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Nano Materials in Water and Waste Water Treatment

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Abstract

Providing clean and affordable water to meet human needs is a grand challenge in 21st century. Now a days there is a continuously increasing worldwide concern for the development of wastewater treatment technologies. The utilization of iron oxide nanomaterials has received much attention due to their unique properties, such as extremely small size, high surface-area-to-volume ratio, surface modifiability, excellent magnetic properties and great biocompatibility. A range of environmental clean-up technologies have been proposed in wastewater treatment which applied iron oxide nanomaterials as nanosorbents and photo catalysts. Moreover, iron oxide based immobilization technology for enhanced removal efficiency tends to be an innovative research point.

Worldwide, pure water supply struggles to keep up with the fast growing demand. In the area of water purification, nanotechnology offers the possibility of an efficient removal of pollutants and germs. Today nanoparticles, nanomembrane and nanopowder used for detection and removal of chemical and biological substances include metals (e.g. Cadmium, copper, lead, mercury, nickel, zinc), nutrients (e.g. Phosphate, ammonia, nitrate and nitrite), cyanide, organics, algae (e.g. cyanobacterial toxins) viruses, bacteria, parasites and antibiotics. Nanomaterials (Titania, carbon nanotubes (CNTs), zero-valent iron, dendrimers and silver nanomaterials) which are currently used in environmental remediation and particularly in water purification.

Keywords: Nanoparticle, dendrites, zeolite, ceramics, nanosilver.

1. Introduction

Water is the most essential substance for all life on earth and a precious resource for human civilization. Reliable access to clean and affordable water is considered one of the most basic humanitarian goals, and remains a major global challenge for the 21st century. 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). The World Health Organization recommended that any water intended for drinking should contain fecal and total coliform counts of 0, in any 100 mL sample. When either of these groups of bacteria is encountered in a sample, immediate investigative action should be taken. The world is facing formidable challenges in meeting rising demands of clean water as the available supplies of freshwater are depleting due to

i). Extended droughts,
ii). Population growth,
iii). More stringent health based regulations and
iv). Competing demands from a variety of users.

Clean water (i.e., water that is free of toxic chemicals and pathogens) is essential to human health. Moreover, global climate change accentuates the already uneven distribution of fresh water, destabilizing the supply. Growing pressure on water supplies makes using unconventional water sources (e.g., storm water, contaminated fresh water, brackish water, wastewater and seawater) a new norm, especially in historically water-stressed regions.

Today most of the countries are facing drinking water problems and conditions are very severe especially in developing countries. In countries such as India, 80% of the diseases are due to bacterial contamination of drinking water. 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. The increasingly stringent water quality standards, compounded by emerging contaminants, have brought new scrutiny to the existing water treatment and distribution systems widely established in developed countries.

The removal or inactivation of pathogenic microorganisms is the last step in the treatment of waste water. The protection of water treatment systems against potential chemical and biological terrorist acts is also becoming a critical issue in water resources planning. Today a number of techniques are used for treatment of water i.e. chemical and physical agent such as chlorine and it's derivatives, Ultraviolet light , Boiling, Low frequency ultrasonic irradiation , Distillation, Reverse Osmosis, Water sediment filters (fiber and ceramic)

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Activated carbon, Solid block, Pitcher and faucet-mount filters, Bottled water, Ion exchange water Softener, Ozonisation, Activated alumina 'Altered' Water. Halogens such as chlorine (Cl) and bromine (Br) are well known and widely used as antibacterial agents, but the direct use of halogens as bactericides has many problems because of their high toxicity and vapour pressure in pure form. The most common cation in water affecting human and animal health is NH4+. In drinking water ammonia removal is very important to prevent oxygen depletion and algae bloom and due to its extreme toxicity to most fish species. It can be replaced with biologically acceptable cations, like Na+, K+ or Ca2+ in the zeolite.

Nanomaterials are typically defined as materials smaller than 100 nm in at least one dimension. At this scale, materials often possess novel size-dependent properties different from their large counterparts, many of which have been explored for applications in water and wastewater treatment. Some of these applications utilize the smoothly scalable size-dependent properties of nanomaterials which relate to the high specific surface area, such as fast dissolution, high reactivity, and strong sorption. Others take advantage of their discontinuous properties, such as super paramagnetism, localized surface plasmon resonance, and quantum confinement effect.

2. Nanoparticles in Waste Water Treatment

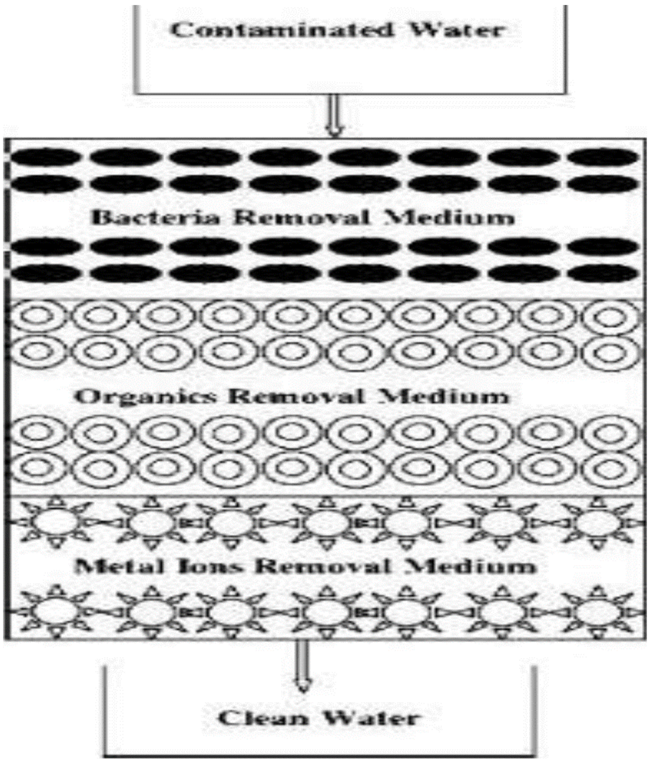

Fig 1: Schematic of a composite nanomaterial packed bed reactor for purification of water
Contaminated by mixtures of (i) Metal ions, (ii) Organic solutes and (iii) Bacteria

In this article, I have provided a succinct review of the most common and popular nanomaterials (Titania, carbon nanotubes (CNTs), zero-valent iron, dendrimers and silver nanomaterials) which are currently used in environmental remediation and particularly in water purification

In the area of water purification, nanotechnology offers the possibility of an efficient removal of pollutants and germs. Today nanoparticles, nanomembrane and nanopowder used for detection and removal of chemical and biological substances include metals (e.g. Cadmium, copper, lead, mercury, nickel, zinc), nutrients (e.g. Phosphate, ammonia, nitrate and nitrite), cyanide, organics, algae (e.g. cyanobacterial toxins) viruses, bacteria, parasites and antibiotics. Basically four classes of nanoscale materials that are being evaluated as functional materials for water purification e.g. metal-containing nanoparticles, carbonaceous nanomaterials, zeolites and dendrimers. Carbon nanotubes and nanofibers also show some positive result. Nanomaterials reveal good result than other techniques used in water treatment because of its high surface area (surface/volume ratio). It is suggested that these may be used in future at large scale water purification. It is also found that the coliform bacteria treated with ultrasonic irradiation for short time period before Ag- nanoparticle treatment at low concentration, enhanced antibacterial effect. In future, combination of both may be the best option for treatment of waste water.

Nanotechnology has revolutionized plethora of scientific and technological fields; environmental safety is no exception. One of the most promising and well-developed environmental applications of nanotechnology has been in water remediation and treatment where different nanomaterials can help purify water through different mechanisms including adsorption of heavy metals and other pollutants, removal and inactivation of pathogens and transformation of toxic materials into less toxic compounds. For this purpose, nanomaterials have been produced in different shapes, integrated into various composites and functionalized with active components. Nanomaterials have also been incorporated in nanostructured catalytic membranes which can in turn help enhance water treatment.

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. Nanoparticles are expected to play a crucial role in water purification. The environmental fate and toxicity of a material are critical issues in materials selection and design for water purification. No doubt that nanotechnology is better than other technique used in water treatment but today the knowledge about the environmental fate, transport and toxicity of nanomaterials is still in infancy.

Advances in nanoscale science and engineering suggest that many of the current problems involving water quality could be resolved or greatly diminished by using nonabsorbent, nanocatalysts, bioactive nanoparticles, nanostructured catalytic membranes, submicron, nanopowder, nanotubes, magnetic nanoparticles, granules, flake, high surface area metal particle supramolecular assemblies with characteristic length scales of 9-10 nm including clusters, micromolecules, nanoparticles and colloids have a significant impact on water quality in natural environment . Nanotechnology used for detection of pesticides chemical and biological substances including metals (e.g. Cadmium, copper, lead, mercury, nickel, zinc), Nutrients (e.g. Phosphate, ammonia, nitrate, nitrite), Cyanide Organics, Algae (e.g. Cyanobacterial toxins) Viruses, Bacteria, Parasites, antibiotics and Biological agents are used for terrorism. Innovations in the development of novel technologies to desalinate water are among the most exciting and seem to have promis. Opportunities and challenges of using nanomaterials in the purification of surface water, groundwater and industrial wastewater streams is a matter of continuing concern. Misconceptions and One of the many impressions that people have about the future of nanotechnology is the expectation that nanoparticles can be used to kill harmful organisms, repair body tissue, in water quality improvment and to cure disease. Recent applications of nanoparticulate silver have included open wound and burn treatment and preliminary studies have shown that a 20 ppm silver colloidal suspension (~30 nm diameter) in purified water has a 100% cure rate for malaria. Titanium dioxide, especially as nanoparticulate anatase, is also an interesting antibacterial, with notable photocatalytic behavior. But ultrafine anatase has also been identified as cytotoxic and *in-vivo* studies have shown that it can be severely toxic in the respiratory system. Nanocapsules and nanodevices may present new possibilities for drug delivery, gene therapy, medical diagnostics, antimicrobial activity etc. The effect of particle size on the adsorption of dissolved heavy metals to iron oxide and titanium dioxide nanoparticles is a matter laboratory-scale experiments. Iron oxide and titanium dioxide are good sorbents for metal contaminants. Spherical aggregates of nanoparticles that have a similar size and shape to the resin beads already used in water purification. Ligands, Fulvic acid, humic acids and their aggregates have a significant impact on contaminant mobility, reactivity and bioavailability. Nanoparticles can also be designed and synthesized to act as either separation or reaction media for pollutants. The high surface area to mass ratios of nanoparticles can greatly enhance the adsorption capacities of sorbent materials. Nanotechnology is a deliberate manipulation of matter at size scales of less than 100 nm holds the promise of creating new materials and devices which take advantage of unique phenomena realized at those length scales. In addition to having high specific surface areas, nanoparticles also have unique adsorption properties due to different distributions of reactive surface sites and disordered surface regions. Their extremely small feature size is of the same scale as the critical size for physical phenomena for example, the radius of the tip of a crack in a material may be in the range 1-100 nm.

3. 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 nanotechnologies highlighted in this review are still in the laboratory research stage, some have made their way to pilot testing or even commercialization. Among them, three categories show most promise in full scale application in the near future based on their stages in research and development, commercial availability and cost of nanomaterials involved, and compatibility with the existing infrastructure: nanoadsorbents, nanotechnology enabled membranes, and nanophotocatalysts. All three categories have commercial products, although they have not been applied in large scale water or wastewater treatment. Several other water treatment nanotechnologies have found their niche applications in POU systems. 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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