Application of Membrane Technology in Japan

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ABSTRACT

Membrane filtration is a promising technology for efficient solid/liquid separation in water purification. In FY 1991, the Ministry of Health and Welfare, Japanese Government launched a comprehensive research project "*MAC 21*" for development of membrane technology and its application to public water supply. The project was conducted by the Water Purification Process Association (WPPA), under the supervision of the Institute of Public Health.

By the research project from FY 1991 to FY 1993, we confirmed that microfiltration (MF)/ultrafiltration (UF) technology was applicable to water purification and MF/UF was a effective method for the removal of such contaminants as particulate matter and coliforms.

The Guideline Committee organized under the Technical Committee prepared a the guidelines on application of membrane system to small-scale public water supplies, based on the results as written above. The guidelines has been published in Dec., 1994 by WPPA.

Then, the Ministry of Health and Welfare, Japanese Government, started a new research project "*NEW MAC 21*" from FY 1994 to FY 1996. The purpose of this research project is to establish advanced membrane filtration systems that are able to remove such contaminants as the precursors of disinfection by-products, microorganic pollutants, offensive taste and odor, and viruses for supplying drinking water of better quality, based on the results of the last project "*MAC 21*". In the new Project, beside MF/UF, nano-filtration (NF) is studied.

INTRODUCTION

Membrane filtration technology, if it is applied to water purification, seems to have many advantages such as improvement of drinking water quality, saving water purification chemicals and operating cost, easier operation and maintenance, and saving space, time and cost for construction of a water purification plant. Therefore, the Department of Water Supply and Environmental Sanitation, Ministry of Health and Welfare, Japanese Government, launched a three-years' comprehensive research project "*Membrane Aqua Century 21 (MAC 21)*" for development of membrane technology in FY 1991. This project was conducted by the Water Purification Process Association, under the supervision of the Institute of Public Health. One component of this project was demonstration plant experiments by eighteen water purification plant manufacturers that were the members of the association. The other component was a series of basic researches by eight research groups of university professors. The project was funded by both the Ministry and the participating manufacturers.

The three years' research project "*MAC 21*" from FY 1991 to FY 1993 was completed successfully and we could obtain fruitful results.

Therefore, the Department of Water Supply and Environmental Sanitation, Ministry of Health and Welfare, Japanese Government, has launched a new three-years' comprehensive research project "*New Membrane Aqua Century 21* (*NEW MAC 21*)" for development of more advanced membrane technology in FY 1994. This project is conducted by the Water Purification Process Association, under the supervision of the Institute of Public Health, and the components of this project are demonstration experiments and basic researches, as was in the last project. Twenty-four water purification plant manufacturers participate in this project and this the project is funded by both the Ministry and the participating manufacturers.

I. *MAC 21* PROJECT

OUTLINE OF THE PROJECT

PURPOSE

Now in Japan, we face such problems in water purification as deterioration of raw water quality, necessity of advanced process application and the old facility renovation, difficulty of new land space acquisition, and shortage of skilled operators. Then there is a strong need for developing a more compact and efficient water purification system than the conventional one.

The purpose of "*MAC 21*" project was to develop a new water purification system applying membrane technology as a breakthrough of the water supply technology in order to overcome the problems as written above. Membrane filtration technology seems to have a high potential not only for efficient solid/liquid separation, but also for improvement of drinking water quality, reduction of plant scale, automation of plant operation and so forth.

OBJECTIVE

The objectives of this research project were as follows:

1) To obtain practical knowledge concerning design, operation and maintenance of a membrane

system for its application to small-scale public water supplies,

2) To accumulate basic knowledge concerning application of membrane technology to water purification, and
3) To prepare the guidelines on application of a membrane system to small-scale public water supplies.

DEMONSTRATION PLANT EXPERIMENT

A series of field experiments for obtaining practical knowledge were undertaken in the period of April 1992 through March 1994 (for two years) with three terms of eight months for each. Each of the eighteen participating manufacturers conducted experiments in two turns with different methods by using its own demonstration plant applying membrane technology.

BASIC RESEARCH

The eight research groups of university professors, that were the members of the Technical Committee as written below, undertook the basic researches for accumulating basic knowledge of membrane technology.

ORGANIZATION

The project organization, as shown in Figure 1, consisted of four committees and a secretariat. The Technical Sub-Committee had three Task Groups under it. The functions of the committees and task groups are also shown in the figure. The feature of this research project was that it involved a wide variety of human resources such as government officials, university professors of sanitary and chemical engineering, and engineers from water purification plant manufacturers.

RESEARCH FUND

The project was funded by both the Ministry of Health and Welfare and the participating companies. For three-years' project, totally 480 million yen were funded in which the Ministry and the participating companies contributed 150 million yen and 330 million yen, respectively. Out of the fund, 320 million yen was used for the demonstration plant experiments, and 99 million yen was used for the basic researches.

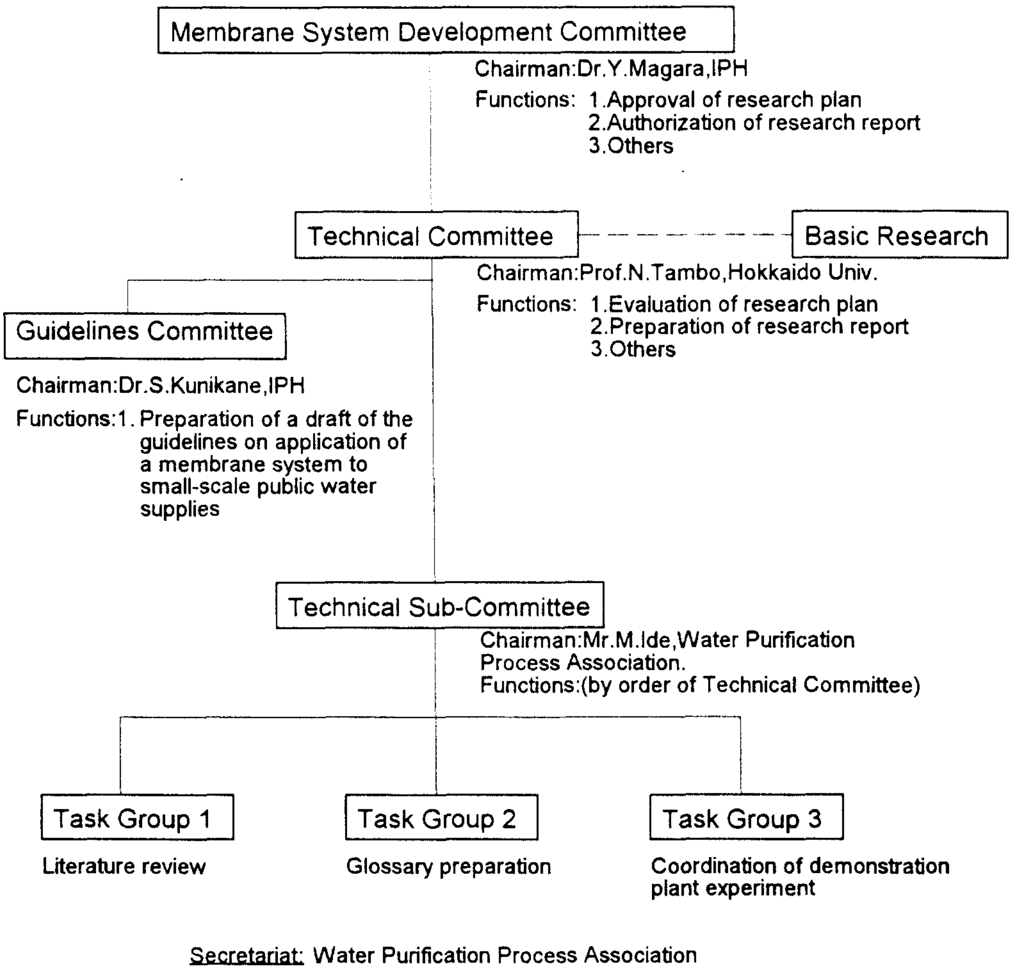

Figure 1. Organization of the membrane system research project

DEMONSTRATION PLANT EXPERIMENT

EXPERIMENTAL METHODS

The facility for the demonstration experiment was constructed at a intake of the Kita-Chiba Regional Water Supply Authority located in Matsudo City, Chiba Prefecture. The raw water of the authority coming from Edo River was taken from a grit chamber of the intake and used as the raw water for the experiment.

A flow diagram of the experimental facility is shown in Figure 2.

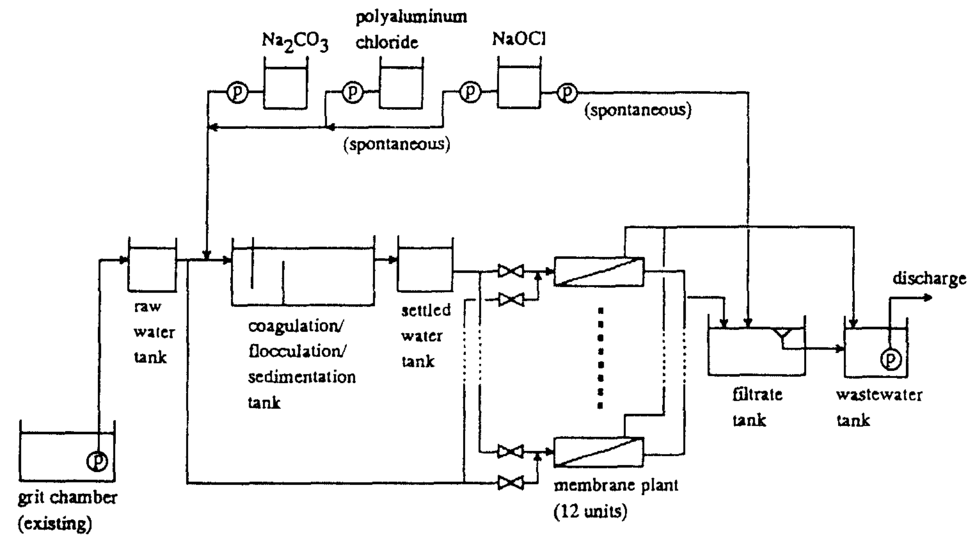

Figure 2. Schematic flow diagram of the experimental facility

Twelve membrane filtration plants were installed in a building constructed for the experiment and operated at one time. The capacity of each plant was around 30 m^3/d. Both of the waters (after grit removal) without any pretreatment and with pretreatment, coagulation with polyaluminum chloride and sedimentation by a common pretreatment facility, were supplied to each membrane plant so that one could select a raw water depending on its experimental conditions.

The experimental conditions of the totally thirty-five membrane plants used in the first, second and third runs of the experiment are classified in Table 1 and Table 2.

Microfiltration (MF) membrane was used in twenty-two plants, and ultrafiltration (UF) membrane was used in thirteen plants. Organic hollow fiber membrane was used in most of the plants, but inorganic membrane and other type of organic membrane were used in the other plants. Flow control by a constant flow rate method was dominant.

Three plants took the raw water treated by the common pretreatment facility throughout or during a part of the operation period. Thirty-two plants were operated with individual pretreatment in their own plants. Coagulation with polyaluminum chloride was adopted for individual pretreatment in nineteen plants. "Encased membrane filtration" (i.e. the membrane is encased in a housing) was dominant. "Tank-dipped membrane filtration" (i.e. the membrane is dipped in a tank) was used in eight plants.

Table 1. Method of demonstration plant experiment

No.	Name of Participating Manufacturers	Period[1] 1st	2nd	3rd	Membrane MF/UF	Material[2]	Type of Module[3]	
1	Ishigaki Mechanical	*			MF	CRM	multi-lumen	E
	Industry Co., Ltd.			*	MF	CRM	multi-lumen	T
2	Ebara-Infilco Co., Ltd.	*			MF	PE	hollow fiber	T
				*	MF	PE	hollow fiber	T
3	Japan Organo Co., Ltd	*			UF	PES	hollow fiber	E
			*		UF	CA	hollow fiber	E
4	KUBOTA Corp.	*			MF	CRM	tubular	T
			*		MF	CRM	tubular	T
5	Kurita Water	*			MF	PS	hollow fiber	E
	Industries Ltd.		*		UF	PS	hollow fiber	E
6	Chlorine Engineers		*		MF	EC	flat sheet	T
	Corp., Ltd.			*	UF	CRM	multi-lumen	E
7	Sanki Engineering		*		MF	PP	hollow fiber	E
	Co., Ltd.			*	MF	PP	hollow fiber	T
8	Shinko Pantec		*		MF	PP	hollow fiber	E
	Co., Ltd.			*4)	MF	PP	hollow fiber	E
				*5)	UF	PAN	flat sheet	T
9	Suido Kiko	*			UF	PAN	hollow fiber	E
	Kaisha Ltd.			*	UF	PAN	hollow fiber	E
10	Sumitomo Heavy Industries, Ltd.			*	MF	PS	flat sheet	T
11	Tsukishima Kikai	*			MF	PAN	hollow fiber	E
	Co., Ltd.		*		UF	PS	hollow fiber	E
12	DIC-Degremont	*			UF	C	hollow fiber	E
	Co., Ltd.		*		UF	C	hollow fiber	E
13	Nishihara Environmental		*		UF	PAN	hollow fiber	E
	Sanitation Research Corp., Ltd.			*	UF	CA	hollow fiber	E
14	NGK Insulators, Ltd.		*		MF	CRM	mulit-lumen	E
				*	MF	CRM	mulit-lumen	E
15	NKK Corp.	*			MF	PP	hollow fiber	E
				*	MF	PP	hollow fiber	E
16	Hitachi Plant Engineering	*			MF	PP	hollow fiber	E
	& Construction Co., Ltd.		*4)		UF	PAN	hollow fiber	E
			*5)		UF	PS	flat sheet	T
17	Maezawa Industries, Inc.	*			MF	PS	hollow fiber	E
			*		UF	PS	hollow fiber	E
18	Unitika Ltd.	*			MF	PS	hollow fiber	E
				*	MF	PS	hollow fiber	E

NOTE: 1) "1st"; April-November 1992, "2nd"; December 1992-July 1993, and "3rd"; August 1993-March 1994.

2) "C"; cellulose. "CA"; cellulose acetate. "CRM"; ceramic. "PAN"; polyacrylnitrile. "PE"; polyethylene. "PES"; polyethersulfon. "PO"; polyolefin. "PS"; polysulfon. "PT"; polyester. "EC"; chlorinated etylene.
3) "E"; encased in a housing, "T"; tank-dipped.
4) main line.
5) recovery line.

Table 2. Classification of the thirty-five membrane plants used in the first, second and third runs of the experiment.

Classification			first	second	third	total
Membrane	Kind	MF(0.01-0.4 μm)	9	5	8	22
		UF(1.3x10^4-2x10^6 Dalton)	3	7	3	13
	Material	Organic	10	10	8	28
		Inorganic	2	2	3	7
Module	Type	Hollow fiber	10	9	7	26
		Tubler	1	1	0	2
		Multi-lumen	1	1	3	5
		Flat sheet	0	1	1	2
Operation	Flow type	Crossflow	5	8	7	20
		Dead-end	5	4	4	13
		Others	2	0	0	2
	Flow control	Constant flow rate	10	11	11	32
		Constant pressure	1	1	0	2
		Others	1	0	0	1
	Pretreatment	Individual (coagulation)	10(6)	11(6)	11(7)	32(19)
		Common	1	0	0	1
		Common+individual	1	1	0	2
	Others	Encased filtration-pressure	10	10	7	27
		Tank dipped membrane filtration-pressure	0	1	2	3
		Tank dipped membrane filtration-suction	2	1	2	5

Note) In the "pretreatment", "common" pretreatment means coagulation and sedimentation by the common pretreatment facility; "individual" pretreatment means the one in each membrane plant.

RESULT

FLUX AND WATER PRODUCTION

The results of net water production (filtrate quantity subtracted backwashing water quantity) in the six months' operation of the first and second runs are shown in Figure 3. The plots in the figure denote chemical cleaning of membrane. Some membranes experienced only once chemical cleaning at the end of the operation period, but some other membranes experienced several times of chemical cleaning during the period. The figure shows that most of the membrane plants were operated and chemically cleaned very well because the most of the lines in the figure are fairly straight. The transmembrane pressure difference was less than 300 kPa in all membrane plants, less than 100 kPa in many plants, throughout the operation period.

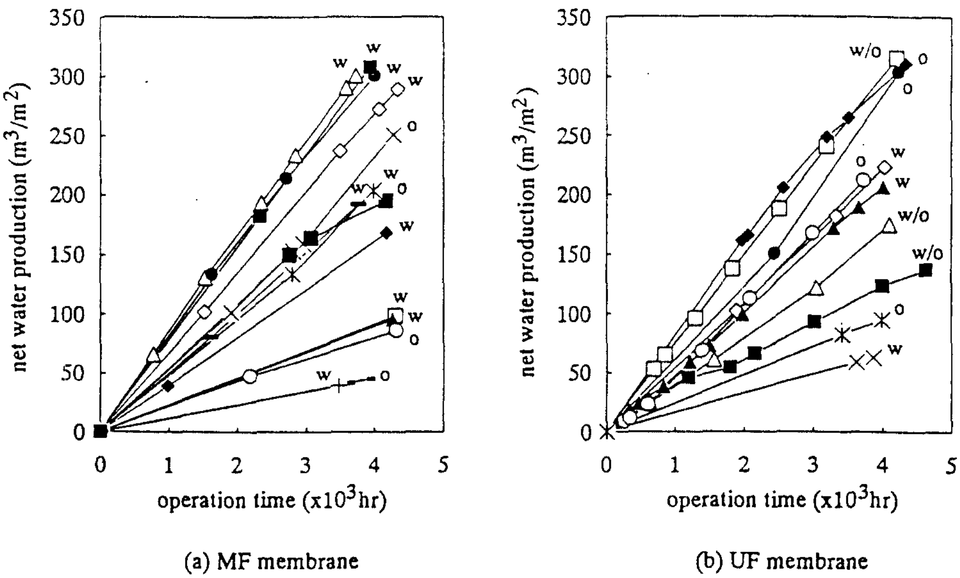

Figure 3. Net water production per unit surface area of membrane in the first run and the second run

Plots denote chemical cleaning in six months' operation;
"w"-with polyaluminum chloride and "o"-without polyaluminum chloride.

The total water production per unit surface area of membrane was in the ranges of 45 to 307 m^3/m^2 for MF membrane and 63 to 315 m^3/m^2 for UF membrane. The net flux, which is shown as the slope of each line in the figure, was in the ranges of 0.27 to 1.93 $m^3/m^2/d$ for MF membrane and 0.39 to 1.80 $m^3/m^2/d$ for UF membrane as a mean of the six months' operation. No significant difference in areal net water production or net flux was found between MF membrane and UF membrane. Figure 3 also shows that the individual pretreatment by coagulation with polyaluminum chloride (PAC) was necessary especially for MF membrane in order to maintain a high flux. However, such a result could not be found in the case of UF membrane. It is considered that the difference between MF and UF membranes might be resulted from the difference of pore size.

The raw water temperature was in the ranges of 10.3 to 28.5 ℃ in the first run, 4.6 to 23.0 ℃ in the second run and 2.5 to 21.1 ℃ in the third run. Therefore, the difference of the raw water temperature has also affected the result of water production and flux to a certain extent.

It was demonstrated as the results of six months' operation that the net flux per 98.1 kPa of transmembrane pressure difference was over 0.5 $m^3/m^2/d$ for both MF and UF membranes in the six months' operation period.

The water recovery of all membrane plants was in the range of 80 to more than 99 %. Individual pretreatment and recycled treatment of wastewater in some plants are not taken into account to calculate the result. No significant interrelation between water recovery and experimental conditions could be found.

CONTAMINANT REJECTION

The result of contaminant rejection on physical and chemical parameters is summarized in Table 3. There was no significant difference in the results on membrane filtrate quality between MF and UF membranes. It is shown in the table that particulate matter could be removed very effectively by MF and UF membranes. Coliforms were also removed very well, i.e. no coliforms were found in the filtrate samples weekly taken from nine membrane plants in the first run, ten membrane plants in the second run and ten membrane plants in the third run throughout the operation period.

The number of particles with a size of 0.1 to 10 μm in a membrane filtrate sample was mostly in the range of 10^4 to 10^5/ml , while that in a sand filtrate sample was mostly in the range of 10^6 to 10^7/ml.

Thus, it was demonstrated that the MF/UF membrane filtration process was superior to the conventional one in particulate matter removal. Dissolved matters were not removed effectively, but ammonia nitrogen was removed in some plants employing a tank-dipped membrane filtration system.

As shown in the table, the raw water taken from a river was a little polluted with organic matters, iron, manganese and other substances, which could cause fouling of membrane. The necessity of coagulation with PAC for MF membrane as mentioned above may have been related to such characteristics of the raw water quality.

Table 3. The result of contaminant rejection on physical and chemical parameters in the three runs of the experiment

Parameter	Run	Raw water	Clarified water	Membrane filtrate
Turbidity (unit)	1st	16.1 (100)	1.60 (9.9)	0.01 - 0.17 (0.1 - 1.1)
	2nd	15.8 (100)	1.14 (7.2)	0.00 - 0.02 (0.0 - 0.1)
	3rd	10.2 (100)	1.40 (14)	0.00 - 0.02 (0.0 - 0.1)
Color (unit)	1st	10 (100)	4 (40)	1.6 - 4 (16 - 40)
	2nd	11 (100)	4 (33)	3 - 4 (25 - 32)
	3rd	13 (100)	4 (33)	3 - 3.1(22 - 26)
Permanganate value (mg/L)	1st	7.3 (100)	2.8 (38)	1.7 - 2.8 (23 - 42)
	2nd	7.7 (100)	2.8 (36)	1.4 - 3.1 (16 - 41)
	3rd	5.7 (100)	2.7 (47)	2.3 - 3.1 (40 - 54)
E_{260}, 50mm (-)	1st	0.174 (100)	0.134 (77)	0.1 - 0.172 (59 - 96)
	2nd	0.161 (100)	0.117 (73)	0.074 - 0.150 (46 - 93)
	3rd	0.139 (100)	0.107 (77)	0.111 - 0.131 (80 - 93)
Ammonia nitrogen (mg/L)	1st	0.06 (100)	0.05 (83)	0.01 - 0.06 (16 - 100)
	2nd	0.22 (100)	0.22 (100)	0.09 - 0.30 (42 - 92)
	3rd	0.24 (100)	0.22 (89)	0.06 - 0.28 (26 - 100)
Total manganese (mg/L)	1st	0.049 (100)	0.020 (48)	<0.005 - 0.016 (0 - 32)
	2nd	0.054 (100)	0.029 (54)	<0.005 - 0.024 (0 - 49)
	3rd	0.044 (100)	0.022 (51)	0.004 - 0.034 (7 - 77)
Total iron (mg/L)	1st	0.83 (100)	0.03 (4)	<0.01 - 0.01 (0 - 2)
	2nd	0.94 (100)	0.09 (10)	0.00 - 0.01 (0 - 1)
	3rd	0.64 (100)	0.11 (17)	0.00 - <0.01 (0 - 2)
Aluminum (mg/L)	1st	1.10 (100)	0.34 (31)	0.01 - 0.09 (1 - 8)
	2nd	0.91 (100)	0.33 (37)	0.00 - 0.05 (0 - 5)
	3rd	0.47 (100)	0.37 (79)	0.01 - 0.04 (2 - 10)
THMFP (mg/L)	1st	0.046 (100)	0.027 (59)	0.021 - 0.036 (45 - 78)
	2nd	0.045 (100)	0.024 (53)	0.017 - 0.045 (34 - 100)
	3rd	0.035 (100)	0.026 (74)	0.024 - 0.032 (69 - 90)

Note) "Clarified water" means the water after coagulation using polyaluminum chloride and sedimentation by the common pre treatment facility. The figures in the column of "membrane filtrate" show the range of mean values obtained in the twelve membrane plants. The figure in parentheses is residual per cent.

ENERGY CONSUMPTION

Energy consumption is also a very important aspect for practical application of membrane technology. Figure 4 shows the relationship between energy consumption per unit surface area of membrane and net flux. Energy consumption was estimated based on the experimental data assuming that a real plant of 1,000 m^3 per day with the same system as the experimental plant would be constructed, because the pumps and other parts consuming energy in each membrane plant were not at their optimum capacity. The values of assumed areal energy consumption were distributed in a wide range of 0.1 to 2.1 $kWh/m^2/d$. However, it is generally shown in the figure that higher net flux was obtained at higher areal energy consumption. It is also clear that deadend filtration was more efficient than crossflow filtration, because the former showed higher ratio of net flux to areal energy consumption than the latter. No difference in energy consumption characteristics could be found between MF and UF membranes.

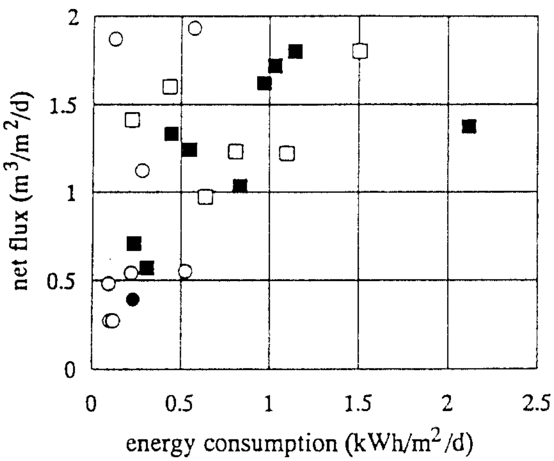

Figure 4. Relationship between energy consumption per unit surface area of membrane and net flux in case of $1{,}000m^3/d$
symbols: white-MF membrane and black-UF membrane; square-crossflow and circle-deadend.

MAIN FINDINGS

The results of the demonstration plant experiment in the "*MAC 21*" project are as follows:

(1) The MF/UF technology can be applicable to river water purification for public water supply from such viewpoints as treatment efficiency and effectiveness of contaminants rejection.

(2) The removal of particulate matter, e.g. turbidity and coliforms, was nearly 100%. Dissolved matter was not removed effectively.

(3) The net flux per 98.1 kPa of transmembrane pressure difference was over 0.5 $m^3/m^2/d$ in six months' operation period.

(4) The water recovery was over 90% in many plants

(5) The pretreatment by coagulation with polyaluminium chloride was effective in maintaining a high flux and avoiding the transmembrane pressure difference increasing rapidly. The dose of coagulant was 30 to 40% of that needed in a conventional rapid sand filtration system.

(6) As the membrane systems were simple and could be operated automatically, the maintenance and operation were very easy.

(7) It was confirmed that the reliance and stability of the systems were very well.

II. *NEW MAC 21*

OUTLINE OF THE PROJECT

PURPOSE

By the research and experiment enforced from FY 1991 to FY 1993, we confirmed that the membrane filtration by MF/UF was a effective method for the removal of particulate matters, coliforms and others, and we developed new technology for application of MF/UF membrane to the water purification system.

The purpose of new research project "*NEW MAC 21*" is to establish advanced membrane filtration systems that are able to remove such contaminants as the precursors of disinfection by-products, microorganic pollutants, offensive taste and odor, and viruses for supplying drinking water of better quality, based on the results of the last project "*MAC 21*".

OBJECTIVE

The subjects of this research project are as follows;

(1) Research and Development of the technology for reduction of disinfection by-products:

The objective of this research is to establish the efficient removal technology for such contaminants as THM precursors, by using membrane filtration such as nanofiltration (NF), in order to accomplish the reduction of disinfection by-products.

In the research about NF systems, we prepare the standard of membrane selection for water works, performance evaluation method of membrane, and competent pretreatment systems. And also, we examine for the suitable chlorination on the treatment process.

(2) Research and Development of the technology for removal of agricultural chemicals, offensive taste and odor:

The objective of this research is to establish the efficient removal technology for such microorganic matter as agricultural chemicals, and offensive taste and odor by such hybrid membrane filtration as MF or UF combined with biological treatment, ozone and activated carbon, in order to ensure the physical-chemical safety on membrane filtrate.

In the combination systems of the membrane filtration and advanced treatment process as written above, the specifications and operating method of the system have important influence on the treatment performance of it. So, we prepare the most suitable methods for the system design and operation, applicable for the condition of raw water quality.

(3) Research and Development of the technology for removal of virus and other contaminants:

The objective of this research is to establish the efficient removal technology for viruses, toxic water-bloom and others in order to ensure the biological safety on membrane filtrate.

Concerning to the removal of those microorganism, the relation between the size of microorganism and pore size of membrane is very important. So, we examine the problems of leakage from damaged part of membrane.

And we also study for the progress of standardization of nominal pore size and molecular weight cutoff.

(4) Research and Development of the technology for sludge concentration by membrane:
The objective of this research is to develop the new technology for membrane concentration of sludge discharged from the membrane filtration process and such conventional process as sedimentation and sand filtration.
On the maintenance of water purification plant, it is desirable to reduce sludge quantity discharged from the water purification process. So we prepare the method for the system design and operation, in consideration of sludge quantity reduction.

DEMONSTRATION EXPERIMENT

JOINT RESEARCH AND EXPERIMENT

A series of joint researches and experiments is undertaken by twenty-four participating manufacturers at a intake of the Kita-Chiba Regional Water Supply Authority.
The objective of the joint experiment is to develop NF systems as a method for removal of such contaminants as the precursors of disinfection by-products, microorganic pollutant, offensive taste and odor, and viruses, and to develop sludge concentration systems by membrane.
In the experiment of NF, three trains of NF process combined with MF/UF process are used, as shown in Figure 5. In this experiment, NF is the main treatment process, while MF/UF is the pretreatment process for NF.

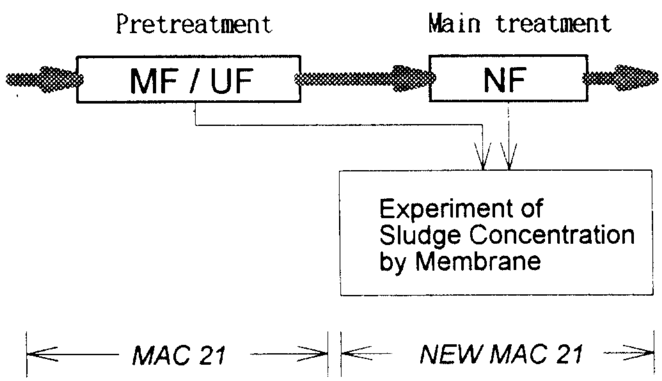

Figure 5. Example of joint experiments

INDIVIDUAL EXPERIMENT

A series of individual researches and experiments is undertaken by fifteen participating manufacturers in Kita-Chiba or other places.
The objective of the individual experiments is to develop hybrid systems combined MF/UF with activated carbon, ozone and biological treatment as another method for removal of such contaminants as written above.
A number of the individual experiments are about ten trains, and examples of the experiment are

shown in Figure 6.

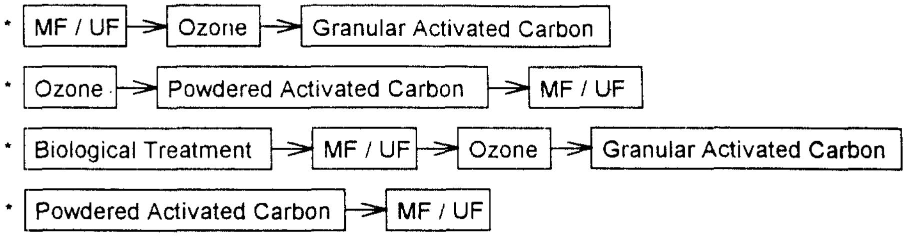

Figure 6. Example of individual experiments

BASIC RESEARCH

The ten research groups of university professors, that are the members of the Technical Committee as written below, undertake the basic research about such the subject 1 to 4 as written in OBJECTIVE, for accumulating basic knowledge of more advanced membrane technology.

ORGANIZATION

The project organization, as shown in Figure 7., consists of four committees and a secretariat. The Technical Sub-Committee has several Task Groups under it. The functions of committees are also shown in the figure. The feature of this research project is that it involves a wide variety of human resources such as government officials, university professors of sanitary and chemical engineering, and engineers from water purification plant manufacturers, as was in the last project.

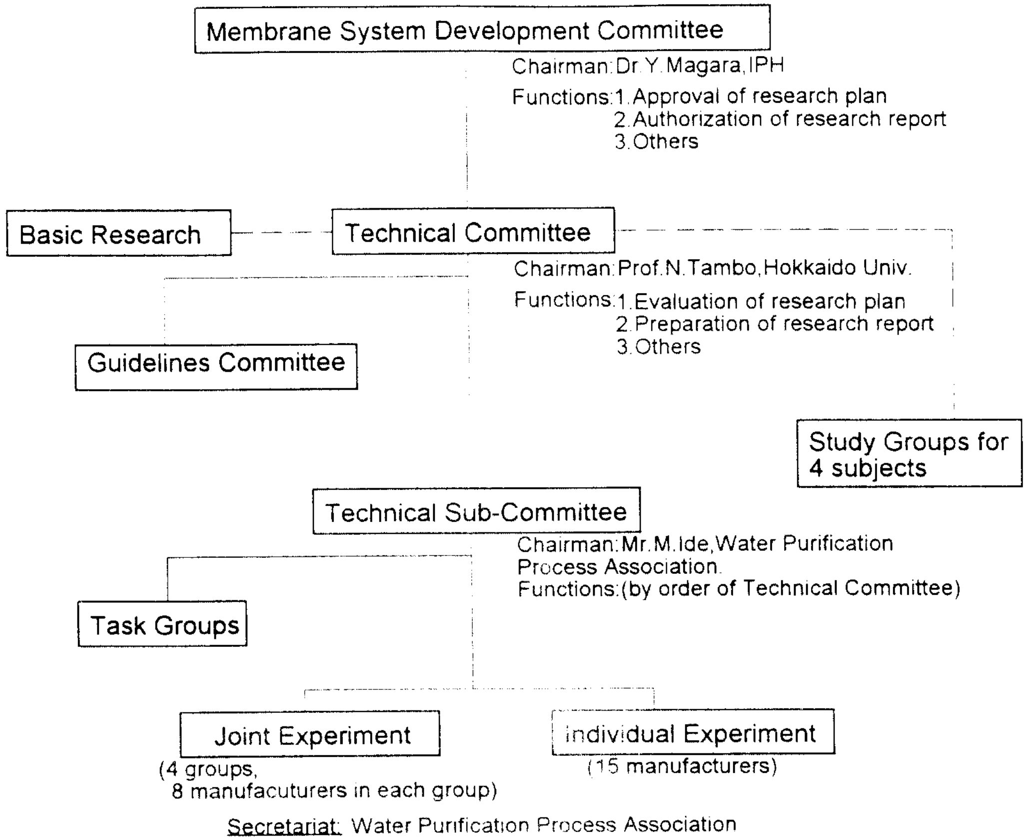

Figure 7. Organization of the *NEW MAC 21* project

RESEARCH FUND

The project is funded by both the Ministry of Health and Welfare and the participating companies. For three-years' project, totally 560 million yen are funded in which the Ministry and the participating companies contribute 180 million yen and 380 million yen, respectively.

CONCLUSION

In order to innovate the water purification technology, the "*MAC 21*" project, funded by the Ministry and participating companies, was undertaken by the Water Purification Process Association under the supervision of the Institute of Public Health. As the result, it has been demonstrated that MF/UF technology is applicable to water treatment to produce drinking water of good quality.

On the basis of the fruitful results as written above, the guidelines on application of a membrane system to small-scale public water supplies was published. We expect that the membrane technology will be adopted to the several actual water treatment plant in 1995.

And also, from FY 1994 the Ministry of Health and Welfare, Japanese Government, launched a new three-years' comprehensive research project "*NEW MAC 21*" for the development of more advanced membrane technology that is able to remove such contaminants as the precursors of disinfection by-products, microorganic pollutants, offensive taste and odor, and viruses for supplying drinking water of better quality.

The organization of the "*NEW MAC 21*" is almost the same as the "*MAC 21*", but the numbers of participating university professors and manufacturers are more than those in the "*MAC 21*". We expect that the "*NEW MAC 21*" will surely bring a fruitful results and largely contribute to the development of advanced water treatment technology.

GUIDE LINES

The guide lines has been published by WPPA in Dec. 1994. The objectives of the guide lines are for the following cases.

① When "Membrane Filtration System" is subject to be considered as a new plant or renewal / improvement of the existing plant.
② When plan and design "Membrane Filtration System" for the actual plant.
③ When, start to operate the actual plant.

ACKNOWLEDGEMENT

The author express thanks to Mr. Toshio Kawanishi and Water Purification Process Association who have permitted to present their data.

[illegible] plant (100, 500 m³/d) built. 500 m³/d [illegible]

organo use ; Daicel CA HF. membrane (In → out. ID 0.8 mm MWCO ≈ 150,000)
1 min. back wash every 15 min.
two plants to be built 500, 1000 ton/d
- pretreatment ; (100 µm. strainer, coagulants + fiber filter) (depending seasonal water variation)
- PAC : difficulty with handling
→ use wet PAC (50% water)

(New Mac 21 [illegible] NF [illegible]) : → 90% recovery