A REVIEW ON APPLICATION OF NANOPARTICLES IN WASTEWATER TREATMENT

Drashti Kheni [(a)], Heta Naik[(b)]
Environmental Science & Technology
Shroff S.R. Rotary Institute of Chemical Technology

ABSTRACT

Nanoparticles which are of 1-100 nm size have gained special attraction due to higher surface area. There are several types of Nanoparticles viz. Iron, silver, copper, alumina, Titanium etc. Nanoparticles efficiently remove organic & inorganic solute, toxic ions from wastewater. These study focuses on application of nanoparticles in treatment of wastewater from several industries. In present study, In this modern era, nanotechnology is offering great potential for the treatment of wastewater in an extraordinary way as compared to the commercial methods. Traditional wastewater treatment involves high costs and deal with heavy metals. Use of nano materials for cleaning waste water is recent approach. The fields of nano biotechnology and nano technology are under active research for the application of wastewater treatment.

Keywords: Nanoparticles, % of reduction, Wastewater, Heavy metals removal Etc.

INTRODUCTION

Water is one of the most important resources for sustaining human life. Reliable and sustainable supply of water is one of the most basic humanitarian goals and yet remains a challenge to meet globally. Water on earth is one of the most abundant natural resources, but only about 1% of that resource is available for human consumption (Grey et al., 2013; Adeleye et al., 2016). Nanotechnology holds great potential in advancing water and wastewater treatment to improve treatment efficiency as well as to augment water supply through safe use of unconventional water sources. The major challenge in water supply chain is continuous contamination of freshwater resources by a variety of organic and inorganic pollutants (Schwarzenbach et al., 2006). The existing technologies of wastewater treatments have several drawbacks such as high-energy requirement, incomplete pollutant removal and generation of toxic sludge (Ferroudj et al., 2013). Among the various emerging technologies, the advancement in nanotechnology has proved an incredible potential for the remediation of wastewater and various other environmental problems (Zare et al., 2013; Sadegh et al., 2014; Gupta et al., 2015).

The nano-particles are those that have structure components with one dimension at least less than 100 nm (Amin et al., 2014). Nanomaterials are of interest because at this scale unique optical, magnetic, electrical, and other properties emerge.

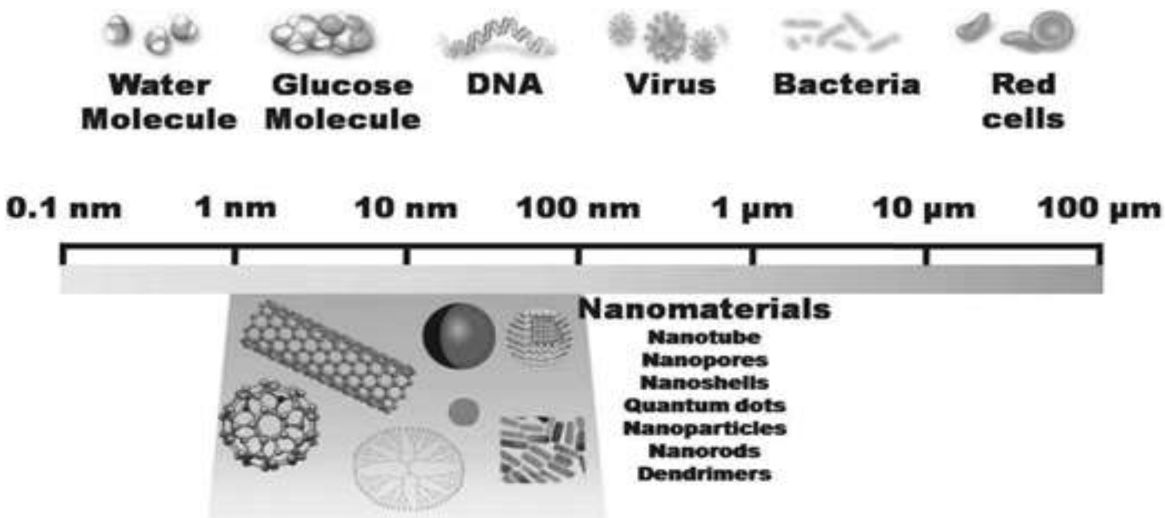


Fig (1) Nano-scale

Nanotechnology is the field of nanoscience, the phenomena applied on a nanometre scale level. Nano-materials are the smallest structures that humans have developed, having size of a few nanometres (Chaturvedi et al., 2012). Nano-materials have been developed in variety of forms such as nanowires, nanotubes, films, particles, quantum dots and colloids (Edelstein and Camerata, 1998; Lubick and Betts, 2008). In wastewater treatment application, a variety of efficient, eco-friendly and cost-effective nanomaterials have been developed having unique functionalities for potential decontamination of industrial effluents, surface water, ground water and drinking water (Bromfield, 2003; Theron et al., 2008; Gupta et al., 2015).

It may be classified based on the nano-materials nature into three main categories:
(1) Nano-adsorbents
(2) Nano-catalysts
(3) Nano-membranes

Aim to investigate the removal of pollutants from wastewater using nano-adsorbent materials (Zhang et al., 2014a, b; Tang et al., 2014; Shamsizadeh et al., 2014; Kyzas and Matis, 2015).

Nano-adsorbent can be produced using the atoms of those elements which are chemically active and have high adsorption capacity on the surface of the nano-material (Kyzas and Matis, 2015). The used materials for development of nano-adsorbents include activated carbon, silica, clay materials, metal oxides and modified compounds in the form of composites (El-Saliby et al., 2008). The second class of the nanomaterials is nano-catalysts. The nanomaterials such as metal oxides and semiconductors have gained a considerable attention of the scientists in developing wastewater treatment technologies. Different types of nano-catalysts are employed for degradation of pollutants in wastewater, for instance, electrocatalysts (Dutta et al., 2014), Fenton based catalysts (Kurian and Nair, 2015) for improving chemical oxidation of organic pollutants (Ma et al., 2015) and catalysts having antimicrobial properties (Chaturvedi et al., 2012). The third class of the nano-materials used in the wastewater treatment processes is using nano-membranes. In that technology, the pressure driven treatment of wastewater has been proved ideal for improving water quality of desire (Rao, 2014). Among various types of membrane filtration, (Lau and Ismail, 2009; Ouyang et al., 2013; Blanco et al., 2012) the nano-filtration (NF) is extensively applied for treatment of wastewater in industries because of small pore sizes, low cost, high efficiency and user friendliness (Petrinic et al., 2007; Hilal et al., 2004; Babursah et al., 2006; Rashidi et al., 2015). Nanomembranes can be developed from nano-materials such as nano metal particles, non-metal particles and nano-carbon tubes among others (El Saliby et al., 2008).

The main objective of nanotechnology is to;

1) Minimize environmental risks
2) Minimize health hazard

3) Replace existing hazardous particle with nanoparticles which are of minimal unwanted effects.

TYPES OF NANOPARTICLES:

Silver Nanoparticles:

Silver nanoparticle is one of the most important and widely used types of nanoparticles. Nano silver has been used for more than 150 years in the form of colloidal silver, and has been registered as a biocidal material in the United States since 1954 (Kim, *et al.*, 2010).

Silver nanoparticles are known as excellent antimicrobial agents, and therefore they could be used as an alternative disinfectant agent. Silver nanoparticles are increasingly used as biocides in a wide range of products. The application of nanoparticles in silver form varies from household paints to artificial prosthetic device. The extensive application of the silver nanoparticle results in their inevitable release into the environment. On the other hand, released silver nanoparticles could pose a threat to naturally occurring microorganisms.

It is currently being used in a wide variety of commercial products including medical applications, water purification, antimicrobial uses, paints, coatings, food packaging. Impregnating other materials with silver nanoparticles is a practical way to exploit the germ fighting properties of silver (Bogumila, *et al.*, 2013).

Titanium Dioxide:

One of the important nanoparticles which acts as photocatalyst is Titanium di oxide nanoparticle. Generally, titanium oxide is available in three different phases such as anatase, rutile and brookite. Each of them will be in different sizes (Parthasarthi, 2009). Nowadays Titanium dioxide is widely used for the preparation of nanomaterials such as nanotubes, nanowires. $TiO2$ has the potential application for removing the toxic compound from waste water. The nanocrystalline titanium di oxide (NTO) is often used in photocatalytic water treatment (Dhermendra, 2008).

Carbonaceous Nanoparticle:

Morphology of carbon nanoparticle is spherical and is available in the form of black powder. Density of carbon nanoparticle is 2.2670 g/cm3 and molar mass is 12.01 g/mol. The main characteristic feature of the carbonaceous nanoparticle is high capacity. Fullerenes which are nanoparticle originated from the smoke and soot of the campfire. These smokes evolve out with some other combustion by-products (Li, et al., 2007). These can be termed as crude nanoparticle. These crude nanoparticles are used in art. Fullerenes and carbon nanotubes have their own applications in a verity of fields. These are used in cosmetics, skin rejuvenation formulas. These can also be used in antibacterial functions. But this application of antibacterial aspects is under research and many more findings are being coming out. Even though these nanoparticles are lighter, they have their own remarkable strength as their property. These are also used in bicycle components, golf clubs, skis and tennis rackets. Ultra-light and strong materials can be prepared with the use of carbon nanotubes (Babak Kakavandi et al., 2013). These materials are used in aircraft and cars which will be used for energy saving and energy usage purposes. These carbon nanotubes act as adsorbents in order to treat the wastewater (Metcalf, 2003). These adsorbents act on the impurities and toxic substances present in the wastewater. Carbon nanotubes are used for the removal lead, cadmium and organic pollutants from water, since CNTs have excellent adsorption property promising (Li, *et al.*, 2007).

Activated carbon nanoparticle is one important type of carbon nanoparticle. The material activated carbon nanoparticle makes it porous. This will be used in adsorption process or chemical reactions. Large surface area is the main characteristic feature of activated carbon nanoparticle (Babak Kakavandi, *et al.*, 2013). Activated carbon nanoparticle is used in the process of cancer treatment.

Gold Nanoparticles:

Gold has always been the one precious material people like best. Due to its intrinsic value, buying the yellow metal has been seen as a good way of securing one's money. As a result of extensive research and continuous development, it has been discovered that gold can be used successfully for scientific purposes as well. Gold Nanoparticles have been utilized for centuries due to the vibrant colours produced by their interaction with visible light. Recently, these unique Optica electronics properties have been researched and utilized in high technology applications such as organic photovoltaics, sensory probes, therapeutic agents, drug delivery in biological and medical applications, electronic conductors and catalysis (Huifeng, *et al.*, 2013). Gold nanoparticles are versatile materials.

Copper Nanoparticles:

Mesopotamia A copper nanoparticle is a copper-based particle 1 to 100 nm in size (Khan, F. A., 2011). Like many other forms of nanoparticles, a copper nanoparticle can be formed by natural processes or through chemical synthesis. These nanoparticles are of particular interest due to their historical application as colouring agents and their modern-day biomedical ones (Heiligtag et al., 2013).

Copper nanoparticles display unique characteristics including catalytic & antifungal activities that are not observed in commercial copper. With the small size & great porosity, the nanoparticles are able to achieve a higher reaction yield and a shorter reaction time when utilised as reagents in organic and organometallic synthesis (Dhas, N. A., et al., 1998).

Aluminium oxide:

Aluminium oxide or aluminium oxide is a chemical compound of aluminium and oxygen with the chemical formula Al_2O_3. It is the most commonly occurring of several aluminium oxide and specifically identify as aluminium (III) oxide. Al_2O_3 is significant in its use to produce aluminium metal, as an abrasive owing to its hardness and as a refectory material owing to its high melting point (Alumina oxide- the different types of commercially available grades, 2007).

The most common form of crystalline aluminium oxide is known as corundum, which is the thermodynamically stable form (I. Levin, D Brandon, 1998).

Iron oxide nanoparticles:

In 2001, Asher reported co-precipitation method using oleic acid as the surface modification agent to obtain Fe_3O_4 nanoparticles (2-15 nm) (Linyan Yang et al., 2018). Magnetite (Fe_3O_4) is a ferromagnetic black colour iron oxide of both Fe (III) and Fe (II) which has been the most extensively studied (Cun Li et al., 2018).

Iron oxides exist in many forms in nature with magnetite (Fe_3O_4), hematite (α- Al_2O_3) and maghemite (γ- Al_2O_3), being most probably common and important technologically (A.S. Teja et al., 2009). It has been reported that surface effects have a strong influence on the magnetic properties of iron oxide nanoparticles (T. Neuberger et al., 2005). As the surface area of iron oxide based magnetic materials decreased, their response to external magnetic field decreased, making it difficult to recover the adsorbents after treatment has been completed (C.T. Yahuz et al., 2006).

The recent development of IONP synthesis methods highlighting the links between IONP physical characteristics and magnetic properties (Shoeb Anwar et al., 2018-19).

Methodology:

Chemical precipitation:

In this strategy the size is control by arrested precipitation technique. The basic trick has been to synthesis and studies the nanomaterial in situ i.e. in the same liquid medium avoiding the physical changes and aggregation of the tiny crystallites. The synthesis involve reaction between constituent material in suitable solvent. The dopant is added to the parent solution before precipitation reaction. The formed nano crystals are separated by centrifugation, washed and vacuum dried (Namita Rajput, 2015).

Sol-gel technique:

Colloidal particles are much larger than normal molecules or nanoparticles. However, upon mixing with a liquid colloid appear bulky whereas the nanosized molecules always look clear. It involves the evaluation of networks through the formation of colloidal suspension (sol) and gelatine to form a networking continuous liquid phase(gel) (Namita Rajput, 2015).

Sol-gel formation occurs in four stages:

1) Hydrolysis
2) Condensation
3) Growth of particles
4) Agglomeration of particles

Adsorption:

Among the conventional methods, chemical precipitation and other are less efficient and also produce large quantity of sludge which is very difficult to treat. This suggest the emerging need for technological advancements in water treatment to benefit people in many parts of the world. Nano adsorbent offer significant improvement with their extremely high specific surface area and associated sorption sites, short intra particle diffusion distance and tuneable pore size and surface chemistry (Rakhi M.S et al., 2016).

Types of adsorption:

1) Carbon based nano adsorption
    a. Organic removal
    b. Heavy metal removal
2) Metal based nano adsorption
3) Polymeric nano adsorption
4) Zeolites

Benefits of water treatment nanofiltration:

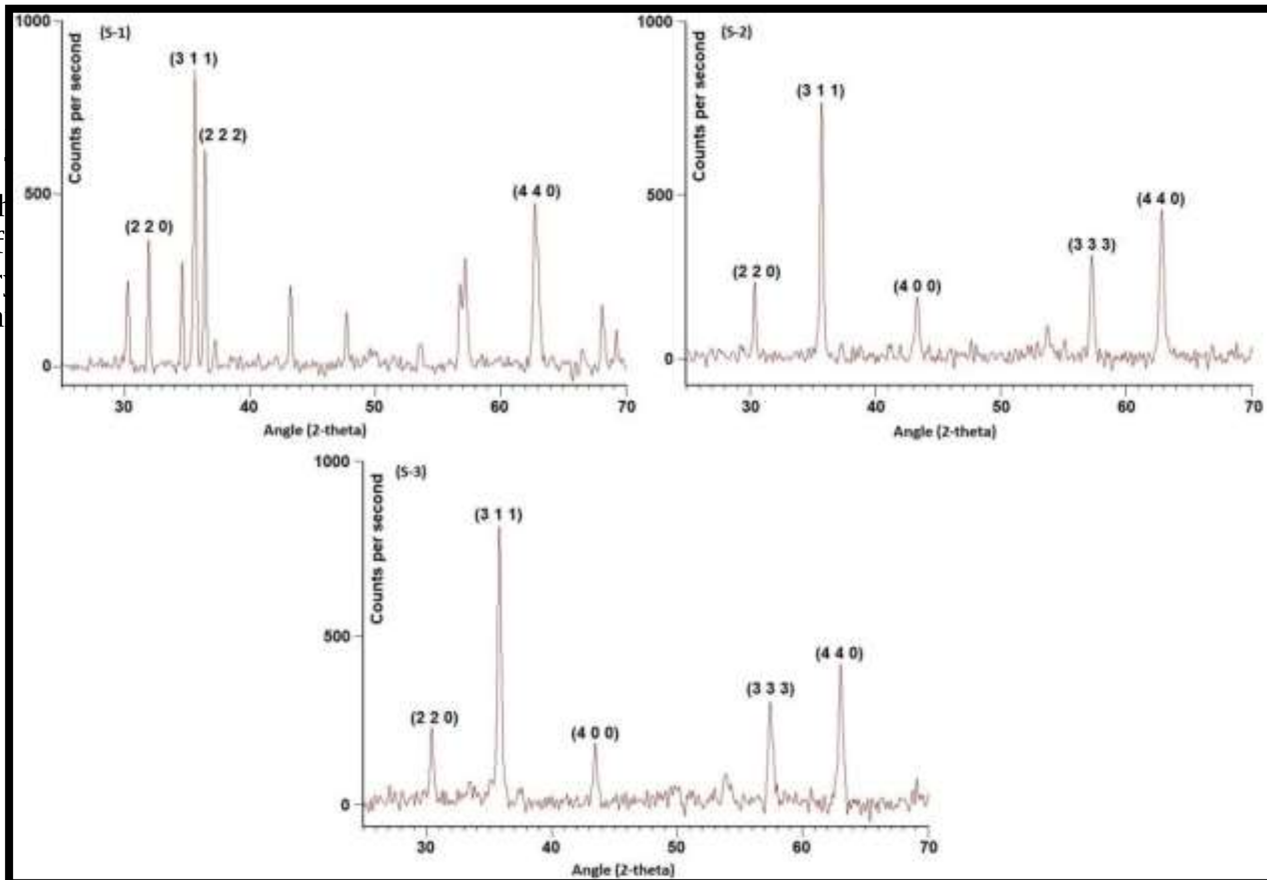
- Lower operating cost
- Lower energy cost
- Lower discharge and less wastewater than reverse osmosis
- Reduction of TDS content of slightly brackish water
- Reduction of heavy metals
- Reduction of pesticides and organic chemical
- Reduction of nitrates and sulphate
- Reduction colour and turbidity
- Hard water softening

Experimental Procedure for Nickel Ferrite Nanoparticles:

Synthesis of Nickel Ferrite Nanoparticles:

- Dissolve calculated amount of hexa-hydrated nickel chloride, hexa-hydrated ferric chloride and zinc-chloride, acetone in distilled water.
- When precipitation take place maintain its pH around 12-13 by adding NaOH solution under continuous stirring for 120 minutes.
- Place the beaker with the dark brown precipitate in water filled preheated water bath.
- For the preparation of each sample, temperature of water bath was maintained at 75 degree Celsius for 2 hours.
- The precipitates were carefully filtered and cleaned with purified water to clear them from chloride ions and sodium.
- The filtration continues unless solution pH reach the value of 7. To extract moisture content, the material was dried in an electric oven for 4 hours at a heating temperature of 70 degree Celsius.
- To get fine ferrite powder, the fully dried samples were grinded with pestle and mortar.

- Both components were thoroughly cleaned with acetone before grinding to avoid contamination.
- The grinded product was calcined at 800 degree Celsius for 3 hours.



Sample product of Nickel Ferrite:

Conclusion:

We concluded that this study showed that the iron nanoparticles could be used as an alternate to the conventional adsorbents for removal of heavy metals ions from wastewater with high removal efficiency within very short time. During study we came to know that the nanoparticles have unique properties like greater surface area, able to work at low concentration etc... The small size and high surface area of magnetite nanoparticles make them ideal adsorbent. Iron nanoparticles are recommended as fast, effective and less expensive Nano- adsorbents for rapid removal of metal ions from industrial wastewater. But before the bulk application health effect and fate into environmental issues should be addressed. In near future, there should be further improvement in the methods for qualitative analysis of nanoparticles after synthesis. The further research could be extended in order to increase the yield of the product by using alternate methods of synthesis.

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