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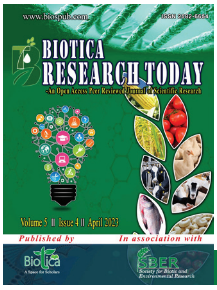

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Application of Nanotechnology in Wastewater Treatment

Narendra Kumar Maurya*, T.S. Annapaswamy, Bhooleshwari, Shiwam Dubey and Vaijnath Aitwar

College of Fisheries, Mangaluru, Karnataka Veterinary, Animal and Fisheries Sciences University, Bidar, Karnataka (575 002), India

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Corresponding Author

Narendra Kumar Maurya

✉: mauryanarendra678@gmail.com

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Abstract

The water cycle continually recycles the planet's finite and a valuable source of water. Wastewater is defined as water that's physicochemical, or biological characteristics have altered as a result of the presence of pollutants like diseases, heavy metals, organic or inorganic chemicals, or other toxins that render it detrimental to the environment. Enhancing the efficiency of current methods and making nanomaterials more reusable, nanotechnology focuses on enhancing the existing methods in order to lower the cost of operating the plant or operations. Because of their unique properties, which include high surface-to-volume ratios, high reactivity, sensitivity, the ability to self-assemble into films on substrates, high adsorption, *etc*., nanomaterials are well suited used in the purification of water. Because of their powerful capabilities, nanomaterials are effective against the various harmful bacteria found in contaminated water, as well as a wide range of pollutants, both inorganic and organic, heavy metals, and other contaminants.

Keywords: Nanofiltration, Nano-sorbent, Photocatalysis, Wastewater

Introduction

The Earth's surface is approximately two thirds covered by water. However, the lack of accessibility to hygienic water continues to be an issue for humanity on a global scale. Nature has set up a mechanism for recycling water and giving us an ample supply of safe water. Potable water is in limited supply because of unplanned construction and unrestricted expansion of the population that have slowed down the natural purification processes. The majority of poor nations have a sickness rate of about 90%, and drinking unclean water is the primary source of these illnesses. Wastewater must be adequately treated before being released in order to protect our ecology. Natural processes recycle water and provide us with an adequate supply of clean water. Lack of drinkable water is the result of uncontrolled development and unregulated population increase impeding the natural purification processes (Bora and Dutta, 2014).

The name "Nano" derives from a Greek word that means "dwarf". One billionth of a metre (10^{-9}) or ten hydrogen atoms in a row would make up one nanometre, which is one billionth of a metre. When molecules began to organise themselves into complex shapes and structures that gave rise to life on Earth billions of years ago, the first manifestation of nanotechnology could be seen. Nanotechnology offers the possibility of creating alternative wastewater treatment methods. Materials that are utilised in nanotechnology are typically between a few nanometres and roughly 100 nm along any or all dimensions. Nanomaterials are well suited for the treatment of both wastewater and drinking water owing to their high reactivity, level of functionalization, and huge specific surface area and other features that depend on their size. This article primarily discusses some recent advancements and uses of nanotechnology in purification of wastewater, with a focus on the potential use of these techniques to address various issues with the current wastewater treatment systems (El Saliby *et al.*, 2008).

Wastewater Treatment

A range of physicochemical techniques are used to separate the pollutants from the liquid stage before the water is discharged into the environment. Although there are numerous methods for treating both residential and nonpresidential wastewater, the municipal sewage treatment plant receives the wastewater most frequently. These treatment plants have the capacity to remove a sizable

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part of the contaminant if constructed and run correctly. Preliminary, primary, secondary and Tertiary treatment stages make up the bulk of the normal treatment process. 50% of the organic matter in wastewater is made up of proteins, 40% is made up of carbohydrates, 10% is made up of fats and oils, and the remaining 2% is trace amounts (*e.g.*, 1 g L^{-1}) of surfactants, emerging contaminants, and priority pollutants. Conversely, wastewater frequently contains 101-103 protozoan cysts, 105-108 coliform colony-forming units (CFU) m L^{-1}, 103-104 faecal streptococci CFU m L^{-1}, and 101-102 viral components (Ellis, 2004).

The composition of wastewater directly affects how wastewater is treated in treatment facilities. The traditional sewage treatment typically entails the following stages:

- Inorganic materials having a range of size greater than 0.01 mm that are coarse and easily settleable should be removed during the initial treatment.
- The primary treatment is the removal of most suspended materials, includes debris that is both inorganic as well as organic (0.1 mm to 35 m).
- Breaking down the nutrients and organic debris that can biodegrade as a further biological treatment.
- In the final stage of treatment, pathogenic bacteria, leftover organic and inorganic elements, and other contaminants are removed using filtration. After this treatment, chemical disinfection is used.

The entire procedure of a typical wastewater treatment plant, including the primary, secondary and tertiary treatment stages, is schematically depicted in figure 1.

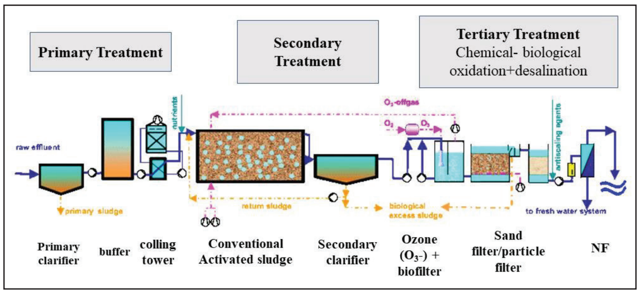

Figure 1: A diagram of a typical wastewater treatment facility illustrating the three basic steps of the wastewater treatment process

Nanoparticles in Wastewater Treatment

Nanoparticles remove or separate pollutants from water when used as adsorbents, and they act as catalysts for chemical or photochemical oxidation when employed as catalysts, they cause the degradation of any pollutants present. Researchers examined four categories of nanoscale materials that are useful for purifying water: zeolites, carbonaceous nanomaterials, dendrimers, and metal-containing nanoparticles. These materials are particularly appealing as separation and reactive media for purifying water because they contain metals (Madhuri *et al.*, 2018).

1. Dendrimers

Dendrimers are molecules that are repeatedly branched. Dendrimers are usually symmetric around the centre and have a spherical three-dimensional shape. A dendron typically has a single chemically accessible group known as the focus point. Dendrimers are nanometre-sized, highly branching, star-shaped macromolecules. The central core, the inner dendritic structure (the branches), and the outside surface with functional surface groups are the three components of dendrimers. These three parts are neatly organised, hyper-branched polymer molecules with end groups, cores, and branches. These components work well together to create various sizes and forms with secure internal cores that are suited for use in biological and material sciences.

2. Zeolites

Alkaline and earth metal hydrated aluminosilicate crystals make up zeolite. The porous nature of zeolites allows them to hold a range of cations, including Na^+, K^+, Ca^{2+}, Mg^{2+}, and others. These positive ions can swap places with other ions in a contact solution due to their slack holding. In cartridge or column filters, synthetic zeolites are employed as sorbents or ion-exchange media. They are frequently produced using coal fly ash or silicon-aluminum solutions. Zeolite can be broken up into nanoparticles by using a laser. The capacity of zeolites' nanoparticles to act as efficient sorbents and ion-exchange medium for metal ions is being studied for its potential for eliminating contaminants from acid mining wastewaters. Nanoparticle-infused zeolite is prepared to better treat dioxin-contaminated water and make it suitable for daily use. The effluent from acid mines and metal electroplating has reportedly been treated with zeolites to remove Chromium (III), Nickel (II), Zinc (II), Copper (II) and Cadmium (II), are examples of heavy metals.

3. Metal Nanoparticles

Researchers often employ nanoscale metals and metal oxides in environmental cleanup, citing metal, iron, gold, titanium oxides and iron oxides as examples. For instance, silver nanoparticles have been shown to be potent antibacterial agents that may effectively cure bacteria, viruses, and fungus found in wastewater. When activated by light, nanoscale titanium dioxide can also eliminate microorganisms and purify water. As compared to bulk materials, nanosized metal oxides have higher surface areas and a greater number of surface-active sites, which contribute to their excellent removal efficiency of heavy metal from wastewater. Noble metal doping into TiO_2 can speed up the breakdown of organic compounds, as a result of greater hydroxyl radical generation and other factors, leading numerous researchers to build polymer-based nano sorbents.

4. Carbonaceous Nanomaterials

Carbon-based nanomaterials, one of the inorganic materials, are presently widely employed in the sector as a result of their high sorption, for the elimination of heavy metals capacities and lack of toxicity. The development of nanotechnology resulted in the production and application of carbon nanotubes (CNTs), fullerene and graphene as nano-sorbents. Because of its special characteristics, such as chemical resistance, morphological and thermal resistance, and large surface area, CNTs have a lot of promise as a new sort of adsorbent. Applications for this include the storage of hydrogen, the treatment of water and the purification of proteins. Removing heavy metals from industrial effluent is the main issue of today. Heavy metal adsorption purposes to minimise environmental problems, CNTs are great choices. According to research on the CNTs' ability to absorb poisonous substances like lead, cadmium and 1,2-dichlorobenzene, these substances can be removed from water by using CNTs as an effective adsorbent.

Wastewater Treatment using Nanotechnology

Nanotechnology produces materials, structures, components, devices and systems by manipulating, regulating and integrating atoms and molecules at the nanoscale. There is now a fresh possible wastewater treatment method more successfully and economically thanks to the development of several instruments and methods made possible by nanotechnology in recent years, particularly in the field of water purification. The followings are some effective water treatment methods or instruments made possible by nanotechnology.

1. Nano-sorbents

Through numerous physical or chemical interactions, one substance - the sorbate - adsorbs to another - the sorbent - during the sorption process. To purify polluted water of organic and inorganic impurities, sorbents are typically used as separating media in the process. Contamination from water absorption onto the sorbent surface typically involves three stages:

- Pollutant transportation involves moving the contaminants in the water to the sorbent surface,
- Adsorbing at the sorbent surface, and
- Moving the pollutant inside the sorbent.

Because of their nanoscale pores, nano-sorbents aid in the sorption of pollutants. Removing the absorbed contaminants allows for the regeneration of nano-sorbents.

2. Nanofiltration

Due to its distinct charge-based repulsion feature and rapid rate of penetration, nanofiltration (NF), a pressure-driven separation of membrane technology, is immediately emerging in the area of water treatment and wastewater treatment. Since reverse osmosis (RO) processes demand higher pressures (20-100 atm), NF procedures require less pressure (7-30 atm), and as a result, it is a technique with lower energy usage. Because of their affordability, great flexibility, and ease of preparation, synthetic polymers are employed to create the bulk of NF membranes. The use of NF in wastewater treatment is a relatively new development, and numerous businesses, including those in the textile, pharmaceutical, dairy, and petrochemical sectors, are paying close attention to this technology. Nearly all organic and inorganic contaminants, including some dangerous bacteria, may be removed from wastewater using thanks to its unique filtration method and the availability of various membrane types, NF filter has an advantage over competing filters. Figure 2 demonstrates the NF technique's water softening procedure (Bellona *et al.*, 2008).

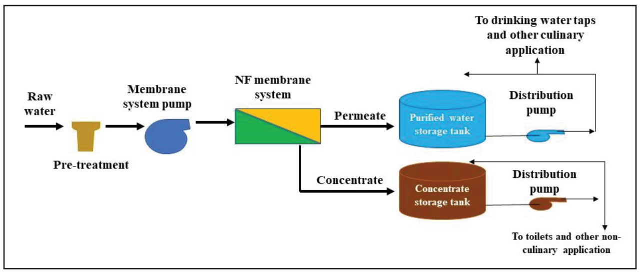

Figure 2: A schematic illustration of the nanofiltration system

3. Photocatalysis

The description of photocatalysis is as a result: "a change in the pace of a chemical reaction or its start caused by ultraviolet, visible or infrared radiation in the presence of a substance that absorbs the light and participates in the chemical transformation of the reaction partners." In a conventional photocatalysis system, the catalyst medium is a semiconductor material, which produces an electron-hole (e-h) pair when exposed to light with an energy greater than its band gap energy. In water, the photogenerated e-h pair produces super reactive ions of hydroxyl (OH^-), super oxides (O_2^-), and other electrons.

The photocatalytic reaction that takes place on the surface of a nano-structured semiconductor catalyst is depicted in figure 3.

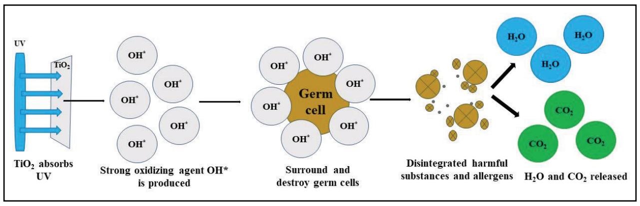

Figure 3: A schematic illustration of the photocatalysis on the surface of a nanostructured metal oxide semiconductor photocatalyst

Importance of Nanotechnology in Wastewater Treatments

Nanomaterials are made with properties including high aspect ratios, reactivity and customizable pore volumes, as well as electrostatic, hydrophilic, and hydrophobic interactions. These properties are important for adsorption, catalysis, censoring, *etc*. Nanotechnology enables high-performance, low-cost water and wastewater treatment solutions that are extremely effective, modular and multipurpose in nature. These methods provide innovative and sustainable ways to address the growing demand for water and wastewater treatment. Nanoparticles use could be very advantageous for wastewater treatment. It has a unique virtue of having a wide surface area to efficiently remove harmful ions of metal, microbes, organic and inorganic solvents from water. Nanotechnology has made it feasible to purify water in a variety of precise and dependable ways, both on a large and small scale.

Conclusion

In this article, new developments and applications of nanotechnology for wastewater treatment are briefly discussed. Several novel methods for creating nanoparticles that are ultimately used in wastewater treatment are given under the heading of nanotechnology. These methods include everything from creating membranes out of nanomaterials to using catalysts to break down toxic substances in water. In terms of new breakthroughs in research, zeolites, mixed oxides, bimetallic nanoparticles, metals and carbon compounds are all being looked at for usage in wastewater treatment. The future of wastewater treatment may be profoundly affected by nanotechnology. Future industrial and wastewater treatment systems will need to use nanomaterials as greater advancements in the creation of economically and environmentally sound technology are produced.

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