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Recycling of Direct Dyes Wastewater by Nylon-6 Nanofibrous Membrane

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Abstract: Textile processing industry generally requires significant amounts of process water for cleaning, rinsing, and dyeing purposes and therefore releases significant amounts of dye polluted waste streams into the environment. In recent years considerable attempts have been made to remove pollutants from these waste streams. One of the promising methods in this regard is membrane filtration. Utilizing this separation method would necessitate the manufacture of effective membranes, such as nanofibrous membranes. Electrospinning is a relatively simple method to produce nanofibers from solutions of different polymers and polymer blends. This paper presents the results of a research on manufacturing a membrane filter by electrospinning Nylon-6 nanofibers on a carbon coated polyurethane substrate and implementing this membrane for dye removal in a filtration system. The membrane sample contained nanofibers with an average diameter of 211 nm. Experiments were run with C.I. Direct yellow 12 as a typical dye pollutant. The effect of coating time, transmembrane pressure, and two different pretreatment methods were investigated and it was observed that by the application of 150ppm coagulant material at 0.75 bar pressure, a filtration efficiency of 98% was achieved.

Keywords: Electrospinning, nanofibrous membrane, filtration, salt removal efficiency, dye removal efficiency, Chemical Oxygen Demand, coagulant materials, static state, wastewater, nylon 6, recycling, absorbance wavelength, polyurethane, scanning electron microscope, flux.

1. INTRODUCTION

Textile industries produce large volumes of wastewater polluted with dyes [1-3]. Among all dyeing processes, direct dyes and basic dyes, release the highest quantities of dye molecules in the wastewater [4]. Various methods have been used for removal of dye molecules include ozonation [5,6], biological treatment [7,8], adsorption [9-11], ion exchange [12,13], coagulation [14], membrane processes [15-18] and etc. Recently, pressure-driven membrane processes, such as reverse osmosis, nanofiltration, and ultrafiltration have been considered for the treatment of dye containing industrial wastewater.

A membrane acts as a barrier for separating two distinct phases. Its major function is to discriminate species in between the two phases in which it comes into contact with, and transport the species from one phase to another. The first phase of the separation process is referred to as "feed" and the second is known as "permeate". This separation is usually done under a driving force such as pressure or concentration gradient. Membranes can perform all types of separations that conventional separation processes can. Compactness, low-cost operation, energy-efficiency, and high throughput are qualities of membrane separation processes that enable them to compete with conventional separation processes. Most importantly, membranes are highly utilized in waste treatment, water purification, and in clarification and concentration processes.

Electrospinning as an appealing field of investigation has been considered more and more in recent years. This process has the ability to produce fibers from sub-micron to nanometer scale diameter through an electrically charged jet of polymer solution or melt. During the electrospinning process, a polymer solution is ejected from a small nozzle under the influence of a voltage as high as 30 kV. The build up of electrostatic charges on the surface of a liquid droplet induces the formation of a jet. The jet is subsequently stretched to form a continuous fiber. The solvent evaporates before it reaches the collecting screen, and solid fibers are collected on a conductor surface, and form nonwoven mats [19].

So far a large number of polymers have been successfully electrospun. Electrospun nanofibrous membranes possess several attributes such as high porosity (with pore sizes ranging from submicron to several micrometers), interconnected open pore structures, high permeability for gases, and a large surface area per unit volume. These properties make them very attractive in separation technologies. One of the most important applications of these fibers is in membrane filtration. Membrane filtration includes air filtration and liquid filtration. In the field of air filtration, many studies have been conducted on high efficiency air filters [20], antimicrobial filters [21-24], coalescence filters [25], catalytic filters [26,27] and affinity filters for highly selective separation [28,29]. In the field of liquid filtration, some researchers have used nanofibrous membranes such as polysulfone, nylon-6, cellulose and Poly(vinylidene fluoride) as a pre-filter [30-33]. The application of nanofibrous membranes as filters has been mentioned in various other studies [34, 35].

However, the application of electrospun nanofibrous membranes should make more progress in other areas of separation, especially in pressure-driven liquid separations such as micro-(MF), ultra-(UF) or nano-(NF) filters/membranes. The major problem with electrospun nanofibers is that they are difficult to handle as they usually accumulate electrostatic charges during the electrospinning process. This accumulation would increase as the thickness of the electrospun mesh grows. Hence, in contrast with conventional cast membranes, electrospun fibrous membranes require additional support in order to provide sufficient strength [33]. Thus, nowadays much of the applications of electrospun nanofibrous membranes in separation technologies are based on hybrid systems [36, 37]. In such systems, nanofibers can be placed over a support (as in commercial air filters) [38], 'sandwiched' between various layers [36] or blended together with microfibers [37].

This paper explores the construction of a new kind of nanofibrous membrane for the purification of dyes from textile wastewater. An electrospun nylon-6 fibrous membrane was prepared and used as a membrane material without any treatment for water filtration due to its excellent chemical and thermal resistance and high wettability.

2. MATERIALS AND METHODS

2.1. Nanofibers Processing

Nylon-6 solutions were prepared from Nylon-6 pellets purchased from Tehran Polymer Industry. The formic acid, purchased from Merck, was utilized as a solvent. Polymer solutions of several

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