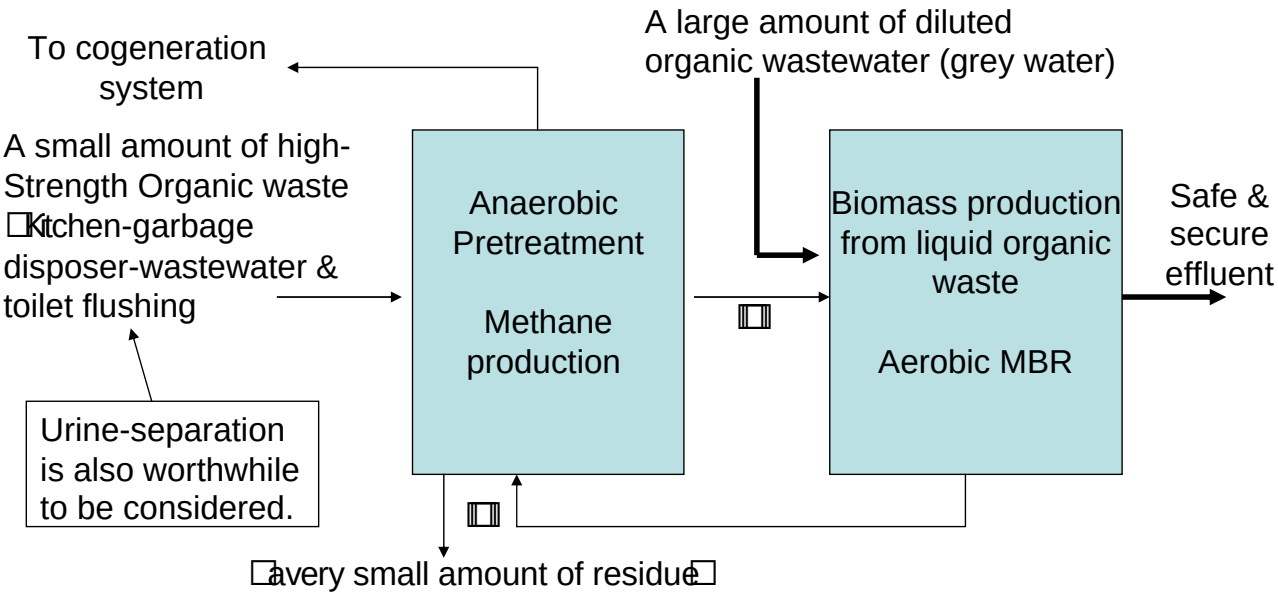
Anaerobic combination for on-site advanced MBR (small system)



Other renewable energy utilization
IT-base maintenance service system
User participation in monitoring

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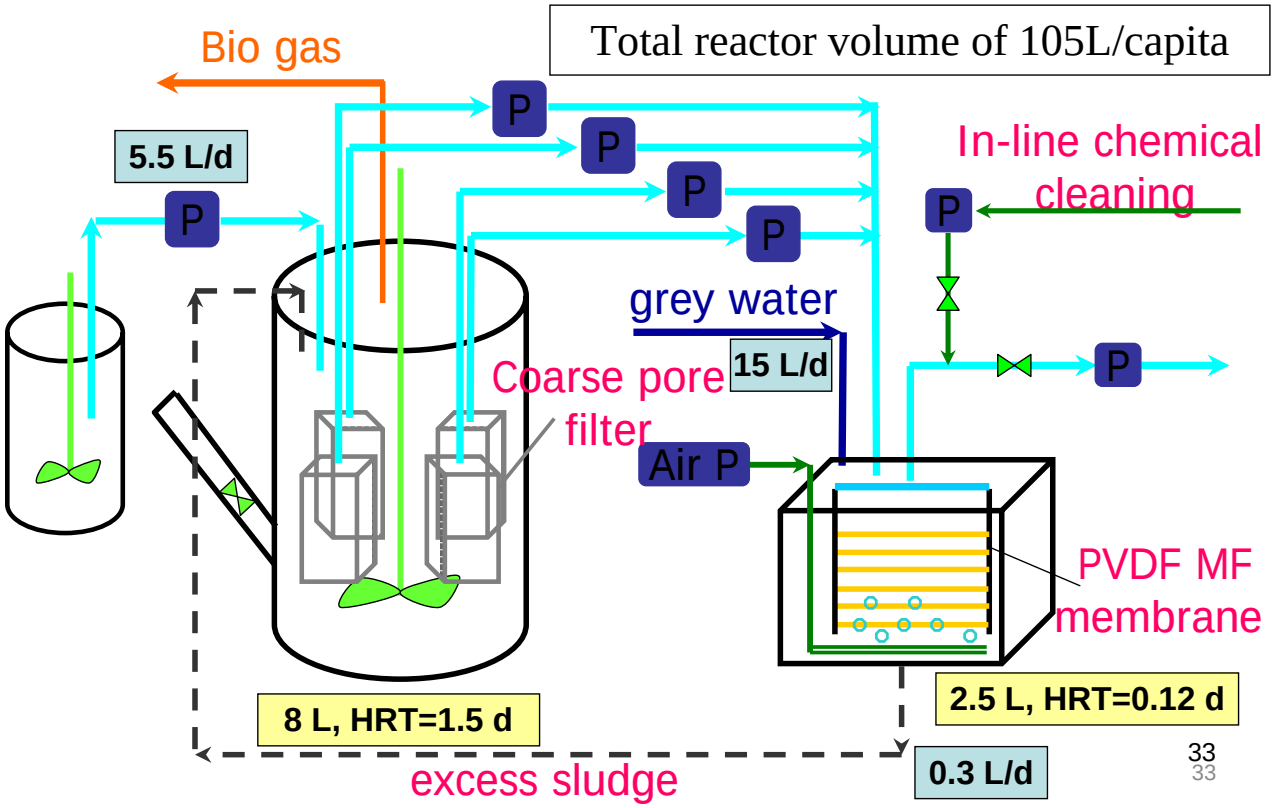
Laboratory-scale anaerobic-aerobic MBR (0.1 p.e.)



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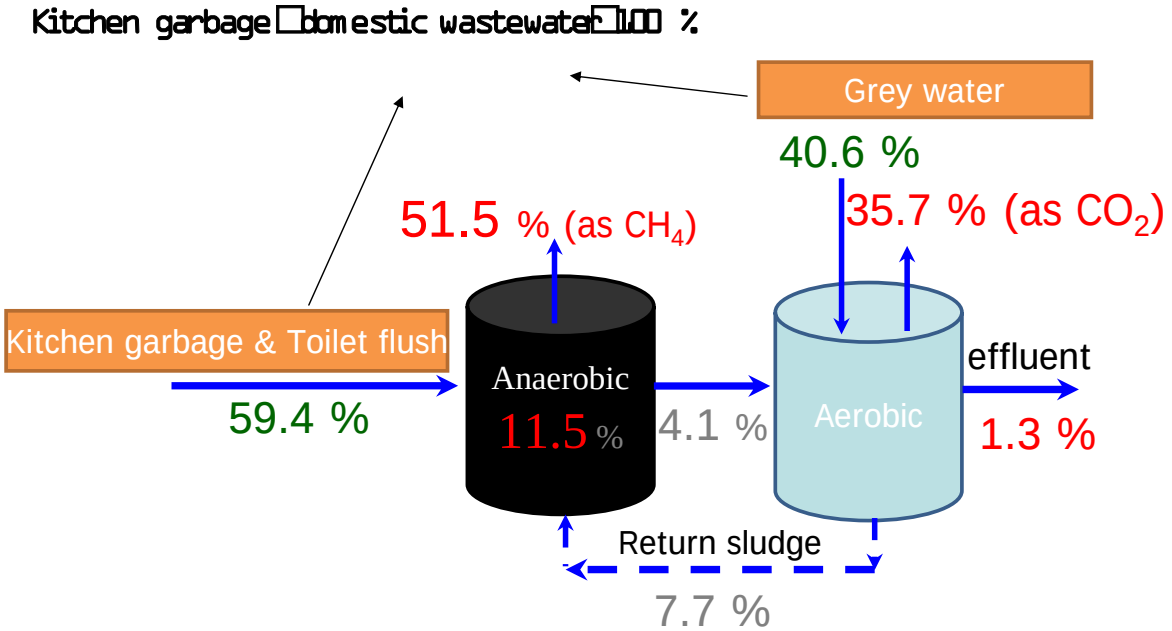
COD-base mass balance



(Grant-in-Aid Scientific Research (S) No.17106007, JSPS)

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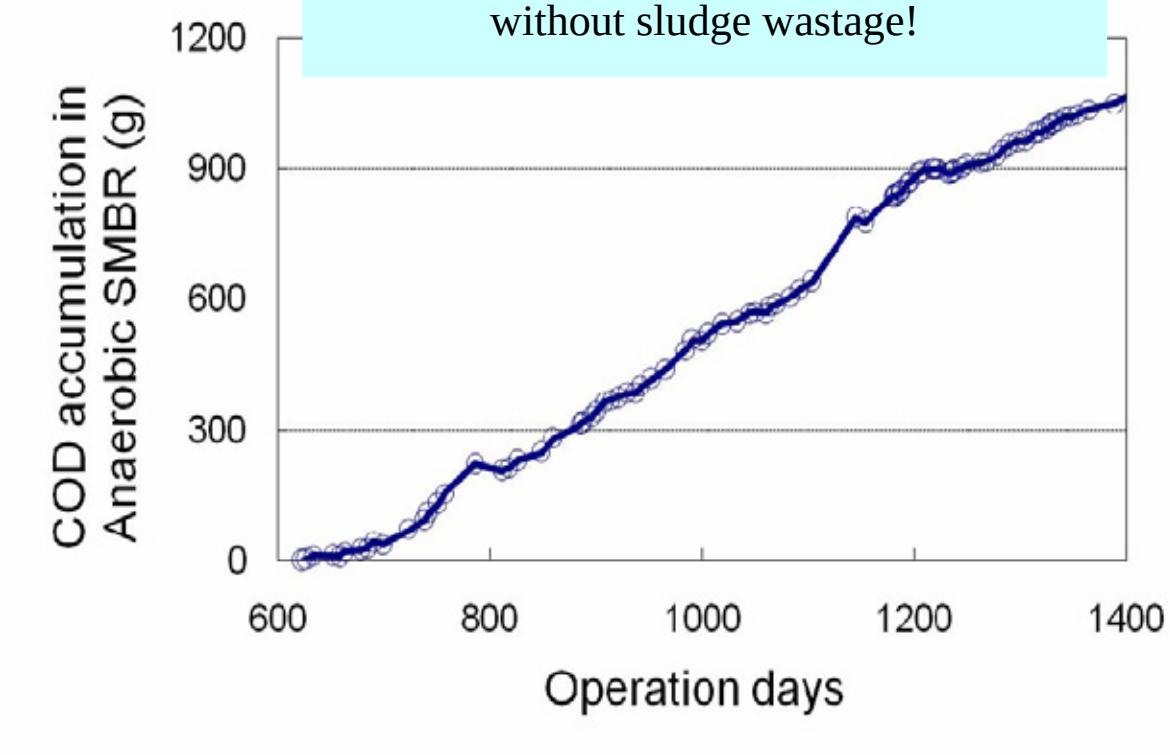
Stably operated without any cleaning without sludge wastage!



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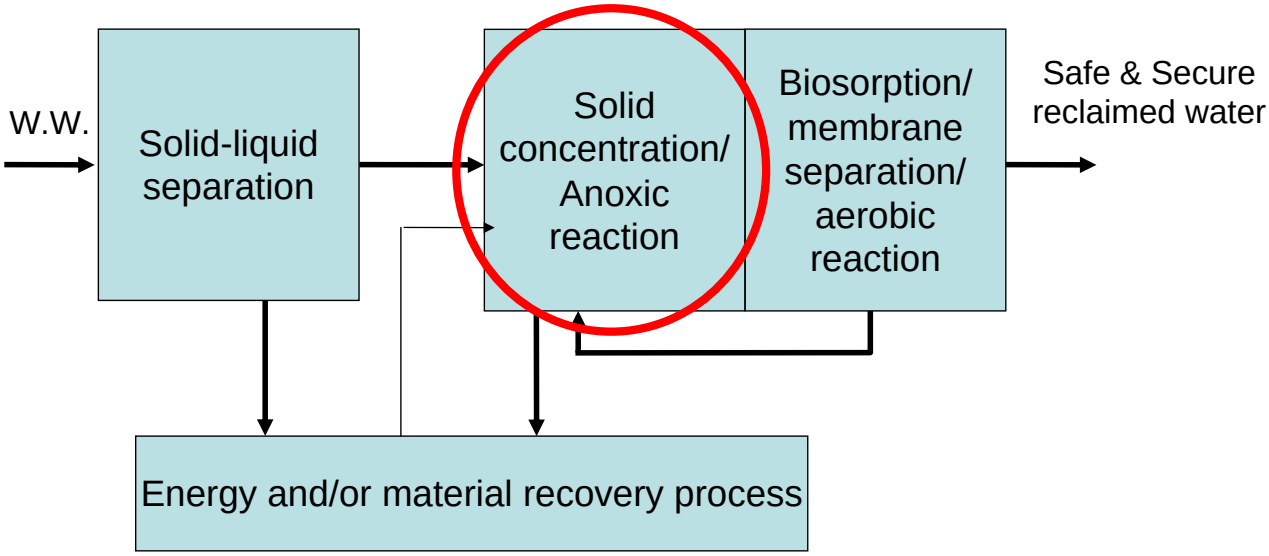
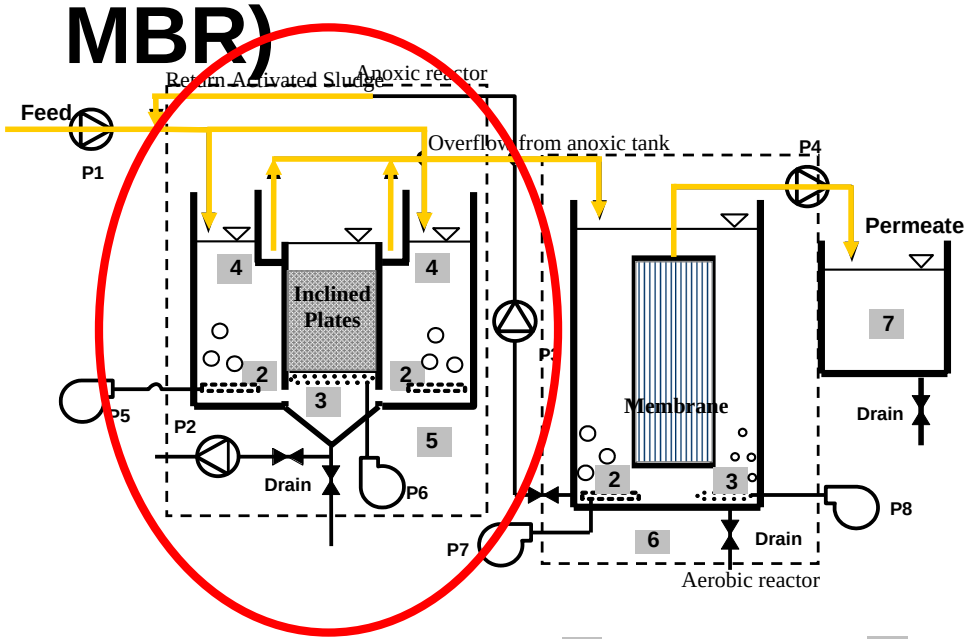
Another example of Advanced MBR (Renovation of existing wastewater treatment plants)



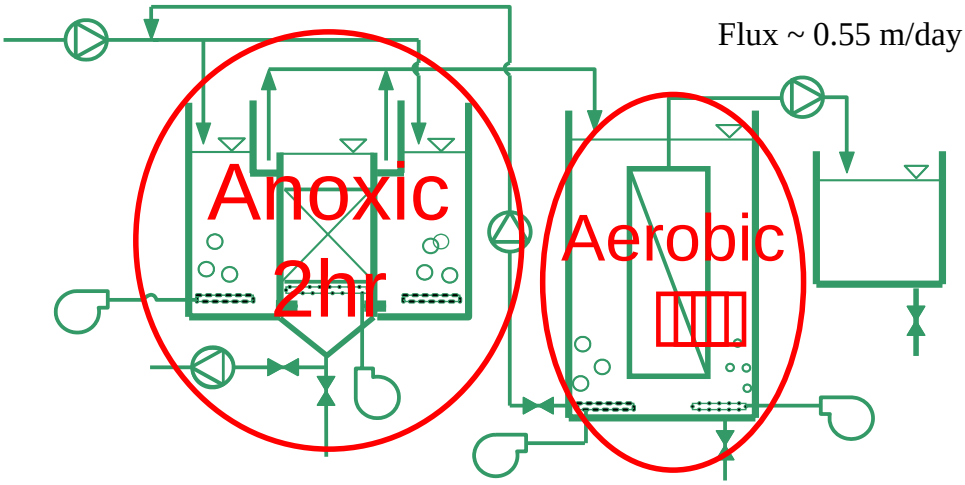
Other than biogas production, physicochemical treatments are also candidates for energy recovery, e.g., supercritical water gasification of sludge-water mixture where the biomass sludge is utilized as energy source to produce hydrogen from water molecules (coupling clean energy production).

iPMBR (inclined-plate MBR)



P1:	Feed Pump	**P5:**	Air Pump for Degasing	1	Inclined Plates	5	Anoxic Reactor
P2:	Anoxic Sludge Pump	**P6:**	Air Pump for Blowing	2	Coarse Bubble Diffuser	6	Aerobic Reactor
P3:	Return Sludge Pump	**P7:**	Air Pump for Scouring	3	Fine Bubble Aerator	7	Permeate Tank
P4:	Permeate Pump	**P8:**	Air Pump for Oxygenating	4	Double-sided Weir	8	Membrane Module

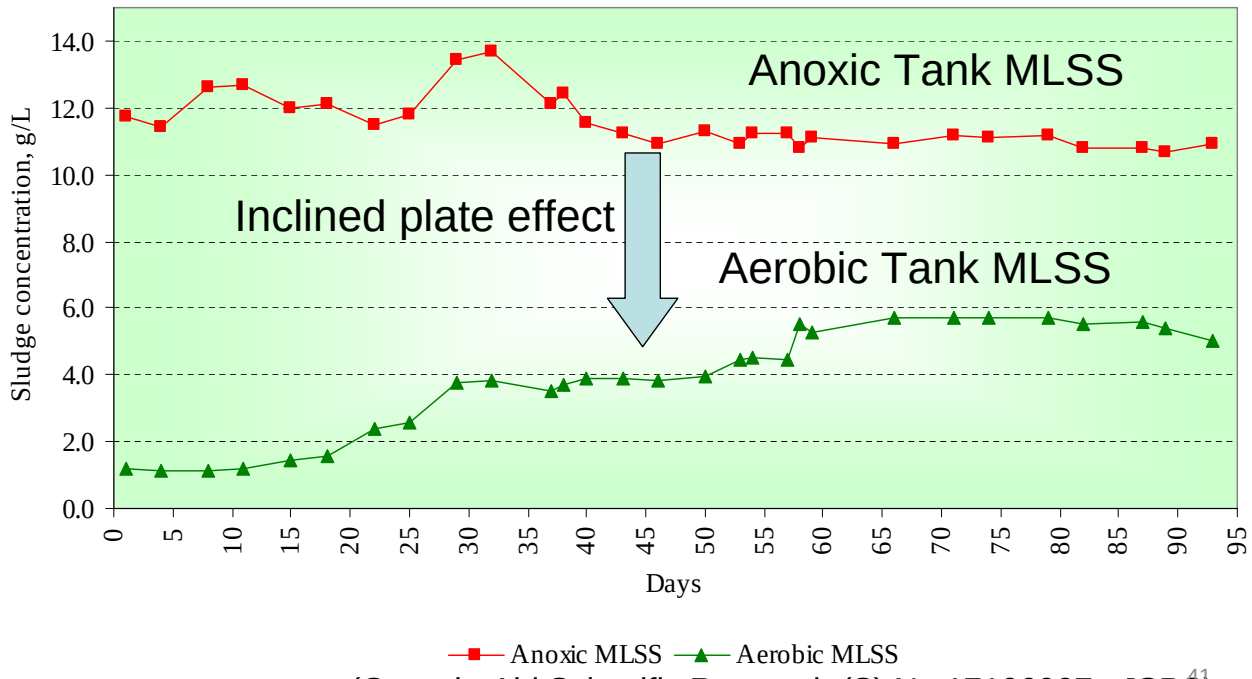
Operational Conditions



Parameter	Value
Hydraulic retention time	3 hours
Sludge retention time	5 years
Volumetric organic loading rate	1.7 kg COD/m^3-day

Due to sampling of sludge

Sludge Conditions in the iPMBR



(Grant-in-Aid Scientific Research (S) No.17106007, JSPS)

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Is it applicable to developing countries?

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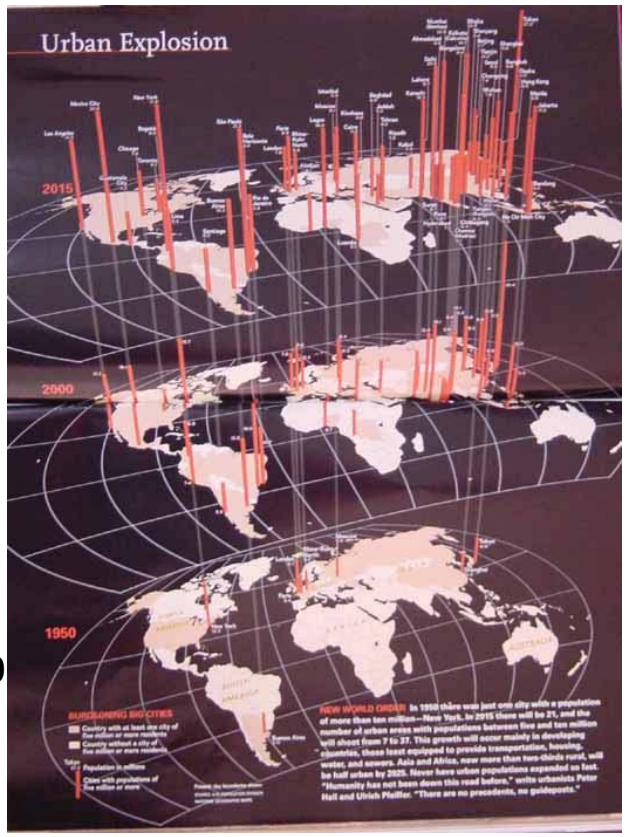
Urbanization especially in Asian region



2015

2000

1950

©National Geographic, Nov. 2002

World mega-cities (population over 5 million)

Poor people suffer from urban deteriorated water environment

(Source: *Global Environment Outlook 3*, UNEP, 2002)

Huge solid waste deteriorates waters

By Curtsey of Dr. Chart Chiemchaisri, Kasert Unikversity

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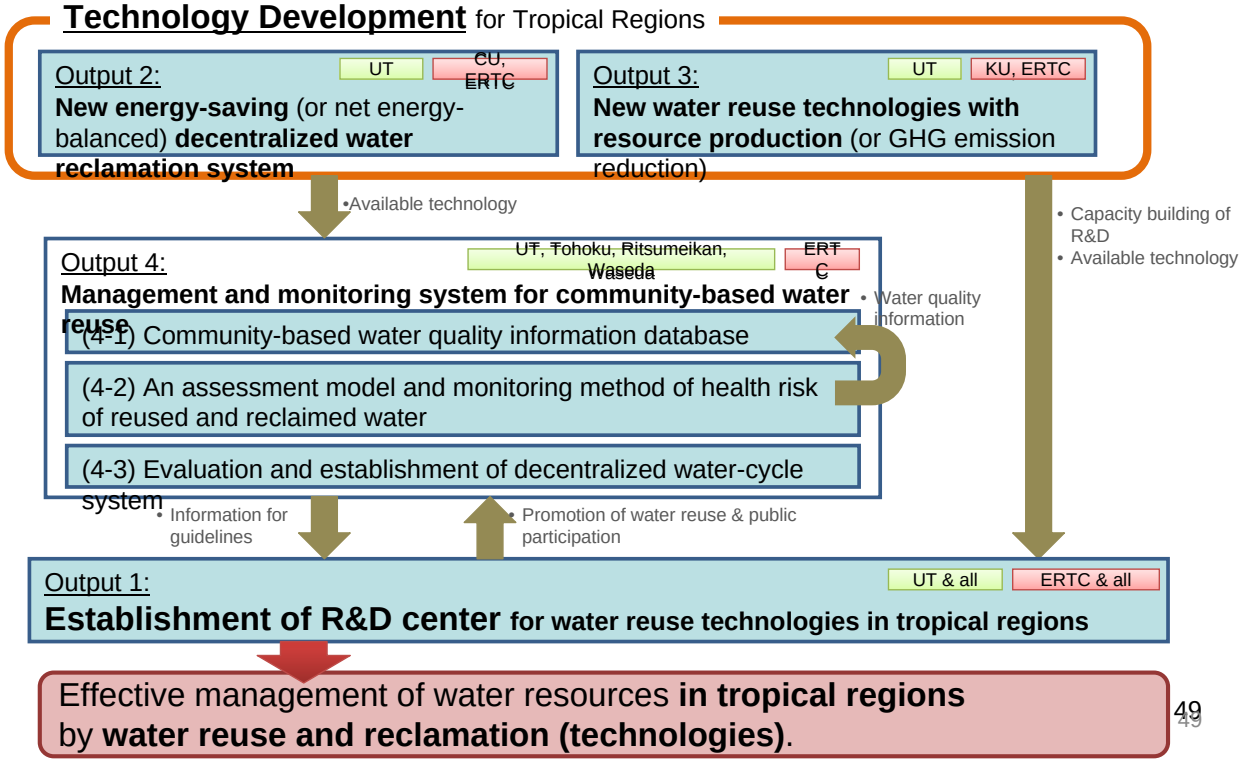
JST-JICA Project

Research and Development for Water Reuse Technologies in Tropical Regions

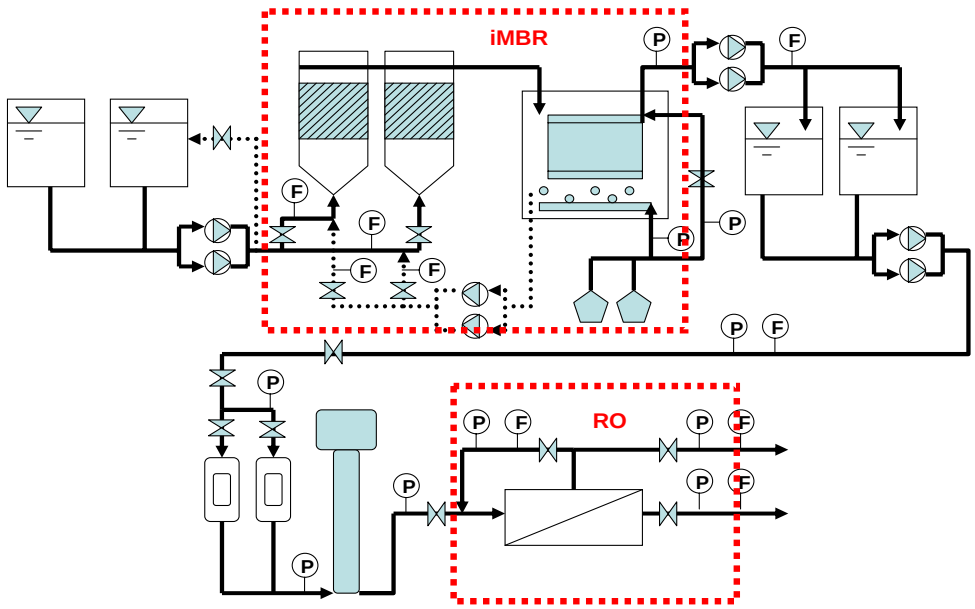
Aims of the Project

- R&D of water reuse technologies in tropical regions
  - Collaborative research in Thailand
  - Mitigation for water vulnerability and secured water supply
- Establishment of R&D Center for water reuse technologies in Thailand
  - Innovative adaptation of the developed technologies and its management in tropical conditions
  - Capacity building for technology transfer to other countries in tropical regions

Project Scheme



Water reclamation and methane gas emission reduction in municipal landfill leachate treatment by ipMBR-RO system



Yes, we need innovation for sustainable urban water system all over the world.

MBR-Network Project

- Binz, C, “Development perspectives of on-site MBR treatment plants in the municipal wastewater sector of China”
- M.N.Bino *et al*.,”Potential for MBR applications for wastewater treatment in the Middle East and North American region.

Thank you!

Danke!