Chapter 8
Polymers in Water Purification

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ABSTRACT

Polymers play an important role in water purification due to advantages such as the enhanced capacity of the treatment plant, the lowering of sludge production compared to inorganic coagulants, etc. The formation of clay/polymer complex during the coagulation-flocculation process facilitates the removal of toxic pollutants from water. Although polymers have been utilized in the coagulation-flocculation processes, there is not much information about the relationship between polymer structure and treatment performance. The use of polymers as membranes is mainly due to their flexibility, ease of handling, and cost-effectiveness compared to inorganic membranes. However, they also have some disadvantages, such as chemical attacks, membrane fouling, etc. Therefore, recent studies have focused on improving chemical resistance, antifouling properties, etc. through blending and surface modification. This chapter will review the applications of various polymers in water purification, the deficiencies of current membranes, and possible ways of improving them with novel polymer chemistry.

INTRODUCTION

One of the most significant challenges of the 21st century is to provide clean water at an affordable cost. According to a 2017 report by the World Health Organization (WHO), 2.1 billion people lack access to a safe drinking water supply at home. Although much water is available on the earth, most of it is not good (pure) enough for human consumption due to the various impurities in water such as suspended solids, dissolved solids, synthetic chemicals, metal ions, nitrate, phosphate, and pathogens. Therefore,

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drinking water resources require appropriate treatment to remove these disease-causing agents. The treatment methods depend on the water source (surface water, underground water, etc.) and the end-use (drinking, irrigation, etc.). The most common water treatment steps to provide safe drinking water involve coagulation, flocculation, sedimentation, filtration, disinfection, fluoridation, and pH correction.

Polymers play an important role in coagulation, flocculation, and filtration. (Kawamura, 1976; Geise et al., 2010) The formation of clay/polymer complex during the coagulation/flocculation process facilitates the removal of toxic pollutants from water. The coagulation step is followed by a separation step of sedimentation or flotation with a final polishing by filtration. The use of polymer in the coagulation/flocculation process offers some advantages, such as the increased capacity of the treatment facility, the lowering of the dosage of other chemicals, and sludge production. The use of polymer in coagulation/flocculation also widens the range of water that can be treated.

Polymers are also used as membranes in reverse osmosis, nanofiltration, ultrafiltration, and microfiltration processes. (Geise et al., 2010) Membranes made from polymeric materials are cheaper than those obtained from inorganic materials. (Ng et al., 2013) Polymeric membranes can also be used to achieve high water production capacity. (Giwa et al., 2019) These membranes are easy to handle. These can also be arranged in different configurations for optimum performance. (Le & Nunes, 2016) This chapter will review the applications of various polymers in water purification, the deficiencies of current membranes, and possible ways of resolving them with novel polymer chemistry.

Background

The vast majority (~97%) of Earth's water is saltwater. Out of all freshwater (~2.5%) on Earth, most of it is locked into polar icecaps or mountain snow cover and thus, is inaccessible. Thus, only ~1% of all freshwater is usable by humans. This amount is not enough since more than 1 billion people worldwide are without safe drinking water. (Shannon et al., 2008) The lack of safe drinking water not only impacts human health (via various water-related diseases) but also impacts the economy and energy sectors. For example, the overall loss in Southeast Asian countries (Indonesia, Cambodia, Philippines, and Vietnam) is $ 9 billion (2% of GDP) due to the lack of clean water and basic sanitation. (Geise et al., 2010) The world population is going to increase by 2 billion by 2050. The increased population will enhance the demand for water. Thus, it is clear that developing low-cost and highly efficient water purification methods is of utmost importance.

Coagulation is a process where the original dispersion is destabilized by overcoming the forces which maintain the stability (Hutchison & Healy, 1990). Flocculation is a process where the destabilized particles come together to form larger agglomerates. It is worth mentioning that the two processes can take place following the addition of a single organic polymer instead of an inorganic salt followed by a polymer. These high molecular weight polymers are also known as polyelectrolytes. Polymers are also used as membranes in reverse osmosis, nanofiltration, ultrafiltration, and microfiltration processes. Because of their energy efficiency, membranes are receiving much attention recently. The type of polymer used for filtration is crucial in determining the quality of water and the cost of water production. Proper selection of membrane is required to avoid problems such as frequent membrane replacement and undesired energy consumption. Although many polymeric materials have been developed and successfully used in removing pollutants from wastewater under laboratory settings, improvement in their performance in removing suspended and dissolved impurities, heavy metals, dyes, etc., to meet the environmental legislation is necessary. Thus, further research is needed to develop polymers capable of removing pol-