CHAPTER

ELECTROSPUN NANOFIBROUS FILTRATION MEMBRANES FOR HEAVY METALS AND DYE REMOVAL

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1 INTRODUCTION

Recently, water pollution has been the foremost environmental complication, demanding the vital improvement of novel materials that could provide effective and applied ways for detecting and eliminating deadly agents from water bodies [1, 2]. Furthermore, the contamination of the water surface, including heavy metal ions, such as Cr^{6+}, Cd^{2+}, Pb^{2+}, Hg^{2+}, and Cu^{2+}, among others; dyes; and other pollutants, signifies a latent hazard to human and aquatic life [1–5]. Drinking water that contains heavy metals can cause cancer, kidney diseases, memory problems, high blood pressure, premature birth, brain damage, hearing loss, learning disabilities, and a lower IQ level in children [6–8]. Thus, eliminating these toxic metal ions from water bodies is very essential. Numerous approaches have been used for eliminating the metal ions from the water surface, such as ion. Exchange [9], reverse osmosis [10], chemical precipitation [11], membrane separation [12], and adsorption. Among all these methods, adsorption is generally observed as an outstanding process for wastewater treatment owing to its simplicity, effectiveness, and inexpensiveness [4–6].

Lately, agricultural waste- and bio-organic waste material-constructed adsorbents, such as husk rice, orange waste, and pinewood, have been employed for treating wastewater, owing to their high availability, low cost, and high adsorption effectiveness [13, 14]. Yet, these organic wastes typically include high amounts of chemicals and biological oxygen that are subsequently dumped into water bodies. It can be hazardous to marine life and can produce other ecological complications [13].

Nanostructured materials have recently been considered as the finest adsorbents, offering excellent metal binding sites owing to their outstanding high specific surface area-to-volume ratio [13, 15]. However, there are restrictions for using these materials because of their agglomerate tendencies, difficulties of control in morphology, and leaching problems that reduce the adsorption properties of materials [15, 16]. Some of these nanoparticles have already been recognized as toxic in much of the literature [17]. Many researchers have reported the toxic [12] and inflammatory [13] effects of metal and metal

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oxide nanoparticles in living cells. It has also been reported that carbon-based nanotubes are toxic [10] and allure granulomas in animal lungs [11]. The demands for an alternative technique for developing novel material include that it should be nontoxic, eco-friendly, nonagglomerate, and nonleaching, with high specific surface area-to-volume ratio and a high porosity for the effective purification of water, as well as protect the environment. Owing to the excellent characteristics of electrospun nanofibers, such as high porosity, flexibility, light weight, and low cost of membranes, they have appeared as the most favorable, vigorous materials for filtering and trapping metals ions, dyes, and other pollutants from wastewater [8, 9]. Lately, electrospinning technique has developed a widespread technique that is cost-effective and simple, allowing the manufacture of large micro or nanofibers membranes [12–14].

Polymer fibers manufactured through the electrospinning technique have drawn attention because of their extremely high porosity, high specific surface area-to-volume ratios, greater permeability, and slight interfibrous pore sizes that permit many potential applications in various fields [18, 19]. These excellent characteristics of electrospun fibers were effectively used as membranes or sorbents in a wide range of applications in the biotechnology, health care, and environmental fields, including submicroparticle separation, protein purification, air cleaning, and heavy metal ions and dye removal [12–19]. In addition, they show versatile applications for energy storage, defense, and security [19]. Fig. 1 shows the various applications of electrospun nanofibers in different areas. The data on the advanced applications of electrospun nanofibers, based on the published literature, is shown in Fig. 2.

However, the versatile applications of nanofibers as a water-filtering medium, which include the elimination of metal ions and dyes from water sources, are well recognized. Electrospun nanofibers, such as polyacrylonitrile (PAN) via amine assemblies, were reported as successfully eliminating toxic metal ions such as Pb^{2+}, Cu^{2+}, and CrO_4^{2-} from aqueous solution [20, 21]. Similarly, aminated PAN nanofiber mats were inspected for the successful adsorption of metal ions such as Pb^{2+}, Cu^{2+}, Fe^{2+}, and

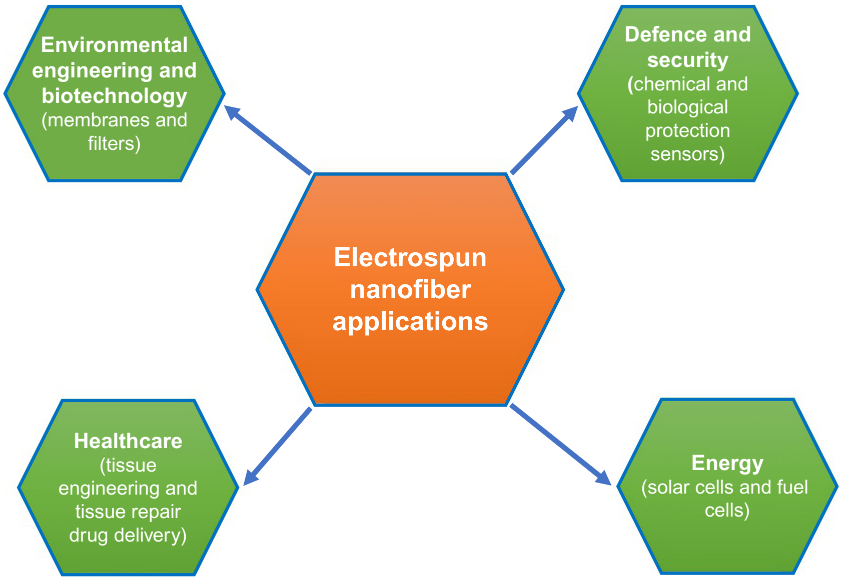

FIG. 1

Latent applications of electrospun fibers in different fields.

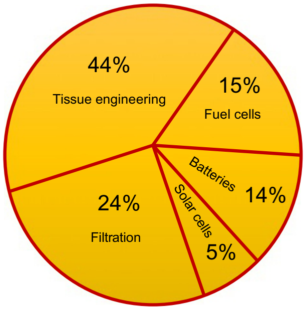

FIG. 2

Statistics data on the advanced applications of electrospun nanofibers reported in the literature (search made through med-link database).

Ag^+ from water [22, 23]. The effective adsorption of metal ions such as Pb^{2+}, Cd^{2+}, and Cu^{2+} and anionic dyes using polyethyleneimine nanofibers with a sufficient quantity of amino and amino groups have been reported [24, 25]. The excellent adsorption of Cu^{2+} and Pb^{2+} using Chitosan nanofiber mats from water have also been reported [26]. The adsorption of Cu^{2+} was studied using modified ultra-fine hydrolyzed PAN nanofiber mats [27]. A conductive polymer, such as polypyrrole, displays an outstanding capability for eliminating chromium from aqueous solutions [28–31].

To improve the adsorption properties of electrospun nanofibers, many researchers incorporated metal/metal oxide and organic nanoparticles into the nanofibers. PAN/$FeCl_3$-composite membranes are reported to remove 110 mg/g of chromium, including changes Cr^{4+} to Cr^{3+}, which is less harmful [32]. The iron content in PAN nanofibers increases the adsorption of chromium by diffusing into the solution and reacting the chromium ions, dropping the chromium concentration in the solution. Li et al. informed the successful adsorption of 150 mg/g of Cr^{6+} from aqueous solution using composite polyamide 6 and Fe_xO_y membrane [33]. The growth of Fe nanoparticles into polyamide 6 supports in reduction/adsorption of Cr^{6+} to Cr^{3+}.

In this chapter, we provide the overview investigation of processing technique, fundamental aspect, electrospinning parameters, and their potential application of nanofiber membranes for eliminating heavy metal ions and dyes from water bodies. Furthermore, future trends and challenges of electrospun nanofibers are also reported.

2 PROCESSING TECHNIQUE

In recent years, many techniques have been explored for the manufacture of polymer electrospun nanofibers. Yet, their worth is limited because of inadequate production rates, cost, and possible fiber assembly. A few of these techniques include the following:

2.1 DRAWING

This method produces extensive single strands of polymer nanofibers at one time. The dragging method is carried out via solidification, which changes liquid material into electrospun fiber. Solvent evaporation is required in the circumstance of dry spinning, whereas for melt spinning, a cooling step is essential. However, it has restrictions of using only a viscoelastic material that can experience widespread distortions while creating the fibers.

2.2 TEMPLATE

This progression uses a membrane that has a nanoporous pattern with self-possessed cylindrical pores to produce nanofibers, including solid nanofibers called fibrils and hollow nanofibers called tubules. Nanofibers such as tubules and fibrils can be used for numerous materials; conducting polymers, carbon, semiconductors, and metals/metal oxides can be fabricated. Nevertheless, a disadvantage of this technique is that it cannot produce large numbers of nanofibers at one time.

2.3 THERMAL-INDUCED PHASE SEPARATION

In thermal-induced phase separation, the polymer is distorted into a nanoporous foam. This method is a time-consuming process that splits a homogeneous polymer solution into a multiphase solution through thermodynamic variations. The method is extensively used to produce frameworks for tissue engineering.

2.4 SELF-ASSEMBLY

This method is employed to yield peptide nanofibers and peptide amphiphiles. This process is encouraged via the three-dimensional structures of the naturally folding progression of amino acid remains to obtain proteins. The progression involves numerous driving forces, including hydrophobic interactions, hydrogen bonding, van der Waals forces, and electrostatic forces. It is affected by exterior parameters, such as solution pH and ionic strength. This technique is also time-consuming.

2.5 ELECTROSPINNING

Electrospinning is the most frequently used method to fabricate fibers extending in diameter from the submicron level to the nanometer level by using an electric force to induce the charged filaments of polymer solutions into fibers [18, 19]. This method does not need high temperatures and coagulation chemistry to yield nanofibers from a polymer solution, which results in the predominant production of fibers using bulky and composite molecules [18]. Electrospinning is an old technique of fiber whirling; nevertheless, it is presently the utmost effective, progressive technique for producing large nanofibers. The name "electrospinning" was first coined from "electrostatic spinning," which dates to 1897 [18, 19].

History places the beginning of electrospinning in the 19th century. Rayleigh was the first to observe the electrospray technique in 1897, and later it was detailed deliberately by Zeleny in 1914 [34]. Anton Formhals brought further developments to electrospinning, bringing it to commercialization and obtaining patents for the manufacture of textile yarns between 1934 and 1944 [35, 36]. He set up an experimental process for producing electric charges using artificial filaments for the manufacture of textile yarns. Furthermore, in 1960, Taylor reported the creation of cone-shaped droplet of the polymer at the tip of the needle after applying an electric field to it, which he later called "Taylor cone" [37].

In 1988, Simon reported that electrospinning could possibly be used to manufacture nanoscale and submicron-scale fibrous mats of polystyrene and polycarbonate and precisely proposed in vitro cell substrates be used. He further reported that the changes in the fibers' surface chemistry depend on the electric field polarity during electrospinning [38]. In the 1990s, Reneker and Rutledge confirmed that through electrospinning, various organic polymers could form nanofibers [39, 40]. Subsequently, publications regarding electrospinning have increased greatly.

3 FUNDAMENTAL ASPECT OF ELECTROSPINNING

The processing tools for electrospinning include a high voltage supply, a metal-collecting screen, and a capillary tube with a pipette/small-diameter needle. To obtain an electrospun fiber, a sufficiently high voltage is applied to capillary tube end, which holds the polymer solution. The solution is detained by the surface tension, which ultimately generates a charge on the liquefied surface. As the liquefied surface develops the charge, electrostatic repulsion offsets the surface tension; then finally the droplet is strained. The hemispherical droplet at the tip of the capillary tube stretches to form a conical shape, which is called the Taylor cone.

As soon as the applied electrical field reaches a critical value, the repulsive electric force disables the force of surface tension, which results in an ejection of a charged jet of the solution from the tip of the Taylor cone. As the jet travels through the air, the solvent evaporates. In the case of melt, the discharged jet solidifies while traveling through the air. Finally, the charged polymer fiber is arbitrarily dumped onto a collector, for example, a rotating drum or a metal frame [18–20]. The morphologies and uniform diameters of electrospun fiber can be controlled via parameters such as jet stream movement and polymer concentration. The systematic diagram of basic electrospinning set up to obtain fibers is shown in Fig. 3.

4 ELECTROSPINNING PARAMETERS

Electrospinning parameters are very vital to comprehend because they affect the diameter and morphologies of electrospun fibers. The wanted morphologies and diameter of fibers can easily be attained by governing these parameters. The three main categories that affect electrospun fiber parameters, such as the morphology and diameter, are (a) the intrinsic properties of the solution, (b) the processing conditions, and (c) the ambient parameters [19].

The major task is the formation of fiber diameter uniformity. In electrospun fiber, defects, including beads and pores, are a foremost problem that needs to be sorted out [18]. Fig. 4 shows the scanning electron microscope (SEM) images of uniform (A) and beaded (B) electrospun PAN-SiO_2 nanofibers prepared in our laboratory. The optical images of uniform (A) and beaded (B) electrospun Fe_3O_4-cellulose nanofibers are shown in Fig. 5. Therefore, the intrinsic properties of the polymer solution are among the utmost significant measures in electrospinning. The effects of various electrospinning parameters are summarized in the following.

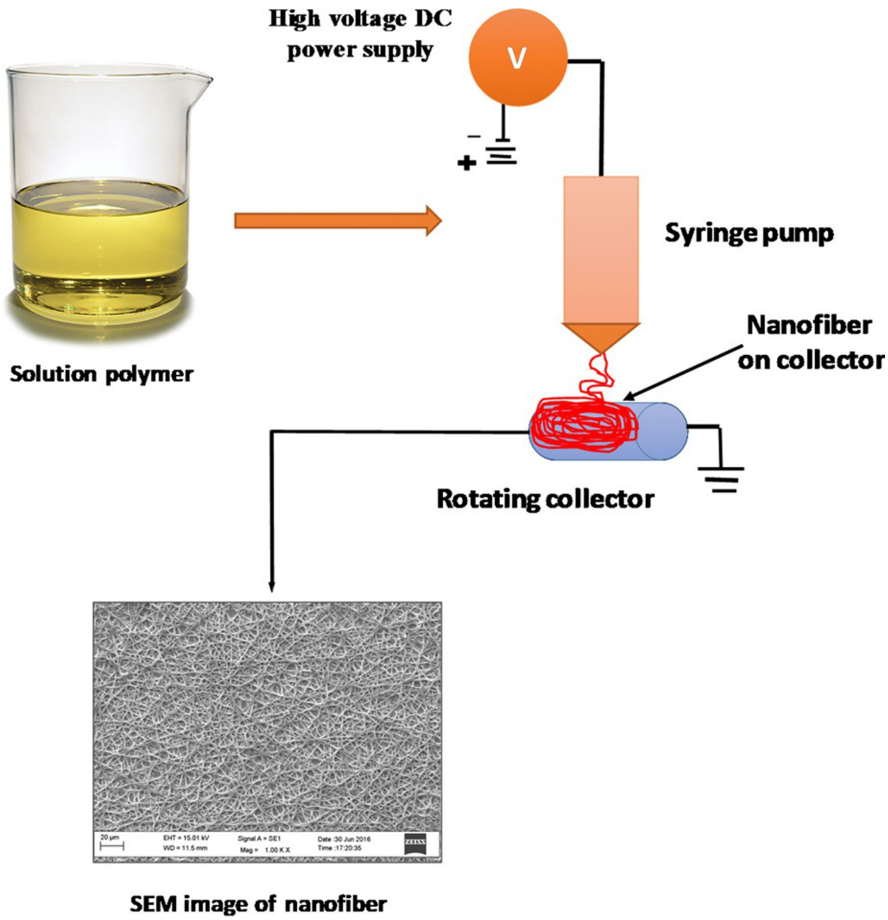

FIG. 3

Schematic diagram of basic electrospinning set up to obtain nanofiber.

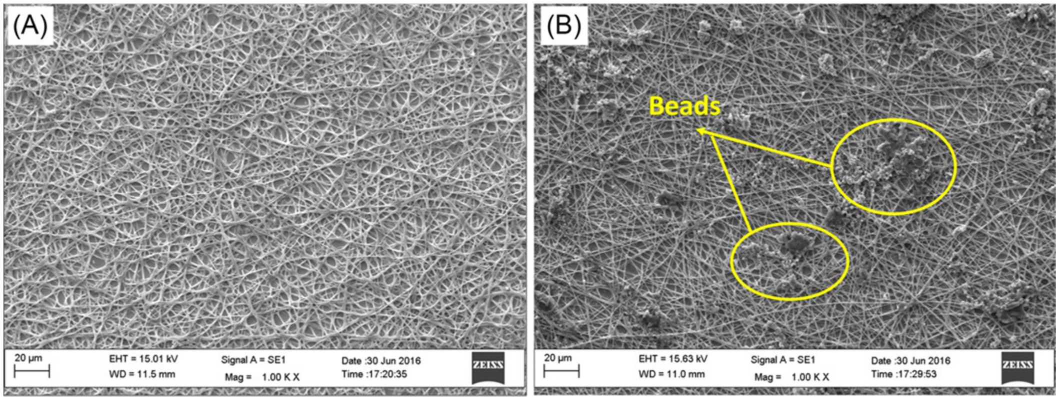

FIG. 4

SEM images of electrospun PAN-SiO_2 nanofiber (A) uniform; (B) beads, prepared in our laboratory.

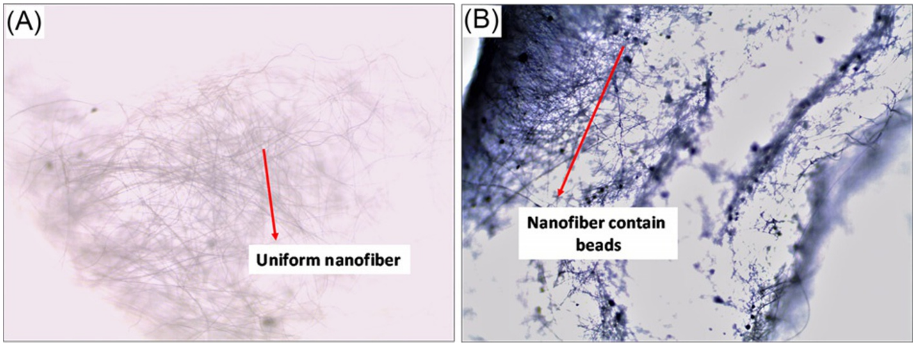

FIG. 5

Optical images of electrospun Fe_3O_4-cellulose anofibers: (A) uniform; (B) beads, prepared in our laboratory.

4.1 THE INTRINSIC PROPERTIES OF THE SOLUTION PARAMETERS

4.1.1 Concentration

The concentration of polymer solution has enormous effects on the formation of electrospun nanofibers. It is well known that the viscosity of the solution is relative to the polymer solution. The higher the viscosity of the solution, the larger the nanofiber diameter. Therefore, a minimum concentration is essential for fiber formation in electrospinning. Furthermore, electrospray arises in its place by electrospinning at very low concentrations. This happens owing to the high surface tensions and low viscosity of the solution [19, 41]. A combination of fibers and beads are obtained when the solution concentrations are low. As the concentration rises, the beads vary from sphere-shaped to spindle-shaped. Last, uniform fibers of enlarged thickness are obtained [42].

Fong et al. reported that the number of beads in the structure will be fewer if the polymer solution concentration is higher [43]. Liu et al. stated that as soon as the concentration of the polymer rises, the number of beads is reduced [44]. It is further specified that with a lower surface tension, more beads will form. Simultaneously, an increase in the polymer concentration leads to a rise in surface tension, resulting in fewer beads.

4.1.2 Molecular weight

Molecular weight has huge effects on the morphology of electrospun nanofiber. It basically affects the surface tension, viscosity, and conductivity of polymer solution. It is reported by many researchers that lower molecular-weight polymer form beads instead of fibers, while smooth fibers are obtained through an increase in the molecular weight. Furthermore, larger-diameter electrospun fibers are obtained at very high molecular weights [44–46].

4.1.3 Solution viscosity

Viscosity is another parameter that affects the formation of fibers during the electrospinning process. If a solution has a very low viscosity, fibers will not form, whereas with a solution with a very high viscosity, there is difficulty discharging the jets from the solution polymer. It is further stated that viscosity is very essential for the morphology of electrospun fibers. Usually, solution viscosity, molecular weight, and the concentration of the polymer are linked to one another. Uniform and larger-diameter fibers will be obtained with a rise in the solution's concentration or viscosity. However, a low viscosity results in the formation of beaded fibers [42, 44].

4.1.4 Surface tension

Surface tension is another crucial parameter that affects the formation of electrospun fibers. Doshi and Reneker et al. stated that a decrease in surface tension leads to the establishment of electrospun fibers deprived of beads [39, 47]. Yang et al. reported that different solvents contribute to different surface tensions and investigated the morphology of electrospun fiber PVP with DMF, ethanol, and MC as solvents [48]. It is further stated that by keeping the polymer concentration fixed, smooth nanofibers can be obtained by reducing the surface tension, whereas beaded nanofibers can be obtained by an upsurge in surface tension.

4.1.5 Conductivity/surface-charge density

The conductivity of the solution is another important parameter that can affect the morphology of electrospun fiber formation. Basically, the solution conductivity is made resolute by a solvent, a polymer, and the existence of salts. Mostly, the higher the conductivity of a solution polymer, the smaller the diameter of the electrospun nanofibers. It has been further illustrated that the surface-charge density and conductivity of polymer solution rise when salts are added [19, 42, 45]. Numerous polymers, including polyethylene oxide (PEO), polyacrylic acid, collagen-type IPEO, and polyamide 6, among others, need additional salt to increase the conductivity of solution [26].

4.2 PROCESSING PARAMETERS

The processing parameters of applied voltage, flow rate/feed rate, and collector and tip distance play effective roles in the electrospinning process. In addition, processing parameters have large an effect on the morphology and diameter of the nanofibers. The details of these parameters and their effect on fiber diameter and morphology follow.

4.2.1 Applied voltage

Applied voltage is a vital factor in electrospinning for the formation of electrospun fibers. This is because fiber formation occurs only when the applied voltage surpasses the threshold voltage (about $\sim$1 kV/cm, dependent on the gel solution). As previously discussed, a rise in the applied voltage increases the electrostatic force of the polymer solution, which indicates the stretching of the jet, which ultimately leads to a decrease in fiber length. It has been found that changing the applied voltage will change the shape of the initial drop, thereby resulting in a change in the structure and morphology of the fibers [19, 45].

Various arguments have been made about the effect of applied voltage on the electrospinning process. Zhang et al. reported that at higher voltages, there is more polymer ejection, enabling the development of larger-diameter fiber [49]. The researchers reported on the fiber morphology and the diameter of poly(vinyl alcohol) (PVA)/water solution. Reneker et al. stated there is no effect on the fiber diameter of polyethylene oxide when the applied voltage is increased [47]. Other researchers have reported that a rise in the applied voltage results in a decrease of fiber diameter. Furthermore, it was observed that at higher applied voltages, bead formation was obtained on the fibers [45, 50].

4.2.2 Flow rate/feed rate

In the electrospinning technique, the flow rate of the polymer solution is another active parameter that directly affects jet velocity and material transfer. A slower feed rate is proposed to provide enough time for the evaporation of the solvent, whereas a high flow rate results in a beaded fiber structure. As the feed rate of the solution increases, the charge density will decrease. A high charge density may lead to the electrospinning jet undergoing secondary bending instabilities, which contribute to the production of fibers with smaller diameters [19, 43–45]. Thus, with an increase in the feed rate, there is a consistent increase in the diameter of the fibers. It is worth noting that fibers with beads are molded when the feed rate of solution is too high because not enough time is provided for the solvent to evaporate [43, 45].

4.2.3 Collector and tip distance

The distance between the collector and the tip is another parameter that affects controlling the diameters and morphology of nanofibers. It is necessary to select an ideal distance to avoid the polymer solution evaporating before the fiber reaches the collector. Therefore, in the electrospinning technique, a minimum distance is required to ensure enough time for the solvent to evaporate before the fibers reach the collector. Longer distances have yielded thinner fibers [39]. Beads will be produced when the distance was too far or too close [19, 39, 48].

4.2.4 Ambient parameters

The ambient parameters, for example, temperature and humidity, also have enormous effects on the morphology and diameter of electrospun fibers. A rise in temperature produces fibers with reduced diameters, while low humidity could dry the solvent completely. Similarly, a rise in humidity results in small pores forming on the surface of the fiber [44, 45].

5 APPLICATION OF ENMs IN WATER TREATMENT

In the current industrialized era, one of the biggest water pollution problems is the contamination of heavy metals/metalloids in water bodies. Heavy metal-contaminated water results from several industries, such as electroplating, battery construction, tanneries, chemical manufacturing, and metallurgical and mining industries, all of which employ enormous amounts of metal ions [4, 5]. Wastewaters from these industries are directly discharged into freshwater forms, not only hurting the aquatic organisms but also damaging human and animals via their food chain. In many parts of the world, heavy metal concentrations in drinking water are higher than the guidelines reported by the Bureau of Indian Standard and the World Health Organization (WHO). Metals/metalloids ions such as lead, arsenic, fluoride, chromium, zinc, copper, silver, and iron, among others, have nonbiodegradable and high-toxicity properties [4–6]. Thus, eliminating these pollutants from water resources is a foremost priority, and many investigations are concentrating on addressing this issue.

Lately, keen interest has developed regarding nanoscopic materials as effective adsorbents for metal/metalloid ions because of their high surface area-to-unit mass. A lot of research has been carried out on nonadsorbents, including magnetic [2–4], nanocomposites [30, 31], and nanofibrous matrices [19–40] for eliminating heavy metal/metalloids from water bodies. Among these nanomaterials, electrospun nanofibrous matrices have attracted a prodigious consideration because of their numerous benefits, such as high porosity, high specific surface area per unit mass, and high gas permeability, which results in maximum adsorption capacity [19, 40, 45]. Various polymer, including cellulose [51], Chitosan, Chitosan/polylactide [52], bovine fibrinogen [53], gelatin [54], polyaniline/gelatin [55], and polymer blends such as gelatin/polycaprolactone [56], among others, were used for the preparation of electrospun nanofibers and have been explored for use in water treatment applications. In this section, a few of such pollutants and their removal using nanofibers are discussed.

Kampalanonwat et al. reported successful removal of Ag^{+}, Cu^{2+}, Pb^{2+}, and Fe^{2+} ions via aminated polyacrylonitrile (PAN) (APAN) nanofiber mats [22]. The metal ions' highest adsorption capacities using Langmuir sorption were obtained as 150.6, 155.5, 116.5, and 60.6 mg/g, respectively. The used APAN nanofiber mats were effectively regenerated through hydrochloric acid (HCl) from water. Wang et al. reported the effective elimination of Cr^{6+} ions from water with polyacrylonitrile/polypyrrole (PAN/PPy) nanofibers equipped via in situ polymerization of pyrrole monomer by electrospinning technique [57]. Within 30 and 90 min, the adsorption equilibrium reached, as the concentration of the initial solution was amplified from 100 to 200 mg/L. The pseudo-second-order model was well fitted. Langmuir isotherm model shows the best-fitted result. A thermodynamic study stated that the process of adsorption is spontaneous and endothermic in nature. A successful desorption of 80% was obtained.

Aliabadi et al. examined the adsorption of cadmium (Cd), nickel (Ni), copper (Cu), and lead (Pb) from water using poly ethylene oxide (PEO)/chitosan nanofiber [58]. To inspect the effect of diverse adsorption parameters, experiments were carried out at various temperatures, contact times, and initial concentrations, respectively. The selectivity of adsorption of copper, lead, nickel, and cadmium on the (PEO)/chitosan was $Pb^{2+} < Cd^{2+} < Cu^{2+} < Ni^{2+}$. Isotherm models such as Langmuir, Freundlich, and Dubinin-Radushkevich were used to designate the equilibrium data for the metal ions. Thermodynamic studies revealed that the adsorption of metal ions onto PEO/Chitosan nanofiber membrane was endothermic, spontaneous, and feasible. The successful reusability of the PEO/Chitosan membrane was obtained for next five cycles of sorption-desorption. Haider et al. stated the successful adsorption of metal ions Cu^{2+} and Pb^{2+} using Chitosan electrospun nanofiber mats from aqueous solution. Langmuir isotherms showed the best adsorption data for Cu^{2+} and Pb^{2+} [26]. The obtained Langmuir equilibrium adsorption capacity for Cu^{2+} and Pb^{2+} were 485.44 mg/g (2.85 mmol/g) and 263.15 mg/g (0.79 mmol/g), respectively. This suggests that Chitosan nanofiber mats provide a high adsorption capacity to filter out (or neutralize) toxic metal ions from wastewater.

Alcaraz-Espinoza et al. investigated the high adsorption of Cd^{2+}, Cu^{2+}, Hg^{2+}, Pb^{2+}, and Cr^{2+} from water using polyaniline-polystyrene (PANI-PS) composite electrospun PS mats [8]. The researchers further stated that the composite nanostructured PANI was highly dispersed in the NW PS mat, which showed good electrical properties and surface-wetting characteristics that can be easily precise.

Neghlani et al. reported the high elimination of Cu^{2+} ions from aqueous solution using polyacrylonitrile nanofibers (PAN-nFs) obtained via the electrospinning method [59]. Furthermore, to yield aminated polyacrylonitrile (APAN) nanofibers, the electrospun fibers were improved with diethylenetriamine. The maximum adsorption of Cu^{2+} ions obtained from the Langmuir model was 116.522 mg/g. Sharma et al. investigated successful removal of As^{3+} from water using cerium-loaded Chitosan (CHT)-polyvinyl alcohol (PVA) composite (Ce-CHT/PVA) nanofibers obtained via electrospinning [60]. The result stated that Ce-CHT/PVA composite nanofibers competently remove As^{3+} from water at a limit lower than that prescribed by the WHO and the Environmental Protection Agency. The maximum adsorption capacity obtained from the Langmuir isotherm was 18.0 mg/g. Najafabadi et al. reported maximum removal of Cr^{6+}, Pb^{2+}, and Cu^{2+} from water using a novel Chitosan/Graphene oxide

(GO) nanofibrous material via electrospinning [61]. The maximum monolayer adsorption capacity of Pb^{2+}, Cu^{2+}, and Cr^{6+} metal ions was obtained as 461.3, 423.8, and 310.4 mg/g, respectively. It was further stated that Chitosan/GO nanofibers can be reused without any loss in adsorption capacity.

Tian et al. informed of the successful elimination of Cd^{2+}, Cu^{2+}, and Hg^{2+} from water using a cellulose acetate (CA) nonwoven membrane obtained through surface modification by poly (methacrylic acid) (PMAA) using electrospinning [62]. As the solution pH increased, the capacity of adsorption process increased. The membrane showed the highest adsorption for Hg^{2+}. The successful reusability of the membrane was obtained by using saturated ethylenedinitrilotetra acetic acid.

Saeed et al. stated that they effectively adsorbed Cu^{2+} and Pb^{2+} using polyacrylonitrile (PAN) nanofibers by the electrospinning technique. HM-PAN adsorption capacity increased as the time interval was lengthened, and it remained constant after 24 h at 114 and 217 mg/g for Cu^{2+} and Pb^{2+} ions, respectively [63]. Desorption studies showed more than 90% of recovery of adsorbed metal ions using a 1 M HNO_3 solution.

6 OUTLOOK TRENDS AND CHALLENGES

Although electrospun nanofibers have exhibited great promise for water purification, such as toxic metal ion and dye remediation, there still are numerous challenges. These include the mass manufacture of quality nanofibers, nanofiber-based composites, and the desired functionality to improve the novel chemistry of nanofibers. All these trials are not minor but are insuperable. Innovative approaches in manipulating nanofiber structures, such as porous nanofibers, the modification of nanofiber surfaces, and interfiber adhesion, have been quickly established. In addition, the progression of manufacturing multifunctional nanofibers through several properties, including bi/multicomponent nanofibers and core-shell nanofibers, would be a novel approach for water filtration applications. Nanofiber surface properties can also be measured by using plasma treatment and chemical grafting. All these novel processes and innovative chemistries will increase the parameters in fabricating nanofibers for better filtration membranes, such as their becoming more efficient, having higher flux, and being stronger. Furthermore, electrospun nanofibers can be explored for applications to diverse water filtration/purification because of the intrinsic versatility of electrospinning, including the ease of material selection and the ability to regulate the morphology and functionality of nanofibers.

7 CONCLUSION

Water pollution via heavy metal ions is the foremost problem in the 21st century because of an upsurge in population and a rise in industrial activities. Electronspun fibers have countless advantages in the field of water purification because of their high surface area-to-volume ratio, high porosity, eco-friendliness, high flexibility, light weight, and the low cost of membranes. This chapter has cast a wide-ranging review of the electrospinning skills, electrospinning assemblies, processing technique, the effects of its parameters on nanofiber morphology, and its advanced application for trapping and filtering metals ions from aqueous solutions.

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