



Analysis of PAN and PEGDA Coated Membranes for Filtering Water with Reduced Fouling and Increased Heavy Metal Adsorption

Kristin Wong^{1,3,*^}, Brendan Liu^{1,3,*}, Serena McCalla², Benjamin Chu⁴, and Benjamin Hsiao⁴

Student¹, Teacher²: Jericho High School, 99 Cedar Swamp Road, Jericho, NY 11753

Intern³, Mentor/Professors of Chemistry⁴: Stony Brook University, Stony Brook, New York 11794

*These authors contributed equally

^Correspondence: knw1095@gmail.com

Abstract

An increase in United States water pollution has been denoted over the past 30 years. With a rise in water pollution, enhanced filtration and heavy metal remediation methods are imperative. Membrane fouling, the process whereby extraneous particles deposit onto a membrane surface and degrade the membrane's performance, is a major issue facing ultrafiltration. This study's goals were to enhance membrane flux and anti-fouling performance with a PEGDA filter and to compare the efficiency of PVAm and PEI for heavy metal adsorption. Electrospinning was employed to create membrane platforms for coating and grafting polyethylene glycol diacrylate (PEGDA), N,N'-Methylenebisacrylamide (MBAA), cellulose nanofibers (CNF), polyvinyl alcohol (PVAm) and polyethylenimine (PEI). The anti-fouling performance of electrospun PAN membranes was determined by coating the surface with CNF, PEGDA, and MBAA, which were chosen due to their hydrophilic and low-fouling properties. Coating the top layer of the membrane with these hydrophilic polymers achieved a flux that remained constant at the quickest rate, at least 20% quicker than that of polyethersulfone (PES) commercial filters. The membrane containing .02% CNF and 0.2% PEGDA exhibited 90% rejection and 99% recovery, indicating that CNF and PEGDA exhibited better fouling resistance than PES. The high fouling performance of the commercial membranes can be attributed to the highly hydrophobic nature of PES, making it prone to membrane fouling. In order to evaluate heavy metal adsorption membrane performance, electrospun PAN membranes were immersed in concentrations of H₂SO₄ (50-70 wt%) to introduce negative charges creating bonds between PVAm, PEI, and the PAN membrane. The outcomes of static adsorption tests indicated that PVAm adsorbed heavy metals at a rate that was ~8-30 mg/g greater than PEI. The higher adsorption rate can be attributed to the increased surface area resulting from the grafted PVAm. In the future, a combined PEGDA, PAN, and polyvinyl chloride (PVC) membrane should be designed to adsorb heavy metals while reducing fouling. The efficacy of modified periods of extensive filtration should also be evaluated.

Introduction

Although the world population is 6.8 billion, 1.2 billion people do not have clean drinking water access¹. It is estimated that one-third of the population will face severe water shortages by 2025². As the world population increases by 80 million annually, water shortages also threaten to reduce the global food supply³. Most

desalination plants currently rely on flash evaporation, distillation, and electrodialysis for the removal of contaminants, like salt, from water. However, widespread applications are limited by high-energy costs in many third world countries⁴.

In parallel, high levels of heavy metal pollution have been detected in various water resources throughout the world⁵. Over 80% of wastewater in developing countries is discharged without treatment, contaminating coastal areas, rivers, and lakes⁶. With the alarming increase in industrialization and urbanization, the consumption of Chromium (VI) water has been categorized as a major dilemma across the United States⁷. Ingestion of this heavy metal causes detrimental and permanent health damage due to its carcinogenic effects. Apart from lung cancer and death, the most common effects of ingestion of Chromium (VI) on humans are respiratory problems, genetic alteration, kidney and liver damage, and weakened immune systems⁸.

Current day filtration techniques include reverse osmosis, hydroxide precipitation, ion exchange, and solvent evaporation. However, many of these methods require large quantities of time and energy, yet produce miniscule filtration and adsorption capabilities.

Electrospinning, a process that uses an electrical current to draw very fine fibers from a liquid, reduces fabrication time for membranes, while introducing small pore sizes for efficient filtration. The use of electrospinning in creating the fibrous membranes allows for random, yet minute pore sizes to be established onto the substrate⁹. Introducing small pore sizes on the surface of the membrane increases surface area for enhanced heavy metal ions adsorption.

Polymer grafting produces one or more types of polymer blocks and chains connected to a primary chain of a macromolecule¹⁰. The introduction of sulfuric acid etches negative charges on the surface of the membrane for polymer grafting¹¹. These negative charges are complemented by the positively charged polymers, which will present active sites that attract the heavy metal ions onto the membrane surface¹².

The use of thin film composite (TFC) membranes, which typically consist of 2-3 thin layers, is a robust and efficient method of purifying water¹³. Yung et al. (2010) demonstrated a novel type of TFCs, called thin film nanocomposite (TFNC) membranes. The bottom layer of this three-tier membrane is a tough, non-woven fibrous material, polyethylene terephthalate (PET). The mid-layer, which supports the barrier layer, consists of electrospun polyacrylonitrile (PAN) fibers, which are typically used for the fabrication of microfiltration (MF) and ultrafiltration (UF) membranes¹⁴. The top coating layer, which serves as the barrier between solutes and permeates, is constructed with ultra-

