Commentary

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Silver Nanoparticles (AgNPs) were Synthesized in an Environmentally Friendly Manner Using Leaf Extracts

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Description

Membrane modification with nanoparticles is a promising method to minimize bio-fouling during membrane preparation. However, the high cost of the modifying agents has limited the practical application of this method. In this study, we developed a cost effective and environmentally friendly method to produce polyvinylidene fluoride films with potent antibacterial activity by loading Silver Nanoparticles (AgNPs). In this method, Gallic Acid (GA) was used as a capture and reducing agent for *in situ* synthesis of AgNPs on the membrane surface. The resulting AgNP-functionalized membrane showed 3.5 times higher pure water flux and improved antifouling ability compared to the control membrane. Specifically, AgNPs impart convincing antibacterial activity to the membrane against gram positive and gram negative bacteria, as evidenced by the results of the diffusion inhibition zone and bacterial proliferation assay. More importantly, GA rich pomegranate peel extract was effectively used in such membrane functionalization method. Taken together, this work demonstrates the robust *in situ* fabrication of AgNP unctionalized antibacterial membranes *via* bio-derived AG and constitutes a promising alternative for applications their potential reality.

Silver nanoparticles

Membrane separation process is a widely used technology to alleviate the serious challenge of global water scarcity. Biofouling is a major obstacle to the limited application of membrane processes. In fact, approximately 60% of the operating costs of membrane bioreactors are related to biofouling. Biofouling is created in part by the adhesion, growth and colonization of bacteria on membrane surfaces. The cohesive biofilm structure reduces membrane permeability, reduces water quality, shortens membrane life, and increases operating costs. Use of antimicrobial membrane has been recognized as a rational strategy to alleviate biofouling.

To date, various agents including polymers, biocidal nanoparticles and lysozyme have been loaded onto membranes to improve their antimicrobial activity and biofouling resistance. Among them, Silver Nanoparticles (AgNPs) are commonly used nanoparticles for membrane modification because of their strong, broad spectrum antimicrobial activity, relatively low toxicity to human beings but extremely high toxicity to bacteria. The incorporation of silver nanoparticles was found to improve the antibiofouling performance for Pseudomonas colonies. To immobilize AgNPs onto a Thin-Film Composite (TFC) membrane surface, sodium borohydride is usually selected as a reducing agent for *in situ* synthesis of AgNPs, but use of sodium borohydride reduces the membrane permeability and is not eco-friendly because of the utilization of sodium borohydride, a strong reducing agent. Additionally, bio-inspired modification of AgNP membranes, as an environmentally friendly approach, is attracting increasing interest.

In the natural environment, mussels can firmly adhere to various rock surfaces thanks to adhesive proteins, rich in catechol groups. Inspired by this, Polydopamine (PDA), a dopamine polymer, has been used as a capture and reducing agent for antibacterial regulation. AgNPs can be synthesized *in situ* on the polysulfone membrane surface by dipping the PDA modified membrane into a silver ion solution. The resulting film has both anti-adhesive and antibacterial properties. Due to the strong adhesion ability of PDA to various materials, the modified method based on PDA has been further applied to other types of membrane and material fixation. The economic and ecological properties of biologically derived materials have promoted their application in various fields, e.g. lithium-sulfur batteries, potassium-ion batteries, supercapacitors and hydrogen storage. Although PDA is effective in membrane modification, its application is somewhat hindered by its relatively high cost and undesirable PDA agglomeration. On the other hand, biomimetic materials may offer an interesting and effective method to modify membrane surfaces with nanoparticles, but so far related information is very limited. PDA mediated AgNP synthesis is attributed to the catechol groups in PDA, and the O site of PDA can act as an anchor to immobilize the formed AgNPs. Coincidentally, such catechol groups also exist in Gallic Acid (GA), a type of natural plant phenols. Notably, GA is relatively cheap with a cost of approximately 25% of that of PDA. Furthermore, GA can be extracted from plants, such as pomegranate peel, green tea and gallnut. Thus, it is reasonable to anticipate that pomegranate peel extracts might be an efficient and cost-effective surface modification agent for antimicrobial membrane fabrication. Therefore, in this work pure GA reagent was used as a bio-inspired succedaneum to functionalize Polyvinylidene Fluoride (PVDF) membrane with AgNPs, and later the modification process was extended to pomegranate peel extracts. The morphology and chemical composition of the membrane surface were characterized using a series of methods. The hydrophilic and antifouling properties of the pristine and modified membranes were then evaluated and compared. Diffusion inhibition zone and bacterial proliferation tests were performed to evaluate the antibacterial properties of AgNP-functionalized PVDF membranes.

Medicinal plant

Environmentally friendly biosynthesis of medicinal plant nanoparticles is a reducing agent has gained importance due to its potential therapeutic use. In this study, Silver Nanoparticles (AgNPs) were synthesized in an environmentally friendly manner using leaf extracts of the medicinal plant *Tropaeolum majus*. In conclusion, the antibacterial, antifungal, antioxidant and anticancer properties of AgNPs synthesized from *Tropaeolum majus* serve as a major therapeutic drug against bacterial infectious diseases and related disorders. Nanotechnology has recently made significant advances in many areas of research and technological development. The development of new materials at the nanoscale is from 1 nm to 100 nm, which is what a nanoparticle means. Metal nanoparticles in particular have recently attracted much attention due to their unique properties such as large surface area, high stability, ease of chemical modification, effectiveness as a filler for enhance permeability and synthetic flexibility. Metal nanoparticles can be fabricated from non-metric metals using destructive or constructive processes. Aluminum (Al), Cadmium (Cd), Cobalt (Co), Copper (Cu), Gold (Au), Iron (Fe), Lead (Pb), Silver (Ag) and Zinc (Zn) are some types of metals used to synthesize nanoparticles. Nanoparticles have exceptional properties as compared to their metal counterparts in bulk from the aforementioned metal types, nanoparticles synthesized from silver have been extensively studied for their wide range of different applications based on their well-known properties, such as antibacterial activities, thermal and electrical conductivity, which help to develop health care related items, conductive consumer products, pharmaceuticals and sensors in various industrial sectors. Silver nanoparticles can be synthesized using physical, chemical and biological methods. In the synthesis methods, the biological synthesis method is getting more attention due to the possibility of producing nanoparticles with high stability. Active components such as flavonoids, saponins, alkaloids, tannins, phenolic, terpenes, steroidal glycosides, triterpenoides and several sesquiterpene lactones that can be extracted from plants have the capability of capping and reducing the nanoparticles.