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Treatment of laundry wastewater using polyethersulfone/polyvinylpyrollidone ultrafiltration membranes

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ABSTRACT

In this study, laundry wastewater filtration was studied using hydrophilic polyvinylpyrollidone (PVP) modified polyethersulfone (PES) ultrafiltration membranes. The performances of PES/PVP membranes were assessed using commercial PES membrane with 10 kDa in ultrafiltration. Operating parameters The influence of transmembrane pressure (TMP) and stirring speed on laundry wastewater flux was investigated. A higher permeate flux of 55.2 L/m^{2}h was obtained for modified PES membrane with high concentration of PVP at TMP of 500 kPa and 750 rpm of stirring speed. The separation efficiencies of membranes were also studied with respect to chemical oxygen demand (COD), total dissolved solids (TDS), turbidity and conductivity. Results showed that PES membrane with 10% of PVP had higher permeate flux, flux recovery and less fouling when compared with other membranes. Higher COD and TDS rejection of 88% and 82% were also observed for modified membranes due to the improved surface property of membranes. This indicated that modified PES membranes are suitable for the treatment of surfactant, detergent and oil from laundry wastewater.

1. Introduction

The three major fundamental concerns of current and future water resources are lack of water, poor water quality and water related debacles (UNESCO, 2003). Enhancing water quality and moderating water shortage are nearly connected to the grey water management. Laundry water is one type of gray water, which consists of high concentrations of chemicals from soap powders as well as bleaches, suspended solids and possibly oil, paints etc. These have chemical oxygen demands (COD) values of 1200–20,000 mg/l, while laundries that wash items from households and hotels contain effluents with COD values of 400–1200 mg/l (Ciabatti et al., 2009). The toxic effects of these pollutants are listed in Table 1. These pollutants are major alarming threaten to the ecosystem and toxic to the humans (Gross et al., 2007).

Treating laundry water before its release into aquatic frameworks therefore, significantly add to ensuring the earth and enhancing general wellbeing and living states of groups. Thus proper laundry wastewater treatments are mandatory to remove contaminants before its discharge into the environment. The major conventional treatment of laundry wastewater methods are coagulation, floatation, adsorption, chemical oxidation and biological treatments (Kim et al., 2008). Coagulation and flocculation techniques are followed to facilitate the agglomeration of large particles. However, such methods have a drawback as ineffective in the decolourisation of laundry effluent (Nicolaidis and Vyrides, 2014). Another method such as chemical treatment has propensity of generate waste, which require secondary unit operation steps. Later, biological treatment was employed prior to chemical treatment for the effective removal of COD (Nicolaidis and Vyrides, 2014). It requires a higher time for the reclamation.

Recently, effective treatment of industrial effluents as well as ground water can achieve using membrane separation process. Such membrane also paid in stringent regulation made by environmental agencies. The membrane separation process have number of advantages over conventional methods including fulfillment of higher standards, reducing environmental impact of effluents, land requirements (Janpoor et al., 2011; Braeken et al., 2004). Bhattacharyya (1987) attempted the treatment of laundry wastewater using commercial ultrafiltration membrane. Ramon et al. (2004) compared the filtration efficiency of low load gray water using ultrafiltration and nanofiltration membranes. In addition, Ciabatti et al. (2009) employed an ultrafiltration membrane and achieved an effective removal efficiency of contaminants in laundry effluent.

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Table 1
Toxic effects of laundry water constituents.

Source of pollutants	Effects	References
Surfactant	• The surfactants had both high or moderate toxicity and most toxic (mmol/L) components. They contributed between 10.4% and 98.8% of the toxicity of the detergents with a mean contribution of 40.7%.	Warne1 and Schifko (1999), Braga and Varesche (2011), Morel and Diener (2006)
	• Surfactants create a bacterial population rise, transmitting through the food chain to protozoa, which are more sensitive to laundry wash toxins	
	• Linear alkyl benzene sulfonate (LAS) is the most widespread anionic surfactant and its concentration may vary from 17 to 1024 ppm. It is derived from petroleum bi-products, is quite rapidly degraded aerobically, but only very slowly or not at all under anaerobic conditions. It generate carcinogenic and toxic by-products.	
Detergents	• All detergents will destroy fish mucus membranes and gills to some degree. The gills may lose natural oils, interrupting oxygen transfer. Damaged mucus membranes leave fish susceptible to bacteria and parasites. Detergents are toxic to fish near 15 ppm, killing fish eggs at 5 ppm and cause endocrine disrupting and estrogenic effects in fish.	Zaneti et al. (2011)
Oil/grease	• Laundry water contains 8–35 mg/l of oil/grease. It adversely affect the esthetic merit, water transparency and Dissolved Oxygen (DO) content in the water	ChristovaBoal et al. (1996), Brasino and Dangler (2007)

However, the major disadvantage of membrane process is fouling (Koh et al., 2005; Zhao et al., 2013). The general methods required to overcome fouling are the modification of membrane with hydrophilic additives and optimization of operating parameters. The process parameters such as transmembrane pressure (TMP), stirring speed and cross flow velocity are help to enhance the flux and improving the membrane performance (Mohammadi et al., 2003; Sondhi et al., 2000).

Treatment of laundry water using ultrafiltration membranes and its studies are limited. In this study, ultrafiltration membranes were used for laundry wastewater treatment by optimizing the parameters of transmembrane pressure and stirring speed for its reuse and recovery. PVP modified PES membranes were compared with commercial PES membrane with 10 kDa as a function of the removal and flux performance of laundry wastewater. It is expected that the result of this work will provide suitable use of laundry water for landscape irrigation in small communities and households.

2. Materials and methods

2.1. Materials

Commercial grade Polyethersulfone (PES 3000) was purchased from M/s solvay chemicals India Ltd. and polyvinyl pyrollidone (PVP) from M/s Central drug house, India Limited. The solvent dimethyl formamide (DMF) was obtained from M/s Loba Chemie Pvt Ltd. Sodium Lauryl sulfate (SLS) were purchased from M/s. Qualigens fine chemicals, India Ltd. The commercial membrane Polyethersulfone with 10 kDa molecular weight cutoff (MWCO) was received from M/s Orelis Environmental SAS, France.

2.2. Membrane synthesis

The modified membranes were fabricated by phase inversion method using PES as base polymer and water as non-solvent. PVP as modifier was added in varying concentration of 5% and 10%. The procedure for the membrane fabrication was followed by our earlier publication (Thuyavan et al., in press). Initially PES was dried in a hot air oven at the temperature of 60 °C for 8 h to remove moisture. The casting solutions were prepared by adding PES and respective additives in DMF as solvent at room temperature. The casting solutions were stirred continuously for 4 h until clear homogenous solutions were obtained. The solution then cast onto the glass plate for the thickness of about 400 μm with the help of a thin film applicator followed by evaporation for a period of 30 s. The glass plate was immersed immediately into a distilled water bath maintained at 20 °C. The modified PES membranes were cut into the required area corresponding to dead-end UF experiments employed in this study. Later, synthesized membranes were stored in 0.1% formalin solution.

2.3. Membrane water uptake capacity and porosity

Both modified and commercial membrane samples were cut into 2 cm × 2 cm size and immersed in distilled water for 24 h at 30 °C. The weight of the wet membrane samples (W_1) were calculated after removing the surface water by blotting with tissue paper. It was dried at a temperature of 75 °C in an oven for 24 h and again weighed (W_2). The water uptake (%) was calculated by (Srivastava et al., 2011)

$$\text{Water uptake } (\%) = \frac{W_1 - W_2}{W_1} \times 100 \quad (1)$$

The porosity of the membranes was analyzed by considering the weight of membranes at dry and wet states. It was calculated by the following equation (Gohari et al., 2013)

$$\text{Porosity } (\%) = \frac{W_1 - W_2}{\rho_w \times A \times l} \times 100 \quad (2)$$

where, ρ_w = density of water at room temperature (1 g/cm^3); A = area of membrane (cm^2); l = thickness of wet membrane.

2.4. Ultrafiltration membrane process

The membrane filtration experiment was studied using a