Polymeric Membrane with Nanomaterial’s for Water Purification: A Review

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Abstract. This review summarizes the work principles used for polymer membrane in water treatment. The performance of traditional polymeric films was improved after adding some nanometals such as nano silver AgNPs and gold AuNP's and nanomaterials, especially the use of titanium dioxide, carbon nanotube and zinc oxide (TiO2, CNT, ZnO, ...etc.), which is available, cheap and environmentally friendly. The theoretical aspects of the polymeric films coated with nanomaterials and the use of the advanced water treatment, removal of microorganisms, chemical compounds, heavy metals, and others are presented. The use of nanomaterials has helped to enhance the water resistance ability, suppress the accumulation of pollutants and contamination, enhance the reject efficiency and improve mechanical properties and thermal stability. Thus, the goal of the present work is to provide updated information regarding the membranes of the new nanocomposites (NC) and their contribution to water treatment applications.

Keywords: polymeric membrane, Nanomaterials, titanium dioxide (TiO2), Water Purification.

1. Introduction

Drinking water is a precious gift from the God and it was available free for all across the globe, but due to rising of water pollution, the quantity and quality of pure drinking water get declined and thus, it became costly and not easily available for all. Water shortages pose a threat to the human community's sustainable development. Nanomaterial technology has been developed to meet the need for water remediation systems by advancement of nanotechnology [1]. High level of metal ions, oils and most importantly organics pollutant are the most common contaminants that can degrade the quality of any types of drinking water. The crisis is rising dramatically and now its became a global concern because of industrial, urban and agricultural pollution [2].

Nanofibrous membrane such as ultrafiltration and microfiltration doped/coated with different nanomaterials can be used in the structure of porous separators. In order to detect water pollutant levels, nanoparticles (NPs) can also be effectively used to control and install sensors [3].

2. Nanomaterials for Water Purification

For water treatment and control, nanomaterials have numerous advantages, as mentioned above. This unbelievable ability is derived from a large area exposed to water contaminants and improves their interactivity. In this section, we will examine some important applications of nanomaterials for water treatment.

2.1. Polymeric Membrane (PM) with Nanomaterial’s

The membrane made up of nanomaterials-based technology acts as a selective barrier between the two homogenous phases that are currently explore for waste water treatment and water purification systems. The pressure difference between the feed and the permeated sides is used to drive the membrane into action and flow through membrane water [4]. Accordingly, solutes and particles are discriminated against based on charge, scale and form (see Figure1).
The nanocomposite membrane are a thin polymer film surface, commonly coated or decorated with nanofilters, is a distinctive type of membrane that can dynamically cleanse water. Composites membrane have characteristics features that are resulting from a combination of the comprehensive properties of medium and filler [5–6] These characters are not only conventional and predefined, but are also very modern, notably where the dimensions of the filler are in the nanoscale. In the construction of nanocomposite membranes nanomaterials in different shapes and dimensions can be used. For example, nanoparticles were generally used as nanofillers for mechanical reinforcement or hydrophilizing polymer membranes. Rodrigues et al [7] studied that insertion of nanoparticles of clay into ultrafiltration membranes mixed with polysulfide matrix increase the thermomechanical properties and water permeability of the membrane while retaining the highest efficacy of rejection. Further, they reported that the membranes containing clay nanoparticles demonstrated that a decreased fouling property and increased flow recovery using sodium alginate and natural water. The occurrence of bacterial cells on the surface and pores and the reduction of membrane permeability are critical in terms of ultrafiltration (UF) membranes. Subsequent to bacterial cell lysis, extracellular polymer substances (EPS) release on the ultrafiltration (UF) membrane and adsorb it to decrease membrane durability and permeability [8].

Surface hydrophilization through the addition of different antifouling agents is the most promising approach to solving the biofouling problem of UF membranes. Membrane technology is being employed in various ways, such as Graphenoxide (GO), TiO2, Au, Ag, Zn, Cu and CNTs [9]. A wide range of anti-fouling substances has been employed in these situations. While these nanocomposite membranes have a major industrial value in water treatments, it is necessary to carefully evaluate the toxicity of those membranes that may occur when released as a result of the integrated nanomaterials during the high-pressure filtration phase [10]. In a polymer system matrix, the toxicity profile may depend on the size, form, load and condition of the nanoparticles. CNTs include resilient antibacterial agents whose toxic effects was better than others nanofillers. The antibacterial activity of CNTs was due to release of ions and production of reactive oxygen species that causes oxidative damage [11]. This extraordinary performance has directed to the widespread use of CNTs in mixed UF membranes to improve filtration efficiency [12].

Several studies show that, the CNTs enhance water filtering and waste fluoride (PVDF) membranes, synthesized CNT and sulphonated CNT (SCNT) mixtures, and rejects nonpolar contaminants, salts, micro as well as macro contaminants wastes. The bovine serum albumin (BSA) rejection of the latter group of membranes was 90 %. SCNT-PVDF membrane flow decrease was less significant [14], as shown in Figure 2b, when the membranes were permeating the BSA solution because of their hydrophilicity. As shown in Fig 2c, the recovery ratio was 72.74 and 83.52% for CNT and SCNT-PVDF membranes, respectively which means their best anti-failure effect was in the SCNT and CNT.
classes of –SO3H and –OH. Though, CNTs are important and versatile materials for the preparation of membranes and also known as potential adsorbents for coloring, divalent metal ions, natural organic matter, etc, their relative high unit cost is a limiting element for their extensive practical application[15]. Alternatively, chemical-operated CNTs have not yet been proven to be toxic. The functionality of CNTs as adsorbents or membrane inclusions is therefore closely linked to the search for cost effective development processes for and its toxicity, by developing safer alternatives like carbon nanocrystals (CNCs)[16].

Besides nanofiltration membranes, an electric nanofibrous membrane has also been established for the removal of contaminant. Nanostructured membranes are extremely porous and interconnected to a porous system. Combined pores enhance fouling resistance, while high porosity provides significant permeability liquid and to gas streams and this may also decreases the consumption of energy of the membrane process. In addition, huge surface area and surface flexibility boost adsorption and nanofibrous membrane selectivity. Polyethylene terephthalate (PET) unwoven PES electrospun fiber mat, which may be as healthy and chemically functional as nanocomposed [17], has been evaluated as a fluid filtration membrane and removal of polystyrene micro and submicrons of size(PS) from the water. The nanofibrous membrane reduces its porosity and thus the flow of water decreases despite the high initial flow at increased feed pressure. Even if the nanofibrous membrane is highly pre-treated as a microfiltration (MF), water permeability and flow must be improved mechanically, for example. In order to achieve these objectives, nanoparticles ZrO2 and TiO2[18] have been used to stabilize and hydrophilize PES nanofibres.

Nicofibrate membranes may also be separated from a number of pollutants, including viruses, emulsions, proteins and colloids, 1-100 Nm in length for UF, i.e. at a certain point of liquid filtration. The nano-fibrous membrane in surface pores is therefore less than 0.1 μm, which can contribute to a rapid and significant decrease in high surface area. In order to solve this problem, the thin layer of the nanofibrous membrane consists of thin film layers (TFCs)[19]. It has also been shown that this term applies to FO membranes. TFC membranes have been investigated using self-supporting hydrophilic nanofiber-supported supports [20]. Nanofiber (NF) support minimizes the concentration of internal polarization (ICP) optimally and increases the flow of water through the special scaffolding system. In order to counter the danger of biofouling, nanofibers can also produce antimicrobial propagation. For example, Ag nanoparticles can be used for this purpose in nanofiber. This method has previously been used for various applications in wound dressings and water filtration. Breakfast Free et al. For the treatment of FO water [21].

![Figure 2. Antimicrobial nanostructure with TFC FO membrane (Ag/PAN-thin nanocomposite (TFN) and nano-particles showing that Ag incorporated membrane damage to bacterial cell membrane and interfere with DNA Taken from [22].](https://example.com/figure2.png)

As shown in Figure 3, ions in both cell membrane and cell wall protein, lipopolysaccharides and phospholipids can bind almost with thiols, phosphates and organic Amines. In addition, such ions can cross the cell wall and affect the protein and enzymes in the ribosomal subunit,[23] disrupting the DNA structure and causing cell death. A porous and hydrophilic protection of nanofiber, in
addition to bactericidal activity. Water flow in FO mode is constant over time, while PRO mod
dilution causes less differential pressure due to the solution dilution drawn.

Diagram properties i.e. 2D-1-atomically flat carbon-bound sp2 atoms [24], are noteworthy. For
water repair (which is significantly larger than the NF standard membrane), theoretically, graphene
atomic thickness would ensure high fluid permeability, lower energy consumption and thus low
operating cost. 2D nanochannels formed between stacked graphs and nanopores in one graphic layer
allow for selective transport and cure of water (Figure 3a)[25]. Graphene’s can have various types of
desalination membranes including the reduction of pristine graphene, GO and GO (rGO). For
structural graphic membranes, single or multi-layered layers can be constructed. In experimental and
theoretical simulation, graphic membranes with intrinsic pores were studied for NF purposes. O’Hern
et al. are placed on a porous polycarbonate substratum for example in a graph-composite membrane
with a 25-mm active filter region.

Essential nanopores in the graph monolayer were 1–15 nm tall and could contribute to the tall
selective passage by the membrane formed by molecules like KCl, tetramethylammonium chloride,
Allura red AC (496=da-dye), and tetramethyl rhodamine dextran (70 kDa). The diffusion of
tetramethyl rhodamine dextran was impaired as KCl and tetramethylammonium chloride penetrated
across the graphene membrane. The selectivity cannot be regulated due to arbitrary dimensions and
positions of the intrinsic pores, despite the feasibility of selected molecular transport through the
manonanoporous graph membrane. The creation of graph layers with a large number of nanopores and
modified sizes and chemicals nearly monodisperse is a sophist aim that needs to be aimed at
graphic membranes in the new millennium [26].

Figure 3. (a) Water purification mechanism contains customized nanopores and a multi-layer
graphic membrane. Copyright 2018, Elizabeth. (b) Schematic shows nanochannels between adjacent
GO sheets that contain hydr. Taken from [27]

Graphene layer is not long enough to resist the usual pressure of filtration. In comparison,
scalable multi-layered, high pressures of GO membranes can be formed and survive. Between
stacked polar nanosheets nano-canals allow the water to penetrate the membrane [28]. Due the
exceptional slippage length of the water inside the interlay channels, the stacked GO prevents the
movement of solution particles. Figure 4b shows how water molecules slip into hydrophilic regions
across hydrophobic nanochannels. As for selectivity, when dipped in ionic solutions due to
hydration, the interlayer distance between the GO nanosheets is increased to 0.9 nm. This structural
shift helps the K+ and Na+ ions to permeate and disqualifies the membrane for desalination [29].

However, the promising water purification potential of graphene membranes should be
considered for their release into water and thus the environment. Several literature reviews address
extensively the fate and transformation of nanomaterials of this type [30-31] and their toxicological
effects on the environment. But it is also important to calculate the environmental effects of
graphene nanomaterials in a realistic and durable way. These accurate ecotoxicological and life cycle
studies help us examine the benefits and disadvantages of graphene nanomaterial and learn how we
can use the safest to deal with lower environmental and health problems.
As has been emphasized so far, the use of nanomaterials for water treatment is very reliable. Table 1 shows some of these latest trends (as of 2019) in this sector.

**Table 1.** A sample of recent research (as of 2019) on water treatment nanomaterials

| Composite | Type of membrane | Pollutants | Mechanism of removal | Application | Ref |
|-----------|------------------|------------|----------------------|-------------|-----|
| Cu NP/CNT/PVDF | Nanocomposite film (NCF) | Arsenic | Dynamic adsorption and oxidation | As oxidizer and adsorbent | 32 |
| Co doped ZrO2 | NPs | MO dye | Visible light / photodegradation | As photocatalyst | 33 |
| NiO | NPs | ciprofloxacin | Adsorption | As adsorbent | 34 |
| Fe3O4NP/AC | NC | MO and RhB dye | Adsorption | To enable magnetic recovery and to raise adsorption capacity | 35 |
| Fe3O4@MIL-100(Fe) | NC MOF | Diclofenac sodium (DCF) | Adsorption and photodegradation | Magnetic recovery | 36 |
| FeCo3−xO4 | NPs | CR dye | Adsorption | To offer adsorption activity with easy magnetic recovery | 37 |
| ZnO-ZnFe2O4 | NF | CR dye | Adsorption | To raise adsorption efficiency | 38 |
| Ag/ZnO/PANI | NCF | BG dye | Adsorption | To raise adsorption efficiency | 39 |
| ZnS NP/PES | Film membrane | Humic acid | Adsorption | To raise adsorption efficiency | 40 |
| Boehmitite NP/EPVC | NCF | MB dye | Adsorption | To improve hydrophilicity and water flux | 41 |
| ananpropyl-trimethoxysilane) APTES-Fe3O4 NP/PES | NCF | arsenic | Adsorption | Heavy metal ion adsorption | 42 |
| PEI/PD/Ag NP | NCF | BSA/HA/Oil | Ultrafiltration | As anti-fouling and anti-biofouling agent | 43 |
| Carbon dioxide plasma treated PVDF | NF | CV dye and iron oxide NPs | Adsorption | To improve hydrophilicity and water flux | 44 |
| Bentonite NP/PES | NCF | NaCl | Reverse osmosis | To improve water permeability | 45 |
| PVA/PAN | NF | Nanoparticles and Cr (VI) and Cd (II) ions | Adsorption and microfiltration | PVA nanofibers as the mechanical support and PAN nanofibers for selective adsorption of the ions | 46 |
| Clay NP/mixed matrix PS | NCF | PEG and sodium alginate | Ultrafiltration | To improve antifouling properties, membrane thermal/ mechanical resistance and permeability with minimal loss in rejection | 47 |
| Clay NP/mixed matrix PS CS NP & Ag-CS | NCF | PEG and sodium alginate | Ultrafiltration | To improve antifouling properties, membrane thermal/ mechanical resistance and permeability with minimal loss in rejection | 48 |
| NP/polyphenylsulfone | Hollow fiber membrane | Reactive black dye | Adsorption | Efficiency, hydrophilicity, and antifouling property | 49 |

Nano adsorbents and nanomembranes for large-scale processing and industrialization are currently under development. As water recycling is considered an essential component of sustainable development in human society, particularly in view of the growing worldwide water scarcity crisis, we also emphasize the importance of consumption using nanomaterials to develop advanced water treatment technologies. However, if unregulated release to the atmosphere, these mini functional blocks may also become problem-free and unsafe for sustainability. The next section will look at
how they are spread and how they affect the biota that lives on these systems in various waters and soil media.

3. Conclusions
Membranes with nanostructure might be used as constructive units for a porous separator. The membranes and adsorbents with nanostructure are of great and economical production. TiO2 and CNT are one of the most extensively reported nanomaterials for colorant absorption. Nevertheless, they are toxic and expensive, with high temperatures and pressure. There are many long-term environmental and biological impacts of nanomaterials for water treatment and control and appropriate measures must be taken to establish water treatment systems based on nanomaterials, which are considered healthy for humans, plants and animals in the short term but are not sure about their long term protection from environmental damage.

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