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REVERSE OSMOSIS AND ULTRAFILTRATION MEMBRANE FOR HOSPITAL WASTEWATER TREATMENT

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ABSTRACT

A laboratory scale studies have been conducted at Analitika EcoLab Pvt.Ltd, Gwalior using reverse osmosis (RO) and ultra filtration (UF) membrane to remove chemical oxygen demand (COD), biochemical oxygen demand (BOD), total nitrogen (TN), ammonia nitrogen (NH_4), nitrate nitrogen (NO_3), total phosphorus (TP) and suspended and dissolved solids from hospital wastewater. Spiral wound polyamide and cellulose acetate membrane with pore size 0.001 µm for RO and 0.01 µm for UF and thickness of 0.002-0.003 mm were employed in the experimental unit. The experiments conducted were based on batch process condition. Hospital wastewater contained 200.00-235.00 mg/l of COD, 95.00-115.00 mg/l of BOD, 16.00 - 25.00 mg/l of TN, 7.00-11.00 mg/l of NH_4, 0.00-0.10 mg/l of NO_3, 3.90 - 4.50 mg/l of TP, and 320.00-365.00 mg/l of total suspended solids (TSS) and 525.00-575.00 mg/l of total dissolved solids (TDS).The inlet flow rate was kept between 10-14 l/hr for the pressure applied between the feed and permeate was varying accordingly. The percentage removal efficiency of COD and BOD were found to be more than 99.00 % for RO and more than 97.00 % for UF. The TSS and TDS were found to be removed almost 100.00 % for both the RO and UF unit. It is found that for polyamide membrane TN, NH_4 and NO_3 removal found to be 85.00 %, 95.00 %, 95.00 % respectively for UF and it were 90.00 %, 98.00 %, 96.00 % respectively for RO. The experimental results follow Indian drinking water standards for both the membrane filtration systems, but the performance of RO found to be much better than UF. Polyamide membrane found to be much better than cellulose acetate. To avoid membrane fouling, membrane cleaning had been done on daily basis. But, marginal effect of cleaning on the performance of RO and permeability were detected.

Keywords: Reverse osmosis, ultra filtration, hospital wastewater

[I].INTRODUCTION

In recent years, water scarcity, and disposal of wastewater from municipal as well as industrial areas are the two most serious problems in India. Disposal of wastewater into the river and in the land is not solving the problem; instead, it is contaminating both the ground water and river water. So, it is necessary to treat the wastewater in order to maintain the above said problems as well as to meet the drinking as well as water reuse standards. Many activated sludge process plants are in operation in India to treat wastewater, but they are not efficient enough to meet the reuse standards. Therefore, in this investigation, the membrane separation system is considered as an alterative for wastewater treatment that would provides excellent water quality. Water and wastewater treatment membranes are typically classified in order of decreasing pore size as microfiltration (MF), ultrafiltration (UF) , nanofiltration (NF) and reverse Osmosis (RO). As a general rule, MF is suitable for the removal of suspended solids, including larger microorganisms like protozoa and bacteria. UF is required for the removal of viruses and organic macromolecules down to a size of around 20 nm. Smaller organics and multivalent ions may be removed by NF, while RO is even suitable for the removal of all dissolved species. **[1]**.

Membrane technology, specifically RO, can produce water which should meet even the most stringent guidelines [2, 3]. RO is a successful desalination method applied to seawater, brackish and industrial wastewater. It relies on a membrane separation technique that requires pressure to force clean water through the membrane, and thus removes dissolved salts and harmful contaminants including bacteria, virus and chemicals with the reject steam [4, 5, 6]. The discovery in the mid-sixties of the flat plate RO membrane and the development of the spiral wound configurations are replaced the tubular or the plate and frame configurations. The polyamide membranes were introduced in the hollow fiber configuration in 1970**[7]**.A great volume of research work was devoted to develop the performance of RO membrane such as COD removal **[8, 9]**, TOC removal **[10]** and nitrogen removal **[11]** from municipal wastewater. The most common reverse osmosis (RO) membranes which attained the stage of economic application in desalination plants are made of cellulose acetate (CA) or polyamide (PA), in either hollow fiber (HF) or spiral wound configuration **[12]**. Performance in RO is determined by several variables, which can be classified into three categories, such as, variables concerning the membrane, variable concerning the feed water, and variables concerning the conditions of operation **[13]**. The RO membrane hydraulic permeability, selectivity, structural configuration and the chemical characteristics of its base polymer are the main membrane parameters, which determine RO process efficiency and mechanism **[7]** .This study focused on removal of COD, nitrogen and phosphorous contents from the hospital wastewater using RO and UF membranes to achieve the target.

[II]. MATERIAL AND METHODS

The experimental unit consists of two modules - RO and UF process. The schematic diagram of the experimental unit is shown in fig. 1. The experiments conducted were based on batch process condition. During the operation feed goes from feed tank (1) to pump (P1) from where pressurized feed comes to inlet header. From inlet header it goes to RO or UF module. Feed comes to the outlet header from RO or UF module by pump (P2). The pure collected in permeate tank (2) and rejected water collected in retentate tank (3).High pressure cut off is provided for safety purpose. If pressure exceeds beyond certain limit it stops the motor automatically. The RO/UF membrane module consists of spiral wound cellulose acetate and polyamide membrane with pore size of 0.001 μm for RO and 0.01μm for UF with the thickness of 0.002-0.003 mm. The operating parameters for the systems are given in table 1.The inlet flow rate was kept between 10-14 l/hr for the pressure applied between the feed and permeate was varying accordingly. Hospital wastewater collected in this study was various hospital outlets in Gwalior, India. Characteristics of wastewater are shown in table 2.The wastewater collected on daily basis for four months from August, 2004 to November, 2004.During this period the temperature of wastewater varies between 21 and 30^{O}C and variation in pH value was between 7.1 and 7.7.Conventional analysis of sample collected from feed, retentate and permeate include pH, Temperature, COD, BOD, TN, NH_4, NO_3, TP, PO_4, TSS and TDS. They were carried out according to the Indian standard methods **[14]**. Frequent cleaning has been done once a day (before starting with new sample) for the better performance of membrane using the solution of sodium Metabisulfate, Trisodium Phosphate and Sodium Lauryl Sulphate.

[III]. RESULTS AND DISCUSSION

The range of effluent concentration and average value of percentage removal efficiency by RO and UF system for removing BOD, COD, TN, NH_4, NO_3 ,TP, PO_4, TSS and TDS from hospital wastewater for the period of four month is presented in Table 3 and Figure 2 to 7.

It is found that the average COD removal efficiency of RO system was 99.00 % for cellulose acetate and 99.50 % for polyamide membrane, where as for UF it was 97.10 % for cellulose acetate and 97.60 % for polyamide .Similarly BOD removal efficiency of RO system found to be 99.80 % for cellulose acetate and 99.90 % for polyamide membrane and that for UF system it was 98.00 % for cellulose acetate and 98.50 % for polyamide.

For nitrogen content such as TN, NH_4 and NO_3, average percentage removal efficiency found to be 88.00, 96.00 and 94.00 respectively for cellulose acetate and 90.00, 98.00 and 96.00 for polyamide in the RO system. The average percentage removal for TN, NH_4 and NO_3 found to be 82.00, 91.00 and 91.00 respectively for cellulose acetate and 85.00, 95.00 and 95.00 respectively for polyamide in the UF system.

For phosphorus content such as TP and PO_4, average percentage removal efficiency found to be 67.00 and 88.00 respectively for cellulose acetate and 70.00 and 90.00 for polyamide in the RO system. The average percentage removal for TP and PO_4 found to be 63.00 and 85.00 respectively for cellulose acetate and 66.00 and 87.00 respectively for polyamide in the UF system.

Table 3 shows that solids content in the wastewater was complete removed by both the RO and UF system. The percentage removal efficiency found to be almost 100 % for TSS and TDS.

Figure 2 to 7 shows that concentration of COD, BOD, nitrogen and phosphorus content in the effluent of RO and UF system found to be slightly increased. The values of effluent concentration meet the Indian drinking water standards for all the parameters. In addition, figure 8 shows the change in flow rate with operation period and figure 9 shows the variation of permeability with operation period. Both the flow rate and permeability decrease with operation period .This indicates that the chemical cleaning is done to the avoid the fouling in the membrane seems to be effective, but the marginal effect on the performance of RO and UF shows that the daily chemical cleaning should be avoided. Otherwise, it may affect the membrane life.

The results show that polyamide membrane is better than cellulose acetate; it may due to the inadequate mechanical and thermal stability of cellulose acetate polymer, which result in decline of performance due to membrane compaction and shrinkage. The results also show that the performance RO membrane is much better than UF membrane; it may be due to the membrane characteristics such as pore size and configuration, and separation mechanisms.

[IV] CONCLUSIONS

The laboratory studies for performance of UF and RO system for hospital wastewater shows that RO system is much better than UF system.

The removal efficiency of COD and BOD were found to be more than 99.00 % for RO and more than 97.00 % for UF.The suspended and dissolved solids were found to be removed almost completely for both the RO and UF unit. It is found that for polyamide membrane TN,NH_4 and NO_3 removal found to be 85.00 %, 95.00 %, and 95.00 % respectively for UF and for it were 90.00 %, 98.00 %, and 96.00 % respectively for RO.It is also found that TP and PO_4 removal found to be 66.00 %and 87.00 % respectively for UF and are 70.00 %and 90.00 % respectively for RO. It is concluded that the polyamide with RO system may be the best option for the present condition. The experimental results also observed to follow the Indian drinking water standards for both the membrane filtration systems. To avoid membrane fouling, membrane cleaning had been done on daily basis, but, marginal effect of cleaning on the performance of RO and UF system and that of membrane permeability were detected.

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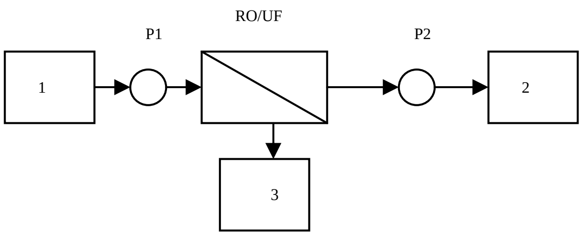

Figure 1: Flow diagram of RO /UF system

Table 1: Membrane specifications used in the experiments

Characteristics	**Reverse Osmosis**	**Ultra filtration**
Membrane Configuration	Spiral wound	Spiral Wound
Membrane material	1) Polyamide 2) Cellulose Acetate	1) Polyamide 2) Cellulose Acetate
Filtration Principle	Cross flow	Cross flow
Membrane Surface area ,m^2	0.5	0.5
Maximum operating Feed flow rate (m^3/day)	21.6	21.6
Maximum operating Pressure (bar)	13.6	6.8
Maximum operating temperature ^{O}C	45	45
Maximum feed turbidity, NTU	1	1
Maximum feed SDI	4	4
Allowable pH range	2-11	2-11

Table 2: Characteristics of wastewater (Aug., 2004 – Nov., 2004)

Parameters	**August**	**September**	**October**	**November**
Temp. OC	25 – 30	23-26	21-24	20-23
pH	7.5-7.7	7.1-7.4	7-7.2	7-7.1
COD (mg/l)	225-235	200-212	217-224	219-228
BOD (mg/l)	108-115	95-101	97-102	98-105
TN (mg/l)	18-25	17-21	16-19	21-22
NH4 (mg/l)	8-11	7-8	7-8	8-11
NO3 (mg/l)	0-0.10	0-0.10	0-0.10	0-0.10
TP (mg/l)	4.3 - 4.5	3.90-4.20	4.20-4.50	4.20-4.50
PO4 (mg/l)	3.7 - 4.1	3.40-3.70	3.60-3.70	3.60-3.70
TSS (mg/l)	340-365	320-330	325-339	335-350
TDS (mg/l)	560-575	525-545	535-545	540-560

Table 3: Performance of UF and RO

Para-meters	Effluent (mg/l)				Percentage Removal			
	UF		RO		UF		RO	
	PA	CA	PA	CA	PA	CA	PA	CA
COD	4.8-5.6	5.8-6.8	1-1.18	2-2.4	97.6	97.1	99.5	99
BOD	1.4-1.7	1.9-2.3	0.09-0.12	0.19-0.23	98.5	98	99.9	99.8
TN	2.4-3.75	2.88-4.5	1.6-2.5	1.92-3	85	82	90	88
NH_4	0.35-0.55	0.63-0.99	0.14-0.22	0.28-0.44	95	91	98	96
NO_3	-	-	-	-	95	91	96	94
TP	1.33-1.53	1.44-1.67	1.17-1.35	1.29-1.49	66	63	70	67
PO_4	0.39-0.44	0.45-0.51	0.30-0.34	0.36-0.41	87	85	90	88
TSS	0.48-0.55	0.96-1.1	-	0.03-0.4	99.85	99.7	100	99.99
TDS	1.58-1.73	1.94-2.13	-	0.53-0.58	99.7	99.63	100	99.9

UF-Ultra Filtration, RO-Reverse Osmosis, CA-Cellulose Acetate, PA-Polyamide

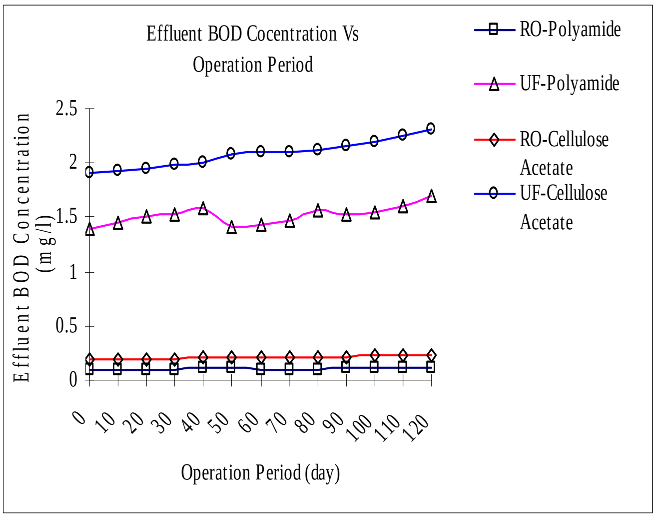

Figure 2: Conc. of BOD in the effluent of RO and UF system

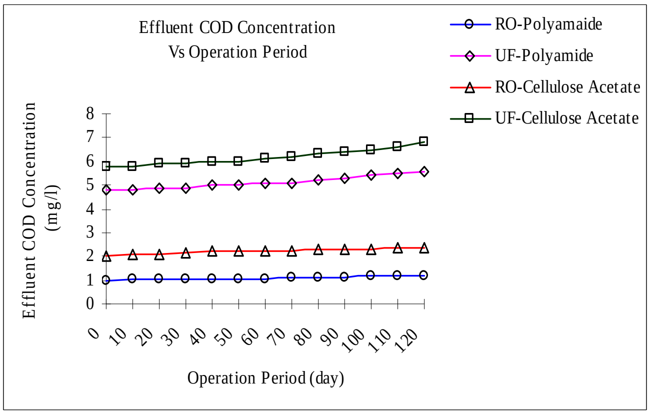

Figure 3: Conc. of COD in the effluent of RO and UF system

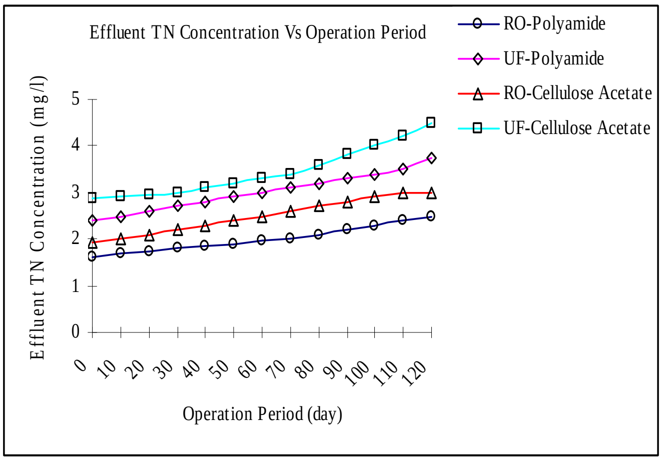

Figure 4: Conc. of TN in the effluent of RO and UF system

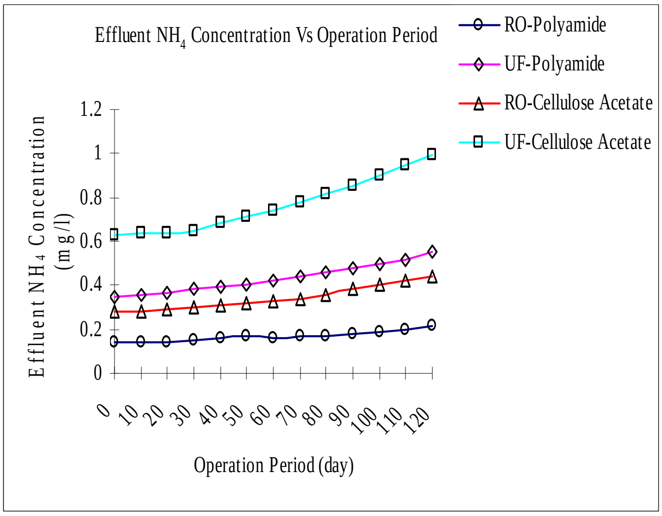

Figure 5: Conc. of NH_4 in the effluent of RO and UF system

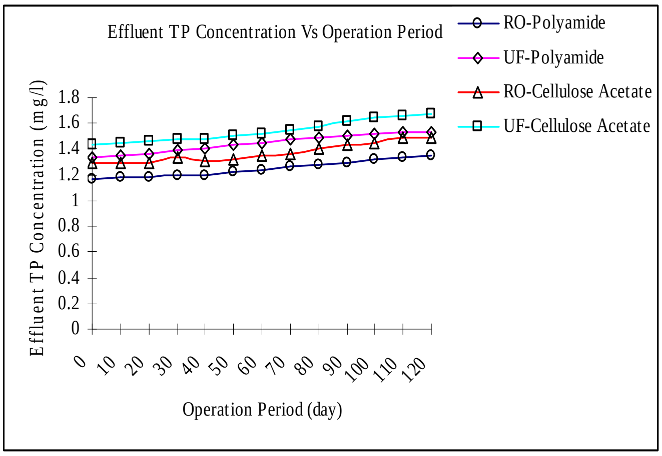

Figure 6: Conc. of TP in the effluent of RO and UF system

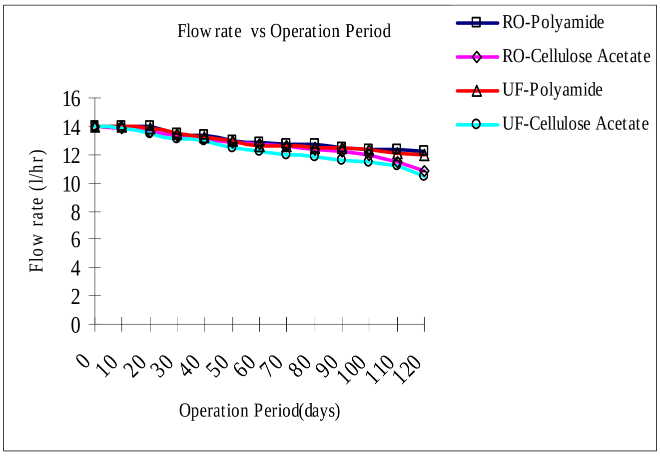

Figure 8: Flow rate of RO and UF system

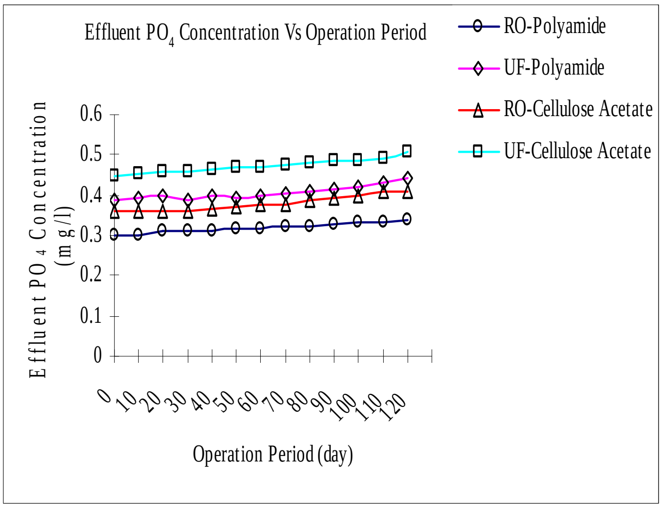

Figure 7: Conc. of PO_4 in the effluent of RO and UF system

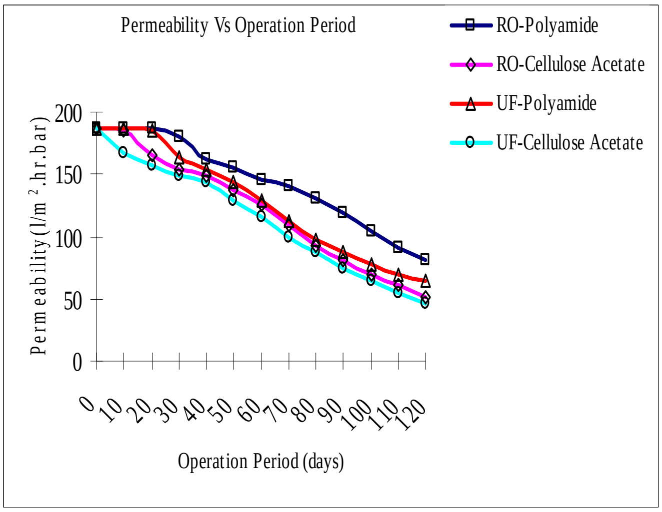

Figure 9: Permeability of RO and UF system