IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology
5th National Conference on Science, Technology and Communication Skills – NCSTCS 2K22
Narula Institute of Technology, Agarpara, Kolkata, India
Vol. 9, Special Issue 2, September 2022

Use of Nanotechnology for Water Purification Process: The Indian Scenario

Indrani Sarkar[1], Saswata Ghosh[2] and Soma Mukherjee[3]

Associate Professor, Basic Science and Humanities, Narula Institute of Technology, Kolkata, India[1]

Student, Mechanical Engineering, Narula Institute of Technology, Kolkata, India[2]

Associate Professor, Applied Science and Humanities, Guru Nanak Institute of Technology, Kolkata, India[3]

Abstract: Only 30% of all water on the Earth is not trapped in the ice or glaciers and only 0.08% of it is clean water. Scarcity of clean water has become an important issue, and it is quite difficult to solve In order to face challenges in the global water situation due to population growth and climate change, novel innovative technologies are required to reduce water pollution and to supply pure drinking water. Nanotechnology is now replacing traditional engineering methods by advanced processes to clean and recycle wastewater. Here recent advances in nanotechnology for water treatment processes in India is provided. It includes nano-based materials, such as nano adsorbents, nanometals, nanomembranes, and photocatalysts. The beneficial properties as well as harmful side of these materials are reported. Further research opportunities is given for each type of nano based material and process. The legal framework according to nanoengineered materials and processes that are used for water and wastewater treatment is considered for vastly populated countries like India

Keywords*:* nanotechnology, nanocatalysts, nanoadsorbents, nanomembranes, water remediation, nano filters

I. INTRODUCTION

Nanotechnology is the understanding and control of matter at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications" [National Nanotechnology Initiative (NNI) 2008]. Nanotechnology has become one of the most explored technologies of the 21st century. It deals with manipulating matter at nanoscale. These nanosized particles follow physical and chemical laws which are quite different from the laws applicable for materials in the macroscopic world. Due to enormous surface area to volume ratio, nanoparticles exhibit exclusive properties. Unique properties of nanomaterials include, High surface to volume ratio, small size, Well-organized structure, Competence of filtration These properties help the removal of heavy metals from polluted wastewater. Based on the type of nanomaterial, wastewater treatment is divided into three main groups: Nano catalysts, Nano adsorbents, Nanomembranes.

Nan catalysts: This treatment involves the photocatalytic activities that include the interaction of light energy with metallic nanoparticles. The photocatalytic activities destroy microorganisms (bacteria) and organic substances via the reaction with hydroxyl radicals. The materials used in nano catalysts are typically inorganic materials such as metal oxides and semiconductors.

Nano adsorbents: These materials consist of organic or inorganic nanomaterials having high reactivity, great catalytic potential and large surface area to adsorb substances. Nano-adsorbents are of different types, i.e., metallic nanoparticle, magnetic nanoparticles, nanostructured mixed oxides, and metallic oxide nanoparticles.

Nan membranes: Nan membranes can remove of heavy metals, dyes, and other contaminants. Nanotubes, nanoribbons, and nanofibers are commonly used nanomembranes. Silver nanoparticles are antimicrobial agents used to treat water containing high loads of bacterial contaminants. Silver nanoparticles and graphene oxide nanoparticles play a dual role, i.e., disable bacterial cells), and, due to their hydrophilic nature, they can reduce microbial attachment by forming a strong water layer.

II. METHODS AND MATERIALS

Nanotechnology methods can be used to improve water quality. These methods use reactive media for separation and filtration, bioremediation and disinfection. Remediation is the process to remove, minimize or neutralize the pollutants detrimental to human health or environment. There are three categories for remediation process – thermal, physicochemical and biological methods. Methods used in this regard are extraction, adsorption and oxidation. These are less effective, expensive and time-consuming. Another method is biological degradation which is inexpensive and environmentally friendly, but very time-consuming. Nanomaterials can be used to enhance affinity, capacity and selectivity for contaminants like heavy metals. Nanomaterials have properties like higher reactivity, larger surface contact and better disposal capability. Some nanomaterials used for remediation of water are zeolites, carbon nanotubes (CNTs), biopolymers, nanoparticles of zero valent iron (ZVI).

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

5th National Conference on Science, Technology and Communication Skills – NCSTCS 2K22

Narula Institute of Technology, Agarpara, Kolkata, India

Vol. 9, Special Issue 2, September 2022

Water remediation with iron nanomaterial: One of the systems to remediate water is known as a 'pump and treat' system. The system (Figure 1(a)) first pumps water from the soil to the surface, purifies it and then injects it back into the ground. Until 1998, the pump and treat system was used as a way to remediate water. Another method to remediate water is to use a permeable reactive barrier (PRB). PRB cleans subsurface groundwater and remediate (Figure 1(b)). This treatment can be used to clean up pollutants such as chlorinated hydrocarbons, aromatic nitro compounds, polychlorinated biphenyls (PCBs), pesticides and chromate compounds The PRB method, has some disadvantages. It is very expensive) and there is no definite time of replacement. Sometimes the reactivity of iron is reduced due to the presence of impurities like metal hydroxide and metal carbonate compounds. Efforts are being made to overcome these weaknesses. In the 1990s, it wasdiscovered that some zero-valent metals such as iron (ZVI), can be used as a filter material of PBR.   This can reduce dangerous contaminants in the water in large quantities.

ZVI is classified into two types: (1) nanoscale ZVI (nZVI) and (2) reactive nanoscale iron product (RNIP). They are made using the basic techniques of nanotechnology. Nanoscale ZVI (nZVI) particles have a diameter of 100–200 nm composed of zerovalent iron (Fe), whereas RNIP particles consist Fe and Fe_3O_4 of 50/50 in wt%. It is found that ZVI is highly reactive to contaminants like Cu^{2+}, chlorinated hydrocarbons, CrO_2^{-} and NO_3^{-}. Nano-iron can also be used via direct injection into the soil. Once injected, the particles will remain in the form of a suspension and a treatment zone will be formed. Another method is to attach the nanoparticles to a solid matrix like activated carbon. Metals such as zinc and tin have also the ability to reduce contaminants. Two metal alloys such as iron and iron–nickel–copper have been employed to degrade trichloroethene and trichloroethane Some commonly used metals are palladium, silver, platinum, cobalt, copper and gold.

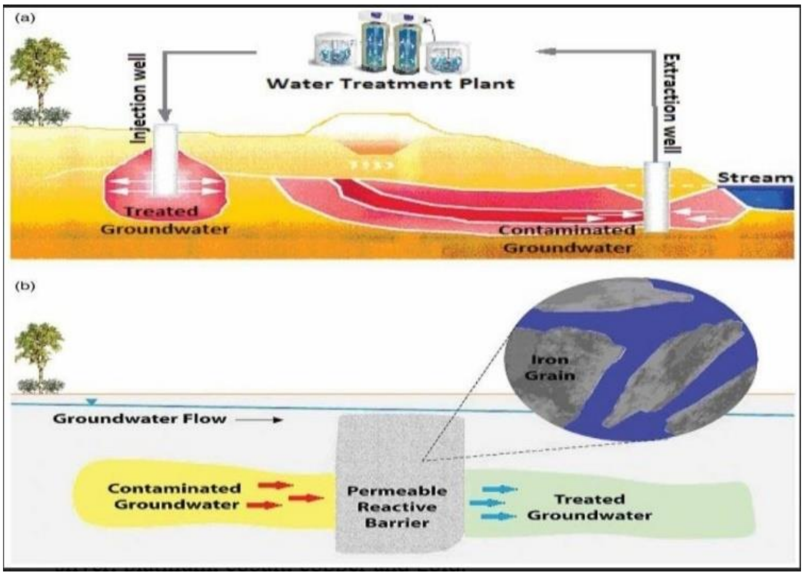

Fig.1 A schematic diagram of (a) pump and treat system and (b) permeable reactive barrier (PRB) application made with millimeter-sized construction-grade granular iron

Water remediation with ferritin: Ferritin: is an iron-containing protein structure found in animals and plants and its function is to store iron. Ferritin is formed when 24 polypeptides form a cage-like protein structure. The iron molecules can enter the cavity through the protein shell. The mineralization process transforms iron molecules into ferrihydrite nanoparticles. Ferritin can remediate toxic metals and chlorocarbon under visible light or solar radiation. The advantages of ferritin over ordinary iron catalyst are: (1) ferritin does not react under photoreduction; and (2) it is also more stable. Another application of ferritin which has been proven in the laboratory is to change chromium Cr (VI) into Cr (III). Cr (VI) is a carcinogenic pollutant found in the industrial waste, while Cr (III) is less poisonous and insoluble in water.

Water remediation using polymer nanoparticles: Polymer nanoparticles are used in water treatment. Polymeric nanoparticles have amphiphilic properties like surfactant micelles, where each molecule has hydrophobic and hydrophilic parts. In presence of water, the polymer forms a polymer cell with a diameter of several nanometers inside the hydrophobic part, while the hydrophilic part is outside. Crosslink occurs on polymer nanoparticles before the particles aggregate to maintain their stability. Amphiphilic polyurethane (APU) nanoparticles have good prospects as a remediation agent.

Bioactive nanoparticles for water disinfection: Nanotechnology can give solutions in cleaning up germs in water. Due to the population explosion, there is growing need for clean water. One of the alter- natives offered is antimicrobial nanotechnology. Several nanomaterials show strong antimicrobial properties through diverse mechanisms, such as (1) photocatalytic production of

IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

5th National Conference on Science, Technology and Communication Skills – NCSTCS 2K22

Narula Institute of Technology, Agarpara, Kolkata, India

Vol. 9, Special Issue 2, September 2022

reactive oxygen species that damage cell components and viruses (e.g. TiO2, ZnO and fullerol), (2) compromising the bacterial cell envelope (e.g. peptides, chitosan, carboxy fullerene, CNTs, ZnO and silver nanoparticles), (3) interruption of energy transduction (e.g. Ag and aqueous fullerene nanoparticles) and (4) inhibition of enzyme activity and DNA synthesis (e.g. chitosan). Among all materials, TiO2 has been found to be the best candidate as it is stable in water, nontoxic when ingested and low cost

Nano-fibres and nano-biocides for water purification: Nano-fibres and nano-biocides are used to improve the quality of water filtration membranes. Growth of bacteria in water can be inhibited by the surface-modified nano-fibres. Polyvinyl alcohol (PVA) and polyacrylonitrile (PAN) nano-fibres containing silver nanoparticles have excellent antimicrobial activity, PVA nano-fibres can reduce bacteria between 91% and 99% in a contaminated water sample and PAN nano-fibres kill 100%. PVA is a non- toxic and biodegradable synthetic polymer and PVA–silver nanofibres show excellent antimicrobial activity.

2.6 Nanofiltration: Nanofiltration membranes reject multivalent ions, pesticides and heavy metals more efficiently compared to conventional treatment methods. This technology has become the most cutting-edge technology in water treatment and is now available for practical use at home, business or manufacturing sectors. Depending on the requirement, nanofiltration membranes can be manufactured to target different molecules based on their molecular weight. As an example, Dow Filtec offers a nanofiltration membrane with the capability to remove molecules higher than 90, 200 or 270 g/mol.

III. CASE STUDIES

3.1 IIT Delhi technologies in water purification (https://fitt-iitd.in/wp-content/uploads/2020/05/IIT-Delhi-Technologies-inwaterpurfication.pdf)

IIT Delhi has the following technologies on water purification.

1.MYCO-Capsules for Bio remediation of waste water and Method for preparation of myco-tablets for bioremediation and myco-tablets thereofA polyacrylonitrile ultrafiltration membrane for removal of arsenic and chromium.
2.PVA supported resins for arsenic separation and product thereofan apparatus and a process for removal of arsenic.
3.Recyclable Smart Mesh for on Demand Separation of Oily Water
4. nano-adsorbent for removal of Lanthanide ions from water and associated methods.
5.Polyelectrolyte gels for sorption of crude oil and its emulsions with sea water and deionized water and its process.
6. An apparatus and method for mobile-phone based water purification
7. Antimicrobial non-woven fabric for safe water filtration
8. Water purification system

3.2 IIT Delhi-incubated Startup Launches Antimicrobial Water Storage Containers 'AqCure' (Areport)

(https://indiaeducationdiary.in/iit-delhi-incubated-startup-launches-antimicrobial-water-storage-containers-aqcure/#)

IIT Delhi-incubated startup Nano safe Solutions has developed a range of antimicrobial i.e., antiviral, antibacterial and antifungal water storage containers and launched it as "AqCure". This is based on the inherent antimicrobial properties of copper.

AqCure is a patented technology in which active nano-copper is released in a sustainable manner from a polymer matrix. The released copper makes the outer and inner surface of the container antimicrobial, reducing transmission of microbes upon direct contact, and making the stored water microbiologically safe.

Additionally, the released copper in water is within permissible limits and thus fortifies stored water as copper is also an essential micronutrient, needed for growth.

AqCure water containers have>99.99% antibacterial, >99.99% antifungal, and >99% antiviral activity tested as per ISO and ASTM standards. These containers are made from BPA/BPS-free high quality food grade polymers and is ideal for home and office use."

AqCure water storage containers are available in different size variants from 700 ml office bottles to 1-liter refrigerator bottles to be used at homes to 10-20-liter bubble tops and cans used for storage and distribution of potable water.

AqCure polymer masterbatch (polymers compounded with active nano-copper) granules based on different carrier polymers are also available, which can be used in polymer molding and extrusion operations to make the final products antimicrobial.

The concept has also won the Biotechnology Ignition Grant (BIG), sponsored by BIRAC, Department of Biotechnology, GoI.

3.3 IIT KGP Faculty Makes Purified Drinking Water Available for Rs. 1 (A newspaper report) [https://kgpchronicle.iitkgp.ac.in/iit-kgp-faculty-makes-purified-drinking-water-available-for-rs-1/]

Faculty from IIT KGP has developed a model for purified drinking water supply, costing Rs. 1 per family per day, for a village in Southern Bengal. Dr. Somnath Ghosal from the Rural Development Centre of IIT Kharagpur has involved participatory management offering villagers access to purified drinking water in a sustainable manner, using Water Cards, Water ATM Vending Machine, etc. The unique set-up has been built in the Porapara village in West Midnapore district of Bengal. He has installed a fully automated multi filtered UV treated drinking water facility which can provide close to 1000 litres of purified drinking water to 60 families every day at Rs. 1 per family. While the land was freely provided by the villages, IIT KGP helped built the required infrastructure and water purification technologies and funded the entire project]

3.3 Green manufacturing: All manufacturing processes produce a wide range of wastes harmful to the environment. An environment-friendly manufacturing process should use minimum raw materials. It should also minimize waste production and energy consumption. The method to achieve these goals is called Green manufacturing. Green manufacturing aims at the development of industrial processes (e.g., water-based processes replace organic solvent-based processes). Hazardous substances, i.e., metals, are used in less quantities. Green chemicals are produced which are less harmful to the environment. An example of green nanotechnology is the development of microemulsions (aqueous) as an alternative to VOCs in the cleaning industry. Toxic and carcinogenic compounds, such as chloroform, hexane and perchloroethylene, are used in textile, cleaning and many other industries. Microemulsions containing nano-sized aggregates can be used as receptors for the extraction of specific molecules at the nanoscale level. Scientists have synthesized a microemulsion that becomes the connector between water- attractive and water-repellent substances. The microemulsion is able to clean textiles from oil and is very competitive to the conventional cleaning compounds.

3.4 Risk of nanotechnology: Although nanotechnology offers solution to many problems, it may also have adverse effects on human health and the environment. Materials that are harmless in bulk forms can become highly toxic at the nanoscale; the inhalation of airborne nanoparticles cause lung disease. CNTs like asbestos particles, if inhaled in sufficient quantities cause lung cancer. The behaviour of nanoparticles in humans and the environment is not still properly understood. Many international organizations, such as the Royal Commission on Environmental Pollution (RCEP) and European Union, are aware about the toxicity and potential health risks of nanomaterials. IITs in India are trying to provide clean water where drinking water is scarce: Some leading Indian Institutes of Technology (IITs) are taking the initiative to provide clean water with the help of science and innovation in places where clean drinking water was not available easily. This effort has been made with the encouragement and vision of the Union Ministry of Science and Technology.

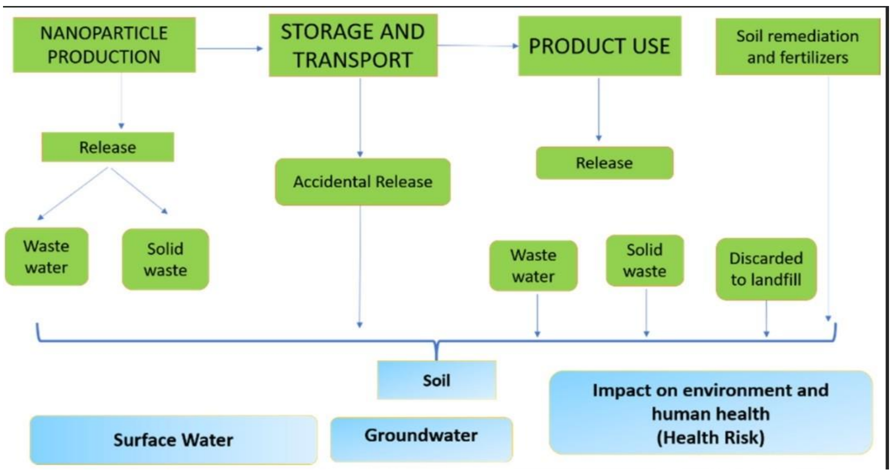

Fig. 2 Sources of nanoparticles in different environmental media

Toxicity of NPs depends on its shape, size and reactivity Researchers have reported harmful effects of NPs on animals and human as well. There has been a lot of development to treat suspended solids present in water or wastewater treatment plants. But no technology is yet developed to remove nanoparticles from water treatment plants because they undergo various chemical processes in suspension, like aggregation (forming larger particles) , dissolution (i.e., release of ions), and transformation (i.e., change of shape and properties). The filters available for removing suspended solids are not economical to remove these NPs from water for potable purposes. Hence more research is required to understand the behavior of NPs in a water suspension (Fig 2)

IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

5th National Conference on Science, Technology and Communication Skills – NCSTCS 2K22

Narula Institute of Technology, Agarpara, Kolkata, India

Vol. 9, Special Issue 2, September 2022

In India, very few scientists are working on understanding issues and challenges in removing NPs from water. In this regard, the researchers at IIT Delhi are trying to understand what exactly happens to zinc oxide and copper oxide NPs in different water matrices. These NPs were chosen due to their usage in various industries of medicine, personal care products, etc. The study of mixture of more than one type of NPs is important as it represents a realistic condition of contamination of a water body. The research is to find out the settling capacity of these NPs or to remain in suspension for a long period of time. The findings of research indicates that mixture of more than one types of NPs can be removed by sedimentation easily. So, It could suggest new techniques to treat water containing multiple NPs in a sedimentation tank.

3.5 Nanotechnology in water treatment, case study in Bangalore: Bangalore in using nanotechnology to solve the water problems .The study concluded that although nanotechnology can help to solve the problems ,there is some challenge using nanotechnology ,these challenge include technology, market challenge and human health risk at Bangalore .waste water treatment is the process of converting waste water that is no longer needed or is no longer suitable for uses into bilge water that can be discharged back into the environment .it is formed by a number of activities including bathing ,washing ,rainwater runoff.

3.6 Regulatory Measures in India: The Ministry of Environment and Forest proposed the new National Environmental Protection Agency (NEPA) (Ministry of Environment and Forest, Government of India 2009). NEPA was supposed to interact with agencies such as the DST, CSIR institutes, the MoHFW, and Ministry of Food Processing Industry (MoFPI), It is critical for policymakers to focus attention on developing regulatory measures to address the public health and safety challenges due to nano technology based products launched in Indian market

IV. CONCLUSION

Nanotechnology has been developed to save environment and human life. Technologies have been developed to replace the conventional technologies. The water purification process using nanotechnology can use iron nanoparticles, ferritin, polymeric nanoparticles, nano fibres, nano biocides, nano enzymes and nano filtration techniques. Nano technology can also be applied to clean the air from toxic gases such as CO, VOCs and dioxins using CNTs, gold nanoparticles and other adsorbents. Nanoparticles and nanotubes can also be applied as a sensor for toxic substances that are difficult to detect with conventional technology due to their small size and concentration. Nanotechnology can also be useful to prevent the creation of pollutants. Its applications include the synthesis of green materials to prevent the release of hazardous substances into the environment. Although nanotechnology has entered in the field of Green technology, more research is needed to assess its risk. This is in accordance with the principle that the more sophisticated the technologies, the greater the risks they pose.

REFERENCES

[1] I.J. El Saliby H.K. Shon, J. Kandasamy and S. Vigneswaran (2003) , Nanotechnology for waste treatment in brief, water and waste treatment technologies. Available:https://www.eolss.net/sample-chapters/c05/E6-144-23.pdf

[2] Lusiafillpoonoi and Duncan Sutherland (2007) application of nanotechnology, environment, nanotechnology capacity building NGOS, Available : https://nanopinion.archiv.zsi.at/sites/default/files/download07ab.pdf

[3] Eman Ahmed Hashem, (2014), Nanotechnology of waste water treatment, Case Studies :Egypt, Journal of Economics and Development Studies September 2014, Vol. 2, No. 3, pp. 243-259

[4] B.P. Naveen and P.V. Sivapullaiah, (2019), Solid Waste Management: Current Scenario and Challenges in Bengaluru, Available : https://www.intechopen.com/chapters/71641

[5] Ajay Kumar Sahu , Prangya Paramita Acharya , Barsha Rani Kar , Rahul Nemani and Manjunath Gowda, (2019), Nanotechnology in Water Treatment , Case studies in Bangalore,International Journal of Advanced Research, Vol 7(2), p.p.142-149

[6] Shilpi Srivastava, Atul Bhargav, (2016), Green nanotechnology, Journal of Nanotechnology and Materials Science, Available: https://doi.org/10.15436/2377-1372.16.022.

[7] Roco Mihail C (2011), The long view of nanotechnology development, the national nanotechnology initiative at 5 years. Available:https://inis.iaea.org/search/search.aspx?orig_q=RN:43082779.

[8] Nanotechnology Patent Literature Review: Graphitic Carbon-Based Nanotechnology and Energy Applications Are on the Rise.(February 2014), Mc Dermott, Will & Emery