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Nanomaterials for Purification of water

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Abstract

Water contamination by numerous toxic contaminants has become one of the gravest problems in the universe. Clean water is vital for human beings. The requirement of pure water is useful for many purposes like, drinking, preparation of food, proper hygiene and others. Appropriately, from the total number of the world population, one-half of the earth population faces severe challenges for getting clean water. About 2.1 billion people unavoidably drink water from sources having fecal contamination resulting in the death of a couple of million children once a year. To solve the shortage of clean water in the world, researchers are developing various economic technologies to decontaminate and to bring purify water. Nanomaterials-based knowledge offers a commercial and effective substitute for water purification and for reduction of decontamination. Developing nanomaterial base technologies have remarkable advantages for the reduction of antimicrobial activity and thus the power to effectively remove organic and inorganic pollutants from water. As nanomaterials exhibit notable antimicrobial and antiparasitic activities against waterborne pathogens and parasites of primary concern. Nm also demonstrates the facility to take in toxic chemicals like mercury and dyes from polluted water. Nanomaterials are being advanced to exhaust these problems and to combine two or more desirable properties for water purification. In extensive and in large scale use of nanomaterials for water purification presently may become a reality because of the improved technologies and the vast problems of the cleaned water. However, for successful commercialization of the technology, some inherent holdups need to be addressed adequately. This review discusses the potential role of nanomaterials within the purification of water.

Keywords: *Nano composite, antimicrobial, antiparasitic, nanomaterials*

Introduction

Clean and safe water is the most important component for living beings on the earth. It is the one and the foremost important elements for all living organisms in the earth to sustain life (Shams Tabrez Khan, 2018). Water is one of the most abundant resources in nature. Many local water and wastewater treatment techniques don't fully eliminate contaminants and are not capable of removing enough to meet increasingly stringent water quality standard. Disease such as cholera, dysentery, enteric fever, and hepatitis are quite common due to lack of clean water. Endemic diarrheal diseases place individuals, particularly children, in danger of arrested growth, malnutrition, and neurological conditions. The United Nations estimates that 1.1 billion people, or eighteen per cent of the world population, cannot obtain safe water at this time (Narayan, 2010). The World Health Organization states that more than 2.1 million individuals, mostly young children, die from diarrheal diseases annually. In developing countries, large-scale water treatment systems have face difficulties like, inadequate maintenance, intermittent delivery, contamination with microorganisms; lack of chlorination and etc. Low-cost point-of-use technologies were developed to convert of water from untreated sources like springs, wells, community taps, and rivers. Chlorination, flocculation, boiling, and filtration are the most commonly used type from point- of-use water purification technologies (Shams Tabrez Khan, 2018). The nanomaterials or engineering nanomaterials for water treatment is presently limited to exploring their potential to act as effective adsorbents, filters, disinfectants and reactive agents, although they show promise for full scale water treatment and environmental (Shams Tabrez Khan, 2018). Nanostructured material-based water purification technologies also are being incorporated within centralized water systems in developed countries.

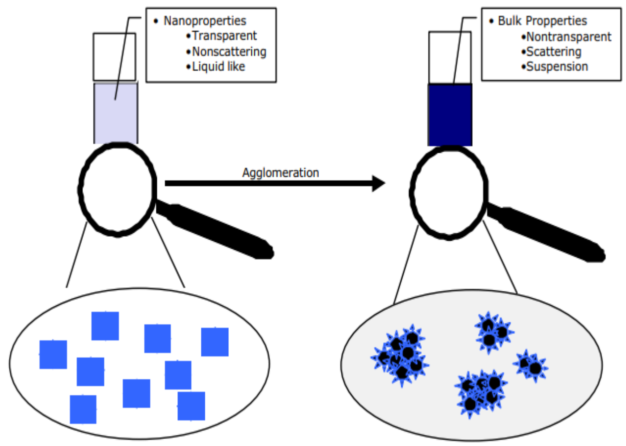

Figure 1 Nano and bulk properties

Dispersed Nanoparticles are needed in order to retain their specific properties for the technological applications (Paul JA Borm, 2006).

In the last two decades, nanotechnology has emerged significantly with its applications in almost all branches of science and technology. As a matter of fact, various nanomaterials are prepared and used for the removal of aquatic pollutants. Micro-organisms may form biofilms on the surfaces of water purification membranes. Biofilms decrease membrane permeability and increase water purification costs (Chella Santhosh, Role of nanomaterials in water treatment applications: A review, 2016). In addition, some microorganisms may release substances that degrade water quality, like metabolic products and biological toxins. In view of the importance of water quality and emerging utilities of nanotechnology, attempts have been made to discuss various aspects of water treatment by adsorption using nanomaterials. In this regard, promoting nanomaterials presents opportunities to develop local and practical solutions for tackling global water pollution. The following figure shows the design of engineering nanomaterials for water purification

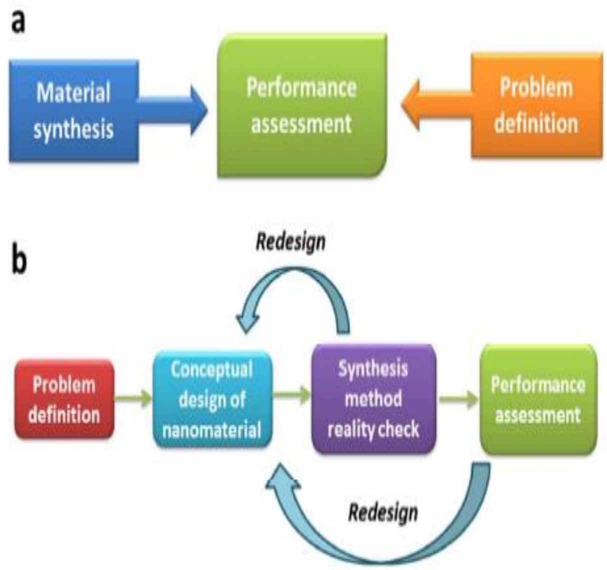

Figure 2, Approach vs. Design of Nano materials.

The above figure (figure 2) shows the Trial-and-error approaches versus rational design of nanomaterials (Renyuan Li, 2015).

From different side of study, various techniques have been developed for purifying of water. Among them, most important methods are solvent extraction, micro and ultrafiltration, sedimentation and gravity separation, flotation, precipitation, coagulation, oxidation, evaporation, distillation, reverse osmosis, adsorption, ion exchange, electrodialysis, electrolysis, etc. From above mentioned techniques, adsorption is one of the considerable techniques for treating the wastewater, since it's easy in operation, low cost and the availability of a wide range of adsorbents. In addition, adsorption can also pragmatic for the removal of soluble and insoluble organic, inorganic, and biological impurities. Moreover, adsorption also can be used for source reduction and reclamation for potable, industrial, and water. In spite of those facts, adsorption has certain limitation like it couldn't achieve hones status at commercial levels.

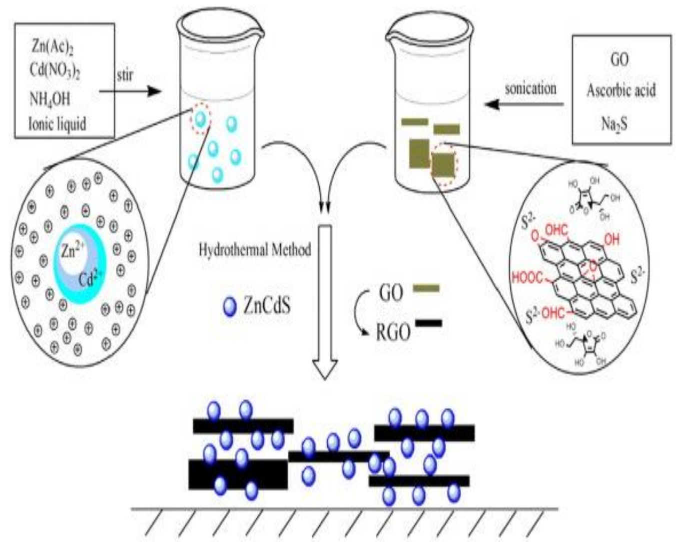

Figure 3, Application of Nanomaterials

The above figures (figure 3) shows nanomaterials application for water purification (Chella Santhosh, Role of nanomaterials in water treatment applications: A review, 2016).

This is due to lack of suitable adsorbents with high adsorption capacity and limited use of adsorbents on commercial scale columns. As well, a solo adsorbent cannot be used for eliminating all pollutants. A number of adsorbents are used for pollutants based on their properties. In developing countries, non-governmental organizations promote centers of disease control and prevention systems in rural areas using sodium hypochlorite as a disinfectant. They also came out with the use of visible light irradiation for destroying the waterborne pathogens present in polyethylene terephthalate bottles.

Post Treatment of Water

The treatment of product of water is required in many cases based on its intended use and quality. The post-treatment of water include carbon dioxide removal, chemical addition, pH adjustment and disinfection. This kind of treatment is a significant step to production water right for drinking and many more purposes. This treatment of water is needed to improve both taste and quality of water. (Sandeep Kumar, 2014).

Nanomaterials as adsorbents for water treatment

Nanomaterials are used to describe materials with one or more components that have at least one dimension in the range of 1 to 100 nm and include Nanoparticles, nanofibres and nanotubes, composite materials and Nano-structured surfaces. Nanotechnology gained wide attention and various nanomaterials are for the water treatment technology (Paul JA Borm, 2006). Currently, there's an excellent concern on the event of water treatment technologies. Nanomaterials have good solution for this matter. So from nanomaterial nanoadsorbents are the one that have nanoscale particles from organic or inorganic materials and have a high affinity to adsorb substances. Due to porosity, small size, and active surface, nanoadsorbents aren't only capable of appropriating contaminants through varying molecular size, hydrophobicity, and speciation behavior; however also enable manufacturing process to consume raw materials efficiently without releasing its toxic payload. Nanoadsorbents even have considerable pollutant-binding capacities. They're chemically redeveloped after being exhausted.

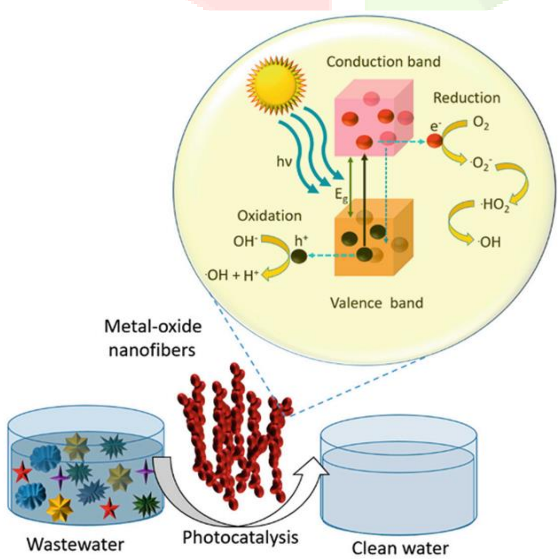

Figure 4, Purification from Photocatalytic activities.

Above figure (figure 4) shows water purification from photocatalytic activities.

Interests of nanotechnology are growing rapidly due the high validity of the appliance. Nanoscaled materials indicate unique characteristics thanks to their small size; they need an outsized area and 'surface area to volume' ratio. This improves the adsorption capacity of the nanoparticles.

Additionally to the massive area, these particles show unique characteristics, like catalytic potential and high reactivity, which make them as better adsorbing materials than conventional materials. As results of the particle size, nanoparticles have a greater number of active sites for interaction with different chemical species. For better results for the removal of pollutants from unsafe water, nanoparticles are getting new alternatives for the purification of water.

Classes of Engineered Nanomaterials

Selection of the simplest method and material for wastewater treatment may be a highly complex task, which should consider variety of things, like the standard standards to be met and therefore the efficiency also because the cost. Therefore, the subsequent four conditions must be considered within the decision on wastewater treatment technologies: (1) treatment flexibility and final efficiency (2) reuse of treatment agents, (3) environmental security and friendliness, and (4) low cost. because the size of a particle decreases, its specific area (i.e., area per unit mass) increases drastically and it had been the ultra-high specific area of nano-sized materials that first attracted attentions from the water treatment field because many water treatment processes believe interface-related processes (e.g., adsorption, reaction, catalysis), whose performance is positively hooked in to the fabric area. Tremendous published results have demonstrated the effectiveness of the strategy of getting to Nano-size for enhanced performance by making smaller and smaller materials (Adeyemi S. Adeleye, 2015).

Carbon Nanomaterials

Carbon nanomaterials abbreviated by C-ENMs and are composed of carbon atoms. They'll include SWCNTs (single walled carbon nanotube) or MWCNTs (multi-walled,) carbon nanotubes, carbon Nanofibers, fullerene, graphene and derivatives, and amorphous carbonaceous composites. Carbon engineered nanomaterials have high area, that make them the ENM are best and applicable for adsorption of pollutants. Additionally, the surfaces of those inherently hydrophobic materials are often functionalized to focus on specific pollutants via chemical or electrical relations. Some carbon engineered nanomaterials, could also be aligned to make efficient filters or incorporated into conventional membranes for removal of pollutants. The surface properties of ENMs are crucial for his or her aggregation behavior, mobility in aquatic and terrestrial systems and for his or her interactions with algae, plants and fungi. The processes involve photochemical transformation, dissolution and precipitation, adsorption and desorption, oxidation and reduction, combustion, biotransformation, agglomeration and abrasion (Chella Santhosh, Role of nanomaterials in water treatment applications: A review, 2016).

Carbon nanotubes

Carbon nanotubes are tubes made up of carbon with diameters typically measured in nanometers. It often refers to single walled carbon nanotube with diameter in the range of nanometer. Carbon nanotubes also refer to multi-wall carbon nanotubes consisting of nested single-wall carbon nanotubes bounded by van derwaals interaction in a tree ring like structure. Sometimes carbon nanotubes refer to double and triple – wall carbon nanotubes and the diameters less than 100 nanometers. All NT, SWNT and MNWT have exceptional tensile strength and thermal conductivity because of nanostructured and strength of the bonds between carbon atoms with several nested tubes, at lengths varying from 100 nm up to many tens of micrometers. However, the degree of aggregation, stabilization effects and the bioavailability of the nanotubes will have to be considered with attention for antimicrobial properties to be fully effective. So, carbon nanotubes are the best and the most valuable allotrope of carbon for purification of water (Chella Santhosh, Role of nanomaterials in water treatment applications: A review, 2016).

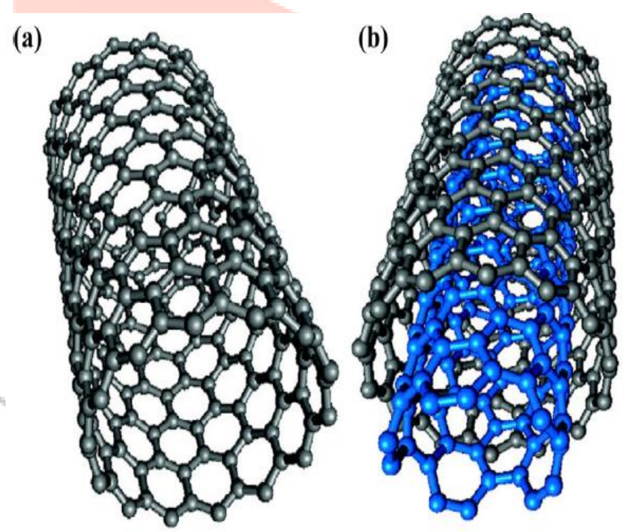

Figure 5: Structure representations of (a) SWCNTs and (b) MWCNTs (Chella Santhosh, Role of nanomaterials in water treatment applications: A review, 2016).

Fullerenes

Fullerene is an allotrope of carbon whose molecule consists of carbon atoms connected by one and double bonds so on form a closed mesh with fused rings of five to seven atoms. The molecules of fullerenes are hollow sphere, ellipsoid, tube or many other shape and size. It is denoted by C60 and it is informally called buckyballes for their resemblances to the standard ball of association football. Cylindrical fullerenes also are called carbon nanotubes or buckytubes. The bulk solid sort of pure or mixed fullerenes is named fullerite. The ability to synthesize fullerenes is introduced a new material with high electroconductivity, tensile strength, and unique thermal and optical properties. Fullerenes have a range of applications from simple nanoelectronics to nanocomposites materials for the improvement of the materials. From the study of Heymann, fullerenes (C60, C70, etc.) are highly insoluble in water (Heymann, 1994), however they can be made water-soluble by derivaticefezation. From the study of Tsao and Spesia, several C60 derivatives shows antibacterial effects ((Lin, 2002)), but then again the toxicity has depends on the specific derivative as the description of Sayes and Tang (Abdallah, P., 2007). Fullerenes also form stable aqueous suspensions of nanoparticles, termed nC60 as Fortner explanation (Fortner, 2005.) with a range of sizes (Brant et al., 2006). However, studies observing that, the nC60 in prokaryotic systems assert that antibacterial activity is mediated via direct oxidation of the cell. It is also debatable whether the antimicrobial activity observed is thanks to the organic solvent residual from the preparation. So, from the study we observed that, there is a great concern on the development of the microbial killing on the purification of water.

Metal and metal oxides

Metal and metal oxide engineered nanomaterials are a various class of nanomaterials that are composed of two, or, less commonly, three metals and their oxides. Metal and metal oxide engineering nanomaterials are denoted by Me/MeO ENMs. There are several types of Metal and metal oxide engineering nanomaterials for intended use. The most and commonly applied metal and metal oxides for water treatment/environmental remediation are nanoscale zero-valent iron (nZVI) TiO2, Ag, and ZnO. Some of the mechanisms for water treatment or remediation include adsorption, chemical degradation, photo degradation, and chemical disinfection. Many new improved techniques for water purification aimed at, making the process economic, effective and accessible are being developed.

Silver (Ag)

From the metal and metal oxides, silver are one of the disinfectant of bacteria's and any other unwanted things from water. It is the major element for the purification of water. Silver may be a element with the symbol Ag. A soft white, lustrous transition metal, exhibits the highest electrical conductivity, thermal conductivity and reflective of any metals. The reflective characteristics of the silver show the application in any area of it. The Silver ions are being added to water purification system in hospitals, community water system pools and spa. It also helps to prevent disease caused by buildups in pipes connections and water tanks. Water born disease is a major problem in developing countries. Silver can help to treat the issue of cleaning water for drinking has seen in a various researchers. The study used to show its usage to be an exciting development for the global water supply. In another way, silver illustrate an antibacterial mechanism due to the interaction through phosphorus and sulfur, which are the thiol groups (S–H) present especially in cysteine and various other biochemical compounds. Damage to bacterial proteins, dimerization of DNA and interruption in electron transport chain occurred by the interaction of ionic silver with thiol groups forming S–Ag or disulfide bonds. Even without releasing silver ions, silver NPs may kill some bacteria and viruses. From total silver, silver ion dissociation accounts for approximately 1 percent, which concludes that toxicity cannot be explained only by the release of silver ions; in fact some mechanism exist in NPs that results in toxicity.

TiO_2 for Purification of water

In a water treatment either for home or for other things, the benefits of TiO2 can be wide spread and it highly reduces the cleaning cost of water treatment and its plants (Adeyemi S. Adeleye, 2015). It has a range of catalytic capabilities that improve the facility used to treat drinking water, making them more durable and efficient. From metal and metal oxide of purification of water, TiO2 nanomaterials are the one and widely used nanomaterials for water purification. Certain reasons of titanium nanomaterials include the outstanding photocatalytic activity, substantial antimicrobial activity and the nontoxic nature of it at the concentration. One of the most important properties of TiO2 nanomaterials are photocatalytic properties. Photocatalysis is the action of a substance whose function is activated by the absorption of a photon. Different, experiments suggested that the Nano form of TiO2 or the ions released from TiO2 nanoparticles cause a number of biochemical and physical changes in the microbial cells consequently leading to their death. From different studies of antimicrobials, the antimicrobial action of TiO2 nanoparticles are famous waterborne pathogens including bacteria and protozoa. Activation occurs due to the transfer of energy in the form of a photon to the substrate and the oxidation which becomes easier due to the activated state of the substrate is the steps of it (Adeyemi S. Adeleye, 2015).

Iron oxide

Magnetite (Fe3O4), maghemite (γ-Fe2O3), and hematite (α-Fe2O3) are the common forms of existence of iron oxides in nature. In recent years, the synthesis and utilization of iron oxide nanomaterials with novel properties and functions have been widely studied, through their size in high surface area to volume ratios and superparamagnetism (Adeyemi S. Adeleye, 2015). The utilization of iron oxide nanomaterials has received much attention thanks to their unique properties, like extremely small size, high surface-area-to-volume ratio, surface modifiability, excellent magnetic properties and great biocompatibility. The need for contaminants removal has become a must for staying a long life in the world. Particularly, the easy synthesis, coating or modification, and the ability to control or manipulate matter on an atomic scale could provide unparalleled versatility. The spread of a wide range of contaminants in surface water and groundwater has become a critical issue in the world, due to population growth, rapid development of industrialization and long-term droughts. Contaminants persisting in wastewater include heavy metals, inorganic compounds, organic pollutants, and lots of other complex compounds. All of these contaminants releasing into the environment through wastewater are harmful to human beings and ecological environment. It is thus of necessity to control the harmful effects of contaminants and improve the human living environment. A range of environmental clean-up technologies are proposed in wastewater treatment which applied iron oxide nanomaterials as nanosorbents and photocatalysts. Moreover, iron oxide based immobilization technology for enhanced removal efficiency tends to be an innovative research point. Additionally, iron oxide

NMs with low toxicity, chemical inertness and biocompatibility show an incredible potential together with biotechnology (Piao Xu, 2012).

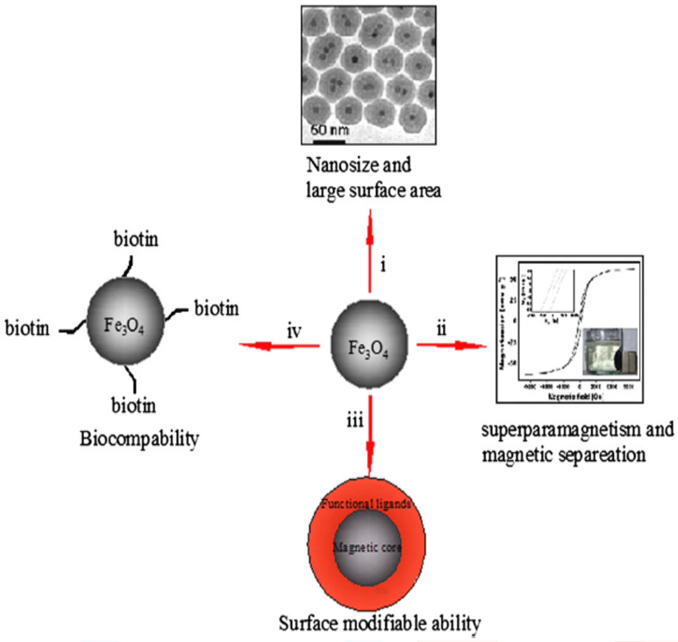

Figure 2 Important properties of iron oxide magnetic nanoparticles for wastewater treatment applications (Piao Xu, 2012).

ZnO as water purification

For successful elimination of pathogens from water, the interaction of pathogens and photocatalyst surface is necessary. TiO_2 doped with nitrogen (TiON), or a transition metal such as palladium is the most commonly used photocatalysts (Qilin Li, 2008). In addition to this, TiO2, ZnO are dopant for the purifying methods of water. Us we know chlorine, ozone, chloramines and chlorine dioxide are commonly used disinfectants for treating drinking water. ZnO has a large band-gap semiconductor and the emission is very sensitive to organic compounds, such as chlorinated phenols, present in its immediate vicinity. Zinc Oxide film-based sensors are used to monitor the decontamination process for determining the quality of water. ZnO-CeO_2 nanostructures are quite easy to synthesize, are low cost, have high sensitivity to ethanol and show high photocatalytic degradation for organic compounds such as methylene blue and acridine orange. ZnO has an advantage over TiO2; i.e., its strong emission in the visible region that mostly occurred from anionic vacancies (Qilin Li, 2008).

Magnetic composite particles

Magnetic materials are one of solution for water treatment plants because of the overtaking of the hazardous metallic materials from the water. From many methods of water purifying mechanisms, Magnetic Nano composite particles are the other methods of purifying the water. This method is by making coating. This coating can develop particle chemical stability, prevent oxidation, and also provide specific functionalities like selectivity for ion uptake or enhancing the water solubility of hydrophobic contaminants. Such like Nano particles are made with magnetic elements such as iron, nickel, cobalt or their oxides and alloys with ferromagnetic or super paramagnetic properties, and organic or inorganic shells. Shells can be made of inorganic components like silica or alumina or organic molecules such as polymers or surfactants. Magnetic particles can be made in sizes ranging from the nanoscale to several microns. One of the main benefits of magnetic particles is that their superparamagnetism facilitates rapid separation of pollutant-laden particles from treated water via an external magnetic flux, requiring less energy to achieve a given level of separation than non-magnetic particles.

Conclusion

More than half of the world population lives under the condition of severe water scarcity at least for a few months every year. Many lose their life and thousands suffer from waterborne diseases every year in various parts of the world. The problems related to unsafe water and waterborne diseases are expected to complicate further with the increasing world population and climate change. It is therefore both urgent and necessary for the scientific community to develop technology ensuring the safe water supply and to devise methods for effective and wise use of water resources. Innovations are required to address these local challenges and to develop new technologies appropriate for the local population. Some technologies have already been developed and commercialized providing solutions to these problems, while other technologies are being developed. Nanotechnology is one of the most promising technologies for the future of the water purification system as it can provide customized solutions employing multifunctional nanomaterials catering to the needs of different parts of the world. Furthermore, their excellent antimicrobial and antiparasitic activities against waterborne pathogens make nanomaterials suitable for water purification. As of now, nanomaterials developed for water purification are either based on nanoadsorbents or on nanomaterial-based membranes. Furthermore, the use of these nanomaterials for water purification should be regulated to avoid the overuse and misuse of the nanomaterials. The economy of the nanomaterials based purification is one of the most important aspects of the problem of water scarcity is more prevalent in developing and underdeveloped countries. Advances are made to develop nanotechnology-based solutions for water purification addressing many of the above mentioned concerns. Therefore, it can be concluded that Nanotechnology materials hold great potential in providing customized solutions for water purification.

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