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Experimental test of TOYOBO membranes for seawater desalination at Las Palmas, Spain

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Abstract

CEDEX (Centro de Estudios y Experimentacion de Obras Publicas) and EMALSA (Empresa Mixta de Aguas de Las Palmas, S.A.) had been performing experimental tests for seawater desalination at Las Palmas, Gran Canaria Is., Spain, using a TOYOBO hollow-fiber membrane. A Hollosep HM10255FI module made by TOYOBO is used in the largest desalination plants around the world, especially in the Middle East. CEDEX and EMALSA confirm that the Hollosep module can produce stable water production and high-quality water for long-term operation without any chemical cleanings during 4600 h operation thanks to the its high chlorine resistance and anti-biofouling tolerance.

Keywords: RO; Seawater desalination; Hollow-fiber membrane; Biofouling; Scaling; Hollosep

1. Introduction

TOYOBO Hollosep is known for its high performance, its permeate water quality and reliability for long-term operation based on many practical applications. The 10" diameter double element type module Hollosep HM10255FI has especially been applied to the largest seawater RO plants in the world, including Jeddah-1 phase-1 (56,800 m^3/d) in 1989 and Jeddah-1 phase-2 (56,800 m^3/d) in 1994 in Jeddah, Kingdom of Saudi Arabia, and Medina-Yanbu plant (128,000 m^3/d), which is the largest RO plant in the world and has been in commercial operation since 1998.

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This study's focus is to confirm the performance of the Hollosep membrane when it is operated under continuous operation, high recovery ratio and feeding open sea intake water at Las Palmas, Gran Canaria Is., Spain.

2. Characteristic of hollow-fiber membrane

There are two types of RO membranes used in seawater desalination: hollow-fiber and spiral wound. The Hollosep made by TOYOBO is the type of hollow-fiber membrane module made from CTA (cellulose triacetate) material. The Hollosep has typical characters such as (1) more chlorine resistance than other conventional membranes (see Fig. 1), and thus it can restrain bio-fouling in the module efficiently; and (2) superiority against organic matter contamination thanks to its material. In addition, Hollosep has high anti-fouling tolerance thanks to its original structure that the hollow-fiber bundle is wound helically around the center tube. This structure causes fouling matter of the feeding water passing through the clearance in between the hollow fiber so that fouling matter is not trapped on the surface of hollow fiber and goes out easily from the inside of the module.

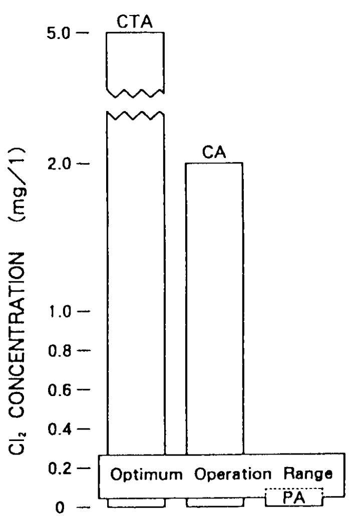

Fig. 1. Chlorine tolerance property of various membranes. CTA, cellulose triacetate; CA, cellulose acetate; PA, polyamide.

Table 1
Specifications of the Hollosep MH10255FI membrane

Hollow-fiber material	CTA
Size:	
No. of elements	2
Diameter, mm	390
Length, mm	2915
Weight, kg	450
Product flow rate, m^3/d:	
Nominal	45
Minimum	40
Salt rejection, %:	
Nominal	99.4
Minimum	99.2
Evaluation condition:	
Feed water, NaCl solution, mg/l	35,000
Pressure, kg/cm^2 G	55
Temperature, EC	25
Recovery ratio, %	30
Operation condition:	
Max. pressure, kg/cm^2 G	70
Temperature, EC	5–40
Min. brine flow rate, m^3/d	50–150
Feed water quality:	
Max. fouling index (SDI15)	4
pH	3–8
Residual chlorine, mg/l	0–1.0

The general specification of the Hollosep HM10255FI is shown in Table 1 and its structure is shown in Fig. 2.

3. Experimental test at Las Palmas — flow diagram of the test

Filtered seawater from Las Palmas-3 (39,000 m^3/d) is supplied to the test plant. Raw

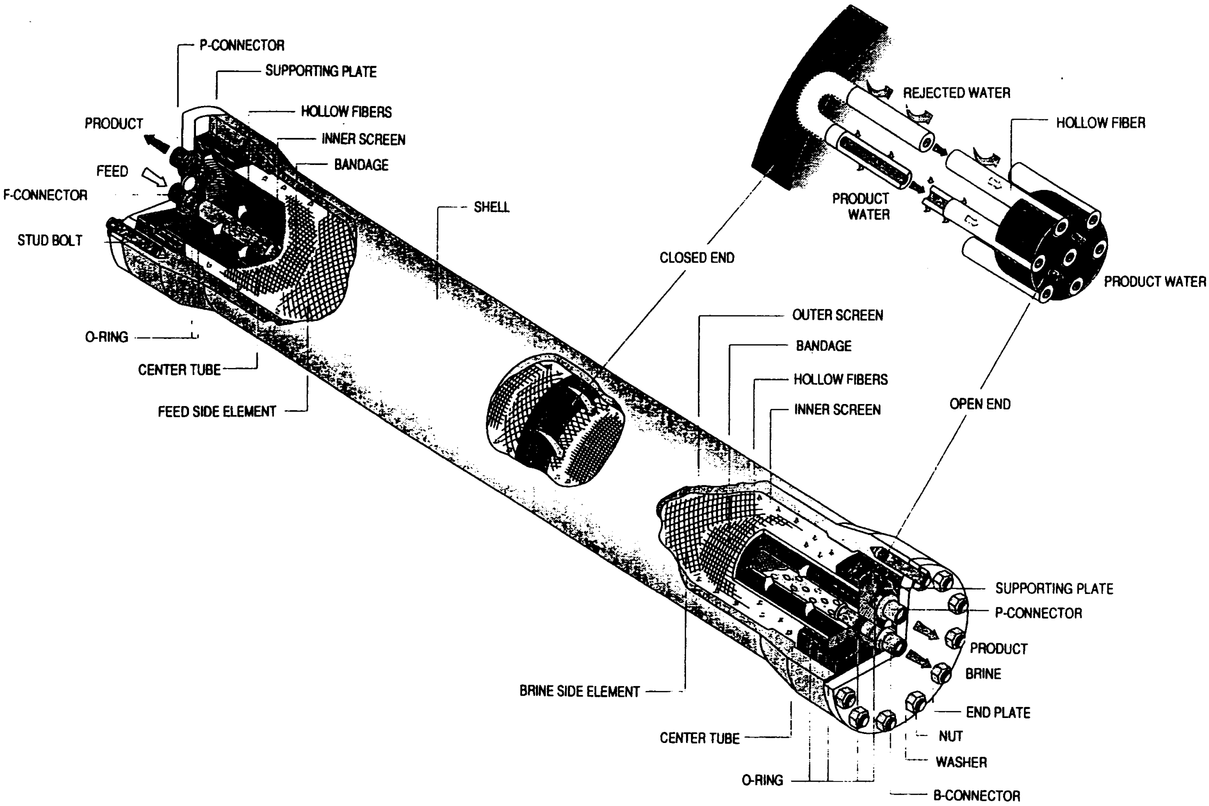

Fig. 2. Structure of the Hollosep MH10255FI.

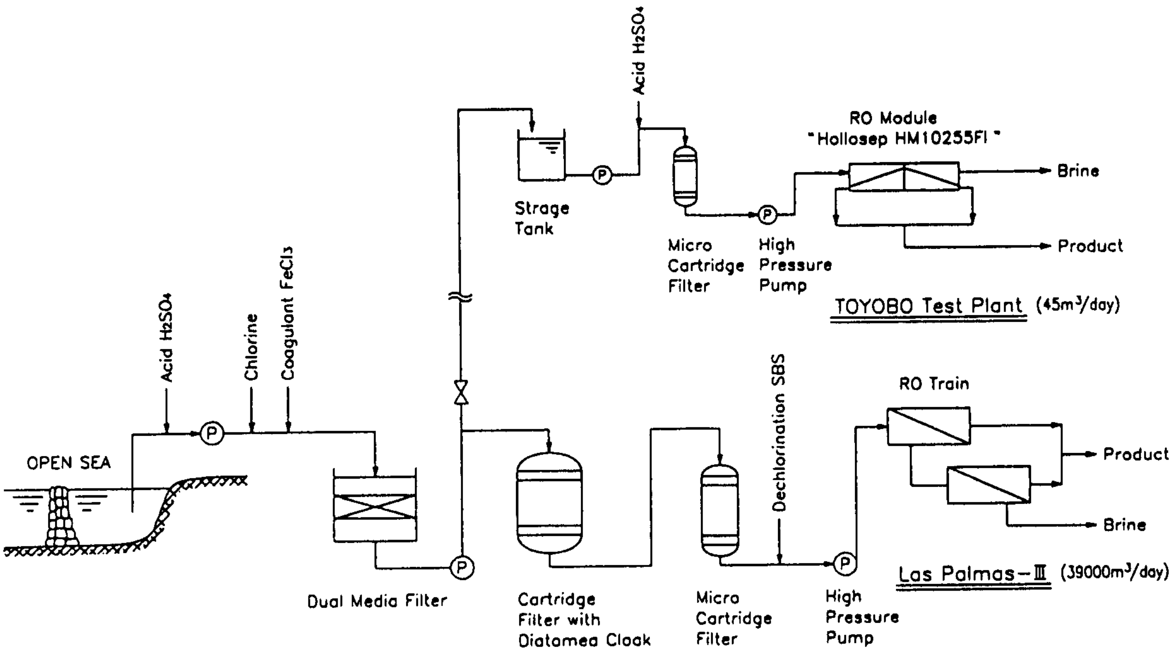

Fig. 3. Flow sheet of the TOYOBO test plant.

seawater is taken from the surface of the seawater (open intake) in Las Palmas Bay and it is forwarded to the dual-media filter. After this pretreatment, the seawater is sent to the test plant. There, after pH adjustment has been made, filtered water is passed through a 10 micron cartridge filter before being supplied to the RO module. The RO module was operated during the test under 65 kg/cm2G and 45% to 50% of recovery ratio. Other polisher treatments, before supplying to the RO train in Las Palmas-3, were made.

The pretreatment process at the TOYOBO test plant is much simpler than the rest of it at Las Palmas-3. The flow diagram of the test plant is shown in Fig. 3.

4. Operation condition

4.1. Operation period

The test operation period is shown in Table 2. The test is divided twice; the first phase was operated from June 2, 1998, to October 5, 1998 (accumulated time is 2900 h), and the second phase operated from October 5, 1998, to April 16, 1999 (accumulated time is 4600 h). The first phase of the test was operated under the intermittent chlorine injection (ICI) method, and the

Table 2
Time period

	Phase 1	Phase 2
Starting date of trial operation	5.6.98	5.10.98
Ending date	5.10.98	16.4.99
Total time of test period, h	2928	4632
Shut-down time except membrane maintenance, h	75.7	406.5
Maintenance time of membrane, h	0	0
Total operation time, h	2878	4225.5
Ratio of operation time regarding membrane, %	100	100

second phase of the test under continuous chlorine injection (CCI) method. It has never stopped during the test caused by the membrane maintenance or trouble. This result demonstrates that Hollosep can operate continuously for a long time without any chemical treatment thanks to its ICI and CCI operation. This paper describes the second phase of the test which was operated using the CCI method, a heavy condition for the membrane.

4.2. Feed water condition

TDS concentration and temperature of the feed water is shown in Figs. 4 and 5. TDS of the feed water has a stable value of approximately 33,000 mg/l during the test. Seawater temperature is low, around 16 to 23EC, because of the cold current of the oceans. pH and chlorine concentration of the feed water is shown in Figs. 6 and 7. It suggests an operating seawater pH around 6.5 pH to prevent oxidation damage to the membrane caused by heavy metals in the seawater and chlorine, and it has operated almost at the same value of pH during the test. A chlorine concentration is suggested less than 0.5 mg/l for continuous long-term operation. Chlorine concentration of the test is valued at approximately 1.0 mg/l, a higher than suggested value, 0.5 mg/l, because the test water was pretreatment water supplied from Las Palmas-3. The test conditions are shown in Table 3.

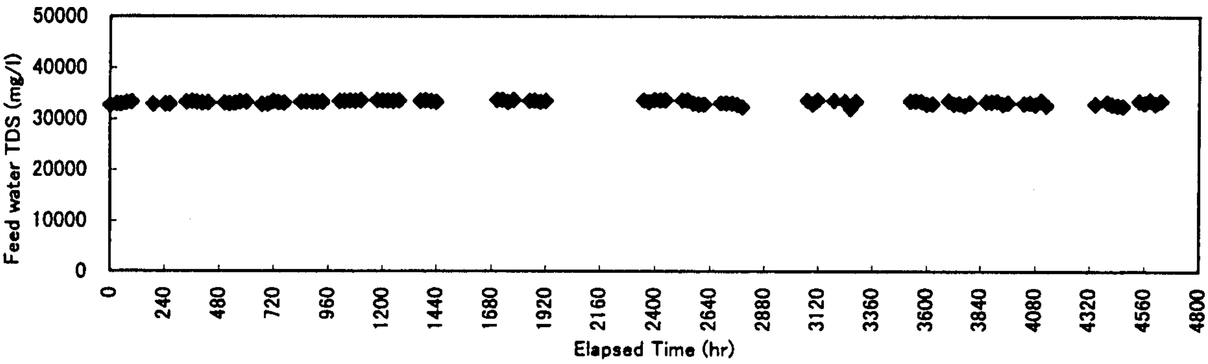

Fig. 4. Feed water TDS.

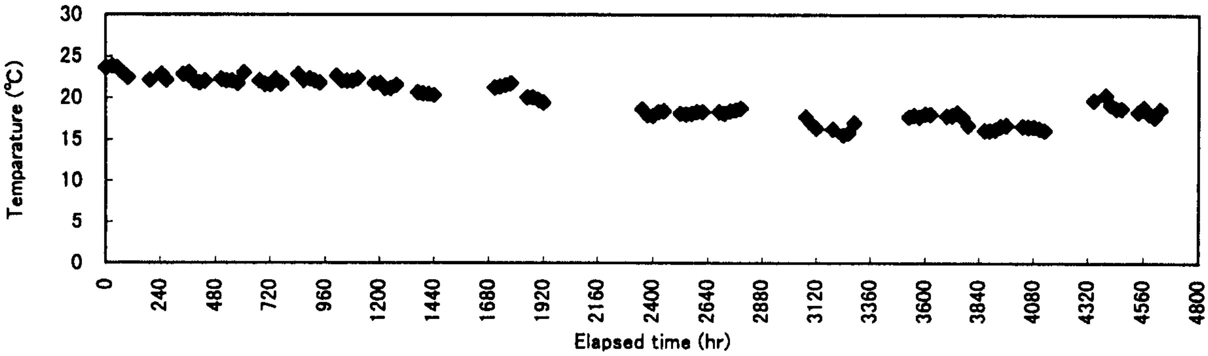

Fig. 5. Temperature.

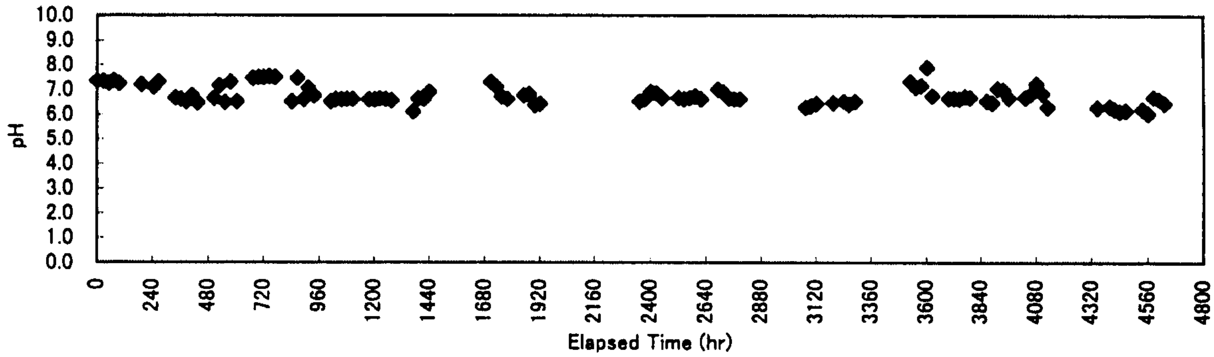

Fig. 6. pH value of feed water.

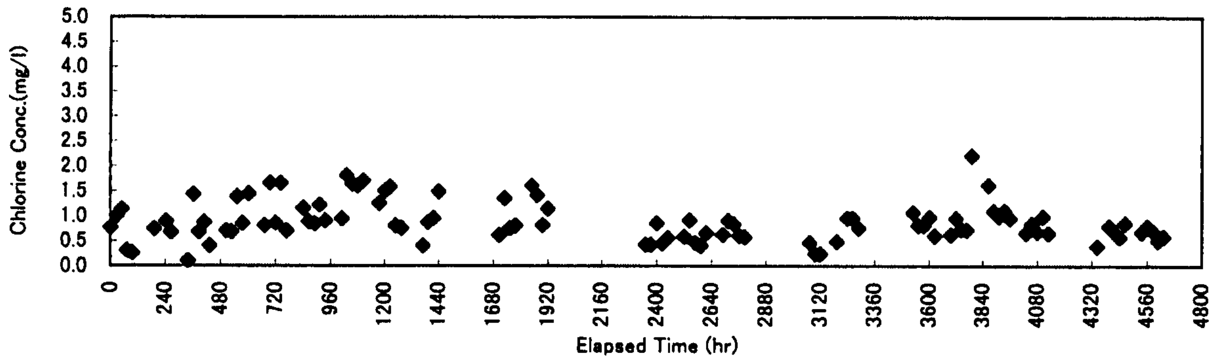

Fig. 7. Chlorine concentration.

Table 3
Test conditions during phase-2

Conditions	Phase-2
Feed water:	
TDS, mg/l	~33,000
Temperature, EC	16–23
pH	6.75 avg.
Chlorine conc., mg/l	0.9 avg.
Operation condition:	
Pressure, kg/cm^2 G	65
Recovery ratio, %	45–50
Chlorine injection	Continuous

5. Feed pressure and recovery ratio

The actual value of feeding pressure and the recovery ratio is shown in Figs. 8 and 9. The membrane was operated under 65 kg/cm^2 G of operating pressure, 45% to 50% of recovery ratio from October 5, 1998, to April 16, 1999, accumulated time 4600 h. This operation condition is the same as in Spanish commercial seawater desalination plants or a little higher recovery ratio than that. The fluctuation of the pressure and recovery ratio caused by the RO membrane was not found during the test. This result proves that Hollosep can be operated very stably. Also differential pressure is stable during

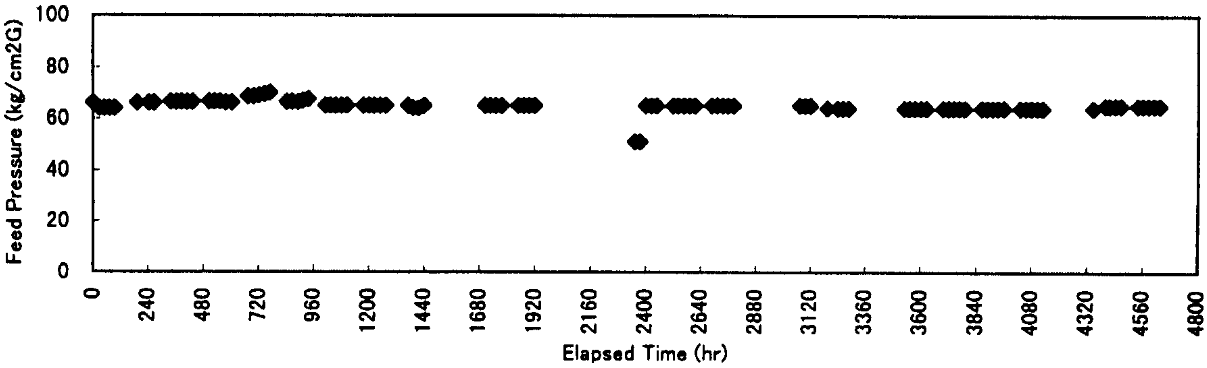

Fig. 8. Feed pressure.

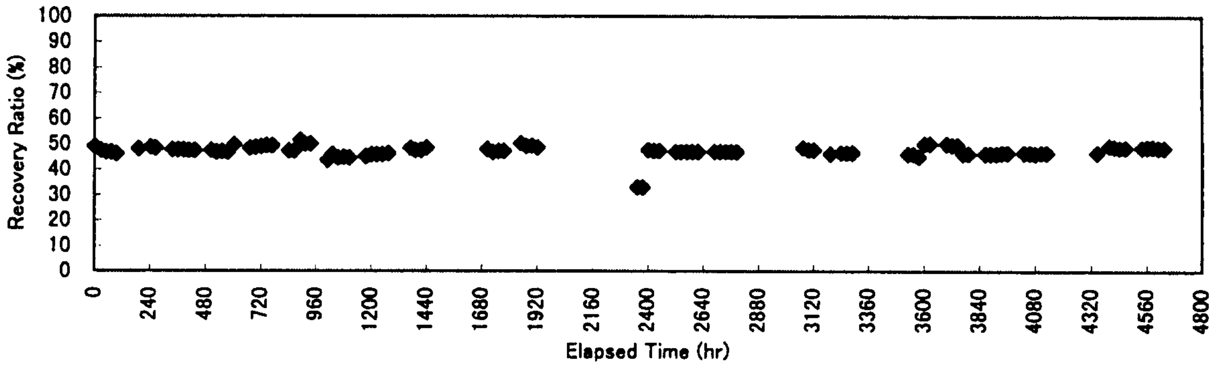

Fig. 9. Recovery ratio.

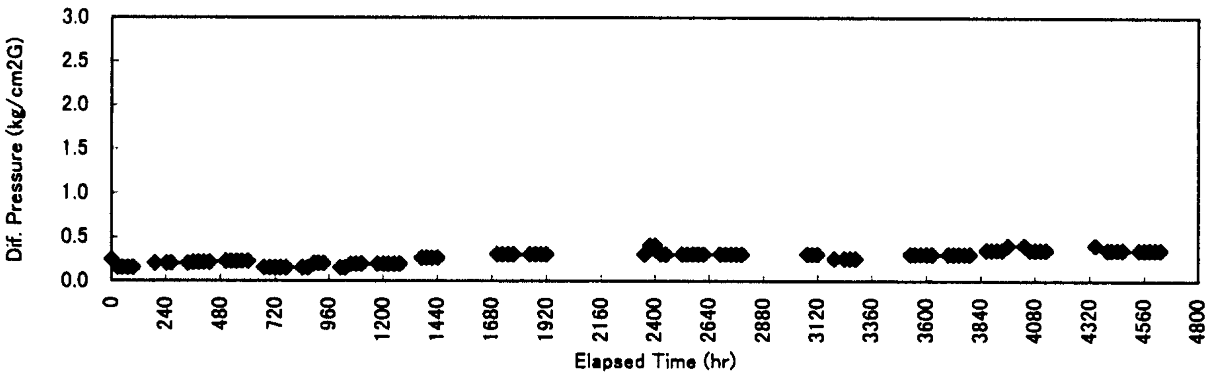

Fig. 10. Differential pressure.

the test as shown in Fig. 10. It also means that no bio-fouling and no scaling occurred in the membrane.

6. Permeate water condition

Actual production volume ratio and quality of the permeate water are shown in Figs. 11 and 12. Though the Hollosep did not have any chemical treatments, it kept stable production and quality of permeate water during the test. This result proves that Hollosep can operate stably and maintenance high performance when it is used for open intake seawater in Spain under the CCI method. From an objective point of view, the actual data of the permeate water were calculated as the standardized A-Value and B-Value (Figs. 13 and 14). This result is very stable and marked on standard Hollosep specifications. It also means there is no problem occurred in the module during the test.

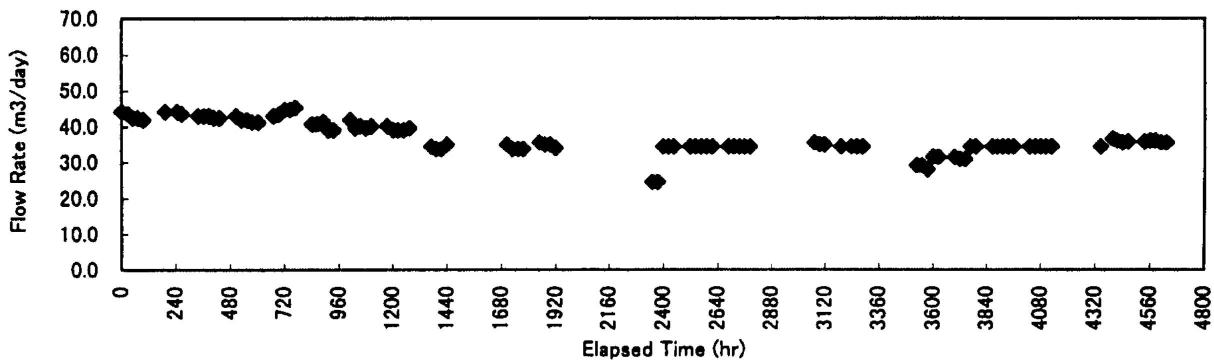

Fig. 11. Permeate flow rate.

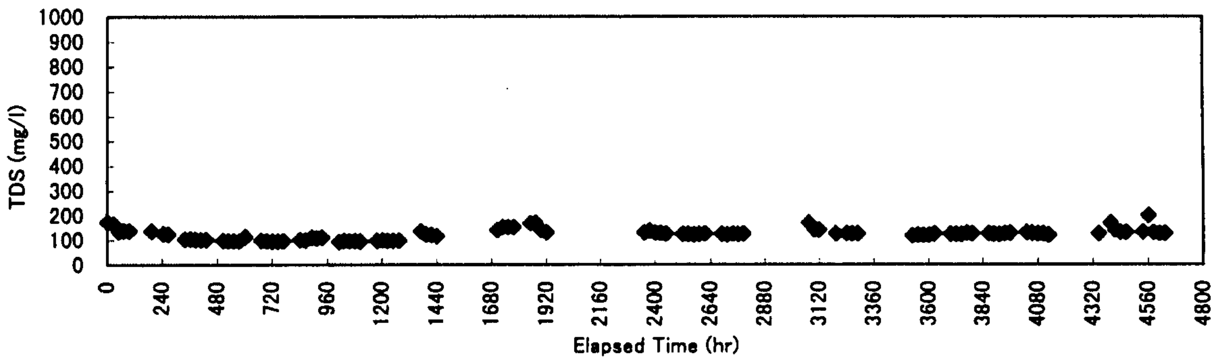

Fig. 12. Permeate TDS.

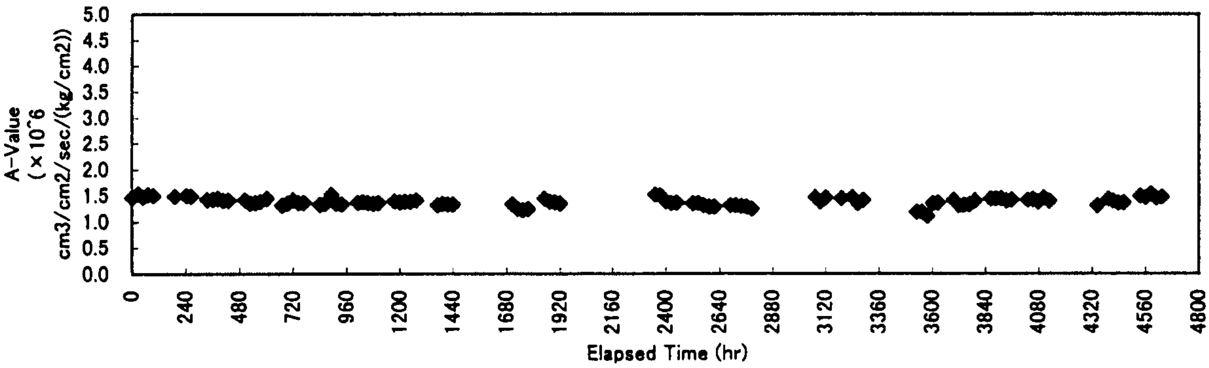

Fig. 13. A-value.

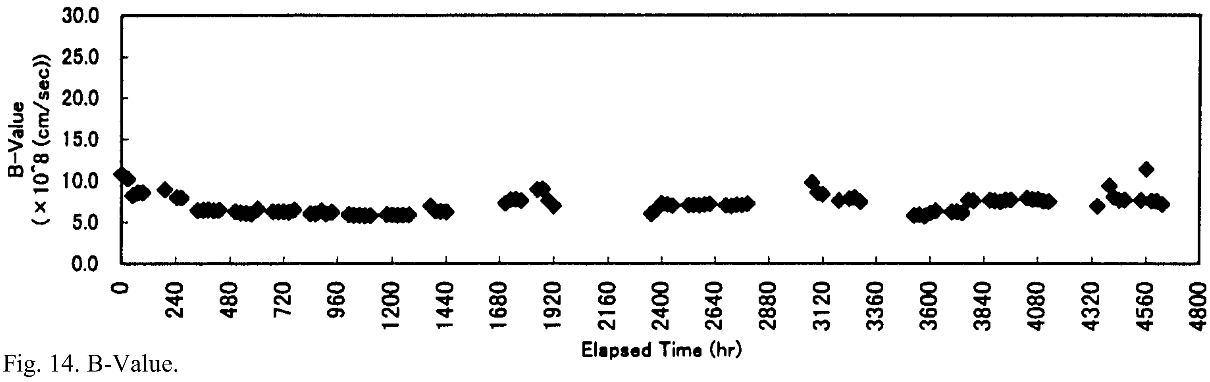

Fig. 14. B-Value.

7. Future point of view

The Hollosep demonstrated its ability to maintain high performance not only for Middle East seawater but also for Spanish seawater. It will be available to reduce chemical ingredients in the RO desalination process and improve operation running time of plants. In addition, though this paper describes the result under the CCI operation method , the Jeddah plant required no membrane replacement for 5 years under the ICI method operation. When Hollosep is operated under the ICI method, it may reduce membrane replacement cost drastically. Special features of Hollosep such as high-chlorine resistance and anti-biofouling tolerance due to its membrane material made of CTA has advantages not only for seawater desalination but also for brackish water desalination and wastewater treatment use.

8. Conclusions

1. Hollosep is a high chlorine resistance membrane which can present high quality and stable volume ratio of permeate water for a long time operation for RO desalination plants having open sea intake water.

2. Hollosep can perform long-term operation without chemical treatments due to CTA membrane material which has high chlorine tolerance. The Hollosep brings seawater desalination plant operation easily using CCI or ICI.

Acknowledgments

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