Scientific Journal of Impact Factor (SJIF): 5.71

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Conference of Nanotechnology & Applications In Civil Engineering-2018.
Volume 5, Special Issue 03, Feb.-2018 (UGC Approved)

Nano materials in water purification

H.O.D Dr.Komal Mehta[1], Prachi Sata[2], AdityaSaraswat [3] ,Devanshu Mehta[4]

[1]Civil Department, ITM Universe
[2]Civil Department, ITM Universe
[3]Civil Department, ITM Universe
[4]Civil Department , ITM Universe

Abstract - *It is said that water is life and clean water is health . Due to long term development and industrialization use of water has increased immensely since 15-20 years .Population explosion and higher standards of living also contributeto increase in demand. On the other hand this has also lead to contamination of water which promotes water borne diseases. According to climate researchers it has led to water scarcity and 15-20% population suffer from water scarcity . Currently used techniques are cheap but are not accurate enough. Adopting nanoengineered materials and nanotechnology imbibes new opportunity to explore and adopt water treatment and purification processes. Due to better properties and characteristics of nano materials such as specific surface area , reactivity , electrical and optical properties use of nanomaterials is encouraged. The use of nano materials is limited due to cost parameter , safe disposal and commercial availability. Further researches and advancements in nanomaterials , nanoadsorbents and nanocarbons are carried out .In this paper the most extensively studied nano materials are discussed and highlighted .Besides future aspects of nano materials in water and and waste water treatment are discussed.*

Keywords-*adsorbents, carbon based Nano adsorbents , carbon nanotubes , zeolites , Nano polymers , Nano metals , Nano metal oxides ,.*

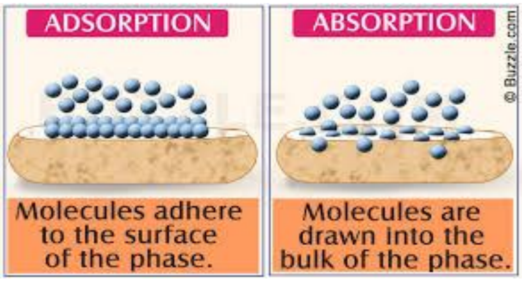
I. INTRODUCTION

Generally, Nano materials describe materials of which the structural components are sized between 1 and 100nm. Due to the Nano scale size of nanomaterial; there properties such as mechanical, electrical, optical, magnetic properties, adsorption, high reactivity are significantly different from conventional materials. In particular the application of Nano materials in water treatment has drawn wide attention. At present, the most extensively studied Nano materials for water purification include CNT, zeolites, Nano metals, Nano composites, etc.

Adsorption

Adsorption is the adhesion of atoms, ions, or molecules from a gas, liquid or dissolved solids to a surface. Solids that are used to adsorb gases or dissolved substances are called adsorbents and the adsorbed molecules are referred as the adsorbate. Adsorption creates a film of adsorbate on the surface of adsorbent. It is a surface base process unlike absorption. Due to high specific surface area, Nano adsorbents show a considerably higher rate of adsorption for organic compounds as compared to conventional activated carbon. They are more efficient and do faster dcontamination processes aimed at removal of organic and inorganic polltants like heavy metals and micropollutants. These enables implementation of more compact water and wastewater treatment devices with smaller footprints.
Research activities mainly focus following nano adsorbents

- Carbon nano tubes
- Polymeric nano adsorbents
- Zeolites
- Metal based nano adsorbents



Carbon nanotubes

Carbon nano tubes are allotropes of carbon.CNT are grapheme sheets rolled up in cylinders with diameter as small as 1 nm. These cylindrical carbon molecules have unusual properties which are valuable for nanotechnology , electronics , optics and other fields of material science and technology . Depending on their manufacturing characteristics they are characterized as single wall nanotubes and multi wall nanotubes. CNT have attracted great interest as an emerging adsorbent due to their unique properties . With an extremely large specific are and abundant porous structures , CNT possess exceptional adsorption capabilities and high adsorption efficiency for numerous kinds of contaminants. Due to their hydrophobic structure CNT have to be stabilized in aqueous suspension in order to avoid aggregation that reduces the active surface. They can be used for adsorption of persistent contaminants as well as to pre concentrate and detect contaminants.

Metal ions are adorbable by CNT through electrostatic attraction and chemical bonding . Although chemical oxidation occurs no toxic bybroducts are produced which is an important advantage over conventional disinfection processes such bas chlorination and ozonation .They can be simply regenerated through appropriate adjustment of operating conditions like Ph shift. Meanwhile , Stafieg and Pyrzynska found out that the solution conditions such as Ph and metal ion concentration could affect the adsorption characteristics of CNT . Oxidised CNT have also shown exceptionally high sorption capacity and efficiency for Pb(II) , Cd(II) , Cr(VI) from water.

Coventional desalination methods are energy consuming and technically demanding, where as adsorption based techniques are simple and easy to use for point of use systems . Plasma modified ultralong CNts that feature an ultra high specific adsorption capacity for salt that is two orders of magnitude higher when compared with conventional carbon based water treatment systems.

Inspite of the exceptional properties of CNTs , the development and application of CNTs are aminly limited by their low volume of production and high cost.

Polymer Nano adsorbents.

Polymeric nanoadsorbents such as dendrimers (repetitively branched molecules) are utilizable for removing organics and heavy metals. Organic compounds can be adsorbed by the interior hydrophobic shells, whereas heavy metals can beadsorbed by the tailored exterior branches. Diallo et al integrated dendrimers in an ultrafiltration device in orderto remove copper from water. Nearly all copper ions were recovered by use of this combined dendrimer-ultrafiltrationsystem. The adsorbent is regenerated simply through a pH shift. Sadeghi-Kiakhani et al produced a highly efficient
bioadsorbent for the removal of anionic compounds such as dye from textile wastewater by preparing a combinedchitosan-dendrimer nanostructure. The bioadsorbent is biodegradable, biocompatible, and nontoxic. They achieveremoval rates of certain dyes up to 99% .

Zeolites

Zeolites in combination with silver atoms have been known since the early 1980s. Zeolite has a very porous structure inwhich nanoparticles such as silver ions can be embedded. There they are released from the zeolite matrix by exchangewith other cations in solution. Egger et compared various materials containing nanosilver, including zeolites. Whenused for sanitary purposes, the silver attacks microbes and inhibits their growth, as shown by Agion® (Sciessent LLC,
Wakefield, MA, USA). A small amount of silver ions is released from the metallic surface when placed in contact withliquids. The success of this composition in water disinfection was shown once again by Petrik et al.20 The Water ResearchCommission Report No KV 297/12 shows the innovative use of zeolites as an adsorbing platform for silver nanoparticles asa source of silver ions for a disinfectant. Another possibility is applying zeolites themselves as nanoparticles, as shown byTiwari et al, who prepared nanozeolites by laser-induced fragmentation of zeolite Linde type A microparticles and Junget al, who used nanozeolites in sequencing batch reactors for waste water treatment.

Properties, applications, and innovative approaches of nanoadsorbents

Both CNTs and nanometals (see section on Nanometals and nanometal oxides) are highly effective nanoadsorbents for the removal of heavy metals such as arsenic. With regard to this application field, nanometals and zeolites benefit from theircost-effectiveness and compatibility with existing water treatment systems since they can be implemented in pelletsand beads for fixed absorbers. In contrast, the production of CNTs is very costly, and additional technical devices, forexample, membrane filtration plants, have to be integrated in order to make absolutely sure that no nanoparticles aredischarged into the aqueous environment. A major advantage of CNTs in terms of micropollutant removal is their strongadsorption capacity for polar organic compounds due to the diverse interactions between contaminants and CNTs.Whereas CNTs and nanometals are commercially available for diverse applications, market entry of polymericnanoadsorbents is ongoing. From the point of view of process efficacy, polymeric nanoadsorbents are highly advancedmaterials allowing both removal of heavy metals as well as organic contaminants within one process step. The major limitation of this novel adsorption technology is the technically demanding and cost-intensive production process for polymeric dendrimers that has to be improved.

Nanometals and metal oxides

Nanoscale metal oxides are promising alternatives to activated carbon and effective adsorbents to remove heavy metals and radionuclides. . Nanosized metals or metal oxides, including $Fe3O4$, $MnO2$, $TiO2$, MgO , CdO and ZnO , provide high surface area and specific affinity. Iron is one of the most widespread elements in the earth. The facileness of resource and ease of synthesis render nanosized ferric oxides to be low-cost adsorbents for toxic metal sorption. Since elemental iron is environmentally friendly, nanosized ferric oxides can be pumped directly to contaminated sites with negligible risks of secondary contamination . Many reports discussed the influence of different parameters on the removal of metal ions by Fe3O4 magnetic nanoparticles .Metal oxides possess minimal environmental impact, low solubility, and are not involved in secondary pollution formation

As well as having a high specific surface area, they feature a short intraparticle diffusion distance and are compressible without a significant reduction of surface area. Some of these nanoscale metal oxides (eg, nanomaghemite and nanomagnetite) are superparamagnetic, which facilitates separation and recovery by a low-grad ientmagnetic field. They can be employed for adsorptive media filters and slurry reactors. Nano iron hydroxide [α-FeO(OH)] is a robust abrasion-resistant adsorbent with a huge specific surface area that enables adsorption of arsenicfrom waste and drinking water. Surface functionalised (COOH, NH2,SH)Fe3O4 is more effective than bare Fe3O4.It removes contaminants by ion echachange method or electrostatic attraction based on the surface function . In addition, the adsorption process was found to be highly dependent on the amount, surface functionality and pH of the medium, which caused these nanoparticles to selectively adsorb metal ions . An almost 100% removal rate of Cr(III), Co(II), Ni(II), Cu(II), Cd(II) and Pb(II) ions from water was reported at pH>8 by these functionalized nanoparticles .

Nano Silver and Nano titanium dioxide

Nanosilver exhibits a strong and broad-spectrum antimicrobial activity, it has hardly any harmful effects inhumans. It is already applied to point-of-use water disinfection systems and antibiofoulingsurfaces.24 Nano-titanium dioxide (TiO2), featuring high chemical stability and low human toxicity at a cheap price, isutilizable in disinfection and decontamination processes.25,26 Further information is provided in thesection on photocatalysis. The main advantage of nano-TiO2 over nanosilver is the nearly endless life time ofsuch coatings, since TiO2 as a catalyst remains unchanged during the degradation process of organic compounds andmicro-organisms. The antimicrobial effect of nanosilver is based on the continuous release of silver ions. A disadvantage of bactericidal nanoparticles in general except for nano-TiO2 is that no bactericidal substances such as hydroxyl radicals remain in the water past the contact time that could ensure the water quality in storage and distribution devices (depot effect).

Properties, applications, and innovative approaches for nanometals and nanometal oxides

Photocatalytic TiO2 benefits from its low price, high availability, inertness, and broad-spectrum effect on the chemical degradation of the majority of organic contaminants and micro-organisms. This makes it an ideal, robust, durable and effective nanomaterial for chemical-free water and wastewater treatment processes in both large-scale and small-scale treatment plants. However, up until now, the efficacy of ultraviolet-visible photocatalytic TiO2 in particular has been relatively low compared with similar oxidation processes like ozonation. Nanosilver benefits from its low toxicity, high availability, and well proven bactericidal effect. However, since it is dissolved during the duration of the process, its application is restricted to low feed volumes where a maximum life time can be achieved, for example, with point-of-use devices.

Magnetic nano materials

The use of magnetic nanoparticles (magnetite Fe3O4) for separation of water pollutants has already been established in ground water remediation, in particular for the removal of arsenic. The conventionally applied “pump-and-treat”technology for groundwater treatment comprises pumping up the groundwater to the surface and further treatment, usually by activated carbon for final purification. The considerably extended operating hours and higher environmental clean-up costs can be reduced by applying in situ technologies. Magnetic nanoparticles can be injected directly into the contaminated ground, and loaded particles can be removed simply through a magnetic field. Besides ground water remediation, magnetic recovery makes such nanoparticles an ideal compound to increase the osmotic pressure of draw solutions used in forward osmosis. Forward osmosis as contrary process to reverse osmosis draws water from a low osmotic pressure to one with a higher osmotic pressure (draw solution) using the osmotic gradient.

Limitations of nanobased materials and processes for water applications

Commercialization of nanoengineered materials for water and wastewater technology strongly depends on their impact onthe aqueous environment. Numerous studies including toxicity tests, life cycle analysis, technology assessment, andpathways and dispersal of nanoparticles in water bodies have been carried out in order to evaluate the health risks of nanomaterials. The results of these studies have led to a better understanding of the behavior of nanoparticles such as

CNTs, TiO2, and silver nanoparticles in aqueous systems; thus, stakeholders from administration, politics, and industry are supported to create new laws and regulations or modify present ones.

Conclusion and future aspects

The presence of heavy metal ions and dyes in wastewater is a major concern for environment conservation and human health. The removal process of these ions has not reached the optimum conditions. Based on the unique properties of nanomaterials, they have been widely studied for heavy metals and dye removals from wastewater due to their high surface area, low particles size which leads to high numbers of adsorption active centers. The recent trends is cost effective and environmentally acceptable adsorbents for water purification are studied. Further researches are being carried out for low production costs and easy disposal of some nano materials. One of the most important advantages of nano materials when compared with conventional water technologies is their ability to integrate various properties. This results to formation of multi-functional systems. This article reviews the past, present and future approaches for using nanomaterials as effective adsorbents for the removal of heavy metal ions and dyes from wastewater. The recent trends of using nanomaterials as cost-effective and environmentally acceptable adsorbents for water purification were discussed in this article. Thisreview highlights the promising present applications of nanomaterials as adsorbents because of their unique morphological and structural properties.

References

.
[1] By how much do land, water and crop yields need to increase by 2050?. The resource outlook to 2050; Presented at the Food and Agriculture Organization of the United Nations Expert Meeting entitled "How to Feed the World in 2050"; Rome, Italy. June 24–26, 2009.

[2] World Water Development Report 4 Managing water under uncertainty and risks. 2014. [Accessed July 24, 2014]. Available from: http://www.unesco.org/new/en/natural-sciences/en vironment/water/wwap/wwdr/wwdr4-2012.

[3] Schewe J, Heinke J, Gerten D, et al. Multimodel assessment of water scarcity under climate change. Proc Natl Acad Sci U S A. 2013;111:3245–3250. [PMC free article] [PubMed]

[4] Encyclopaedia Britannica Adsorption. [Accessed April 9, 2014]. Available from:http://www.britannica.com/EBchecked/topic/6565/ adsorption.

[5] Pan B, Xing BS. Adsorption mechanisms of organic chemicals on carbon nanotubes. Environ Sci Technol. 2008;42:9005–9013. [PubMed]

[6] Rao GP, Lu C, Su F. Sorption of divalent metal ions from aqueous solution by carbon nanotubes: a review. Separation and Purification Technology. 2008;58:224–231.

[7] Liu X, Wang M, Zhang S, Pan B. Application potential of carbon nanotubes in water treatment: a review.J Environ Sci (China) 2013;25:S1263–S1280. [PubMed]

[8] Yan HY, Han ZJ, Yu SF, Pey KL, Ostrikov K, Karnik R. Carbon nanotube membranes with ultrahigh specific adsorption capacity for water desalination and purification. Nat Commun. 2013;4:2220. [PubMed]

[9] Hashim DP, Narayanan NT, Romo-Herrera JM, et al. Covalently bonded three-dimensional carbon nanotube solids via boron induced nanojunctions. Sci Rep. 2012;2:363. [PMC free article] [PubMed]

[10] De Volder MF, Tawfick SH, Baughman RH, Hart J. Carbon nanotubes: present and future commercial applications. Science. 2013;339:535–539. [PubMed]

[11] Ji L, Chen W, Duan L, Zhu D. Mechanisms for strong adsorption of tetracycline to carbon nanotubes: a comparative study using activated carbon and graphite as adsorbents. Environ Sci Technol. 2009;43:2322–2327. [PubMed]

[12] Cong Q, Yuan X, Qu J. A review on the removal of antibiotics by carbon nanotubes. Water Sci Technol.2013;68:S1679–S1687. [PubMed]

[13] Qu X, Alvarez PJ, Li Q. Applications of nanotechnology in water and wastewater treatment. Water Res.2013;47:3931–3946. [PubMed]

[14] Hajeh M, Laurent S, Dastafkan K. Nanoadsorbents: classification, preparation, and applications (with emphasis on aqueous media) ChemRev. 2013;113:S7728–S7768. [PubMed]

[15] 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 and terminal NH2 groups. Environ Sci Technol. 2005;39:S1366–S1377. [PubMed]

[16] Sadeghi-Kiakhani M, Mokhtar Arami M, Gharanjig K. Dye removal from colored-textile wastewater using chitosan-PPI dendrimer hybrid as a biopolymer: optimization, kinetic, and isotherm studies. J Appl Polym Sci. 2013;127:2607–2619.

[17] Baker MD, Ozin GA, Godber J. Far-infrared studies of silver atoms, silver ions, and silver clusters in zeolites A and Y. J Phys Chem. 1985;89:305–311.

[18] Egger S, Lehmann RP, Height MJ, Loessner MJ, Schuppler M. Antimicrobial properties of a novel silver-silica nanocomposite material. Appl EnvironMicrobiol. 2009;75:2973–2976. [PMC free article][PubMed]

[19] Nagy A, Harrison A, Sabbani S, Munson RS, Jr, Dutta PK, Waldman WJ. Silver nanoparticles embedded in zeolite membranes: release of silver ions and mechanism of antibacterial action. Int J Nano medicine. 2011;6:1833–1852. [PMC free article] [PubMed]

[20] Petrik L, Missengue R, Fatoba M, Tuffin M, Sachs J. Silver/zeolite nanocomposite-based clay filters for water disinfection. Report to the Water Research Commission. No KV 297/12. [Accessed July 24, 2014]. Available from: http://www.ircwash.org/resources/silver-zeolite-na no-composite-based-clay-filters-water-disinfection.
[21] Tiwari DK, Behari J, Sen P. Application of nanoparticles in waste water treatment. World Applied Sciences Journal. 2008;3:417–433.
[22] Jung JY, Chung YC, Shin HS, Son DH. Enhanced ammonia nitrogen removal using consistent biological regeneration and ammoniumexchange of zeolite in modified SBR process. Water Res.2004;38:347–354. [PubMed]
[23] Aredes S, Klein B, Pawlik M. The removal of arsenic from water using natural iron oxide minerals. Journal of Cleaner Production. 2012;29–30:208–213.
[24] Nowack B, Krug HF, Height M. 120 years of nanosilver history: implications for policy makers. Environ Sci Technol. 2011;45:1177–1183. [PubMed]
[25] Kim ES, Hwang G, El-Din MG, Liu Y. Development of nanosilver and multi-walled carbon nanotubes thin-film nanocomposite membrane for enhanced water treatment. J Memb Sci. 2012;394:37–48.
[26] Nora S, Mamadou SD. Nanomaterials and water purification: opportunities and challenges. J Nanopart Res. 2005;7:331–342.
[27] Quang DV, Pradi B, Sarawade SJ, et al. Effective water disinfection using silver nanoparticle containing silica beads. Appl Surf Sci. 2013;287:84–90.
[28] Gupta AK, Deva D, Sharma A, Verma N. Fe-grown carbon nanofibers for removal of arsenic (V) in wastewater. Ind Eng Chem Res. 2010;49:7074–7084.
[29] Kim YC, Han S, Hong S. A feasibility study of magnetic separation of magnetic nanoparticle for forward osmosis. Water Sci Technol. 2011;64:469–476. [PubMed]
[30] Sadegh, H., Ghoshekandi, R.S., Masjedi, A., Mahmoodi, Z., Kazemi, M.: A review on Carbon nanotubes adsorbents for the removal of pollutants from aqueous solutions. Int. J. Nano Dimens. 7(2), 109 (2016)
[31] Theron, J., Walker, J., Cloete, T.: Nanotechnology and water treatment: applications and emerging opportunities. Crit. Rev. Microbiol. 34(1), 43–69 (2008)
[32] Savage, N., Diallo, M.S.: Nanomaterials and water purification: opportunities and challenges. J. Nanopart. Res. 7(4–5), 331–342 (2005)
[32] Machida, M., Mochimaru, T., Tatsumoto, H.: Lead (II) adsorption onto the graphene layer of carbonaceous materials in aqueous solution. Carbon 44(13), 2681–2688 (2006)
[33] Sharma, Y., Srivastava, V., Singh, V., Kaul, S., Weng, C.: Nanoadsorbents for the removal of metallic pollutants from water and wastewater. Environ. Technol. 30(6), 583–609 (2009)