Nigerian Research Journal of Engineering and Environmental Sciences 3(1) 2018 pp. 268-272

Nigerian Research Journal of Engineering and Environmental Sciences
Journal homepage: www.rjees.com

Review Article

APPLICATION POTENTIALS OF NANOTECHNOLOGY FOR POLLUTANTS REMOVAL IN WATER AND WASTEWATER IN NIGERIA: A REVIEW

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ARTICLE INFORMATION

Article history:
Received 17 March, 2018
Revised 31 March, 2018
Accepted 03 April, 2018
Available online 30 June, 2018

Keywords:
Nanotechnology
Water
Wastewater
Pollutants
Nanomaterials
Treatments

ABSTRACT

The rapidly increasing population, depleting water resources, and climate change resulting in prolonged droughts and floods have rendered drinking water a competitive resource in many parts of Nigeria. The development of cost-effective and stable materials and methods for providing freshwater in adequate amounts is the need of the water sector. In Nigeria several methods are currently been used for treatment of water and wastewater with varying degrees of success. In recent past, development and application of nanotechnology in treatment of water and wastewater is becoming a major area of research. Nanotechnology is the art and science of manipulating matter at the nanoscale to create new and unique materials and products with enormous potential to change society. The aim of this paper is to review the possible applications of nano-particles for the removal of pollutants from water and wastewater in Nigeria. The review will focus on adsorption, membranes, disinfection, heavy metals and organic contaminants present in surface water, ground water, and/or industrial water.

1. INTRODUCTION

The impact of water is felt on all aspect of human life, and this includes health, economy, food as well as energy. With the addition of the environment, economic and social impacts of poor water supply, sanitation, the component of fresh water supply is essential for the safety and well-being of the vulnerable in society (Lu *et al*., 2006). Water in its unique state as a resource plays an important role in the existence of all on earth as well as the backbone for civilization of human evolution. In times of rains, water flows in form of surface runoff into water bodies and carries various substances that are added to water bodies which make it contaminated. Contaminated water is described as water which contains undesired material which has the potential to affect the quality unfavorably thereby making it undesirable for human use.

Wastewater quality parameter varies extensively with direct relation to its originated source (Adlhart *et al.*, 2018). Untreated wastewater when disposed into the environment poses great danger to living things. Wastewater treatment conventionally includes a variety of processes (physical and biological) (Prachi *et al.,* 2013). These treatment methods currently in practice combined with systems of water distribution and habits of wastewater disposal in addition with centralized existing water treatment systems. However, centralized schemes currently practiced in Nigeria are no more sustainable, hence the need to explore the application potentials of nanotechnology.

Nanotechnology is the design, manipulation, and precision, placement, modeling of matter at nano scale to control the formation of two or three-dimensional assemblies of molecular blocks into well-defined scale (Dave *et al.*, 2015). This is the engineering of functional systems at the molecular and atomic level. It will make most products lighter and stronger, cleaner and cheaper and less expensive (Clounon *et al.*, 2013). The application of nanotechnology in the treatment of water and wastewater has enormous positive credentials. This is obvious through its enormous benefits like reuse, lower cost and high efficiency in pollutants removal (Adlhart *et al.*, 2018). In the field of water and wastewater treatment, there is an increasing nanotechnology application (Dave *et al.*, 2015). The nanotechnology is based on the application of nanomaterials which are known as material smaller than 100 nm in at least one dimension (Dave *et al.*, 2015). These materials at nanoscale have distinctive properties which are dependent on size with regards to surface area volume ratio relationship, absorption, as against the characteristics from the convectional bulk water and wastewater treatment material. Its importance also includes surface area per unit mass, its tiny size, incredible light weight and strength (Prachi *et al.,* 2013). The high efficiency recorded is attributed to these distinctive properties which enable nanomaterials to be used for treatment of water and wastewater effectively in an environmentally sustainable manner (Abdalla *et al.*, 2015). As a result, there is the need for this technology to be considered in Nigeria.

The National Water Resources Institute (NWRI) which is foremost water institute in the country is a promising ground for its application as a pilot project. Application of nanotechnology in treatment of water and wastewater treatment is hereby elucidated.

2. WATER AND WASTEWATER TREATMENTS USING NANOTECHNOLOGY

2.1. Adsorption

There is increasing research in areas of applicability of nanomaterials-based technology in forms like absorptive membrane, biomemetic membrane and nanocomposite membrane for treatment of water and wastewater (Prachi *et al.,* 2013). Currently in practice, the use of carbon nano tube (CNT) have high absorptive rate of different organic chemicals than the convectional activated carbon (Pan *et al.*, 2008). There is high absorptive capacity using CNT for metal ions which can serve as a superior substitute to the traditional activated carbon (Pan and Xing, 2008). This claim is supported by Rao *et al.* (2007) as iron oxides and ferrous oxide which are nanoscale metal oxide have been reported to be effective and presumably of low cost adsorbents for heavy metals.

2.2. Nanomembranes

A membrane in water treatment is a microporous plastic film with specific pore size rating known as screen, sieve or microporous filters which retains particles or microorganism larger than their pore size primarily by surface capture. Lu *et al.* (2006) reported that membranes with nanofibre can effectively remove pollutants (micro-size particles) with potentially high elimination rate without considerable fouling. These membranes are used as pretreatment method to reverse osmosis. A large number of studies on membrane nanotechnology have focused on creating multifunction membrane by adding nanomaterials into polymeric or inorganic membranes known as nanocomposite membranes (Lu *et al.,* 2006). Antimicrobial nanomaterials such as nanosilver are doped or surface grafted on polymeric membranes to inhibit bacterial attachment and biofilm formation on the membrane surface (Huang *et al.,* 2007). With the presence of antibacterial nanomaterial in membranes used as nanomembranes, there is reduction in membrane bio-fouling development of the membrane thin film and in addition makes the viruses present inactive (Huang *et al.,* 2007). The is achieved by adding nanomaterials to the active layer surface through surface membrane modification or insertion in casting solution of the developed membrane. However, there is a direct correlation between efficiency and nanomaterial used, as the sort, dimension and quantity of nanoparticle used is a function of the membrane permeability (Lu *et al.,* 2006). A brief summary is shown in Table 1 describing application of nanotechnology in water treatment.

Table 1: Nanotechnology in water and wastewater treatment (Chaturvedi *et al.,* 2012)

Types of Nanoparticles	Types of Pollutant Removed
Carbon Nano Tubes	Organic Contaminates
Nano Scale Metal Oxide	Heavy Metals Radionucleides
Nano Catalyst	PCB, Azodyes, Pesticides etc
Nano Structured Catalyst	Decomposition of organic pollutant, in-activation of micro - organism.
Bioactive Nanoparticle	Removal of bacteria, fungi etc.
Biomimetic Membranes	Removal of salts.

2.3. Disinfection

This is basically the elimination of most pathogenic microorganisms (excluding bacterial spores) on inanimate objects to the destroy microorganisms that are living on the objects. Contaminants on water and wastewater resulting from biological sources can be classified into three main classes: micro-organisms, natural organism and biological toxins (Huang *et al.,* 2007). Gusseme *et al.* (2011) reports that microbial contaminants include human pathogen and living microbes. There is research gap in finding an effective way in cyano-bacteria removal in water treatment systems. Disinfection is necessary in water treatment as there is the presence of protozoan's, bacteria and other viruses as contaminants in water bodies. Already, there is concern from the standard chlorine chemical disinfection as it is regarded as toxic (Chaturvedi *et al.,* 2012). This is in addition to the carcinogenic and very harmful by-product formed. The production process of chlorine dioxide is regarded as expensive and its associated products like chlorate and chlorite are considered hazardous. Despite the progress made in technological advancement, the occurrence in outbreaks from water-borne infection-based diseases is still prevalent. Advancement in technology with regards to disinfection should the potential of at least eliminating emerging pathogen (Abdalla *et al*., 2015). This however is not the case. The application of nanotechnology in disinfecting water-borne diseases causing microbes is becoming prevalent (Pendleton *et al.,* 2001). The most common nanomaterials for disinfection include silver, titanium and zinc. They have antibacterial properties due to their charge capacity (Abdalla *et al*., 2015). It was reported that metallic and metal-oxide nanoparticles are among the most promising nanomaterials with antibacterial properties (Pena *et al.,* 2008).

2.4. Removal of Heavy Metals

Heavy metals are chemical elements which are metallic in nature with relatively high density that even in low concentration, they are regarded as toxic or poisonous. The application of nanotechnology in removal of heavy metals is a new area of research. According to Huang *et al.* (2007), different types of nanomaterials have been introduced for removal of heavy metals from water and wastewater as nanosorbents including Carbon Nano Tubes (CNTs), Zeolites, which have exceptional absorption properties and this view is shared by Pena *et al.* (2001). Metal based nanomaterials proved to be efficient in terms of heavy metals and ion removal in water and wastewater (Zodrow *et al.,* 2009). Toxicity in water and wastewater is greatly reduced with the utilization of photo-catalysts nanoparticles such (TiO_2) (Srivastava *et al.,* 2004). The capability of heavy metals like arsenic removal in water and wastewater using nanomaterials (Fe_2O_3 and Fe_3O_4) has been reported (Song *et al*., 2009). High specific area of Fe_3O_4 nanoparticles also shows increasing removal rate of arsenic in water and wastewater (Jeong and Hoek, 2007).

Table 2: Examples of potential applications of nanotechnology in water/wastewater treatment (Dave *et al.,* 2015)

Applications	Examples of Nanomaterials	Some of Novel Properties
Adsorption	CNTs/nanoscale metal oxide and nanofibers	High specific surface area and assessable adsorption sites, selective and more adsorption sites, short intra-particle diffusion distance, tunable surface chemistry, easy reuse etc.
Disinfection	Nanosilver/titanium dioxide (Ag/TiO_2) and CNTs	Strong antimicrobial activity, low toxicity and cost, high chemical stability ease of use etc.
Membranes	Nanosilver Ag/TiO_2/Zeolites/Magnetite and CNTs	Strong antimicrobial activity, low toxicity to humans, high mechanical and chemical stability, high permeability and selectivity, etc.

3. CONCLUSION

The application of nanotechnology has seen a continuous increase as researchers are discovering more nanomaterials and their possible application in water and wastewater treatment. The nanoadsorbents, nanotechnology enabled membranes and nanophotocatalysts, are the three categories of particles for nanotechnology. In Nigeria however, these categories of particles nanotechnology have commercial production. Globally, researchers have continued to make several discoveries on water and wastewater treatment using nanotechnologies that have made immense enhancement in recent past for handling wastewater problems with the view of more advancements in coming future. This is because nanotechnology-based treatment has offered very effectual, competent, resilient and eco-friendly approaches. These methods are more viable, less tedious with near absence of generation than conventional methods for water and wastewater treatment.

4. ACKNOWLEDGEMENT

The authors wish to acknowledge the assistance and contributions of the Library Department of National Water Resources Institute, Mando – Road, Kaduna, Nigeria towards the success of this work.

5. CONFLICT OF INTEREST

There is no conflict interest associated with this work.

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