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응집-여과-중화 공정에 의해 전처리된 아크릴 폐수의 한외여과와 역삼투 모듈 조합 공정에의 적용

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Application in Ultrafiltration and Reverse Osmosis Module Set with Acrylic Wastewater Pretreated by Coagulation-Filtration-Neutralization Process

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요 약: 아크릴 폐수를 응집-여과-중화의 전처리 공정에 적용하여 막오염 인자를 최소화 한 후 UF/RO공정에 적용하였다. 막의 형태 및 종류에 따라 한외여과 및 역삼투 모듈을 조합을 이루어 전처리 수를 온도 및 압력변화에 따라 적용하여 분리 특성을 고찰하였다. 투과 플럭스는 모듈 set 1의 UF모듈보다 모듈 set 4의 UF모듈의 투과량이 약 2~3배 더 많이 배출됨을 확인하였다. 최종적인 투과량은 관형모듈과 조합을 이룬 모듈 set 2와 모듈 set 3이 좋은 결과를 나타내었다. 모든 UF 모듈에서 TDS, T-N 및 COD의 제거 효율은 온도 및 압력변화에 영향을 받지 않고 제거 효율 또한 낮음을 알 수 있었다. RO모듈에서 TDS, T-N 및 COD가 우수한 제거 효율을 보였다. 아크릴 폐수의 최종적인 수질결과는 공장폐수의 배출 허용기준을 만족하였고, 막모듈 조합은 폐수의 재활용 가능성을 확인할 수 있었다.

Abstract: After membrane fouling factors in acrylic wastewater were minimized by pretreatment process accompanied with coagulation-filtration-neutralization, it was utilized in UF/RO process. After composing of ultrafiltration and reverse osmosis module set according to types and kinds of membrane, the separation characteristics were examined with the variation temperature and pressure using pretreated acrylic wastewater by membrane module sets. It was found that permeate flux of UF module in module set 4 was about two ~ three times larger than that of UF module in module set 1. Final quantity of permeate from the module set 2 and module set 3 combined with tubular module was shown very good result. It was shown that the removal efficiency of TDS, T-N and COD was very low and was not dependent on the variation of temperature and pressure in all UF modules. The removal efficiency of TDS, T-N and COD was very excellent in RO module. Final water quality of acrylic wastewater was satisfied with effluent allowances limit and membrane module sets were ascertained to reuse wastewater.

Keywords: *acrylic wastewater, pretreatment process, removal efficiency, ultrafiltration, reverse osmosis*

1. Introduction

The concerns of environmental problem are increasing day by day. Especially, the interest of shortage and pollution for water resources is amplifying. The weather of Korea is composed of four seasons. The variation range of water resources quantity is high according to climatic change. In summer, that is the rainy season, water resources are plentiful, but in winter or spring with the shortage of snow and rain, deficiency phenomena of industrial water and farming water become visible. Until now, water is utilizing after storage by dam or reservoir constructed previously but the more demand is expected

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in the future. The indiscreet construction of dam or reservoir is the direct and indirect cause of environmental disruption, therefore, the erection of dam or reservoir is faced with much difficulties. The study for utilizing membrane separation system in this area is proceeding to solve this problem. Because the wastewater containing hard-decomposable and toxic material is discharging in a large amount, it is very hard for existing treatment facility to treat the wastewater. The amount of acrylic wastewater is increasing continuously owing to increment of acrylic fiber consumption in Korea. The acrylic wastewater is occupying 28% of total discharged fiber wastewater in 'T' fiber-plant of Korea. The hard-decomposable pollutant and solid material in acrylic wastewater is very difficult to dispose with existing clean water treatment process. The membrane separation system is composed and applied in effective treatment of acrylic wastewater containing hard-decomposable material.

The clean water treatment process using membrane with simple facility and operation can obtain higher treatment quality than existing clean water treatment process with coagulation-sedimentation-filtration. Also, membrane filtration can remove several pollutants in tap water simultaneously and maintain good quality of treated water continuously. The kinds of membrane according to particle and molecular weight can be divided in microfiltration, ultrafiltration, reverse osmosis, etc.. It can be used variously according to the target wastewater[1-5].

Microfiltration and ultrafiltration are very closely related processes and pressure-driven membrane processes with reverse osmosis process. But permeate flux decreases from membrane fouling due to pollution material when membrane separation process is applied in wastewater containing much dissolved solids without pretreatment[6-8]. After pretreatment with coagulation-filtration-neutralization process in order to minimize membrane fouling, it is applied in UF/RO process[9-11].

This study was to apply pretreatment process with acrylic wastewater containing hard-decomposable material and much dissolved solids. The separation characteristics of pretreated acrylic wastewater with the variation of temperature and pressure according to membrane types and kinds were investigated from the application of UF/RO process after minimizing the membrane fouling factor.

2. Experimental Material and Method

2.1. Pretreatment Process

Hard-decomposable acrylic wastewater was fed in pretreatment process composed of coagulation-filtration-neutralization before applying it with membrane. The upper floating liquid was collected after coagulating with CaO dosage. The sand filter was used as physical treatment, and it was maximized with effect from the inserting active carbon inside the layer sand. Also, the neutralization process using H_2SO_4 solution was introduced in order to decrease pH elevation owing to CaO coagulation.

2.2. Membrane

Ultrafiltration membrane with the several kinds of molecular weight cut-off and membrane material are GUF 3050, GUF 2050-0950, made by 'P' company, and KCF-1205 made by 'K' company. Also, U1H3-02-C made by 'S' company was applied in UF process, which is ceramic material having very good resistivity in distortion with high temperature heat shock than existing polymer membrane. Reverse osmosis membrane was applied with RO W-60, RO 11-50 and RO NO-50 made by 'S' company. The characteristics of each module are indicated in Table 1.

2.3. Experimental Method

The acrylic wastewater pretreated was sent to feed tank and applied with the variation of temperature and pressure. Process flow is shown in Fig. 1. The circulating constant bath was used in order to maintain feed temperatures (15°C, 25°C, 35°C) constantly. The experiment was conducted with 4 step changes of reverse osmosis membrane pressure after fixing the pressure of ultrafiltration membrane. Because the constant pressure of ultrafiltration membrane was influenced by the change

Table 1. Specifications of Ultrafiltration and Reverse Osmosis Membrane

	Model	Membrane material	Type	Area of membrane (m^2)	MWCO (Daltons)	Module set No.
UF	GUF 3050	polysulfone	hollow fiber	2.20	30,000	1
RO	11-50	polyamide	spiral wound	0.50	-	
UF	GUF 2050-0950	polysulfone	hollow fiber	2.20	50,000	2
RO	W-60	polyamide	spiral wound	0.50	-	
UF	KCF-1205	PVDF	tubular	1.18	200,000	3
RO	W-60	polyamide	spiral wound	0.50	-	
UF	U1H3-02-C	Al_2O_3	multi-channel	0.24	0.02 μm	4
RO	NO-50	polyamide	spiral wound	0.50	-	

Table 2. Experimental Conditions for Ultrafiltration and Reverse Osmosis Membrane Module

Item	Unit	Value
Pressure, kg_f/cm^2	UF	1.6, 2.0, 2.4, 2.8
	RO	4, 5, 6, 7
Temperature, °C		15, 25, 35

of reverse osmosis membrane pressure, the reservoir fed with ultrafiltration permeate was installed in order to exclude this effect.

All permeate and reject were circulated in feed tank in order to maintain concentration of feed constantly. Experimental condition applied in UF/RO process is shown in Table 2 and UF/RO process equipment is shown in Fig. 2. Permeate of ultrafiltration membrane was measured directly from the connected pipe with RO membrane feeding reservoir after steady state was attained. Reject flow rate was calculated with the addition of each measured flow rate after measuring flow rates of the reject pipe and reject detour pipe. Sampling for wastewater analysis was done simultaneously with the measurement of flow rate.

3. Result and Discussion

3.1. Pretreated Process

The final removal efficiency of COD in pretreated process was about 70%[12]. Also, the reference was showed the minimized membrane fouling due to the constant removal of dissolved solids.

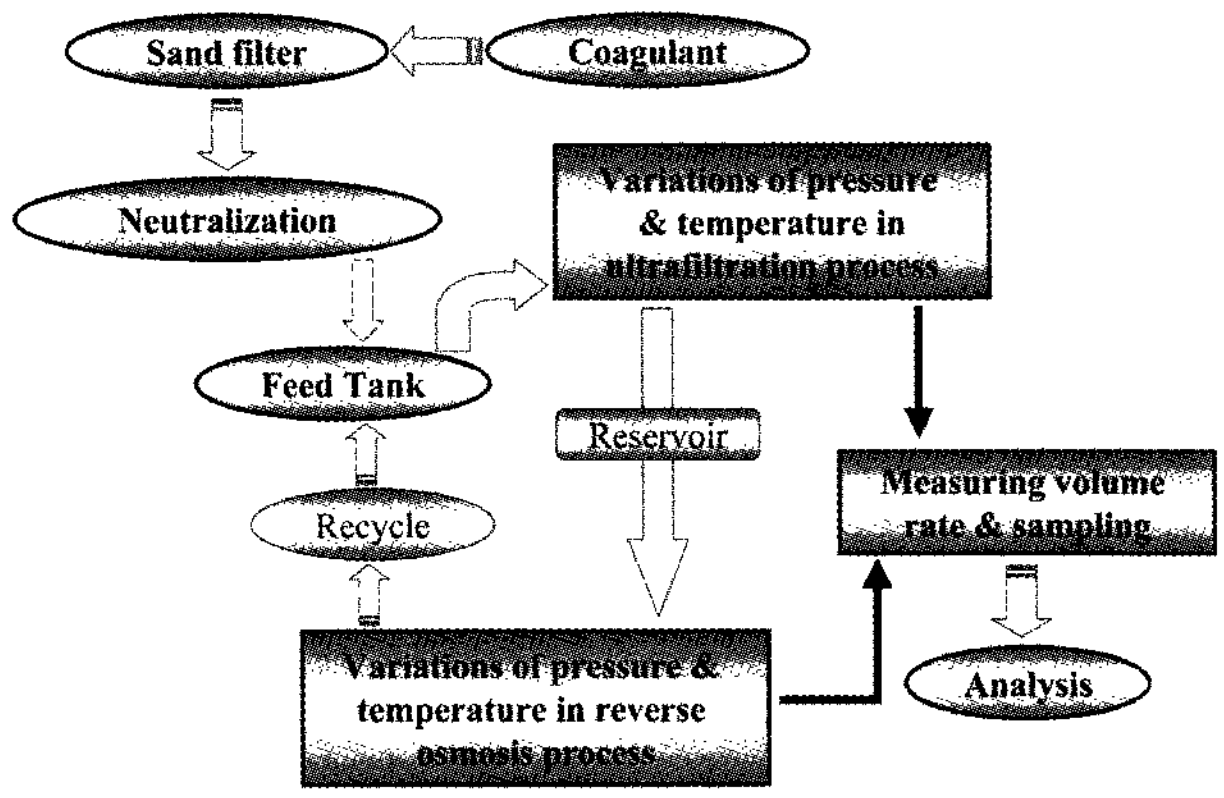
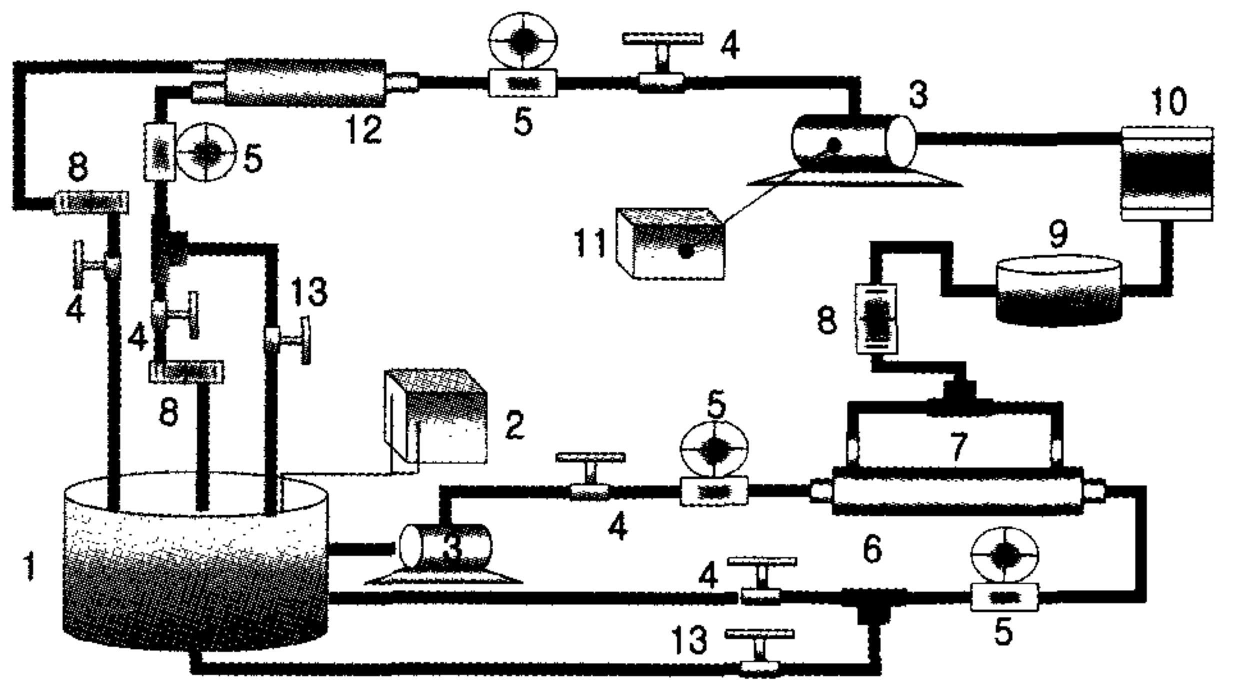


Fig. 1. Flow diagram of pretreatment and membrane separation system.

3.2. Permeate Flux

When distilled water is applied in UF/RO process, the pure water permeate flux of ultrafiltration and reverse osmosis module was linearly increased with the variation of temperature and applied pressure. From the above result, experiment was carried out after the identification of good condition without no drainage and plug from the application of membrane hybrid system. The permeate flux of wastewater pretreated with coagulation-filtration-neutralization showed that permeate of module set 4 was about two ~ three times higher than that of module set 1 (Fig. 3). This might be analyzed with the difference of molecular weight cut-off in ultrafiltration modules. In case of reverse osmosis spiral wound type module using permeate of ultrafiltration as a feed, it was identified that permeate of module set 3 was higher than that of module set 1 (Fig. 4).



Legend : 1.Feed Tank 2.thermocontroller 3.Pump 4.Gate valve 5.Pressure gauge 6.UF module 7.T-type unit 8.Flow meter 9.Reservoir 10.Filter housing 11.Controller 12.RO module 13. Bypass valve

Fig. 2. Schematic diagram of membrane separation system.

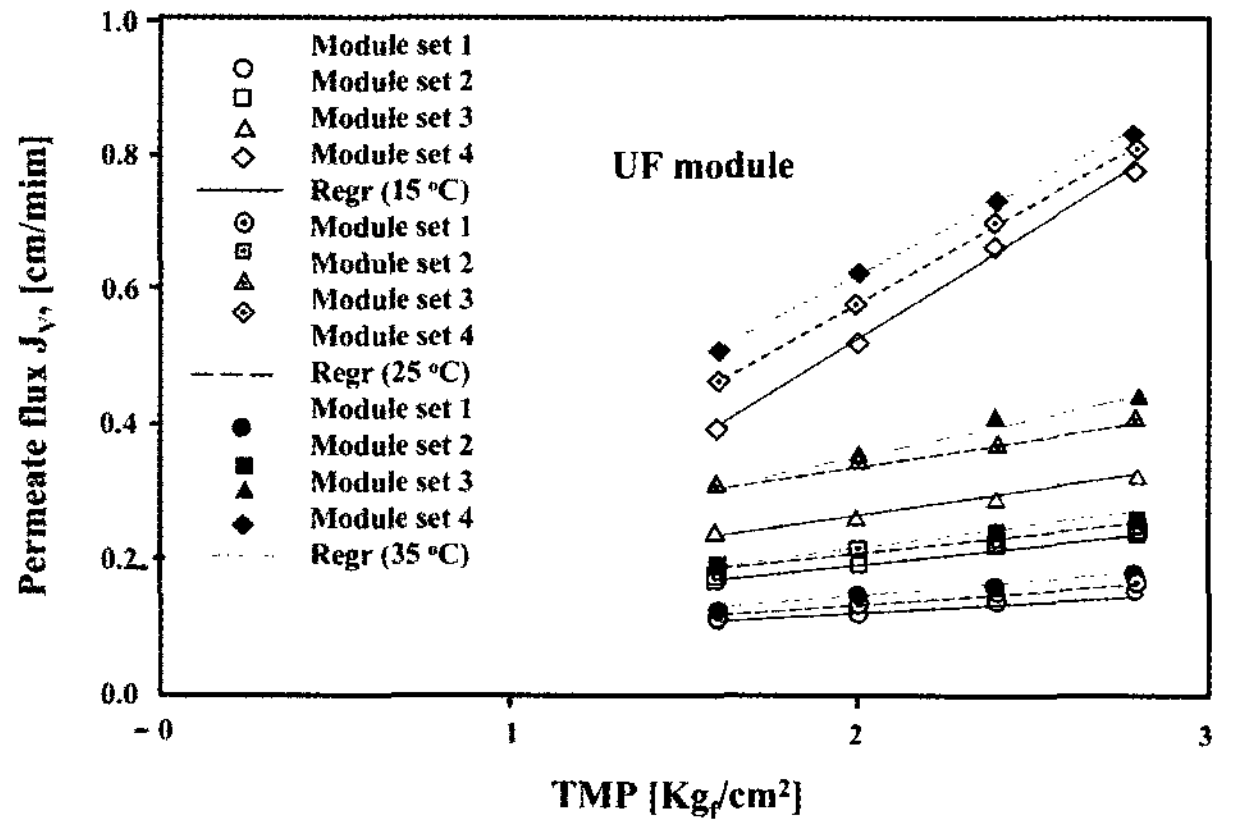


Fig. 3. Permeate flux versus pressure difference for ultrafiltration and microfiltration modulus.

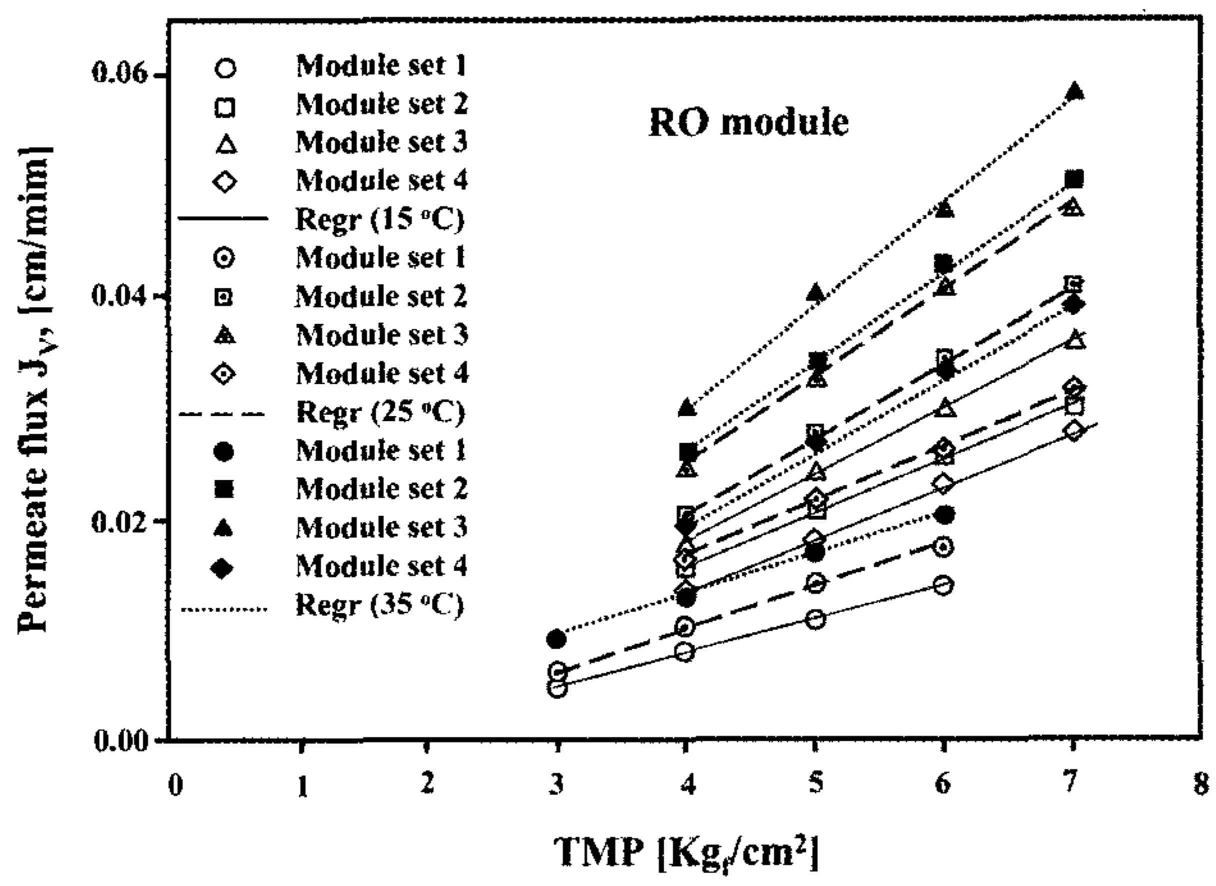


Fig. 4. Permeate flux versus pressure difference for reverse osmosis spiral wound module next UF modulus.

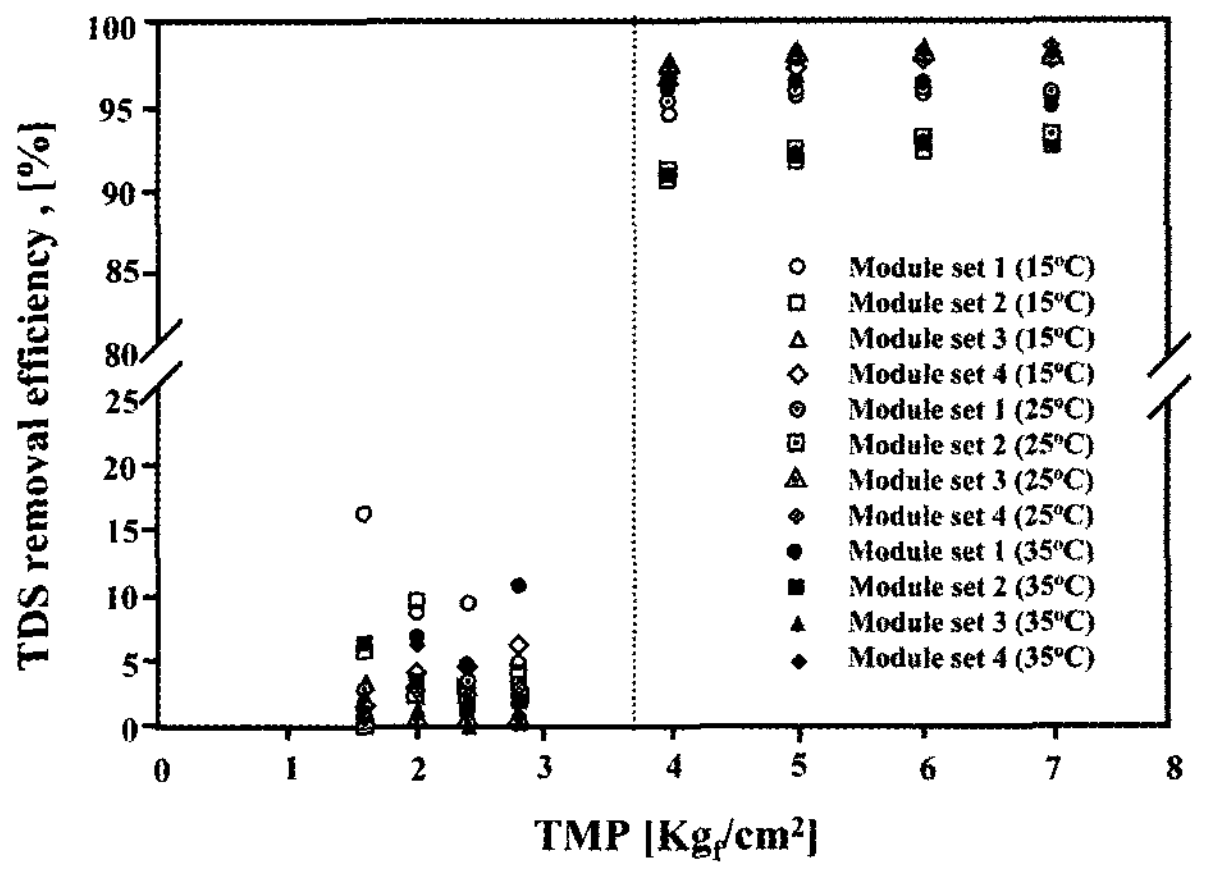


Fig. 5. TDS removal efficiency versus pressure difference for ultrafiltration and reverse osmosis modulus set.

3.3. TDS

From the application in ultrafiltration and reverse osmosis process of pretreated acrylic wastewater with coagulation-filtration-neutralization process, the removal efficiency of TDS was not nearly affected by the variation of temperature and pressure. When the permeate of ultrafiltration membrane was applied to a reverse osmosis process, the removal efficiency of reverse osmosis spiral wound type module was maintained higher than 95% except that of module set 2 (Fig. 5).

3.4. Turbidity

When coagulation-filtration-neutralization pretreated acrylic wastewater was applied to ultrafiltration process under the condition of constant feed flow rate, turbidity removal efficiency with the change of temperature and pressure was shown to increase in all UF modules except the module set 2 (Fig. 6). The removal efficiency of reverse osmosis module did not show stable value due to the variation of turbidity removal efficiency of ultrafiltration module.

3.5. T-N

When coagulation-filtration-neutralization pretreated wastewater was applied to ultrafiltration and reverse osmosis module set process, the removal efficiency of it with the variation of temperature and pressure was not nearly affected in all module sets. In all UF modules, the removal efficiency of pretreated wastewater was lower than about 7%. In the case of application of per-

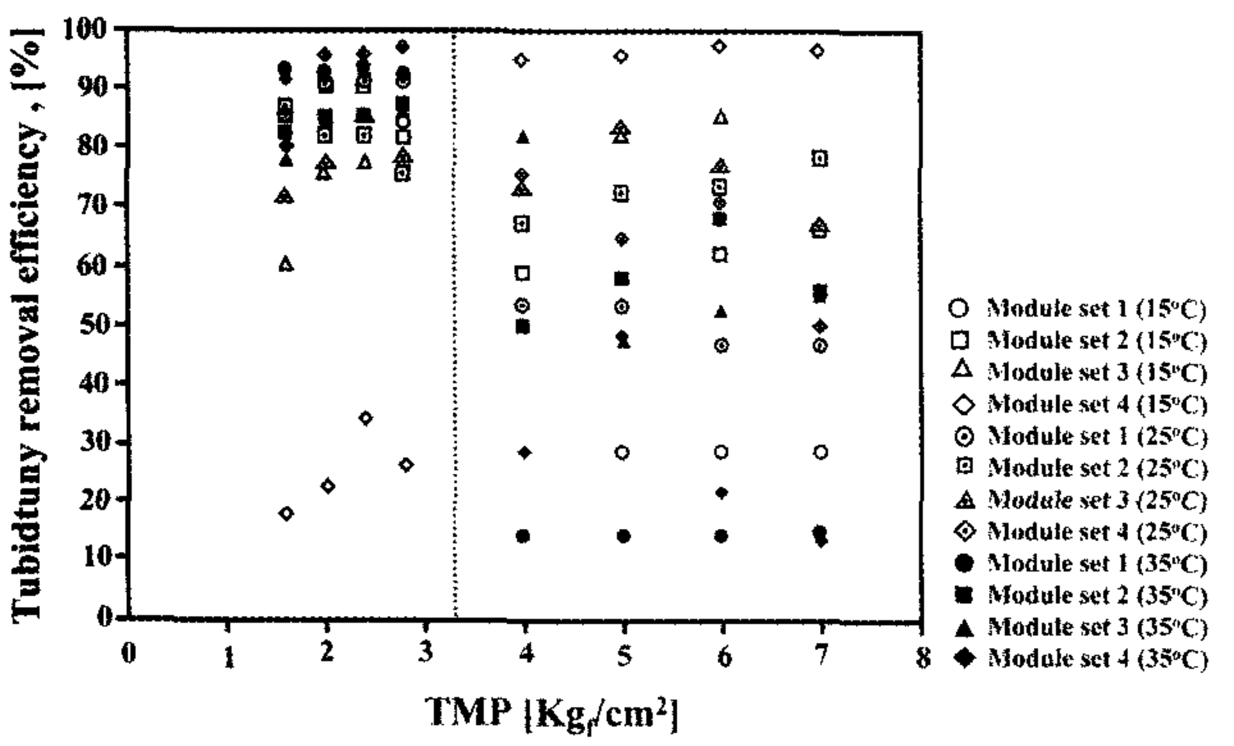


Fig. 6. Turbidity removal efficiency versus pressure difference for ultrafiltration and reverse osmosis modulus set.

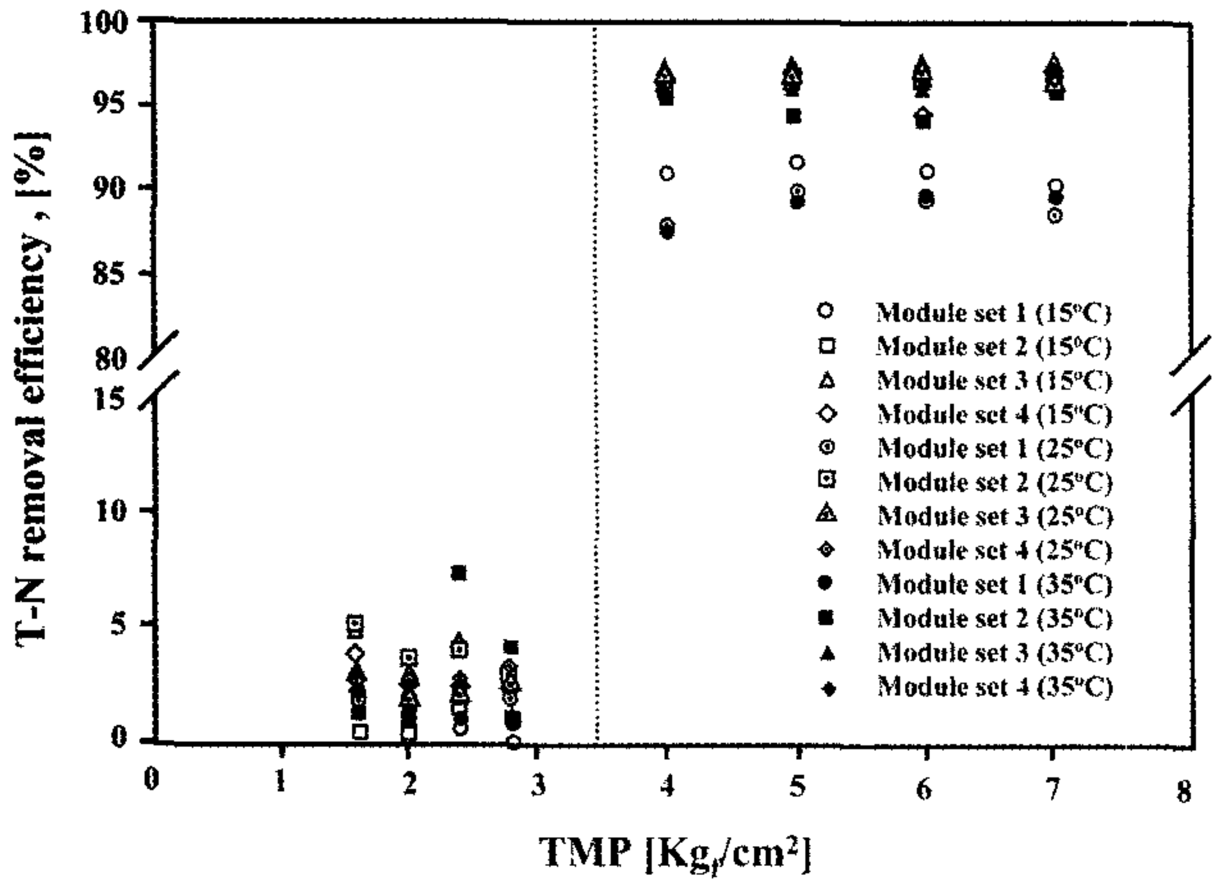


Fig. 7. T-N removal efficiency versus pressure difference for ultrafiltration and reverse osmosis modulus set.

meate of ultrafiltration to reverse osmosis spiral wound type module, the removal efficiency of all other modules except reverse osmosis spiral wound type module (set 1) was maintained with higher value than 95% (Fig. 7). It was known that T-N could be removed mostly with the use of RO module due to the high value of removal efficiency.

3.6. COD

In applying coagulation-filtration-neutralization pretreated wastewater to ultrafiltration and reverse osmosis module set process, COD removal efficiency was not affected with the change of temperature and pressure. When the permeate of ultrafiltration was applied to reverse osmosis module, the removal efficiency of reverse osmosis module of module set 3 was about 15% higher

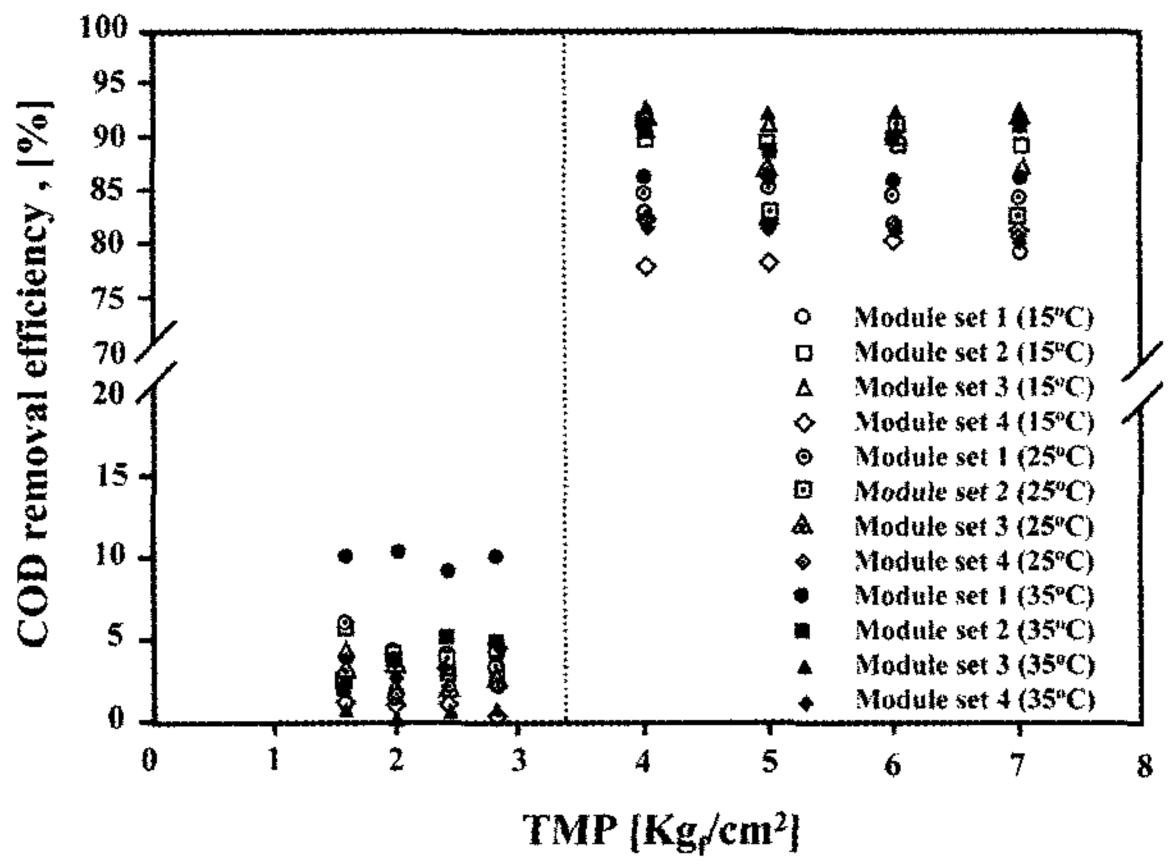


Fig. 8. COD removal efficiency versus pressure difference for ultrafiltration and reverse osmosis modulus set.

than that of module set 4 (Fig. 8). But, removal efficiency in reverse osmosis module set was higher than about 78% totally.

3.7. pH

The coagulation-filtration-neutralization pretreated wastewater was applied in ultrafiltration and reverse osmosis module set process. In all module sets, pH was not largely affected with the change of pressure (Fig. 9).

4. Conclusions

From the application of acrylic wastewater pretreated by coagulation-filtration-neutralization process to UF and RO module set, the following results were obtained. The permeate flux of module set 4 was about two ~ three times larger than that of module set 1 because the difference in molecular weight cut-off was identified. In the case of considering only UF module, ceramic ultrafiltration module of module set 4 showed very good permeate amount. But, final permeate quantity in module set 2 and module set 3 showed very good results when they were combined with tubular module.

In all UF modules, the removal efficiency of TDS, T-N and COD was not affected with the change of temperature and pressure, and it showed very low value. From this result, it was shown that the removal efficiency of TDS, T-N and COD in RO module is very

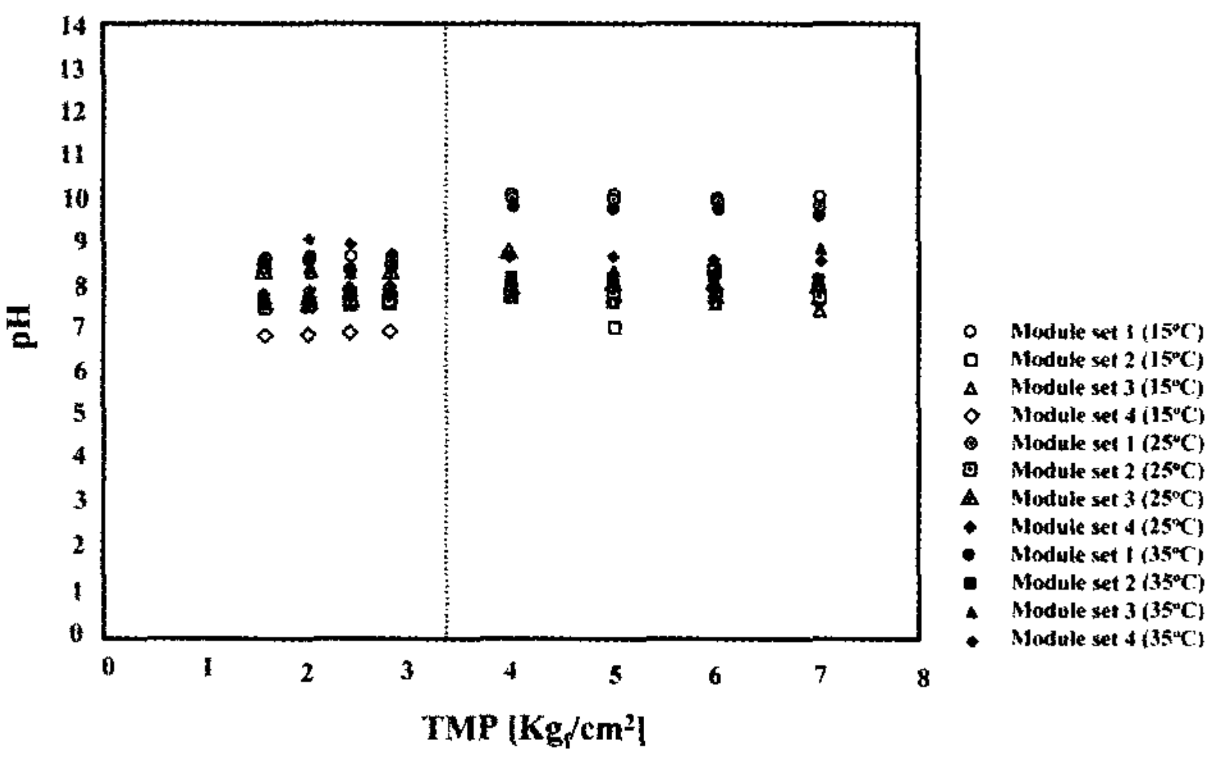


Fig. 9. pH versus difference for ultrafiltration and reverse osmosis modulus set.

high with the variation of temperature and pressure.

The turbidity removal efficiency of UF module with the change of temperature and pressure is inclined to increase with all UF modules except the module set 2.

In the case of pH, pH was not affected largely with the variation of pressure.

The result of final water quality for each item was satisfied with discharge allowances limit value. The membrane hybrid system could be identified with the reclamation possibility of wastewater.

Acknowledgements

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