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Application of nanotechnology in water and wastewater treatment: A short review

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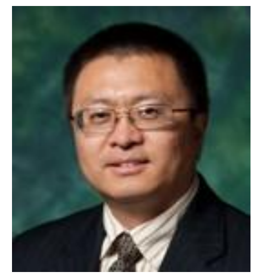

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The world is facing formidable challenges in meeting rising demands of clean water. Providing clean and affordable drinking water is one of the modern-times challenges. The article briefly reviews the recent advances and application of nanotechnology for wastewater treatment. Nanomaterials have high reactivity, large specific surface area, and size-dependent properties which makes them acceptable for applications in wastewater treatment and for water purification.

Introduction

According to World Health Organization, 884 million people lack access to adequate potable water and 1.8 million children die every year from diarrhea mainly due to water contamination. The world is facing formidable challenges in meeting rising demands of clean water as the available supplies of freshwater are depleting due to extended droughts, population growth, more stringent health-based regulations and competing demands from a variety of users (U.S. Bureau report 2003; EPA, 1998; WHO, 1996).

Most manufacturing processes generate large volumes of polluted wastewater. The specific pollutants present in industrial wastewater depend on the manufacturing process and can include specific organic constituents, high salinity, heavy metals, extreme pH, and high turbidity from inorganic particles. The occurrence of new/emerging microcontaminants (e.g., endocrine disrupting compounds (EDCs)) in polluted water/wastewater has rendered existing conventional water/wastewater treatment plants ineffective to meet the environmental standards. These chemicals can create problems with development, behavior and reproduction in a variety of species. Biological treatment systems such as activated sludge and biological trickling filters are unable to remove a wide range of emerging contaminants and most of these compounds remain soluble in the effluent. Physicochemical treatments such as coagulation, flocculation, proved ineffective for removing different EDCs and pharmaceutical compounds. Chlorination only provide residual protection against regrowth of bacteria and pathogens. Ozonation has been a less attractive alternative due to expensive costs and short lifetime. Some advanced treatments like ultraviolet (UV) photolysis and ion exchange are not viable alternatives for micro pollutants.

Twenty-first century has brought to the water sector exciting new opportunities associated with nanotechnology. 'Nano' is derived from the Greek word for 'dwarf'. The high surface area to mass ratios of nanoparticles can enhance the adsorption capacities of sorbent materials. Nanotechnology is a deliberate manipulation of matter at size scales of less than 100 nm (Fig.1) in at least one dimension meaning at the level of atoms and molecules as compared with other disciplines such as chemistry, engineering, and materials science.

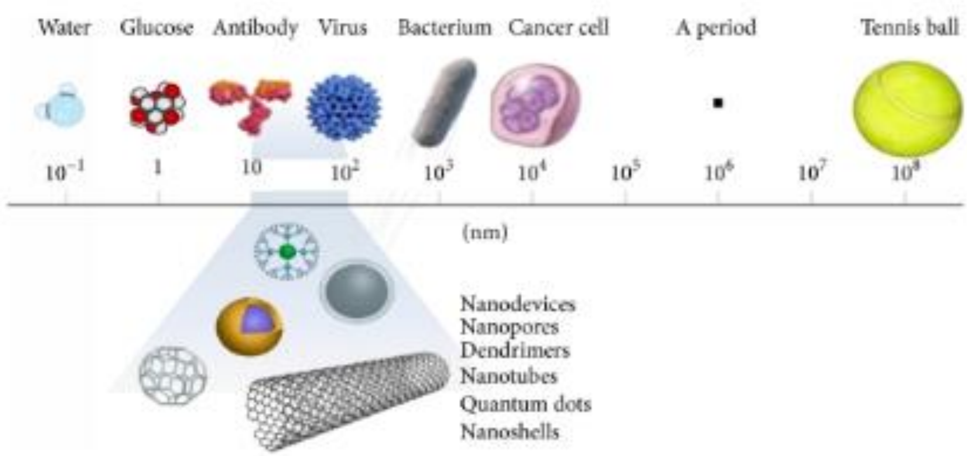

Figure 1: A size comparison of nanoparticle with other larger-sized materials

Through control over material size, morphology and chemical structure, nanotechnology offers novel materials that could endow some water treatment systems that enhance treatment cost-efficiency.

Zero-Valent Metal Nanoparticles:

As a good antimicrobial agent, silver nanoparticles have been widely used for the disinfection of water. In recent years, AgNPs have been reported to be able to adhere to the bacterial cell wall and subsequently penetrate it, resulting in structural changes of the cell membrane and thus increasing its permeability. Even the incorporation of nAg into polymer materials have also shown microbial properties against *E. coli* and *Salmonella entrica*.

In recent years Fe, Zn, Al, and Ni are some zero-valent metal nanoparticles, which are used in water pollution treatment.

Metal Oxides Nanoparticles

Titanium oxide (TiO_2) Nanoparticles

Among the existing adsorbents nanosized metal oxides, TiO_2 is classified as one of the promising oxides for pollutant's removal the most exceptional photocatalyst due to its high photocatalytic activity reasonable price, chemical and biological stability. Besides, TiO_2 NPs show little selectivity and thus are suitable for the degradation of all kinds of contaminants, such as chlorinated organic compounds, phenols, pesticides, arsenic, cyanide, and heavy metals. The photocatalytic properties of TiO_2 NPs can kill a wide array of microorganisms, such bacteria, fungi, algae, protozoa, and viruses.

Zinc oxide Nanoparticles (ZnO NPs)

In the field of photocatalyst candidate in water and wastewater treatment because of their unique characteristics, such as direct and wide band gap in the near-UV spectral region, strong oxidation ability, and good photo catalytic property. ZnO NPs are not only environment-friendly they are compatible with organisms which makes them suitable for the treatment of water and wastewater.

Iron Oxides Nanoparticles

Magnetism is a unique physical property that independently helps in water purification by influencing the physical properties of contaminants in water. Iron oxides nanoparticles, in recent years iron oxides nano particles is used for the removal of heavy metal due to their simplicity and availability. Magnetic magnetite (Fe_3O_4) and magnetic maghemite (γFe_2O_4) and nonmagnetic hematite (α-Fe_2O_3) are often used as nano-adsorbents due to their simplicity and availability. Laboratory investigation indicated that iron oxide NMs could effectively remove a range of heavy metals, including Pb^{2+}, Hg^{2+}, Cd^{2+}, and Cu^{2+} and organic contaminants.

Carbon nanotubes

Carbon nanotubes are one of the allotropes of carbon and has diverse application in wastewater treatment due to their exclusive properties like large specific area, fast kinetics and selective towards aromatic compounds. Carbon nanotubes are graphene sheets rolled up in cylinders with diameter as small as 1nm. CNTs can be classified into two types (Fig. 2) Multiwalled carbon nanotubes (MWCNT) Is comprised of multiple layers of concentric cylinders with a spacing of about 0.34 nm between the adjacent layers, and single-walled carbon nanotubes (SWCNTs), which consist of single layers of graphene sheets seamlessly rolled into cylindrical tubes. The use of CNTs as a catalyst is also reported for wastewater treatment due to their mechanical strength, mesoporous nature, and large surface area.

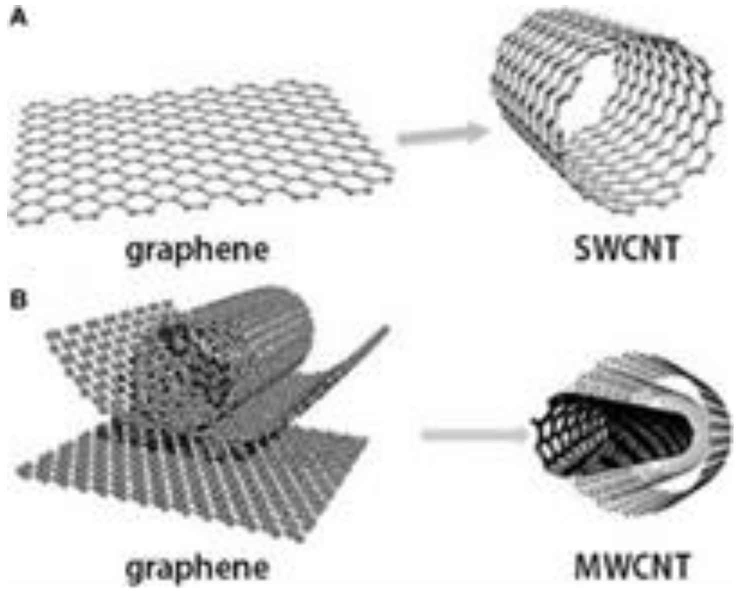

Figure 2: Classification of carbon nanotubes [A] Single walled carbon nanotubes [B] Multi-walled carbon nanotubes.

Extensive studies have reported both MWCNTs and SWCNTs have been applied for the removal of contaminants in water like organic, inorganic, and biological contaminants including heavy metals, radionuclide and organic dye.

Membranes and membrane processes

Nano Filtration (NF) Membranes

NF membrane is a type of pressure driven membrane with properties between reverse osmosis and ultra-filtration membranes and can be utilized ground surface and waste water treatment. Nano filtration has been used to treat ground water having relatively low TDS (total dissolved solids) and high total hardness and color. Studies were conducted to remove pesticides, micro pollutants, arsenic and multivalent anions from ground water successfully. NF is a reliable surface water treatment as the surface water keeps changing according to seasons. Removal of pollutants from a water of pH 7-9 was achieved implying that the pH adjustment of water prior to treatment is not required as well as bacteria Bacillus subillus was removed from surface water.

In the last two decades, the development of polymeric and ceramic membranes has positively impacted on the use of membranes. Porous carbons have a great potential in adsorption and in membrane synthesis for water filtration as they are considered as "molecular sieve materials". Those filters were re-usable, sustainable and showed effective removal of bacterial pathogens (Escherichia coli and Staphylococcus aureus) and Poliovirus Sabin 1 from contaminated water.

Conclusion

Nanotechnology is a very promising area that can show the wastewater treatment a new dimension. The use of nanotechnology in wastewater treatment holds the promise of transforming many of these processes by lowering the treatment cost and offer great potential for 'point of use' systems.The challenge of the growing nanomaterials industry is to ensure that this novel technology emerge as tool mitigating risk to environmental and public health and enable sustainable water management.

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