Appendix 7.1.5-2

Latest Water Analysis Data of RO Desalination

Date : 19/11/94

General Analysis of feed water and permeate water

Sea Water

		mg/L	mg/L as CaCO3
Cation	Na+	13050	28370
	K+	490	627
	Ca++	496	1240
	Mg++	1506.6	6200
	Total Cation	**15542.6**	**36436**
Anion	M-alk		132
	Cl-	23800	33568
	SO4--	3100	3229
	Total Anion	**26900**	**36930**

1- Feed water of TORAYmembrane

		mg/L	mg/L as CaCO3
Cation	Na+	13128	28539
	K+	571	730
	Ca++	472	1180
	Mg++	1482.3	6100
	Total Cation	**15653.3**	**36549**
Anion	M-alk		73
	Cl-	23750	33498
	SO4--	3260	3396
	Total Anion	**27010**	**36967**

2- Brine water of TORAY membrane

		mg/L	mg/L as CaCO3
Cation	Na+	17240	37478
	K+	621	794
	Ca++	632	1580
	Mg++	1701	7000
	Total Cation	**20194**	**46852**
Anion	M-alk		95.4
	Cl-	29760	41975
	SO4--	4050	4219
	Total Anion	**33810**	**46289**

3- Permeate water of TORAY

		mg/L	mg/L as CaCO3
Cation	Na+	112	243
	K+	7.8	10
	Ca++	0.4	1
	Mg++	1.5795	7
	Total Cation	121.7795	261
Anion	M-alk		10
	Cl-	172	243
	SO4--	3.2	3
	Total Anion	175	255

1- Feed water of TOYOBO membrane

		mg/L	mg/L as CaCO3
Cation	Na+	13230	28761
	K+	496	634
	Ca++	480	1200
	Mg++	1482.3	6100
	Total Cation	**15688.3**	**36695**
Anion	M-alk		88
	Cl-	24100	33992
	SO4--	3226	3360
	Total Anion	**27326**	**37440**

2- Brine water of TOYOBO membrane

		mg/L	mg/L as CaCO3
Cation	Na+	17650	38370
	K+	745	953
	Ca++	560	1400
	Mg++	1749.6	7200
	Total Cation	**20704.6**	**47922**
Anion	M-alk		118
	Cl-	30880	43554
	SO4--	4270	4448
	Total Anion	**35150**	**48120**

3- Permeate water of TOYOBO

		mg/L	mg/L as CaCO3
Cation	Na+	35	76
	K+	1	1
	Ca++	0.4	1
	Mg++	2.3085	10
	Total Cation	38.7085	**88**
Anion	M-alk		7
	Cl-	65	92
	SO4--	5	5
	Total Anion	70	104

3/12/94

1- Feed water of NITTO DINKO membrane

		mg/L	mg/L as CaCO3
Cation	Na+	13120	28522
	K+	455	582
	Ca++	484	1210
	Mg++	1533.33	6310
	Total Cation	**15592.33**	**36624**
Anion	M-alk		97
	Cl-	23788	33551
	SO4--	3187	3320
	Total Anion	**26975**	**36968**

2- Brine water of NITTO DINKO membrane

		mg/L	mg/L as CaCO3
Cation	Na+	15370	33413
	K+	579	740
	Ca++	520.8	1302
	Mg++	1792.854	7378
	Total Cation	**18262.65**	**42833**
Anion	M-alk		111
	Cl-	27500	38787
	SO4--	3645	3797
	Total Anion	**31145**	**42695**

3- Permeate water of NITTO DINKO membrane

		mg/L	mg/L as CaCO3
Cation	Na+	55	120
	K+	3.5	4
	Ca++	2	5
	Mg++	5.832	24
	Total Cation	**66.332**	**153**
Anion	M-alk		8
	Cl-	125	176
	SO4--	12	13
	Total Anion	**137**	**197**

General Water Analysis

	Raw	Feed Water			Brine			Permeate		
Contents	Sea .W	TORAY	TOYOBO	NITTO.DEN	TORAY	TOYOBO	NITTO.DEN	TORAY	TOYOBO	NITTO.DEN
Cl -	23800	23750	24100	23788	29760	30880	27500	172	65	125
SO4 - -	3100	3260	3226	3187	4050	4270	3645	3.2	5	12
M-alk	132	73	88	97	95	118	111	10	7	8
Mg++	1506	1482	1482	1533	1701	1749	1792	1.5	2.3	5.8
Ca++	496	472	480	484	632	560	520	0.4	0.4	2
Na+	13050	13128	13230	13120	17240	17650	15370	112	35	55
K+	490	571	496	455	621	745	579	7.8	1	3.5
TDS	48060	47000	46600	45980	60926	63281	54432	380	120	229

		TORAY			TOYOBO			NITTO.DEN		
	R.S.W	Fee water	Brine water	Permeate	Fee water	Brine water	Permeate	Fee water	Brine water	Permeate
TTHM . ppb	0.10248	1.1467	1.1542	0.43668	1.539	1.4222	3.2336	0.93646	1.46776	0.171791
COD_{Cr}, ppm	200	110	20	ND	166	114	ND	100	>1	ND
Borne . ppm	3.2	2.9	3	ND	2.85	3.1	ND	3.1	3.4	ND
Cu . ppb	4	1.7	NR	NR	1.5	NR	NR	1.43	NR	NR
Fe ,ppb	8		NR	NR		NR	NR		NR	NR
Co ,ppb	0.5	ND	NR	NR	ND	NR	NR	ND	NR	NR
Cr ,ppb	0.1	ND	NR	NR	ND	NR	NR	ND	NR	NR
NI ,ppb	1	ND	NR	NR	ND	NR	NR	ND	NR	NR

ND = Not detected
NR = Not required
Sampling Date : R.S.W, TORAY and TOYOBO ; 1994. Nov. 19
NITTO DEN; 1994. Dec. 3

THM analysis for different kinds of water by using defferent membranes

		TORAY Membrane			*TOYOBO Membrane*			*NITTO.DEN Membrane*		
THM , (ppb)	Seawater	Feed Water	Brine Water	Permeate Water	Feed Water	Brine Water	Permeate Water	Feed Water	Brine Water	Permeate Water
CHCl3	0.001453	0.0021	0.0018	0.00156	0.0065	0.0021	0.006628	0.0016	0.0012	0.00185
CHBrCl2	0.01187	0.0976	0.0824	0.12	0.0915	0.0931	0.207	0.0632	0.0866	0.0441
CHBr2Cl	0.006215	0.113	0.101	0.03812	0.116	0.115	0.254	0.0507	0.086	0.008841
CHBr3	0.08294	0.934	0.969	0.277	1.325	1.212	2.766	0.821	1.294	0.117
TTHM	0.102478	1.1467	1.15422	0.43668	1.539	1.42217	3.233628	0.93646	1.46776	0.171791

Appendix 7.2.3-1

Investigation of Pre-Filtration with MF or UF Membrane for RO Desalination

Literature Survey

The pre-filtration of the RO desalination process with MF and UF membranes is a possible method for pretreatment of oil-polluted seawater, and small-scale experiments on this process are now being carried out in Japan.

On the other hand, various equipment with separation membranes are already in practical use for the treatment of water supply and wastewater.

The results achieved with these devices can be used as reference for evaluating the practicality, on the basis of performance and cost, of separation membrane equipment. It was for that purpose that we investigated the practical use of MF and UF membranes for pretreatment in RO systems.

Also, in the desalination treatment of seawater, the effects of trihalomethane pose a problem when the product water is used for drinking, so investigations were carried out on the current methods used in Japan to suppress the generation of trihalomethane.

In addition, since the disposal of sludge created by pretreatment filtration equipment in reverse osmosis seawater desalination systems was a problem, we investigated the measures that were available to counteract this problem.

We report herewith the results of our investigations of the above three subjects.

I. Treatment of water supply and Waste Water with MF and UF Membranes

1. Application of MF Membranes to the Treatment of Water Supplies

The Ministry of Health and Welfare started the Membrane Aqua Century 21 Project (MAC-21 Project), an advanced water treatment project involving membrane separations toestablish counter-measures to the contamination of drinking water.

Various local governments, including more than seven cities such as Yokosuka, Kobe and Nagoya, are running independent proving trials with similar membrane separation.

The background to this is the increasing demand from the people for palatable drinking water and the fact that the benefits of membrane separation are recognized by many people.

Membrane treatment systems have the following advantages over conventional systems for treating water by flocculation, sedimentation and filtration:

(1) Easy operation

Completely closed system with no need to add flocculant means less pollution at the water purification plant. Can be automated and unmanned.

(2) Reduced area of installation

Can be prefabricated, occupies less space.

(3) Reduced chlorination

Simultaneous clarification and removal of bacteria allows reduced chlorination.

(4) Reduced sludge treatment

Less added chemicals means less sludge production.

(5) Running costs

It was said to be more expensive but dead end filtration with microfiltration membrane operating at 1 kg/cm^2 is said to be less expensive.

(6) Shorter construction time

In the case of Japan in particular, there are more than 12,000 water works but 80% of them are small scale, simple water supplies which are operated by 0.5 workers per installation and there is a demand for labor-saving water treatment technology such as membrane separation. Also, the fact that existing water purification plants are approaching the end of their life (50 years) and many are facing the time for their replacement is another factor in the background to thedesirefor establishing the membrane system.
In order to introduce the membrane system into water purification, I believe progress will only be made after the safety and reliability of membrane technology has been proved and clear solutions to the following problems have been found.

(1) Membrane life

Chemical cleaning method for membrane surface contamination and membrane deterioration with time are still unclear.

(2) Membrane cost

(3) Emergency back-up technology

In a conventional water purification system, thefeed water flows intoa receiving sump and several hours are required for it to reach the clean water pond. When the feed water is contaminated, time and distance canbe varied accordingly but with a membrane system it will be necessary to develop a method of detecting minute leaks.

Currently, Japan is at the stage of conducting pilot plant tests for technical confirmation of these points. Some of the new Japanese research and development in this field is shown below:

(1) Submerged separation membrane system
(2) Energy-saving vacuum leg system of membrane filtration
(3) Ceramic membrane
(4) Rotary type system with circular plate membrane

The following shows some technical information on membrane plants for the treatment of drinking water in Japan.

1.1 MAC-21 (A National Project)[1]

As mentioned previously, MAC-21 is a project which has been sponsored by the Ministry of Health and Welfare. The proving trials of Step 1 have been completed and presently the proving trials to improve water quality with NF membranes, etc. which constitute the Step 2 experiments are about to begin.
I shall summarize the results of Step 1 by quoting from the paper of Dr. Kunikane, which is a comprehensive summation of the results [3].

1) Outline of the Project

Sponsor: Department of Water Supply and Environmental Sanitation,
Ministry of Health and Welfare (MHW), Japan
Research period : FY 1991-1993
Research initiative : Institute of Public Health, MHW
Participants in demonstration experiment: 18 companies in collaboration with the Water Purification Association
Mode of operation : Three six-monthly periods of continuous operation of the Project's plant with different methods using microfiltration or ultrafiltration

Experimental facility: Kita-Chiba Regional Water Supply Authority, located in Matsudo City, Chiba Prefecture
Source of experimental feed water: Edo River
Flow diagram of the experimental facility: Fig. 1
Capacity of each plant: 30 m^3/d
Classification of plants in 1st and 2nd runs: Table 1

2) Summary of Results

Net water production (filtrate less membrane cleaning water): Fig. 2
Net water flux: 0.27 to 1.93 $m^3/m^2/d$ for microfiltration, 0.39 to 1.80 $m^3/m^2/d$ for ultrafiltration as a mean of the six months' operation
Water recovery for all membrane plants: 80% to more than 99%
Rejection of contaminants: Table 2

There was no significant difference in membrane filtrate quality between MF and UF membranes. Coliform removal was excellent, that is, no coliforms were found in any of the 100 ml filtrate samples taken weekly throughout the operation period from nine of the membrane plants in the first run and ten plants in the second run.
Fig. 3 shows estimated energy consumption based on the experimental data, assuming that a real plant with a capacity of 1,000 m^3/d would be constructed.

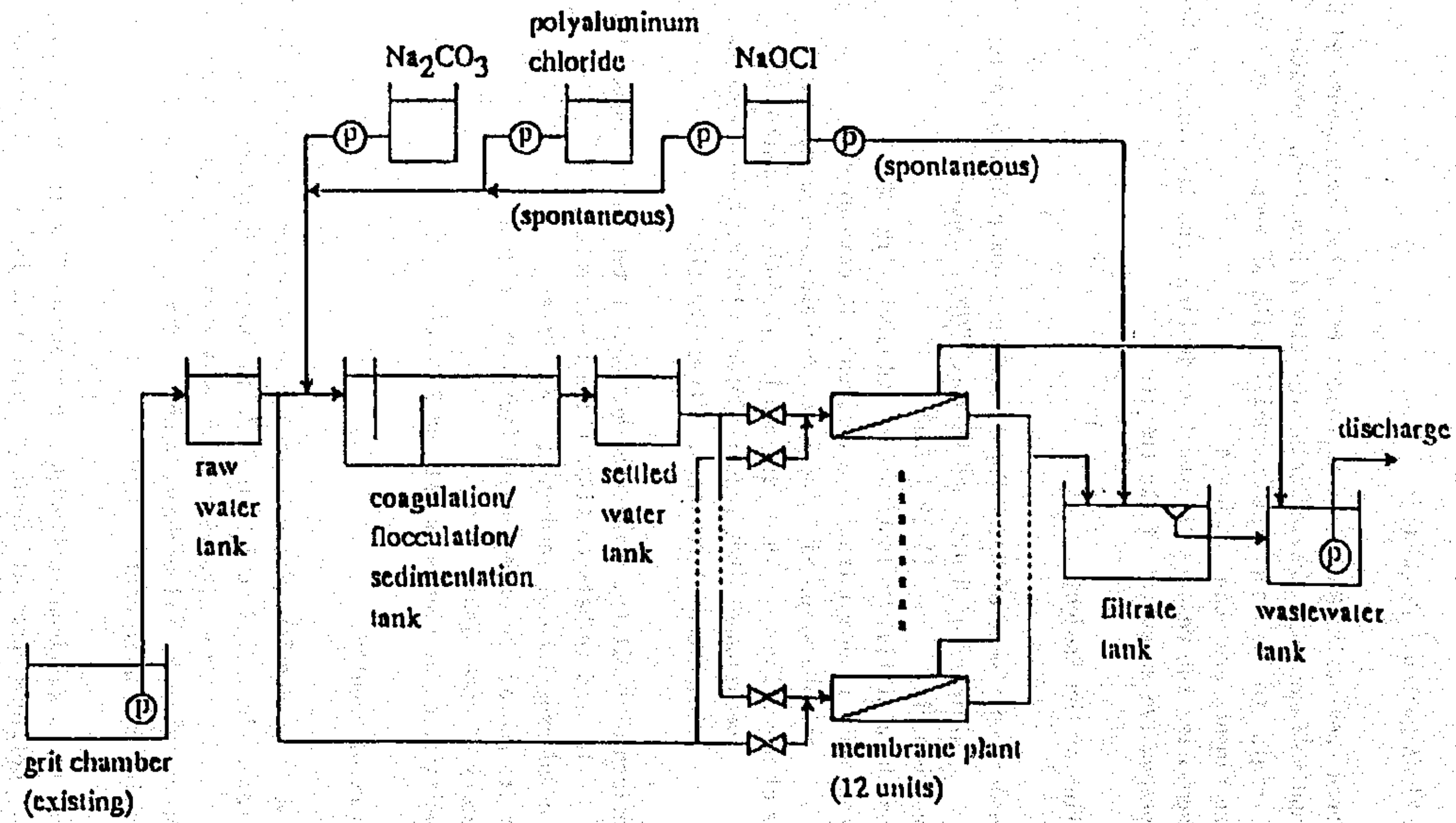
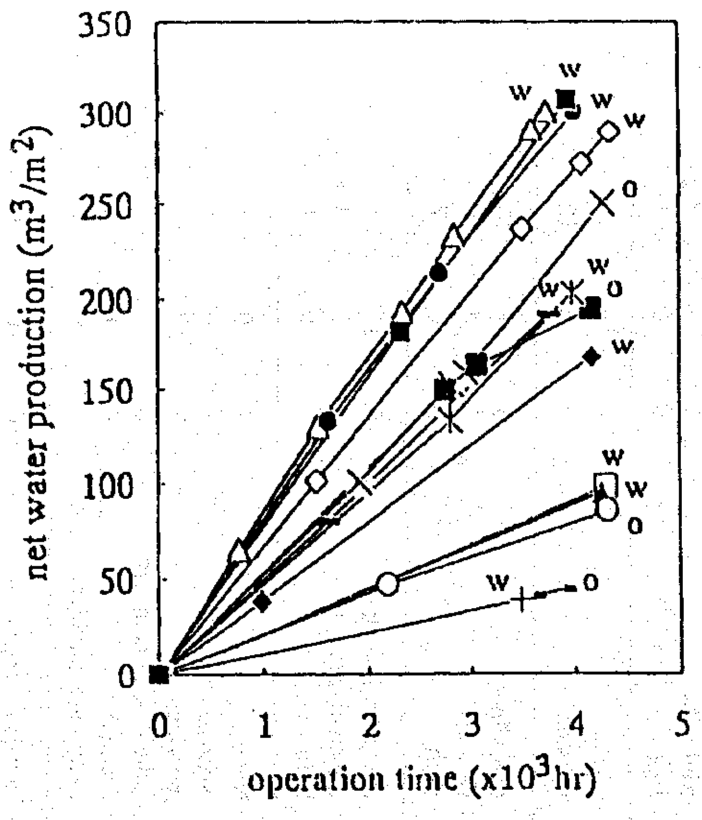


Fig. 1 Schematic flow diagram of the experimental facility

Table 1 Classification of the twenty-four membrane plants used in the first and second runs of the experiment

Classification			first	second	total
Module	Kind	MF(0.01–0.4μm)	9	5	14
		UF($1.3x10^4$–$2x10^6$ Dalton)	3	7	10
	Material	Organic	10	10	20
		Inorganic	2	2	4
	Type	Hollow fiber	10	9	19
		Tube	1	1	2
		Multitube	1	1	2
		Bag	0	1	1
	Skin	Inside	5	7	12
		Outside	7	5	12
Operation method	Flow type	Crossflow	5	8	13
		Deadend	5	4	9
		Both	2	0	2
	Flow control	Constant flow rate	10	11	21
		Constant pressure	1	1	2
		Both	1	0	1
	Pretretment	None	2	0	2
		None or common	1	0	1
		Individual	8	10	18
		Individual or common	0	1	1
		Common	0	1	1
		Common+individual	1	0	1
	Others	Housing–pressure	10	10	20
		Tank–pressure	0	1	1
		Tank–suction	2	1	3

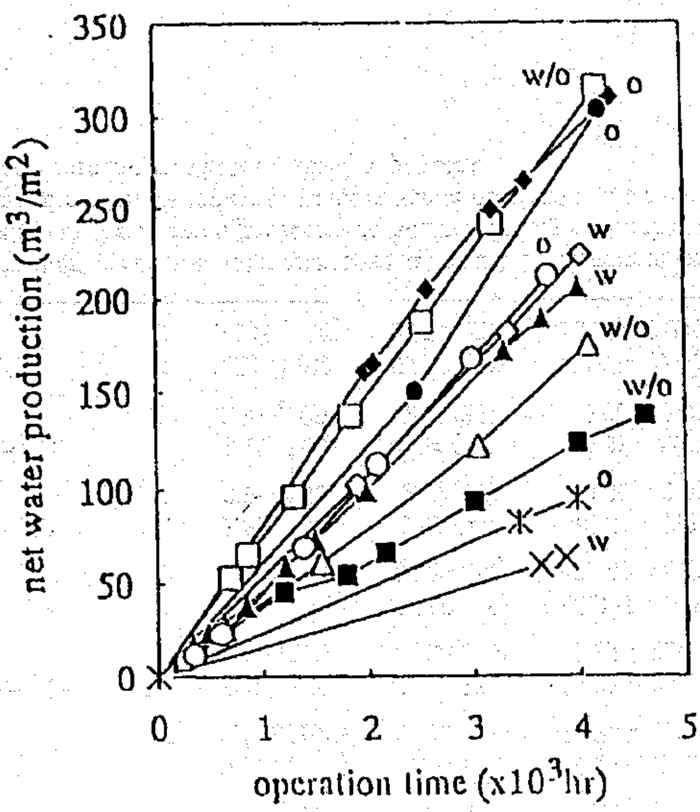
Note) In the "pretreatment", chlorination is not taken into account; "common" pretreatment means coagulation and sedimantation by the common pretreatment facility; "individual" pretreatment means the one in each membrane plant; six cases of pretreatment by coagulation with polyaluminum chloride in each run of the experiment are included in the account of "individual" pretreatment.



(a) MF membrane

Fig. 2 Net water production per unit surface area of membrane

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



(b) UF membrane

Fig. 2 Net water production per unit surface area of membrane

Plots denote chemical cleaning in six months' operation;

"w"–with polyaluminum chloride and "o"–without polyaluminum chloride.

Table 2 The result of contaminant rejection on physical and chemical parameters in the first and second runs of the experiment

Parameter	Run	Raw water	Clarified water	Membrane filtrate
Turbidity (unit)	1	16.1 (100)	1.60 (9.9)	0.01 – 0.17 (0.1 – 1.1)
	2	15.8 (100)	1.14 (7.2)	0.00 – 0.02 (0.0 – 0.1)
Color (unit)	1	10 (100)	4 (40)	1.6 – 4 (16 – 40)
	2	11 (100)	4 (33)	3 – 4 (25 – 32)
Permanganate value (mg/L)	1	7.3 (100)	2.8 (38)	1.7 – 2.8 (23 – 42)
	2	7.7 (100)	2.8 (36)	1.4 – 3.1 (16 – 41)
E_{260}, 50mm (–)	1	0.174 (100)	0.134 (77)	0.1 – 0.172 (59 – 96)
	2	0.161 (100)	0.117 (73)	0.074 – 0.150 (46 – 93)
Ammonia nitrogen (mg/L)	1	0.06 (100)	0.05 (83)	0.01 – 0.06 (16 – 100)
	2	0.22 (100)	0.22 (100)	0.09 – 0.30 (42 – 92)
Total manganese (mg/L)	1	0.049 (100)	0.020 (48)	<0.005 – 0.016 (0 – 32)
	2	0.054 (100)	0.029 (54)	<0.005 – 0.024 (0 – 49)
Total iron (mg/L)	1	0.83 (100)	0.03 (4)	<0.01 – 0.01 (0 – 2)
	2	0.94 (100)	0.09 (10)	0.00 – 0.01 (0 – 1)
Aluminum (mg/L)	1	1.10 (100)	0.34 (31)	0.01 – 0.09 (1 – 8)
	2	0.91 (100)	0.33 (37)	0.00 – 0.05 (0 – 5)
THMFP (mg/L)	1	0.046 (100)	0.027 (59)	0.021 – 0.036 (45 – 78)
	2	0.045 (100)	0.024 (53)	0.017 – 0.045 (34 – 100)

Note) "Clarified water" means the water after coagulation using polyaluminum chloride and sedimentation by the common pretreatment 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.

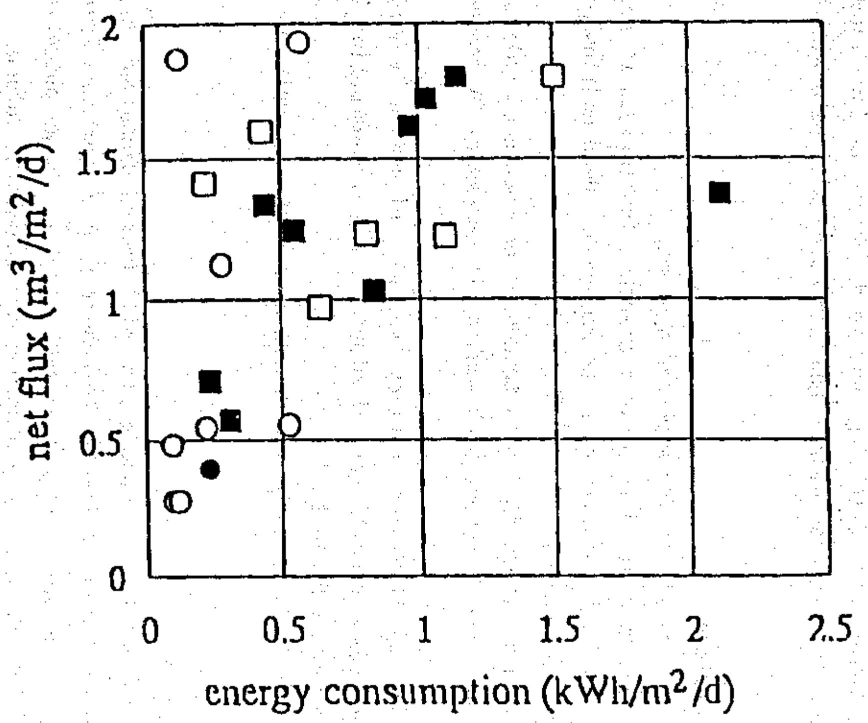


Figure 3 Relationship between energy consumption per unit surface area of membrane and net flux

Symbols: white–MF membrane and black–UF membrane; square–crossflow and circle–deadend.

It is clear that dead end filtration was more efficient than cross-flow filtration and no difference in energy consumption could be detected between MF and UF membranes.

1.2 Technical aspects of membrane performance in the treatment of drinking water

(1) Selection of membrane type

Before deciding on a system, feed water quality should be evaluated in order to select the optimum type of membrane.

Flocculation followed by microfiltration is effective for removing organic substances and it is clear that flocculation contributes to reduced clogging of the MF membrane by foulants.

Ultrafiltration is suitable for filtering raw feed which is low inorganic substances such as well water. In the future, nanofiltration will be available for improving water quality.

(2) Selection of flow mode pattern

Two types of flow modes are available for membrane systems.

Cross flow mode is usually applied to prevent membrane fouling but it requires higher energy to maintain a high velocity over the membrane. Dead endflow mode is an option which requires less energy.

With the dead end flow mode, there is a high tendency for suspended solids to accumulate on the membrane and frequent back-washing is necessary to remove the suspended solids.

Pilot plant test results show that for tertiary treatment of sewage by membrane separation, with a back-wash cycle every 15 minutes, energy consumption is less than 0.5 kwh per cubic meter of product.

Flow mode selection must be determined by the design of a system to suit the water quality.

(3) The role of flocculation

Eventhough flocculation generates more sludge, it will remove dissolved organic matter and discoloration which are difficult to remove with a membrane system. In any case, it is clear that membrane separation systems have a high potential for improving the quality of drinking water and have a very promising future.

2. Application of Membrane Separations to the Treatment of Waste Water

2.1 Advanced treatment of sewage

More than 9.8 billion cubic meter of sewage is treated annually in Japan and it is expected to become a valuable resource.

With the stringent supply and demand for water, treated sewage is gradually becoming more widely recognized as a convenient, constantly available water resource which is beginning

to be reused in a variety of applications.
Here I shall introduce some composite MF membrane and RO membrane systems as one of the advanced treatment of sewage.

2.1.1 The Tokyo Metropolitan Government's Ochiai Waste Water Treatment[2)]

(A sewage waste water reclamation plant for scenic and recreational purposes)

(1) Summary of facilities

Plant site : The Tokyo Metropolitan Government's Ochiai Waste Water Treatment Facility
Commencement of operations: April 1993
Feed water : Sand filtered sewage waste water
Treatment method: MF membrane and RO membrane
Plant capacity : 50 m^3/d
Usage of treated water: To feed the source of a brooklet and a fountain at the main entrance to the treatment facility
MF membrane specifications
Type: Hollow fiber Membrane pore diameter: 0.2 micron
Applied pressure : 1.0 to 1.5 kgf/cm^2
External pressure mode, Cross-flow
Membrane area : 30 m^2
Membrane cleaning: Automatic backwash with compressed air each 15 minutes and semi-monthly chemical cleaning
RO membrane specifications
Type: Spiral wound type
Applied pressure : 15 to 20 kgf/cm^2
Membrane area : 84 m^2
Membrane cleaning: Bi-monthly chemical cleaning
System flow diagram: Fig. 4

(2) Treatment capacity
Both quantity and quality are in accord with design capacity.

Water quality : Table 3

This plant is easily operated. Maintenance involves daily inspections and membrane cleaning several times monthly.

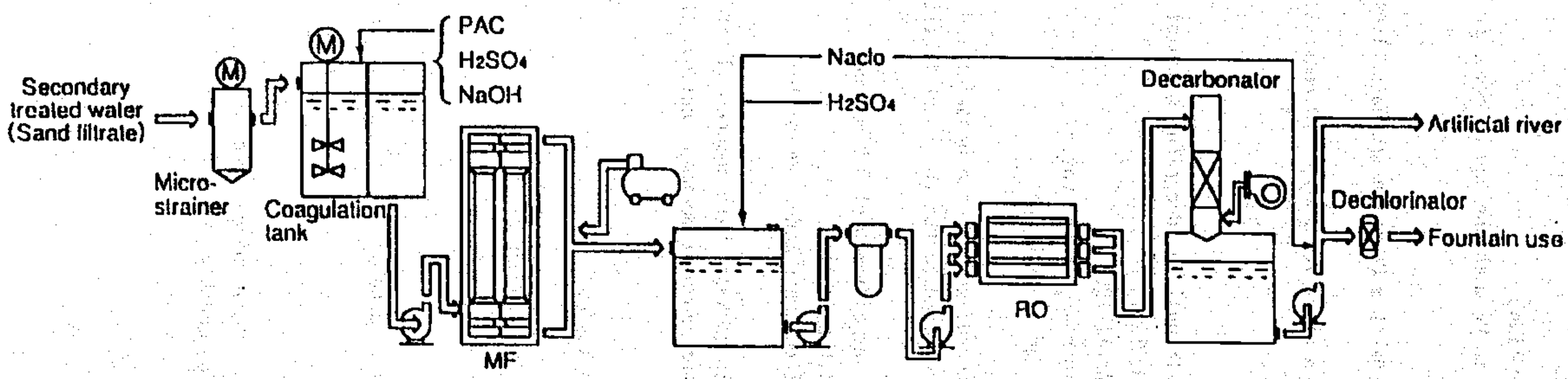


Figure 4 Flow-diagram of membrane separation plant.

Table 3 Results of water analysis

Contaminant	Unit	Sand filtrate(without disinfect.)	RO permeate
Appearance·odor	-	Slight brown with musty	Color-less, Clearness a little smell with chlorine
Color	unit	24	1 >
Turbidity	unit	-	-
SS	mg/ℓ	1 >	1 >
BOD	mg/ℓ	(1.0)	(0.36)
COD_{Mn}	mg/ℓ	7.7	0.5 >
NH_4-N	mg/ℓ	4.8	1.1
NO_3-N	mg/ℓ	5.8	3.1
T-P	mg/ℓ	0.51	0.01 >
pH	-	7.5	6.6
Bacteria	cfu/100mℓ	4.1×10^5	N.D
Coliforms	cfu/100mℓ	1.8×10^4	N.D
Viruses	MPN fu/mℓ	2.75	N.D

2.1.2 Nagoya City's Hojin Municipal Sewage Treatment Plant[3)]

(1) Summary of facilities

Plant site : Hojin Municipal Sewage Treatment Plant, Nagoya
Commencement of operations: June 1993
Feed water : Sewage effluent after final settling
System flow : Coagulation, MF membrane and RO membrane
Plant capacity : 100 m3/d
Usage of treated water: To feed a brooklet, for landscape improvement and to provide aquatic harmony

MF membrane specifications
Type: Hollow fiber   Membrane pore diameter: 0.2 micron
Applied pressure : 0.3 to 1.0 kgf/cm^2
External pressure mode, Dead end flow
Membrane material: Polypropylene
Membrane area : 40 m^2 (4 elements each 10 m^2)
Coagulant : PAC 2 ppm as Al
Water recovery : 85%
Membrane cleaning: Automatic backwash with compressed air (6 kgf/cm^2) each 15 minutes

RO membrane specifications
Type: Spiral wound type
Membrane material: PVA
Applied pressure : 7 kgf/cm^2 Cross flow
Membrane area : 56 m^2
Water recovery : 64%
System flow diagram: Fig. 5

(2) Treatment capacity

Chemical cleaning of membranes: Not necessary for one year
The microfiltration pressure differential increased by up to $2.5 \times 10^{-2} kg/cm^2/d$ during operation.
Both quantity and quality are in accord with design capacity.
Water quality: Table 4

It was concluded that dead end mode filtration using microfiltration gave good results with low energy consumption and less chemical cleaning of the RO membrane during one year's operation.

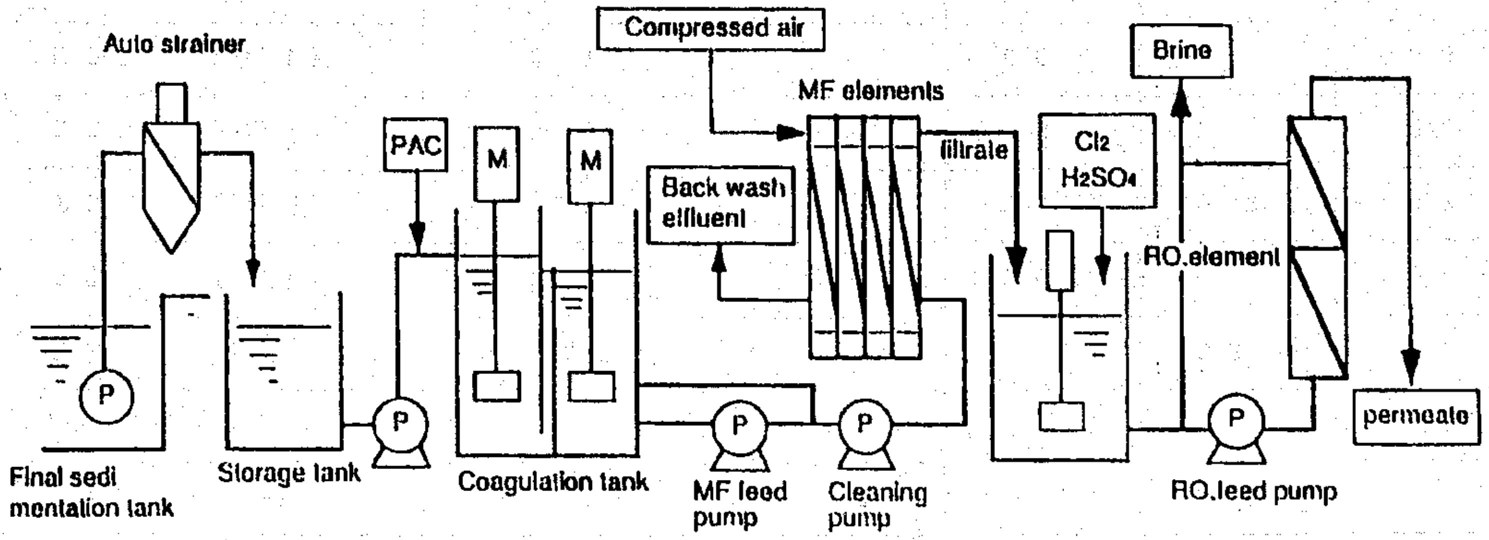


Figure 5 Flow diagram of pilot prant

Table 4 Results of water analysis

Contaminant	Raw water	MF		MF + RO	
		Filtrate	Rejection (%)	Permeate	Rejection (%)
pH (-)	7.58	7.34	—	5.6	—
Conductivity (μS/cm)	1870	1854	0.9	972	48.0
TS (mg/ℓ)	1393	1300	7.2	623	55.3
SS (mg/ℓ)	6.1	0	100	0	100
TOC (mg/ℓ)	9.7	6.4	34.0	0.2	97.9
COD (mg/ℓ)	8.3	6.9	16.7	0	100
BOD (mg/ℓ)	3.5	0	100	0	100
T-N (mg/ℓ)	16.8	16.2	3.6	15.2	9.5
T-P (mg/ℓ)	2.0	0.54	73.0	0	100
Color (unit)	17.5	13.8	21.1	0	100
Coliforms(cfu/ml)	630	0	100	0	100

2.2 Grey Water

I have already introduced the fact that the recycling of waste water from buildings, etc. is being promoted as a means of saving water resources, based on administrative guidelines. I shall now present some typical examples which are in operation in Japan.

2.2.1 Grey water recovery system combined with membrane in a department store building[4)]

Plant site : Underground level 3, Takashimaya Department Store (Tokyo)
Established: July, 1987
Type of waste water: Kitchen wastes
System flow: Biological treatment ... UF membrane
Flow sheet: Fig. 6
Plant capacity: 450 m^3/d

<Specifications of membrane treatment equipment>

Module type: Tubular module (109 mm x 2619 mm length)
Tube internal diameter: 11.5 mm
Membrane material: Polyolefin
Molecular weight cut off of membrane: 20,000
Total number of modules: 162/3 units (1.6 m^2/module x 162 = 259 m^2)
Inlet pressure: 8.5 to 9.5 kg/cm2
Intake flow: 30 m^3/h
Outlet flow: 24 m^3/h

<Performance of membrane treatment equipment>

Variation in fluid permeation through membrane (Fig. 7)

Despite additions made in 1990, the rate of permeation has been stable for the last eight years at 1.0 to 1.3 $m^3/m^2 \cdot d/25°C$

Variation in quality of treated water (Table 5)

The quality of the permeate from ultrafiltration is extremely high and the membranes were able to be operated for three years without replacement.

<Maintenance of membrane treatment equipment>

Physical cleaning : Sponge balls insertion once a month
(13 mm diameter tube)
Chemicalcleaning : NaOH, NaClO

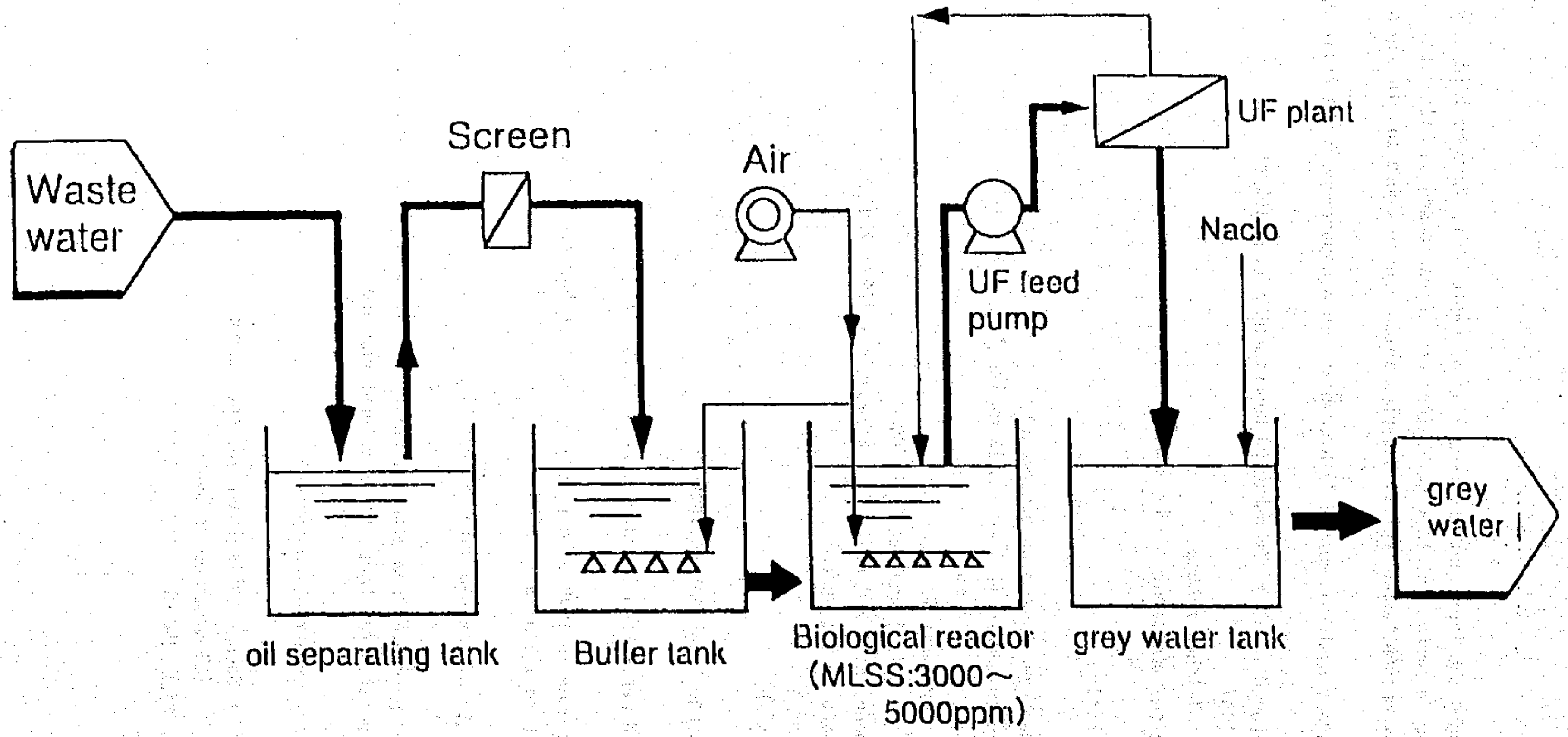


Fig. 6 Flow diagram of grey water recovery system

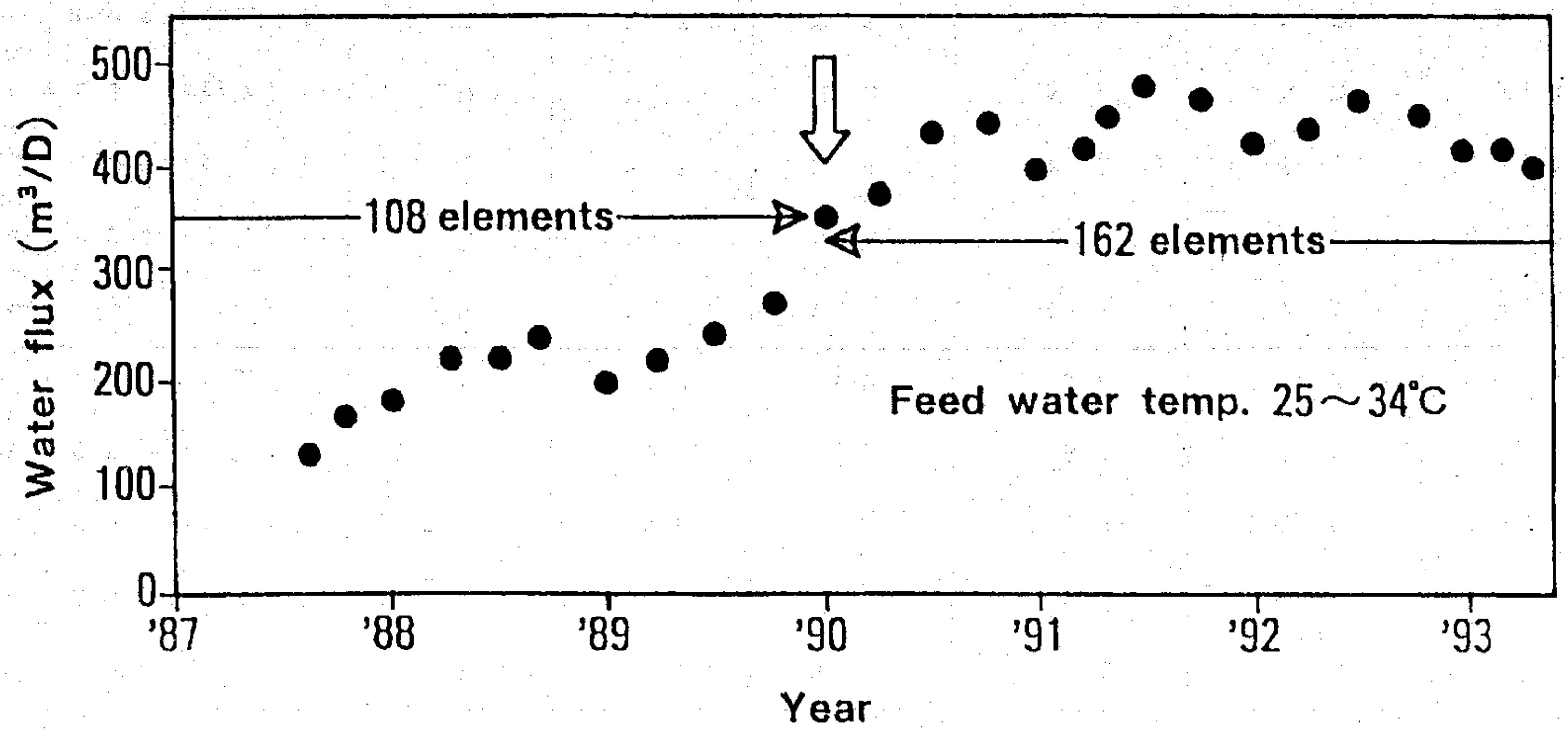


Fig.7 **Record of permeated water in each year**

Table 5 Water analysis for each year

	Contaminant	1998. Oct.	1989. May	1990. Jan.	1991. Apr.	1992. Dec.	1993. Oct.
Raw Water	pH	5.3	6.4	6.6	5.3	6.5	6.4
	BOD (mg/ℓ)	520	246	293	276	214	274
	COD (mg/ℓ)	170	86	133	130	95.5	93.5
	SS (mg/ℓ)	210	49	225	162	112	91
	n-Hex (mg/ℓ)	31	48	52	54	43	44
UF-Permeate	pH	7.5	7.2	7.2	7.3	7.1	7.3
	BOD (mg/ℓ)	N.D	N.D	N.D	N.D	1.7	N.D
	COD (mg/ℓ)	4.6	5.5	5.9	6.2	5.9	5.5
	SS (mg/ℓ)	N.D	N.D	N.D	N.D	N.D	N.D
	n-Hex (mg/ℓ)	N.D	N.D	N.D	N.D	N.D	N.D
	Coliforms (cfu/mℓ)	0	0	0	0	0	0

2.2.2 Membrane separation plant for typical regional water recycling systems [5]

1) Summary of facilities

Plant site : Huis Ten Bosch, a 152 ha recreation center in Nagasaki

Established: March 1992

Plant capacity: 2,700 m^3/d

System flow:

Sewage from the center is treated by the normal activated sludge process which is followed by advanced treatment consisting of contact aeration, flocculation, sedimentation, sand filtration and UF membrane.

Specification of the membrane: Table 6

Usage of the produced water: Toilet flushing, make-up water for cooling towers, garden irrigation.

2) UF plant performance

The water produced by the membrane plant was of good quality with high transparency as shown in Table 7.

It was odor-free and suitable for toilet flushing.

Based on the design conditions for plant operation, an average water flux of 40 $l/m^2 \cdot h$ was able to be maintained.

2.3 Treatment of Industrial Waste Water

Generally, industrial waste water is highly concentrated and difficult to treat due to the infinite variety of the properties of the wastes.

Consequently, there is a limit to the conditions which are susceptible to membrane separation methods, comparatively small quantities of wastes with contaminants with good settling characteristics being suitable.

Here are two specific examples of waste water treatment applications.

2.3.1 Treatment of waste water containing fluoride in a semi-conductor factory [6]

1) Two-stage coagulation and sedimentation (Conventional process)

The treatment of wastes containing fluoride from a semi-conductor manufacturing plant is a general two-stage method involvingcoagulation and sedimentation.

The method involves adding calcium hydroxide to flocculate and precipitate the fluoride as CaF_2. Aluminium chlorideis then added to remove the residual fluoride by.

Table 6 Specifications of membrancs

Configuration	Hollow Fiber (ID 0.8mm)
Type	ACV-5010 (Asahi Kasei)
Material	PAN
Cutting-off	13,000
Membrane area	$12.3 m^2$/module
Operation Pressure	$1 \sim 2 kgf/cm^2$
Permeate flux	$30 \sim 70 \ell/m^2.h$ (av. $40 \ell/m^2h$)

Table 7 Water analysis data

	Raw Water	Secondary Treated Waste	Tertiary treatment	
			Coagulation and Sedimentation	UF Membrane Permeate
BOD (mg/ℓ)	242	14.9	5.8	2.0
COD (mg/ℓ)	92	14.6	10.0	6.4
SS (mg/ℓ)	212	8.8	3.1	1.0
T−P (mg/ℓ)	6.2	2.2	1.0	0.3
T−N (mg/ℓ)	43.3	26.2	22.5	20.9

coagulation and precipitation.

Problems with this method include the large amounts of sludge which are produced, the large area required for the facilities and the high cost of waste water treatment.

2) Membrane separation process for the treatment of waste water containing fluoride in a semiconductor factory

Instead of coagulationand sedimentationthissystem applies cross-flow filtration with MF membranes to achieve a solid-liquid separation afteradding $CaCl_2$, PAC and NaOH to waste water containing fluoride at a concentration of 400 to 2000 mg/l in order to produce CaF2.

The specifications of the membrane are as follows:

Membrane type : Hollow fiber MF membrane (internal pressure type), internal diameter of hollow fibers: 5.5 mm
Membrane pore diameter : 0.2 micron
Membrane material : Polypropylene
Dimensions of membrane elements: 200 mm diameter x 3000 mm length
Effective membrane area: 8 m^2/element

Table 8 shows quality of feed and treated water.

By incorporating fluorine adsorbent resin, the residual fluorine in the micro-filtration filtrate can be reduced to between 0.1 and 1.8 ppm.

<Membrane operating conditions>

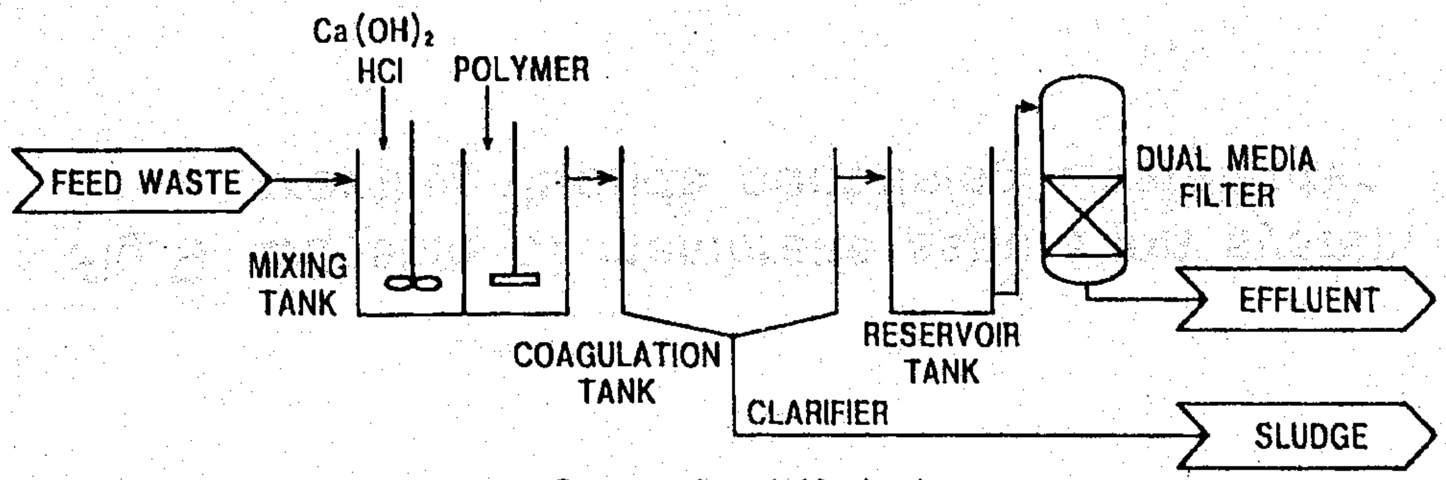
Inlet pressure : 1.4 kg/cm^2
Outlet pressure : 0.8 kg/cm^2
Membrane surface flow rate : 2 m/s
Concentration of circulating slurry : 2 to 5% (shut off at 6%)

Membrane permeation rate is proportional to surface flow rate (0.5 to 4 m/s) (the force required increases)

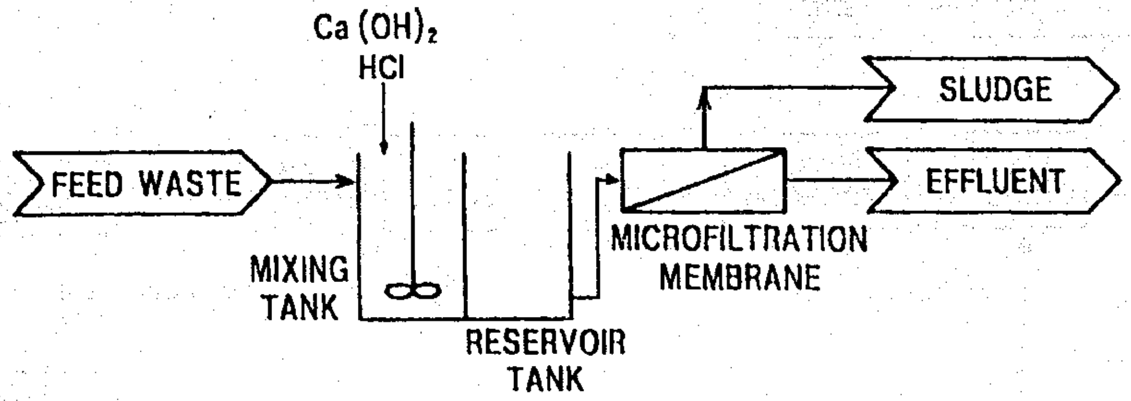
The membrane system reduces the area of the installation by about 60%.

Although both the operating costs and installation costs are higher than the conventional method (two-stage coagulation and sedimentation method), the conventional method cannot completely remove pollutants and heavy metals in thewaste water. The membrane system not only removes these completely but it also has the advantage of substantially reducing the area required for the facilities.

In this treatment example, the membrane permeation rate of $5m^3/m^2/d$ iscomparatively high



Conventional Method



Membrane Separation Method

Fig.8 **Comparison of conventional method and membrane separation method.**

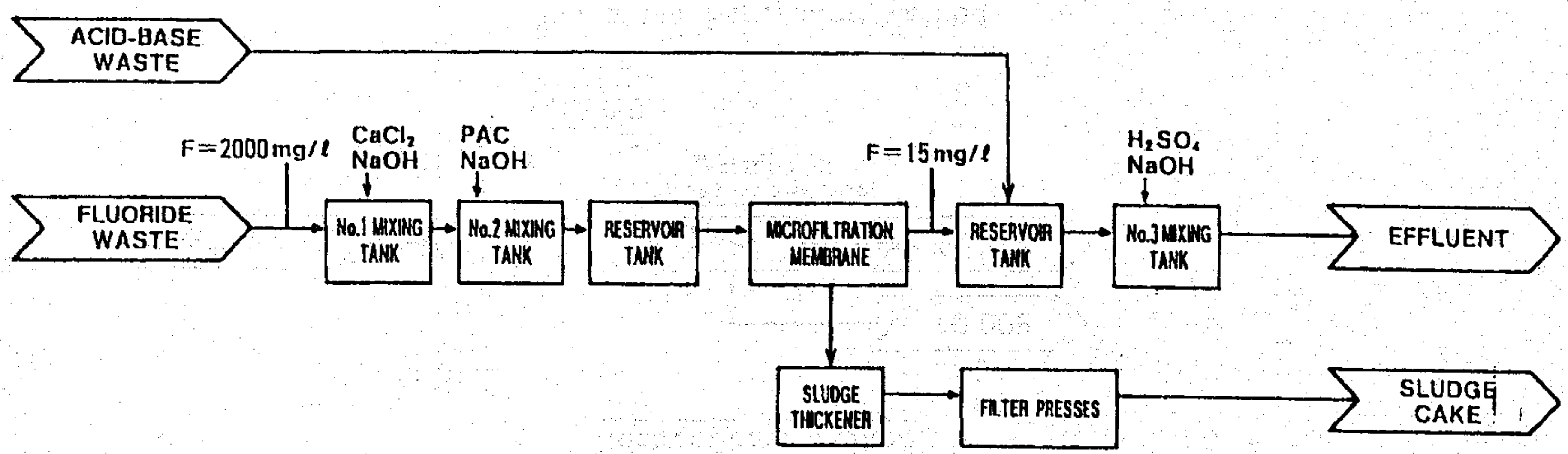


Fig. 9 Scheme of membrane separation system for treating fluoride containing wastewater.

Table 8 Results of water analysis treated with membrane separation system

Item	Feed water	Effluent
pH (−)	−	6 ~ 7
SS (mg/ℓ)	~ 20	0.5 >
F (mg/ℓ)	1600 ~ 2500	11 ~ 17

but the properties of the inorganic suspended solid pollutants permit this high permeation rate. (Particle diameter: 0.5 to 1.0 micron. 10% slurry concentration readily achieved by natural settling) However, if the slurry is circulated for more than 48 hours, the particles become smaller.

2.3.2 Rad-waste filter with hollow fiber membrane(MF)[7]

Pre-coat type filtration systems have been used for purifying condensate and radioactive waste in nuclear power plants.

Recently, some nuclear power stations have started using hollow fiber membrane filters in those applications in order to minimize the quantity of secondary waste.

Here is a typical example of a system, approved by the Power Reactor and Nuclear Fuel Development Corporation of Japan, for radioactive waste filtration in an advanced thermal reactor in the Fugen nuclear power plant.

1) Hollow fine fiber (HFF) membrane specifications
Specifications of the HFF membrane applied to radioactive waste filtration are shown in Table 9.

2) Preliminary evaluation of the HFF membrane in field tests.
A small field test unit fitted with a HFF membrane was used to remove suspended matter in the radioactive waste treatment facility. Hot test data are shown in Table 10. As a result of the hot test, membrane life is estimatedto be about three years.

3) Actual plant performance
The flow diagram of a commercial plant and operational test data are shown in Fig. 10 and Table 11.
It was expected that the volume of sludge as secondary waste would be reduced to between one-eighth and one-forty-fourth of that produced by precoat filtration.

2.4 Future development of the application of membranes in the treatment of waste water

The value of membrane separation systems in special, commercially based waste water treatment applications is already recognized. But there are some technical and economic improvements which will promote future applications. The following are some of them.

(1) The development of new module devices to prevent clogging by suspended matter
(2) Larger module elements
(3) Membranes to tolerate high temperatures
(4) Highly efficient physical cleaning devices
(5) Operating systems with low energy consumption
(6) Reduced plant costs

Table 9 Specification of hollow fine fiber

Manufacturer	Toyobo Co.
Material	Tri-cellulose acetate
Fiber size (O.D.xI.D.xt)	0.52x0.35x0.085mm
Pore size	Outer Surface 0.08 μm Inner Surface 0.5 μm
Heat resisting property	No strength reduction up to 90℃
Irradiation stability	No strength reduction up to 10^4 Gy irradiation
Burnability	No noxious- gas production
Chemical resisting property	Available pH 3～10
Water flux	520 ℓ/m^2h/(kgf/cm^2)
Outlet quality	Less than 1 ppb(when inlet of 1ppm)
DF(Decontamination Factor)	More than 1000 (when inlet of 1 ppm)

Table 10 Hot test data

Waste water treated		Suspended solid concentration	Back washed water volume / Membrane permeated volume
Equipment drain	Normal operation	Less than 1 ppm	About 1/300
	During periodical plant maintenance	Less than 4ppm	1/20 ~ 1/30
Scrubbing water of demineral-izer	Rad-waste demineralizer	40 ~ 70 ppm	About 1/15
	Condensate demineralizer	Less than 20 ppm	About 1/30
Special drain	Suppression pool water	Less than 6 ppm	About 1/300
	Steam drum hydro test water	3 ppm	About 1/130
Floor - drain		65 ppm	1/2 ~ 1/20
Laundry - drain		125 ppm	About 1/8

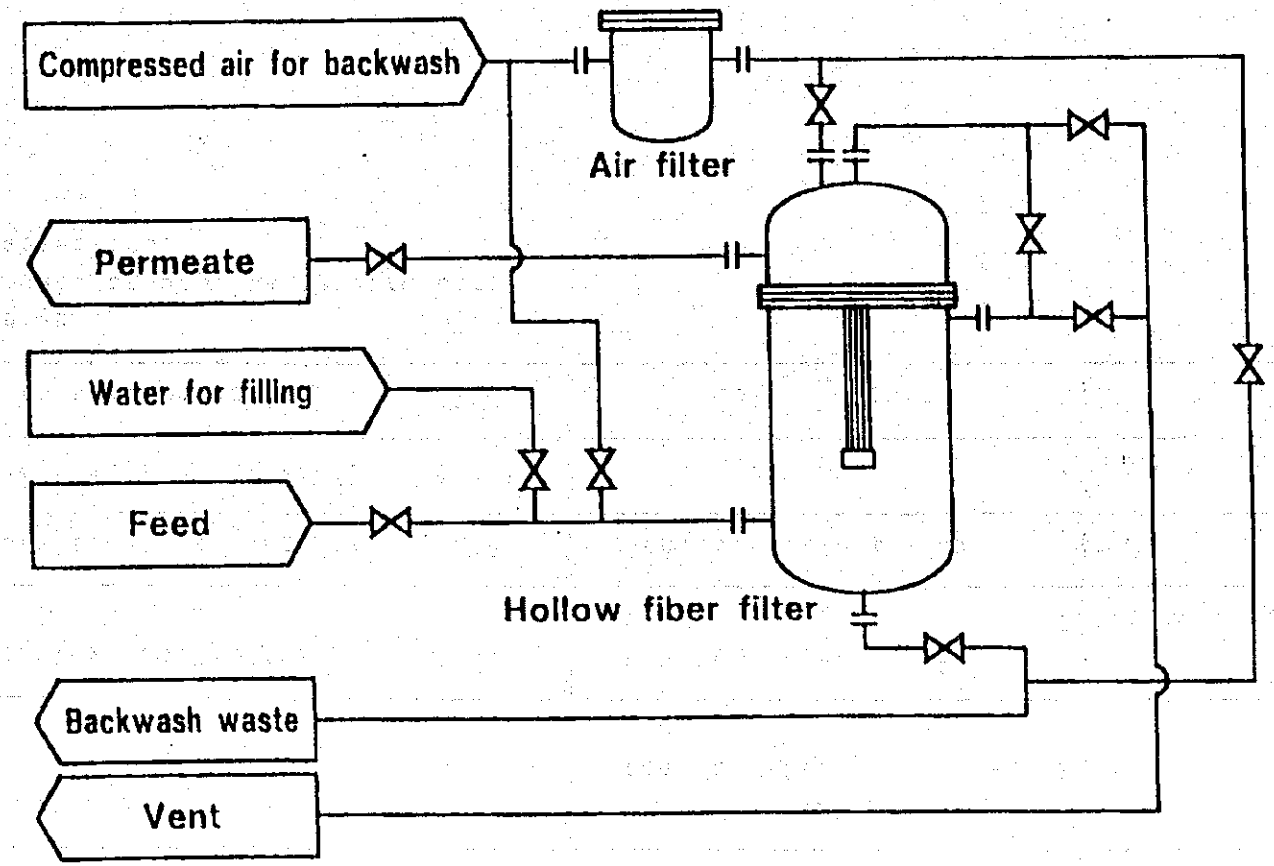


Fig. 10 Hollow fiber filter system

Table 11 Operational test data

Operational parameters		Water quality	inlet	outlet
Flow rate (m^3/h)	10.1	Suspended soild concentration*1 ppm	2～4	<0.1*3
ΔP at running temp(kgf/cm^2)	0.32	Fe Concentration*2 ppm	0.59～1.10	<0.05*3
ΔP calibrated at 25℃ (kgf/cm^2)	0.40	Conductivity μS/cm	32～39	Ditto
ΔP increase at 25℃ (kgf/cm^2)	0.035	pH	4.1～4.3	Ditto
Feed water temperature(℃)	37.7	Oil ppm	<0.1	Ditto

*1. By weight
*2. By atomic absorption spectrometry
*3. Not detective

3. Cost Evaluation

Cost comparisons between plants are generally difficult because plant cost calculations are dependent on the scope of the plant and on local conditions and each case is different. We can merely evaluate the data to make a rough comparison.

Table 12 shows some of the cost data for a waste water treatment plant. These data were collected from actual commercial plants in Japan.

It is clear that these costs are much higher than those in overseas countries.

As mentioned before, municipal sewage water is a useful industrial water resource and we already have some membrane plants treating municipal sewage, especially the recovery of boiler feed water from tertially treated sewage followed by small capacity RO desalination.

We are now at the initial stages of evaluating membrane microfiltration for the treatment of municipal sewage to produce water for toilet flushing, cooling and scenic and recreational use.

There are many reasons why these costs are much higher than those in other countries.

(1) Compensation for guaranteed performance
We are usually obliged to compensate the customer if, for any reason, there is any deterioration in the plant during operation.

(2) Preliminary service fee for plant design
We need much time and manpower to negotiate before the plant is finally designed.

(3) High prices and costs
Costs of manpower, land, taxation, etc. are higher in Japan than inother countries.

Plant cost estimates vary according to the scope of the system and whether or not public engineering works such as concrete tanks are involved. If the scope of the plant is not well-defined, this is another reason for saying that our plant cost estimates are higher.

Costs vary widely due to differences in design specifications and the way water supply facilities are managed. That is to say, matters such as whether or not spare membrane modules and pumps will be included, the quality of the materials used for piping, the complexity of control instrumentation, etc. will have a major bearing on the cost of the facilities and should be carefully considered.

And, even if the cost estimates are high, they will be competitive with conventional processes which are also expensive in Japan.

Nevertheless, this system of high prices in Japan can certainly not be maintained. It is sure to collapse in the near future.

Table 12 Cost data of water treatment plant with membrane

	A	B	C
Waste water	Community waste water (Grey water recovery)	Building waste water (Grey water recovery)	Industrial waste water (Reclamation)
Plant capacity(m^3/D)	2700	450	160
System flow	Contact aeration + Coagulation + sand filtration + UF membrane	Biological reactor + UF	Coagulation + MF
Running cost (Yen/m^3)			
· Membrane replacement	84	76	75
· Electric power	17	95	–
· Chemicals	2	65	–
· Man power	17		–
· Total	110	236	259 *2
Capital cost(Yen/m^3/D)	248×10^3 *1	440×10^3	625×10^3
Membrane type	UF/Hollow fiber	UF/Tubular	MF/Hollow fiber
Membrane life(years)	2	5	2
Pore size	M.W.C : 13,000	M.W.C : 20,000	0.2 μm
Applied pressure(kg/cm^2)	2.0	9.0	1.4
Water flux(m^3/m^2.D)	1.0	1.2	10.0
Membrane module(Yen/m^2)	25×10^3	150×10^3	225×10^3

*1 : 40% of the cost consist of public engineering works such as concrete tanks
*2 : Cost including electric power, sludge recovery

4. Conclusion

It is only recently that implementation and research was commenced in Japan on water purification systems such as MF and UF membranes. At present, we areat the stage where the government is taking a lead in conducting running tests to ensure the safety and reliability of the technology and cost estimates are being compiled.
As I have mentioned already, the fact is that many local governments have started in dependent experiments to introduce membrane separations into their own public water supply and they have become aware of the benefits of MF and UF, with theresultthat they are appreciating that these benefits will offset the high costs.
Nevertheless, it is certain that it is in the small scale water works, which account for 80% of all water works, that membrane separations will actually be used. Their reputation will be made here and I think they will spread to the largerplants after experience has been gained.

In the case of the treatment of clean water to be supplied for drinking, from the aspect of the safety of the technology, it is important to establish a back-up system which can cope immediately if ever the quality of membrane treated water deteriorates.

Concerning the application of membrane separations to the treatment of waste water, the technical reliability and safety have already been proven and implementation is for selected types of waste water is progressing. The economic benefit are also being demonstrated.

It is possible that they will also be used in the future for specific types of waste water, such as the reduction of the amount of radioactive waste, the space-saving and compact aspects of grey water, but it is inconceivable that the demand for advanced treatment of sewage will suddenly increase. It can be expected to spread inlimited areas, such as places where water is critically scarce, for instance. For this reason it is to be hoped that the costs will come down.

The following are some reasons for the suitability of advanced membranetreatment of sewage:

(1) With conventionalcoagulation andsandfiltration, the coagulation effect varies dueto theunstablequality ofthe sewagewater and temperature variations. The membrane method, on the other hand, gives astableperformance and the quality is better than with coagulation and filtration.

(2) The record shows that installing MF membraneas apre-treatment forRO has kept RO performance stable for a year or more and enabled RO cleaning to be reduced.

(3) Costs are reasonable compared with existing systems, ifdischarge feesare included.

In any of these applications, the costs are higher thanconventional systemsbut I believe these can be offset by the benefits of the membrane system. Furthermore, in future, it is highly probable that new separationmembraneswillbe developed and separation systems will be modified and improved.

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7) Y.Ohmori, etal, Ebara Jiho, No.148 (1990-7).

Appendix 7.3.2-1

Operation of Maintenance Manual of RO Plant

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ATTACHMENT

1. Engineering Drawing

1) Basic and Mechanical Drawings

JICA Dwg. No.	Kurita Dwg. No.	Title
SAJ-R1001 1	0T9A-2N03-Y001 1	Plot plan of MSF & RO test plants
" -R1002(1/4) 1	" -Y002(1/4) 1	Pretreatment section-piping & instrument diagram
" -R1002(2/4) 1	" -Y002(2/4) 1	Spiral wourd type RO equipment section-piping & instrument diagram
" -R1002(3/4) 1	" -Y002(3/4) 1	Hollow fiber type RO equipment section-piping & instrument diagram
" -R1002(4/4) 1	" -Y002(4/4) 1	Chemical and utility-piping & instrument diagram
" -R4003 1	" -Y003 1	Plot plan indoor & side view
" -R4004 2	" -Y004 2	Foundation of pipe & cable trench in tes plant facility

JICA Dwg. No.	Kurita Dwg. No.	Title
SAJ-R4005 2	0T9A-2N03-Y005 2	Foundation of control panel
" -R4006 1	" -Y006 1	Foundation of pre-treatment skid & chemical feeder skid
" -R4007 1	" -Y007 1	Foundation of tanks
" -R4008 1	" -Y008 1	Connection point of utilityies in RO test plant facility
" -R4009	" -Y009	Foundation of RO skid
" -R4101	" -Y101	Pretreatment skid assembly-section-100
" -R4111	" -Y111	Spiral wound type RO equipment skid assembly-section-200
" -R4112	" -Y112	Hollow fiber type RO equipment skid assembly-section-300
" -R4113	" -Y113	Chemical feeder skid assembly-section-500
" -R4201	" -Y201	Piping assembly
" -R4203(1/3)	" -Y203(1/3)	Detail of piping assembly in pipe trench
" -R4203(2/3)	" -Y203(2/3)	Detail of piping assembly in pipe trench

CHAPTER I. GENERAL

1. INTRODUCTION

This volume provides the system level operation and maintenance instructions for "Reverse Osmosis Process Test Plant". And the original equipment manufacturer's operation and maintenance manuals for purchased system compornents are provided in the Attachment.
Engineering drawings for system assemblies are included in this volume.

2. GENERAL DESCRIPTION

The plant is "Reverse Osmosis Process Test Plant" for Japan-Saudi Arabia Reseurch Project of Seawater Desulination organized by Japan International Cooperation Agency.
In order to investigate, evaluate and establich the most suibable and economical "Reverse Osmosis Desalination System" considering the climatic and environmental conditions and the quality of the seawater in Saudi Arabia, the plant is operated in the various condition and the following confirmation will be made:

1) Performance of Pretreatment System
   (Disinfection, coagulation and filtration)

2) Performance of the membrane elements against the feed seawater salt content, operating pressure, recovery rate.

3) Life of the membrane against high temperature and or high pressure operation.

4) Performance and establishment of Reverse Osmosis Desalination System.

5) Eualuation and establishment of the operation and maintenance for "Reverse Osmosis Desalination System".

CHAPTER II. DESIGN BASE

1.0 Equipment Design

Ambient temperature	:	5 ~ 45°C
Humidity	:	56 ~ 70%
Rain fall	:	0 ~ 47.8 mm/year (in 1976 ~ 1980) (10% voltage fluctuation or less)

2.0 Seawater Quality

pH	:	8.2
TDS	:	44,500 ppm
Cℓ	:	25,000 ppm
Turbidity	:	less than 2

3.0 Seawater Temperature

21°C ~ 32°C

4.0 Water Recovery Rate of RO

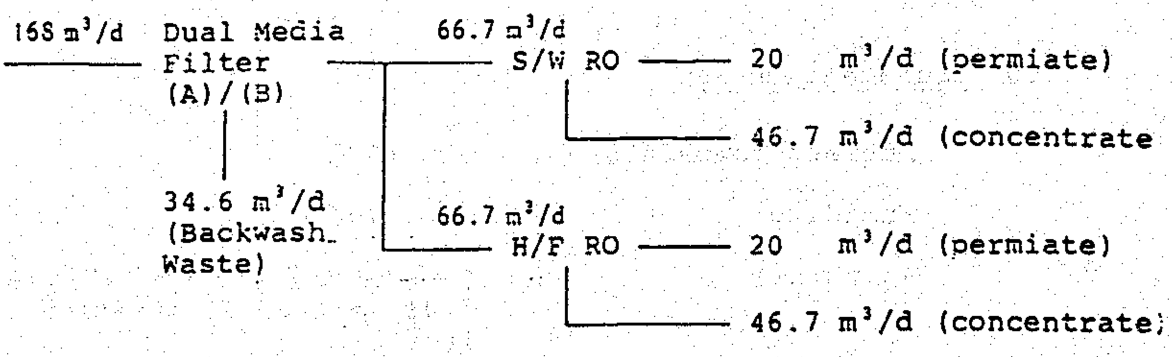
30%

5.0 Permeate Water Quality and Quantity

(Spiral wound type RO and Hollow fiber type RO)

Permeate TDS	:	500 ppm
Permeate productivity	:	20 m^3/d

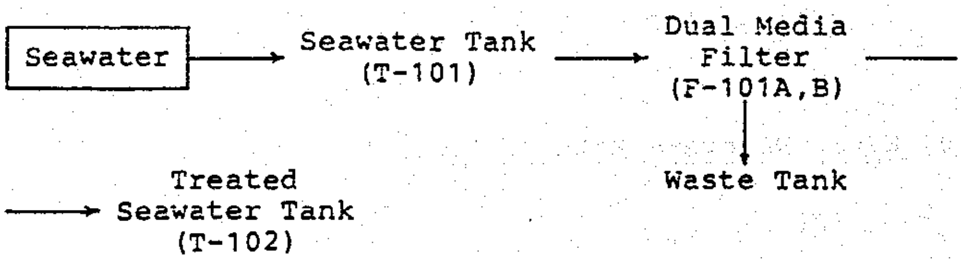
6.0 Flow Balance



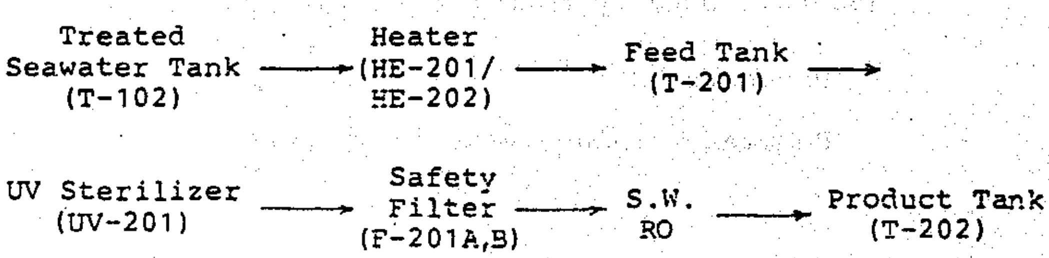
Required water at filter inlet	:	168 m³/d
RO product water	:	20 m³/d each
Brine water to dispose	:	46.7 m³/d
Backwash waste water	:	34.6 m³/cycle

7.0 Overall Figures of Reverse Osmosis Process Test Plant

1) Pre-treatment Equipment Section



2) Spiral Wound Type RO Equipment Section



3) Hollow Fiber Type RO Equipment Section

Treated Seawater Tank (T-101) → Heater (HE-301/ HE-302) → Feed Tank (T-301) →

UV Sterilizer (UV-301) → Safety Filter (F-301A,B) → H.F. RO → Product Tank (T-302)

4) Chemical and Utility

a) Chemical Dosing Equipment Section

Chlorine Tank (T-501) (NaCℓO) → Pre-treatment Equipment
→ H.F. Type RO Equipment

Coagulant Tank (T-502) ($FeC\ell_3$) → Pre-treatment Equipment

Acid Tank (T-503) (H_2SO_4) → S.W. Type RO Equipment
→ H.F. Type RO Equipment

Deoxidant Tank (T-504) (SBS) → S.W. Type RO Equipment

b) Steam

Steam → Heater for S.W. Type RO Treatment (HE-201/HE-202)
→ Heater for H.F. Type RO Treatment (HE-301/HE-302)

c) Instrument Air

Compressor (P-401) → Air Dehumidifier → RO Plant
→ MSF Plant

8.0 General Process Description

The plant can be divided into four sections constituting pretreatment, S.W. type RO system, H.F. type RO system and chemical dosing system.

1) Pre-treatment Equipment

Suspended matters in the seawater shall be removed before application to the RO equipment.
The pre-treatment equipment section is accommodated to remove the aforementioned suspended matters.
Seawater received in Seawater Tank (T-101) is transferred to Dual Media Filter (F-101A and F-101B) by Seawater Pump (P-101A,B).
Two Dual Media Filters are installed in series.
Suspended matters are removed by 1st Dual Media Filter (F-101A).
2nd Dual Media Filter is accommodate to polish the seawater.
The treated seawater is stored in Treated Seawater Tank (T-102).
Sodium hypochlorite (NaCℓO) and ferric chloride are fed to the seawater at the inlet of Dual Media Filter.
Sodium hypochlorite (NaCℓO) is fed for sterilization, and ferric chloride is fed for coagulant.
Pre-treatment equipment is mounted on the skid.
The 1st Dual Media Filter (F-101A) will be automatically operated by programing timer mounted in control

panel. Therefore, service and regeneration of the 1st Dual Media Filter (F-101A) will be automatically carried out by the programming timer.
The 2nd Dual Media Filter (F-101B) will be manually operated.
Treated seawater is monitored by Automatic Fouling Index Monitor located in test plant control room, and in case of more than 4.0 of fouling index, the alarm will be annunciated.

2) Spiral Wound Type RO Equipment Section
Treated seawater is desalinated by Spiral Wound Type RO Equipment.
Treated seawater stored in Treated Seawater Tank (T-102) is transferred to Feed Preheater (HE-201) and Feed Heater (HE-202) to adjust temperature of the seawater by Feed Pump (P-201), and stored in Feed Tank (T-201). Heating media for Feed Pre-heater (HE-201) and Feed Heater is steam and concentrate respectively. And then, seawater is transferred to UV Sterilizer (UV-201) and Safety Filter (F-201A,B) and to S.W. type RO Module through High Pressure Pump (P-203) to desalinate.
Permeate (Product) is stored in Product Tank (T-202) and concentrate is discharged to trench.
Safety Filter (F-201A,B) is provided with 10 micron polypropylene tube and replacement of filter tube

shall be required when the pressure drop will reach approx. 2.45 kg/cm². Spare tubes are provided.

UV Sterilizer (UV-201) is provided for disinfection of the seawater.

Life of germicidal lamp will be within 4000 Hrs.

Replacement of germicidal shall be required accordingly.

Spare lamps are provided.

Sulfuric acid and SBS (deoxidant) is fed for pH adjusting and removing residual chlorine and dissolving oxygen respectively.

S.W. Type RO Equipment is mounted on the skid.

3) Hollow Fiber Type RO Equipment Section

Treated seawater is also desalinated by Hollow Fiber Type RO Equipment. Treated seawater in Treated Seawater Tank (T-301) is transferred to Feed Preheater (HE-301) and Feed Heater (HE-302) to adjust temperature of the seawater by Feed Pump (P-201) and stored in Feed Tank (T-301).

Heating media for feed heater and feed pre-heater is steam and concentrate respectively. And then, the seawater is transferred to UV Sterilizer (UV-301) and Safety Filter (F-301A,B), and to H.F. type RO Module through High Pressure Pump (P-302) to desalinate.

Safety Filter (F-301A,B) is provided with 10 micron

polypropylene tube and replacement of filter tube shall be required when the pressure drop will reach approx. 2.45 kg/cm^2. Spare tubes are provided.
UV Sterilizer (UV-301) is provided for disinfection of the seawater.
Life of germicidal lamp will be within 4000 Hrs.
Replacement of germicidal shall be required accordingly.
Spare lamps are provided.
Permeate (Product) is stored in Product Tank (T-302) and concentrate is discharged to trench.
H.F. Type RO Equipment is mounted on the skid.

4) Chemical Dosing Equipment Section

Total four (4) chemical feeders are accommodated in the chemical dosing equipment skid.

a) Chlorine Feeder

Sodium hypochlorite 1.0% solution is used for pretreatment process, and H.F. type RO system.
The dosage of chlorine is adjusted so as to keep 0.2 to 1.0 ppm of residual chlorine at filter inlet and RO inlet respectively.
The dosage of chlorine may vary depending on the contamination of the seawater. One Chlorine Tank (T-501) and two Dosing Pump (P-501A,B) are provided.

b) Coagulant Feeder

Ferric chloride 5% solution is used for pretreatment process in regards to coagulation of suspended matters in the seawater, so that Dual Media Filter can well filtrate.

Dosage of ferric chloride will be manually adjusted in 2 to 3 ppm against the seawater.

One Coagulant Tank (T-502) and one Dosing Pump (P-502) are provided.

c) Acid Feeder

70% of sulfuric acid is used for pH adjustment for both S.W. type RO and H.F. type RO dosage of acid is monitored by pH Recorder (PHRA-301) mounted on the control panel located in Test Plant Control Room and adjusted manually by changing pump stroke. High and low pH alarms are set in pH recorder for annunciation.

One Acid Tank (T-503) and two acid Dosing Pump (P-503A,B) are provided.

d) Deoxidant Feeder

SBS (Sodium Bisulfite) is dosed to scavenge residual chlorine and dissolved oxygen which is contained in the seawater for disinfection.

S.W. type RO Module is not permitted to contain 0 ppm of residual chlorine and 0.5 ppm of dissolved oxygen.

One Deoxidant Tank (T-504) and three Dosing Pump (P-504A,B,C) are provided. Two Dosing Pump (P-504A,B) are operated normally and one Dosing Pump (P-504C) are operated as shock treatment for stopping S.W. type RO treatment.
Dosage of SBS will be monitored by ORP indicator (Oxygen reduction potential indicator - ORP-201) mounted on the control panel located in Test Plant Control Room and adjusted manually by changing pump stroke.

e) Spare Dosing Pump
Eight (8) complete chemical dosing pumps are provided as spare to the event such that failure of any chemical dosing system and/or dosing of rejuvenating chemical for the R.O. membranes when necessary.

CHAPTER III. OPERATION PROCEDURE

1.0 Operation Summary

The followings are summary of important practices to be observed during normal operation.

1) Pretreatment

The flow adjustment for Dual Media Filter (FIL-101A,B) should be checked.

Feed water flow	7.0 m^3/Hr
Backwash water flow	25.0 m^3/Hr
Backwash air flow	36.0 m^3/Hr

2) S.W. Type RO System

2-1) The flow adjustment for S.W. type RO system should be checked.

Permeate flow	0.84 m^3/Hr
Concentrate flow	1.95 m^3/Hr

(The above figures base on 30% of water recovery rate.)

2-2) The pressure adjustment for S.W. type RO system should also be checked.

Operating pressure will be 50 to 60 kg/cm^2G.

2-3) Residual chlorine and dissolving oxygen in RO feed

Keep 0 ppm of residual chlorine and max. 0.5 ppm of dissolving oxygen.

(This will be caused the perfect remedy for operating S.W. RO system.)

2-4) pH in RO feed

Keep RO feed pH 4.0 to 8.5.

2-5) Fouling index

Keep RO feed fouling index 4 or less.

Always ensure pretreatment operation.

2-6) Temperature in RO feed

Keep 21 to 50°C of temperature in RO feed.

3) H.F. Type RO System

3-1) The flow adjustment for H.F. type RO system should be checked.

Permeate flow	0.84 m^3/Hr
Concentrate flow	1.95 m^3/Hr

(The above figures base on 30% of water recovery rate.)

3-2) The pressure adjustment for H.E. type RO system should be checked.

Operating pressure will be 50 to 65 kg/cm^2G.

3-3) Residual chlorine in RO feed

Keep 0.2 to 1.0 ppm of residual chlorine.

3-4) pH in RO feed

Keep 4.0 to 7.0 of pH in RO feed.

3-5) Fouling index

Keep RO feed fouling index 4 or less.

Always ensure pretreatment operation.

3-6) Temperature in RO feed

Keep 21 to 50°C of temperature in RO feed.

2.0 Check List Prior to Plant Start Up

1) Verify that all high pressure victaulic couplings are properly tightened.

2) Verify that all electric sequences are healthy.

3) Verify that pretreatment system are producing adequate water quality which meet membrane requirement.

4) Verify that instrument air system is healthy.

5) Verify that no leak on the water, air and chemical dosing lines.

6) Verify that all necessary chemicals are properly prepared with adequate freshness and dilution.

7) Verify that all chemical metering pumps are healthy and well stroke-adjusted.

8) Verify that all membrane elements are properly loaded.

9) Verify that high pressure pump is well prepared in the alignment, V-belt tension, oiling, etc.

10) Verify that all automatic valves are properly functioning.

11) Verify that all timers are properly set.

12) Verify that correct electric source is wired.

3.0 Start, Stop Procedure

1) Start up Procedure

a) Verification for manual valves

Verify that the manually operated valves located throughout the system have been set as follows. (For valve number, refer to the attached "Piping and Instrument Diagram, DWG No. SAJ-R-4002 (1/4 ~ 4/4)".

Valve No.	Situation	Remarks
V-101	Open	
V-102	Close	
V-103	Open	Note-1
V-104	Open	
V-105	Open	
V-106	Open	
V-107	Close	
V-108	Close	Note-2
V-109	Close	
V-110	Close	
V-111	Close	
V-114	Close	Note-3
V-115	Open	
V-116	Open	
V-117	Close	Note-4
V-118	Open	
V-120	Close	
V-121	Close	) Note-5
V-122	Close	

Valve No.	Situation	Remarks
V-123	Open	
V-124	Open	
V-201	Open	
V-202	Open	Note-6
V-203	Close	
V-204	Open	
V-205	Open	Note-6
V-206	Open	
V-207	Open	
V-208	Close	
V-209	Open	Note-6
V-210	Open	
V-211A,B	Open or Close	
V-212A,B	Close or Open	
V-216	Throttled and adjusted	
V-218	Open	Note-7
V-219	Close	
V-220	Close	Note-8
V-221	Close	
V-222	Open	
V-224	Open	Note-9
V-225	Close	
V-226	Close	
V-227	Close	Note-5
V-228	Close	
V-229	Close	
V-230	Open	Note-7
V-231	Close	
V-232	Open	
V-233	Close	
V-240	Close	Note-11

V-301	Open	
V-302	Open	Note-6
V-303	Close	
V-304	Open	

Valve No.	Situation	Remarks
V-305	Open	Note-6
V-306	Open	
V-307	Open	
V-308	Close	
V-309	Open	Note-6
V-310	Open	
V-311A,B	Open or Close	
V-312A,B	Close or Open	
V-316	Throttled and adjusted	
V-318	Open	Note-7
V-319	Close	
V-320	Open	Note-8
V-321	Close	
V-322	Open	
V-324	Open	Note-9
V-325	Close	
V-326	Close	
V-327	Close	Note-5
V-328	Close	
V-329	Close	
V-330	Open	Note-7
V-331	Close	
V-332	Open	
V-333	Close	
V-340	Close	
V-401	Open	
V-402	Close	
V-403	Open	
V-404	Close	
V-501A,B	Open	
V-502	Open	
V-503A,B	Open	
V-504A,B,C	Open	

Valve No.	Situation	Remarks
V-505	Close	Note-6
V-506	Close	
V-507	Close	
V-508	Close	

Note-1 When UV Sterilizer (UV-101) will be out of order, by-pass of UV-101 shall be used. In the case, sodium hypochlorite shall be dosed by P-501A.

Valve No.	Situation
V-102	Open
V-103	Close
V-104	Close

Note-2 Dual Media Filter - B (F-101B) for polishing shall be manually operated.

Machine No. Valve No.	Service	Backwash					
		Drainage	Air Bubbling	Pause	Back-washing	Pause	Flashing
V-105							
V-106							
V-107							
V-108							
V-109							
V-110							
V-111							
P-101							
P-102							
P-103							
Operating Time	*1	*2	10 min.	3 min.	15 min.	5 min.	15 min.
Flow Rate	7 m^3/Hr	-	36 m^3/Hr	-	25 m^3/Hr	-	7 m^3/Hr

*1. Backwash shall be manually carried out once a week or when pressure drop of F-101B will reach 0.5 kg/cm at the service.

*2. Drainage shall be made until water level in Dual Media Filter (F-101B) will reach at the surface of the anthracite.