International Journal of Advance Research in Science and Engineering
Volume No.07, Special Issue No.04, March 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

Potential of Nanotechnology in Wastewater Recycling – An overview

Sakiba Nabi, Bilal Malik

[1]*Department of Civil Engineering, NIT Srinagar, (India).*

[2] *Department of Civil Engineering, NIT Srinagar, (India).*

ABSTRACT

Water, the most vital element for the survival on earth has become one of the emerging environmental issues our ecosystem is facing today. Issue of water quality, quantity and availability are the three major concerns and are vital to the existence of life on the earth. Current and future fresh water demand could be met by enhancing water use efficiency and demand management. Thus, wastewater/low quality water is emerging as potential source for demand management after essential treatment. Nanotechnology offers a variety of promising solutions to filter out contaminants such as organic and inorganic solutes; heavy metals such as mercury, lead, arsenic, and cadmium; and biological toxins that causes water-borne disease such as cholera and typhoid. All existing technologies for water purification have many limitations, and nanotechnology contributes a scaffold for offering rapid detection and removal of contaminants by providing water treatment systems at low cost. Nano particles have very high absorbing, interacting and reacting capabilities due to its small size with high proportion of atoms at surface. Nano particles can achieve energy conservation due to its small size which can ultimately lead to cost savings. Nano particles have great advantage of treating Wastewater in depths and any location which is generally left out by other conventional technologies.

Keywords : Contaminants, Nanoparticles, Nanotechnology, Wastewater.

1. INTRODUCTION

Water is a precious natural resource, a basic human need and a prime national asset. The extent to which water is plentiful or scarce, clean or polluted, beneficial or destructive, profoundly influence the extent and quality of human life but the water resources are being depleted very fast and the relentless increase in population and the resulting spurt in the demand for water for agriculture, industrial and urban purposes require careful planning and management. The oceans occupy about 70.8% of the earth surface and only 29.2% is land. About 97.5% of the world water resource is in the ocean and is saline. Of the remaining, 2.5% of the global water resource, about 2% is in ice cap and glaciers and is generally not available for the requirements of mankind. A major part of the balance amount of water occurs as ground water, of which about half the volume lies in water bearing formation deeper than 800 m below ground surface and is not ordinarily available for economical development. Human use of water has increased more than 35 folds over the past three centuries. Globally, 3240 km^3 of fresh water are withdrawn and used annually. Of this total, 69% is used for agriculture, 23% for industries and 8% for domestic use. Water use varies considerably around the world (UNESCO World water report, 2014). The trends around the globe indicate that due to ever-increasing demand for water, resource availability-supply-demand pattern is continuously changing. In almost all countries including India the demand-supply gap is widening. The water demand in our country in the year 2000 was 634 BCM and it is going to be 1093 BCM by the year 2025.The maximum amount of water usage is for irrigation purposes, efforts therefore, need to be made to increase the utilizable quantity by conservation, improving efficiencies and increasing supply sources. With rapid expansion of cities and domestic water supply, quantity of gray/wastewater is increasing in the same proportion. As per CPHEEO estimates about 70-80% of total water supplied for domestic use gets generated as wastewater. As per CPCB estimates, the total wastewater generation from Class I cities (498) and Class II (410) towns in the country is around 35,558 and 2,696 MLD respectively. While, the installed sewage treatment capacity is just 11,553 and 233 MLD, respectively thereby leading to a gap of 26,468 MLD in sewage treatment capacity. Thus, overall analysis of water resources indicates that in coming years, there will be a twin edged problem to deal with reduced fresh water availability and increased wastewater generation due to increased population and industrialization. Also the conventionally treated wastewater is being discharged into the water bodies, thereby, increasing their weed content and contaminating the water. Since the early twentieth century, conventional methods have been used for water treatment, which consist of coagulation, sedimentation, filtration, disinfection, decontamination and desalination. The above processes are chemically and operationally intensive and require large systems, infrastructure and engineering expertise, which make them burdensome, ineffective, time consuming and costly. Further, the chemicals used for the chemical treatment of water involves chlorine, ammonia, hydrochloric acid, ozone, permanganate, ferric salts, corrosion control chemicals, ion exchange resins and residuals can contaminate freshwater resources to a great extent. At the very forefront of the emerging technologies lies the development of nanotechnology for Wastewater treatment. Nanotechnology represents an extremely broad field, which encompasses a number of materials and technologies spanning multiple disciplines. Currently a wide variety of potential remedial tools employing nanotechnology are being examined at the bench-scale for use in waste water remediation. One emerging nanotechnology, nanosized zero valent iron and its derivatives, has reached the commercial market for field-scale studies. In terms of wastewater treatment, nanotechnology is applicable in detection and removal of various pollutants. Heavy metal pollution poses as a serious threat to environment because it is toxic to living organisms, including humans and not biodegradable. Various methods such as Photolysis, Nano filtration, Adsorption and Electrochemical oxidation involve the use of nano wire membranes, polymer membranes, carbon nano tubes, submicron Nano power, metal oxides, magnetic nano particles, etc are used to resolve or greatly diminish problems involving water quality in natural environment. Nano particles have very high absorbing, interacting and reacting capabilities due to its small size with high proportion of atoms at surface. Nano particles can achieve energy conservation due to its small size which can ultimately lead to cost savings. Nano particles have great advantage of treating

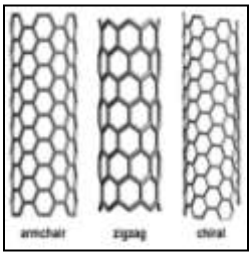
Wastewater in depths and any location which is generally left out by other conventional technologies. There are various recent advances on different nano materials (nano structured catalytic membranes, nano sorbents, nano catalysts, bioactive nano particles) for removing toxic metal ions, disease causing microbes, organic and inorganic solutes from water. Thus the potential of nanotechnology in terms of treating wastewater is enormous.

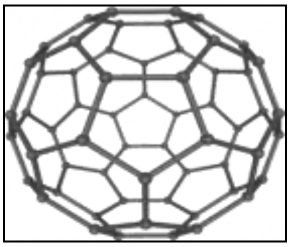
2. POTENTIAL OF NANOTECHNOLOGY

Water containing unwanted substances which adversely affect its quality and thus making it unsuitable for use is termed as wastewater. Wastewater is generated from various sources such as residential areas, commercial/industrial properties, agriculture etc. composition of wastewater varies widely and depends upon the source from which it is generated. Common constituents of wastewater are pathogenic and non-pathogenic microorganisms, organic substances such as excreta, plants material, food protein and inorganic substances like meal particles, ammonia along with gases. When left untreated these constituents may pose threat to living beings and the environment, which makes it essential to treat wastewater before disposal various physical, chemical and biological treatment processes are used for wastewater treatment. Among these methods, currently nanotechnology has been extensively studied by researchers as it offers potential advantage like low cost, reuse and highly efficient in removing and recovering the pollutants.

2.1. Nanotechnology: A brief review

Nanotechnology is the manipulation of matter at the nanometer scale to create novel structures, devices and systems. It deals with structures sized between 1 to 100nm and involves developing materials or devices with this size. Substances or materials generated having nanoscale dimensions are referred to as 'nanomaterials'. There are generally two categories of nanomaterials: fullerenes and nanoparticles. At the nanoscale level, materials show different chemical, physical and biological properties than their normal sizes. The surface area of particles increases with a decrease in particle size; so nanomaterials exhibit different optical, magnetic and electrical properties in comparison to macro particles. A fullerene is any molecule composed entirely of carbon, in the form of a hollow sphere, ellipsoid, or tube. Spherical fullerenes are called buckyballs. Cylindrical ones are called carbon nanotubes or buckytubes. The carbon nanotubes have a length to diameter ratio of 132,000,000:1. Have diameter of order 1nm and length up to 18cm. They exhibit extraordinary strength and unique electrical properties. They are categorized as single walled and multiwalled nanotubes.





(a) **(b)**

Figure 2.1. Types of nanomaterials: (a) Carbon Nanotubes & (b) Buckyball.

A nanoparticle is a metallic, semiconductor or oxide particle having dimensions between 1 to100nm. They are having a large surface area, very reactive and exhibit different properties compared to the bulk material of the same substance. They exhibit very interesting mechanical, magnetic, optical, chemical and other properties.

2.2. Nanotechnology in Water and Wastewater Treatment

Recent advances in nanoscale science and engineering are providing unprecedented opportunities to develop more cost effective and environmentally acceptable water purification processes. It is suggested that many of the issues involving water quality could be resolved using the products resulting from the developments in nanotechnology. Development of affordable novel technologies to desalinate water is among the most exciting and promising features of nanotechnology. Utilization of specific nanoparticles either embedded in membranes or on other structural media that can effectively, inexpensively and rapidly render unusable water is being explored at a variety of institutions. Innovative use of nanoparticles for the treatment of industrial waste water is another potentially useful application. Many types of nanomaterials are being evaluated and used in purification of water contaminated with toxic metal ions, radio nuclides, organic and inorganic solutes, bacteria and viruses. The classes of materials being evaluated as functional materials for water purification are metal containing nanoparticles, fullerenes, zeolites and dendrimers. These have a broad range of physicochemical properties that make them particularly attractive as separation and reactive media for water treatment.

Zeolites are microporous, alluminosilicate minerals commonly used as commercial adsorbents. Zeolites have a porous structure that can accommodate a wide variety of cations such as Na^{+}, K^{+}, Ca^{2+}, Mg^{2+} and others. These positive ions are rather loosely held and can be exchanged for others in a contact solution. They can be acquired from natural sources or fabricated in laboratories. Synthetic zeoloites are usually made from silicon-aluminium solutions or coal fly ash and are used as sorbents or ion exchange media in cartridge or column filters (Zhang, 2005). Nanoparticles of zeolites are being evaluated for the water treatment processes. Dendrimers are repeatedly branched, roughly spherical large molecules. A Dendron usually contains a single chemically addressable group called the focal point. The properties of dendrimers are dominated by the functional groups on the molecular surface. Dendrimers can be considered to have three portions a core, an inner shell and an outer shell. Ideally a dendrimer can be synthesized to have different functionality in each of these portions to control properties such as solubility, thermal stability and attachment of compounds for particular applications.

2.2.1.Nanofilters

Membrane processes play an important role in water purification, since conventional water treatment techniques such as coagulation, flocculation, sedimentation, activated carbon adsorption are not always able to remove organic pollutants to prescribed specifications. Because membrane components are considered key components of advanced water purification and desalination technologies. In this regard nanomaterials (e.g. carbon nanotubes, dendrimers) are contributing to the development of more efficient and cost effective water filtration processes. Nanofiltration is one of the membrane technologies, which utilizes pressure to effect separation of contaminants from water streams. The other are microfiltration, ultrafiltration and reverse osmosis. All of these technologies utilize semi-permeable membrane that have the ability to hold back (reject) dissolved and/or suspended solids from a water stream containing these contaminants. The characteristics of the four technologies are summarized in the table.

Table 2.1. Comparison of membrane technologies:

Feature	Microfiltration	Ultra filtration	Nanofiltration	Reverse Osmosis
Polymers	Ceramics, Polypropylene, Polysulfone, Polyvinylidene fluoride, Polytetraflour-Ethelyene.	Ceramics, Cellulosics, Polysulfone, Polyvinylidene flouride	Thin film cellulosics	Thin film composites, Cellulosics, Polysulfonated Polysulfone.
Pore size range	0.1-1.0	0.001-0.01	0.0001-0.001	<0.0001
Operating pressure range (psi)	<30	20-100	50-300	225-1,000
Suspended solids removal	Yes	Yes	Yes	Yes
Dissolved organics removal	Yes	Yes	Yes	Yes
Dissolved inorganics removal	None	Yes	Yes	Yes
Microorganism removal	Protozoan cysts, algae.	Protozoan cysts, algae, bacteria.	All	All
Permeate purity	Moderate	Moderate	High	High
Energy usage	Low	Low	Low-moderate	Moderate

Operating costs($/1000 gal)	0.50-1.00	0.50-1.00	0.75-1.50	1.50-5.00

(Source: Grenshaw, 2009).

A defining characteristic of the nanofilter membrane is that they reject multivalent ions to a significantly greater degree than monovalent ions. This characteristic is greatly exploited in rendering hard water soft. Water softening generally involves the removal of hardness ions, specifically calcium and magnesium. Because these ions are multivalent, they are preferentially removed by nanofilter membranes. Many institutions and countries are deploying desalination units using nanofilter membranes. Research is also being carried out. It has been reported that these technologies are being used in places such as Israel and in certain U.S. municipalities, notably in the Long Beach, California Municipal Water District. The particular advantage of the nanofilter membrane technology is that the nanofilter has a higher flux rate. This means that fewer membrane components are required and it operates at a lower pump pressure, thereby offering savings in pumping costs. Additionally at nanoscale these filter membranes may be engineered with specific properties e.g. alumina nanofilms reduce fouling by providing an electropositive surface which repels many clogging agents. Similarly, nanoscale zeolite membranes are highly chemical, mechanical and temperature resistant with a large surface area and absorption capacity. Also, it has been reported that the membranes made of carbon nanotubes can be readily cleaned by ultra sonication and autoclaving and hence the problem of fouling of these membranes can be addressed to greater extent. Also backwashing at regular intervals is an easy option which can be preferred to address this problem (Bartels *et al.,* 2007).

2.2.2. Nanosorbents

Sorbents are used as separation media in water purification to remove inorganic and organic pollutants from contaminated water. Nanoparticles have two key properties that make them particularly attractive as sorbents. On a mass basis, they have much larger surface areas than bulk particles. Nanoparticles can also be functionalized with various chemical groups to increase their affinity towards target compounds. Nanocrystalline zeolites have the ability to remediate water containing cationic species such as ammonium and heavy metals, as well as chemicals, such as ^{137}Cs and ^{90}Sr. These radioactive species are found in nuclear plant waste water and polluted ground water. Along with these the carbonaceous nanomaterials i.e. fullerenes, serve as high capacity and selective sorbents for organic solutes in aqueous solutions.

Table 2.2. Applications of various nanosorbents.

S.no.	Nanosorbent	Applications
01.	Carbon-based nanosorbents	Water containing nickel ions (Ni^{2+}). (high specific surface area,excellent chemical resistance, mechanical strength, and good adsorption capacity).
02.	CaptymerTM	Contaminants (perchlorate, nitrate, bromide and uranium) branched macromolecules forming globular micro particles.
03.	Regenerable polymeric nanosorbent	Many organic and inorganic contaminants in wastewater.

04.	Nanoclays	Hydrocarbons,dyes and phosphorus.
05.	Carbo-Iron	Activated carbon is for sorption while the elementary iron is reactive and can reduce different contaminants.

(Source: Prachi et al., 2013).

2.2.3. Nanometals and Nanoparticles

Nanoparticles have great potential as water-purification catalysts and redox active media due their large surface areas and their size and shape dependent optical, electronic and catalytic properties. They can chemically degrade pollutants instead of moving them somewhere else, including pollutants for which existing technologies are inefficient or prohibitively expensive. Researchers from Indian Institute of Science, Bangalore are using the nano titanium oxide particles for this very purpose. TiO_2 particles are very versatile and can serve both as oxidative and reductive catalysts for organic and inorganic pollutants. It has been reported that the removal of total organic carbon from waters contaminated with organic wastes was greatly enhanced by the addition of TiO_2 particles. Another set of nanoparticles - the magnetic nanoparticles have large surface areas relative to their volume and can easily bind with chemicals. In water treatment applications, they can be used to bind with contaminants, such as, arsenic or oil and then be removed using a magnet. Several companies are commercializing such technologies and researchers are frequently publishing new discoveries in this area.

Table 3.3. Applications of nanometals and nanoparticles.

S.no.	Nanometals and Nanoparticles	Applications
01.	Nanosilver and nano-TiO_2	Point-of-use water disinfection, anti biofouling surfaces, decontamination of organic compounds, remote areas.
02.	Magnetic nanoparticles	Groundwater remediation.
03.	Nano zero-valent iron	Groundwater remediation, Removal of organics and heavy metals.

(Source: Gehrke et al., 2015).

2.2.4. Bioactive Nanoparticles

A variety of strong oxidants (e.g., chlorine) are used as disinfectants for pathogens (e.g. bacteria and viruses) in water treatment. Because these compounds tend to generate toxic disinfection by products such as

International Journal of Advance Research in Science and Engineering
Volume No.07, Special Issue No.04, March 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

trihalomethanes, haloacetic acids and aldehydes, alternative disinfectants are critically needed to comply with certain safe drinking water rules. Nanomaterials are providing unprecedented opportunities to develop chlorine free biocides. It has been reported by Bhattacharya *et.al;* (2004) that MgO nanoparticles are very effective biocides against Gram-positive and Gram-negative bacteria and bacterial spores. Because AgI and silver nanoparticles have been used as antimicrobial compounds in various biomedical products and applications, it has been reported that several investigators are evaluating use of silver nanoparticles as biocides. Silver nanoparticles have been found to be effective nanoparticles against both Gram-positive and Gram-negative bacteria including Staphylococcus aureus, Escherichia coli, Klebsiella pneumonia and Pseudomonas aeruginosa. There are various Nanotech products in the market which have been recently introduced. These are summarised in table 2.4.

Table 2.4. Nanotech products in market.

Product	**How it works**	**Importance**	**Developers**
Nanorust to remove arsenic	Magnetic nanoparticles of iron oxide suspended in water bind arsenic, which is then removed with a magnet.	India, Bangladesh and other developing countries suffer thousands of cases of arsenic poisoning each year, linked to poisoning of wells.	Rice University, United States.
Desalination membrane	A combination of polymers and nanoparticles that draws in water ions and repels dissolved salts.	Already in the market, this membrane enables desalination with lower energy costs than RO.	University of California, Los Angeles.
Nanofiltration Membrane	Membrane made up of polymers with a pore size ranging from 0.1-10nm	Field tested to treat drinking water in China and desalinate water in Iran.	Sachen Industries, Korea.
Nanomesh waterstick	A straw like filtration device that uses carbon nanotubes plaed on a flexible, porous material.	The waterstick cleans the water as it is drunk. Doctors in Africa are using a prototype and the final product is said to be available at an affordable cost in developing countries.	Seldon Laboratories , United States.

World Filter	Filter using a nanofibre layer, made up of polymers, resins, ceramics and other materials that remove contaminants.	Designed specifically for the household or community level use in developing countries. The filters are effective, easy to use and require no maintenance.	KX Industries, US
Pesticide Filter	Filter using nanosilver to adsorb and then degrade three pesticides commonly found in the Indian water supplies.	This pesticide filter can provide a typical Indian household with 6000 litres of clean water over one year.	Indian Institute of Technology, Chennai, India and Eureka Forbes Limited, India.

Source: (Grenshaw,2009).

Table 2.5. Current and potential applications of nanotechnology in water and wastewater treatment.

Applications	Representative nanomaterials	Desirable nanomaterial properties	Enabled technologies
I. Adsorption	1. Carbon nanotubes	High specific surface area, highly assessable adsorption sites, diverse contaminant-CNT interactions, tunable surface chemistry, Easy reuse.	Contaminant preconcentration/detection, adsorption of recalcitrant contaminants.
	2. Nanoscale metal oxide	High specific surface area, short intraparticle diffusion distance, more adsorption sites, compressible without significant surface area reduction, easy reuse, some are super paramagnetic.	Adsorptive media filters, slurry reactors.
	1. Nano-zeolites	Molecular sieve, hydrophilicity.	High permeability thin film nanocomposite membranes.
	2. Nano-Ag	Strong and wide-spectrum antimicrobial activity, low toxicity to humans.	Anti-bio fouling membranes.

II. Membranes and Membrane processes	3. Carbon nanotubes	Antimicrobial activity (unaligned carbon nanotubes), Anti-bio fouling membranes Small diameter, atomic smoothness of inner surface, tunable opening chemistry, high mechanical and chemical stability.	Anti-bio fouling membranes.
III. Photo- catalysis	1. Nano-TiO2	Photocatalytic activity in UV and possibly visible light range, low human toxicity, high stability, low cost.	Photocatalytic reactors, solar disinfection systems.
	2.Fullerene derivatives	Photocatalytic activity in solar spectrum, high selectivity.	Photocatalytic reactors, solar disinfection systems.
IV. Disinfection and microbial control	1. Nano-Ag	Strong and wide-spectrum antimicrobial Activity, low toxicity to humans, ease of use.	POU water disinfection, anti-biofouling Surface.
	2. Carbon nanotubes	Antimicrobial activity, fiber shape, conductivity.	POU water disinfection, anti-biofouling surface.
	3. Nano-TiO2	Photocatalytic ROS generation, high chemical stability, low human toxicity and cost.	POU to full scale disinfection and decontamination.
V. Sensing and monitoring	1.Noble metal nanoparticles	Enhanced localized surface, high conductivity.	Optical and electrochemical detection.
	2. Carbon nanotubes	Large surface area, high mechanical strength and chemical stability, excellent electronic properties.	Electrochemical detection, sample preconcentration.
	3. Magnetic nanoparticles	Tunable surface chemistry, superparamagnetism.	Sample preconcentration and purification.

(Source: Xiaolei et al; 2013).

2.3. Carbon Nanotubes (CNTs)

CNTs are allotropes of carbon with a cylindrical nanostructure. Depending on their manufacturing process, CNTs are categorized as single-walled nanotubes and multiwalled nanotubes, respectively. Besides having a high specific surface area, CNTs possess highly assessable adsorption sites and an adjustable surface chemistry. Due to their hydrophobic surface, CNTs have to be stabilized in aqueous suspension in order to avoid aggregation that reduces the active surface. They can be used for adsorption of persistent contaminants as well as to preconcentrate and detect contaminants. Metal ions are absorbable by CNTs through electrostatic attraction and chemical bonding.

Furthermore, CNTs exhibit antimicrobial properties by causing oxidative stress in bacteria and destroying the cell membranes. Although chemical oxidation occurs, no toxic by-products are produced, which is an important advantage over conventional disinfection processes like chlorination and ozonation. They can be simply regenerated through appropriate adjustments of operating conditions, like pH shift. Recently, a team of US researchers developed a sponge made of pure CNTs with a dash of boron that shows a remarkable ability to absorb oil from water. The oil can be stored in the sponge for later retrieval or burned off so the sponge can be reused. If they succeed in generating large sheets or find a way to weld the sheets, the sponge material can be applied in removing oil spills for oil remediation. CNTs have significant advantages over activated carbon and point-of-use applications that require removal of heavily degradable contaminants such as many antibiotics and pharmaceuticals are being treated using CNTs. For these reasons CNTs can being used in the design of the WWTP.

2.4. Nano Iron Particles

Nano iron are particles with catalytic properties that can chemically break down pollutants. Their use mitigates the extensive cost of transporting them elsewhere. This, in turn, has the potential for treating contaminants at very low levels, especially where the current treatment techniques are ineffective or very expensive. Magnetic nano iron particles have large surface areas relative to their mass and easily bind with chemicals. Their ability to bind with contaminants, such as arsenic or oil, which can be easily removed using a magnet, makes them an appealing solution for water treatment**.** As an alternative, nano-zero valent iron can even be used for remediation of groundwater contaminated with chlorinated hydrocarbon fluids and per chlorates. A suspension of nano-zero valent iron can be injected into the groundwater, allowing in situ treatment of the ground water. On the one hand, due to its high specific surface, nano-zero valent iron is much more reactive in comparison with conventional granular iron; on the other, as a result of its high reactivity, the life time of nano-zero valent iron is very low, so that further research work, for example, on surface modifications, is necessary for stabilization of these nanoparticles. Nano iron particles can be injected in the trickling filter being used in the design of WWTP.

2.5. Risks, Challenges And Opportunities

Some researchers have called for more research on potential health and environmental risks of using nanotechnology for water treatment. For example, there are concerns that the enhanced reactivity of nanoparticles makes them more toxic. Their small size also means they could be hard to contain, so can more easily escape into the environment and potentially damage aquatic life. The full effects of exposure to nanomaterials, from handling them at water treatment facilities to drinking them in treated water are not known. But a distinction can be made between active and passive nanoparticles, in terms of risk assessment. Passive nanoparticles, such as, coating are likely to present no more or less a risk than active nanoparticles, which can move around the environment leading to risks associated with control and containment. Another key challenge is the integration of the nanomaterials into existing water purification systems. Many laboratory investigations and pilot plant studies are needed to integrate the novel nanostructured and reactive nanomembranes into existing water purification systems. However it is reported that nanosorbents(e.g. inorganic nanocrystals, carbonaceous nanoparticles, and zeolites), redox active nanoparticles(e.g. Fe^0 and bimettalic Fe^0) and bioactive nanoparticles (e.g. MgO and Ag) can be readily integrated into existing water plants. Nanomaterials are the drivers of the nanotechnology revolution. The bottleneck to the applications of nanotechnology to water purification will be the availability of the suppliers who can provide large quantities of nanomaterials at economically viable price.

2.6. Concluding Remarks

There is an overwhelming demand for new technologies that can improve the cleanliness and reliability of water, whether it be for human consumption or for agricultural or industrial applications. As noted, there are several promising commercial applications of nanotechnology in the process of being developed and brought to market. Many of the applications are still in their infancy and will require further testing to prove their reliability. Furthermore, implementing many of these technologies will require additional capital investment by existing water treatment centres to upgrade equipment and train personnel. However, though the proponents of nanotechnology face a challenge in convincing private and public entities to incur the up-front costs of adopting these new water purification technologies, nanotechnology holds out the promise of long-term benefits in the form of decreased costs of purifying the world's water supplies and the enormous savings that would accompany reliable access to potable water in those areas of the world that currently suffer from lack of adequate drinking water and basic sanitation services.

3. CONCLUSIONS AND RECOMMENDATIONS

Nano-Technology can being used for wastewater treatment plant, the load on the further treatment units will decrease and less maintenance will be required, resulting in low maintenance cost. By using Nano-materials like carbon nano tubes , nano silica , nano iron particles , the treatment capacity of the plant will be enhanced as the specific surface area of the nano materials is much high than the conventional materials like coke ,alum ,gravel bed. The efficiency of the plant can remain intact even in winters which is a drawback in the present plants.The effluent is proposed to be used for irrigation purposes thus can be recycled back and the excess of effluent can be either dumped off or stored for future uses. The effluent coming out from the proposed WWTP will be as per or much higher in quality than the national and international standards, and can be directly dumped in the Dal lake without effecting its aquatic life as well as its aesthetics. The comparison of nanotechnology with other technologies shows its higher efficiency and it can be used as an emerging technology for recycling water and conserving water.

4.SUGGESTIONS FOR FUTURE WORK

All over the world clean and safe water demand is rapidly rising with the increased concern and awareness about the health and environment. Nanotechnology has a great potential to overcome the cost and technical capacity barriers for providing the clean water to current and future generations. Also the reuse of wastewater is highly increased by using nanotechnology. With the advancement in science and technology, more techniques for water purification will be available in the coming future.Green manufacturing by using natural materials to develop nanomaterials will resolve the environmental and cost problems related to nanomaterial synthesis. It is essential to invest in the leapfrogging opportunities provided by nanotechnology to save both water quantity and quality. Many issues have been raised by different researchers related to some of the applications and properties of nanomaterials. Being very small in size, they may transfer to human body and other aquatic organisms. They may or may not be toxic depending upon the interaction, concentration, pH etc. Thus, a great effort is needed to explore every side of this new technology to have more benefits and reduce the side effects. The future of nanomaterials for wastewater treatment looks very promising and requires dedicated and sincere efforts from the scientific community, industrial enterprises and government machinery. Nanomaterials can help to a great extent for providing fast, economical, energy efficient and feasible water purification technologies.

REFERENCES

[1] UNESCO. (2014). *World Water Report.* United Nations Educational, Scientific and Cultural Organization.<http://www.unesco.org/environment/worldwaterreport/.html>.

[2] CWC. (2010). *Water and related statistics*. Water Planning and Project Wing, Central Water Commission, India.

[3] CPCB. (2009). *Status of water supply, wastewater generation and treatment in Class I cities and Class II towns of India*. Series: CUPS/70/2009-10. Central Pollution Control Board, India.

[4] Zhang W. X. (2005). *Nanoscale Iron Particles for Environmental Remediation.* Journal of Nanoport and Nanotechnology. Vol. 5, pp. 323-332.

[5] Grenshaw D. *Nanotechnology for Clean Water Treatment*: Facts and figures. 6-May-2009.

[6] Bartels C., Lai K., Wilf M. (2007). *New Generation of Low Fouling Nanofiltration Membranes*. EDS Conference, Halkidiki, Greece, 2007.

[7] Prachi K., Gautam P., Madathil D., Nair A. B. (2013). *Nanotechnology in Wastewater Treatment- A review*. International Journal of Chem tech Research, Vol. 5, pp. 2303-2308.

[8] Gehrke I., Geiser A., Somborn A. (2015). *Innovations in Nanotechnology for Wastewater Treatment.* Nanotechnology, Science and Applications, Vol. 13, pp. 1-17.

[9] Bhattacharya A., Ghosh P. (2004). *Nanofiltration and reverse osmosis membranes: theory and application in separation of electrolytes*. Rev. Chem. Eng. 20, pp. 223-230.