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Investigation of mini pilot scale MBR-NF and MBR-RO integrated systems performance—Preliminary field tests

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ABSTRACT

Recovery of wastewater has become compulsory due to the reasons like lowered discharge limits, pollution of water resources, and increasing water cost depending on the population growth and increasing water use. Even though membrane bioreactor (MBR) processes seem to be an alternative solution providing high quality output water, still, another treatment process after MBR might be essential to be able to use obtained water as irrigation water or process water. In this study, applicability of nanofiltration (NF) and reverse osmosis (RO) methods for reuse of industrial wastewater treated with advanced treatment method at Organized Industrial Zone (OIZ) is investigated. Studies have been implemented with the mini pilot-scale spiral wound NF/RO system installed at OIZ, under applied pressure of 10 bar. For this purpose, NF membrane (NF90-2540 DOW Filmtec) and RO membrane (BW30-2540 DOW Filmtec) were used. According to results obtained, NF90 permeate flux is higher than that of BW30 membrane from December to August. The maximum water recovery obtained with NF90 was about 52.5% while BW30 achieved a maximum water recovery of 44.5%. From September to November, NF90 and BW30 membranes showed similar performances in water recovery as a result of membrane fouling/scaling. NF90 membrane performed rejection percentages of analyzed parameters in the range of 80–100% while the rejection efficiencies of BW30 membrane were in the range 83–100%. Moreover, in comparison of permeate water of NF90 and BW30 membranes with the irrigation water standards; product water qualities of these membranes were found to be suitable for irrigation. According to Turkish water quality classification, first class water quality was produced with BW30 and NF90 membranes except chloride concentration for NF90 membrane.

1. Introduction

The decrease in natural waters resources brought about by drought and population growth is inciting authorities to establish and encourage the reuse of wastewater [1].

Currently, treated municipal wastewater is discharged to the environment and generally considered as a waste. However, municipal wastewater effluent should be regarded as a resource from which high quality water for reuse can be produced. An added benefit is that water reuse reduces the discharge of municipal wastewater to the environment and thus insures source water protection against pollution [2].

Wastewater treatment is based on the abatement of (i) solids in suspension by physical processes (settling and/or filtration) and (ii) soluble compounds mainly by biological processes when compounds are biodegradable or physical or thermal specific processes (chemical oxidation, ion exchange, desorption, etc.) when they are not biodegradable [3].

The MBR system is one of the most suitable technologies for secondly wastewater treatment. The advantages of MBR technology over conventional activated sludge (CAS) plants are better effluent quality, good disinfection, smaller footprint and reactor volume, less sludge production and the possibility of operating at higher biomass concentrations [4]. However, this process is still a little bit more expensive than CAS because of the membrane fouling, which requires stopping the process for membrane cleaning (physical cleaning by aeration and chemical cleaning by basic and acid chemical reagents), increasing the operation cost. Additionally, some of

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Table 1
Characteristics of the NF90-2540 and BW30-2540 membranes.

Membrane type (Designation)	NF90-2540	BW30-2540
Manufacturer	Dow FilmTech	Dow FilmTech
Classified as	NF	RO
Active layer material	Polyamide	Polyamide
MWCO (Dalton)	200	Dense
MgSO4[a] and NaCl[b] rejection (%)	>97.0[a]	99.0[b]
Maximum pressure (bar)	41.0	41.0
pH Range	3.0–10.0	4.0–11.0
Membrane charge (pH 7)	−26.5	−5.20
Membrane Area	28 ft^2 (2.6 m^2)	28 ft^2 (2.6 m^2)
Pure water permeability [L/m^2day kPa] (25 °C)	2.49	0.67

[a] salt rejection based on the following test conditions: 2000 ppm MgSO4, applied pressure 70 psig (4.8 bar), 77 °F (25 °C) and 15% recovery.
[b] salt rejection based on the following test conditions: 2000 ppm NaCl, applied pressure: 225 psig (15.5 bar), 77 °F (25 °C) and 15% recovery.

Table 2
MBR feed characteristics fluctuation during the year.

Months		December	February	March/April	May	June/July	August/September	October	November	Yearly Average of MBR Feed characteristics
Parameters	Unit									
TDS	g/L	3.43	2.74	2.47	2.75	2.54	1.96	1.96	2.62	2.56 ± 0.47
EC	mS/cm	6.87	4.88	4.93	5.51	5.07	3.91	3.92	5.25	5.04 ± 0.94
T	°C	17.9	16.1	19.9	27.8	30.7	30.4	21.7	19.0	22.9 ± 5.9
pH	–	7.67	7.93	7.75	7.34	7.78	7.86	8.03	7.76	7.77 ± 0.21
Salinity	psu	3.73	2.95	2.58	2.97	2.70	1.97	1.99	2.78	2.71 ± 0.57
Turbidity	NTU	0.41	0.36	0.42	1.23	1.24	1.29	1.22	1.08	0.91 ± 0.43
Na^+	mg/L	1240	1075	866	1066	1005	619	638	638	893 ± 239
Ca^{2+}	mg/L	123	120	170	148	131	103	144	170	139 ± 24
K^+	mg/L	838	153	272	337	373	555	524	395	431 ± 209
Mg^{2+}	mg/L	23.3	17.2	21.3	21.5	23.6	32.2	25.6	36.9	25.2 ± 6.4
NH_4-N	mg/L	0.29	2.87	1.55	1.04	0.58	0.18	0.29	0.31	0.89 ± 0.93
HCO_3^-	mg/L	275	362	192	294	315	619	383	392	354 ± 126
SO_4^{2-}	mg/L	552	553	805	654	1012	493	566	634	659 ± 171
Cl^-	mg/L	2051	1389	1652	1862	1323	829	856	934	1362 ± 468
PO_4-P	mg/L	0.17	0.18	0.20	0.29	0.26	0.30	0.22	0.23	0.23 ± 0.05
NO_3-N	mg/L	37.1	12.7	39.1	39.9	31.8	49.3	40.1	25.3	34.4 ± 11.2
NO_2-N	mg/L	0.06	0.06	0.23	0.26	0.06	0.07	0.17	0.05	0.12 ± 0.09
Si	mg/L	1.53	1.38	1.65	1.42	1.39	0.96	1.01	1.18	1.32 ± 0.24
COD	mg/L	13.9	39.8	22.4	24.2	32.1	20.9	30.1	19.5	25.4 ± 8.2
Color	Hazen	19.5	37.4	25.9	29.6	36.5	26.7	23.5	31.3	28.8 ± 6.2
TC	mg/L	117	133	103	117	111	215	122	99.0	127 ± 37
IC	mg/L	81.3	114	78.8	105	87.3	160	92.6	70.2	97.7 ± 28.7
TOC	mg/L	35.5	18.9	23.8	12.2	27.7	54.4	28.7	28.9	28.8 ± 12.5

pollutants and dissolved salts are not completely removed by just using an MBR technology [4].

Some municipalities and industries are dealing with high salt concentration in their wastewaters. The high concentration of salt may come from industrial effluents. Saline effluents are conventionally treated through physicochemical means, as biological treatment is strongly inhibited by salts. Most of such systems involve anaerobic or aerobic biological treatment. Biological treatment systems offer the best alternative to treat wastewaters containing carbonaceous organic and nitrogen matter. However, high salt content in wastewater is known to significantly reduce the treatment efficiency of conventional activated sludge, anaerobic, nitrification and denitrification processes [5]. Advanced membrane treatment processes such as MF (microfiltration), UF (ultrafiltration), NF, RO and MBR processes are used to treat municipal and industrial wastewaters [6–10]. Although MBR process seems to be alternative solution by providing a high quality effluent to discharge, it is not always possible to use this water directly as irrigation and process water if especially the salinity in water is high. Therefore, additional treatment for desalination would be needed [4].

Membrane separation processes have exhibited a great potential for the treatment of waters and wastewaters by complying with the increasingly strict legislation concerning potable water quality and allowable wastewater discharges worldwide. The MF, UF, RO processes including low pressure RO (LPRO) and NF have been progressively used for water and wastewater treatment in order to remove suspended solids and reduce the content of organic and inorganic matters. Application of NF and RO processes highly reduces TDS, salinity, hardness, nitrates, cyanides, fluorides, arsenic, heavy metals, color and organic compounds, e.g., total organic carbon (TOC), biological oxygen demand (BOD), chemical oxygen demand (COD) and pesticides, besides the elimination of bacteria, viruses, turbidity and TSS from surface water, groundwater, and seawater [11].

In this paper, practicability of membrane separation methods such as NF and RO for reuse of wastewater treated with MBR process was studied. Product water quality that was obtained by RO membrane (BW30) and NF membrane (NF90) was assessed by comparison of the membrane permeate water quality with Turkish water quality classification and FAO irrigation water standards.

2. Materials and methods

Studies were done using a mini pilot-scale spiral wound NF/RO membrane system installed in a portable laboratory that is located at ITOB Organızed Industrial Zone Wastewater Treatment Plant (Fig. 1). MBR treated wastewater was primarily sent to two car-