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A Study on the Nanotechnology in Water and Waste Water Treatment

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Abstract: *In most parts of the world, increases in population, the use of huge quantities of fertilizers and pesticides in modem agriculture, the expansion of food processing industry and the growth of other industrial processes contribute to the volume of sewage and waste water. Therefore wastewater treatment attempts to remove compounds with a high BOD, pathogenic organisms and harmful chemicals. Waste water treatment issues have been emergent problems these days. Its treatment is fetching must in this Industrial world. Nanotechnology holds great potential in advancing water and wastewater treatment to improve treatment efficiency as well as to augment water supply through safe use of unconventional water sources. Here we review recent development in nanotechnology for water and wastewater treatment. Nanoparticles have a great impending to be used in waste water treatment. Some of the inimitable characteristics of it having elevated surface area can be used efficiently for removing mortal metal ions, disease causing microbes, inorganic and organic solutes from water. The different classes of nanomaterials also have the authority to be efficient for water treatment like metal-containing nanoparticles, carbonaceous nanomaterials and zeolites. Nanotechnology has led to various efficient ways for treatment of waste water in a more precise and accurate way on both small and large scale.*

Keywords *– Wastewater Treatment, Water reuse, Nanotechnology, Nanoparticles, Nanomaterials, Membrane processes.*

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I. Introduction:

Our current water supply faces enormous challenges, both old and new. Worldwide, some 780 million people still lack access to improved drinking water sources (WHO, 2012). It is urgent to implement basic water treatment in the affected areas (mainly in developing countries) where water and wastewater infrastructure are often non-existent. In both developing and industrialized countries, human activities play an ever-greater role in exacerbating water scarcity by contaminating natural water sources. At the time of Independence, i.e., in 1947, the per capita availability of water in India was 6,008 cubic metres a year. It came down to 5,177 cubic metres a year in 1951 and to 1,820cubic metres a year in 2001. According to MidTerm Appraisal (MTA) of the 10th Plan, per capita availability of water is likely to fall down to 1,340 cubic metres in 2025 and 1,140 cubic metres in 2050. Wastewater from numerous industries such as paints and pigments, glass production, mining operations, metal plating, and battery manufacturing processes are known to contain contaminants such as heavy metal. These heavy metals in wastewater are not biodegradable and their existence in receiving lakes and streams causes bioaccumulation in living organisms, which leads to several health problems in animals, plants and human beings such as cancer, kidney failure, metabolic acidosis, oral ulcer, renal failure and damage for stomach of the rodent (El-Latif et al. 2013). As trace elements, some heavy metals (eg. Copper, zinc, selenium) are essential to maintain the metabolism of the human body. However, at higher concentration they can lead to poisoning (Singanan 2011). Gakwisiri et al. (2012) in his study reported that when zinc is present in less quantity in humans body, it affects health considerably. Heavy metals can enter a water supply by industrial and consumer waste, or even from acidic rain breaking down soils and releasing heavy metals into streams, lakes, rivers and groundwater (Renge et al. 2012). Wastewater regulations were established to minimize human and environmental exposure to hazardous chemicals.

Nanotechnology, the engineering and art of manipulating matter at the nanoscale (1-100 nm), offers the potential of novel nanomaterials for the treatment of surface water, groundwater and wastewater contaminated by toxic metal ions, organic and inorganic solutes and microorganisms. At the present time many nanomaterials are under active research and development. Recent advances in nanotechnology offer leapfrogging opportunities to develop next-generation water supply systems. Our current water treatment, distribution, and discharge practices, which heavily rely on conveyance and centralized systems, are no longer sustainable. The highly efficient, modular, and multifunctional processes enabled by nanotechnology are envisaged to provide high performance, affordable water and wastewater treatment solutions that less relies on large infrastructures (Qu et al., 2013). Nanotechnology-enabled water and wastewater treatment promises to not only overcome major challenges faced by existing treatment technologies, but also to provide new treatment capabilities that could allow economic utilization of unconventional water sources to expand the water supply.

Nanotechnology And Water Treatment:

Nanotechnology, the engineering and art of manipulating matter at the nanoscale (1-100 nm), offers the potential of novel nanomaterials for treatment of surface water, groundwater and wastewater contaminated by toxic metal ions, organic and inorganic solutes, and microorganisms. Due to their unique activity toward recalcitrant contaminants and application flexibility, many nanomaterials are under active research and development. Accordingly, literature about current research on different nanomaterials (nanostructured catalytic membranes, nanosorbents, nanocatalysts and bioactive nanoparticles) and their application in water treatment, purification and disinfection is reviewed. Moreover, knowledge regarding toxicological effects of engineered nanomaterials on humans and the environment is presented.

Potential Application In Water Treatment:

Nano-adsorbents can be readily integrated into existing treatment processes in slurry reactors or adsorbers. Applied in the powder form, nano-adsorbents in slurry reactors can be highly efficient since all surfaces of the adsorbents are utilized and the mixing greatly facilitates the mass transfer. However, an additional separation unit is required to recover the nanoparticles. Nano-adsorbents can also be used in fixed or fluidized adsorbers in the form of pellets/beads or porous granules loaded with nano-adsorbents. Fixed-bed reactors are usually associated with mass transfer limitations and head loss; but it doesn't need future separation process. Applications of nano-adsorbents for arsenic removal have been commercialized, and their performance and cost have been compared to other commercial adsorbents in pilot tests (Aragon et al., 2007; Chong et al., 2010). ArsenXnp is a commercial hybrid ion exchange medium comprising of iron oxide nanoparticles and polymers. ADSORBSIA is a nanocrystalline titanium dioxide medium in the form of beads from 0.25 to 1.2 mm in diameter. Both nano-adsorbents were highly efficient in removing arsenic and ArsenXnp required little backwash (Aragon et al., 2007; Sylvester et al., 2007). The estimated treatment cost for ArsenXnp is $0.25w$0.35/1000 gal if the medium is regenerated, similar to $0.37/1000 gal of Bayoxide E33, a highperformance granular iron oxide adsorbent (Aragon et al., 2007; Westerhoff et al., 2006). ArsenXnp and ADSORBSIA have been employed in small to medium scale drinking water treatment systems and were proven to be cost-competitive.

Nanofibers And Nanobiocides In Water Purification:

Electrospun nanofibers and nanobiocides show potential in the improvement of water filtration membranes. Biofouling of membranes caused by the bacterial load in water reduces the quality of drinking water and has become a major problem. Several studies showed inhibition of these bacteria after exposure to nanofibers with functionalized surfaces. Nanobiocides such as metal nanoparticles and engineered nanomaterials are successfully incorporated into nanofibers showing high antimicrobial activity and stability in water. Research on the applications of nanofibers and nanobiocides in water purification, the fabrication thereof and recently published patents are reviewed in this article.

Nanofiber Membranes:

Electrospinning is a simple, efficient and inexpensive way to make ultra fine fibers using various materials (e.g., polymers, ceramics, or even metals) (Cloete et al., 2010; Li and Xia, 2004). The resulting nanofibers have high specific surface area and porosity and form nanofiber mats with complex pore structures. The diameter, morphology, composition, secondary structure, and spatial alignment of electrospun nanofibers can be easily manipulated for specific applications (Li and Xia, 2004). Although nanofiber membranes have been commercially employed for air filtration applications, their potential in water treatment is still largely unexploited. Nanofiber membranes can remove micron-sized particles from aqueous phase at a high rejection rate without significant fouling (Ramakrishna et al., 2006). Thus they have been proposed to be used as pretreatment prior to ultrafiltration or reverse osmosis (RO). Functional nanomaterials can be easily doped into the spinning solutions to fabricate nanoparticle impregnated nanofibers or formed in situ (Li and Xia, 2004). The outstanding features and tunable properties make electrospun nanofibers an ideal platform for constructing multifunctional media/membrane filters by either directly using intrinsically multifunctional materials such as TiO2 or by introducing functional materials on the nanofibers. For example, by incorporating ceramic nanomaterials or specific capture agents on the nanofiber scaffold, affinity nanofiber membranes can be designed to remove heavy metals and organic pollutants during filtration.

Nanofiltration For Water And Wastewater Treatment:

Nanofiltration (NF) is a new type of pressure driven membrane process and used between reverse osmosis and ultrafiltration membranes. The most different speciality of NF membranes is the higher rejection of multivalent ions than monovalent ions. NF membranes are used in softening water, brackish water treatment, industrial wastewater treatment and reuse, product separation in the industry, salt recovery and recently desalination as two pass NF system. In this chapter, a general overview of nanofiltration membranes, membrane materials and manufacturing techniques, principles such as performance and modelling, module types, membrane characterization and applications on water and wastewater treatment were given.

Reverse Osmosis: Membranes, Materials, Applications And Nanotechnology:

This chapter provides a review about the membrane separation technologies focusing on reverse osmosis (hyperfiltration) and nanofiltration. The first one is based on the basic principle of osmotic pressure, while the latter makes use of molecule size for separation. Recent advances on nanotechnology are opening a range of possibilities in membrane technologies. This chapter also reviews some of these aspects: new membrane preparation and cleaning methods, new surface and interior modification possibilities, the use of new nanostructured materials, and new characterization techniques.

Forward Osmosis:

Forward osmosis (FO) utilizes the osmotic gradient to draw water from a low osmotic pressure solution to a high osmotic pressure one (i.e., the draw solution). The diluted draw solution is then treated by reverse osmosis or thermal processes to generate pure water. FO has two major advantages over the pressure-driven reverse osmosis: it does not require high pressure, and the membrane is less prone to fouling.

The key to FO is to have a draw solute with high osmolality and easily separable from water. Chemicals currently employed for draw solutions include NaCl and ammonia bicarbonate. Therefore, RO or thermal treatment, both energy intensive, is required to recover water from the draw solution. Magnetic nanoparticles were recently explored as a new type of draw solute for its easy separation and reuse. Hydrophilic coating was employed to aid dissolution and increase osmotic pressure. An FO permeate flux higher than 10 L m2 h1 was achieved using 0.065 M poly(ethylene glycol) diacid-coated magnetic nanoparticles when deionized water was used as the feed solution (Ge et al., 2011). Magnetic nanoparticles were also applied to recover draw solutes. In a recent study, magnetic nanoparticles (Fe3O4@SiO2) were used to recover Al2(SO4)3 (the draw solute) through flocculation (Liu et al., 2011).

Nanotechnology In Water Treatment On Human Health:

The risk assessment of nanoparticles and nanomaterials is of key importance for the continous development in the already striving new field of nanotechnology. Humans are increasingly being exposed to nanoparticles and nanomaterials, placing stress on the development and validation of reproducible toxicity tests. Tests currently used include genotoxicity and cytotoxicity tests, and in vivo toxicity models. The unique characteristics of nanoparticles and nanomaterials are responsible for their toxicity and interaction with biological macromolecules within the human body. This may lead to the development of diseases and clinical disorders. A loss in cell viability and structure can also occur in exposed tissues as well as inflammation and granuloma formation. The future of nanotechnology depends on the responsible assessment of nanoparticles and nanomaterials.

II. Conclusion:

Nanotechnology for water and wastewater treatment is gaining momentum globally. The unique properties of nanomaterials and their convergence with current treatment technologies present great opportunities to revolutionize water and wastewater treatment. Although many nanotechnology enabled water/wastewater treatment processes have shown great promise in laboratory studies, their readiness for commercialization varies widely. Some are already on the market, while others require significant research before they can be considered for full scale applications. Their future development and commercialization face a variety of challenges including technical hurdles, cost-effectiveness, and potential environmental and human risk. There are two major research needs for full scale applications of nanotechnology in Water/wastewater treatment. First, the performance of various nanotechnologies in treating real natural and waste waters needs to be tested. Future studies need to be done under more realistic conditions to assess the applicability and efficiency of different nanotechnologies as well as to validate nanomaterial enabled sensing technologies. Secondly, the long-term efficacy of these nanotechnologies is largely unknown as most lab studies were conducted for relatively short period of time. The challenges faced by water/wastewater treatment nanotechnologies are important, but many of these challenges are perhaps only temporary, including technical hurdles, high cost, and potential environmental and human risk. To overcome these barriers, collaboration between research institutions, industry, government, and other stakeholders is essential. It is our belief that advancing nanotechnology by carefully steering its direction while avoiding unintended consequences can continuously provide robust solutions to our water/wastewater treatment challenges, both incremental and revolutionary.

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