Towards Autonomous and Decentralized Water System for Wise Use of Water and Creating Healthy and Sound Water Environment

自律型分散水システムの活用に向けて

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Introduction

The issues on the globe facing Water Crisis are the problems against sustainable development of water resources due to the overpopulation, resulting in food shortage and sanitation crisis. In addition to tackle on mitigating these global population pressures, Japan is to be facing a significant population drop in near future. Another question arises: how can we regenerate big cities after their end of growth? The time has passed already, when we built dams far away from the cities in order to meet their high-growth of water demand. It is, now, emphasized that we need to create a society by wise-use of water but not by further dam construction. However, looking at the cities in reality, water in the cities is neither wisely nor rationally utilized yet. It is because the existing water systems are not able to cope with such a demand.

Since Meiji Era, a rapid development of modern water supply systems had certainly realized safe and a low cost supply of drinking water all over Japan and had dramatically reduced the risks of water-born infectious diseases; this contributes to long-life expectancies of Japanese, coupled with a remarkable progress in medical and health cares. Water pollution, from which we had seriously suffered during the high rate of economic growth period after the World War II due to untreated domestic and industrial wastewater, has been significantly improved by sewerage construction. However, present city water systems become a bit rigid and are losing flexibility.

For example, although the major uses of water in cities are non-potable ones, so-called 'tasty water' is equally supplied after a high-cost advanced treatment and long pipe-transportation regardless of its use. The younger generation, nevertheless, likes to buy bottled water and doesn't drink tap water. Although urban shallow aquifer is worthwhile to be considered as an urban water stock, it is still over regulated. Of course, we need to learn the lessons from our experiences of excess groundwater usage that had seriously caused land subsidence and saline water intrusion in the past, but the groundwater-uptake ban already gained a remarkable recovery of the groundwater level especially in the downtown area of some big cities in Japan. Too much rise of the groundwater level creates another problem of floating urban underground structures like subway stations, city buildings, and so on. That's why we need to wisely use of urban groundwater. It is also pointed out that we can positively prevent from groundwater pollution when we use it.

The groundwater usage, especially shallow one, must be balanced with its cultivation. Rainwater infiltration is one of the major sources of the cultivation. It is, therefore, important to control the rainwater quality from the viewpoint of the cultivation as well as the quantity control to which we have paid attention much from the viewpoint of infiltration capacity and urban storm water management. Rainwater harvesting is also an alternative of wise-use of water.

Water shortage comes from drought period. We can't expect the rainwater infiltration for that period, while urban wastewater is constantly produced as long as the urban activity is maintained. The treated wastewater must be considered as a stable and ubiquitous urban water resource, and it can be used for groundwater recharge. This also contributes a rehabilitation of urban creaks indirectly. It is emphasized that large centralized wastewater treatment plants located at river downstream or seaside are not expected to have such a role. A wastewater treatment plant is not just a treatment plant but an environmental water plant to create sound urban water environment. We need to reconsider the wise-use of their ubiquitous nature by decentralization of wastewater treatment plants.

Furthermore, a new aspect of wise-use of water is to positively use the latent heat of water to mitigate urban heat-island. In addition to evapotranspiration though plants, a variety of direct and indirect uses of water are worthwhile to be considered such as water film on city building walls, sprinkling water on roads, revival of water-cooling air-condition, and so on. It is noted that we must carefully choose or develop the water technologies that assures safety in order to prevent from pathogen contamination into the generated mist or aerosol.

Autonomous, Decentralized, and Sustainable Water Systems

The 3Es (Economy, Environment and Equity) are indispensable to us in getting regional sustainability as well as the global one. Public participation is believed most effective to achieve 3Es. Reviewing presently available technologies in our society, most of them have been developed and continuously improved seeking for efficiency and scale of merit as much as possible. But we have to consider how to change the traditional values of mass-production and mass-consumption to the ones of sustainable production and consumption. In this regard, longer life products and their maintenance are becoming more important on the way to make our society recycle-oriented.

The sustainability of a water system is not an exceptional case.

Then, we may raise the question: Autonomous, decentralized, and sustainable water systems: Can we realize them in mega cities?

'Autonomous' means that a water system is autonomously managed, choosing a variety of available water resources; existing and new ones depending on their technical development. Decentralization makes the management boundary small enough for the people concerned to participate in the decision making process on risk-benefits of the community water system. The decentralization consisting of a network of small systems also enables us to disperse the system risk in fragments. Sustainability must be realized in the maintenance. As a whole, through a participatory management and maintenance in the community water system, the system creates community employments and a continuous and active improvement will be done by autonomous adjustment among the network of the water systems, seeking the global sustainability. The question is whether such water systems can replace existing big water supply and sewage infrastructures in the context of urban regeneration especially for mega cities. This makes an epoch of water system seeking a sustainable society with wise-use of water.

Needs for Technological Development to Realize the Decentralized System

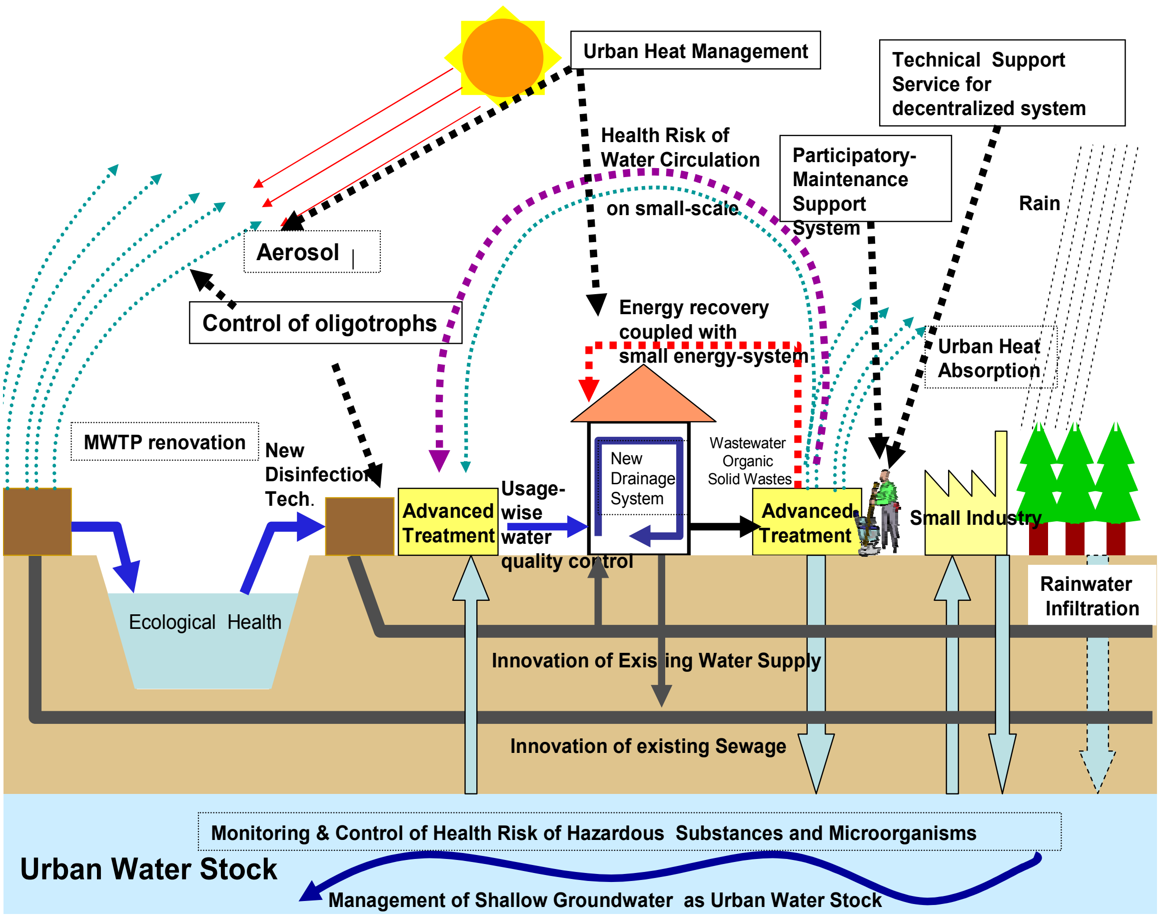
Centralized large-scale water system consisting of water supply and sewerage has a certain scale-merit in terms of life cycle cost and energy consumption. But the concentration of wastewater means, at the same time, the concentration of the pollutants included and transported. The water demands, i.e., the use points are dispersed in cities; this exactly corresponds the dispersed wastewater generation in the cities. If the wastewater is regarded as an urban water resource, its ubiquitous nature is preferable to its dispersed utilization. The wastewater, of course, requires advanced treatment in order to ensure its public acceptance as safe environmental water. The treated water can be re-used directly, but it is also used as a recharge source of groundwater. The shallow aquifer is regarded as a stock yard of the treated water, expecting its further maturation and stabilization. This open recycle system must effectively work in decentralized network of water systems, having a function of equalization of imbalance between individual demand and supply.

In general, the drawbacks of decentralization are well recognized that not only increase in number of maintenance points and but also their diffusion consequently cause difficulty in maintenance and increase their cost and energy consumption. This is true as far as presently available technologies considered. However, recent information technology development enables us to help the users to participate in the maintenance by having an interactive guidance or on-demand professional maintenance service. Cheap monitoring tips for various water qualities will be available in near future. On site energy recovery as bio-gas in combination with cogeneration of city gas-fuel cell system will also be cost competitive in small-scale in near future. For example, an on-site advanced anaerobic treatment system of domestic wastewater equipped with a garbage disposer is becoming promising more as one of the best mix in the light of rational energy recovery from both wastewater and solid wastes. Therefore, the bottle neck of the present drawbacks of the decentralization will probably disappear in near future, if proper technologies are developed and applied.

We really need R&D for the above. The following are the list of research topics we need to comprehensively organize, although the list is still fragmental. .

1) On-site advanced interface technologies between water system and environmental waters
2) Shallow groundwater management
3) Urban rainwater quality management
4) Safe-water technology and management for urban heat control
5) Public participation & user-friendly maintenance support system
6) Urban-water regeneration planning for decentralization.

The figure below shows the relation between the research topics required.



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Introduction

- Global Water Crisis
  due to population explosion

- Japan, facing population decrease in near future
  127.8 million in 2007 (peak)
  app. 100 million in 2050
  app. 70 million in 2100 ?

Introduction

- Reverse-urbanization
  How can we regenerate big cities after their end of growth?
- Great success history:
  Modern water supply & sewerage
  Industrial waterworks
- Chance to make a society sustainable with wise-use of water

Introduction

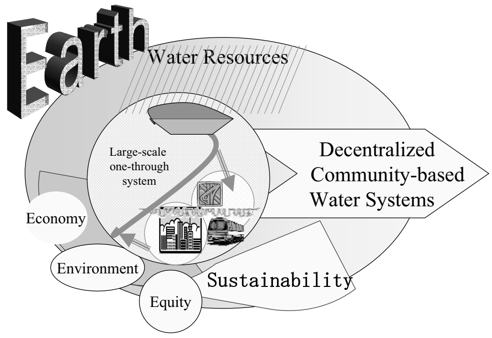
- Urban Water System
  unified management of water supply & sewerage, and environment

- Groundwater management
  use and conservation
- Urban heat management
  green and water

Sustainable system

- The 3Es, indispensable to Sustainability (Economy, Environment and Equity)

- Public participation is believed most effective to achieve 3Es.
- What would be the appropriate size?



Autonomous, Decentralized, and Sustainable Water Systems

- 'Autonomous' means that a water system is autonomously managed, choosing a variety of available water resources; existing and new ones depending on their technical development.

Autonomous, Decentralized, and Sustainable Water Systems

- Decentralization makes the management boundary small enough for the people concerned to participate in the decision making process on risk-benefits of the community water system

Autonomous, Decentralized, and Sustainable Water Systems

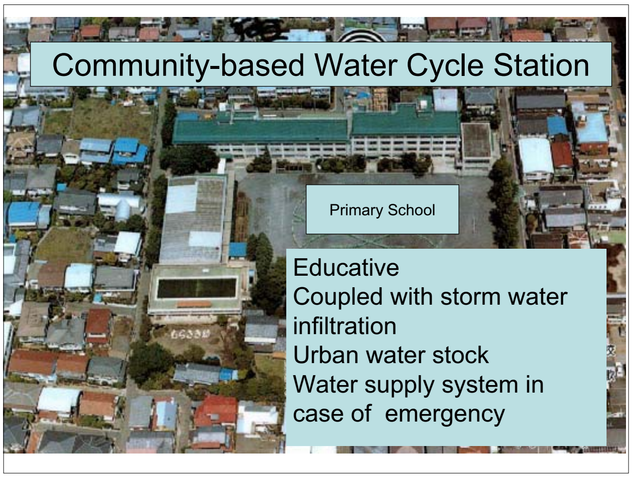
- The decentralization consisting of a network of small systems also enables us to disperse the system risk.
- Sustainability maintenance must be realized.

Autonomous, Decentralized, and Sustainable Water Systems

- As a whole, through a participatory management and maintenance in the community water system, the system creates community employments and a continuous and active improvement will be done by autonomous adjustment among the network of the water systems, seeking the global sustainability.

Autonomous, Decentralized, and Sustainable Water Systems

- The question is whether such water systems can replace existing big water supply and sewage infrastructures in the context of urban regeneration especially for mega cities.
- This makes an epoch of water system seeking a sustainable society with wise-use of water.



Needs for Technological Development to Realize the Decentralized System

- Centralized large-scale water system consisting of water supply and sewerage has a certain scale-merit in terms of life cycle cost and energy consumption.

Needs for Technological Development to Realize the Decentralized System

- The water demands, i.e. the use points, are dispersed in cities; this exactly corresponds the dispersed wastewater generation in the cities.
- If the wastewater is regarded as an urban water resource, its ubiquitous nature is preferable to its dispersed utilization.

Needs for Technological Development to Realize the Decentralized System

- The wastewater, of course, requires advanced treatment in order to ensure its public acceptance as safe environmental water..

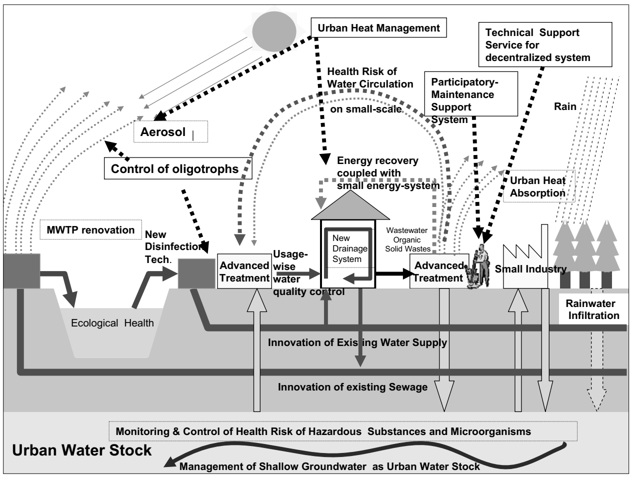
Needs for Technological Development to Realize the Decentralized System

- In general, the drawbacks of decentralization are well recognized that not only increase in number of maintenance points and but also their diffusion consequently cause difficulty in maintenance and increase their cost and energy consumption.
- This is true as far as presently available technologies considered.

- However, recent information technology development enables us to help the users to participate in the maintenance by having an interactive guidance or on-demand professional maintenance service.
- Cheap monitoring devices for various water qualities will be available in near future.
- On site energy recovery as bio-gas in combination with cogeneration of city gas-fuel cell system will also be cost competitive in small-scale in near future.

- Therefore, the bottle neck of the present drawbacks of the decentralization will probably disappear in near future, if proper technologies are developed and applied. We need R&D as listed below.

- On-site advanced interface technologies between water system and environmental waters
- Shallow groundwater management
- Urban rainwater quality management
- Safe-water technology and management for urban heat control
- Public participation & user-friendly maintenance support system
- Urban-water regeneration planning for decentralization.



Among advanced treatment technologies

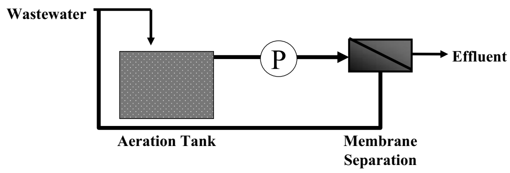
- Advanced oxidation processes
- ozonation
- ultra violet irradiation
- photocatalytic reaction
- and so on
- Super critical water oxidation

- Adsorption
- Membrane Technology

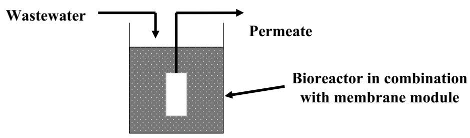
- easy to get public acceptance
- supporting risk-communication

Potential of MBR Application

■ ***Side-Stream MBR***



■ ***Submerged Membrane Bioreactor (MBR) process***

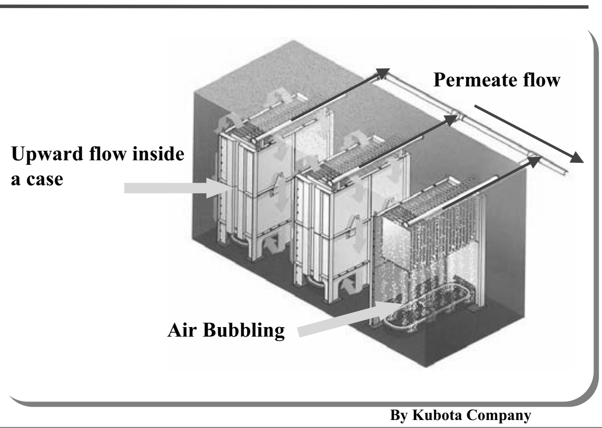


Applications: *Submerged MBR*

- industrial wastewater treatment and reuse
- sewage treatment plant
- on-site domestic wastewater treatment (Jokaso)
- retrofit and improvement of old-type Jokaso
- night soil treatment, and so on.

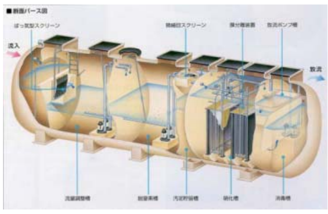
- In total, about 2,000 MBR plants are in operation in Japan.

Plate & Frame type membrane module



By Kubota Company

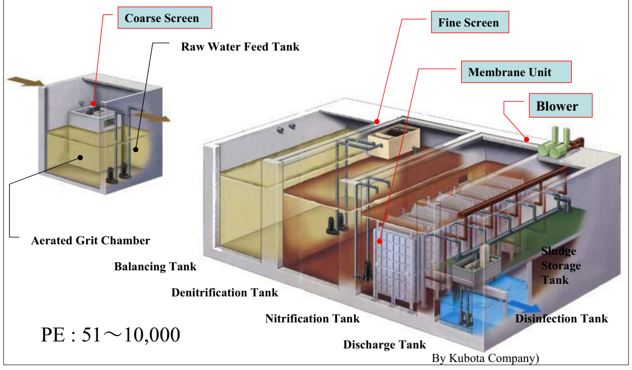
Johkaso
(FRP Package Type)



PE: 51～3,040

(by Kubota Company)

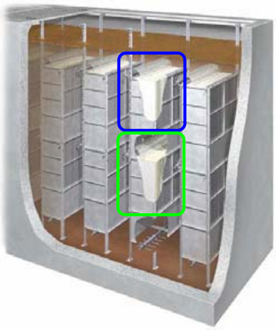
Johkaso
(Concrete Type)



PE : 51～10,000

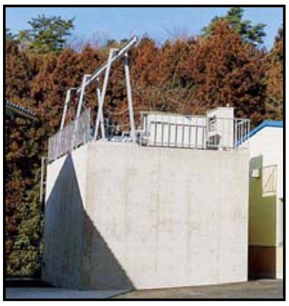
By Kubota Company)

Double Decker



(by Kubota Company)

Hollow Fiber MBR System

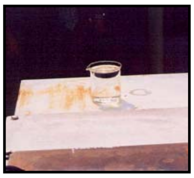


(by Mitsubishi Rayon Co., Ltd.)

Photos of the MBR System

Membrane modules placed in tanks

The inside of a aeration tank



The treated water

(by Mitsubishi Rayon Co., Ltd.)

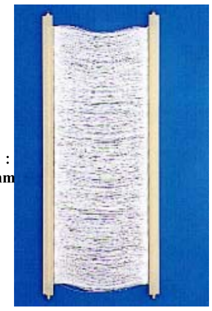
Hollow Fiber Membrane

Cross section of hollow fiber : X 50

Membrane surface : X 5,000

About 400mm

length : 1034mm



(by Mitsubishi Rayon Co., Ltd.)

Membrane unit

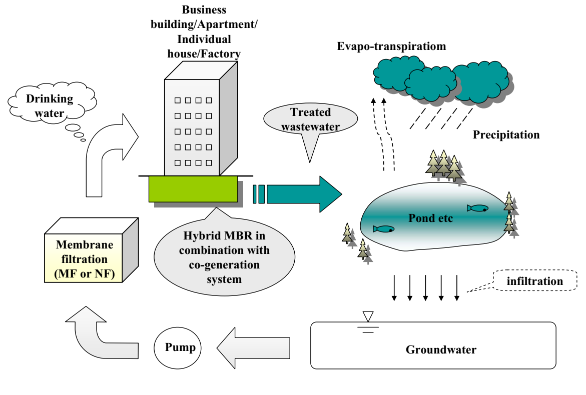
SUR10534
(surface area : 105m²)

SUR31534
(surface area : 315m²)
3 stacked module of sur10534

(by Mitsubishi Rayon Co., Ltd.)

Performance of MBR

- Excellent effluent water quality is achieved regardless of plant size.
- Maintenance requirement is very easy especially for a small system
- Further treatment like RO for water reuse is easily added.
- Submerged MBR is successfully applied to small decentralized system.



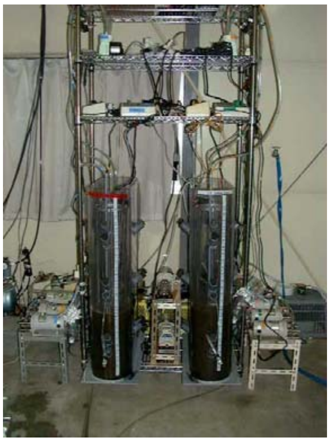
Possible on-site wastewater reclamation system

Potential of membrane bioreactor application

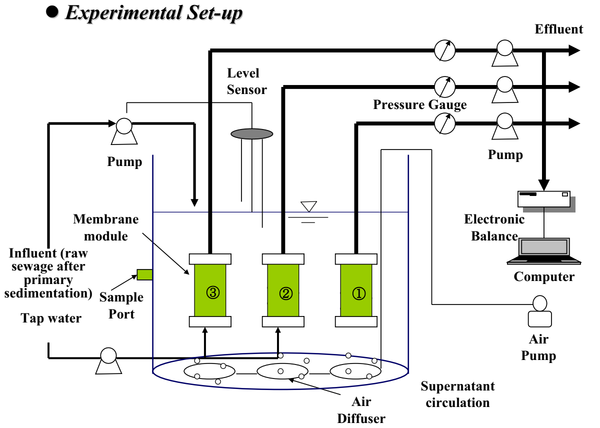
- More hybrid functions to gain more value-added water; e.g.,
- MBR-AC combination
- MBR-NF(RO) combination
- Hybrid NF/MBR, and so on

Development of NF(nanofiltration) MBR

- **The demands for advanced wastewater treatment in terms of further removal of dissolved and small molecular-weight organic matters are certainly increasing.**
- **Neither UF nor MF is sufficient.**
- **It is worthwhile to develop a NF MBR where a NF membrane is used.**



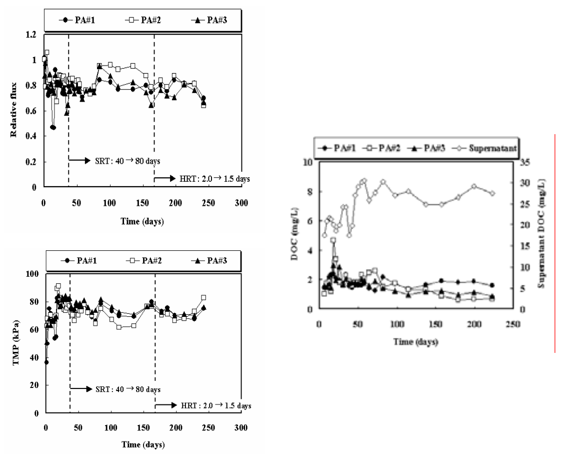
● ***Experimental Set-up***



Properties of the nanofiltration (NF) membranes

Items	PA membranes
Membrane configuration	U-shaped hollow fiber
Membrane material	Polyamide
Outer diameter	205 μ m
Inner diameter	86 μ m
Number of hollow-fiber / module	60,000
Module surface area	10.4 m^2
Membrane length	270 mm
Salt rejection*	94 %
Manufacturer	Toyobo Co., Ltd.

*Test conditions;
(1)target solution: 500 mg/L NaCl solution, (2) operating pressure 0.98 MPa,
(3) temperature: 25 ℃, (4) recovery ratio: 30 %



Needs for Further Research on Molecular Design of Nanopores of NF Membrane to develop such as,

- NF membranes with a very high retention of organic compounds but a low retention of salts with a reasonable flux.
- NF membranes with a higher retention of nitrate comparing chloride

Potential of membrane bioreactor application

- Sustainable energy utilization; e.g.,
- Anaerobic submerged MBR in combination with a decentralized energy supply/cogeneration system (such as a fuel cell)
- Solar or natural energy utilization
- Waste minimization, and so on

Potential of membrane bioreactor application

- Development of MBR system with IT-based user participation in maintenance
- Educative & self-supporting system