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An Overview on Nano Applications for Waste Water Treatment and Purification

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Anuya Verma, Rohini Trivedi*, Anshul Kandara, Dhanusha Karki

Department of Environmental Sciences, Faculty of Earth Science, M L Sukhadia University, Udaipur (Raj.), India

**Department of Botany, M L Sukhadia University, Udaipur (Raj.), India*

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ABSTRACT

Many strong challenges are being faced on daily basis related to high water demand, stress on surface water supply and increasing contamination. These threats need innovative solutions so that waste water can be treated efficiently, economically and applying techniques which can produce clean water by recycling. Nanotechnology in recent years has proven effective and sustainable solution. The accumulation of nanoparticles plays an imperative part of its natural impact as shape and size of nanoparticle will decide magnitude of any possible toxic harmful effect to the environment. Nanotechnology plays an indispensable role to replace the existing technology, reform time tested and newer materials and chemicals to perform efficiently with lesser energy and material consumption. Nanotechnology has also offered immense possibilities for removal of harmful germs and pollutants from water. Today metal based nanoparticles like silver, silicon, cadmium, copper, zinc and many more have proven useful for removal of various contaminants from water. Most important issue related to various upcoming challenges is application of nanoparticles for purifying water available in form of surface, ground and industrial wastewater. As there is a long history of usage of nanoparticles in daily products, the way in which metal based nanoparticles act in environment and their relation to humans have yet to be elucidated fully. Predicted environment concentrations based on the current usage are low but expected to increase as their application increases.

INTRODUCTION

Water being vital for survival is facing uncounted problems leading to deterioration of its attributes. As we know water is a gift to mankind, hence it should be sustainably utilized. In the present century, it is extremely challenging to arrange clean water for enormous population. Over few decades, accelerated industrial growth and urbanization have paved way for several environmental problems like supply of clean water, wastewater collection, treatment and its proper disposal (Verma and Trivedy, 2016). World Health Organization (WHO) has reported environmental degradation mingled with rapid industrialization and growth of world population as some of the causes for swift increase in water quality degradation and related pollution issues. The challenges for environmental engineering are enduring and immense in today's world. The ponderous concerns related to every aspect of the environment are precursors and torchbearers for environmental science and recognition of environmental stability. The progress in science, newer innovations into engineering and ample scientific innovations are all leading way to efficient applications of nanotechnology in environment protection.

Nanoparticles (NPs) have been analyzed in utilization for betterment in field of environmental science. It is significant to know the chemistry, arrangement, reactivity and possible mechanisms of the NPs involved and their collaboration with natural components present in aquatic ecosystem. It is essential to understand the fate and extent of toxicity of these particles in environment (Nam *et al.*, 2008). As there is a state of noticeable distress that can be witnessed in our immediate domain, application of the NPs is the need of the hour. The use of biological organisms for synthesis and assembly of NPs is gaining importance because of its success and ease with which NPs are formed (Bhattacharya *et al*., 2005; Mali *et al*., 2019).

NPs are nanostructure with dimensions in the range of 1 to 100 nm also known as superfine particles. They constitute a completely new form of matter which exhibits patterns of behavior quite different from those of the substance's corresponding solid form (Ichinose *et al.,* 1992). Mostly metal based NPs have hydrophilic nature and show finite but low solubility. They have large ratio of surface area to volume as compared to their bulk equivalents. Nanotechnology is among the most widely studied techniques, which is examined by researchers so that it could be applied in wastewater treatment.

VERSATILITY OF NANO APPLICATIONS

Nanotechnology is versatile and is applied to many fields such as chemistry, biology, medicine, environment studies etc. This technology is already a solution provider for many of the environmental hazards because of its high potential to act on various components of the system and for future developments. Nanotechnology plays an indispensable role in advancement of methods for manufacturing new products, to replace the production equipments that already exist and to reform materials and chemicals so that they have higher performance along with lesser energy and material consumption. Nanotechnology is being utilized in environmental remediation and to reduce the harm to environment as it has the potential to remediate the problems sustainably. In this aspect, application of this technology in recent years has been versatile as in production of cheaper and efficient solar cells, eco-friendly nano coatings which are more effective and non-toxic to the environment.

Water treatment process involves chemical use that is of high environmental concern. Water treatment using magnetic iron nanoparticle and protein functionalized nanoparticle resulted in reduced water turbidity (Lakshmanan and Rajarao, 2013). One of the inexpensive as well as promising technique is use of APTS coated iron particles for lake restoration (Vicente *et al.*, 2010).

At present, more attention is given to behavior and effects of engineered NPs but only limited information is available. There is more work being done with the natural NPs and the knowledge gained will be helpful in assessment of fate of engineered NPs (Nowack and Bucheli, 2007). As compared to conventional or other pollutants, NPs create new challenges because of the particle size with respect to toxicity. It is also important to note that many engineered NPs are functionalized and this affects their behavior. These concepts need to be included in experimental designs and in appropriate analytical methods. (Holsapple *et al.*, 2006).

Soil contaminated with Polynuclear Aromatic Hydrocarbons (PAHs) can be remediated with Amphiphilic Polyurethane (APU) NPs (Tungittiplakorn *et al.*, 2004). NPs are being used extensively in soil remediation particularly heavy metals (Araujo and Fiuza, 2015). Magnetite and haemetite NPs can be used potentially for removal of arsenic in sandy soil (Shipley *et al.*, 2011). Application of NPs in *in vitro* conditions is utilized in improvising plant disease resistance, enhanced plant growth and efficient nutrient utilization (Nair *et al*., 2010). NPs are being used for *in vivo* imaging in living tobacco cells using trojan peptoids as vehicles (Eggenberger *et al.,* **2010).**

NANOPARTICLES BEHAVIOR IN AQUATIC AND TERRESTRIAL REALMS

Navarro *et al.*, (2008) observed various sources of NPs and concluded that with the development of nanotechnology there will be a substantial increase in the production and release of new Engineered NPs (ENPs). Volcanic eruption, pollen grains, vehicular emissions, coal combustion are natural and anthropogenic sources of NPs along with some engineered NPs in the environment from production processes, production facilities, waste water treatment plants and accidents during transport (Farré *et al*., 2009).

Most extensively used NPs in household and industries are of silver and titanium dioxide. Increased use of such manufactured NPs releases them in natural environment from where they dispersed widely. Serious concerns are being raised about environmental impacts and related health risks in aquatic ecosystems. The particles are being stored through alteration in properties such as shape, size, structure and chemical composition, thereby challenging the ability to understand nanoparticle aggregation in environment (Hotze *et al.*, 2010).

Nam *et al*., (2014) observed nanoparticle characteristics, test designs, model studies and standardized test plans where they found that bioaccumulation is essential to understand while assessing the potential dangers posed by metal based NPs. The investigation made by Batley *et al.*, (2013) conferred that the NPs can be used directly as fertilizers for soils or indirectly in wastewater treatment components such as sludge or bio solids.

A discharge of nano titanium dioxide from sources where they are applied to water environment may result in exposure due to their toxic effects and bioavailability. Titanium dioxide accumulation plays an imperative role as their shape and size will decide magnitude of any possible harmful effect. Ionic behavior, pH and ionic character (inorganic and natural) of water suspensions have marked effects on aggregation. Metal based NPs enter into the aquatic environment and are taken up by variety of species and so the possibility that these particles pass through aquatic food web arises (Tangaa *et al.*, 2016).

Sharma (2009) observed the size dependent effect for interaction between the nano titanium dioxides and the biological systems.

Batley (2013) gave a review to understand how nanoparticle affects water and soils. Higher organisms can ingest NPs directly and can transfer in a food web of both terrestrial and aquatic ecosystems. Gough *et al.,* (2008) observed metal contamination in lake system resulting in decreased microbial biomass by altering the biogeochemical cycles mediated by microorganisms in the sediments. Organic carbon has been found high in contaminated sediments (Chander and Brookes, 1991; Kelly and Tate, 1998; Valsecchi *et al.,* 1995). Due to widespread use of ENPs, concerns have been raised over their effects on the ecosystem. They get accumulated in organisms at the lower trophic levels and get transferred to higher trophic level (Hou *et al.,* 2013). Long term exposure to aquatic organisms may alter the growth of these organisms at both individual and population levels (Zhu *et al.,* 2010).

Matzke *et al.,* (2014) explained that silver NPs show antimicrobial properties as they discharge silver ions–charged particles which hinder living cell processes. They have deteriorating effect on the micro and larger organisms due to bioaccumulation. These nanoparticles get accumulated in microorganisms present in wastewater and show detrimental effects (Choi *et al.,* 2008). Silver NPs are used into many buyers and medical products due to their antimicrobial action; however, the potential environmental risks are yet to be fully understood (Massarsky *et al.,* 2014). Suresh *et al.,* (2012) showed that cytotoxicity induced by AgNPs depends on surface coatings and cell types.

NANOPARTICLES IN RESTORATION PROCESS

Nowadays many NPs are used for water purification mostly metal containing NPs where organic pollutants can be removed from water by decomposing.TiO_2 NPs when released on surface water in controlled conditions can help in reduced organic carbon load due to oxidative photochemical degradation. (Savage and Diallo, 2005). Nano materials can be used for contamination removal like chiral compounds, pharmaceuticals, from water. (Richardson, 2003). Zinc oxide NPs were used for removal of organic pollutants like phenol that cause problems when present in water. (Hassan *et al.,* 2017). Heavy metal separation from water of a contaminated river was carried out with the help of high performance iron oxide nanoparticle based heavy metal sorbents. It was noticed that these combination were much more effective than the sorbent materials and iron oxide NPs that are found commercially (Warner *et al*., 2010). Crane *et al.*, (2011) removed Uranium from polluted and carbonate rich water by application of magnetite and zero-valent iron NPs. Singh *et al.*, (2012) used zero-valent iron particles on water samples collected from ground water polluted with hexavalent chromium that resulted in 100% removal of the contaminants.

Mansoori *et al.*, (2008) gave a comprehensive note about the current research and developmental activities of nanotechnology in the field of environmental remediation, where various treatment methods were assessed using different nanomaterials from contaminated wastewater, groundwater etc. It was also suggested that for creating innovative perspectives of nanotechnology, broader environmental impacts models must be considered.

Wigginton *et al.*, (2007) focused on recent advances in understanding various properties of the NPs like cadmium, copper, zinc, etc that affect the characteristics of water. In future, this will be important in continuing efforts of water treatment and remediation. Tiwari *et al.*, (2008) emphasized that research is going on how to efficiently use nanotechnology for purified drinking water. Christian *et al.*, (2008) focused on NPs' ability to attach themselves to molecules like sediments proved useful in determining their final fate. Previous exposure and risk assessments of NPs have not modeled fate processes at the nano level, but at much higher system levels (Mueller and Nowack, 2008; Blaser *et al.*, 2008). Karn *et al.*, (2009) observed that Nano remediation methods have been used to protect the environment from pollution by transformation and detoxification of pollutants where it can reduce the overall cost and time for cleaning of large scale contaminated sites, thus eradicating the need of treatment of the polluted soil and lessen the concentration of pollutants to nearly zero. Evaluation of Nano remediation is required to avoid any severe environmental impacts.

NANOPARTICLES FOR WASTE WATER REMEDIATION

NPs have vast application in many fields, be it medicine, gene delivery, detection and diagnosis, agriculture, etc. It is important to have specialized techniques for better application of nanoparticle for effective working. Application of this technique on environment has resulted in development of solutions for various environmental problems, measures to prevent any future problems that may result from the interactions between various components of environment and any further risk that may arise by nanotechnology itself. Many studies have revealed that nanoparticles have adverse effects on environment (Ma *et al*, 2013; Li *et al.*, 2015).

NPs face limitations in terms of their application in water treatment plants at a larger scale, requirement in high quantity and their inefficiency to fulfill regulations of drinking water (Simeonidis *et al*., 2016). Small size and large specific surface areas are the unique properties of nanoparticle that result in high adsorption capacities and reactivity. By these properties, NPs have immense potential in waste water treatment (Khin *et al*., 2012; Mali *et al.*, 2020). Excessive use of NPs makes its way to aquatic environment and affects the organisms. Because of its small size and easy penetration into the cells, they are much toxic as compared to larger particles of same substance (Liu *et al*., 2014).

CONCLUSION

There is no doubt that the increasing demands of safe water can be achieved using nanotechnology especially metal based nanoparticle. In the near future successful removal of pollutants from soil and water might cause a major risk if we develop a new pollutant based on NPs acting at its core. Nanotechnology has proved to be beneficial in environmental remediation sustainably as it is more effective, have less energy and material requirement. NPs are applied in methods for removal of contaminants from aquatic ecosystems. Due to its nano size, contaminants get easily adsorbed, thus producing cleaner site. This technology provides solution for many environmental hazards due to its potential to act on various components of the ecosystem. Also some of the NPs exhibit antibacterial properties which is a plus point in water treatment methods. But they also destroy the microorganisms of ecological importance.

With advancements in technology these particles are released in environment due to increased production of ENPs. NPs have high capacity to undergo changes and show properties unknown to us. They enter the ecosystem and get ingested by living organisms which might produce toxic effects in them, eventually leading to bioaccumulation. This might produce deteriorating effect on health of higher organisms because of bioaccumulation.

In future we will require studying both quantitative and qualitative attributes of NPs as well as the route and ultimately the end fate of the particles and various factors affecting the particle characteristics and how they show different effects on various components of an ecosystem.

When detailed studies are made they will provide us with more accurate information which will help in utilizing the technology at its maximum. Hence to conclude there is a need to carry further studies to determine NPs safer use over long period of time before commercializing it.

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Author -1 & corresponding Author	**Dr. Anuya Verma** Assistant Professor, Department of Environmental Sciences, Faculty of Earth Science, M L Sukhadia University, Udaipur (Raj.), India
Author -2	**Dr. Rohini Trivedi** Assistant Professor, Department of Botany, M L Sukhadia University, Udaipur (Raj.), India
Author -3	**Anshul Kandara** *Research Scholar Scholar* Department of Environmental Sciences, Faculty of Earth Science, M L Sukhadia University, Udaipur (Raj.), India
Author -4	**Dhanusha Karki** *Research Scholar Scholar* Department of Environmental Sciences, Faculty of Earth Science, M L Sukhadia University, Udaipur (Raj.), India