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Evaluation of MBR treated industrial wastewater quality before and after desalination by NF and RO processes for agricultural reuse

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ABSTRACT

In this study, the quality evaluation of membrane bioreactor (MBR) treated wastewater was performed for its reuse in irrigation. In addition, the qualities of MBR effluents desalinated with nanofiltration (NF) and reverse osmosis (RO) processes were compared with the irrigation standards. MBR effluent was not found as appropriate water for irrigation because of its high salinity. According to water quality measurements (especially SAR and EC values) it was considered that NF and RO permeates could decrease the soil permeability if they are used directly for irrigation. According to the results of SAR-EC analyses, the mixture of MBR effluent with RO permeate at a volume ratio of 2:1 (MBR effluent:RO permeate) was found to be suitable for irrigation to suppress the harmful effects of MBR permeate such as salinity. Using such mixture could also ameliorate adverse effects of RO permeate in terms of infiltration.

1. Introduction

Requirement for clean water increased with increasing population, climate change and increasing industrialization. Fresh water resources are sufficient only in some parts of the World. It was estimated that 50% of the world population will live in water stressed regions by 2025 [1,2]. This shows that it is important to manage available water resources and find new sources by using advanced water treatment processes.

Limitations of water resources lead to decrease in usage of water for irrigation purposes since other requirements are more imminent [3]. Agricultural applications use nearly 70% of the total amount of water withdrawn [1]. Specific quality requirements have to be sustained in order to utilize water for optimum crop production.

There is an increasing interest for the reclamation of industrial wastewaters for irrigation purposes. The main driving force of this interest is harder to achieve requirements for drinking water and process water production [1].

Membrane bioreactor (MBR) systems have been used for wastewater treatment as a potential technology for especially municipal wastewater treatment. MBR is an alternative biological treatment method combined with membrane filtration to conventional activated sludge process (CAS) with its low footprint, ability to operate under high total suspended solid (TSS) and production of higher quality effluent [4]. Depending on the desired effluent quality, industrial organizations often prefer CAS over MBR due to its lower costs [5,6]. On the other hand, MBR effluent should be demineralized if the salinity is high prior to utilization of MBR effluent for irrigation. Therefore, nanofiltration (NF) or reverse osmosis (RO) processes as post-treatment steps should be integrated with MBR system for demineralization.

Recently, some studies with NF and RO membranes were performed for desalination of the effluents of municipal wastewater treated with activated sludge processes [7,8]. Also, it is known that the use of MBR prior to RO as a pre-treatment unit, when a biological treatment is needed, gives better results than other conventional treatment combinations [9,10].

Some preliminary tests on the performances of integrated MBR-NF and MBR-RO systems were published also [11,12].

There are some plants operating to produce water for agricultural irrigation purposes by the use of RO technology [13–15].

There are variety of parameters to be achieved in order to obtain the optimum irrigation water such as salinity, pH, ionic toxicity (depending on the concentrations of sodium, chloride, borate, nitrate, etc.) and sodium hazard on soil infiltration [16].

One of the most important measures in evaluating irrigation water quality and infiltration problem potential is sodicity in water and soil,

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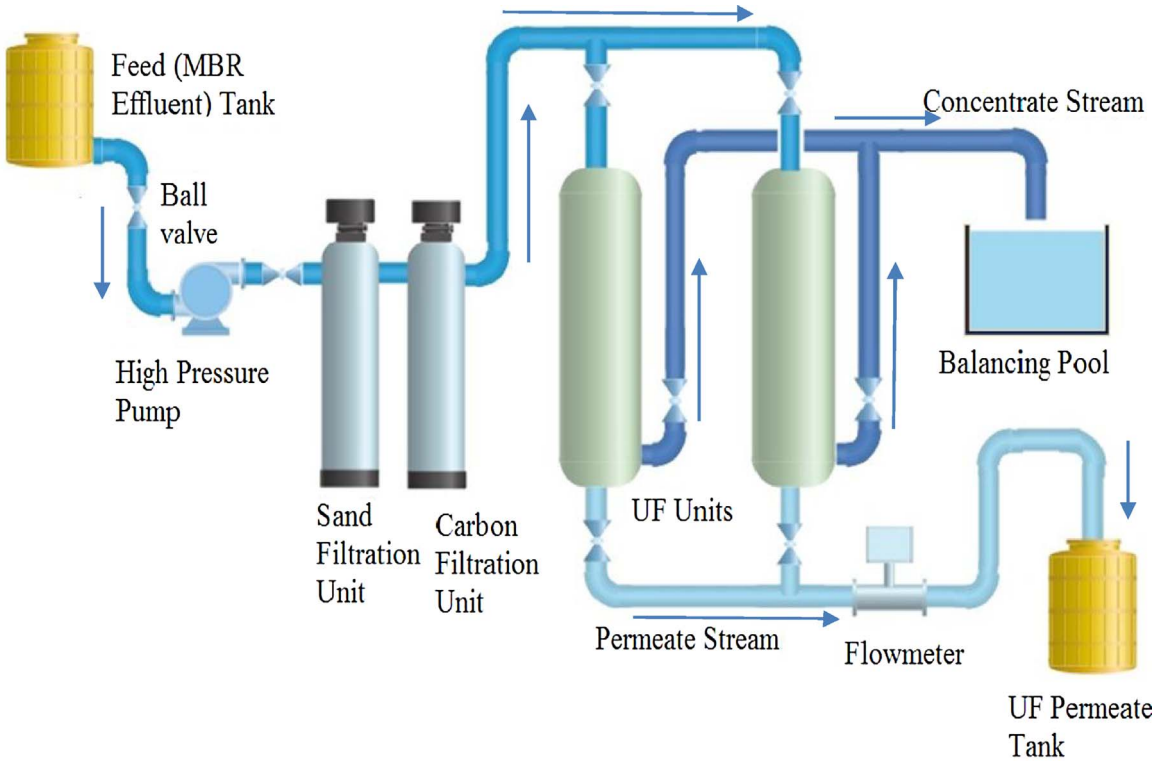

Fig. 1. Flow scheme of pilot UF system.

Table 1
NF/RO membrane properties [21,22].

Membrane	Membrane Type	Producer	Active membrane area (m^2)	pH range	Maximum Temperature (°C)	Maximum Pressure (bar)
TM620-400	NF	Toray	37	2–9	45	41
TM720D-400	RO	Toray	37	1–13	45	41

stated by a dimensionless parameter which is called the Sodium Adsorption Ratio (SAR) and defines sodicity in terms of the relative concentration of sodium (Na) compared to the sum of calcium (Ca) and magnesium (Mg) ions in a sample [17]. The SAR value was calculated by using Eq. (1).

$$SAR = \frac{Na^{+}\left(\frac{meq}{L}\right)}{\sqrt{\frac{1}{2}(Mg^{2+} + Ca^{2+})\left(\frac{meq}{L}\right)}} \quad (1)$$

Similar to SAR, PAR [Potassium Adsorption Ratio] is also stated as a standard sometimes and it shows the negative effects of potassium ion on soil, which is calculated by using Eq. (2) [18].

$$PAR = \frac{K^{+}\left(\frac{meq}{L}\right)}{\sqrt{\frac{1}{2}(Mg^{2+} + Ca^{2+})\left(\frac{meq}{L}\right)}} \quad (2)$$

Smith et al. [18] stated extra parameters to evaluate the effect of water on soil properties such as monovalent cation adsorption ratio (MCAR) and cation ratio of structural stability (CROSS); yet there are no standards about these parameters.

Although so-called toxic compounds may create harmful effects on plant, most of these compounds are also required in small amounts [19]. Therefore, it is predictable that RO permeate, due to its high rejections, may not be feasible to use in irrigation.

Some studies indicated that blending MBR and RO effluents can both produce water viable for irrigation in the means of salinity and influence on soil, and reduce the amount of treated wastewater discharged at the same time [16,20].

The aim of this study is to identify, treat and evaluate MBR treated wastewater for its reuse in agricultural irrigation in accordance with various international standards. A quality analysis was performed for MBR permeate, NF and RO permeates of MBR effluent and tap water (control unit).

2. Material and methods

2.1. Treatment of MBR effluents by NF and RO processes

The MBR effluent was collected from the exit stream of wastewater treatment plant of ITOB Organized Industry Zone located in Tekeli, Menderes, Izmir. The desalinated water samples of MBR effluents were obtained through a pilot-scale NF/RO treatment systems installed at ITOB wastewater treatment plant. A pre-treatment process was applied to MBR effluents prior to NF/RO treatment system as a pre-treatment method. This pre-treatment system includes a sand filtration unit, carbon filtration unit and two Inge Dizzer XL 0.9 MB 60 W model UF membranes. Flow scheme of UF system was shown in Fig. 1.

The NF system has three TM620N-400 model Toray NF membranes while the RO system consists of three TM720D-400 model Toray RO membranes. Both systems are connected in a pyramidal configuration where the concentrate stream of the first two membranes (TM620N-400 model Toray NF membrane or TM720D-400 model Toray RO membrane) is fed to the third membrane. This configuration was selected over single membrane application due to its higher water recovery. All membranes are made up of spiral wound modules. Properties of