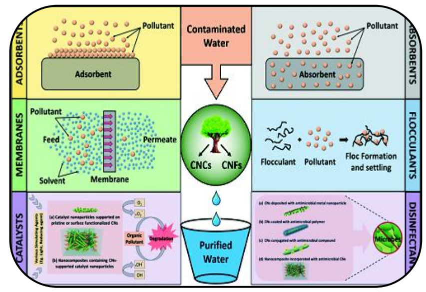
REVIEW OF RESEARCH
IMPACT FACTOR : 5.7631(UIF) UGC APPROVED JOURNAL NO. 48514 ISSN: 2249-894X
VOLUME - 8 | ISSUE - 7 | APRIL - 2019

NANOTECHNOLOGY RESEARCH: THE BREAKTHROUGH IN WATER AND WASTEWATER TREATMENT



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ABSTRACT

Adequate daily supply of clean, safe, and potable water are the key issues people are facing nowadays. To accomplish this purpose wastewater should be treated so that it can be reused, and the detrimental impact of the untreated wastewater will save the world.This paper has focused on nanotechnology that can help in water and wastewater treatment. From the literature it is clear that this technology has many advantages over traditional methods but still requires a lot of work before effective industrial implementation. The restriction on the use of nanotechnology in water and wastewater treatment is that it may be difficult for the NPs to isolate from the treatment solution, resulting in loss of the NPs.Nevertheless, the immobilization of the NPs on suitable substrate may reduce this problem. Also under study are the toxicity and environmental effects of NPs to consider their effect on human health and the climate.Multifunctional and highly efficient processes based on nanotechnology offer inexpensive solutions for treating wastewater that do not need large infrastructures or centralized systems. The purpose of this study is to examine the potential applications of the nanotechnology to extract contaminants from wastewater.

KEYWORDS: *Nanotechnology, Water, Waste Water, Environment, Wastewater Treatment.*

INTRODUCTION :

Water containing undesirable substances which adversely affect its quality and therefore render it unsuitable for use is called wastewater. Wastewater is generated from various sources such as residential areas, commercial / industrial property, farming etc. Wastewater composition varies widely, and depends on the source it is produced from.Common wastewater constituents include pathogenic and non-pathogenic micro-organisms, organic substances such as excreta, plant material, milk, protein, and inorganic substances such as metal particles, ammonia and gases. Such constituents can pose a threat to living beings and the environment when left untreated;Which makes wastewater treatment indispensable before disposal. Various methods of physical, chemical, and biological treatment are used for treating wastewater. Nanotechnology has been extensively studied by researchers among these methods at the moment, as it provides potential benefits such as low cost, reuse and highly effective in eliminating and recovering the pollutants.Wastewater is the water that contains superfluous substances that adversely affect its consistency and, thus, make it unfit for use. Wastewater is produced from various sources, such as in residential areas, commercial areas, industrial property, lands of agriculture etc. Wastewater composition varies widely, and depends largely on the source from which it is produced.Common constituents of wastewater include inorganic substances such as solutes, heavy metals, metal ions, ammonia and gases, complex organic compounds such as excreta, plant material, milk, oil, natural organic matter, nitrate, and other pollutants contained in surface water, groundwater, and/or industrial water;Such constituents can pose a threat to living beings and the environment when left untreated, making it vital to treat wastewater before disposal. Various methods of physical, chemical, and biological treatment are used for treating wastewater.

Traditional materials and treatment techniques such as activated charcoal, oxidation, reverse osmosis (RO) membranes and activated sludge are not successful in the treatment of complex and volatile contaminated water consisting of pharmaceuticals, surfactants, various industrial additives;And professed an abundance of chemicals. The current and decade-old methods of water treatment can not sufficiently tackle the elimination of hazardous substances, organic materials, and micro-organisms found in raw water.

NANOTECHNOLOGY:

As established by the National Science, Engineering & Technology (NSET) Initiative, nanotechnology is 'Research and technology production at the atomic, molecular or macromolecular levels, with a length scale of approximately 1-100 nanometers, to provide a basic understanding of nanoscale phenomena and materials and to establish a fundamental understanding of nanoscale phenomena. And use structures, tools and systems with novel characteristics and functions due to their small and/or intermediate scale.

Matter may exhibit some extraordinary and useful properties when modified at nanoscale,This has not been known since. Nanotechnology research promises breakthroughs in areas such as data storage for medicinal goods, food industry, molecular biotechnology, electronics, defense, robots, textiles, climate and sanitation.Another exciting and ambitious use of nanotechnology in water purification would seem to be water desalination. Despite its lucrative applications in different fields, the celebration of nanotechnology as the next technological revolution clouds some environmental and ethical concerns[19].

Nanotechnology is among the world's most innovative innovations. The word nanotechnology defines a variety of technologies with widespread applications conducted on a nanometer scale as enabling development in various industries.Nanotechnology is the development of materials, tools, and systems that use individual molecules and atoms. Nanotechnology uses the particles 1/80,000 of a human hair's diameter. New physical, chemical, and biological properties are visible at such a small scale.

It is a multidisciplinary science that explores how we at the molecular and atomic level can manipulate matter. To do this, we need to work on the nanoscale, which is such a small scale that we can not see it with a light microscope. One nanometer is currently just one-billionth of a meter in thickness. Atoms are much smaller. It's hard to measure the size of an atom-they don't appear to hold any specific shape.But in general, a typical atom is about one-tenth of a nanometer in diameter.

Matter may exhibit some extraordinary and useful properties when modified at nanoscale, which are not observed before. Nanotechnology research promises breakthroughs in such fields as medicine, data storage, food processing, molecular biotechnology, electronics, defence, robotics, textiles, climate and sanitation.Another exciting and successful use of nanotechnology in water purification is apparently water desalination[20].

WATER IN NANOTECHNOLOGY:

In a study that examined the interplay between nanoscopic interfacial layers of water and their contact environment, we proposed that order is not only imposed by the substratum on the water layers, but that the ordered layers of water themselves have the ability to induce order, for example, to biological structures.With focus on the existence of water layers masking living cells and the interface between di erently polar structures in the body, such as hydroxyapatite crystallites and organic matrix, biomineralization and biocrystallization processes were predicted to be regulated by the order of nanoscopic interfacial layers of water[1]. The prediction has recently received partial confirmation. In addition, the study of nanoscopic interfacial layers of water provided intuitive hints that justified their importance in nanotechnology, evolutionary modeling.Starting with the ability of nanoscopic interfacial water layers to impose order, we developed an origin-of-life model, or a simple explanation for facilitating the self-assembly of primordial amino acids to the polymers on naturally hydrogenated natural diamonds covered by nanoscopic interfacial water layers.The catalytic ability of the nanoscopic interfacial water layers and their interplay with laser light has recently been exploited in the manufacture of highly ordered body-centered cubic carbon nanocrystals from the meta-stable carbon phase[2], a modification predicted by Johnston and Ho mann.We have demonstrated earlier that the findings obtained from modulating nanoscopic interfacial layers of water on model surfaces can be applied to biology. We could demonstrate that intermittent irradiation with 670 nm laser light applied at non-destructive rates was capable of modulating the interfacial layers of water expected to mask the myriads of macromolecules in crowded space[4]Within, the breathing cells. For example, we used moderate levels of 670 nm laser light to force cancer cells to take in-vitro cytostatic / cytotoxic drugs[5]. Using a common technique we lowered concentrations of amyloid-β in neuroblastoma cells[6]. Related non-destructive biological acts of low irradiation rates are therefore not limited to the visible light spectrum[7].

Water is important to all life, and its importance spans many crucial areas for society: food, electricity, health and the climate. Projected population growth over the coming decades and related increases in water demand intensify the increasing need to tackle water sustainability.Yet, fresh water is just 2.5 per cent of the world's water, and some of the most serious impacts of climate change are on the water supplies of our country. In 2012, for example, droughts impacted about two-thirds of the continental United States, affecting water supply, tourism, transportation, electricity, and fisheries – costing $30 billion to the agricultural sector alone.In addition, the ground water in many of the Nation’s aquifers is being depleted at unsustainable rates, which necessitates drilling ever deeper to tap groundwater resources. Finally, a highly significant yet often neglected element of water treatment and delivery is the water infrastructure. These problems need both technical and socio-political solutions.[8]

In particular, the small size and special properties of engineered nanomaterials (ENMs) are promising to solve the pressing technological challenges of water quality and quantity.For instance, the increased surface area and reactivity of ENMs can be exploited to create precious-metal-free catalysts for water purification, and the enhanced strength-to-weight properties of nanocomposites can be used to make piping systems and components stronger, lighter, and more robust.The Water Sustainability through Nanotechnology Signature Initiative (the "Water NSI") aims to harness the unique properties of engineered nanomaterials to produce major breakthroughs in addressing the water challenges facing our country.The aim of this initiative is to help develop technical solutions that can mitigate current pressures on water supplies and provide methods for potential sustainable use of water resources. The Water NSI three special thrusts are as follows:

1. Enhance the supply of water using nanotechnology.
2. Boost water distribution and usage efficiency with nanotechnology.
3. Enable next-generation nanotechnology water monitoring systems.

NANOTECHNOLOGY IN WASTE WATER TREATMENT

Nanotechnology is the development and application of atoms, molecules, and particles of nanometer-scale sizes (1-100 nm). Studies have shown that nanoparticles (NPs), most notably nano-metal oxides, have enhanced and/or unusual physico-chemical properties compared to the related bulk materials.Therefore, these peculiar properties make NPs very useful in medicine, electronics, biomaterials, energy production, treatment of water and wastewater etc. Different methods such as gas phase synthesis (carbon condensation collection, chemical vapor condensation, plasma collection and synthesis of combustion flame)Ball milling, co-precipitation, sol gel, micro-emulsion and surfactant have been widely documented in the development of NPs over the years. Conventional technologies are available which are inexpensive and can be generated locally to efficiently extract pollutants from water and wastewater.However, there are many concerns regarding the cost and efficiency of eliminating such contaminants, most notably the persistent organic contaminants and endocrine disruptors that these traditional technologies pose.Nanotechnology to the world viz. In conjunction with traditional technologies, nanotechnology and/or nanotechnology will handle organic and inorganic con- taminants at appropriate levels. There is currently strong scientific interest in water and wastewater treatment nanotechnology; but there are concerns about the toxicity and environmental effects of NPs.

Nano titanium dioxide, zerovalent iron, zinc oxide, silver oxide, carbon nanotube, and composites have been used widely in water and wastewater treatment as photocatalysts, membranes, and adsorbents. Chemically modified NPs have drawn significant attention as well.Likewise, the combination of NPs with other processes such as the physical, chemical, bio-logical, and advanced oxidation processes yielded enhanced performance. Nanotechnology application to eliminate harmful contaminants such as pharmaceutical and personal care goods, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, phthalates, furans and dioxins, agrochemicals Several nanotechnology researchers have reported extensively on pesticides, volatile organic compounds, viruses and bacteria, dyes, inorganic contaminants etc. Some of the investigations recently mentioned include the use of copper NPs by Dankovich and Smith in paper filters for point-of-use water purification[9], Adsorption of methylene blue on synthesized nanoscale zerovalent iron-bamboo and manganese-bamboo composites by Shaibu et al.[10], use of synthesized nano-silver bioconjugate material to treat organophosphorus pesticides mentioned by Das et al.[11], removal of boron from water using iron oxide / hydroxide-based NPs (NanoFe)And NanoFe-impregnated granular activated carbon as an adsorbent by Zelmanov and Semiat[12], and the application of green nano-iron particles for adsorptive removal of As(III) and As(V) from aqueous solution reported by Prasad et al.[13]. In addition, Cai et al.[14]'s research on graphene focused on the desalination of seawater by nano Ag and Ag@C.Ayati et al.[15] provided a comprehensive analysis of the catalytic applications of Au / TiO2 NPs for the removal of water pollutant, while Ayanda et al.[16] and Fatoki et al.[17] assessed the ability of nano-oxides and composites for the remediation of organotin compounds (tributyltin and triphenyltin chlorides).Interestingly, the findings showed that environmental nanotechnology could be used effectively to extract organic and inorganic pollutants from drinking water, sewage, urban wastewater, industrial wastewater and processes[18].

Nanotechnology is revolutionizing many application areas, and has tremendous potential to shift the conventional model of water supply and wastewater treatment. Many nanomaterials 'unique properties allow for new technologies for contaminant removal, microbial control, sensing and monitoring, and resource recovery. It is expected that the super-high surface area, high reactivity and catalytic properties of nanomaterials can significantly enhance the kinetics and efficiency of various chemical and physicochemical processes used in water and wastewater treatment, thereby reducing device size as well as chemical and energy use.These unique features have the potential to enable the paradigm shift to distributed wastewater treatment and water supply, a much-needed change in large metropolitan areas that faces challenges of rapid population growth and aging infrastructures.

Four grades of nanoscale materials tested for water purification as usable materials:

(1) Dendrimers
(2) metal-containing nanoparticles,
(3) Zeolites and
(4) Carbonaceous nanomaterials.

These have a wide range of physicochemical properties that make them especially attractive for water purification as separation and as reactive media. Characterisation of Atomic Force Microscopy (AFM) nanoparticles interactions with the bacterial contaminant;Transmission Electron microscopy (TEM) and laser confocal microscopy reveal significant improvements in cell membrane integrity, resulting in the bacteria's death in most cases. Work is under way to use advanced nanotechnology for healthy drinking in water purification.Nanotechnology, the deliberate manipulation of matter at a size of less than 100 nm, holds the promise of producing new materials and devices that take advantage of special phenomena at such longitudinal scales due to their high reactivity due to the broad surface-to-volume ratio[21].Nanoparticles are expected to play a crucial role in water purification.

The key way in which nanotechnologies can help to remove water issues is to overcome the technological challenges of eliminating water pollutants including bacteria, viruses, toxic metals, pesticides and salts. Usage of nanotechnology to extract harmful contaminants like the pharmaceutical Several nanotechnology investigators have reported extensively on personal care ingredients, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, phthalates, furans and dioxins, agrochemicals and pesticides, volatile organic compounds, viruses and bacteria, colouring, inorganic pollutants, etc.[22].The claims of numerous scientists that nanotechnologies offer more inexpensive, reliable, efficient and durable ways of achieving specific water treatment nanoparticles would enable manufacturers to prepare less toxic particles using conventional methods.Interestingly, the findings showed that environmental nanotechnology could be used effectively to extract organic and inorganic pollutants from sewage, urban, chemical, and wastewater systems. On the other hand, the possible effect of nanomaterials on human health and the environment is uncertain as for any new class of materials.Ironically, the results showed that nanotechnology for the environment could be used effectively to remove organic and inorganic pollutants from sewage, industrial, chemical and wastewater systems. At the other hand, as with any new class of materials, the potential impact of nanomaterials at human health and the environment is unknown.

NANOTECHNOLOGY APPLICATIONS IN WASTEWATER TREATMENT:

Nanotechnology is useful in the identification and elimination of specific pollutants in terms of wastewater treatment. Heavy metal contamination poses a significant threat to the ecosystem because it is harmful and not biodegradable to living organisms like humans.

Specific approaches such as photocatalysis, nanofiltration, adsorption, and electrochemical oxidation include the use of TiO_2, ZnO, ceramic membranes, nanowire membranes, polymer membranes, carbon nanotubes, submicron nanopowder, metal (oxides), magnetic nanoparticles, nanostructured boron doped diamonds to overcome or substantially diminish water quality problems in natural environments.When used as adsorbents, nanosizedzerovalent ions, or nanofiltration membranes, nanoparticles cause pollutant removal / separation from water, while nanoparticles used as catalysts for chemical or photochemical oxidation cause contaminant destructionScientists categorized nanoscale materials that are being tested as usable water purification materials into four groups: dendrimers, metal-containing nanoparticles, zeolites, and carbonaceous nanomaterials. The following are the different types of materials which are or may be used by nanotechnology in wastewater treatment and purification[8].

Dendrite polymers include random hyperbranched polymers, polymers with dendrigraft, dendrons, and dendrimers. They are symmetrical and spherical macromolecules, consisting of a fairly dense shell consisting of a heart, branching sites, and terminal groups that typically shape a well-defined surface.Dendrimers are available in a variety of shapes, such as cones, circles, and disc-like sizes, typically 2 to 20 nm long. A dendrimer structure with a multifunctional center is obtained by reaction of several dendrons. More than one hundred compositionally different families of dendrimers were synthesized and more than 1000 differentiated chemical surface modifications were reported[8].

Nanoparticles for metal oxide (Natural or Engineered) include titanium dioxide (TiO_2); zinc oxide (ZnO); cerium oxide (CeO_2). They are highly reactive and possess photolytic properties[31]. Since they have a wide surface area, they are considered good adsorbent for water purification and their affinity can be improved by using various functional groups.In 2002 Stoimenov and his colloquies demonstrated efficacy of MgO nanoparticles and magnesium (Mg) nanoparticles as biocides against Gram-positive and Gram-negative bacteria (Escherichia coli and Bacillus megaterium) and bacterial spores (Bacillus subtillus). Nano TiO_2 and Cu_2O electrodes were used for the oxidation of organic components by electrocatalysis and COD removal was observedto be high. There is strong biocidal activity against Escherichia coli and Staphylococcus aureus in the silver loaded nano- SiO_2 composite coated with crosslinked chitosan. Zinc oxide nanoparticles were used to extract arsenic from soil. Some adsorption processes have used ferrites for wastewater treatment And a range of mineral iron such as Akaganeite, Feroxyhydrate, Ferrihydrate, Goethite, Hematite, Lepidocrocite, Maghemite and Magnetite. Magnetic nanoparticles are stated to be protective when compared with magnetic beads, 2-3 orders of magnitude smaller than a bacterium. Iron oxide and titanium dioxide are strong metal contaminant-sorbents[8].

Metal nanoparticles contain nanosized particles such as silver, gold, palladium etc. Nanosilver (Engineered) types include silver colloidal, spun metal, nanosilver powder and metal polymeric. They are usually in size of 10 to 200 nm. Comprising several silver atoms in the form of silver ions, they are extremely reactive to the surface and have good antimicrobial properties.Applications in pharmacy, water purification, and use of antimicrobials. They are used for a wide variety of commercial products. Nanomaterials may also be used for biomolecular detection, for example gold nanorods have been used to detect polynucleotides such as cysteine and glutathione in colorimetric low concentrations.Ag (I) and silver compounds were used as coliform antimicrobials present in waste water. Palladium-coated gold nanoparticles are highly efficient catalysts for removing tri-chloroethane (TCE) from groundwater 2 200 times stronger than palladium alone[8].

Zero-V alent Metals (Engineered) nanoparticles include zero-valent iron (nZVI), zero-valent emulsified iron (EZVI), and nanoscale bimetallic particles (BNPs). BNPs contain iron elements and a metal catalyst (such as gold, nickel, palladium, or platinum). Their size depends on the zerovalent metal containing nanomaterial and is usually about 100-200 nm.They have high reactivity of the surface which can be regulated by varying the form of reductant and the conditions of reduction. Ferric (Fe [III]) or ferrous (Fe [II]) salts with sodium borohydride are various materials which can be used for their development.ZVI reactivation mechanism is identical to corrosion mechanism. We bring in water, sediment and soil remediation by reducing pollutants such as nitrates, trichloroethene, and tetrachloroethene[8].

Quantum Dots (Engineered) are made from selenide cadmium (CdSe), telluride cadmium (CdTe), and selenide zinc (ZnSe). Their measurements vary between 10 and 50 nm. They have core reactive controls that control their optical properties. To the key potential structures of metal include:CdSe, CdTe, CdSeTe, ZnSe, InAs, or PbSe and CdS or ZnS are potential metal structures for the shell. Composite nanomaterials are made of two separate nanomaterials or nanomaterials in combination with nanosized clay. They can also be created with a mixture of nanomaterials and synthetic polymers or resins.They have multifunctional components that exhibit novel features such as electrical, magnetic, mechanical, thermal, optical or catalytic [8].

CONCLUSION:

Industrialization and population are the key factors for the rise in wastewater volumes. They are also the key places that claim daily clean water supply. Several methods are employed to ensure that water is provided sustainably for the necessary purposes.Nanotechnology is also being considered to provide an inexpensive, easy and environmentally safe wastewater remediation process. Specific forms of nanoparticles, such as nanosized metals, metal oxides, zerovalent ions, nanofiltration membranes have been shown to be efficient in detecting, eliminating and/or destroying pollutants.

REFERENCES:

1. Sommer AP, Pavláth AE. The subaquatic water layer. Cryst Growth Des. 2007; 7: 18–24.
2. Liu P, Cui H, Yang GW. Synthesis of body-centered cubic carbon nanocrystals. Cryst Growth Des. 2008; 8: 581–586.
3. Johnston RL, Hoffmann R. Superdense carbon, C8: Supercubane or analogue of g-Si?. J Am Chem Soc. 1989; 111: 810–819.
4. Trepat X, Deng L, An SS, Navajas D, Tschumperlin DJ, Gerthoffer WT, et al. Universal physical responses to stretch in the living cell. Nature. 2007; 447: 592–595.
5. Sommer AP, Zhu D, Scharnweber T. Laser modulated transmembrane convection: Implementation in cancer chemotherapy. J Control Release. 2010; 148: 131–134.
6. Sommer AP, Bieschke J, Friedrich RP, Zhu D, Wanker EE, Fecht HJ, et al. 670 nm laser light and EGCG complementarily reduce amyloid-β aggregates in human neuroblastoma cells: basis for treatment of Alzheimer's disease?. Photomed Laser Surg. 2012; 30: 54–60.

7. Vatansever F, Hamblin MR. Far infrared radiation (FIR): its biological effects and medical applications. Photonics Lasers Med. 2012; 4: 255–266.
8. Nanomaterials Use in Wastewater Treatment written by Pankaj K. Tyagi1 Ravikant Singh2, Smriti Vats1, Dharmendra Kumar3 and ShrutiTyagi published by International Conference on Nanotechnology and Chemical Engineering (ICNCS'2012) December 21-22, 2012 Bangkok (Thailand)
9. Dankovich T.A., Smith J.A., 2014. Incorporation of copper nanoparticles into paper for point-of-use water purification. Water Res., 63, 245-251.
10. Shaibu S.E., Adekola F.A., Adegoke H.I., Ayanda O.S., 2014. A comparative study of the adsorption of methylene blue onto syn- thesized nanoscale zero-valent iron-bamboo and manganese-bamboo composites. Materials, 7, 4493-4507.
11. Das S.K., Khan M.M.R., Guha A.K., Das A.R., Mandal A.B., 2012. Silver-nanobiohybride material: Synthesis, characterization and application in water purification. Biores. Technol., 124, 495-499.
12. Zelmanov G., Semiat R., 2014. Boron removal from water and its recovery using iron (Fe^{3+}) oxide/hydroxide-based nanoparticles (nanoFe) and nanoFe-impregnated granular activated carbon as adsorbent. Desalination, 333, 107-117.
13. Prasad K.S., Gandhi P., Selvaraj K., 2014. Synthesis of green nano iron particles (GnIP) and their application in adsorptive removal of As(III) and As(V) from aqueous solution. Appl. Surf. Sci., 317, 1052-1059.
14. Cai P.F., Su C.J., Chang W.T., Chang F.C., Peng C.Y., Sun I.W., Wei Y.L., Jou C.J., Wang H.P., 2014. Capacitive deionization of seawater effected by nano Ag and Ag@C on graphene. Mar. Pollut. Bull., 85, 733-737.
15. Ayati A., Ahmadpour A., Bamoharram F.F., Tanhaei B., Mänttäri M., Sillanpää M., 2014. A review on catalytic applications of Au/TiO_2 nanoparticles in the removal of water pollutant. Chemosphere, 107, 163-174.
16. Ayanda O.S., Fatoki O.S., Adekola F.A., Ximba B.J., 2013. Kinetics and equilibrium models for the sorption of tributyltin to nZnO, activated carbon and nZnO/activated carbon composite in artificial seawater. Mar. Pollut. Bull., 72, 222-230.
17. Fatoki O.S., Ayanda O.S., Adekola F.A., Ximba B.J., 2014. Sorption of triphenyltin chloride to nFe_3O_4, fly ash and nFe_3O_4/fly ash composite material in seawater. Clean – Soil, Air, Water, 42, 472- 479.
18. Nanotechnology: The Breakthrough in Water and Wastewater Treatment written by Olushola S Ayanda*, Leslie F Petrik published by INTERNATIONAL JOURNAL OF CHEMICAL, MATERIAL AND ENVIRONMENTAL RESEARCH 2014 Vol 1, Issue 1
19. J. Zhuang, R.W. Gentry, "Environmental Application and Risks of Nanotechnology: A Balanced View Biotechnology and Nanotechnology Risk Assessment: Minding and Managing the Potential Threats around Us" *ACS Symposium Series*, 2011, 3, 41–67
20. Diallo S, Christie P, Swaminathan JH, Johnson WA. Goddard, Dendrimer enhanced ultra-filtration recovery of Cu (II) from aqueous solutions using Gx-NH2-PAMAM dendrimers with ethylene diamine core". Environ. Sci. Technol., 2005; 39:1366-1377.
21. Ichinose NY, Ozaki, Kashu S. Superfine particle technology. Springer, London, (Book), 1992.
22. Olushola S Ayanda, Leslie F Petrik Nanotechnology: The Breakthrough in Water and Wastewater Treatment. International Journal of Chemical, Material and Environmental Research. 2014; 1(1):1-2.
23. Nanotechnology for waste water treatment Ms. Sulekha published by International Journal of Chemical Studies P-ISSN2349–8528 E-ISSN 2321–4902 IJCS 2016; 4(2): 22-24