Membrane Technology for Water Treatment in Korea

Je-kang Yoo, Kyu-hyun Lee
R & D Center, Sunkyong Engineering & Construction Ltd. KPO Box 222, Seoul, Korea

1. INTRODUCTION

In recent years it has become necessary to design water management system to minimize water consumption as well as satisfy more stringent environmental requirements. This is mainly due to the seasonal water shortage and environmental problems on water pollution that have taken place at many industrialized regions in Korea. Accordingly, membrane technology in Korea is finding increasing application in the water industry because it has been found to be effective and economic treatment method compared with conventional technology. The membrane processes with the greatest potential for water and wastewater treatment are microfiltration(MF), ultrafiltration(UF), nanofiltration(NF) and reverse osmosis (RO), which utilize pressure differentials..

In Korea, RO process has been used mainly to produce ultrapure water for electronic industry and process water of newly developed industrial area where industrial water supply of low TDS is impossible. So several large RO plants for the production of industrial water were installed at newly developed industrial area near the middle west districts. RO process was also used as a pretreatment to ion exchange system or as a stand-alone systems to produce pure water for boiler feed water supply. Ion exchange systems have been generally used for pure water production because total dissolved solid(TDS) of raw water was maintained relatively low value at below 150 ppm. But the quality of surface water has in many cases worsened through an increase of the inflow of domestic and industrial waste water and variation in water quality between the rainy season and dry season appears very large. For example, raw water conductivity supplied from the Nak-dong river was in the range of 500 - 630 μS/cm from January to March, 300 - 500 μS/cm from April to June and 200 - 300 μS/cm in August of this year. A number of papers have dealt with the economics of reverse osmosis and ion exchange and total dissolved solids brake-even point above which it is more economical to use one of these technologies rather than the other. Even though its results were some difference, it appeared that reverse osmosis was more economical for the pure water production than ion exchange if raw water TDS is above 100 - 150 ppm. Therefore application of the RO systems will be considerably increased because most of the industrial water fall within this TDS range.

UF membranes used firstly as a final filtration step for ultrapure water production of electronic industry. And it was also used for electropainting of the automobile industries and for concentrating and separating protein solutions of the food industries. Initially, most of UF systems introduced from foreign company with skid mounted type, but several kinds of polysulfone hollow fiber membranes for ultrafiltration were developed and prepared by several companies of Korea and have been used for water treatment and in industry to separate colloids and organic macromolecules from solutions.

The membrane processes have been also used for wastewater reuse system. However, the water reuse system was only installed at several sites because of its high water production cost compared to water cost supplied from other source such as river, lake and dam etc.. Recently seasonal water shortage and environmental problems on water pollution have made that study for wastewater reuse is started at a various industry that use a lot of process water, because it might be a unique solution to mitigate the water pollution and shortage at present and in the future. For applications of membrane processes to the wastewater reuse system, however, waste water quality and system design parameters should be clarified before actual system design. So pilot tests were required to define process parameters and manage risk

In this study membrane pilot test results for wastewater reuse, which were made to look into the feasibility and reliability for the reclamation of oil refinery wastewater effluent and treatment of landfill leachate, are described

2. OIL REFINERY WASTEWATER REUSE

Oil refinery plants use large quantities of water as feed to water demineralising plants, which produce pure water for boiler make up. Other uses include make up to cooling tower systems, fire fighting systems and is used for production processes and wash down purposes. The characteristics of waste water which comes from each processes are very different, because crude oil quality, complexity of production processes, utility infrastructure and location have a major impact on the individual effluent characteristics.

In response to the increasing need to reuse waste water effluent and minimize the discharge, A-oil refinery company decided to explore and test a proper wastewater reuse technology to recover their waste water effluents and to make available high quality water to be reused as refinery process water or as cooling water. For this purpose it was selected to use reverse osmosis(RO) membrane system because oil refinery wastewater contained a high ionic component above 2500 ppm. The experimentation at pilot scale level conducted to define the characteristic of oil refinery waste water and to find the critical parameter that may affect the performance and reliability of reverse osmosis membrane.

RO Membrane Pilot Plants Description

Fig. 1 shows the schematic diagram of RO membrane pilot plant.

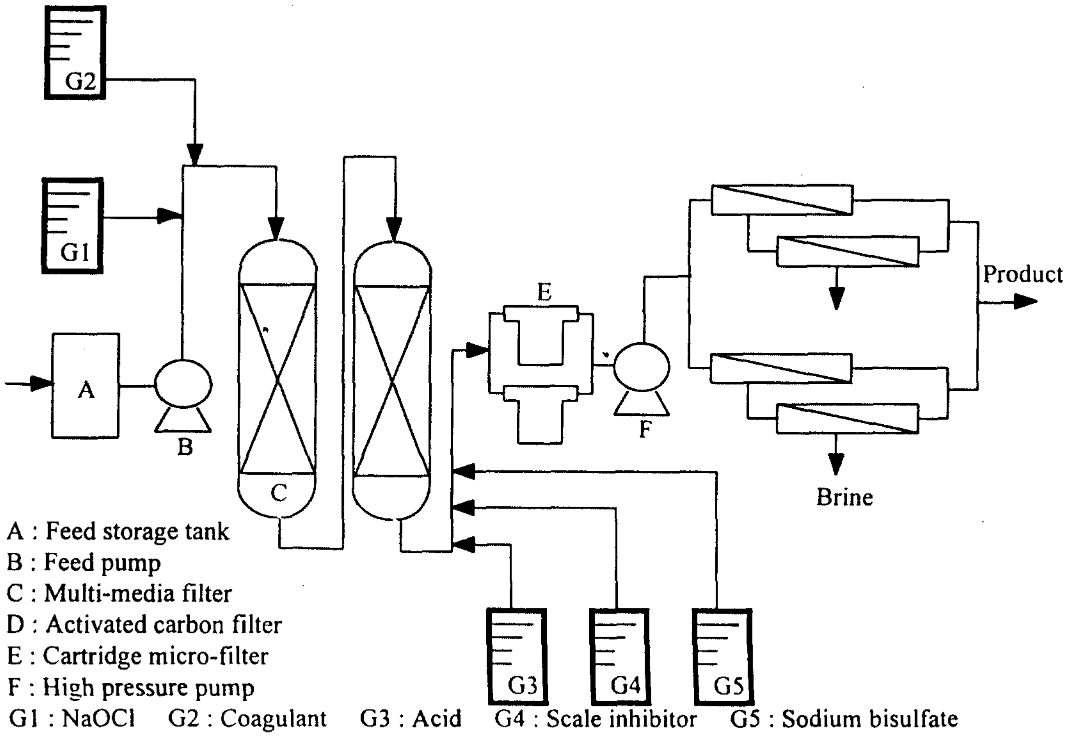

Fig. 1. Schamatic Diagram of RO Membrane Pilot Plant

Waste water effluent is transferred from the discharge pond to feed storage tank(A). Wastewater effluent is disinfected using sodiumhypochlorite and coagulant is added to coagulate suspended solids. Chemically treated feed water is then led to multimedia filter and activated carbon filter to remove a coagulated suspended matter and organic matters. Down stream of the activated carbon filter, sulfuric acid and antiscalant are added. Additionally sodiumbisulfite is added to eliminate residual chlorine. Micro filter(5 micron size), as a final pretreatment step is conducted for further removal of minute particulate matters to protect the membrane elements and high pressure pump impeller.

The pretreated RO feed water is delivered to the RO high pressure pump which boost the feed water to the RO unit. RO unit consists of two parallel units, each unit contains two 2.5-inch diameter poly amide reverse osmosis elements. The membrane elements are Film-Tec model BW30- 2540, rated at 98% nominal salt rejection, 600 GPD product flow rate.

Pilot Test Results

Table 1. shows the average removal efficiencies obtained at the each equipment during the test operation period(about three months). The COD removal efficiency was about 40% in pretreatment system and additional 57.4% was removed at RO membrane module. resulting total removal efficiency 70%. Generally COD is mostly removed by activated carbon filter. But the COD removal efficiency in the AC filter was very low. This low removal efficiency was estimated to be due to the exhausted adsorption capacity of the activated carbon in several days operation.

The oil and SS have to be removed mostly at pretreatment system to prevent a fouling in membrane module. However pretreatment used in this study could not remove these up to RO feed water guideline(no oil and below 5 SDI) because characteristics of effluent were very much variable : suspended solids fluctuate between 7 and 47. mg/l, and oil was in the range of 1.5 - 10 mg/l. It was so recognized that pretreatment system on this effluent have to be improved to control fluctuation of oil and suspended solids.

Table 1. Removal Efficiencies by Pretreatment, R/O Membrane and Total Reuse System.

(Unit : %)

Content	Pretreatment			R/O
	M/F	A/C	C/F	Membrane
COD	29.6	6.5	6.5	57.4 (70.1)
Oil	65.7	9.8	4.9	19.6 (86.4)
SS	86.6	9.1	1.8	2.5 (96.3)
Ions	-	8.0	-	92.0 (97.4)

R/O : reverse osmosis membrane M/F : multimedia filter
A/C : activated carbon filter C/F : cartridge filter
COD : chemical oxygen demand SS : suspended solid
( ) * : removal efficiency by total reuse system

Fig. 2 shows the permeate flux and salt rejection of RO membrane at the operating condition of water temperature 40 °C and membrane inlet pressure 10 - 13 Kg/cm^2 during a continuous operation. The permeate flux was maintained at almost steady state showing 20.7 $L/M^2/hr$ in average except for initial flux 29 $L/M^2/hr$ which is obtained at inlet pressure of 15 Kg/cm^2. Membrane inlet pressure was increased gradually from 10 to 13 Kg/cm^2 because of flux decline due to fouling in membrane module. This means about 20 % flux decline at normalized condition.

During initial test operation salt rejection was in the range of 92 - 96%, while it was increased up to 98% with operation time. Therefore product water quality has remained very stable since initial operation and met the guideline on the water quality to reuse as process water and cooling tower make-up. The quality comparison of RO product water with cooling tower feed water which is used at present is shown in Table 2. RO product water shows a feasible quality for the use of cooling tower feed water despite of the unsteady quality of the wastewater effluent.

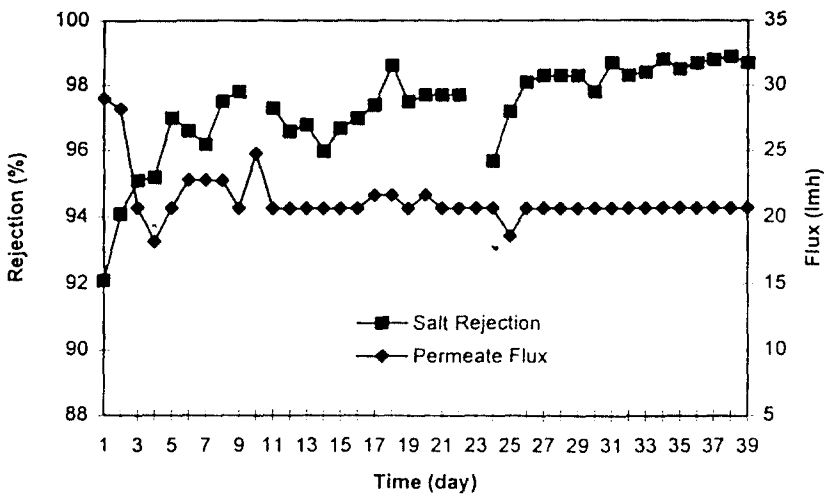

Fig 2. Permeate Flux and Salt Rejection of RO Membrane during a Continuous Operation.

Table 2. Quality Comparison of R/O Product Water with Cooling Tower Feed Water.

	C/T feed	R/O Product
pH	7.0 ~ 7.5	6.4 ~ 7.6
Conductivity(mmho)	<500	20 ~ 205
Calcium hardness (ppm)	<150	0 ~ 0.4
Cl^- (ppm)	<100	6.8 ~ 76.4
Oil (ppm)	0	0.7
COD_{Mn} (ppm)	<1	15
BOD (ppm)	<1	8
Iron (t-Fe) (ppm)	<1	trace

C/T : cooling tower
R/O : reverse osmosis membrane

3. TREATMENT OF LANDFILL LEACHATE

The landfill leachates are very complex waste streams which contain both toxic organic and inorganic compounds. At some landfill sites leachate which is collected is discharged to municipal sewage treatment plant and then treated with conventional sewage treatment processes. At other landfill sites where discharge lines are not available the leachate may be hauled off site for treatment. However it is often not appropriate for treatment by conventional municipal biological processes because of their toxic components. It is necessary for the effective leachate treatment method to be developed. One method to solve this problems is the use of membrane process. Fig. 3 shows block diagram for leachate treatment using ultrafiltration(UF) and reverse osmosis(RO) membrane. Initially leachate which is collected from landfill is treated to reduce organic and heavy metal contaminants by conventional physical and chemical processes. And then it is transferred to UF and RO unit through 10 micron micro filter. The relatively simple pretreatment was considered to prepare a suitable feed to the tubular type UF membrane which has the task to supply to the RO elements a clean, low SDI feed water. At UF system leachate is concentrated until 95% and UF permeate is transferred to RO system. At this system soluble organic and inorganic components are removed and high purity water produced reused as boiler feed water and other uses. The recovery at RO system is 75%, resulting total recovery including UF & RO above 76%. Concentrates which are created at UF and RO are evaporated thoroughly at the drum dryer.

Prior to the selection of a full scale plant it was conducted for pilot test to verify performance of membrane at site in actual operating conditions. Table 4 shows the test results. COD was mostly removed by primary treatment system and 99% of the rest was removed at RO membrane. And total dissolved solid(TDS) was also nearly removed at RO membrane. In conclusion the product water quality allowed it to be discharged without any additional treatment and could also be reused for most applications.

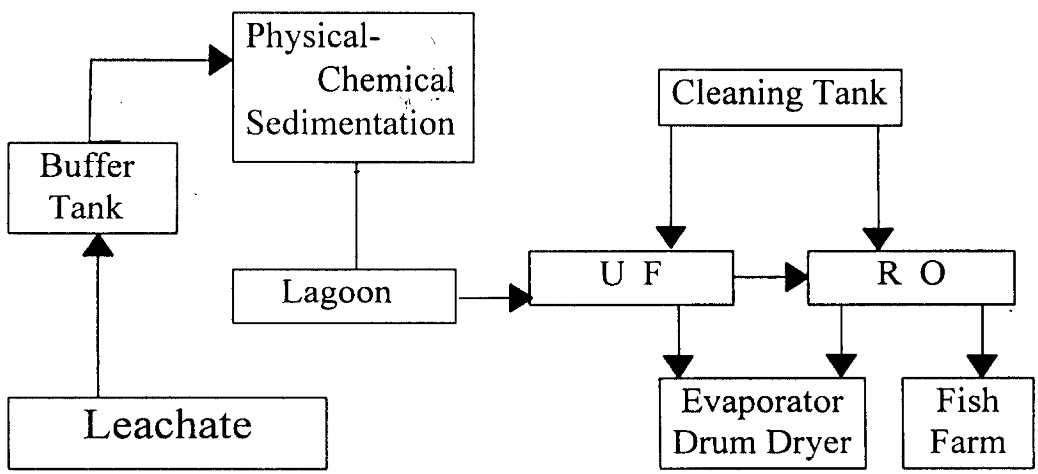

Fig. 3. Block Diagram for Treatment of Landfill Leachate Using UF and RO Membrane.

Table 3. Permeate Qualityies of UF and RO Membranes as Compared to the Raw Leachate Quality.

Item	Leachate Quality	Primary Treatment	UF Permeate	RO Permeate
pH	7.17	6.9	6.95	6.65
	8.58	6.9	6.95	6.65
	7.62	7.0	7.18	6.87
COD (mg/L)	4,520	158.2	139.0	3.1
	3,200	127.5	110.0	2.5
	5,507	141.0	124.5	2.8
TDS (mg/L)	-	14,140	-	141
	-	14,100	-	174
	-	14,270	-	157
SS (mg/L)	65	14.8	1	ND
	23	11.9	1	ND
	36	10.4	1	ND

4. CONCLUSION

Reverse osmosis membrane pilot test for the reclamation of oil refinery wastewater effluent was conducted. The RO permeate flux was maintained constantly at 20.7L/M^2/hr in average in the inlet pressure range of 10 - 13 Kg/cm^2. And salt rejection was increased up to 98% with operation time and shows a feasible water quality to reuse as process water. However the effective pretreatment methods need to be developed to minimize flux decline due to fouling in the membrane module.

In the case of landfill leachate treatment using membrane, the product water quality allowed it to be discharged without any additional treatment and could also be reused for most application.

References

1. S.S. Whipple et al, Ultrapure water, October 1987
2. J.G. Hwang et al, Membrane Journal, 4(4), (1994), 213-220.
3. A.G. Fane, Int. conference on "Dedalination and Water reuse", Perth, Australia, Vol.1 (1994), 1-14
4. K.G. Asylova et al., Chem. Technol. Fuels Oils, 16(1980), 617.