it is necessary to find out the features of the raw water, and to modify the disinfection technology using the ultraviolet light for desalination of the seawater. Some proposals are made on existing equipment and disinfection systems. The following estimation is based on the proposals.

The facility for the treatment of 100,000 T/D (4,167 T/hr)
Treated water by a unit : 115 T/hr/unit
Number of lamps by a unit: 32 tubes/unit
Demand by a unit : 1.92KW/unit
Number of required units : 37 units
Number of required lamps : 1,184 tubes
Facility layout: One module consists of 37 basic units. The raw water flows into the open channel and the lamps are arranged in a bundle. Refer to Fig.3.3.19

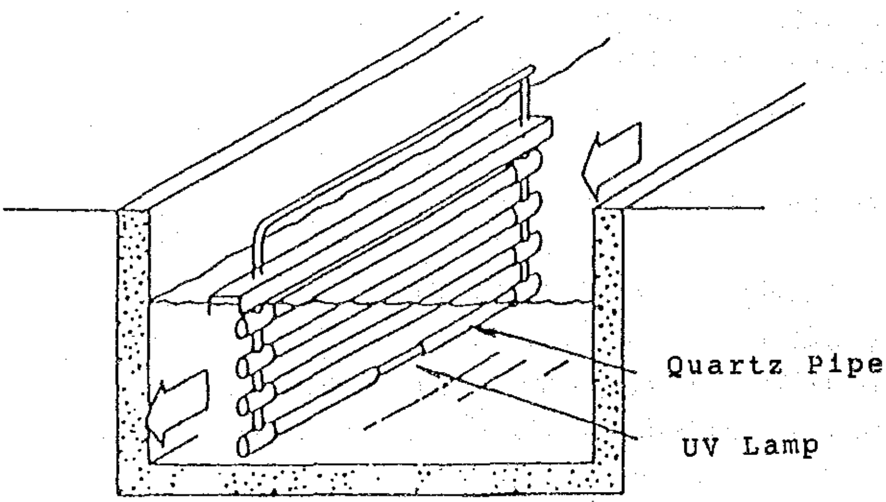

Fig.3.3.19 Concept Picture of Equipment

b. Initial costs

1) The price of a basic unit: 8,500,000 yen/unit; for the installation in Japan, Auxiliary facilities such as panels included. Construction costs of channels etc. excluded.

2) Initial costs for required equipment: 314,500,000 yen = 8,500,000 yen/unit x 37 units
For lamps: 47,360,000yen = 40,000yen/tube x 32tubes/unit x 37 units
For installation and auxiliary facilities: 267,140,000yen

(2) Cost Accounting

<1> Introduction

Unlike the chlorine sterilization, there is little information about the construction of the ultraviolet light disinfection facility for the seawater desalination plant. If cost accounting for UV disinfection is estimated based on the construction cost and the operating cost in Saudi Arabia, it may lead to an error. Therefore, accounting is made here on a prerequisite that the facility shall be constructed and operated in Japan.

<2> Depreciation

a. Prerequisites

The cost of lamps in the initial cost, is accounted as the maintenance expense, because lamps are regarded as consumable supplies, since the life is one year. The lamp installation equipment and the auxiliary equipment including instrumentation are all that is accounted as depreciation.

The channel to flow the raw water, the power supply and the buildings are excluded. Straight line depreciation for 7 years.

b. Cost accounting

Depreciation expense per year: 38,163,000 yen/year = 267,140,000 yen/7 years
Depreciation expense per day: 105,000 yen/day; for permeate production: 30,000 T/D
Depreciation expense per 1 ton of water production: 3.49 yen/T

<3> Maintenance Expense

a. Prerequisites

As mentioned above, the life of a lamp is one year. Only the cost of lamps is estimated as maintenance expense. All of the lamps will be exchanged every year.

b. Cost accounting

Maintenance expense per year: 47,360,000 yen/year=40,000 yen/tube x 1,184 tubes
Maintenance expense per day: 130,000 yen/day; for water production 30,000 T/D
Maintenance expense per 1 ton of permeate production: 4.33 yen/T

<4> Electric Power Expense

a. Prerequisites

Electric power expense is estimated based on the value (1.92KW/unit) described in the catalogue of the proposed equipment. The unit price of electric power in Japan is set at 17 yen/KWH, although it depends on the type and the size of the plant.

b. Cost accounting

Electric power expense per year:
10,580,000/yen=1.92KW/unit x 87 units x 8,760 H/year x 17 yen/KWH

Electric power expense/day: 29,000 yen/day; for water production: 30,000 T/D
Electric power expense/ 1 ton of permeate production: 0.97 yen/T

Note: 71 KW(1.92 KW/unit x 37 units) is enough for the power supply, and the depreciation is small.

<5> Labor expense

a. Prerequisite

It is almost unnecessary to take labor expense into account, because special operators of the system are not required. The monitoring at the central control room and the maintenance and the periodical inspection of the whole desalination plant covers this disinfection system. But one hour per day is estimated as labor expense, because the maintenance and the inspection of the lamps may be necessary according to the features of the raw water, and the replacement of lamps must be completed by personnel.

b. Cost accounting

Labor expense: 719,000 yen/year; working days= 290days/year;
actual working hour= 7 hours/day,

Wages: 400 million yen/year base

Labor expense per day: 1,970 yen/day; 30,000 T/D for water production

<6> Disinfection cost for water production 30,000 T/D

Depreciation expense:	105,000 yen/D
Maintenance expense :	130,000 yen/D
Power expense :	29,000 yen/D
Labor expense :	1,970 yen/D
Total	260,000 yen/D

<7> Unit disinfection cost

Depreciation expense:	3.49 yen/T
Maintenance expense:	4.33 yen/T
Power expense:	0.97 yen/T
Labor expense:	0.07 yen/T
Total	8.86 yen/T

3.4. Disinfection With Copper Sulfate

3.4.1 Outline

It is long known that metal itself has the property to restrain the growth of bacteria, that is, the property to disinfect bacteria. Accordingly, heavy metallic salt has been used to disinfect the wounds made by surgical operations[119], and copper sulfate has been used as the disinfectant of drinking water for a long time. Moreover, it is widely acknowledged that copper sulfate is especially effective for the extermination of algae[120].

(1) Advantages of Copper Sulfate[121]

As copper sulfate is solid, handling of it is not so dangerous as that of chlorine gas, and raw water can be easily treated with copper sulfate. As its effect as a chemical lasts a comparatively long time, it is most widely used as a disinfectant. Copper sulfate is said to restrain the decomposition of organic substances in sludge deposit and the decay of sludge.

(2) Disadvantages of Copper Sulfate[122]

It takes a long time before the copper sulfate has an effect and it is reported that the copper sulfate may actuate the multiplication of the algae which are not affected by copper.

(3) Copper Sulfate Resistance of RO Membrane

Few cases of using copper sulfate as a disinfectant or an agent to exterminate algae in the seawater desalination plants equipped with RO membranes, have been documented. There appears no clear data on actual disinfecting or algae exterminating effects of copper sulfate, or any data on its long-range use on the membranes. According to the report information[123] on model experiments, copper sulfate, used with cellulose acetate membranes, restrains the growth of microorganisms and does not cause definite damage to the membranes.

3.4.2 Principle

(1) Physical and Chemical Properties of Copper Sulfate[124]

Chemical Formula :	$CuSO_4$
Condition :	Colorless powder, Gravity; 3.606
Penta-hydrate Salt:	Absorbs moisture from the air, and becomes blue hydrate salt ($CuSO_4 \cdot 5H_2O$)
Toxicity :	Toxic
Solubility in Water:	0°C about 14%
	30°C about 25%
	100°C more than 75%

Handling Condition: For biological treatment, usually copper sulfate of industrial standard in a moisture-proof paper bag is used.

(2) Disinfecting Properties of Copper Sulfate

Disinfecting and algae exterminating process with copper sulfate is most widely applied to the dead water of reservoirs, lakes and marshes to remove algae[125].

It presumes that it is not appropriate to apply copper sulfate disinfecting process to seawater desalination plants which take water from the sea. The environment of a seawater desalination plant which faces a gulf isolated from ocean currents is, however, quite similar to that of lakes and marshes. Report[126] introduces the pretreatment processes of seawater desalination utilizing RO membranes applied in the desalination complexes of the Middle East. It explains that the RO plants in Umm Luji and Jeddah take raw water from the Red Sea and yet they use copper sulfate as a disinfectant despite the fact that chlorine is most advantageous in cost and the extermination of organisms from the viewpoint of the contamination of the seawater and of the type of RO membrane used (aromatic polyamide). The membranes in those plant are highly sensitive to chlorine.

i) Standard Addition Ratio of Copper Sulfate for Biological Treatment[127]

The addition ratio of copper sulfate required for the extermination of organisms depends on the type of organisms. Standard ratios are shown in Table 3.4.1.

ii) Dependency of Copper Sulfate Disinfecting and Algae Exterminating Properties on Conditions[128]

To carry out disinfection and algae exterminating treatment with copper sulfate; in addition to the injection standard ratios shown in Table 3.4.1, the hardness, the alkalinity, the organisms, and the water temperature must be taken into consideration in deciding the addition ratio. In the case of dead water, the influence of sunshine is further taken into account in the decision. The hardness, the alkalinity and the organisms abate the efficiency of copper sulfate, and high water temperature and sunshine promote its efficiency.

For every 1°C rise in the water temperature from the standard 15°C, the addition ratio can be lowered by 2.5% from the injection ratio shown in Table 3.4.1. On the contrary, for every 1°C fall, the addition ratio must be raised by 2.5%.

As for the organisms, the addition ratio must be raised by 2% for the rise of every 10ppm in the concentration.

As for the alkalinity, it is reported that the addition ratio must be raised by 0.5% to 5% for the

Table 3.4.1 Addition ratio of copper sulfate required for biological treatment[128]

Organisms		$(CuSO_4 \cdot 5H_2O)$ (ppm)
sulfur bacteria	*Beggiatoa*	0.50
	Thiothrix	
Iron bacteria	*Crenothrix*	0.33 ~ 0.50
	Gallionella	
	Sphaerotilus	0.40
Fungi	*Leptomitus*	0.40
	Saprolegnia	0.18
Cyanophyceae	*Anabaena*	0.12 ~ 0.48
	Aphanizomenon	0.12 ~ 0.50
	Oscillatoria	0.20 ~ 0.50
	Phormidium	
	Polycystis	0.12 ~ 0.25
Diatoms	*Achnanthes*	0.50
	Asterionella	0.12 ~ 0.20
	Attheya	0.20
	Cyclotella	0.50
	Fragilaria	0.25
	Melosira	0.33
	Navicula	0.07
	Nitzschia	0.50
	Rhizosolenia	0.20 ~ 0.70
	Stephanodiscus	0.25
	Synedra	0.50 ~ 1.00
	Tabellaria	0.12 ~ 0.50
Green algae	*Ankistrodesmus*	1.00
	Chlamydomonas	0.50
	Closterium	0.17
	Coccomyxa	
	Cosmarium	2.00 ~ 3.00
	Draparnaldia	10.33
	Eudorina	0.00
	Gloeocystis	0.50
	Hydrodictyon	0.10
	Microspora	0.40
	Palmella	0.50 ~ 1.00
	Scenedesmus	1.00
	Sphaerocystis	0.25
	Spirogyra	0.12 ~ 0.20
	Staurastrum	1.50
	Tetraspora	0.30
	Ulothrix	0.20
	Volvox	0.25
	Zygnema	0.50
Golden-brown algae	*Dinobryon*	0.25
	Mallomonas	0.50
	Synura	0.12 ~ 0.25
	Uroglenopsis	0.05 ~ 0.20
	Ceratium	0.33
	Peridinium	0.50 ~ 2.00
Crustacea	*Cyclops*	
	Daphnia	2.00
Oligochaeta	*Nais*	—
Insecta	*Chironomus*	—

rise of every 10ppm in the alkalinity.

The chemical reason for the above is that when the hardness and the alkalinity are high, copper sulfate becomes hydroxide salt of low solubility and precipitates, reacting with alkali in the water. It is said that the efficiency of copper sulfate is lowered when there are many organisms, for the same reason.

iii) Copper Sulfate Resistance of RO Membrane and of Fouling of Membrane

To use copper sulfate as an organism treating agent, especially as an algae exterminating agent, other conditions than the objects of treatment; algae, bacteria and other organisms, must also be taken into account in deciding the addition amount, the concentration and the adding method of copper sulfate as mentioned above. In the desalination of seawater with RO membranes, the recipe must be adjusted ensuring that the sulfate does not damage the membrane chemically, foul the membrane, reduce the permeability of the membrane as a result of progressive fouling from the synergistic effect of copper sulfate or the microorganisms remaining in the raw water. Fouling of the membrane caused by copper sulfate and the effect of copper sulfate in restraining the growth of microorganisms like bacteria and algae, are indicated in the table below, in this case cellulose acetate membranes were used. Table 3.4.2 shows effect of copper sulfate in restraning the growth of microorganisms.

Table 3.4.2 Effect of copper sulfate in restraining the growth of microorganisms[129]

Storage Solution Conditions	Obsereved			
	Storage pH time (months)	Membrane constant ($10^{-5}g/cm^2$-atm)	Salt rejection (%)	Total plate count (counts/ml)
Distilled Water	0～6.5	0.43	98.2	no data
	26 no data	0.48	97.1	no data
	31～6.7	0.68	98.4	no data
	44～7.2	0.70	97.8	3600
Cupric Sulfate (800ppm)	0～5.1	0.43	98.2	no data
	26 no data	0.45	98.1	no data
	31～5.1	0.59	98.8	no data
	44～5.4	0.68	96.9	0

1) Measured at 800 psi and 25± 5 ℃

2) Test periods of time up to 45 months

3.4.3 Seawater Desalination Plants Which Use Copper Sulfate as a Disinfectant

(1) Outline

As already mentioned, biological treatment with copper sulfate has been widely applied to remove algae, especially when the raw water is taken in from dead water. There are, however, few seawater desalination plants which actually introduce biological treatment utilizing copper sulfate, even at the test stage.

As a result of the literature investigation, it was found that two plants[190] use copper sulfate. These two plants are located on the seashore of the Red Sea in Saudi Arabia, and TFC polyamide membranes are employed as the RO membranes.

(2) Umm Luji RO Plant – Saudi Arabia

Location : 154km north of the Yanbu City, on the Red Sea

Designed Production Amount of Water: 4,400M^3/D

Total Content of Solid Dissolved: Less than 200mg/1

Reverse Osmosis Membrane Used: TFC 1501 Polyamide

Designed SDI: Less than 5

Chlorine Amount: 0

Process: Chlorination (at first), sedimentation, precipitation, filtration, dechlorination, RO membrane

At first, after disinfection and algae extermination with chlorine and succeeding dechlorination, water was pressed through membranes. At the end of the 28 days of operation, however, the water desalting capacity of the plant and the quality of the water produced began to fall. As a result of studying disassembled membranes, it was found that the membranes were damaged by the halogen compound. Consequently, copper sulfate (3mg/1) was used instead of chlorine for disinfection and algae extermination, and the problem was solved. Information on the effect of copper sulfate on the surroundings is not given. Nevertheless, information from the commercial base obtained as a result of long and continuous operation of the plant is not available either. Presently the copper sulfate dosing rate is reduced to 0.5ppm and maybe raised to 1.0 ppm if needed. No biofouling is reported in this plant.

(3) Jeddah 12,000 T/D RO Plant – Saudi Arabia

Location : Jeddah City

Start of Operation : In 1979

Water Production Amount : 12,000T/D, drinking water

Disinfectant, Algae Exterminating Agent : $CuSO_4 \cdot 5H_2O$

The report[131] on this plant refers to book[132], which introduces the plant at its start of operation in 1979. According to the book, chlorine was used as a disinfectant and as an algae exterminating agent, and the composite membrane of PA-3000 polyether/amide and not polyamide membrane was used as the RO membrane. The flow diagram of the whole plant mentioned in the book is shown in Fig. 3.4.1, and how copper sulfate came to be used is explained.

The pretreatment process is composed of sand filtration, disinfection treatment and gravitational filtration. The raw water taken in from the Red Sea is treated with 1.0mg/1 algae exterminating agent CuSO4 at point A, goes through a two-layer filter, and is stored in the filter tank. After pH reduction with the injection of sulfuric acid, the water is sent to the RO equipment.

It is reported that the operation of the whole plant went smoothly, and the 120 hour acceptance test run was completed successfully[131]. Some modifications were, however, made in the operation. Taking advantage of the polyether/amide membrane property not fouled by the microorganisms15), the water was permeated through the RO membranes without any biological treatment in the pretreatment process, sent to the tank of produced water after the injection of chlorine at point B, and then distributed as drinking water via a pump. It is presumed that this modification was made in order to avoid damage to the membranes by the chlorine, so that productivity could be improved with the highly efficient membranes.

3.4. 4 Cost Required for Disinfection with Copper Sulfate

(1) Outline

While the chlorine disinfectant is normally a very dangerous and toxic gas; copper sulfate, although toxic like chlorine, is solid and soluble in water. Equipment for distribution of copper sulfate does not require high technology and high cost. Primarily, biological treatment with copper sulfate is most suitable for algae extermination of the dead water of lakes, marshes and reservoirs, and it is reported that the equipment for the distribution of the copper sulfate into the water of lakes, marshes and reservoirs is installed on a boat[134].

The sprinkling method of distributing copper sulfate, solution sprinkling, powder sprinkling and continuous sprinkling, are outlined. Sprinkling may be applicable to a plant which takes water from the Al-Birk Bay of Saudi Arabia[135], but it is not suitable for usual seawater desalination plants.

The equipment cost required for sprinkling of copper sulfate is quite low compared with whole water production costs or the costs required for equipment to add chlorine. Only the cost of copper sulfate required for biological treatment is estimated in this report.

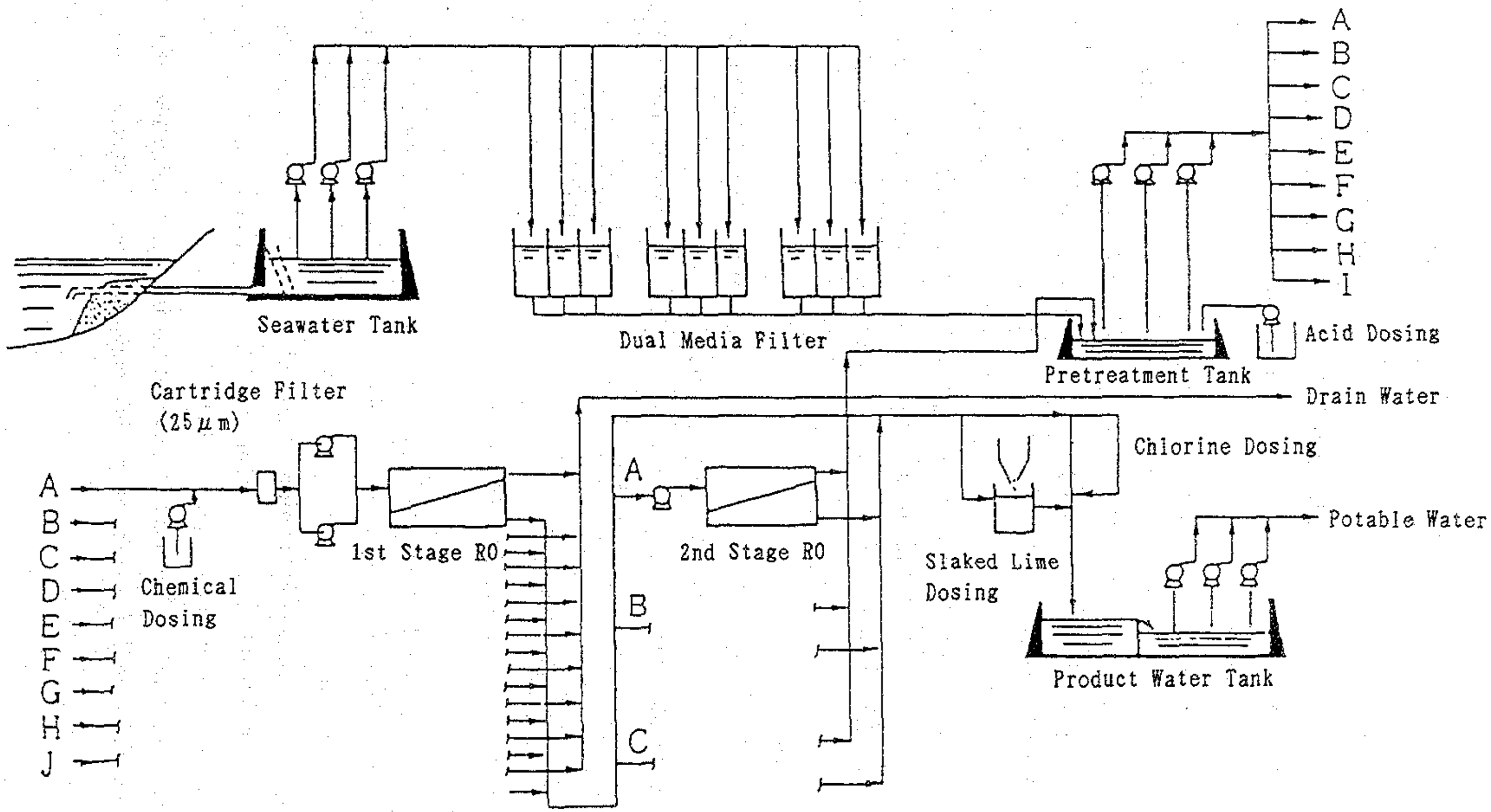

Fig. 3.4.1 Jeddah plant flow diagram[132]

(2) Cost of Copper Sulfate

i) Premise

Generally, copper sulfate of industrial standard in a moisture-proof paper bag is used for biological treatment[136]. Copper sulfate here is presumed to be bought in Japan in penta hydrate salt and by the unit of ton.

Standard addition ratios of copper sulfate are shown in Table 3.4.1. The ratio varies very much depending on the type of bacteria and algae, however, and it is not possible to decide the ratio unless the type of bacteria or algae to be exterminated is known.

The Umm Luji RO Plant ($CuSO_4$(2.5mg/1)) and the Jeddah RO Plant (CuSO4(1.0mg/1)) of Saudi Arabia mentioned above have been successful in the introduction of biological treatment with copper sulfate for the desalination of raw water taken from the Red Sea. The addition ratios these plants apply can, therefore, be a standard. For the estimate, the addition ratio of 2.5mg/1 was selected as a safer value, and other presumptions are that the amount of water to be produced is 30,000T/D, and that the amount of raw water to be treated is 100,000T/D.

ii) Estimate of Cost

Amount of Copper Sulfate Used per Day : 0.25T/D ; Derived from 100,000T/D x 2.5ppm

Unit Price of Copper Sulfate ($CuSO_4 \cdot 5H_2O$) per Ton : 200,000 yen/T

Cost of Copper Sulfate per Day: 50,000 yen/day; for the water production of 30,000T/D

Cost of Copper Sulfate for then Production of 1 Ton of Water: 1.7 yen/T;

50,000 yen/30,000T/D

3.5 Disinfection with SBS (Sodium Bisulfite)

3.5.1 Ooutline

As SBS shows a strong reducing property, it is used as a reducing agent, for the synthesis of dyestuff and chemicals, for coloring and bleaching, as a disinfectant, a dechlorinating agent, an antiseptic, and so forth[137].

In our research on the disinfection introduced in seawater desalination plants applying RO membranes, it is found that only one plant uses SBS as a disinfectant. Even reference books of water treatment[138] scarcely explain or refer to SBS.

On the other hand, SBS is used as a dechlorinating agent in the seawater desalination plants which use RO membranes made of aromatic polyamide or polyether.

3.5.2 Principles

(1) Physical and Chemical Properties of Sodium Bisulfite, SBS

Chemical formula: $NaHSO_3$
State: colorless; monoclinic crystalline; powder
Chemical property: strong reducing property
Water solubility: easily soluble in water; acidic aqueous solution

(2) Standard Addition Ratio of SBS for Biological Treatment

The investigated literatures do not refer to the standard addition ratio of SBS required for biological treatment.

3.5.3 A Seawater Desalination Plant which uses SBS as a Disinfectant

(1) Ras Abu Jarjur RO Plant[139, 140]

It is remarkable that a seawater desalination plant of large scale from its water production amount should use SBS as a disinfectant, while no other plant uses SBS as a disinfectant for seawater desalination applying RO membranes.

1) Outline

The Ras Abu Jarjur RO Plant has been operating for the past four years without any serious trouble utilizing deep ground water containing H2S. After an initial two-year operation, however, fouling gradually formed on the membranes and affected performance. The major cause was found to be the organisms which reacted in the tank of SHMP (sodium hexa-meta phosphate). SHMP is converted to ortho phosphate depending on its concentration, temperature, time and pH. It is well-known that this free phosphate is the nutrition source of organisms. A study on free phosphate in connection with SHMP was carried out. As the raw water of this plant contains H2S, use of even a little chlorine should be avoided. The use of SBS as the disinfectant of the SHMP tank and the addition pipe system was, therefore, examined.

As a result, it was found that there was an optimum concentration of SBS to be added into the SHMP tank which restrains the conversion of SHMP to free phosphate and still disinfects the liquid effectively.

2) Plant Design

i) Specification of Plant

Name: Ras Abu Jarjur RO Desalination Plant of the Ministry of Works Power and Water
Location: State of Bahrain
Water Production Amount : 46,000m^3/D
Water Quality: Drinking water

Start of Operation: November 1984

Raw Water: Taken from 15 deep wells, highly salty water

(Total Solid Dissolved, TDS12,000mg/1[141])

RO Membrane: "Permasep"B-10 684D Permeator(8")[142](aromatic polyamide membrane)

ii) Plant Processes

The flow diagram of the plant is not available. The process of the plant is shown in Fig.3.5.1.

3) Biological Fouling

The start of biological fouling was first detected from the smell of H_2S in the turbidimeter. Then the lamination layer membrane of algae appeared on the dual media filter. Finally, the micron guard filter began to be fouled with algae. It was discovered that the pipes of the whole plant were made of GRP and sunlight passes through, which accelerated the photosynthesis of algae.

The pipes were painted, and the offline treatment of the D.M. filter with chlorine was carried out periodically. The disinfecting processes carried out at the start of operation are as follows. Operation with these processes caused no problems for the first two years.

a. Periodical disinfection of the D.M. filter with chlorine

b. Periodical regeneration of the activated carbon filter

c. Periodical disinfection of the micron guard filter

d. Shock treatment of RO membranes with SBS

e. Periodical disinfection of RO membranes with SBS

f. Periodical disinfection of the SHMP tank (Chlorine aqueous solution is used once a week)

In this way, intermittent shock treatment with SBS was carried out to disinfect RO membranes and to exterminate the algae on RO membranes online.

From November 1986 to January 1987, however, the amount of water produced fell, the osmotic differential pressure of the RO equipment became higher and the amount of salt which passes through membranes increased. Then measures such as the cleaning of RO membranes and the use of more membranes were taken, but the effect of the measures did not last long; the production amount began to fall and the operation remained unstable. These phenomena associated with the first RO membrane equipment are related to biological fouling, and the sources of the fouling are classified as follows:

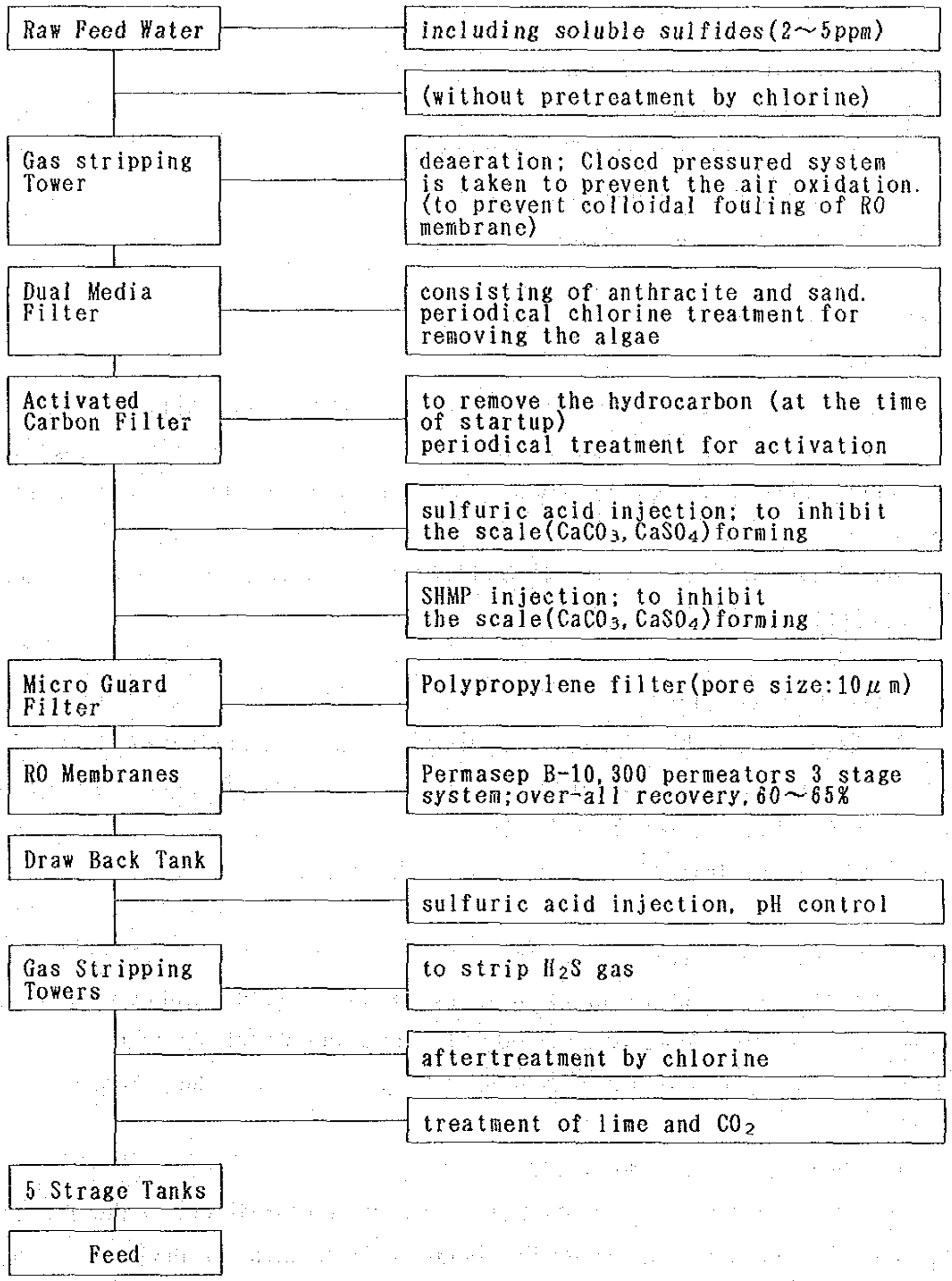

Fig. 3.5.1 Process of Ras Abu Jarjur RO Plant[139,140]

a. SRB, sulfate reducing bacteria and anaerobic bacteria from the wells
b. Algae growth stimulated by light entering the GRP pipes
c. The unremovable bacteria embedded in the permeate
d. Aerobic bacteria from the SHMP tank
e. Free PO_4^{3+} feeding the already embedded bacteria

4) Determination of Fouling

i) Sulfate Reducing Bacteria (SRB)

The bacteria in the raw water of the plant tends to utilize anything nutritious to survive, and with the lack of oxygen, utilize substances rich with oxygen like the SO_4 radical as their energy source. SRB are anaerobic bacteria, reduce sulfate into sulfite and utilize it as their nutrition source and consequently give out the smell of rotten eggs.

As the result of the raw water culture experiment, it was found that the raw water is positive to 1–10 cols/ml SRB.

ii) Growth of Algae with Light

It was discovered that all the pipes of the plants are made of GRP and through which light easily passes. As the water in the plant is very nutritious, multiplication of a large quantity of algae was detected on the parts to which GRP is applied such as the collection pipes, the D.M. filter bed and others. These algae and bacteria block the filters.

iii) Bacteria Settled in the RO Membranes

As a result of various examinations, it was that 72–hour dipping in the 0.5wt.%SBS solution, then a 10–hour Aviel dipping, and further circulation treatment with PT–B(0.5wt.%) of the membranes help stabilize the performance of the RO equipment.

5) Aerobic Bacteria growing with SHMP

It was reported that aerobic bacteria which live on SHMP causes the fouling of pipes, filters and RO membranes and eventually affects the performance of the plant. Analysis of the bacteria, and study on the effect disinfection with SBS were carried out by experiments and plant tests. The results are reported in detail as follows.

SHMP of 7mg/1 concentration is added after the carbon filter process to prevent the sulfate from scaling. The SHMP is prepared in an online tank and in a standby tank, then supplied through the common GRP and PVC pipes. As the number of bacteria at the initial stage of operation was TNTC (too numerous to count), the SHMP tank is treated with chlorine once a week.

It is, however, well-known that SHMP reverts to ortho phosphate by hydrolysis, depending on its pH, time, temperature and concentration. This phosphate was the nutrition of the aerobic bacteria. As a result, fouling by bacteria extended not only to the SHMP adding pipes but also to the M.G. filter and the RO membranes.

As H_2S is contained in the raw water, it was not possible to put chlorine in the SHMP online tank because chlorine reacts with H_2S to produce colloidal sulfur, which blocks the membranes. Removal of fouling caused by colloidal sulfur with normal chemical cleansing is said to be most difficult.

6) Use of SBS in the Plant

i) TBS in the SHMP Tank

Based on the experimental data, SBS of 0.25% concentration was added to the SHMP adjusting tank every day. Fig. 3.5.2 shows the TBC levels before and after SBS addition. The trend of TBC values indicates clearly that the value of aerobic bacteria in the SHMP tank is restrained to zero.

ii) Performance of MGF

Results obtained by checking the performance of the micron guard filter (MGF) are shown in Table 3.5.1 and Fig. 3.5.3. As 7 MGF's were operated in parallel, the differential

Table 3.5.1 Average performance of MSFs[139,140]

	Filter using term (day)	Passing Flow (m3/h)		SDI (−)	Filter Washing Time (hour)
		Initial	Last		
SBS Adding	14	436	325	1.27	13.0
SBS No Adding	14	435	408	0.85	3.0

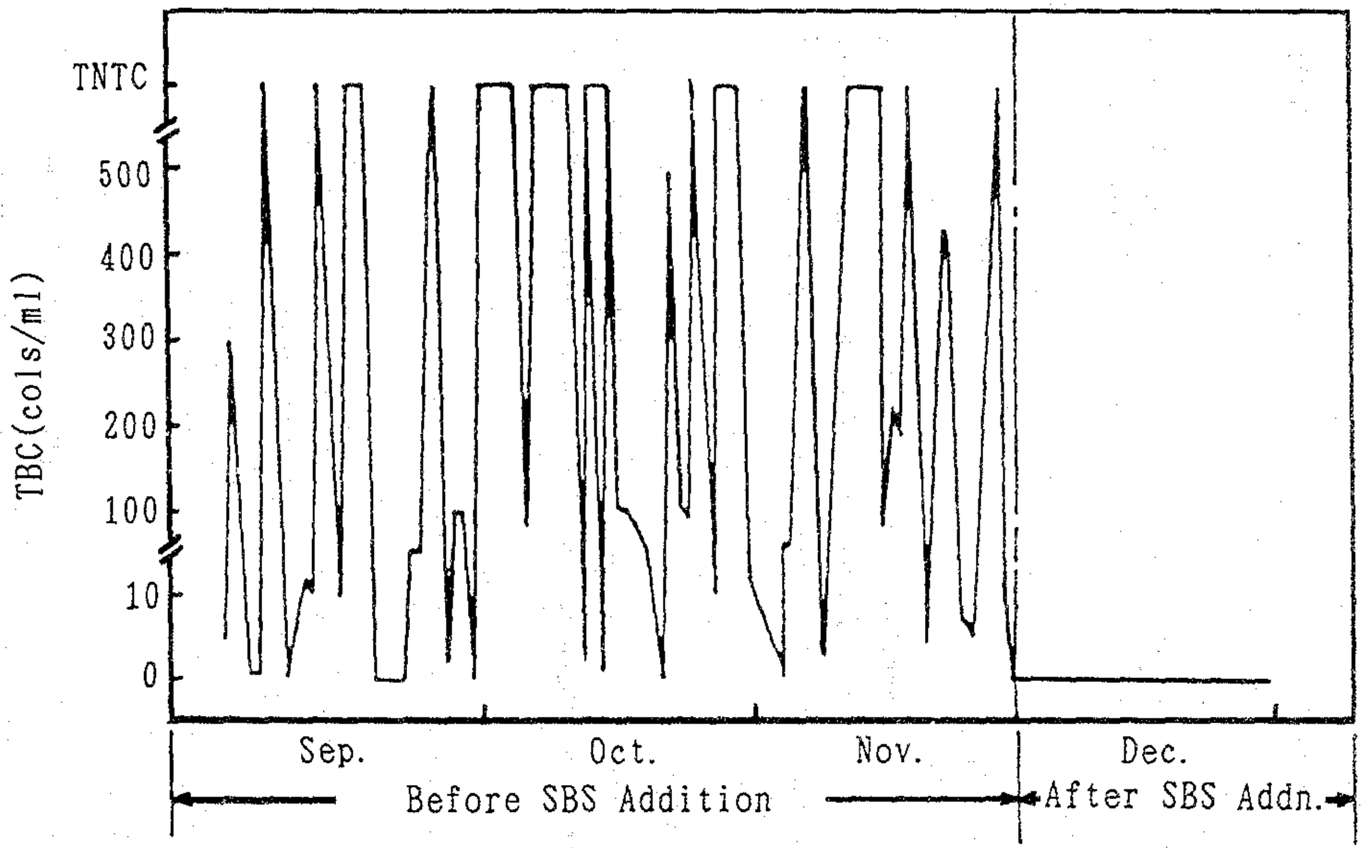

Fig. 3.5.2 TBC level of SHMP tanks[139,140]

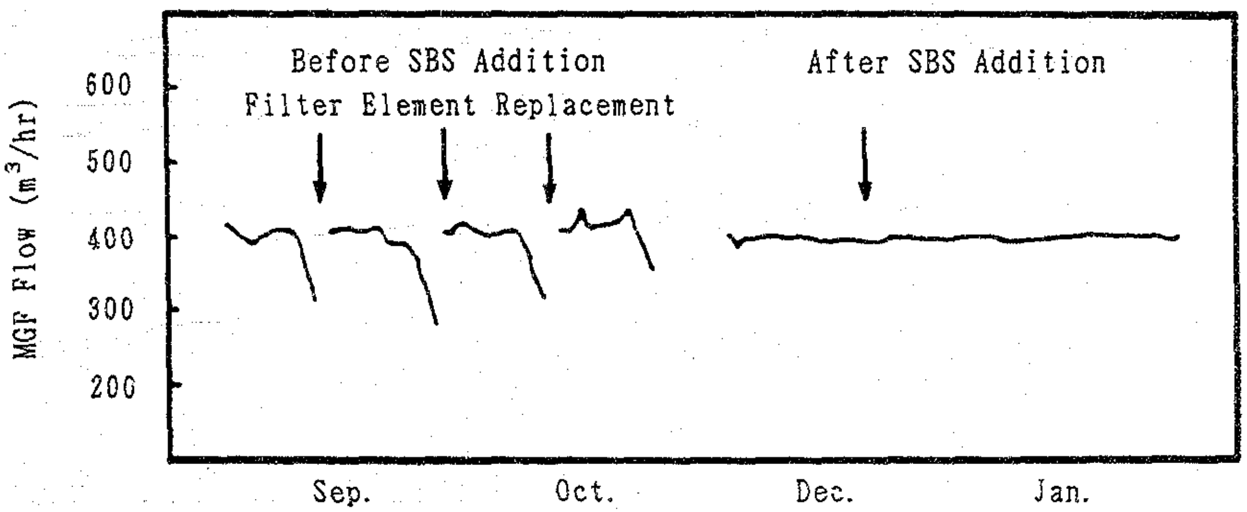

Fig. 3.5.3 Typical micron guard filter flow[139,140]

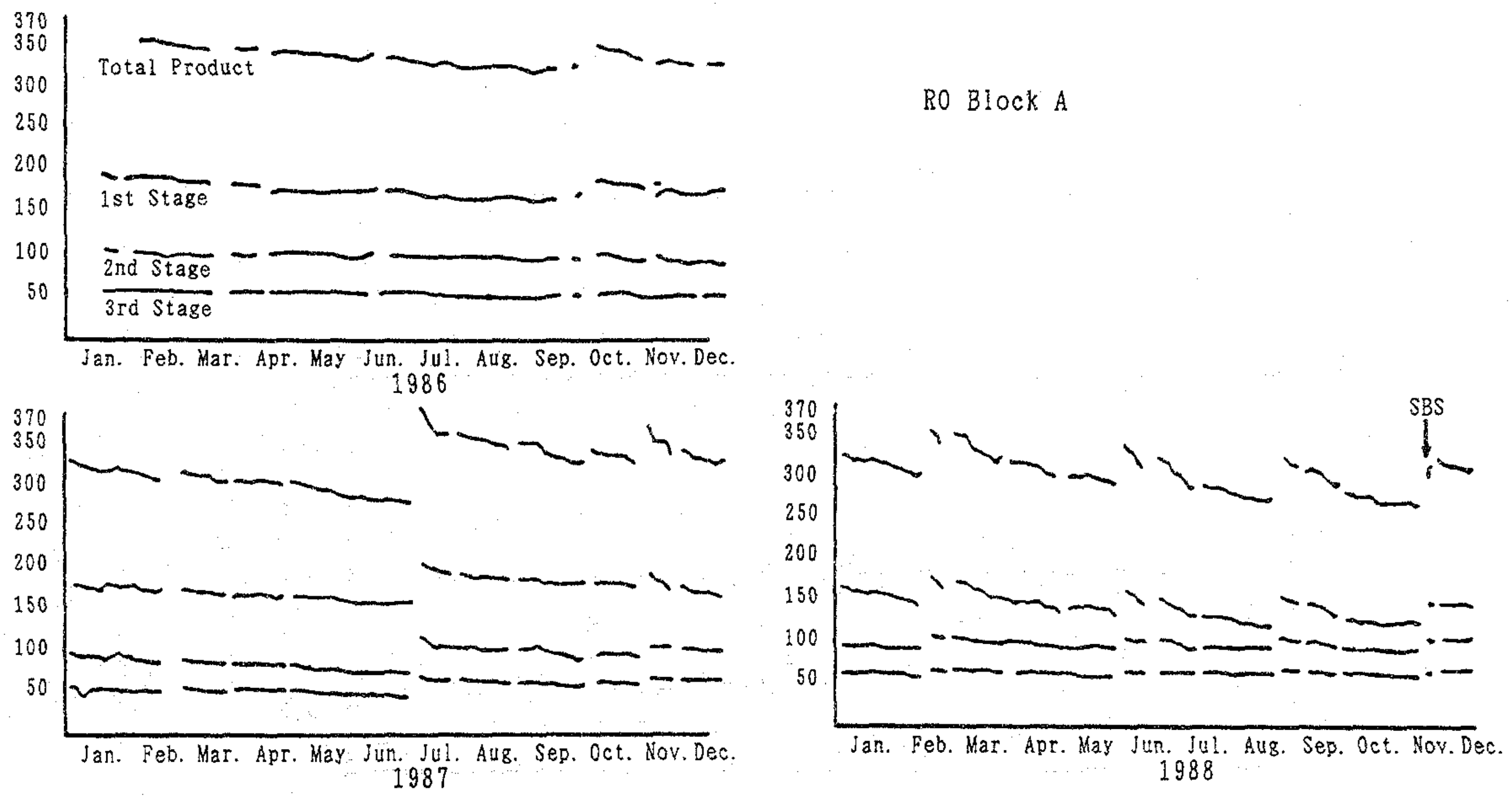

Fig. 3.5.4 RO performance trend[139,140]

pressures before and after the MGF look the same. Due to the blockage of the MGF, however, the flow normally falls as shown clearly in Fig. 3.5.3. After a 14 day operation, the water amount which goes through the MGF fell to 325m^3/hr, but when SBS was added the amount of 408m^3 was maintained. The fluctuation of the SDI values also indicates that the addition of SBS improved performance at the end of the operation period. To be concrete, while the initial SDI values were the same at 0.45 whether SBS was added or not, the value at the end of the operation period was 1.27 when SBS was not added and the value was reduced to 0.85 when SBS was added.

iii) Performance of RO Membranes

Fig. 3.5.4 indicates typical fluctuation of water production amount of RO Black A. No biological fouling was detected until 1985, but it started in 1987. In 1988 fouling began to pose problems. Consequently, membranes were cleaned more often and dipped in SBS by stopping operation in order to recover and increase the water production amount.

As shown in Fig. 3.5.4, after the addition of SBS in the SHMP was introduced, the water production amount was recovered.

(2) Other Reports on Disinfection with SBS

1) Intermittent Addition of High Concentration SBS (Shock Method)

As mentioned above, the Ras Abu Jarjur RO Desalination Plant operates on a commercial base which actually introduces intermittent additions of high concentration SBS for disinfection. Prior to the start of operation of the plant in November 1984, the Chigasaki Seaside Research Laboratory of the Water Re-use Promotion Center Japan studied the effect of the intermittent addition of high concentration SBS (shock method) and confirmed the effect with the operation result of its plant. The result of the study was reported in 1983 by Kunisada and others[142].

2) Limits of SBS as Disinfectant

"Japanese Published Patent 1987-110705"[143] refers to the fact that SBS has its limits as a disinfectant, admitting its effect as a disinfectant.

Aromatic polyamide and aromatic polyether membranes, except for cellulose acetate membranes, are oxidized and fouled by residual chlorine of strong oxidizing property and dissolved oxygen as already mentioned. Seawater desalination plants which use these membranes, therefore, introduce SBS addition and de-airing processes as pretreatment. The "Japanese Published Patent" mentions that it is well-known that hydrogen sulfide often exists or is generated with time lapse in the deoxidized liquid if the concentration of the oxygen dissolved in the liquid treated is less than 2ppm, .It also explains that if an erroneous selection of a disinfectant is made in such a case, microorganisms will not be exterminated, and, on the contrary, fouling of the membranes will eventually be accelerated.

General influences of hydrogen sulfide existing in the liquid under process are as follows:

a. Hydrogen sulfide is oxidized with the oxygen dissolved in the liquid, and precipitates as collide sulfur of simple substance, which becomes the cause of fouling.

b. Hydrogen sulfide reacts with metal ion (especially iron and copper) in the liquid and to produce insoluble metal sulfide which becomes the cause of fouling.

According to the "Japanese Published Patent", taking into consideration the generation of hydrogen sulfide, it is desirable to use a disinfectant which has neither an oxidizing property nor a heavy metal ion content for the deoxidized liquid whose concentration of dissolved oxygen is less than 2ppm. Moreover, the disinfectant must desirably be effective to hydrogen sulfide generating bacteria, that is, sulfate reducing bacteria. (It is reported that anaerobic sulfate reducing bacteria exist in the raw water of the Ras Abu Jarjur RO Desalination Plant.) The "Japanese Published Patent" introduces that SBS is used as such disinfectant and that taking economy and influences on the environment into consideration, SBS is added intermittently to make the SBS concentration of the liquid 500 – 1000ppm.

The "Japanese Published Patent", however, points out that SBS itself does not disinfect hydrogen sulfide generating bacteria, and that an agent of superior disinfecting property is desired to prevent the generation of hydrogen sulfide. It proposes to use the fourth class ammonium salt.

Judging from what is mentioned in the "Japanese Published Patent", further examinations are necessary before coming to a conclusion that disinfection with SBS introduced in the Ras Abu Jarjur RO Desalination Plant is best from the viewpoint of its raw water property.

3.5.4 Cost Required for Disinfection with SBS

We found few examples using SBS as a disinfectant in the literatures we investigated, and we could not obtain any paper on the standard addition amount of SBS required to exterminate specific bacteria and algae. We found some references to the SBS concentration applied to the shock treatment of industrial plants, but found no clear report on the amount of SBS required perton of the water produced. Presuming the amount of SBS required to be almost the same as that of copper sulfate (2 – 3ppm), we estimate the cost required will also be almost the same because the unit price of SBS is about the same as that of copper sulfate at 200,000 yen/T(1,539$/T).

3.6 Technical Problems of Disinfection Currently Introduced and Future Prospects

3.6.1 Disinfection Introduced in Seawater Desalination Plants of Several Countries

Based on the literature investigation, and the information we collected from the manufacturers of RO plant equipment, we listed raw water disinfection introduced in RO seawater desalination plants of several countries as shown below.

In all the Japanese plants chlorine disinfection is adopted. When the RO membrane is cellulose acetate (CA), dechlorination after chlorine disinfection is not required, but when the membrane is other than CA, dechlorination with SBS (sodium bisulfite, $NaHSO_3$) is carried out. The U.S. desalination plants apply similar disinfection.

In the Middle East, too, a similar disinfection is applied, but some plants introduce disinfection with copper sulfate or SBS, probably depending on the property of raw water. (It is impossible to use chlorine when there exists sulfide such as H_2S in raw water.) Table 3.6.1 shows disinfection applied in RO seawater desalination plants of several countries.

Table 3.6.1 Disinfection Applied in RO SeaWater Desalination Plants of Several Countries

Plant	Location	Capacity m^3/D	Membrane	Material	Sterilization	Dechlorination
Yuma Desalination Plant	Arizona (U.S.A)	273,000	(1)Signal (2)Hydranautics	CA	Cl_2	Not used
Doha RO Plant(DROP)	Kuwait	3,000	UOP-PA 1501 UOP-PA 8600 DuPont B-10 DuPont B-9 Enroscheicher Filmtec Hydranautics 8040 B	 PA PA PA	Cl_2 Cl_2 Cl_2 Cl_2 Cl_2 Cl_2 Cl_2	$NaHSO_3$ $NaHSO_3$ $NaHSO_3$ $NaHSO_3$ $NaHSO_3$ $NaHSO_3$ $NaHSO_3$
RA'S Abu Jarjur	Bahrain	46,000	DuPont B-10	PA	$NaHSO_3$	Not used
Al-Birk	Saudi Arabia	2,275	DuPont B-10	PA	Cl_2+NaOCl	—
Umm Lujj	Saudi Arabia	4,400	UOP-TFC-1501	PA	Cl_2 shock treatment, ($CuSO_4$)	$Na_2S_2O_3$
Jeddah ①	Saudi Arabia	12,000	UOP-TFC	PA	$CuSO_4$	—
RA'S AL-Khafji	Saudi Arabia	40	UOP-TFC ROGA 6085 ROGA 4160	PA CA CA	NaOCl	—

Table 3.6.1 (Continued)

Plant	Location	Capacity m^3/D	Membrane	Material	Sterilization	Dechlorination
Culebra	Puerto Rico	575	DuPont B-10	PA	Cl_2	$NaHSO_3$
Grand Cayman Island	British West Indians	400	DuPont B-10	PA	Not used	—
Malta	Malta	20,000	DuPont B-10	PA	Not used	—
Balbuku	Saudi Arabia	60,000	DuPont B-10	PA	SBS Cl_2	—
Buwayb	Saudi Arabia	45,000		CA	Cl_2	—
Jeddah ②	Saudi Arabia	56,800	TOYOBO-HOLLOSEP	CA	NaOCl	$NaHSO_3$
Jeddah ③	Saudi Arabia	56,800	TOYOBO-HOLLOSEP	CA	NaOCl	$NaHSO_3$
Chigasaki Research Center WRPC	Japan	800	(1) TORAY PEC-10	PE	Cl_2	$NaHSO_3$
			(2) TOYOBO HOLLOSEP	CA	Cl_2	Not used

Table 3.6.1 (Continued)

Plant	Location	Capacity m^3/D	Membrane	Material	Sterilization	Dechlorination
Kashima Industrial Water Supply	Japan	13,400	(1) ROGA (2) TORAY	CA CA	Cl_2 Cl_2	Not used Not used
Fukushimacho Drinking Water Plant	Japan	730	—	CA	Cl_2	Not used
Watanaki Village Small-scale Water Works	Japan	240	—	PS	NaOCl	used
Kitadaito Water Works	Japan	240	TORAY PEC-1000	PE	NaOCl	$NaHSO_3$
Hakatajima Desalination Plant	Japan	300	—	PA	NaOCl	$NaHSO_3$
Orandamura Nagasaki Mitsubishi RO Plant	Japan	1,000	—	CA	NaOCl	Not used

Material : CA(Cellulose Acetate), PA(Polyamide), PE(Polyether), PS(Polysulfone)

3.6.2 Technical Problems of Disinfection Currently Introduced

(1) Problems of Chlorine Disinfection

The greatest problem of chlorine disinfection that trihalomethane is generated when seawater is disinfected with chlorine[144]. It is reported that when the seawater of the Arabian Gulf is disinfected with chlorine, trihalomethane of high bromine content like bromoform, trihalo-methane di-bromochloromethane and di-chlorobromomethane are generated, especially when the seawater is contaminated by oil, and that when the chlorine concentration is higher, more trihalomethane is generated. Fig.3.6.1 shows bromoform formation at the seawater intakes as a function of chlorination levles at ambient temperature.

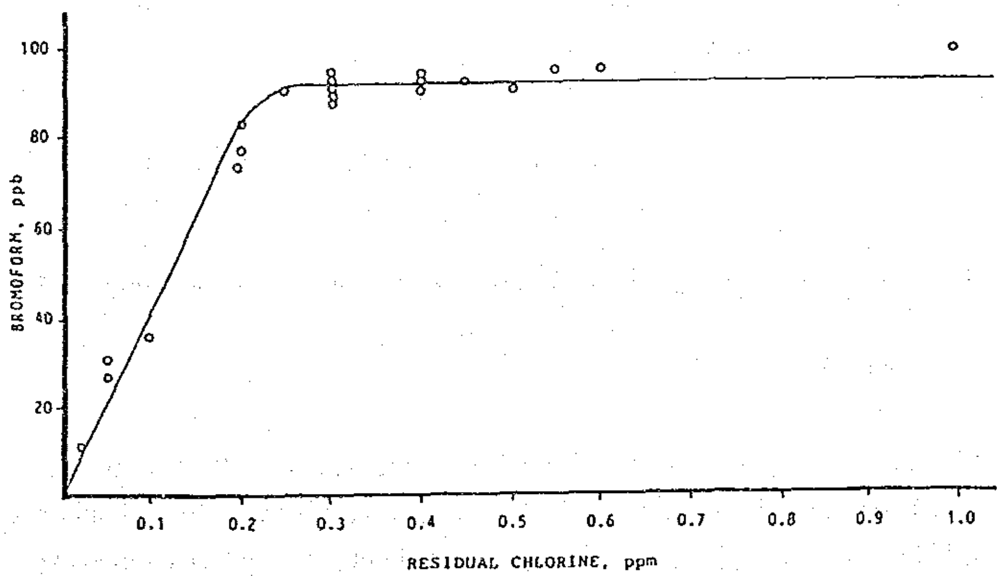

Fig. 3.6.1 Bromform formation at the seawater intakes as a function of chlorination levels at ambient temperature[144]

A report which refers to the trihalomethane rejection ratios of RO membranes (made by Du Pont) was publicized[142]. According to the report, the cellulose acetate (CA) membrane rejection ratio is the lowest, with that of aromatic polyamide (PA) membrane next, and the advanced composite (AC) membrane the highest. However, even the AC membrane performs only 38% rejection ratio of chloroform (see Fig. 3.6.2).

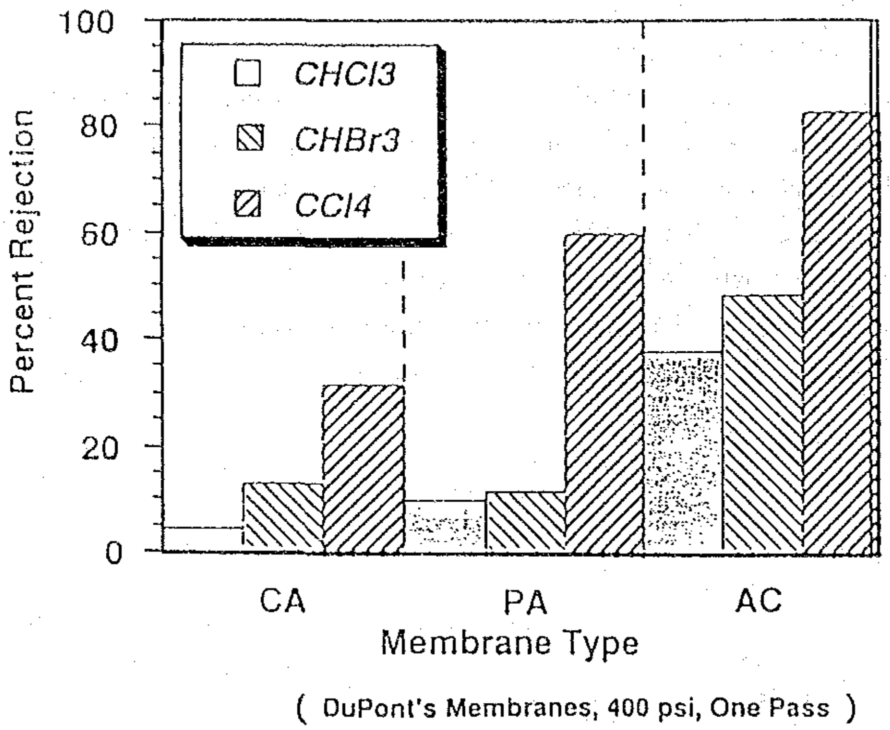

Fig. 3.6.2 Average halocarbon rejection for CA, PA and AC membranes[142]

Normally, chlorine disinfection is applied to most seawater desalination with RO membranes of cellulose acetate. The use of cellulose acetate membranes will probably become controversial in the future though, because its rejection ratio of generated trihalomethane is low.

(2) Problems of Chlorination/Dechlorination

For chlorine disinfection of the raw water of seawater desalination with RO membranes of polyether or polyamide, it is essential to carry out dechlorination with SBS (sodium bisulfite) after chlorination and before the raw water is sent to the RO membrane process because these membranes easily deteriorated with chlorine. Not all bacteria are exterminated with chlorination, however, after dechlorination, after growth of some bacteria which survive during chhlorination, causes biological fouling[143]. It is reported that bacterial aftergrowth depends on the temperature and pH. When the temperature is as high as 25–35°C bacteria aftergrowth is especially accelerated, and so is biological fouling.

It is well-known that chlorine degrades humic acids. Bacteria aftergrowth and biological fouling are also reported to be closely related with the degradation of humic acids by chlorine. The effect of temperature and pH on humic acid degradation by chlorine was studied in Table 3.6.2.

Table 3.6.2 Effect of pH and temperature on humic acid degradation by HOCl[143]

		% Degradation				
pH	Temp.(°C)	1 min.	5min.	10 min.	15 min.	30 min.
8.0	35	41.9	54.6	60.2	65.7	72.2
	25	7.2	19.2	27.0	32.9	47.9
	18	9.3	18.5	27.7	31.3	37.8
7.0	35	40.1	52.3	61.8	64.3	69.7
	25	10.2	18.5	27.0	31.6	42.4
	18	7.1	16.7	22.3	25.4	28.7
6.0	35	13.7	23.6	31.0	36.2	40.7
	25	1.1	7.6	14.2	19.0	22.8
	18	0.5	10.3	17.2	19.8	24.0

a:Humic acid 2.5 mg/l; HOCl 5.0mg/l

3.6.3 Proposition of a New Way of Disinfection–Disinfection with Chloramine

(1) L.E. Applegate (Du Pont) and others indicate in their report[146] that chloramine can be an alternative disinfectant to chlorine, and explain the advantages of chloramine as follows.

i) Chloramine does not decompose humic acid.
ii) Treatment with chloramine does not cause bacterial aftergrowth.
iii) Although chloramine has affinity for aramid membrane, it does not exert a bad influence.

iv) Chloramine has a satisfactory disinfecting property.

Some data which testify the advantages mentioned above are indicated below. Effect of the $NH_4Cl/HOCl$ ratio (regarded as the ratio of chloramine) and pH on the degradation of humic acid is shown in Table 3.6.3.

The table shows that with higher NH_4Cl ratio; a higher chloramine ratio, the degradation of humic acid is more effectively restrained.

Table 3.6.4 indicates the result of bacterial after- growth. As Table 3.6.4 shows, bacterial aftergrowth occurs easily with chlorination (F_2,F_4), but hardly starts with chloramine process (F_3,F_5). When the temperature is as high as 35°C, bacterial aftergrowth begins even with chloramine processes, in much smaller scale compared with the case of chlorination though.

Table 3.6.3 Degradation of humic acid with chloramine[146]

pH	NH_4Cl (mg/L)	$NH_4Cl:HOCl$ Ratio[b]	% Degradation 1 Min.	5 Min.	10 Min.	15 Min.	30 Min.
8.0	10.0	2:1	0.0	0.0	0.0	0.0	0.0
	5.0	1:1	7.5	12.9	14.8	16.6	20.1
	2.5	0.5:1	20.3	26.6	29.9	31.3	34.4
	1.0	0.2:1	33.3	39.6	42.9	46.3	47.1
	0.0	0:1	41.9	54.6	60.2	65.7	72.2
7.0	10.0	2:1	0.0	0.0	0.0	0.0	0.0
	5.0	1:1	2.4	4.7	7.3	9.5	14.2
	2.5	0.5:1	4.0	10.6	13.3	18.0	18.8
	1.0	0.2:1	33.3	38.7	41.1	46.2	51.9
	0.0	0:1	40.1	52.3	61.8	64.3	69.7
6.5	15.0	3:1	0.0	0.0	0.0	0.0	0.0
	10.0	2:1	3.5	6.5	12.5	15.0	17.2
	5.0	1:1	6.8	9.6	15.3	19.2	23.7
	2.5	0.5:1	19.2	26.8	34.8	41.8	46.2
	1.0	0.2:1	22.8	31.6	37.5	40.2	46.2
	0.0	0:1	21.2	33.3	39.4	42.4	48.3

[a]Humic acid 2.5 mg/L; HOCl 5.0 mg/L; 35°C.
[b]Weight ratio.

Table 3.6.4 Bacterial aftergrowth for chloramine and chlorine processes[146]

pH	Temp. (°C)	Media[b]	CFU (X 10^1)/mL After 24 Hours[a] F2	F3	F4	F5
6.1	15	TSBA	<1	<1	11	<1
		MA	2	<1	3	<1
5.3	25	TSBA	<1	<1	<1	1
		MA	<1	<1	<1	<1
5.7	35	TSBA	190	<1	<1	<1
		MA	220	<1	1	<1
7.3	15	TSBA	600	70	41	7
		MA	3,000	75	3,100	550
7.1	27	TSBA	16,000	<1	280,000	<1
		MA	3,100,000	<1	2,300,000	<1
6.7	35	TSBA	930,000	60,000	210,000	<1
		MA	500,000	1,700	210,000	<1
8.2	15	TSBA	25	<1	74	62
		MA	540	7	45	30
7.6	25	TSBA	100,000	<1	140,000	<1
		MA	420,000	<1	650,000	<1
7.6	35	TSBA	50,000	460,000	950,000	610,000
		MA	60,000	510,000	1,300,000	580,000

[a]Limit of Detection 1 X 10^1 CFU/mL.
[b]TSBA (Trypticase[R] Soy Broth Agar); MA (Marine Agar 2216).

References

1) Control of fouling and successful seawater Revers Osmosis Desalination, Dr. Harvey Winters, Fairligh Dickinson University, Teaneck, N.J.

2) *Elimination of 200 plankton by flocculation and filtration*, H. Bernhardt and B.Lusse, Wahnkachtals perrenvenband, K. Ronprinzenster -13, D-5200 Siegburg, Federal Republic of Germany

3) RO Pre-treatment Injectiong. A Little Chemical Contral and Management F.P. Gwalton, Hydro Tecroical Ltd, Abbey Foregate, Shrewsburg, SY2 GAL, UK.

4) Biological Fouling and Contral at Ras Abu Jarjur RO Plant- a New Approach, Reported by S.R. Ahmed, M.S. Alansari, Water Supply Directorate, Minist of Works, Power and Waters. State of Baharain

5) Monitoring and Control of Biological Activity in Permasep seawater RO Plants

6) G.V.ジェームス著, 内藤幸穂訳; 水処理技術事典, P 49～50
G.V. James, Tranlated by Naito, "Dictionary of water purification Technology", p 49 - 50

7) G.V.ジェームス著, 内藤幸穂訳; 水処理技術事典, P 51
G.V. James, Tranlated by Naito, "Dictionary of water purification Technology", p 51

8) 用廃水便覧, P 437 ～439
Handbook of Industrial Water and Wste Water p 437 - 439

9) 用廃水便覧, P 439
Handbook of Industrial Water and Wste Water p 439

10) 日本公開特許, 昭62-11075 (東レ)
JP KOKAI SHO-62-11075

11) 日本公開特許, 平1-135506 (東レ)
JP KOKAI HEI-1-135506
日本公開特許, 昭62-11075 (東レ)

JP KOKAI SHO-62-11075

Desalination, 35(1980), P 384

12) Desalination, 35(1980), P 384

井手哲夫編著; 水処理学, P 632,605

Iide Tetsuo, Water Purification and Wastw water Treatment,p632,605

13) 木村尚史、中尾真一; 膜の劣化, P 66

kimura Shoji, Nakamura Shinichi, Degradation of Membrane p 66

木曽, 北尾; 水処理技術, Vol 25,No 2,1984, P 83～85

Kiso, Kitao, Water Purification and Liquid Waste Treatment Technology p 83 - 85

井手哲夫編著; 水処理学, P 604 ～605

Ide Tetsuo, Water Purification p 604 - 605

14) 用廃水便覧, P 437,439

Handbook of Industrial Water and Wste Water p 437 - 439

15) G.V.ジェームス著, 内藤幸穂訳; 水処理技術事典, P 44

G.V. James, Tranlated by Naito, "Dictionary of water purification Technology", p 44

用廃水便覧, P 441

Handbook of Industrial Water and Wste Water p 441

16) S.R.Ahmed ; Desalination, 74(1989), 69-84

G.V.ジェームス著, 内藤幸穂訳; 水処理技術事典, P 45

G.V. James, Tranlated by Naito, "Dictionary of water purification Technology", p 45

17) Desalination, 74(1989), P 51

G.V.ジェームス著, 内藤幸穂訳; 水処理技術事典, P 45

G.V. James, Tranlated by Naito, "Dictionary of water purification Technology", p 45

18) 用廃水便覧, P 441

Handbook of Industrial Water and Wste Water p 441

19) 用廃水便覧, P 442
Handbook of Industrial Water and Wste Water p 442
20) 用廃水便覧, P 442
Handbook of Industrial Water and Wste Water p 442
21) 用廃水便覧, P 442
Handbook of Industrial Water and Wste Water p 442
22) 用廃水便覧, P 442
Handbook of Industrial Water and Wste Water p 442
23) Desalination, 74(1989), P 51～67
G.V.ジェームス著, 内藤幸穂訳; 水処理技術事典, P 45
G.V. James, Tranlated by Naito, "Dictionary of water purification Technology", p 45
24) 用廃水便覧, P 442 ～443
Handbook of Industrial Water and Wste Water p 442 ～443
G.V.ジェームス著, 内藤幸穂訳; 水処理技術事典, P 45
G.V. James, Tranlated by Naito, "Dictionary of water purification Technology", p 45
25) 用廃水便覧, P 442 ～443
Handbook of Industrial Water and Wste Water p 442 ～443
26) 用廃水便覧, P 442
Handbook of Industrial Water and Wste Water p 442
27) 用廃水便覧, P 442
Handbook of Industrial Water and Wste Water p 442
28) G.V.ジェームス著, 内藤幸穂訳; 水処理技術事典, P 47
G.V. James, Tranlated by Naito, "Dictionary of water purification Technology", p 47
29) 用廃水便覧, P 443
Handbook of Industrial Water and Wste Water p 443
30) 用廃水便覧, P 438､443
Handbook of Industrial Water and Wste Water p 438､443

31) 用廃水便覧, P 443

Handbook of Industrial Water and Wste Water p 443

32) 井手哲夫編著；水処理学, P 604

Ide Tetsuo, Water Purification p 604

33) A.Y.AL-BORNO ANDM.ABDEL-JAWAD ; Desalination, 74(1989), P 3 ～36

用廃水便覧, P 435､436

Handbook of Industrial Water and Wste Water p 435､446

木曽, 北尾；水処理技術, Vol 25,No 2,1984, P 90～91

Kiso, Kitao, Water Purification and Liquid Waste Treatment Technology p 90 - 91

34) S.R.Ahmed ; Desalination, 74(1989), 69-84

Lynn E.Applegate; Desalination , 74(1989), 51-67

日本公開特許, 昭62-11075, (東レ)

JP KOKAI SHO-62-11075

桑名, 藤本, 森岡；PPM , 1980.11 ,P42～45

Kuwana, Fujimoto, Morioka, PPM, (1980) Vol.11, p 44

35) 高分子材料・技術総覧, 1988.12 , 第 6節, 逆浸透膜, P369

Comprehensive Bibriography on High Polimer Materials p 369

36) 埼玉県営水道；パンフレット（埼玉県企業局）

Technical Brocure by Waterworks Bureau of Saitama Prefecture Japan

37) DIRASSレポート, 13-8, 高分子分離膜の製造法及び応用, P 631,637

DIRASS Report 13-8, "Manufacture and Application of High Polymer Membrane"

38) 井手哲夫編著；水処理学, P 632

Ide Tetsuo, Water Purification p 632

39) 木村ら編著；膜分離技術マニアル, 前処理及び逆浸透法プラントの構成機器と運転時の諸問題, P 214

Kimura et,al, Manual on Membrane Separation; Probrems of Equipment and Operation of Pre-treatment of RO Plant

40) 日本公開特許, 平1-135506 ,(東レ)

JP KOKAI HEI-1-135506

桑名，藤本，森岡 ；PPM， 1980.11，P 44

Kuwana, Fujimoto, Morioka, PPM, (1980) Vol.11, p 44

MRC テクノ技術調査，1991.10.26，通産省茅ケ崎臨海施設における技術調査

Technical Report MRC Techno. Co.,Ltd. (1991), "Seawater Desalination Plant at Chigasaki"

41) 井手哲夫編著；水処理学，P 632

Ide Tetsuo, Water Purification p 632

42) MRC テクノ技術調査，1991.10.26，通産省茅ケ崎臨海施設における技術調査

Technical Report MRC Techno. Co.,Ltd. (1991), "Seawater Desalination Plant at Chigasaki"

43) 木曽，北尾；水処理技術，Vol 25,No 2,(1984)，P 83

Kiso, Kitao, Water Purification and Liquid Waste Treatment Technology Vol 25,No 2,1984, P 83

44) 日本公開特許，昭62-11075，（東レ）

JP KOKAI SHO-62-11075

MRC テクノ技術調査；1991.10.26，通産省茅ケ崎臨海施設における技術調査

Technical Report MRC Techno. Co.,Ltd. (1991), Seawater Desalination

高分子材料・技術総覧，88-12，第 4章，物理化学機能材料，P364

Comprehensive Bibriography on High Polymer Materials p 364

45) 木村ら編著；膜分離技術マニアル，前処理及び逆浸透法プラントの構成機器と運転時の諸問題，P 214

Kimura et,al, "Manual on Membrane Separation; Probrems of Equipment and Operation of Pre-treatment of RO Plant, p 214

46) MRC テクノ技術調査，1991.10.26，通産省茅ケ崎臨海施設における技術調査

Technical Report MRC Techno. Co.,Ltd. (1991), "Seawater Desalination Plant at Chigasaki"

47) ditto

48) ditto
49) DIRASSレポート, 13-8, 高分子分離膜の製造法及び応用, P 9,23,24
DIRASS Report 13-8, "Manufacture and Application of High Polymer Membrane",.p 9, 23,24
MRC テクノ技術調査, 1991.10.26, 通産省茅ケ崎臨海施設における技術調査
Technical Report MRC Techno. Co.,Ltd. (1991), Seawater Desalination
50) 木曽, 北尾; 水処理技術, Vol 25,No 2,1984, P 89
Kiso, Kitao, Water Purification and Liquid Waste Treatment Technology Vol 25,No 2,1984, P 89
51) 井手哲夫編著; 水処理学, P 631 ～632
Ide Tetsuo, Water Purification P 631 ～632
52) 沖縄県渡名喜村発行パンフレット, 「渡名喜村簡易水道海水淡水化施設」, P 1～4
"Simple Seawater Desalination Water Supply System at Watanaki Village Japan", Technical Brochure by Watanaki Village Japan
53) 三菱重工業発行カタログ, 「長崎オランダ村ハウステンボス（株）向け三菱逆浸透法海水淡水化プラント設備」
"Motsubishi Revers Osmosis Seawater Desalination Plant for Holand Village in Nagasaki Prefecture Japan", Technical Brochure by Mitsubishi Heavy Industry
54) 膜技術体系, 第 2章, 精製, P 70,71
Systematic Membrane Technology, Chapter 2, Refining P 70,71
55) 井手哲夫編著; 水処理学, P 637
Ide Tetsuo, Water Purification P 631 ～632
膜技術体系, 第 2章, 精製, P 70
Systematic Membrane Technology, Chapter 2, Refining P 70
56) 膜技術体系, 第 2章, 精製, P 71
Systematic Membrane Technology, Chapter 2, Refining P 71
57) 膜技術体系, 第 2章, 精製, P 72
Systematic Membrane Technology, Chapter 2, Refining P 72

58) 中垣正幸監修；膜処理技術大系, 第 3章, 逆浸透システム, P 837

Systematic Membrane Technology, Chapter 3, RO system, P 837

59) 同上, P 830

Systematic Membrane Technology, Chapter 3, RO system, P 830

60) 同上, P 831,836

Systematic Membrane Technology, Chapter 3, RO system, P 831,836

61) 同上, P 836

Systematic Membrane Technology, Chapter 3, RO system, P 836

62) 同上, P 837,838

Systematic Membrane Technology, Chapter 3, RO system, P 837,838

63) 大矢他；化学工学論文集, 1981､7(3), P 272～277

Oya et al. Collected Papers on Chemical Engineering,Vol.7,3(1981)P272

64) H.Motomura,Y.Taniguchi; ACS SYMPOSIUM, SERIES No153,1981, P 79～88

65) 中垣正幸監修；膜処理技術大系, 第 3章, 逆浸透システム, P 835,837

Systematic Membrane Technology, Chapter 3, RO system, P 835,837

66) 用廃水便覧, P 443

Handbook of Industrial Water and Wste Water p 443

67) 用廃水便覧, P 443

Handbook of Industrial Water and Wste Water p 443

68) 用廃水便覧, P 436

Handbook of Industrial Water and Wste Water p 436

69) A.Y.AL-BORNO,M.ABDEL-JAWAD; Desalination, 74(1989), P 26

70) Desalination ,38(1981) ,P 419 ～421

71) WATER/Engineering & Management, APRIL 1982, P 30

72) MAHMOOD.Y.ARI,J.P.RILEY ; Desalination, Vol.23,No 9,P 1099 ～1106

73) MILL WITCHURCH HANTS; Desalination, 35(1980),P 388～391

74) 桑名, 藤本, 森岡；PPM, (1980)No.11, P 42～47

Kuwana,Fujimoto,Morioka,PPM, (1980)No.11, P 42～47

75) K.D.VOS I.NUSBAUM ; Desalination,5(1968), P157～166

76) 大矢晴彦監修；純水・超純水製造法（幸書房、昭60），P 96
Oya Haruhiko, Ultra Pure Water Production Production Technology
Saiwai Shobo Press (1985), p 96
77) 紫外線殺菌技術資料（（株）日本フォトサイエンス），P 1
Technical Report of Photo Science Co. Ltd,."UV-Sterization" p 1
78) 76)と同じ，P 96
Oya Haruhiko, Ultra Pure Water Production Production Technology
Saiwai Shobo Press (1985), p 96
79) 76)と同じ，P 96
Oya Haruhiko, Ultra Pure Water Production Production Technology
Saiwai Shobo Press (1985), p 96
80) 77)と同じ，P 1
Technical Report of Photo Science Co. Ltd,."UV-Sterization" p 1
81) （株）日本フォトサイエンスにおける筆者の技術調査（1991年10月）
Technical Report of Photo Science Co. Ltd,."UV-Sterization"(1991)
82) 81)と同じ
Technical Report of Photo Science Co. Ltd,."UV-Sterization"(1991)
83) 水処理技術，25巻（No.2）1984，P 9
Water Purification and Liquid Waste Treatment Technology Vol.25 (1984), p 9
84) 日本公開特許，昭56-129009(今井)
JP KOKAI SHO-56-129009(Imai)
85) 76)と同じ，P 103
Oya Haruhiko, Ultra Pure Water Production Production Technology
Saiwai Shobo Press (1985), p 103
86) C.S.Rupert他；Comparative Effects of Radiation, New York, 1960, P 49 ～ 61
87) 76)と同じ，P 97
Oya Haruhiko, Ultra Pure Water Production Production Technology
Saiwai Shobo Press (1985), p 97

88) 76)と同じ, P 9

Oya Haruhiko, Ultra Pure Water Production Production Technology

Saiwai Shobo Press (1985), p 9

89) （株）日本フォトサイエンス, パンフレット, P 2

Technical Report of Photo Science Co. Ltd.,"UV-Sterization",p 9

90) 77)と同じ, P 2

Technical Report of Photo Science Co. Ltd.,"UV-Sterization" p 2

91) 76)と同じ, P 98

Oya Haruhiko, Ultra Pure Water Production Production Technology

Saiwai Shobo Press (1985), p 98

92) 76)と同じ, P 98

Oya Haruhiko, Ultra Pure Water Production Production Technology

Saiwai Shobo Press (1985), p 98

93) 86) と同じ, P 49～61

C.S.Rupert他; Comparative Effects of Radiation,New York,1960, P 49 ～ 61

94) 76)と同じ, P 98

Oya Haruhiko, Ultra Pure Water Production Production Technology

Saiwai Shobo Press (1985), p 98

95) 77)と同じ, P 2

Technical Report of Photo Science Co. Ltd.,"UV-Sterization" p 2

96) 76)と同じ, P 105

Oya Haruhiko, Ultra Pure Water Production Production Technology

Saiwai Shobo Press (1985), p 105

97) GMP テクニカルレポート, （薬業時報社, 1988年）4.注射用水の製造に関するバリデーション

Technical Repor of GMP, Yakugyo Jihosha (1988),"Production of Pure Water for Injection"

98) J.E.Kaufman;IES LIGHTING HAND BOOK,P 197

99) 97) と同じ, P 36

Technical Repor of GMP, Yakugyo Jihosha (1988),"Production of Pure Water for Injection",p 36

100) Yip,R.W.and Konasewich,D.E. ; Canadian Journal Water and Pollution Control, June ,1972 "Ultraviolet Sterilization of Water-Its Potential and Limiations"

101) 76)と同じ, P 103

Oya Haruhiko, Ultra Pure Water Production Production Technology Saiwai Shobo Press (1985), p 96

102) 76)と同じ, P 104 ～106

Oya Haruhiko, Ultra Pure Water Production Production Technology Saiwai Shobo Press (1985), p 96

103) 76)と同じ, P 105

Oya Haruhiko, Ultra Pure Water Production Production Technology Saiwai Shobo Press (1985), p 96

104) 76)と同じ, P 105

Oya Haruhiko, Ultra Pure Water Production Production Technology Saiwai Shobo Press (1985), p 96

105) 76)と同じ, P 103

Oya Haruhiko, Ultra Pure Water Production Production Technology Saiwai Shobo Press (1985), p 96

106) 77)と同じ, P 8

Oya Haruhiko, Ultra Pure Water Production Production Technology Saiwai Shobo Press (1985), p 96

107) 76)と同じ, P 103

108) 76)と同じ, P 103

Oya Haruhiko, Ultra Pure Water Production Production Technology Saiwai Shobo Press (1985), p 103

109) 77)と同じ, P 8

Oya Haruhiko, Ultra Pure Water Production Production Technology

Saiwai Shobo Press (1985), p 8
110) 76)と同じ, P 104
Oya Haruhiko, Ultra Pure Water Production Production Technology
Saiwai Shobo Press (1985), p 104
111) 77)と同じ, P 5
Oya Haruhiko, Ultra Pure Water Production Production Technology
Saiwai Shobo Press (1985), p 5
112) 77)と同じ, P 8
Oya Haruhiko, Ultra Pure Water Production Production Technology
Saiwai Shobo Press (1985), p 8
113) 77)と同じ, P 9
Oya Haruhiko, Ultra Pure Water Production Production Technology
Saiwai Shobo Press (1985), p 9
114) 76)と同じ, P 99
Oya Haruhiko, Ultra Pure Water Production Production Technology
Saiwai Shobo Press (1985), p 99
115) 76)と同じ, P 102
Oya Haruhiko, Ultra Pure Water Production Production Technology
Saiwai Shobo Press (1985), p 102
116) 77)と同じ, P 6
Oya Haruhiko, Ultra Pure Water Production Production Technology
Saiwai Shobo Press (1985), p 6
117) 77)と同じ, P 7
Oya Haruhiko, Ultra Pure Water Production Production Technology
Saiwai Shobo Press (1985), p 7
118) 77)と同じ, P 7
Oya Haruhiko, Ultra Pure Water Production Production Technology
Saiwai Shobo Press (1985), p 7
119) G.V.ジェームス著、内藤幸穂訳；水処理技術事典, P 46
G.V. James, Tranlated by Naito, "Dictionary of water purification

Technogy", p 46

120) 用廃水便覧, P 437

Handbook of Industrial Water and Wste Water p 437

121) 同上, P 437

Handbook of Industrial Water and Wste Water p 437

122) 同上, P 437

Handbook of Industrial Water and Wste Water p 437

123) K.D.NUSBAUM ; Desalination, 5(1968), 157 ～166

124) 岩波理化学辞典, P 1427

Dictionary of Physics and Chemistry by Iwanami p 1427

用廃水便覧, P 437

Handbook of Industrial Water and Wste Water p 437

125) 同上, P 439

126) A.Y.AL-BORNO; Desalination ,74(1989),3 ～36

127) 用廃水便覧, P 438

Handbook of Industrial Water and Wste Water p 437

128) 同上, P 437

Handbook of Industrial Water and Wste Water p 437

129) Desalination, 5(1968)157 ～166

130) A.Y.AL-BORNO; Desalination ,74(1989),3 ～36

131) 同上

132) 水処理工学; P 628,629

Waste Water Treatment Engineering, p 628,629

133) 桑名, 藤本, 森岡; PPM, P 44

Kuwana,Fujimoto,Morioka,PPM, (1980)No.11, P 42～47

134) 用廃水便覧, P 439 ～441

Handbook of Industrial Water and Wste Water p 439 ～441

135) A.Y.AL-BORNO; Desalination,74(1989),3～36

136) 用廃水便覧, P 439

Handbook of Industrial Water and Wste Water p 439

137) 理化学辞典, 亜硫酸水素ナトリウム, P 41
Dictionary of Physics and Chemistry by Iwanami p 41
138) G.V.ジェームス著、内藤幸穂訳; 水処理技術事典, P 35～62
G.V. James, Tranlated by Naito, "Dictionary of water purification Technogy", p 35～62
用廃水便覧, P 434 ～447　井手哲夫編著; 水処理工学, P 598 ～607
Handbook of Industrial Water and Wste Water p 434 ～447
Ide Tetsuo, Water Purification P 598 ～607
139) S.R.AHMED ; Desalination,74(1989),69～84
140) A.Y.AL-BORNO ; Desalination,74(1989)3 ～36
141) 同上 ,P19
140) A.Y.AL-BORNO ; Desalination,74(1989)p 19
142) 国定勇一, 岡田清, 園田敏彦, 瀬戸川茂, 石渡哲朗; 造水技術,9(4), 13 (1983)
Kunisada Yuici et al. Water Production Engineering Vol.9,No.4 13 (1983)
143) 日本公開特許, 昭62-110705(東レ)
JP KOKAI SHYO-62-110705
144) A.M.SHAMS EL DIN et al.;Desalination,85(1991)13-32
145) R.CHENG etal.;Desalination,85(1991)33-44
146) L.E.Applegate etal.;Desalination,74(1989)51-67
147) 日本公開特許, 平01-135506(東レ)
JP KOKAI HEI-01135506

4.4 R–3 Pollution Effect of Membrane Cleaning Discharge

RO DESALINATION
LITERATURE SURVEY NO. 4, R-3

POLLUTION EFFECT OF MEMBRANE CLEANING DISCHARGE

JULY 1992

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1. Introduction

Waste water, which is spewed out from the equipment used in the RO desalination process, can be classified by the origin of its generation. It can be divided into waste water from the pretreatment equipment, waste solution the preservation solution for the RO membranes and the cleaning solution for the RO membranes. These waste waters and solutions differ in quantity, water quality and generation frequency determined by the generation source. Also, the nature of the solutions is different, depending on the type of chemical solutions used, which in turn are determined by the type and quality of the RO membranes used. Depending on the chemicals used, waste solutions containing toxic substances can be produced.

The number of sea water desalination plants using RO equipment is expected to increase in the future. Also, it has been predicted that it will expand to larger unit capacity up to 100,000 m^3 per day. Due to this, it will be impossible to ignore the volume of waste water that this equipment will generate.

In Japan, toxic wastes, produced by industry, can be disposed of by leaving it to specialist waste disposal companies, when there is no treatment facilities at the factories. However, in Saudi Arabia whether or not this kind of treatment disposal exists, as part of the social system or if there are specialist disposal companies is not certain.

Re-examination of the plant specification and their washing methods must be considered and the kinds of preservation solutions and washing solutions suitable for use in the equipment, should not be selected without regard of the social system.

Consequently, it is necessary to examine, which includes the social system, the locations of the equipment and the volume and quality of the waste water, in order to minimize any harmful effects to the environment, that may accompany the spread and expansion of the RO sea water desalination equipment.

First of all, investigative research will be conducted using literature survey as the source for examining these treatment processes. The volume and quality of waste water will differ due to the generation source, the process, the membrane materials and the washing process. With each of these several factors, data must be collected and assessed in order to evaluate the volume and quality of the waste water.

Finally, with the results corresponding in general to the evaluation of the waste water, investigations into methods for its treatment will be conducted. Further, information should be obtained from SWCC on the Saudi Arabian disposal system including information on environmental laws and regulations, natural conditions, the existing conditions for the disposal of toxic wastes and customs etc.; and arrangements should be made based on this information.

2. Methods

(1) Literature Survey

The followings will be conducted.

* By means of JOIS, DIALOG data base, screening the past 15 year data related to membrane cleaning and its waste water discharge
* Evaluation of the important references on MSF and RO covering the above period

(2) Information Collection from Membrane Makers

The followings will be conducted.

* Collecting information on cleaning agents, preservation solution and cleaning procedure of membranes made by Nitto Denko Corporation, Toray Industries Inc. and Toyobo Co.,Ltd. and evaluation of the collected materials
* Evaluation of some membranes other than the ones made in Japan by getting information from SWCC

(3) Requests to SWCC

SWCC is requested to offer the following materials with regard to:

1) Brine quality and quantity from the existing RO module.
2) Saudi Arabian laws and rules related to environmental protection, the actual state of disposal of industrial wastes, the local conditions and the conventional way of life.

3. Results

3.1 Literature Survey

A number of large-scale plants for saline water desalination system using the Reverse Osmotic method have been constructed until now, and there are many technical reports on these system. However, most of those reports does not necessarily mention the waste water drained from the system. It is valuable to survey all the literature that has been hitherto presented, and to rearrange the contents of any reports on waste water.

For this purpose, there are 13 files in DIALOG, which has the maximum capacity of database in the world and JICST, the maximum in Japan, concerning water treatment technologies. From those files, we carry out the retrieval of information on the treatment of waste water (pretreatment units, chemical-solution cleaning, storage solution, etc.) of RO applied brine desalination system and its related matters (quality, quantity, frequency, etc. of waste water). The data obtained are summarized in this report.

3.1.1 Overview of Literature Survey

(1) Object of Survey

Table 3.1.1–3.1.3 shows 13 files of 2 systems surveyed.

(2) Literature Selection Method

Abstract of reference materials selected by the retrieval equation shown in APPENDIX R3–1 were read on the screen; and, previous reports concerning the subject were gathered and analyzed. For the DIALOG, the analysis of previous reports was realized for a total of 48 data out of 748 data retrieved, of which 34 data were selected as relevant. By excepting those repeatedly stored in two or more files, 12 data were selected. For the 34 data retrieved by JOIS, the analysis of previous reports was realized for 27 data, of which 13 were chosen as relevant.

3.1.2 Results of Literature Survey

Following the analysis of previous reports, a total of 25 data – 12 from the DIALOG and 13 from the JOIS – were retrieved as useful data. They are shown in APPENDIX R3–3. Of these, 20 data that had been written in English, were summarized in SWCC. For 5 data written in Japanese, a summary of sections related to the theme of this study is shown in APPENDIX R3–4.

For the 25 data thus selected, 5 are concerned with the introduction of actual facilities or experimental facilities of similar capability. Of these, 3 data (index Nos. 1, 15 and 16) deal with the desalination of seawater, while the remaining 2 (Nos. 7 and 24) deal with brackish water. The reference material (index No.1) defines the types and overall volume of chemical solutions to be used, and deals with the impact on environment of the untreated waste water when discharged after the use of these chemical solutions. The reference material (No.7) deals mainly with the pretreatment and the post–treatment.

For the plants introduced therein, a high concentrated brackish water is used as a water source; but at the same time the plant is also defined as a seawater membrane facility. The reference materials (Nos. 15 and 16) concern small–scale seawater desalination plants, and, No. 16 deals with the frequency of cleaning and the chemical solutions used for cleaning purposes. It also indicates that recovery of the membrane was achieved through cleaning by citric acid within a year and 3 months after the start of operation.

But, the reference material (No.24) gives a cleaning cycle of 2 to 3 months; thus, it is concluded that the frequency of cleaning varies widely depending on the water quality and the type of membrane used.

By excluding the above–mentioned reference materials, there were 11 reference materials that dealt with the cleaning method, recovery of membrane by cleaning, and fouling materials. Of these, 3 (Nos. 14, 20 and 21) gave a general outline of the membrane, and also made reference to cleaning chemical solutions. 5 reference materials(Nos.2, 4, 17, 18 and 25) dealt with the

Table 3.1.1 Results of Literature Survey (DIALOG)

File No.	Database	Producer	Subject coverage	Term	No. of survey	
					Ab-stract	Origi-nal
245	Waternet	American Water Works Association (AWWA)	Drinking Water Industry Water Treatment Water Quality Water Analysis Water Utility Management Water Rates Watwer Conservation Water Use Water Law Water Pollution Watershed Management Wastewater Treatment Wastewater Reuse Distrtbution Systems Desalination	1981 ~ 1991	50	2
117	Water Resources Abstracts	Water Resources Scientific Information, U. S. Department of the Interior	Nature and Properties of Water Water cycle and Hydrology Water Supply Augmentation and Conversation Water Quantity Management and Control Water Quality Management and Protection Water Resources Planning and Water Law Resources Data:Net Works, Techniques and Computer Applications Engineering Works and Hydrolics Reviews, Bibliographies and other Water Literature Products and Services	1981 ~ 1991	97	9
399	CA Search	Chemical Abstract Services	Applied Chemistry Biochemistry and Biology Chemical Engineering Classes of Substances Macromolecular Chemistry Organic and Inorganic Chemistry Physical and Analytical Chemistry Properties and Reactions	1981 ~ 1991	64	5
28	Oceanic Abstracts	Cambridge Scientific Abstracts	Marine Biology Physical and Chemical Oceanography and Meteorology Marine Geology, Geophysics, and Geochemistry Marine Pollution/Environmental Protection Living and Nonliving Marine Resources Ships and Shipping Government and Law Engineering and Materials	1981 ~ 1991	74	5

Table 3.1.1 (continued)

File No.	Database	Producer	Subject coverage	Term	No. of survey	
					Ab-stract	Origi-nal
44	Aquatic Sciences and Fisheries Abstracts	UNESCO and FAO	Aquaculture Aquatic Biology Biological Oceanography Chemical Oceanography Coastal Zone Management Commerce, Trade and Economics Ecology and Ecosystems Environmental Studies Fisheries(Harvesting, Processing and Marketings) Fish Products Geological Oceanography Law of the Sea Limnology Man in the Sea-Diving Marine Biology Marine Policy Marine Pollution Marine Technology Marine Meteorology and Climatology Ocean Engineering Ocean Resources(Potable Water, Chemicals, MineralsOil, Gas, Energy) Offshore Stractures Physical Oceanology Underwater Acoustic and Optics Vessels, Underwater Vehicles and Buoys Water Pollutions	1981 ~ 1991	89	9
8	Complex Plus	Engineering Information	Aeronautical and Aerospace Engineering Applied Physics(High Energy, Plasma, Nuclear and Solid State) Bioengineering and Medical Equipment Chemical Engineering, Ceramics, Plastics and Polymers, Food Technology Civil and Structural Engineering, Environmental Technology Electrical, Instrumentation, Control Engineering, Power Engineering Electronics, Computers, Communications Energy Technology and Petroleum Engineering Engineering Management and Industrial Engineering Light and Optical Technology Marine Engineering, Naval Architecture, Ocean and Underwater Technology Mechanical Engineering, Automotive Engineering and Transportation Mining and Metallurgical Engineering, Materials Science	1981 ~ 1991	60	2

Table 3.1.1 (continued)

File No.	Database	Producer	Subject coverage	Term	No. of survey	
					Ab-stract	Origi-nal
41	Pollution Abstracts	Cambridge Scientific Abstracts	Air Pollution Environmental Action Freshwater Pollution Land Pollution Marine Pollution Noise Radiation Sewage and Wastewater Treatment Toxicology and Health Waste Management	1981 ~ 1991	39	5
350 351	World Patent Index	Derwent Publi-cation	Chemical Technology General Technology Electrical Technology Mechanical Technology	1976 ~ 1991	146	JPN. 60 Other 25
6	NTIS	National Technical Information Service of the U. S. Department of Commerce	Administration and Management Aeronautics and Aerodynamics Agriculture and Food Astronomy and Astrophysics Atmospheric Science Behavior and Society Biological Technology and Engineering Building Industry Technology Buisiness and Economics Chemistry Communication Computers, Control, and Information Theory Electrotechnology Energy Environmental Pollution Control Health Planning Industrial and Mechanical Engineering Library and Information Sciences Material Sciences Medicine and Biology Millitary Sciences Missile Technology Natural Resources and Earth Sciences Navigation, Guidance, and Control Nuclear Science and Technology Ocean Technology and Engineering Photography and Recording Devices Physics Propulsion and Fuels Space Technology Transportation Urban and Regional Technology	1981 ~ 1991	58	11
144	PASCAL	Centure National de la Recherche Scientifique (FRANCE)	World's Scientific Literature.	1981 ~ 1991	25	5

Table 3.1.1 (continued)

File No.	Database	Producer	Subject coverage	Term	No. of survey	
					Ab-stract	Origi-nal
96	FLIDEX	Elsvier Science Publishers	Aerodynamics, Meteorology Wind Energy Noise Coastal and Inland Fluid Engineering Works, Offshore Technology Multiphase Flow Mixing Measurement and Instrumentation Oilhydraulics(Fluid Power) Fluidics High Pressure Technology-Jet Cutting Computational Fluid Mechanics, Mathematical Modelling Fluid Sealing Materials-Properties, Corrosion Process Engineering (except Mixing) Heat Exchange Dredging, Mining Oceanography Pumps, Compressors, Hydraulic Turbines; Pipelines, Pipes, Fittings; Storage Vessels Fluid Mechanics in General Tribology Rheology Energy Extraction, Storage, Conversion Corrosion	1981 ~ 1991	23	8

Table 3.1.2 Results of Literature Survey (JOIS)

File No.	Database	Producer	Subject coverage	Term	No. of survey	
					Ab-stract	Origi-nal
010 011	JICST	JICST	World's Scientific Literature.	1976 ~ 1991	25	5

Table 3.1.3 Results of Literature Survey (DIALOG + JOIS)

System	Number of Survey		Remarks
	Abstract	Original	
DIALOG	725	148	Include Repetition
JOIS	34	28	
Total	759	176	

improvement of the cleaning methods. Others included the study and method of pretreatment of fouling materials (No.8); steps of cleaning (No. 21), and tests on the degree of recovery by cleaning (No. 22).

There were 5 data (Nos. 3, 5, 6, 10 and 11) concerning the drain. Of these, Nos. 5 and 6 dealt with the method of drain treatment, thus testifying to the importance of the brine treatment.

The remaining 4 data included one describing the importance of waste water treatment (No.3); the need for measures against sulfate scale in pretreatment when treating brine (No.12); explanation regarding salt water desalination plants using EDR (No.13); and, an explanation of the process taking into account the recovery of chemical materials (No.18).
Refer to APPENDIX R3-2

3.1.3 Additional Study on Formalin Treatment

Through the retrieval on this subject, reference materials describing the cleaning method and cleaning solution of RO membranes were obtained. But, no indication was given regarding the treatment of formalin, which is the solution mainly used for preserving RO membranes. Another retrieval was tried on this theme by JOIS; from the 28 abstracts which were retrieved on the display, previous reports of 10 data were selected. Their summary is shown in Appendix 5.

3.1.4 Summary of Literature Survey

Although the survey was tried over a wide range of reference materials, only a small number of reference materials concerning the theme of this study was found; and, even in those reference materials related to the theme of this study, almost all indicated only a slight reference in the report to the results of the operation. But, the number of reference materials retrieved showed an increase of new data in the recent 2 to 3, or 4 to 5 years; thus, suggesting a high probability that useful data might be obtained by carrying out continuous studies on the same theme.

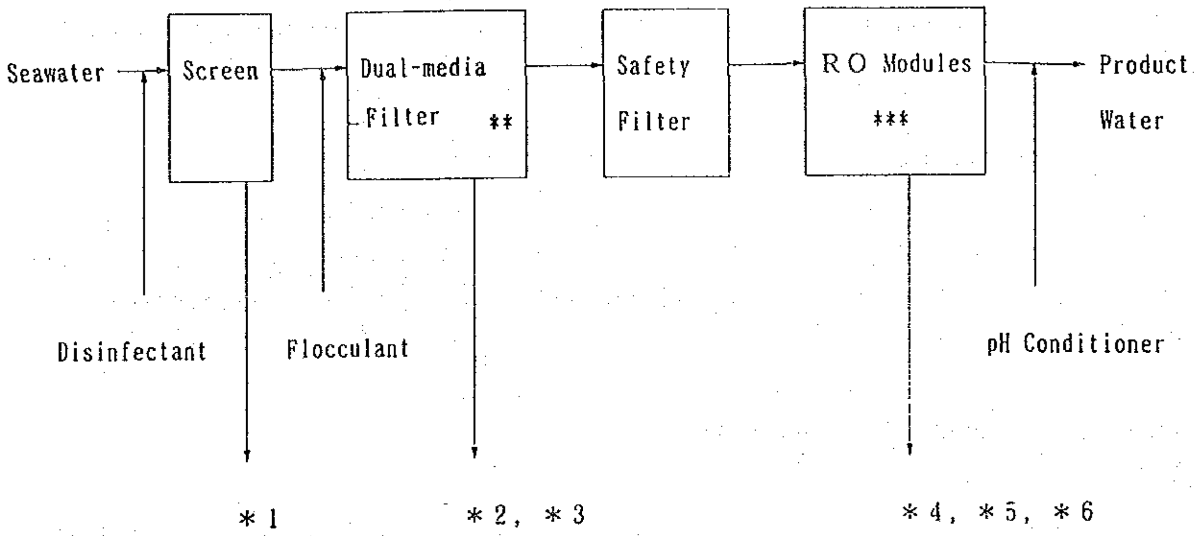
3.2 Survey of Membrane and Plant Manufacturers

Literature survey can give only a little information on the waste water of RO brine desalination system. Information on waste water was collected by choosing 3 leading RO membrane manufacturers and 2 plant makers with records of construction of large-scale plants in Japan. Although there exist certain differences in flow, chemical solutions used, and discharge, depending on the quality of the original seawater, membrane materials and site conditions, the actual condition of waste water discharge at actual plants may be explained as follows:

3.2.1 Actual System Flow

the basic system flow is the same. In either case, screen and dual-media filter are used for treatment prior to RO membrane, and they generate waste waters respectively. RO membrane itself generates concentrated brine and cleaning waste water. The quality of cleaning waste water a little changes, depending on the material of membrane.

The general flow of the RO brine desalination system and the waste water generation points are shown in Fig.3.2.1. This chart shows only the basic flow; various other devices are added to the actual facility depending on the site conditions and the quality of the product water.



* 1 : Screen cleaning wastewater
* 2 : Dual-media filter cleaning wastewater
* 3 : Rinsing wastewater
* 4 : Chemical-solution cleaning wastewater
* 5 : Concentrated brine
* 6 : Membrane storage-solution wastewater

** :Dual-media filter or Dual-media filter and Sandfilter(Polisher)
***:1 stage or 2stage(depend on the quality of the product water)

Fig. 3.2.1 Waste Water Generation Points from Desalination Plant

3.2.2 Quantity and Quality of Waste Water at Each Generation Point

(1) Screen cleaning waste water

1) Outline

This waste water is generated at the screen, the forefront section of pretreatment, when it is cleaned. Cleaning method depends on the screen type. Generally adopted is a traveling screen which performs intermittent cleaning. This screen aims to remove relatively coarse solid suspensions in seawater, so it generates waste water containing coarse solid suspensions once caught by the screen during the cleaning process.

2) Water quality

For cleaning, the screen passed water is used. Accordingly, waste water generated is made up of seawater containing coarse solid suspensions again. As it is hardly supposed that seawater contains a large quantity of coarse solid bodies, there is no problem in considering the quality of this waste water almost equal to that of seawater. Then, no treatment is required for this waste water.

3) Quantity of waste water

The quantity of waste water depends on the screen width and type and the number of screens. Cleaning practice is generally once or twice a day. Cleaning time is 5 min. or so per screen. In a system with a desalination capacity of 50,000 m^3/d, waste water amounts to some 20 m^3/d.

(2) Dual-media filter cleaning waste water

1) Outline

This waste water is generated at the dual-media filter unit installed in the pretreatment process before RO membrane, when it undergoes backwashing. To brine fed to the dual-media filter unit, ferric chloride is added as a flocculant. Accordingly, the waste water drained from the dual-media filter unit contains suspended solids in seawater (SS) and ferric hydroxide produced from ferric chloride.

As cleaning is intermittent, waste water is generated also intermittently. Although sand filtering is provided as a polisher downstream a double-layer strainer, waste water originating from cleaning is also generated from the polisher.

2) Water quality

Water used for cleaning is the dual-media filter unit permeated water, which contains suspended solids in seawater and ferric hydroxide. Besides, it contains a very small quantity of residual chlorine, because chlorine is added for sterilization. The concentration of suspended solids in waste water is high in the early period of backwashing, but it reduces quickly. This waste water has a suspended solids of 100 to 300 ppm or so on average. Suspended solids in seawater and ferric hydroxide both are not harmful.

Further, the average concentration of suspended solids can be controlled to become lower than the effluent standard of the area where the system is operated, by draining this waste water at an averaged density or diluting with concentrated brine.

Thereby, it is possible to release the waste water into the sea area causing no trouble, though it turns reddish brown due to a large quantity of iron content. Sometimes, it will be required to remove solid bodies by means of sedimentation, etc., in consideration of the regulations and environmental conditions of the water releasing area.

3) Quantity of waste water

The cleaning frequency of dual-media filter unit is once in 1 to 2 days per unit. The cleaning practice continues 10 to 15 min. or so for one time. The flow of cleaning waste water depends on the filtering area of each unit. In a system with a desalination capacity of 50,000 m^3/d, the quantity of waste water amounts to some 4,000 to 6,000 m^3/d.

If the density of suspensions in seawater, the quantity of cleaning waste water increases. When setting up a polisher, the volume of waste water discharged from the double-layer strainer decreases, and thus, the overall volume of waste water discharged is more or less the same as when no polisher is used.

(3) Rinsing waste water

1) Outline

This waste water is filtered water that drains just after backwashing of dual-media filter unit until the water quality becomes steady.

2) Water quality

As it is filtered water, though wasted, and is brine little containing suspensions, this waste water requires no treatment for release into the sea area.

3) Quantity of waste water

The draining frequency of this waste water is the same as the cleaning frequency of dual-media filter unit. The draining time depends on SDI requirement of RO membrane. If SDI level is low, the draining practice needs a longer time. To lower SDI down to 3, a draining of 1.5 time or so is necessary. For lowering the SDI to 4, 30 to 40 minutes would be required. The flow is similar to the permeating water quantity of dual-media filter unit.

In a system with a desalination capacity of 50,000 m^3/d, the quantity of waste water amounts to some 2,000 to 6,000 m^3/d.

(4) Waste water from chemical solution cleaning

1) Outline

Waste water is generated when RO membrane is cleaned with a chemical solution. RO membrane increases its permeation resistance because of contamination on the surface if used for a long time. When the resistance value exceeds the prescribed level, chemical-solution cleaning is carried out to recover the proper permeability of the membrane. The cleaning frequency is 1 to 10 times/year depending on the quality of the original seawater, thus causing waste water irregularly.

2) Water quality

This waste water from chemical-solution cleaning contains cleaning solution and contaminants removed from RO membrane. For cleaning solution, if contaminants mainly consist of inorganic matters, used is citric acid or oxalic acid of which pH is controlled by aqueous ammonia. For organic contaminants, a surface active agent is used as a cleaning solution.

The reason why RO membrane has inorganic contaminants on its surface is that RO membrane catches a very small quantity of iron that has permeated through a dual-media filter unit. Accordingly, this cleaning waste water includes iron as well as cleaning solution.

Organic contaminants may attach to RO membrane chiefly due to the propagation of microbes on the membrane surface, of which condition thus varies depending on the material of membrane. If RO membrane is made of a material resistive to chlorine, it is allowed to use a feed water with residual chlorine. If the material is not resistive to chlorine, dechlorinated feed water must be used. It is thought that this difference have some influence on the proportion of organic and inorganic matters in membrane contaminant.

In the actual case of a large-scale plant constructed in Saudi Arabia, only a cleaning solution dedicated for inorganic contaminants is used. With such a cleaning solution, either for inorganic contaminants or for organic contaminants, this waste water have a high COD. So, it should be processed by full dilution with concentrated brine or by independent treatment for waste water from chemical-solution cleaning.

Table 3.2.1 shows some examples of cleaning solution specifications recommended by Japanese leading RO membrane manufacturers.

3) Quantity of waste water

The quantity of waste water depends on module size, train configuration and pipe length. In a system with a desalination capacity of 50,000 m^3/d, the quantity of waste water amounts to some 1,000 m^3/year.

Table 3.2.1 Examples of Membrane Cleaning Solution[1]

Contaminants	Torey Industries Inc.		TOYOBO Co., Ltd.		Nitto Denko Corporation	
	Chemicals	pH Adjustment	Chemicals	pH Adjustment	Chemicals	pH Adjustment
In-organic	Citric Acid 1~2%	Adjust to pH4 with Ammonia water	Citric Acid 2%	Adjust to pH4 with Ammonia water	Citric Acid 2%	Adjust to pH4 with Sodium Hydroxide
	Oxialic Acid 0.1 ~0.2%	pH 2~4 % with Ammonia water				
Organic	Surface-active agent * 0.1 ~1%	pH 8~10 with acid or alkali **			Sodium Tripoly-phosphate 2% Sodium Edetate 0.8% ***	Adjust to pH4 with sulfuric acid
					Sodium Tripoly-phosphate 2% Sodium Dodecylbenzen Sulphonate 0.25%	

*: Dodecyl Sodium Sulfate(DSS) or TC-100 , **:Sodium Tripolyphosphate etc.

***:EDTA(Ethylendiamine tetraacetic acid) tetrasodium salt

(5) Concentrated brine

1) This waste water is part of feed water to RO membrane i.e., separated brine without permea-tion. Since the permeated water is desalted, the salt density of this waste water becomes higher than that of the feed water.

2) Water Quality

Feed water to RO membrane contains little suspensions, because they are almost com-pletely removed by a dual-media filter unit. So, the concentrated brine also contains no suspen-sions. The brine has a high salt density and a low pH of 6.5 to 7, different from normal seawater. If the collecting rate of RO membrane is 35%, the salt density of concentrated brine becomes 1.5 times or so the feed water.

When this waste water is released into the sea, no treatment is required. However, the specific gravity of concentrated brine is larger than that of normal seawater, so that the released brine runs near the bottom of the sea as a density current. If a number of large-scale plants use a narrow sea area in common, it will be sometimes necessary to make a good plan for their effluent pipes.

3) Quantity of waste water

The quantity of waste water depends of the collecting rate of RO membrane. If the rate is 35 %, the quantity of waste water becomes 1.86 times the product water. Accordingly, in a system with a desalination capacity of 50,000 m^3/d, the quantity of waste water amounts to some 93,000 m^3/d.

(6) Membrane storage-solution waste water

1) RO membrane, at the time of construction of a plant, is shipped from the factory in the state of being sealed in a module with a storage solution for sterilization. This storage solution flows out of the module when it is connected with pipes in the plant thus turning into waste water.

For the replacement of RO membrane, a new membrane element is shipped from the factory, being put in a special container filled with storage solution. This storage solution also turns into waste water when the used element is replaced with a new one in the plant. Further, the module is filled with storage solution to prevent the generation of microbes during stoppage, if the RO membrane unit is stopped for a long time.

When this unit is restarted, the storage solution in the module drains as waste water.

2) Water quality

For storage solution, which aims to prevent the propagation of microbes, formalin or sodium bisulfite is used. This waste solution may cause surfacing of fishes if released as it is. Therefore, some treatment, e.g., dilution, oxidization or burning, is needed. For shipping to the systems in Japan, sodium bisulfite is used for storage solution in many cases. On the other hand, when shipped from Japan to Saudi Arabia, in almost all cases, storage solution is formalin.

Sodium bisulfite is a strong reducing agent, but it is relatively easy to make the agent harmless by means of aeration. In contrast, formalin can be resolved by using an oxidizing agent, but it requires more labor and time for the process, compared with sodium bisulfite.

Nevertheless, formalin is used for plants in Saudi Arabia because of its high sterilizing power on which we cannot avoid relying, in consideration of uncertain factors of transport period, interval from shipping to commissioning, etc. existing more in those demands than in domestic ones. Table 3.2.2 shows storage solutions recommended by Japanese leading RO membrane manufacturers.

Table 3.2.2 Storage Solution for RO Membrane[2]

		Torey Industries Inc.	TOYOBO Co., Ltd.	Nitto Denko Corporation
Storage-solution for new modules and spare elements	Storage-solution 1	Formalin 0.5%	Formalin 0.5%	Formalin 0.5%
	torage-solution 2	Sodium bisulfite 500ppm		Sodium bisulfite 1%
Storage-solution for a long-term storage	Storage-solution 1	Formalin 0.5%	Formalin 0.5%	Formalin 0.5%
	Storage-solution 2	Sodium bisulfite 500ppm		Sodium bisulfite 1%
Remarks		In the case of protecting RO modules from freezing, it is necessary to add glycerol(20%).		

3) Quantity of waste water

When a module is shipped from the factory with storage solution in it, the quantity of waste water amounts to a half or so the module volume. When a membrane element is replaced, the quantity of waste water is almost equal to the capacity of a container for element. In the case of long-term storage, the quantity of storage-solution waste water is about two times the volume of membrane module.

Modules have different volumes by manufacturers. Table 3.2.3 shows the quantities of storage solutions in modules and spare elements to TOYOBO at the time of shipping from the factory. Storage-solution waste water is generated in construction, upon replacement of membrane element and at the time of restarting after a long-term storage. The replacing frequency of membrane element depends on the working conditions; as a guide, once or so in five years.

Table 3.2.3 Storage-Solution for Toyobo RO Modules(Reduced Size)[3]

Model of modules Model of elements	Type	Quantity of storage-solution	Size of a module	Permeate rate Collecting rate
HM 8255FI 8155EI	modules spare elements	30 ℓ 3 ℓ	298 mmφ ×2640 mm	27.5 m³/day 30%
HM 9255FI 9155EI	modules spare elements	35 ℓ 4 ℓ	360 mmφ ×2665 mm	35 m³/day 30%
HM10255FI 10155EI	modules spare elements	50 ℓ 5 ℓ	395 mmφ ×2910 mm	40 m³/day 30%

Long–term storage is carried out where the permeating water quantity greatly varies with seasons, where the water demand greatly varies with seasons, or when a large–demand user plant is stopped. Thus, it is difficult to predict the frequency of such occasions. In a system with a desalination capacity of 50,000 m^3/d, the quantity of storage–solution waste water roughly becomes as follows:

Storage–solution waste water ··· 75 m^3 in construction
Storage–solution waste water ··· 7.5 m^3/5 years
1.5m^3/year upon replacement of membrane 1.5 m^3/year
Storage–solution waste water ··· 50 m^3/1 train
after long–term storage (at 5,000 m^3/d in 1 train)

3.2.3 Summary of Plant Waste Waters

Table 3.2.5 summarizes the qualities and quantities of waste water drained from RO brine desalination systems of 50,000 m^3/d desalination capacity. These waste waters are different in quantity and quality according to the material of membrane, the process configuration, the seawater density, the water temperature, etc. In actual design of a waste water treatment equipment, a material balance sheet must be prepared, based on these factors, to estimate the quality and quantity of waste water.

In many cases a polisher (sand filtering) is provided downstream the double–layer strainer. In this case, the increase of waste water discharged from the polisher more or less balances the decrease of waste water discharged from the double–layer strainer, thus the total volume of waste water becomes more or less equal to the values shown in Table 3.2.4.

3.3 Laws and Regulations in Japan

At the conference held between the SWCC Site Survey Group and the first JICA Survey Group SWCC from October to November, 1991, both sides, SWCC and JICA, requested information on the waste quality water standard in the Kingdom of Saudi Arabia and Japan. First, the Japanese legal system for environmental control followed in the later section, the Saudi Arabian regulations on the "Environmental Protection Standards in the Kingdom of Saudi Arabia" are shown in Appendix 1. Details of Japanese regulations on the "Public Nuisance Countermeasures Basic Law", "Water Quality Pollution Prevention Law" and "Law concerning Prevention of Marine Pollution and Marine Disaster" are shown in Appendix 7, Appendix 8 and Appendix 9.

Table 3.2.4 Summary of Plant Waste Water

Type of wastewater (Type of discharge)	Quantity of wastewater		Quality of wastewater				
	average or continuous discharge	for each discharge	TDS mg/l	pH	SS mg/l	residual Chlorine mg/l	COD mg/l
Screen cleaning waste-water (intermittently)	m³/day 20	10m³ ×2 /day	mg/l 43,000		1～5	0	1
* Dual-media filter cleaning wastewater (intermittently)	m³/day 4,000 ～6,000	(400～600) m³ ×10 /day	43,000		100～300	0.1～0.3	10～30
Rinsing wastewater (intermittently)	m³/day 2,000 ～6,000	(200～600) m³ ×10 /day	43,000		0	0.1～0.3	1
** Concentrated brine (continuously)	m³/day 93,000	——	66,000	6.5 ～ 7.0	0	0.1～0.3	0.8
*** Chemicalsolution cleaning wastewater (intermittently)	m³/year 1,000 (2.7m³/d)	50m³ ×20/year		4		0	10,000 以上

Table 3.2.4 (continued)

Type of wastewater (Type of discharge)	Quantity of wastewater		Quality of wastewater				
	average or continuous discharge	for each discharge	TDS mg/l	pH	SS mg/l	residual Chlorine mg/l	COD mg/l
**** Storage-solution — construction (intermittently)	———	75 m^3				0	approx-imately 4,000
**** Storage-solution — replacement of membrane (intermittently)	m^3/year 1.5	m^3/train 0.75 ×2/year				0	approx-imately 4,000
**** Storage-solution — after long-term storage (intermittently)	———	m^3/train 50				0	approx-imately 1,000

* :High SS concentration. Coloured reddish brown by ferric ion. But rather harmless to the environment.

** :Can be discharged without treatment in general. In the case of high residual chlorine content, it should be removed.

*** : Low pH and high CDD.

**** : High COD. As Storage-solution is strong disinfectant, in the case of discharging without dilution, it should be treated to be harmless.

3.3.1 Japanese Legal System for Environment

In Japan, the laws related to environment is systemized in Fig. 3.3.1.

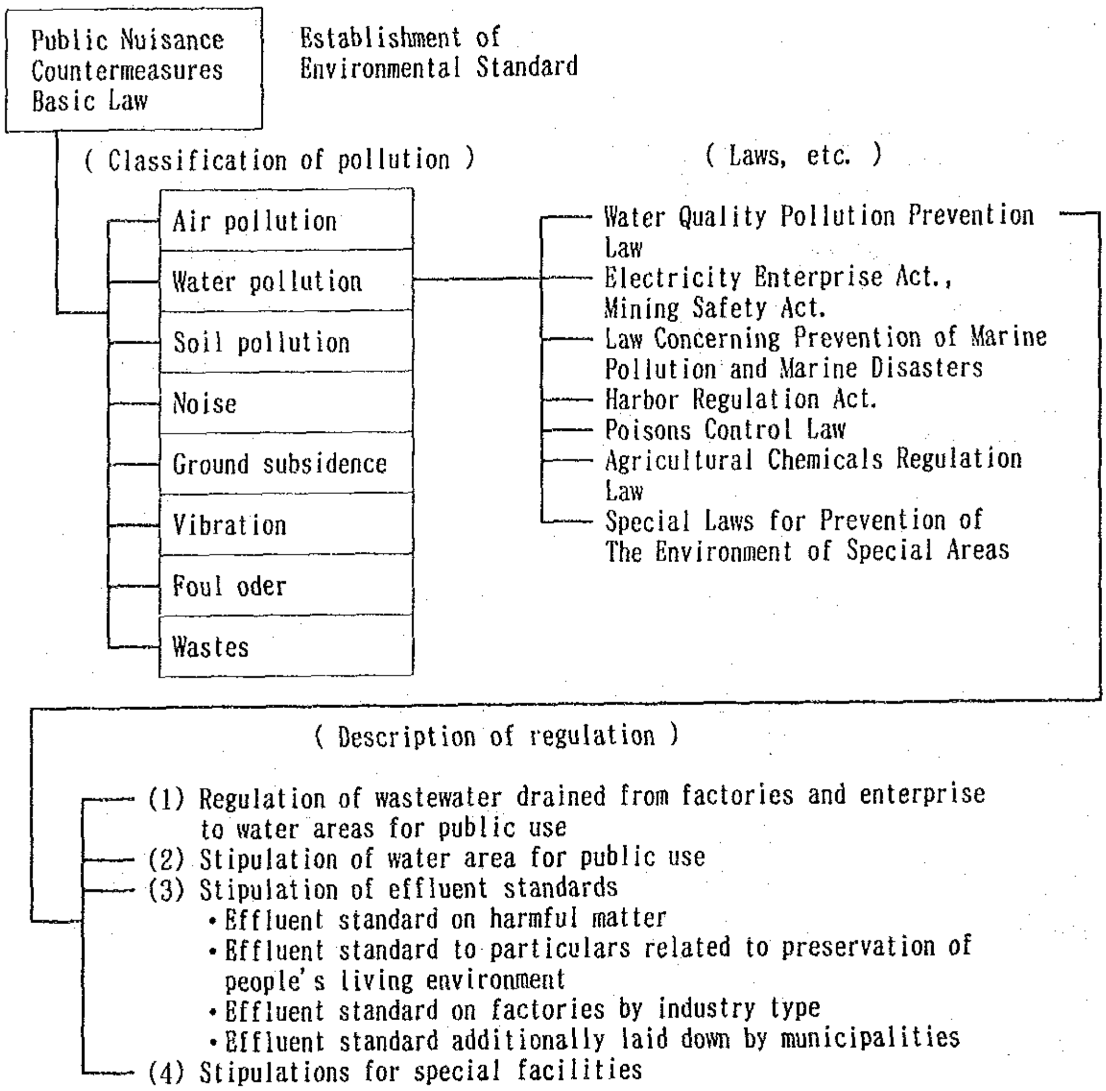


Fig. 3.3.1 Japanese Legal System for Environment[4]

3.3.2 Basic Law for Environmental Pollution Control

This law aims to protect the national health and to preserve the people's living environment. It is a laws which underlies other environmental laws of Japan. Shown below are the general matters stipulated in this law.

(1) Definition of pollution

Pollution problems Japan shall take up to solve administratively are indicated as the following seven items.

1) Air pollution
2) Water pollution
3) Soil pollution
4) Noise
5) Vibration
6) Ground subsidence
7) Foul odor

(2) Responsibility of enterprises

Enterprises are obligated to take all preventive measures so that their enterprise activities cause no pollution, and to cooperate with the Government and municipal corporations when those organizations execute any pollution prevention plans.

(3) Responsibility of the Government

The Government is obligated to draw up basic and general pollution prevention plans and to execute them. Concretely, the following shall be formulated.

1) Establishment and assurance of environmental standards
2) Execution of regulations on drainage
3) Execution of regulations on the utilization of lands and the installation of facilities
4) Promotion of improvements of facilities for pollution prevention (Improvement of sewerage, public waste treatment facilities, etc.)
5) Improvement of monitoring and measuring systems
6) Execution of investigations
7) Advancement of science and technology
8) Diffusion of knowledge
9) Consideration of pollution prevention in regional development plans
10) Protection of natural environment (Preservation of green tracts of land, etc.)

3.3.3 Environmental Standard

(1) Outline

Environmental standard is established concerning air pollution, water pollution, noise and soil pollution. Environmental standard is the target of improvement of environmental pollutions.

In other words, the standard indicates the target of improvement of the whole environmental pollution liable to occur in regional areas (water areas) due to the accumulation of pollutants drained from individual factories and fields of enterprises.

When the Government or municipal corporations establish effluent standard for individual fields of enterprises, they shall stipulate proper regulation values aiming at the accomplishment of this environmental standard. The environmental standard has no legal force, while the effluent standard is followed by legal forces, e.g., facility improvement rules and penal regulations to enterprises. Besides, the environmental standard has been reviewed and revised when necessary, based on scientific judgment.

(2) Environmental standard for water pollution

This standard is classified into two categories, i.e., the standard for the protection of human environment shown in Table 3.3.1 and the standards for the preservation of people's living environment shown in Tables 3.3.2, 3.3.3 and 3.3.4 which respectively specify their target values.

Table 3.3.1 Environmental Standard for Protection of Human Health

Harmful Matter	Standard	Harmful Matter	Standard
Cadmium	< 0.01 mg/l	Arsenic	< 0.05 mg/l
Cyanogen	N.D.	Mercury	< 0.0005 mg/l
Organic Phosphorus	N.D.	Alkylmercury	N.D.
Lead	< 0.1 mg/l	PCB	N.D.
Chromium	< 0.05 mg/l		

Table 3.3.2 Environmental Standard for Preservation of Living Environment
Rivers (Exclusive of Lakes and Marshes)

	Adaptability	Standard				
		pH	B.O.D.	S.S.	D.O.	Coliforms
AA	Waterworks(I) Natural Preservation	> 6.5 < 8.5	< 1 mg/l	< 25 mg/l	>7.5 mg/l	< 50 MPN/100ml
A	Waterworks(II) Fisheries(I), Bath	> 6.5 < 8.5	< 2 mg/l	< 25 mg/l	>7.5 mg/l	<1,000 MPN/100ml
B	Waterworks(III) Fisheries(II)	> 6.5 < 8.5	< 3 mg/l	< 25 mg/l	>5.0 mg/l	<5,000 MPN/100ml
C	Fisheries(III) Industry water(I)	> 6.5 < 8.5	< 5 mg/l	< 25 mg/l	>5.0 mg/l	———
D	Industry water(II) Agricultural water	> 6.0 < 8.5	< 8 mg/l	<100 mg/l	>2.0 mg/l	———
E	Industry water(III) Preservation	> 6.0 < 8.5	<10 mg/l	No Suspended	>2.0 mg/l	———

Ref. 1. Waterworks(I) : Light purificated water for waterworks
Waterworks(II) : Usual purificated water for waterworks
Waterworks(III) : High purificated water for waterworks
2. Industry water(I) : Usual purificated water for industry
Industry water(II) : High purificated water for industry
Industry water(III) : Special purificated water for industry
3. Fisheries(I) : Poor saprogeneous water (EX. for Trout)
Fisheries(II) : Poor saprogeneous water (EX. for Salmon)
Fisheries(III) : Middle saprogeneous water (EX. for Carp)

Table 3.3.3 Environmental Standard for Preservation of Living Environment(Lakes and Marshes)

	Adaptability	Standard				
		pH	B.O.D.	S.S.	D.O.	Coliforms
AA	Waterworks(I) Fisheries(I) Natural Preservation	> 6.5 < 8.5	< 1 mg/l	< 1 mg/l	>7.5 mg/l	< 50 MPN/100ml
A	Waterworks(II, III) Fisheries(II) Bath	> 6.5 < 8.5	< 3 mg/l	< 5 mg/l	>7.5 mg/l	<1,000 MPN/100ml
B	Fisheries(III) Industry water(I) Agricultural water	> 6.5 < 8.5	< 5 mg/l	< 15 mg/l	>5.0 mg/l	———
C	Industry water(II) Preservation	> 6.0 < 8.5	< 8 mg/l	No Suspended	>2.0 mg/l	———

Ref. 1. Waterworks(I) : Light purificated water for waterworks
Waterworks(II) : Usual purificated water for waterworks
Waterworks(III) : High purificated water for waterworks
2. Industry water(I) : Usual purificated water for industry
Industry water(II) : High purificated water for industry
3. Fisheries(I) : Poor saprogeneous water (EX. for Trout)
Fisheries(II) : Poor saprogeneous water (EX. for Salmon)
Fisheries(III) : Middle saprogeneous water (EX. for Carp)

Table 3.3.4 Environmental Standard for Preservation of Living Environment (Sea Area)

	Adaptability	Standard				
		pH	C.O.D.	D.O.	Coliforms	Extraction by n-Hexane
A	Fisheries(I) Bath	> 7.8 < 8.3	< 2 mg/l	>7.5 mg/l	<1,000 MPN/100ml	N.D.
B	Fisheries(II) Industry water	> 7.8 < 8.3	< 3 mg/l	>5.0 mg/l	———	N.D.
C	Preservation	> 7.0 < 8.3	< 8 mg/l	>2.0 mg/l	———	———

Ref. 1. Fisheries(I) : Fisheries water (EX. for Seabream)
Fisheries(II) : Fisheries water (EX. for Laver)

3.3.4 Effluent Standard

(1) Outline

The standard for the quality of waste water is uniformly established for the whole nation in accordance with the Detailed Execution Act of Water Pollution Control, which was set forth based on the Water Pollution Control Law. As for the water quality and environmental items concerning the living environment, each prefectural government set forth further stringent acts by taking into account each specific situation.

(2) Effluent standard related to water pollution

As to the waste water pollution conditions, on those harmful matters which can affect the human health, e.g., mercury and PCB, and on pollution items concerning people's living environment, e.g., BOD, COD, pH and SS, effluent standards are stipulated respectively. Table 3.3.5 shows the uniform effluent standard based on the Water Pollution Prevention Law.

In addition to these prescription of effluent standard, there are factory effluent standards by industrial type and prefectural effluent standards further provided. These standards are working effectively in some areas, where the water quality has been more improved than before. However, there are another areas that still have serious water pollution problems.

Here, we mention the conditions of water pollution particularly in closed water areas. Criteria concerning the discharge and disposal of noxious materials at sea are also established as shown in the Table 3.3.6.

As an example of the additional standards for discharges set forth by the prefectural governments, Table 3.3.7 shows the standard which applies to waste water discharged from factories operating in Tokyo. Tokyo is one of the most densely populated area in Japan, and the Tokyo Metropolitan Government set forth one of the nation's strictest additional standard.

(3) Water pollution in closed water areas

In closed water areas such as inland sea, bays, lakes and marshes, which have large pollution sources on their surrounding lands, pollutants are liable to accumulate with a high influent pollution load. Therefore, these areas can less accomplish the environmental standard than other areas.

Eutrophication is caused by nitrogen and phosphate, which are not necessarily always regulated depending on the standard of waste water. Therefore, in those specific areas, the overall COD control is implemented. There also exist plans to regulate discharge standards for nitrogen and phosphate.

Table 3.3.5 Effluent Standard in Water Pollution Prevention Law

Qulity of Wastewater	Effluent standard (A Government)
Cadmium and Cadmium Compound	0.1 mg/l
Cyanogen Compound	1.0 mg/l
Organic Phosphorus Compound	1.0 mg/l
Lead and Lead Compound	1.0 mg/l
Chromium(VI) Compound	0.5 mg/l
Arsenic and Arsenic Compound	0.5 mg/l
Mercury , Alkylmercury and Mercury Compound	0.005 mg/l
Alkylmercury Compound	N.D.
PCB	0.003 mg/l
Trichloroethylene	0.3 mg/l (From '89, Oct., 1st.)
Tetrachloroethylene	0.1 mg/l (〃)

(Life Environment)

Qulity of Wastewater	Effluent standard (A Government)
pH	5.8~ 8.6 (Sea area : 5.0 ~9.0)
BOD	160 mg/l (Daytime Ave. 120 mg/l)
COD	160 mg/l (〃)
SS	200 mg/l (〃)
Extraction by n-Hexane (mineral oils)	5 mg/l
Extraction by n-Hexane (animal-vegetable oil)	30 mg/l
Phenols	5 mg/l
Copper	3 mg/l
Zinc	5 mg/l
Dissolvable iron	10 mg/l
Dissolvable manganese	10 mg/l
Chromium	2 mg/l
Fluorine	15 mg/l
Coliforms	Ave. 3000 colonies/cm^3 • Day
Nitrogen	120 mg/l
Phosphorus	16 mg/l

Ref. 1. BOD is adapted to rivers , COD is adapted to lakes, marshes and sea area.
2. Nitrogen and phosphorus is adapted to the drain for special lakes, marshes and the public water areas.

Table 3.3.6 Standard on a Decision for Dumping Harmful Matters in the Sea (A Government No. 5)

Harmful Matters	Concentration standard by Elution Test (Sedimentive)	Concentration standard by Elution Test (Diffusible)
Alkylmercury Compound	N. D.	N. D.
Mercury , Alkylmercury	1.0 mg/l	2.0 mg/kg
Cadmium and Cadmium Compound	0.1 mg/l	5.0 mg/kg
Lead and Lead Compound	1.0 mg/l	50.0 mg/kg
Organic Phosphorus Compound	1.0 mg/l	5.0 mg/kg
Chromium(VI) Compound	0.5 mg/l	25.0 mg/kg
Arsenic and Arsenic Compound	0.5 mg/l	25.0 mg/kg
Cyanogen Compound	1.0 mg/l	5.0 mg/kg
PCB	0.03 mg/l	0.15 mg/kg
Organic Chlorine Compound	———	40.0 mg/kg
Oil	100 mg/l Not cognized oil film on the surface of the sea	100.0 mg/l Not cognized oil film on the surface of the sea

Table 3.3.7 Effluent Standard for Factories (Tokyo Met.)

Factry Type		Factries with Livestocks		Other Factries								
Water Area		All area		B		C				D		
Classification		(I, II)		(I, II)		(I)		(II)		(I)		II
Quality of Wastewater / Vol. Restraint		a	b	a	b	a	b	a	b	a	b	
BOD		30	60	20	25	20	25	60	90	20	25	160
COD		30	60	—	—	20	25	60	90	20	25	160
SS		60	120	40	50	40	50	120	160	40	50	200
Extraction by n-Hexane	Mineral Oils	5	5	5	5	5	5	5	5	5	5	5
	Animal, Vegetable Oils	30	30	5	5	10	10	10	10	30	30	30
Phenols		5	5	1	1	5(at specvial river: 1)				5	5	5
Copper		3	3	1	1	3	3	3	3	3	3	3
Zinc		5	5	5	5	5	5	5	5	5	5	5
Others		pH:5.8~8.6 , Appearance:No color and no forms An odor:< 4 deg. , Temperature:40℃ Chromium:2 , Dissolvable iron:10 , Dissolvable manganese:10 Fluorine:15 , Coliform:3000(colonies/m³)										

3.4 Waste Water Treatment of RO Desalination Systems in Japan

At the conference held between the 1st Site Survey Group and the SWCC from October to November of 1991, the Japanese side was asked by the SWCC to provide information on the discharge regulations prevalent in Japan. Therefore, we prepared a brief introduction to the waste water treatment for RO seawater desalination systems used in Japan in this chapter; and, general matters concerning the waste water treatment technology are explained in item 5.

There are not so many cases of large-scale RO desalination systems constructed in Japan. This is because Japan has less necessity of making waters for various purposes by means of saline water desalination than other countries, except for special cases, owing to a mean annual precipitation of some 1,800 mm in Japan.

However, the development of RO desalination technologies have realized the production of desalinated water at low cost using seawater, of which application is then widening its range not only from a small-scale RO desalination equipment for solitary islands and ships but also to rather large-scale equipment. In this chapter, we introduce how waste water is treated in such cases, and industrial waste intermediate treatment business, which holds an important position in the waste treatment of Japan.

3.4.1 Actual Example of Waste Water Treatment of RO Desalination System in Power Generation Plant

(1) Specification of RO desalination system

1) Product water quantity: 1,300m^3/d
2) Application of product water: Cooling water for nuclear power plant
3) RO membrane: Cellulose triacetate hollow fiber membrane(used for two stages)

(2) View of waste water treatment

As this desalination equipment is provided to feed a nuclear power plant with necessary water, there are strict requirements for the quality of such water. Besides, in Japan, all effects that nuclear power plants may have on the environment are closely examined, and it is a social demand to treat waste water completely even if no problem takes place legally. From this point of view, the waste water treatment equipment is provided to this plant.

(3) Waste water treatment method

1) Screen cleaning waste water: Released without treatment
2) Dual-media filter cleaning waste water: Released after diluted by mixing with other waste

waters

3) Rinsing waste water: Released without treatment

4) Chemical-solution cleaning waste water: After aeration and pH adjustment, diluted by mixing with other waste waters and released.

5) Concentrated brine: After aeration and pH adjustment, released by mixing with other waste waters

6) Membrane storage solution waste waters: After aeration and pH adjustment, diluted by mixing with other waste waters and released

In this equipment, sodium bisulfite is used as membrane storage solution, but it is possible to make the solution harmless by means of aeration.

The general flow of waste water treatment is shown in Fig. 3.4.1.

3.4.2 Actual Example of Waste water Treatment of RO Desalination System in Resort Facilities

(1) Specification of RO brine desalination system

1) Product water quantity: 1,000 m^3/d

2) Application of product water: Service water

3) RO membrane: Cellulose triacetate hollow fiber membrane(used for one stage)

(2) View of waste water treatment

As this desalination equipment is provided in resort facilities which are managed as a part of prefectural businesses, the waste water of dual-media filter unit is treated in the same way as water purification plants of which construction is a business under the control of prefectural or municipal corporation.

That is, the waste water is subjected to the process that solid suspensions are separated from the cleaning water, dehydrated and finally solidified. The treatment of waste water from chemical-solution is committed to a subcontractor expert in the intermediate treatment of industrial waste.

(3) Waste water treatment method

1) Dual-media Filter Cleaning Waste Water : Limpid water from which solid suspensions are removed by sedimentation is diluted by mixing with other waste waters and then released.

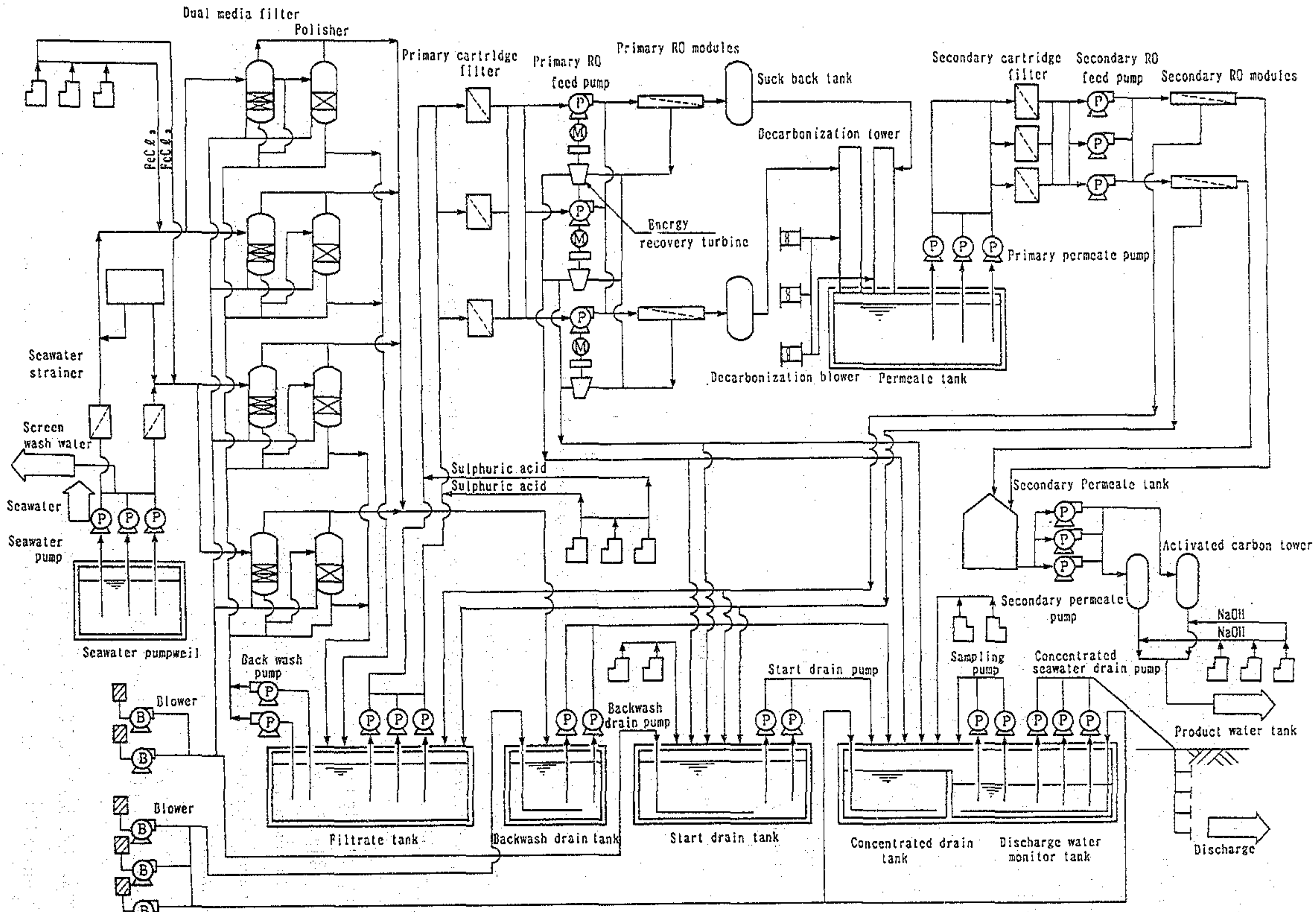


Fig.3.4.1 An Example of RO Desalination Equipment in Power Station

The removed solid sediments are concentrated through condensing filtration, further hydrated and solidified by means of a belt press, and then abandoned. And, the chemical-solution cleaning waste water is mixed with seawater, diluted, then discharged into effluent.

2) Rinsing waste water : Released without treatment
3) Waste water from chemical-solution cleaning : Mixed with condensed seawater, diluted, then discharged into effluent.
4) Concentrated brine : Released without treatment
5) Membrane storage solution waste water : Mixed with condensed seawater, diluted, then discharged into effluent.

The general flow of waste water treatment is shown in Fig. 3.4.2.

3.4.3 Industrial Waste Treatment in Japan

(1) Intermediate treatment businesses

Industrial wastes are the wastes generated through industrial or business activities, and are distinguished from ordinary wastes, such as rubbishes or garbage, generated from ordinary households. The latter is handled by local governments, while each company is obliged to dispose of industrial wastes on its own responsibility. If the relevant company is not going to dispose of its own industrial wastes on its own responsibility. If the relevant company is not going to dispose its own industrial wastes, it will have to entrust intermediate treatment agents authorized by governors with the disposal. The methods of entrusting of wastes to intermediate disposal agents are also stipulated by the relevant laws and regulations.

Wastes are inevitably generated as a result of business activities. If wastes are discharged freely without limitation, they may cause pollution. But, if every single company sets up its own waste treatment facility, it in turn would be a great waste for society. Therefore, in Japan it is aimed at preventing pollution and streamlining waste treatment system by nurturing intermediate waste treatment agents, who have suitable treatment facilities and treatment technology.

Fig. 3.4.3 shows the amount generated, the amount of intermediate treatment, and the amount of final treatment of industrial wastes (fiscal 1985).

(2) Entrusted treatment of waste water

Entrusted treatment of waste water discharged as a result of industrial of business activities, it is to be discharged into public water areas, each company concerned should purity if to reach such water quality level to satisfy the waste water standard explained in the preceding section. In those areas provided with the sewage system, each company concerned is supposed to purify waste water to the water quality level required by the Sewage Water Law.

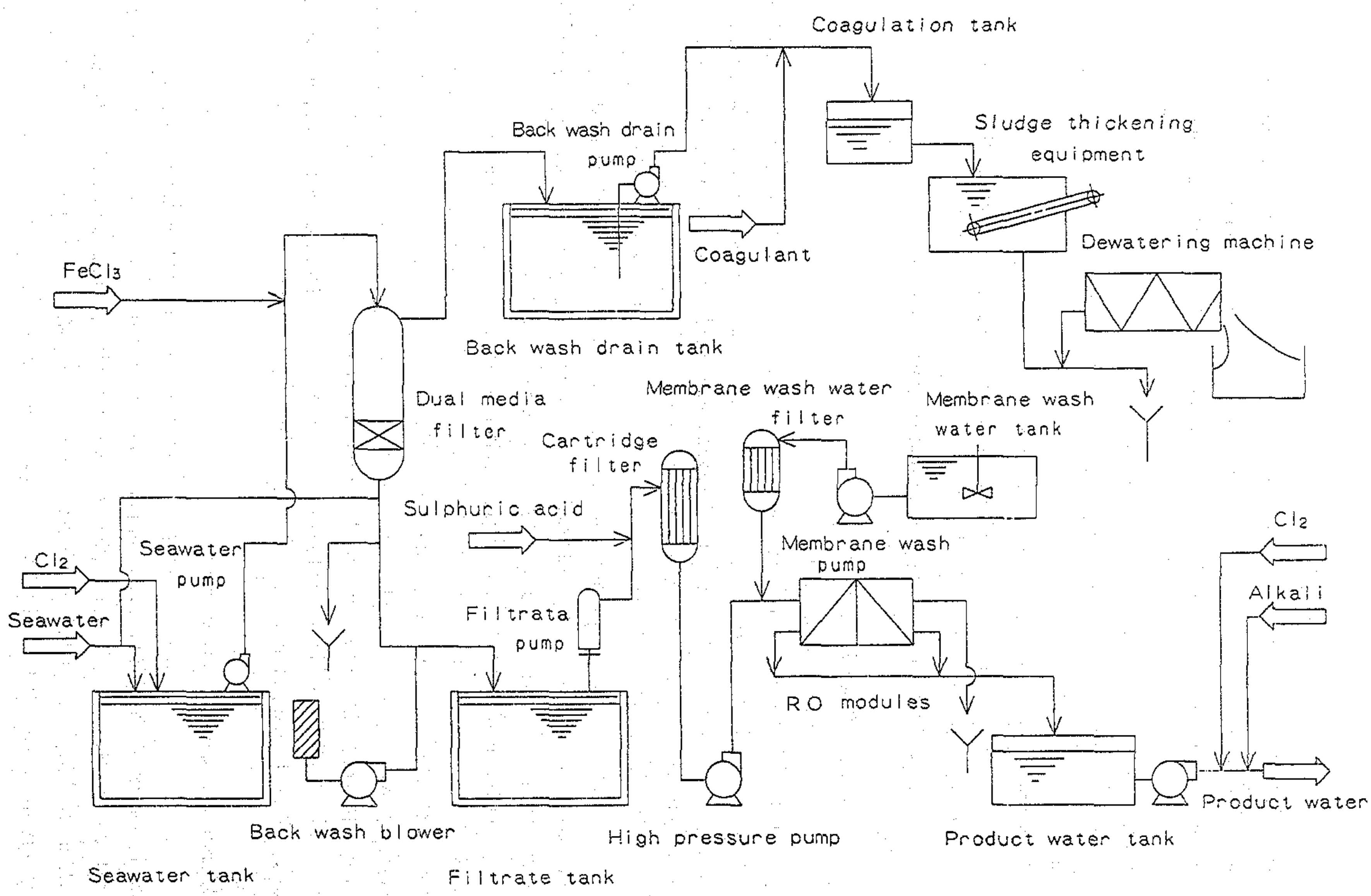


Fig. 3.4.2 An Example of RO Desalination Equipment in Resort Facilities

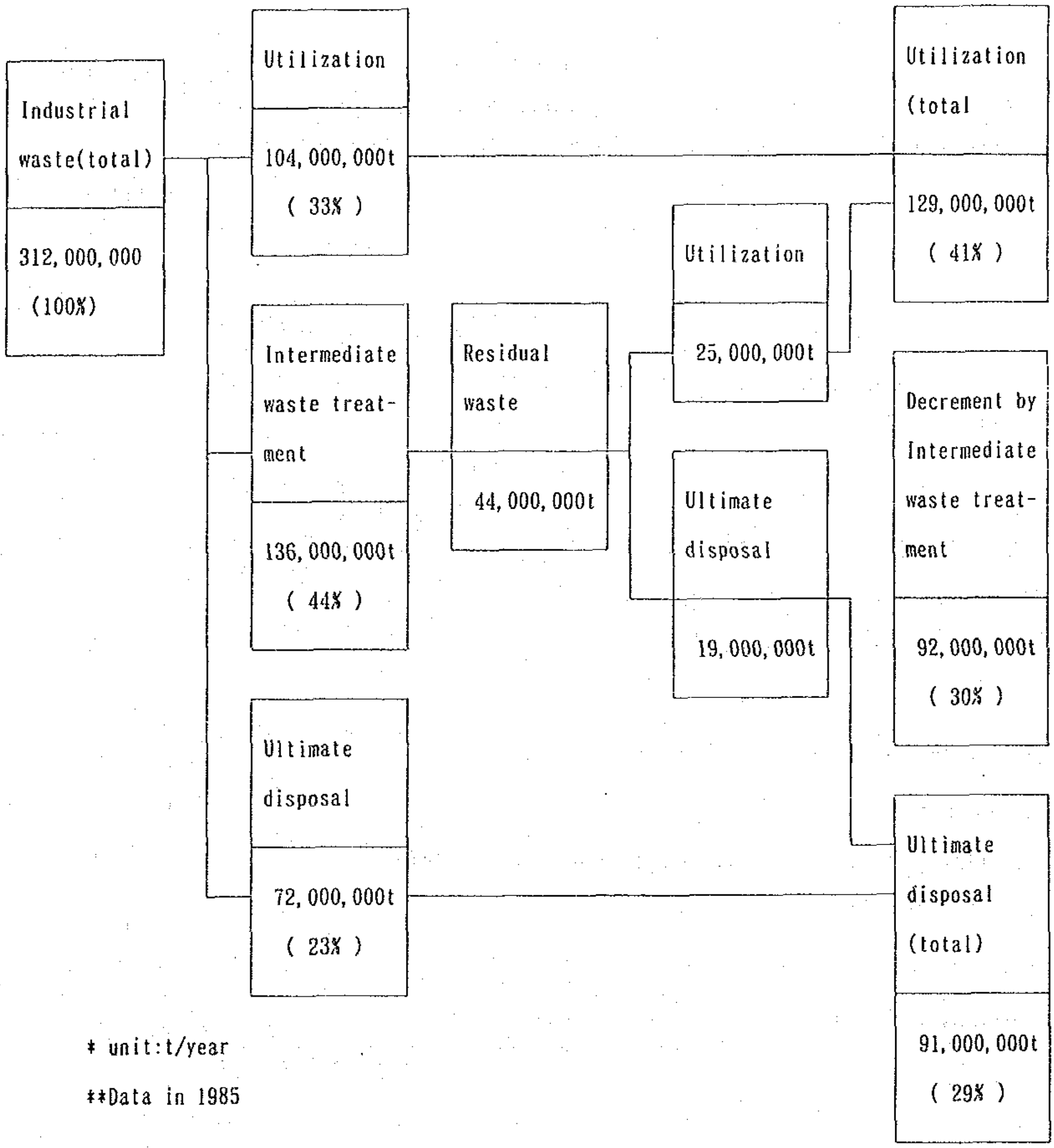


Fig. 3.4.3 The Amount of Industrial Waste in Japan[5]

But, if the relevant company has not treatment facility, or if waste water is generated only intermittently, thus the treatment facility owned by the relevant company results insufficient to treat it, the treatment should be entrusted to the intermediate treatment agents.

Table 3.4.1 shows the current situation of facilities operated by intermediate treatment agents in Tokyo (as of March 31, 1990).

Table 3.4.1 Facilities for Industrial Waste Treatment in Tokyo[6]

Type of facilities	Capacity (m^3/day)	number
Dewatering facilities of sludge	2,840	8
Drying facilities of sludge	2	2
Incinerating facilities of sludge	5	2
Separating facilities of oil/water	77	4
Incinerating facilities of waste oil	7	5
Neutrizing facilities of waste acid and waste alkali	248	24
Crushing facilities of waste plastic	288.2	8
Incinerating facilities of waste plastic	17.6	13
Decomposition facilities of cyanogen compound	1.4	3
Total	3,486.2	

* This table shows the capacity and number of facilities in March 1989.

** This table does not include facilities for crushing waste concrete and wood chip furnaces.

3.5 *Waste Water Treatment of RO Desalination System*

At the conference held between the 1st Site Survey Group and the SWCC from October to November of 1991, the Japanese side was asked by the SWCC to provide information on the discharge regulations prevalent in Japan. In this item, general matters concerning the waste water treatment technology are explained, and at the same time a discussion of waste water treatment facilities is presented by considering RO seawater desalination system having a capacity of 200,000 m^3/d.

3.5.1 *General Matters in Waste Water Treatment*

(1) Pollutants and applicable unit operation

Table 3.5.1 shows the pollutants and the unit operations of waste water treatment that are used for removing those pollutants.

(2) Process of selecting treatment system

In many waste water treatment facilities, no single unit operation would be enough for completing treatment. It is necessary to work out the most suitable treatment system by combining various unit operations by taking into account the economic advantage based on the type and concentration of pollutants, and the quality of the required treated water. Elemental block flow diagram of waste water treatment system is shown in Fig.3.5.1.

3.5.2 *Waste Water Treatment Equipment Plan for RO Desalination System*

(1) Quality and quantity of waste water

1) Specification of RO desalination plant

Estimated quality and quantity of RO desalination plant are shown in Table 3.5.2.

2) Waste water generating points, and quality and quantity of waste water

Waste water generating points, quality and quantity of waste water are shown in Table 3.5.3.

(2) Properties of homogeneous waste water

Although there exist such irregularly-discharged waste water as waste water from cleaning chemicals or from preserving solutions' processes, a trial estimation of the properties mixed waste water is made by presuming that such waste water is evenly discharged throughout the year. Estimated summary of quality and quantity of waste water are shown in Table 3.5.4.

(3) Discharge of full-flow mixed waste water

View of the Japan's waste standards, the full-flow mixed waste water falls far below the

Table 3.5.1 Unit Operation for Waste Water Treatment[7]

Pollution term	Pollutains	Example of waste water	Unit operation for treatment
Turbidity	Suspended matterrs	Coal mine drainage, Pulp and Paper mill, Pigment industries, Smelting industries	Screening, Sedimentation, Floatation, Coagulation, Filtration
Colour	Dyestuff, Humic acid lignin, Heavy metal ions Coloured solids	Pulp mill, Fermentation industries, Dyestuff industries, Dyeing, Tannery, Plating	Screening, Sedimentation, Coagulation, Filtration Adsorption, Ion excange, Oxidation/Reduction, Extraction
Odor Taste	Ammonia, H_2S, SO_2, Phenol, Melcaptane, Indol, Scatol, Fatty acid	Food industries, Pulp mill, Carbonization refineries, Fine chemical industries	Aeration, Adsorption, Oxidation/Reduction, Extraction
pH	Acid, Alkali	Mining, Smelting, Pickling liquor, Dyeing Plating, Tannery, Fine chemical industries	Neutralization, Ion exchange, Evaporation

Table 3.5.1 (continued)

Pollution term	Pollutains	Example of waste water	Unit operation for treatment
BOD	BOD components (Organics, Saccharides, Starch, Proteins, Fatts, etc.)	Fermentation industries, Pulp mill, Petrochemical industries, Food industries, Tannery, Texitile	Screening, Sedimentation, Floatation, Coagulation, Filtration, Activated sludge process, Anaerobic digestion, Aerobic digestion, Adsorption, Ion Exchage, Oxidation
COD	Chmically reducting materials (Sulfites, Sulfides, Fe^{2} , Organics, etc.)	(Waste containing COD)	Screening, Sedimentation, Floatation, Coagulation, Filtration, Activated sludge process, Anaerobic digestion, Aerobic digestion, Adsorption, Ion Exchage, Oxidation
Oil Fatty	Oil and Fat	Refineries, Petrochemical industries, Machinery, Rolling mill, Texitile	Floatation, Coagulation, Micro-filtration, Extraction, Activated sludge process, Adsorption, Oxidation
Salt (Dissolved solids)	Dissolved salts	Smelting industries, Pickling liquor, Plating, Pulp mill	Evaporation, Precipitatio, Ion exchange, Reverse osmosis, Electro dialysis, Ion floatation

Table 3.5.1 (continued)

Pollution term	Pollutains	Example of waste water	Unit operation for treatment
Toxic Materials	Heavy metal ions, Cyan, Phenol, Organomercurial-compounds	Mining, Fine chemical industries, Pesticides industries, Plating	Sedimentation, Coagulation, Adsorption, Ion Exchage, Oxidation/Reduction, Extraction
Radio-active Materials	(Radio-active wastes)	Radio-active materials	Above methods may be applied

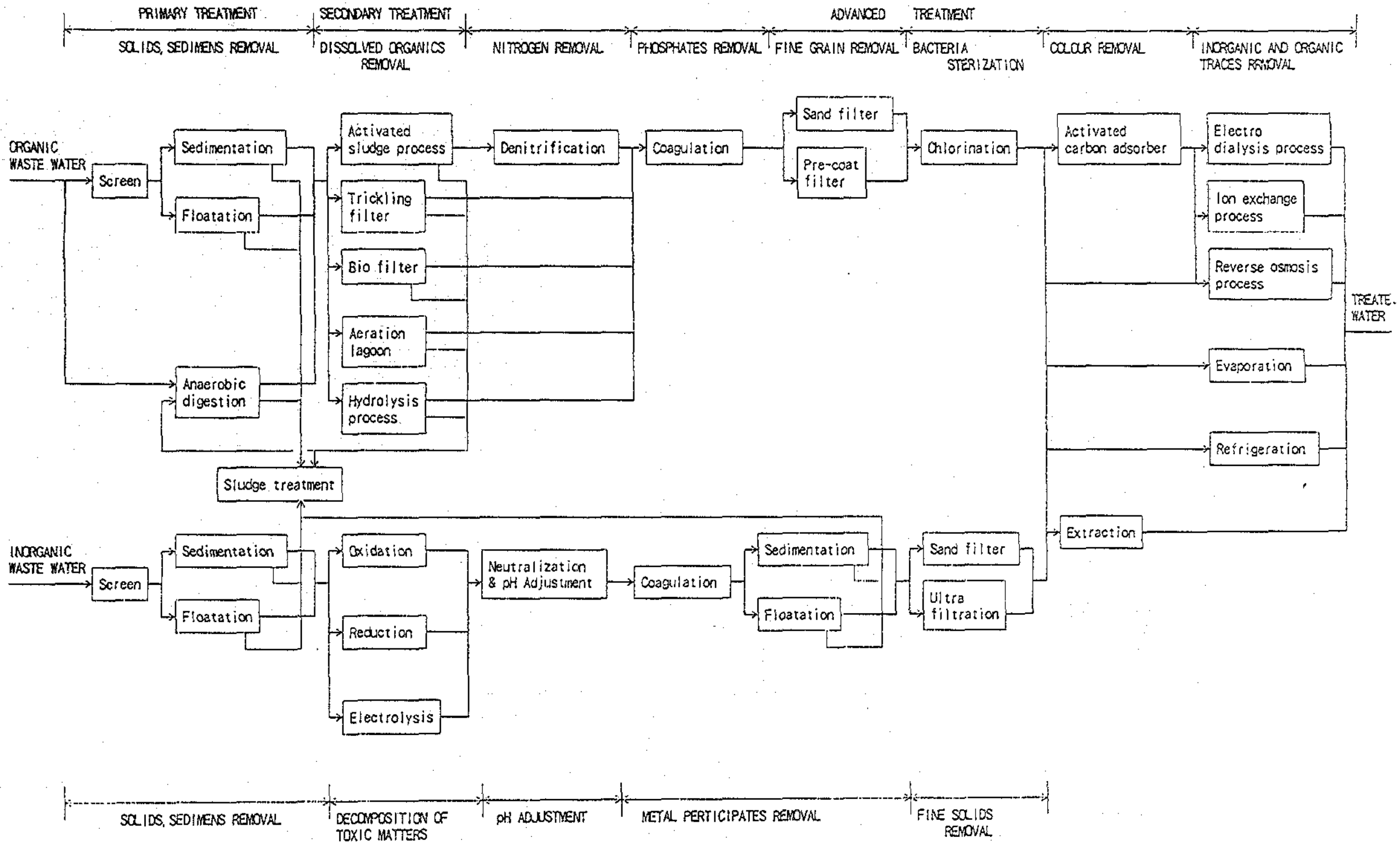


Fig.3.5.1 Elemental Brock Flow Diagram of Foul Water Treatment System[8]

Table 3.5.2 Specifications of RO Desalination Plant

Characteristic of seawater	TDS : 43,300ppm , COD : 1mg/l Temperature : 24～35℃ , SS : 3mg/l
Characteristic of product water	TDS : below 1,000ppm Cl^- ION : below 250ppm Others : WHO (January 1984) standard
Capacity	200,000m³/day
Collecting rate	35%
RO membrane equipment	number of train : 40 (5,000m³/day × 40train)