REVIEW OF RESEARCH
IMPACT FACTOR : 5.7631(UIF) UGC APPROVED JOURNAL NO. 48514 ISSN: 2249-894X

VOLUME - 8 | ISSUE - 4 | JANUARY - 2019

NANOTECHNOLOGY FOR WATER TREATMENT

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ABSTRACT :

To provide clean and fresh water to the living organism is the great challenge of 21st century. The decrease of the availability of clean water is due to both natural and manmade sources. Drought, Climate change, Population growth, Human activities etc. play great role in contaminating natural water sources. Nanotechnology is the branch of science which deals with systems in molecular or nano scale. One of the important applications of Nanotechnology is the low cost detection and treatment of impurities in water. The current advances in nanoscience and nanotechnology provide different methods to overcome the current problems of water quality. This includes the use of Nanosorbents, Nanofibres, Nanomembrane, Nano composites, Nano particle enhanced filtration, Molecular imprinted polymers, Nanoballs etc.

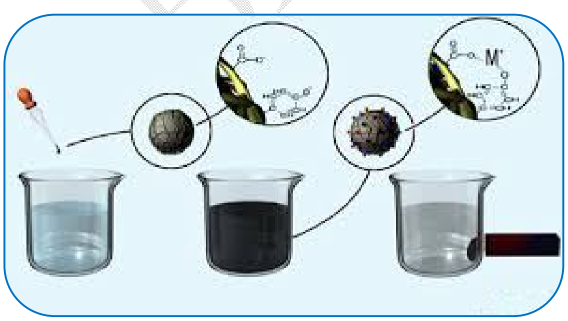
KEYWORDS : *nanotechnology, membrane, nano adsorbent, molecular imprinted polymers, waste water and water treatment.*

INTRODUCTION:

"Agni and water are givers and sustainers of life, they are affectionate mothers, givers of all, giver of life, and they have healing powers".The words from Rig Veda are very relevant in today's world. Water is extra ordinary .From the owesome beauty of giant glaciers to the fragility of snow flakes, from the poetry of rain to the magic of mist, water is the most important input for survival of not only plant, human being , animals and other living being on the earth but also economic development and environmental sustainability(.Bansil, 2004). We are on the threshold of a water crisis.

Comprising over 70% of earth surface, water is undoubtedly the most precious natural resources that exists on our planet. Out of which 97% of earth water supply is from the ocean, of the remaining 3% , 20% is locked in mountain glaciers and polar caps, and only remaining 1% is available for human use. Life on earth without water is non-existent. Although we human recognize this fact, we disregard it by polluting our rivers, lakes and oceans. Subsequently, at a very alarming rate drinking water become scarcer. Water pollution is a global problem, both developed and developing countries (Gopinath & Chandradasan, 2014).

The solution for water pollution does not come from one stream of science or engineering, now it's a multi-disciplinary approach. The characteristics of wastewater depend upon the sources of its discharge. Sewages in general contain organic, inorganic and living matters(B.C.Punmia & Jain, 2003). Nanotechnology enabled water and waste water treatment promises not only overcome major challenges of existing technologies but also to provide new treatment capabilities that could allow economic utilization of unconventional water sources to expand the water supply. This article gives a brief overview of the use of nanomaterial in the purification of water contaminated by toxic metal ions, organic and inorganic solutes, bacteria and virus.



NANOMATERIALS

Nanotechnology is the branch of applied science whose aim is to create devices, materials and systems through the understanding and control of matter at nanometer scale. Nanotechnology may be able to create many materials that have wide application in the field of medicine, electronics, biomaterials, energy production, optical fiber and Purification. Some of these applications utilize size dependent properties of nano materials which relate to the high specific surface area, high reactivity, strong sorption, high strength, thermal stability, low permeability and high conductivity, which are rather different from the bulk counterpart(Richardson & Ternes, 2011).

About 2000 years ago sulfide nano crystals were used by Greeks and Romans and about 1000 years ago gold nanoparticles were used to produce different colors in glass windows. Concept of nanotechnology was first discussed by Richard Feynman, a renowned physicist in 1959 in his talk as “There is plenty of room at the bottom”. The term nanotechnology was first used by Norio Taniguchi in 1974.First reported nanoparticle was synthesized by Michael Faraday. Today nano phase engineering expands in a rapidly growing number of structural and functional materials including both organic and inorganic. Nanostructured materials can be classified according to its structure as zero dimensional (spheres) one dimensional(Nanowires,Nanorods), two dimensional(Nanofilms, Nanoplates) and three dimensional (Nanomaterials) (Madras, 2011)nanostructures. There are natural and synthetic nanomaterials. Some of the carbon based nanomaterials are Fullerenes, Carbon nanotubes and Nanobuds. Nanomaterials can be synthesized by either Top-down or Bottom-up techniques.In top-down bulk material is modified to desired size and shape by milling and grinding.In bottom up process using physical and chemical forces Nano scales are assembled into layer structure.Some methods of preparation of nanomaterials are sol-gel, thin film desorption, Chemical vapor deposition(T.Pradeep, 2007), atomic layer desorption, Nanolithography etc. Nanomaterials are already in industrial and consumer products, including Drug delivery system, stain resistant clothing, Solar cells, Cosmetics and food additives(improvement). Most nanomaterial research is centered on developing new uses for nanomaterials and new products with unique properties; but on the other side there is also significant concern regarding nanomaterials as environmental contaminant. Innovative use of nanoparticle for treatment of industrial and nonindustrial waste water is one of the potential application .Below we highlight some of the selected studies in this field.

APPLICATION OF NANOMATERIALS IN WATER PURIFICATION

The size dependent properties of nanomaterials are responsible for its extensive use in water and waste water treatment.Heavy metal ions(HMI) are one of the micro pollutant that represent an increasing environmental problem. The main sources of this are cosmetics, fertilizers and other industrial and household waste(Roy,2010).The HMI cause various diseases and disorders such as nervous,reproductive and gastrointestinal.Among various heavy metals Pb, Cd, Hg, Cr and As are highly toxic(Pujol et al.,2014)(sharma, 2005).Heavy metals are major water pollutant and dangerous to both human and animal(B.Bansod et al,2017).A number of techniques have been developed for heavy metal ion detection which include absorption spectroscopy, mass spectroscopy, voltrametry and fluorescent spectroscopy. The development of simple, rapid, inexpensive, method is a challenging one which can be met by nanotechnology (Forzan s. et al,2005).

Climate changes due to global warming leads to ice melt, sea level rise, increased evaporations. This makes sea water saltier and decrease the availability of fresh water. The rapid change in human life style over the years has constantly added pollutants to the aquatic system. Adoption of single method for water purification is insufficient due to the threads faced by the conventional methods(Das, Ali, Hamid, Ramakrishna, & Chowdhury, 2014).

Nanomaterials developed by nanotechnology give immeasurable opportunity for water purification and detection of pollutants even in its ionic forms. Gold and iron nanoparticles are especially suited for removing inorganic heavy metals for waste water(S. Kar, R.C. Bindal, P.K. Tewari,2014). Nanomaterials coupled with other metals are also used in this area. This article gives a brief overview of the use of nanomaterials in the purification of water contaminated by toxic metal ions, organic and inorganic solutes, bacteria and virus (S.Diallo, 2005). Absorption, Membrane and Novel Molecular imprinting are discussed here.

Adsorption

Adsorption is a process in which pollutants are adsorbed on a solid surface. It’s a surface phenomenon due to physical or chemical sorption. This can be explained by Langmuir, Freundlich, Halsey and Henderson models. The heavy metal ion is toxic and dangerous to eco system. High level cobalt cause nausea, vomiting and asthma. Zinc leads to poor growth, high level of Nitrate leads to blue baby syndrome.most commonly used nanoparticle for metal ion removal are Al, Fe, and Ti. Fe (0) is used to remove As, Cd, Cr, Zn and Pb(Ponder, S. M.; Darab, J. G.,2000). Al is used to remove Cd, Cu, Pb and Hg ions (Pacheco, S.; Rodriguez, R. J., 2001). Al, Fe and Ti oxides are effective in the removal of organic pollutants like Dye (Red195 azo dye, Blue 19, Red 198) hydrocarbon (phenanthroline) and biological pollutant like viruses and bacteria.

The small size of Fe_3O_4 nano sorbent was favorable for the diffusion of metal ions from solution onto the active sites of the adsorbents surface. The efficiency of Fe_3O_4 can be increased by modifying iron oxide nanomaterials by covalent binding of 1,6 hexadiamine on the surface of Fe_3O_4 for the removal of Cu^{2+} from aqueous solution(Hao YM, Man C, Hu ZB,2010). Fe_3O_4 hallow nanosphere effectively remove red dye. Carbon coated Fe_3O_4 effectively remove organic contaminants. There are various iron oxide structures such as nano crystals, particles, cubes, rods wires and tubes. Novel 3D flower like iron oxide was synthesized by ethylene glycol mediated self- assembly. There are three iron oxide with flower like morphology they are α-Fe_2O_3, μ-Fe_2O_3, or Fe_3O_4 .It remove highly toxic As(V) and Cr(VI) from waste water(Zhong et al., 2006).

Ti-Fe oxide nano adsorbent is a bimetallic oxide adsorbent. Its efficient an economical adsorbent for fluoride removal from water. Fluoride is essential for human skeleton system,but excess of fluoride cause fluorosis. Zr oxide and Fe oxide are used for its removal but its efficiency is very low. Fe-Ti oxide are of high adsorption capacity and low cost(L. Chen et al., 2012).

The adsorption capacity of nanoTiO_2 and Al_2O_3 are much higher than nano ZnO and CuO due to the higher surface area for the removal of methylene blue and As(V) (Zhan, Jiang, & Ma, 2014). 3D graphene has large surface area and porous structure which make them super adsorbent and catalyst. Its development is green, facile and of low cost. These are excellent adsorbent towards dye, organic solvents like n-Dodecanese. Tannic acid induced 3D graphene shows excellent anti-bacterial activity (Luo, Lai, Zhang, Liu, & Liu, 2016).

Carbon nano tubes like SWCNT and MWCNT are used to remove metals from waste water. MWCNT removes Cd(II), Pb(II), Cu(II) while SWCNT is good in removing dissolved organic matter(T.Pradeep, 2007).Dye which is extensively used in textile industry can be best isolated from water using metal organic polyhedral (MOPs)among which Cu^{II} nanoballs are of good application.MOPs purify water by creating porous network accommodate guest molecule(Amayuelas et al., 2016).

Membrane Technology

Membrane technology has emerged as a significant development in water treatment. There are physical chemical and biological techniques for water treatment. Physical biological and chemical methods to remove organic and inorganic matters(sharma, 2005).In this technique we use selective permeable barriers with porous sized to permit the passage of water molecules but small enough to retain wide range of compounds dissolved in it. One of the biggest challenges in desalination is its high energy consumption. Low pressure nanofiltration membrane can be used for the pre-treatment of sea water to enhance system performance and reduce energy consumption.

In the application of polymeric membrane ultrafiltration(UF) and microfiltration(MF) are effective in desalination(X. Chen, Hong, Xu, & Ong, 2012),but these are not commercially and practically available(P.S. Goh, A.F. Ismail, B.C. Ng,2013).Other membrane techniques include dialysis, reverse osmosis, electro dialysis etc. Carbon nano tubes (CNT) are highly selective for size controlled separation of pollutants. Low energy consumption and self cleaning functions have made CNT membrane extraordinary over the conventional one. Smooth and hydrophilic inner core of CNT allow the spontaneous passage of the water molecule(M. Majumder,2005).Functionalized CNT is a precondition for CNT based water purification, here we add positive, negative or hydrophilic groups on the CNT surfaces(Das et al., 2014).

Oil spillage is one of the biggest contribution to the water pollution.CNT in macro/ mesopore channel of ceramic membrane is developed to remove oil droplet from water.CNT is implanted on ceramic membrane by means of chemical vapour deposition(X. Chen et al., 2012). Mg Al-layered double hydride 3D sheet on polyacrilonitril porous nanofibrous membrane and the surface modified with cyclohexane carboxylic acid achieve high oil removing capacity(Shami, Amininasab, & Shakeri, 2016).The efficient de nitrification of water was achieved by coating a polyether sulfone membrane with a hydrothermally synthesised $LiNbO_3$ powder(Xu et al., 2018).

MOLECULAR IMPRINTED POLYMERS

The use of MIP for selective extraction of environmental contaminants also continued to grow(Shen, Xu, & Ye, 2013).MIPs are synthetic polymers made with specific recognition sites that are complementary in shape, size and functional group to the analyte of interest. In the presence of template the MIP are polymerised. The recognition sites mimic the binding site of antibodies and enzymes, for the encapsulation of molecules and pollutants(Zhou, qu, zeng, Zhou, & Shi, 2014). Because they are highly specific to the target analytes of interest, MIPs can be used to extract and isolate them from other matrix component in a complex mixture. MIPs have now been synthesised for a number of emerging contaminants and pesticides(Richardson & Ternes, 2011). These have improved features such as stability, effective cost and rapid fabrication.

Chromatography is a separation technique, MIP coated hollow fibres(MIP-HFs) have been developed combining MIP and Chromatography. Triazine an organic pollutant present in the water sample can be micro extracted using a thin film of toluene which is immobilised in the pores of the MIP-HF(Mart, 2016).Hallow fibres coated with functional polymers are used to extract organo chlorine pesticide and diethyl stilbestrol from milk.MIP have been reported for selective recognition of metal ions, Protein and bacteria(Iskierko, Sharma, Bartold, & Pietrzyk-le, 2016).Molecularly imprinted porous beads are used for the removal of copper ions(Bajwa et al., n.d.).

The TNT templates were efficiently imprinted into the matrix of silica through acid-base pairing nitration between TNT and 3-amino propyl triethoxy silane. Removal of TNT analyte create recognition sites on the walls of silicon nanotubes (Xie et al., 2008). There are lot of sensors are generated using molecular imprinting. Surface MIP on doped ZnS quantum dots are effective in treating pentachloro phenol(Xie et al., 2008). MIP in dendrimers are also studied extensively(Zimmerman, Zharov, Wendland, Rakow, & Suslick, 2003).High mercury level is harmful to our brain, heart, kidney and lungs. Inexpensive and gold nanoparticle based probes are used for screening Hg level in water(Darbha, Ray, & Ray, 2007).

RISKS OF NANOMATERIALS

In spite of the tremendous use of nanomaterials we should have enough knowledge about the safety measures of nano materials. Some of them are non-biodegradable, its disposal can be a problem in near future, all the produced nano materials are not free from the poisonous effect.The issues of water access, availability and quality are a global issue that requires urgent attention today. The small size of nano material makes their entry easy to living organisms. Nanoparticle like Zn, TiO_2 CNT etc. leads to lung inflammation and affect body immune system. It can enter our body through skin, inhalation and injection due to its small size. Through body fluids they can reach our internal organs. But in some cases like textile industry we cannot speak of the risk of nano textiles. Since textiles with silver nano particle eject less silver particle than conventional silver textiles(Mitrano et al., 2014). Due to the potential hazards of nanomaterials new technology should be adopted for waste water treatment.

CONCLUSION

Our mother earth is in a great need of clean and portable water. Nanotechnology provide Gopinath, A., & Chandradasan. (2014). *Environmental Chemistry*. jalandhar: vishal publishing.unique opportunity for the treatment of waste water. Even if some of the nanomaterials are still in the laboratory we can expect to have cost effective and reusable nanomaterials in the near future. I wish that nanomaterials become essential element in industrial and pubic water purification systems the coming years .The solution can come from the collaborate efforts of different groups of people including chemist, engineers, material scientist and policy makers who can adopt a multi-disciplinary approach.

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