International Journal of Advanced Research and Development
ISSN: 2455-4030, Impact Factor: RJIF 5.24
www.newresearchjournal.com/advanced
Volume 1; Issue 4; April 2016; Page No. 25-28

Role of Nanotechnology in waste water treatment

Sulekha

Department of Chemistry, D.A.V. College, Abohar, Punjab, India.

Abstract

Water is a major resource in our day to day life. It is recognized as one of the major source of evolution from origin to degree of civilization. But now a day's waste water is becoming a major hazard in present scenario and waste water treatment is evolving as a major area of investigation. Nanoparticles are having a great prospective to be used in waste water treatment. Its matchless characteristic of having high surface area can be used efficiently for removing toxic metal ions, disease causing microbes, organic and inorganic solutes from water. Various classes of Nanoparticles are proved to be efficient for water treatment like metal-containing nanoparticles (like metal-oxides, metal-sulphides), carbonaceous Nanoparticles and zeolites. Nanotechnology has led to numerous well-organized ways for treatment of waste water in a more accurate way on both small as well as large scale. This paper presents a review on the role of Nanotechnology for waste water treatment.

Keywords: Nanoparticles, Polymers, Nanosorbents, Nanocatalyst, Water contamination, bioactive nanoparticles, Biomimetic membrane, Nanomembranes, Adsorption

Introduction

Water being a prime natural resource, a basic human need and a precious national asset, its use needs appropriate planning, development and management. Water is a mythical substance whose material existence is secondary compared to the symbolic value as it is manifested in our mind as the symbol of life. Increasing population coupled with overexploitation of surface and groundwater over the past few decades has resulted in water scarcity in various parts of the world. Waste water is increasing significantly and in the absence of proper measures for treatment and management, the existing freshwater reserves are being polluted.

Contaminated water contains unwanted substances and it adversely affects the quality and makes it unsuitable for use. Water resources become contaminated from various sources such as residential areas, commercial, industrial practices, agricultural practices etc. Unsustainable uses of resources and indiscriminate applications of pesticides, fertilizers, industrial pollutants are continuously disturbing the status of purity of groundwater. Major water pollutants include microbes (like intestinal pathogens and viruses), nutrients (like phosphates and nitrates), heavy metals and metalloids (like arsenic, lead, mercury), organic chemicals (like DDT, lubricants, industrial solvents), oil, sediments and heat. Parameters of wastewater vary widely and depend upon the source from which it is generated. Commonly they are pathogenic and non-pathogenic microorganisms, organic or inorganic substances.

Nanotechnology has a great potential in enhancing water and waste water treatment as it offers potential advantages like low cost, reuse and highly efficient in removing and recovering the pollutants. Nanoscience is the study of phenomenon and manipulation of materials at atomic, molecular and macromolecular scales, where properties differ significantly from those at a larger scale [1]. Nanotechnology is the design, characterization, production and applications of structures, devices and systems by controlling shape and size at nanometer scale. In recent years, a great deal of attention has been focused onto the applicability of nanostructured materials as adsorbents or catalysts in order to remove toxic and harmful substances from wastewater [2].

A promising application of nanotechnology is in waste water treatment. Nanomaterials are typically defined as materials smaller than 100 nm in at least one dimension [6]. At nano scale, materials possess some new size-dependent properties such as large surface to volume ratio, reactivity, rapid dissolution and adsorption which are different from the bulk material. Like different nano materials, single and multi-metal or doped metal oxides are subject of much interest since these materials possess high surface-to-volume ratio, enhanced magnetic property, special catalytic properties etc [3]. These properties are used for treatment of water efficiently.

Advances in nanoscale science and engineering suggest that many of the current problems involving water quality could be resolved or greatly diminished by using nanosorbents, nanocatalysts, bioactive nanoparticles, nanostructured catalytic membranes, 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 [4]. The defining factor which characterizes the capability of nanoparticles as a versatile water remediation tool includes their very small particle sizes (1–100 nm) in comparison to a typical bacterial cell which has a diameter on the order of 1 μm (1000 nm). Hence nanoparticles can be transported effectively by the groundwater flow [5]. They can also remain in suspension for sufficient time in order to launch an in situ treatment sphere. As a result, nanoparticles can be anchored onto a solid matrix such as a conventional water treatment material like activated carbon and/or zeolite for enhanced water treatment [5]. Realizing the molecular nature of contaminants in drinking water and the need to remove them at ultra-trace levels, significant progress has been made in the recent past to utilize nanomaterials for water purification. This article summarizes our recent efforts to understand the chemistry of nanoscale materials for the purification of drinking water.

Adsorption

Adsorption is the capability of all solid substances to attract to their surfaces molecules of gases or solutions with which they are in close contact. Solids that are used to adsorb gases or dissolved substances are called adsorbents, and the adsorbed molecules are usually referred to collectively as the adsorbate [7]. Due to their high specific surface area, nanoadsorbents show a considerably higher rate of adsorption for organic compounds compared with granular or powdered activated carbon. They have great potential for novel, more efficient, and faster decontamination processes aimed at removal of organic and inorganic pollutants like heavy metals and micropollutants. Various organic chemicals [8] are absorbed more efficiently by using carbon nano tubes (CNT) than activated carbon. Carbon nanotubes (CNTs) can be used as adsorbent to study the adsorption characteristics of some divalent metal ions (Cu, Co, Cd, Zn, Mn, Pb).

The effect of solution conditions such as pH and metal ions concentration can be examined. Organic compounds which have carboxylic, hydroxyl, amide functional groups also form hydrogen bond with the graphitic CNT surface which donates electrons [9]. CNT have high adsorption competence for metal ions [10] and therefore are a good alternative for activated carbon. CNTs have potential applications in water treatment due to their adsorption characteristics. Adsorption mechanisms will be better understood by investigating the effects of properties of both CNTs and organic chemicals along with environmental conditions. Another major factor affecting adsorption by CNTs is their suspendability, which also strongly affects their mobility, exposure, and risk in the environment. Nanoscale metal oxides like iron oxides like ferrous oxide, TiO2, Al2O3 are effective, low cost adsorbants for heavy metals And radio nucleides [11]. Dendrimers [polymeric nanomaterials] are capable of removing both organics and heavy metals [12]. Nanoadsorbents are used as powder, beads or porous granules loaded with nanoadsorbants.

Nanomembranes

Membranes with nanofibres can remove micro-size particles from aqueous phase with a high elimination rate without considerable fouling [13]. Such membranes are used as pretreatment method used proceeding to ultrafiltration or reverse osmosis. Nanofiltration is one of the membrane filtration techniques and can be defined as a pressure-driven process wherein molecules and particles less than 0.5 nm to 1 nm are rejected by the membrane. Nanofiltration membranes are characterized by a unique charge-based repulsion mechanism allowing the separation of various ions [14, 15]. They are mostly applied for the reduction of hardness, color, odor, and heavy metal ions from groundwater. The conversion of sea water into potable water (desalination) is another prosperous field of application since comparable desalination technologies are very cost-intensive.

Large number of studies on membrane nanotechnology has focused on creating multifunction membrane by adding nanomaterials into polymeric or inorganic membranes known as nanocomposite membranes. Nanocomposite membranes can be considered as a new group of filtration materials comprising mixed matrix membranes and surface-functionalized membranes. Mixed matrix membranes use nanofillers, which are added in a matrix material. In most cases, the nanofillers are inorganic and embedded in a polymeric or inorganic oxide matrix. These nanofillers feature a larger specific surface area leading to a higher surface-to-mass ratio [16, 17]. Metal oxide nanoparticles (Al2O3, TiO2) can help to increase the mechanical and thermal stability as well as permeate flux of polymeric membranes. The incorporation of zeolites improves the hydrophilicity of membranes resulting in raised water permeability. Antimicrobial nanoparticles (nanosilver, CNTs) and (photo) catalytic nanomaterials (bimetallic nanoparticles, TiO2) are mainly used to increase resistance to fouling.

Nanocatalysts

Nanocatalysts are also widely used in water treatment as it increases the catalytic activity at the surface due its special characteristics of having higher surface area with shape dependent properties. Due to high surface to volume ratio and shape dependent properties nanocatalytic substances like zero-valent metal, semiconductor materials and bimetallic nanoparticles are widely used in water treatment as they increase the catalytic activity at the surface. It enhances the reactivity and degradation of environmental contaminants such as organochlorine pesticides, halogenated herbicides azo dyes, polychlorinated biphenyls and nitro aromatics [18]. The commonly used catalytic nanoparticles are semiconductor materials, zero-valence metal and bimetallic nanoparticles for degradation of environmental contaminants such as PCBs (polychlorinated biphenyls), azo dyes, halogenated aliphatic, organochlorine pesticides, halogenated herbicides, and nitro aromatics [19]. Since hydrogen is used in making active catalyst in large scale by redox reactions, there is need in reducing its consumption and maintain hydrogen economy by directly making catalysts in metallic form. Silver (Ag) nanocatalyst, AgCCA catalyst, N-doped TiO2 and ZrO2 nanoparticles catalysts can be used which is highly efficient for degradation of microbial contaminants in water and are reusable as well [20]. Waste waters with specific contaminants like traces of halogenated organic compounds (HOCs) can be selectively biodegraded using advanced nanocatalytic activities. The contaminants (HOCs) are first converted into organic compounds using nano-sized Pd catalysts which are followed by its biodegradation in treatment plant. The nanocatalyst can be recycled back and reused due its property of having ferromagnetism which helps it to be easily separated.

Bioactive nanoparticles

Water pollution has caused lots of infectious diseases due to various contaminating pathogens. Many of the microorganisms acting as pathogens are antibiotic resistance and so it's very difficult to remove them from water [27]. Recently the concept of bioactive nanoparticles has emerged which has given the alternative of new chlorine –free biocide [21]. Silver nanoparticles can be biosynthesized extracellularly by bacteria *Bacillus cereus* which is having very high antibacterial potential. This strain was exposed to different concentrations of silver salt [AgNO3] and studied with the help of various analytical instruments like High Resolution Transmission Electron Micrography [HRTEM], Xray diffraction [XRD] and Energy Dispersive spectroscopy [EDS]

Prakash *et al.*, [22] found MgO nanoparticles and Cellulose acetate [CA] fibers embedded Ag nanoparticles effective against bacteria both Gram positive and Gram negative bacteria and spores as well. With the rapid increase in nanotechnology approaches for the detection of microbial pathogens is continuingly adding to the microbial and pathogen detection as well as in diagnostics [25].

Biomimetic membrane

Biomimetic membranes are chemically stable, have high permeability and selectivity34 and show a great degree of removing salts. Biomimetic membranes are developed by Albuquerque-based Sandia National Laboratories and the University of New Mexico. It represents a new and advanced way for water purification based on its specific design and fabrication [23]. The technology uses pressure driven water filtration. Some of the advantages of this technique are advancements, reduced cost, better water flux and improved efficiency with high salt rejection [24]. A biomimetic membrane can be prepared by vesicle fusion on a dense water-permeable support, such as an NF membrane. The membranes remove impurities like salt and others from water with applied pressure powered by electrical energy. The nonporous bio mimetic design enables high salt rejection and faster water flow at lower driving pressures generally used is around 5.5 bars. The process basically uses reverse osmosis principle with doubled efficiency due to its low pressure requirement [26].

A brief summary is shown in table-1 describing application of nanotechnology in water treatment

Table 1: Application of Nanotechnology in water and waste water treatment

Type of Nanoparticle	Type of pollutants removed
Carbon nano tubes	Organic Contaminant
Nano Scale metal Oxide	Heavy metals Radionucleides
Nano catalyst	PCB, Azodyes,Pesticides etc
Nano Structured catalytic	Decomposition of organic pollutant inactivation of micro organisms
Bioactive nanoparticle	Removal of Bacteria, fungi
Biomimetic membranes	Removing Salts

Conclusion

Nanotechnology for water and wastewater treatment is increasing day by day. The exclusive properties of nanomaterials show great opportunities for water and wastewater treatment. All three categories viz. nanoadsorbents, nanotechnology enabled membranes, and nanophotocatalysts have commercial products although they have not been applied in large scale water or wastewater treatment. Several other water treatment nanotechnologies have made immense enhancement in recent past for handling water contamination problems and are going to make additional advancements in coming future. Nanotechnology based treatment has offered very effectual, competent, resilient and eco-friendly approaches. These methods are more commercial, less tedious with very less waste generation than conventional bulk material based methods.

There is a significant need for novel advanced water technologies, in particular to ensure a high quality of drinking water, eliminate micropollutants, and intensify industrial production processes by the use of flexibly adjustable water treatment systems. Nanoengineered materials, such as nanoadsorbents, nanometals, nanomembranes, and photocatalysts, offer the potential for novel water technologies that can be easily adapted to customer-specific applications. Most of them are compatible with existing treatment technologies and can be integrated simply in conventional modules. One of the most important advantages of nanomaterials when compared with conventional water technologies is their ability to integrate various properties, resulting in multifunctional systems such as nanocomposite membranes that enable both particle retention and elimination of contaminants. Further, nanomaterials enable higher process efficiency due to their unique characteristics, such as a high reaction rate.

However, there are still several drawbacks that have to be negotiated. Materials functionalized with nanoparticles incorporated or deposited on their surface have risk potential, since nanoparticles might release and emit to the environment where they can accumulate for long periods of time. Up until now, no online monitoring systems exist that provide reliable real-time measurement data on the quality and quantity of nanoparticles present only in trace amounts in water, thus offering a high innovation potential. In order to minimize the health risk, several national and international regulations and laws are in preparation. Another more technical limitation of nanoengineered water technologies is that they are rarely adaptable to mass processes, and at present, in many cases are not competitive with conventional treatment technologies. Nevertheless, nanoengineered materials offer great potential for water innovations in the coming decades, in particular for decentralized treatment systems, point-of-use devices, and heavily degradable contaminants.

Reference

1. Shah MA, Ahmed T. Principles of Nanoscience and Nanotechnology. Narosa Publishing House: New Delhi, India, 2011, 34-47.
2. Savage N, Diallo MS. Nanomaterials and water purification: Opportunities and challenges. Journal of Nanoparticle Research. 2005; 7:331-342.
3. Gupta K, Bhattacharya S, Chattopadhyay DJ, Mukhopadhyay A, Biswas H, Dutta J *et al.* Ceria associated manganese oxide nanoparticles: Synthesis, characterization and arsenic(V) sorption behavior. Chemical Engineering Journal 2011; 172:219-229.
4. Mamadou SD, Savage N. Nanoparticles and water quality. Journal of Nano. Research. 2005; 7:325-330.
5. Zhang WX. Nano-scale iron particles for environmental remediation: an overview. Journal of Nanoparticle research 2003; 5:323-332.
6. Lelieveld J. The Chemistry of the Future Nanotechnology, Alliance for Chemical Science and Technologies in Europe, 2001.
7. Encyclopaedia Britannica Adsorption. [April 9, 2014]. Available from:http://www.britannica.com /EBchecked/topic /6565/adsorption.
8. Prachi1 P, Gautam D, Madathil Nair ANB. Nanotechnology in Waste Water Treatment: A Review, International Journal of Chem Tech Research. 2013; 5:2303-2308.

9. Pan B, Xing BS. Adsorption mechanisms of organic chemicals on carbon nanotubes, Environmental Science and Technology, 2008; 42:9005-9013.
10. Yang K, Wu WH, Jing QF, Zhu LZ. Aqueous adsorption of aniline, phenol, and their substitutes by multi-walled carbon manotubes, Environmental Science and Technology, 2008; 42:7931-7936.
11. Lu CS, Chiu H, Liu CT. Removal of zinc [II] from aqueous solution by purified carbon nanotubes: kinetics.
12. Diallo MS, Christie S, Swaminathan P, Johnson JH, Goddard WA. Dendrimer enhanced ultrafiltration. 1. Recovery of Cu [II] from aqueous solutions using PAMAM dendrimers with ethylenediamine core andterminalNH2 groups, Environmental Science and Technology, 2005; 39(5):1366-1377.
13. Ramakrishna S, Fujihara K, Teo WE, Yong T, Ma ZW, Ramaseshan R. Electrospun nano fibers: solving global issues, Materials Today, 2006; 9(3):40-50.
14. Qu X, Alvarez PJ, Li Q. Applications of nanotechnology in water and wastewater treatment. Water Res. 2013; 47:3931-3946.
15. Sharma V, Sharma A. Nanotechnology: an emerging future trend in wastewater treatment with its innovative products and processes. International Journal of Enhanced Research in Science Technology and Engineering. 2012; 1:121-128.
16. Wegmann M, Michen B, Graule T. Nanostructured surface modification of microporous ceramics for efficient virus filtration. J Eur Ceram Soc. 2008; 28:1603-1612.
17. Feng C, Khulbe KC, Matsuura T, Tabe S, Ismail AF. Preparation and characterization of electro-spun nanofiber membranes and their possible applications in water treatment. Separation and Purification Technology. 2013; 102:118-135.
18. Zhao X, Lv L, Pan B, Zhang W, Zhang S, Zhang Q. Polymer-suported nanocomposites for environmental aplication: A review, Chemical Enginering Journal. 2011; 170(2-3):381-394.
19. Xin Zhaoa, b, Lu Lva, b, Bingcai Pana, b, Weiming Zhanga, b, Shujuan Zhanga, Quanxing Zhanga, b. Polymer-supported nanocomposites for environmental application: A review, Chemical Engineering Journal. 2011; 170(2-3):381-394.
20. Shalini Chaturvedi A, Pragnesh N, Dave A, Shah NK. Applications of nano-catalyst in new era. Journal of Saudi Chemical Society, 2012; 16(3):307-325.
21. Available at: http://www.nanowerk.com/spotlight/spotid=4662.php 2008.
22. Prakash A, Sharma S, Ahmad N, Ghosh A, Sinha P. Synthesis of Agnps By Bacillus Cereus Bacteria and Their Antimicrobial Potential. Journal of Biomaterials and Nanobiotechnology. 2011; 2(2):155-161.
23. http://www.rdmag.com/ award-winners/2011/08/nano-scale-difference-waterpurification, A nano-scale difference in water purification. The Biomimetic Membranes for Water Purification Development Team, 2011
24. Jeffrey C, Brinker, Ying-Bing Jiang, Shaorong Yang, 2011. Available at: http://stcunm.flintbox.com / public/project/7498/
25. Prachi Pranjali Gautam, Deepa Madathil, Brijesh Nair AN. Nanotechnology in Waste Water Treatment: A Review. International Journal of ChemTech Research. CODEN (USA): IJCRGG ISSN: 0974-4290 2013; 5(5):2303-2308.
26. Dave Sushma, Sharma Richa. Use of Nanoparticles in Water Treatment: A review; International Research Journal of Environment Sciences, ISSN 2319–1414 2015; 4(10):103-106.
27. Sayan Bhattacharya, Indranil Saha, Aniruddha Mukhopadhyay, Dhrubajyoti Chattopadhyay, Uday Chand Ghosh, Debashis Chatterjee. Role of nanotechnology in water treatment and purification: Potential applications and implications International Journal of Chemical Science and Technology. ISSN 2249-8532