Development of Fibrous Systems for Environmental Applications

Student: Marianna Messina

Department of Engineering, INSTM RU, Niccolò Cusano University,
Via Don Carlo Gnocchi 3, 00166, Roma, Italia
marianna.messina@unicusano.it

Mentor: Ilaria Cacciotti

Department of Engineering, INSTM RU, Niccolò Cusano University,
Via Don Carlo Gnocchi 3, 00166, Roma, Italia
Ilaria.cacciotti@unicusano.it

Abstract. *Recently, nanofibers have been considered as one of the sustainable routes with enormous applicability in various fields, such as biomedical and environmental ones. They have promising properties, including interconnected porous structure, lightweight, high porosity, and large surface area, and can be easily modified with the addition of specific nanofillers to enhance their suitability for specific applications. This work is focused on the development of fibrous systems for application in the environmental sector. In particular, functionalized polylactic acid (PLA) fibres were produced for the removal of heavy metals in the environmental sector.*

Keywords. Fibers, biopolymers, electrospinning technique, heavy metals, water purification

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1 Introduction

In the environmental field, toxic heavy metal contamination of the aquatic ecosystem is a significant problem at a global scale [1,2]. This leads to irreversible accumulation of the heavy metals in the various tissues of sea animals, thus endangering the entire aquatic biota [3,4]. The conventional methods currently employed to adsorb these contaminants are precipitation, membrane filtrations and adsorption [5,6]. Nowadays nanotechnologies and nanomaterial sciences have a focus on fabricating nanomaterials that can be used in various water purification applications.

Recently, nanofibers have been considered as one of the sustainable routes with enormous applicability in various fields, such as biomedical and environmental [7].

They have promising properties, e.g., interconnected porous structure, lightweight, high porosity, and large surface area, and can be easily modified with other polymeric materials or nanomaterials to enhance their suitability for specific applications. Electrospinning is one of the most important techniques utilized for their production [7]. Indeed, the electrospinning is a simple technique that allows the production of small diameter fibers. It is a process by which a polymer in solution can be spun into small diameter fibers, thanks to a high potential electric field. A typical electrospinning setup (Fig.1) consists of a syringe pump, a syringe containing the solution/suspension and supplied with a needle, a high voltage generator, and a metallic collector [7].

In this context, fibrous systems were developed for the application in the environmental (e.g., removal of heavy metals) sector, using poly(lactic acid) (PLA), due to biocompostable and biodegradable properties in order to obtain a lower environmental impact (Figure 1). It can be easily electrospun and the obtained fibers were used as supports for the alginate and chitosan deposition. Alginate derived from brown algae is a highly popular material for the biosorption of heavy metals due to its low cost, and high affinity to metals via gelation. Indeed, it is characterised by the presence of carboxy and hydroxy groups which can crosslink with cations. Thus, due to the negatively charged carboxyl groups, it can electrostatically adsorb heavy metal ions by chelation [8]. Similarly, the chitosan, a low- cost natural polysaccharide produced from the deacetylation of chitin, has been used in many studies for the heavy metal ions adsorption [9].

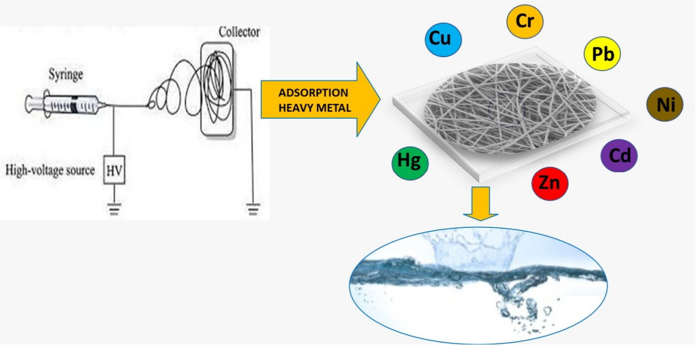

Figure 1. Electrospun fibrous membranes for the heavy metals adsorption

2 Materials and method

Polylactic acid (PLA) electrospun fibres, covered with alginate or chitosan, were produced, as promising heavy metals absorbers. The polylactic acid (PLA) nanofibers were made using the electrospinning technique. The process parameters of PLA nanofibers are the following ones: applied voltage 12 kV, flow rate 0.5 ml/h and needle-target distance 15 cm [10]. Successively, the coating procedures were set up, by dipping, respectively, the obtained nanofibers in chitosan (PLA@CS) and alginate (PLA@Alg) solutions, and then left dry.

As references, alginate and chitosan beads and films were prepared by ionic reticulation and solvent casting techniques,respectively.

The obtained fibers, bead and films were fully characterized from a chemical-physical characterisation. In particular, he produced beads were observed at optical microscope, whereas the films and fibers at scanning electron microscope (SEM). Swelling and solubility tests were carried out for the beads and films, respectively.

3 Results

The morphology of the electrospun PLA fibers was observed at SEM, evidencing the obtainment of uniform and randomly oriented defect free fibers. The obtainment of defect free chitosan and alginate coatings on the PLA fibers was demonstrated by means of SEM, as well as through water contact angle measurements, that evidenced a lower hydrophobicity due to the presence of the coating. The produced alginate and chitosan films looked homogeneous and uniform on the surface, without cracks and defects, as well as the obtained polysaccharide beads. Swelling tests carried out on alginate beads showed a slow water absorption in the initial phase, and the maximum water absorption (250 %) after 5 hours, reaching an equilibrium between 240 and 360 minutes, with an increase in size as high as 60 % of the initial diameter.

4 Conclusions

Homogeneous fibrous systems were successfully produced and the efficacy of the set up procedure for the polysaccharides coating was demonstrated by observation at SEM and contact angle measurements. Moreover, the not performed tests have shown that the developed fibrous systems present the physico-chemical characteristics appropriate for the heavy metals absorption. Future perspectives include the production of coated systems, in order to properly tailor their permeability, and of composite and blend systems, using selected inorganic fillers and also other biopolymers, as well as the demonstration of the heavy metals absorption capability by means of innovative analytical techniques.

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