International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 04 | Apr 2020 www.irjet.net p-ISSN: 2395-0072

Nanotechnology Methods for Water Treatment

R Deepak Prasad[1], Vidya C[2]

[1]*Bachelor Student, Chemical Engineering, RVCE, Bengaluru, India*
[2]*Assistant Professor, Dept. of Chemical Engineering, RVCE, Bengaluru, India*

Abstract – *Advancement in technology and innovative ideas are rapidly changing the traditional methods of water distribution, supply, and to be more precise it's the purification techniques. Nanomaterials are widely used for water purification, medical care, and treatment applications as they have a massive specific area, high reactivity, size-dependent properties, affinity for specific target contaminants, etc. Membranes and filters synthesized exploit the properties that nanomaterials have such as selective porousness, sensible flux rates, and inflated sturdiness, dependability in purification and reusability, and thus are energy-saving and efficient. In this paper various nanomaterials like antimicrobial nanomaterials, carbon nanotubes CNTs), nonabsorbent, dendrimers, self-assembled monolayers on mesoporous oxide (SAMMS), single catalyst nanoparticles (SCNs), their mechanisms, synthesis, and applications are reviewed. Also, some key problems and challenges are addressed.*

***Key Words*: Nanotechnology, Nanomembranes, Antimicrobial Nanomaterials, Water Purification, Wastewater Treatment, CNT (Carbon Nanotubes)**

1. INTRODUCTION

Global sustainability depends on the availability of energy sources (oil, petroleum, natural gas, nuclear fuel, etc.) and clean water. Clean water is essential and important for all human activities, from simple homework to very complex industrial and agricultural processes. Direct sources of clean water are very limited. Growing population, intensive agriculture, rapid urbanization, and sustained industrial growth have put a strain on clean water demand. To meet this growing demand for water, new methods and technologies need to be researched and developed. Nano scale science and engineering advances offer vast opportunities to develop more cost-effective and environmentally acceptable water treatment processes. The nanometer material is well suited for water purification and wastewater treatment due to its large specific surface area, high reactivity, high reactivity, size-dependent properties, and specific target contaminants, similar and unique characteristics (adsorbents, catalysts, and sensors) Nano composite membranes and filters combine ablation and other functions to improve life and efficiency and can be reused several times, making them environmentally friendly. Antimicrobial nanoparticles disinfect contaminated water. Without making harmful pesticide by-products (DBP).

This review paper provides an overview of the various water distribution and supply methods, water treatment and treatment methods currently used, and their shortcomings. Some of its new aspects are reviewed and demonstrated, including an extensive study of the various applications of nanotechnology in water treatment and wastewater treatment.

1.1 Present Summary

Current methods in the distribution and supply of water and various purification and treatment methods are very inefficient and can lead to huge costs. These methods focus on processing large amounts of water, which can lead to increased costs and inefficiency. Water treatment and treatment techniques have the potential to provide good quality clean water, but these methods are not environmentally friendly because they create large quantities of waste products that are harmful to cancer and the environment. The shortcomings of current methods are the driving force for the research and development of various new techniques and technologies.

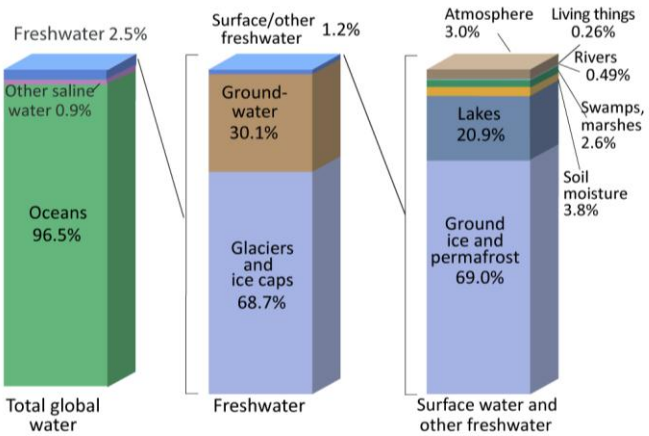
1.2 Water Availability, Supply & Distribution

Earth's surface is covered with more than 71% water, however, there is very little fresh water available for direct use. Fig. 1 shows the distribution of water on the Earth's surface [1]. 97% of all water on Earth is in the oceans and therefore cannot be directly used for human activities. The remaining 3% is freshwater available for use. 68.7% is locked in glaciers and icecaps. Of the remaining, about 30% is groundwater, which contains many pollutants, organic and inorganic, due to the disposal of industrial, agricultural, and domestic waste. Therefore, rivers and lakes that supply surface water for human use constitute only 0.007% of the total water on Earth. In other words, if the earth's fresh water is stored in a 5-liter container, the available freshwater will not fill a teaspoon [2]. Current water supply methods include processing large quantities of water in a centralized treatment plant and then delivering purified water over a long distance to residential and other areas. The drawbacks of this system are the large demand for resources at the centralized plant, the low efficiency in water treatment and treatment, and the high cost of plant maintenance. As water is supplied for longer distances. Pollution increases and this requires special filters at the household level, thereby increasing the overall pressure on resources and increasing costs. Large, centralized water treatment plants are often effectively replaced by Distributed Optimal Technology Networks (Dot-Net) [3]. The DOT-NET concept involves the strategic placement of small distribution plants and highly efficient treatment systems in relatively compact and existing water system networks. Such compact water treatment systems process a comparatively low volume of water and are therefore more efficient. These systems include new technologies (e.g. decentralized water treatment concepts like package refineries, point-of-entry (POE) and point-of-care (POU) treatment units) to satisfy the water needs of population groups like housing subdivisions, apartment complexes, and commercial districts. Factory assembled compact and a Top/faucet).

2. Water Treatment

Current water treatment methods can control organic and inorganic waste from water and purify it to a high degree of purity. These methods use physical separation methods (e.g. membranes and filters) and chemical purification techniques (e.g. chemical disinfection, chemical precipitation, etc.). Membrane and filter processes are better than chemical methods because toxic products are avoided, however, the main drawback of these methods is membrane and filter fouling. Bacteria and other impurities build up on the surface and clog the membranes over time, leading to costly cleaning and restoration. Membrane fouling results in a high energy demand on the pumping system. Chemical methods produce toxic reactive complexes which are then used for incineration or compression and ground filling. Both methods are harmful to the environment and cause environmental imbalance.

Figure -1: Water Distribution



Industry processes demand large amounts of water and generate large amounts of wastewater. This wastewater is usually characterized by strong color, odor, and high density of dissolved organic dyes and inorganic contaminants (e.g. metallic salts, heavy metals, etc.). These therapeutic techniques used include chemical separation techniques such as activated sludge systems, photocatalysis, adsorption, ozonation, and filtration. These conventional systems are ineffective at eliminating the widely used reactive dyes, so purified wastewater has the aroma and color. These treated wastewaters are not reusable and is discharged into the sewage. Also, chemical therapeutics can lead to complex compounds, making it impossible to reuse salts or dyes. Filtering is a viable alternative to chemical separation methods with many filtration methods, such as ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO). One major drawback in the application of filtration technology is the disposal of the reentrant or concentration stream. Filters show fouling over extended periods of time, thereby reducing sewage flow in the filters. Therefore, greater energy requirements and more frequent, more expensive cleaning are required.

2.1 Nanotechnology in Wastewater Treatment and Purification

Nanotechnology has numerous implementations in the field of wastewater treatment and purification. Layers that use nanomaterials composites with selective absorption of target pollutants can develop improved permeability and improved functionality to increase flux. Nanocomposite membranes are often constructed to reduce energy requirements by improving the resistance to fouling. the use of 'functional nanomaterials' to combine two or more processes, like separation and degradation of the reagent, enhances the efficiency of purification and waste treatment systems. Nanotechnology applications specialize in the durability and reuse of filters and membranes to reduce the costs of re-installation. Nanoparticles have an honest range of physicochemical properties, making them attractive as separable and reactive media for water treatment. Functional nanomaterials are often used to build high performance, small-scale or point-of-use systems for water systems that are not connected to the central network and for emergency response within the aftermath of disasters. Within the world of sensing and detection, nanoparticles are very useful thanks to their large specific area.

The ability to form uniform distributions in liquids leading to the detection of organic and inorganic contaminants at nanograms per liter concentrations. Also, nanotechnology allows the event of low-cost compact lab-on-chip sensors. These sensors are often used for on-site detection and applications in remote sensing. Despite the costly initial setup, the use of nanotechnology in water treatment is cheaper within the top of the day as there are savings in operating costs and energy requirements.

2.2 Antimicrobial Nanomaterials in Water Treatment & Purification

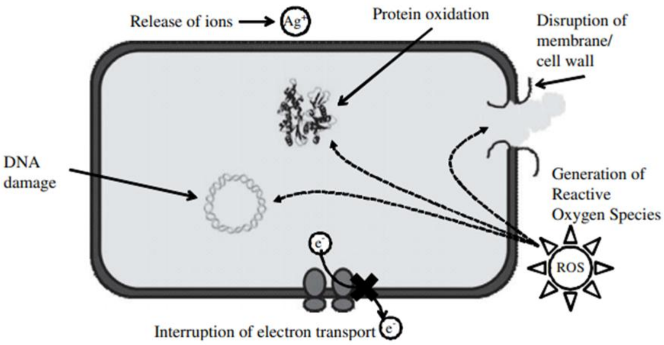
Antibacterial nanoparticles are classified into three general categories: present antibacterial materials, metals, and metal oxides, and novel engineered nanomaterials [4]. These nanoparticles interact with microbial cells through a spread of mechanisms. Various antimicrobial nanomaterials are reviewed during this paper.

The disinfection methods currently utilized in beverage treatment can effectively control microbial pathogens. Unfortunately, current practices result in harmful insecticide by-products (DBPs). Strong oxidants like free chlorine, chloramines, and ozone that contain chemical disinfectants utilized in beverage purification react with different components of natural water to make DBPs (e.g. trihalomethanes, halo acetic acids, and aldehydes), many of which are carcinogens. Conventional chemical disinfectants require very high insecticide resistance to some pathogens, resulting in the formation of DBP. Therefore, replacing existing disinfection methods requires new alternatives that increase the reliability and rigidity of the disinfectant while preventing the formation of DBP. Antimicrobial nanomaterials aren't strong oxidants and are relatively inert in water. Therefore, they are doing not produce malicious DBPs. If properly incorporated into the treatment process, it's possible to exchange or enhance traditional disinfection methods.

2.2.1 Disinfection Mechanisms of Antimicrobial Nanoparticle

Figure 2 shows the various antimicrobial disinfection mechanisms from the literature which are reviewed as following:

Figure -2: Antimicrobial disinfection mechanisms



a. Chitoson and Peptisides

Naturally occurring chitosan and peptide nanoparticles have many potential applications in low-cost water disinfection systems after their synthesis. Antibacterial mechanism of natural peptides Osmotic collapse by the formation of nanoscale channels in bacterial cell membranes. The antimicrobial properties of chitosan nanoparticles have been described by various mechanisms.

Increased membrane permeability and eventual cleavage and leakage of intracellular components when positively charged chitosan cells react with negatively charged cell membranes as the main antimicrobial mechanism. Another mechanism is that chitosan penetrates the cell membrane walls and binds with DNA, thereby inhibiting RNA synthesis in cells. Potential applications of nanoscale chitosan and peptides are surface antibodies or membranes of water storage tanks as antimicrobial agents in sponges.

b. Silver Nanoparticles

Silver nanoparticles release large amounts of silver ions (Ag +) when they interact with bacterial cells. These ions are highly reactive and react with thiol groups in enzymes to form reactive oxygen species (ROS) in the cells. ROS formation inactivates the respiratory enzymes that lead to cell death. The structural integrity and permeability of the cell membrane are compromised by Ag + ions, which cause a large increase in membrane permeability by accumulating inside the membrane. Ag + ions also inhibit DNA replication by damaging DNA and RNA. Silver ions also show photocatalytic activity in the presence of UV radiation and are useful for microbial disinfection. Much current water treatment and disinfection systems use membranes mixed with nanoscale silver particles.

c. TiO_2 Nanoparticles

Ti02 shows excellent photo catalytic activity in the presence of UV radiation. The antibacterial activity of Ti02 is mainly caused by the production of ROS, especially under hydroxyl free radicals and peroxide UV radiation, by a process of oxidation and reduction of chemical reactions taking place in a cell. One of the important features of disinfection using Ti02 nanoparticles is the ability to show photocatalytic activity even in the presence of visible sunlight. This can be improved by doping Ti02 with various metals. Ti02 is now widely used in many disinfection applications. Ti02 is suitable for applications in water treatment because it is stable in water, not toxic by ingestion, and low cost. Ti02 can be used as a thin film or membrane filter coated on the reactor surface or as a suspension in a paste UV reactor.

d. ZnO Nanoparticles

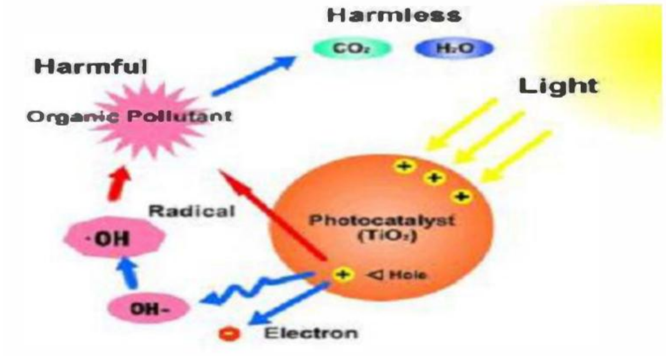
Like Ti02, nano-size ZnO also shows high UV absorption capacity and photocatalytic activity. One of the main mechanisms of photocatalytic degradation by ZnO is the production of hydrogen peroxide in the cells, which oxidizes the cell components.

After contact with the ZnO nanoparticles, they enter the cell envelope and inhibit bacterial growth through the disruption of the bacterial membrane. But, ZnO can be harmful to aquatic organisms if it enters natural water sources. Since ZnO is easily soluble, its applications in drinking water treatment are limited.

e. Carbon Nanotubes (CNT)

CNTs show antimicrobial activity mainly through two pathways, chemically react with pathogens and physically block their pathway through filters. CNTs destroy bacterial cells through physical interaction or

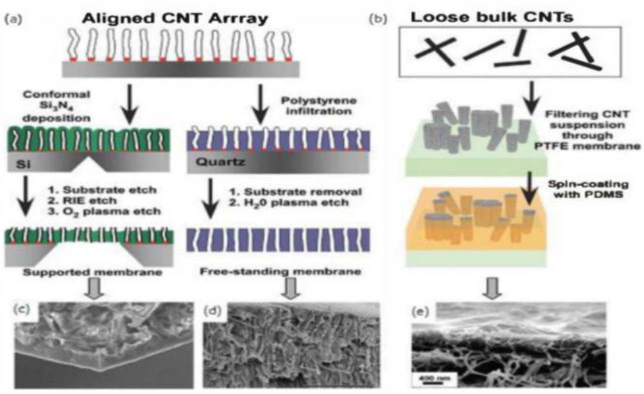
Figure -3: Photo catalytic activity of TiO2



Oxidative stress, which compromises cell membrane integrity and leads to degradation.

Antimicrobial action of CNTs by chemical means requires immediate contact between CNTs and target pathogens. This is difficult and limited by the problem of achieving stable and uniform CNT suspensions in water. Therefore, applications of CNTs in water purification through chemical interaction are limited. CNTs are very effective in filtering out microorganisms, such as bacteria and viruses, by physically blocking their path in membranes and filters. Single-walled carbon nanotubes (SWNTs) have very small diameters of 2 to 5 nm and can filter almost all known pathogens.

Figure -4: Fabrication of CNT membranes; Process flow diagrams for the fabrication of (a) CNT membranes using nanotube array encapsulation with Si3N4 or polymers; (b) filtration-assisted alignment; SEM images of a (c) Si3N4 encapsulated membrane, (d) polystyrene-encapsulated membrane, and (e) filtration-assisted assembly membrane.



3. Nano Composite and Filters

Membrane and filter-based processes are very important components in advanced water treatment, waste treatment, and desalination technologies. But, the main drawback of membrane material fouling, especially organic and biofouling membrane-based processes. Moreover, nanoparticles like Carbon nanotubes, nanoparticles, zeolites, and dendrimers contribute to the development of cost-effective and more efficient water filtration processes [2]. The applications of nanotechnology in membranes can be classified into two types: nonreactive filters and membranes, where the nanoparticles that work exclusively improve the filtration process by selectively targeting the contaminants; And nanostructured filters, where carbon nanotubes or nanocapillary arrays provide the basis for physical separation by nanofiltration. The insertion of photoactive nanomaterials into the membranes makes the membranes reactive instead of the usual physical barrier, achieving multiple treatment goals in one reactor while reducing fouling. Various examples of membranes using nanomaterials include (a) layers made from nanomaterials (inorganic ceramics as well as carbon nanomaterials); (B) membranes made of nanomaterials templates; (C) polymer nanocomposite membranes; (D) Membrane Reactors with Functional Nanoparticles [6].

4. CNT based Membranes

Carbon nanotubes have very small diameters, which are very useful for physical separation processes. Layers and filters made of CNTs have nanoscale holes to strengthen the fillers. CNTs provide easy and fast ways to pass through water molecules and prevent almost all other contaminants. These layers usually have an aligned array of CNTs on top of them.

The lower ends are covered by filler (matrix) material. Although such layers can be fabricated by various methods, the best practices are to increase the alignment of CNTs on a surface and infiltrate them into the matrix material [7]. KL Salipira et al. 8 the p-cyclodextrin polymer / CNT membrane was prepared by chemical synthesis method. P-cyclodextrin and CNT are linked via a dysfunctional linker. The membranes were tested by injecting trichlorethylene (TCE) through the membranes. The results showed 98% effective TCE removal even after recycling the CNT / polymer nanocomposite layer 25 times. CNTs have been observed to strengthen the polymer and thus help maintain the structural integrity of the membrane. Alexander Noy and others. [7] Reviewed different methods of synthesizing CNT impregnated membranes. Some of the methods are illustrated in Figure 3.

a. CNT-Silicon Nitride Membranes

Metallic nanoparticles are catalyzed by chemical vapor deposition (CYD) method on the silicon surface in this manner and the aligned array of double-walled carbon nanotubes (DWNTs). Then the conformal layer of silicon nitride is deposited on the DWNTs by means of a low-pressure CYD method. The surface is sculpted using the appropriate etchant to define the supported membrane area between the ends. After encapsulation, the membrane undergoes a series of etching steps to remove excess silicon nitride from the tips of the CNTs, followed by oxygen plasma to unscrew the CNTs. It produces a layer with a pore size of about 2 nm, the DWNT diameter [7].

b. CNT/Polymer Membrane

Aligned arrays of MWNTs are grown on a quartz substrate and then are infiltrated by a liquid polystyrene precursor. This is then cured to yield a uniform and dense membrane of pore size 7 nm. The substrate is then completely removed to get a free-standing CNT/polymer nanocomposite membrane.

c. CNT Polymer Network Membranes

This method is best for scale-up and commercialization because it is fast and reliable and avoids the slow process of raising CNTs on a surface. In this method, CNTs are prepared separately and dispersed in a liquid medium such as tetrahydrofuran. After this uniform dispersion, the pore-sized hydrophobic polytetrachloroethylene (PTFE) filter was applied to a 0.2 F! M. The filter aligns the CNTs in the Ahnost vertical direction. A polymer solution such as polysulfone is spin-coated on CNTs aligned to obtain a mechanically stable layer.

5. Nanofilters

Filtering is one of the most popular therapeutic methods used in industries. Filtering processes provide the reuse of water and salt while reducing the amount of effluent released. Nano filters offer high dye and salt rejection rates, low pumping pressure, efficient water treatment by performing multiple functions. Aris Preetama et al. [9] prepared a nanofilter with Ti02 Si02 nanoparticles as a filler material in the polyethylene glycol (PEG) matrix. Ti02 nanoparticles are photocatalytic and contribute to the degradation of organic pollutants (Fig. 4) and bacteria, while Si02 nanoparticles act as a filler, resulting in a porous filter at the nanoscale, also makes the filter stronger and more robust.

6. Other Methods

In addition to water treatment and wastewater treatment, microorganisms have great potential applications in groundwater prevention. The current most commonly used method of groundwater prevention is the pump-and-treat method [3]. In this method, the groundwater from the bottom of the contaminant source is pumped into the treatment plant and treated using various chemical separation methods and returned to the groundwater sources upstream of the contamination. Treatment plants use chemical separation pathways as well as membrane technologies, which are energy and time-consuming. These partitioning paths typically use and override the types and reuse of the partitioning medium. Nanoparticles are well suited for these applications because they have a large surface area, reduce the need for large size separation media, could target specific pollutants, and are reusable by eliminating pollutants. Various microparticles such as mesoporous silica (SAMMS), single enzyme nanoparticles (SENs) and self-assembled monolayers on nanosorbents (MWNTs and zeolites) and their uses in water treatment are described in the following text [3], [10]

6.1 Nanosorbents

Sorbents are widely used as a separation medium in water treatment and treatment to remove organic and inorganic pollutants from contaminated water. Nanoparticles have two important properties, which are very effective as sorbents. They have a much larger specific surface area than bulk cells on a mass/volume basis. Nanoparticles can also work with different chemical groups to increase affinity towards target compounds [10]. The various substances and target contaminants are reviewed as follows:

- Nanoporous Activated Carbon Fibers (ACFs): benzene, toluene, p-xylene and 1,2-dichlorobenzene (DCB); MWNTs: Pb (II), Cu (II) and Cd (II); CeO - CNTs: Addition of (V) to Ca (II) & Mg (II) increases the absorption efficiency of (V); NaP 1 zeolites: Cr (III), Ni (II), Zn (II), Cu (II) and Cd (II).

These nanomaterials include nanoscopic pores that help to dissolve contaminants. The nanomaterials can be reused by removing the perceived pollutants and regenerating the nanoparticles. Liang-Shu Zhang et al... Fig. 6 shows mesoscopic cells of iron oxide with flower-like petals containing nanopores. They conducted an experiment in which the orange color was completely absorbed in the nanopores of the petals. Magnetic nanoparticles can be easily separated using the magnetic separation method. Iron oxide nanoparticles were regenerated by catalytic combustion at 300 ° C for 3 hours.

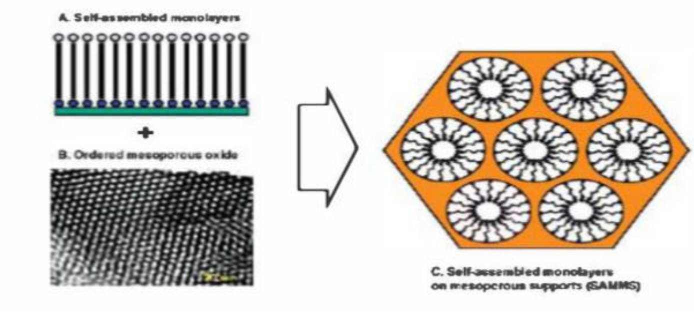
6.2 SAMMS

Fig. 5 shows the typical structure of self-assembled monolayers on mesoporous silica (SAMMS). SAMMS is a nano porous ceramic with a hexagonal honeycomb structure. SAMMS to modifies the exposed functional group of the monolayer allows this class of highly sorbent materials to bind a wide range of molecules, and in terms of groundwater prevention, contaminants and pollutants which is an added advantage [10]

SAMMS can be synthesized in a 3-step process: (i) the formation of ordered liquid crystalline structure micelle templates; (ii) precipitation of oxides on the micelle surface forming the mesoporous anchor; (iii) Calculation of organic-oxide material and the incorporation of functionalized bifunctional silanes to remove surfactants to form monolayers within the mesopores.

SAMMS can be mixed and dispersed in contaminated water, where they bind to specific contaminants according to their performance. These can be filtered and recycled by eliminating the target pollutants.

Figure -5: SAMMS Structure



6.3 SEN's

Enzymes have diverse application areas, such as chemical conversions, biosensing, and bioremediation. Their target effect and specificity make them far more effective than synthetic catalysts. However, enzymes have a short life span and are unstable under severe conditions and therefore their direct application in prevention is limited. Single enzyme nanoparticles (SENs) can be synthesized using nanotechnology, which provides a good method for stabilizing enzymes. SENs are armed enzymes, around a nanometer-thick protective cage [10]. The 3-step process of SEN synthesis is: (i) covalent modification of the enzyme surface by the formation of the vinyl group;

Dissolving in a non-polar solvent; (ii) the creation of vinyl group polymers with free trimethoxy silane groups attached to the enzyme surface by incorporating silane monomers; (iii) Hydrolysis of trimethoxy silane groups to form silicate shell with a thickness of a few nanometers. The shell enhances its life by protecting the enzyme from harsh conditions but enables some active sites that can bind to the enzyme's target pollutants. The advantage of SENs is that a wide range of enzymes are available for specific contaminants and the formation of byproducts is avoided when microorganisms are not involved.

7. Challenges with toxicity issues

The main challenge of incorporating new concepts and nanotechnology into water treatment systems is the availability of large quantities of nanomaterials at economical prices. Nanotechnology enhanced membranes and filters can be made in laboratories under controlled conditions, and hence the repeatability is easily achieved. Increasing these processes at the industrial level remains a major step in the commercialization of nanotechnology applications in water treatment and wastewater treatment. Also, all the characteristics of the nanomaterials, the target pollutants, their interactions with plants and animals are not fully understood and there is a need to conduct research in those areas. The toxicity of nanoparticles towards higher organisms is still a gray area, not fully explored. Critical issues in materials selection and design for water treatment are their environmental function and toxicity. Hydrolytic, oxidative, photochemical and biological stability (e.g., dendrimers, carbonaceous nanoparticles, metal oxides, etc.) in natural and engineering ecosystems needs to be studied extensively. Some studies have shown that CNTs, nanoscale silver and Ti02 nanoparticles are extremely toxic to humans. Most nanoparticles can disrupt normal cellular functions, such as cancer and lungs, immune systems, and even cross the blood-brain barrier and reach the brain through the olfactory nerve and cause severs. For the use of nanomaterials in water treatment systems, effective methods need to be established, which prevents the nanomaterials from entering the treated water or into the treated water sources. Also, research into the toxicity of reaction products and the disposal of them in a safe manner is required when water is disinfected or purified by chemical means. Gain control and public acceptance for using nanomaterials in water treatment due to unknown toxicity and environmental impact. To reduce the costs associated with the loss of nanomaterials and to prevent human health and environmental impacts, nanoparticles need to develop effective and reliable methods to anchor the selective layer of reactor surfaces or filter layers. Also, cost-benefit analysis is essential in assessing the applicability of nanotechnology to water treatment.

8. CONCLUSIONS

Clean water is essential and crucial for all human activities, from simple homework to the most complex industrial and agricultural processes. Current water supply and supply components are ineffective due to various system defects, such as large demand for resources, low efficiency in water treatment and treatment, high cost of plant maintenance, and potential for contamination when transporting to remote areas. Current water treatment and wastewater treatment systems can control organic and inorganic wastes from water. But these methods are not energy efficient and economical

Disposable membranes and filters, inadequate purification of water, inability to reuse the retentate, etc. New techniques such as DOT-NET and nanotechnology are rapidly replacing traditional concepts. Nanotechnology applications rely on the development of new functionalized materials with novel properties and specific affinity for certain contaminants. It focuses on improving existing methods by increasing the efficiency of nanotechnology processes and increasing the reuse of nanomaterials, thereby saving the operating cost of the plant/process. Various nanomaterials and their use in water treatment are reviewed in this paper. Nanomaterials are predicted to be a critical component of industrial and public water treatment systems, as more progress is being made toward the synthesis of cost-effective and environmentally acceptable functional nanomaterials [3]. There are still many key issues and challenges in the successful incorporation, scaling up and commercialization of nanotechnology applications in water treatment and wastewater treatment. The ability to synthesize cost-effective nanomaterials and their availability at the industrial level determines the acceptable rate of nanotechnology applications at the industrial level.

Toxicology issues need to be addressed very comprehensively and systematically with respect to the effects of nanoparticle in different media, at different pH levels, and in its reaction products with various contaminants. CNTs, nanoscale Ag, and Ti02 nanoparticles are highly suitable for nanotechnology applications but are very toxic to cells. The safe use of such nanomaterials in purification procedures is required by the body and the body to be approved by the public, and their use by the general public.

REFERENCES

[1] Earth's water distribution on USGS. [Online]. Available: http://ga.water.usgs.gov/edu/waterdistribution. HTML M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.

[2] Michael Berger, "Nanotechnology and water treatment" on Nanowork Online]. Available: http://www.nanowerk.comlspotlightlspotid =4662.php

[3] Nora Savage and Mamadou S. Diallo, "Nanomaterials and water purification: Opportunities and challenges", Journal of Nanoparticle Research, pp. 331-342, May 2005.

[4] Qilin Li, Shaily Mahendra, Delina Y. Lyon, Lena Brunet, Michael V. Liga, Dong Li, Pedro J.J. Alvarez, "Antimicrobial nanomaterials for water disinfection and microbial control: Potential applications and implications", Elsevier water research, 42, ISSN. 4591 - 4602, 2008.

[5] A. Srivastava, O. N. Srivastava, S. Talapatra, R. Vajta and P. M. Ajayan, "Carbon nanotube filters", Nature Materials, Vol. 3, pp. 610 - 614, September 2004.

[6] Volodymyr V. Tarabara, "Nanotechnology and Water Purification", on Azonano. [Online]. Available: http://www.azonano.comldetails.asp?article 10=2532

[7] A1eksandr Noya, H yung Gyu Parka, b, Francesco Fornasieroa, Jason K. Holta, Costas P. Grigoropoulosb, and Olgica Bakajina, "Nanofluidics in carbon nanotubes", Nanotoday, Vol 2, No 6, pp. 21 - 29, December 2007.

[8] KL Salipira, BB Mamba, RW Krause, TJ Malefetse and SH Durbach, "Cyclodextrin polyurethanes polymerized with carbon nanotubes for the removal of organic pollutants in water", Water SA, Vol. 34, No. 1, pp. 03 78-4738, January 2008.

[9] Aris Pritama, "Titanium Dioxide-based Reusable Microporous Water Filter Using Silicon Dioxide as Filler", Journal of Nanoscience & Technology, ISSN. 1979-0880, August 2009.

[10] Katherine Watlington, "Emerging Nanotechnologies for Site Remediation and Wastewater Treatment", for U.S. Environmental Protection Agency, August 2005.