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Review of Nano Technology in Water Treatment

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Abstract—**This Paper attempt to review the nano technology in water treatment process. Nanotechnology, the engineering and art of manipulating matter at the nano scale (1–100 nm), offers the potential of novel nanomaterials for treatment of surface water, groundwater, and wastewater contaminated by toxic metal ions, organic and inorganic solutes, and microorganisms. Due to their unique activity toward recalcitrant contaminants and application flexibility, much nonmaterial's are under active research and development. Accordingly, literature about current research on different nanomaterials (nanostructure catalytic membranes, nano sorbents, nanocatalysts, and bioactive nano particles) and their application in water treatment, purification and disinfection is reviewed in this article. Moreover, knowledge regarding toxicological effects of engineered nanomaterials on humans and the environment is presented.**

Keywords—Nano Particles, Nano membranes, Water Treatment, Nano Sorbents.

I. INTRODUCTION

Nanotechnology is science, engineering, and technology conducted at the nanoscale, which is about 1 to 100 nanometers. The ideas and concepts behind nano science and nanotechnology started with a talk entitled "There‟s Plenty of Room at the Bottom" by physicist Richard Feynman at an American Physical Society meeting at the California Institute of Technology (CalTech) on December 29, 1959, long before the term nanotechnology was used. In his talk, Feynman described a process in which scientists would be able to manipulate and control individual atoms and molecules. Over a decade later, in his explorations of ultraprecision machining, Professor Norio Taniguchi coined the term nanotechnology. It wasn't until 1981, with the development of the scanning tunneling microscope that could "see" individual atoms, that modern nanotechnology began [1].

Nanotechnology‟ as a field has emerged in 1980s through convergence of K.E. Drexler‟s theoretical and public work has now gained a worldwide attention among both the scientific and public community [2]. Nanotechnology literally means any technology on a nanoscale that has applications in the real world [3]. Nanotechnology refers most broadly to the use of materials with nanoscale (1nm = 10-9m) dimensions [4].Nanotechnology is defined as „„„the understanding and control of matter at dimensions between 1 and 100 nm, where unique phenomena enable novel applications‟‟‟ [2]. Nanotechnology is usually defined as research, development, manipulation, control or use of materials at that level [5-8].Nanotechnology offers the ability to control matter at the nanoscale and create materials that have specific properties with a specific function [9].

Nanotechnology and its products "nanomaterials" are being widely used across fields as healthcare, industrial, electronics, cosmetics, pharmacology, bioclinical, biomedical fields and other areas. Nanomaterials often differ from those of bulk materials in their physical and chemical properties, so they call for specialized risk assessment [10-11]. In today's world where industries have been modernized and advanced, our environment is filled with various types of pollutants emitted from human activities or industrial processes. Examples of these pollutants are carbon monoxide (CO), chlorofluorocarbons (CFCs), heavy metals (arsenic, chromium, lead, cadmium, mercury and zinc), hydrocarbons, nitrogen oxides, organic compounds and sulfur dioxide. Human activities, such as oil, coal and gas combustion, have significant potential to change emissions from natural sources [12]. In addition to air pollution, there is also water pollution caused by various factors, including waste disposal, oil spills and leakage of fertilizers, herbicides and pesticides, by-products of industrial processes and combustion and extraction of fossil fuels [13]. Contaminants are mostly found mixed in the air, water and soil. Thus, we need a technology that is able to monitor, detect and, if possible, clean the contaminants from the air, water and soil. Nanotechnology offers a wide range of capabilities and technologies to improve the quality of existing environment. Nano material is very small and the ratio of surface area to volume ratio is high so that it can be used to detect very sensitive contaminants [14].

Fig 1 Water Treatment by NF Nano Filtration Method

Environmental nanotechnology is considered to play a key role in the shaping of current environmental

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engineering and science. Looking at the nano scale has stimulated the development and use of novel and cost-effective technologies for remediation, pollution detection, catalysis and others [4]. Like the term nanotechnology itself, environmental nanotechnology refers to a disconnected, broad, at times contradictory, set of technologies. The advantage gained by adding environmental to nanotechnology is to narrow the field down to those technologies that affect the conditions or the surroundings within which we live. For most people this would include the effects of the technology on species other than humans. The field of environmental nanotechnology does not include cosmetic nanotechnology, human health nanotechnology, computer technology, instrument and apparatus technology, or the kinds of nanotechnology that improve manufacturing in ways not connected to the environment [15]. The starting point for any discussion on the applications of nanotechnologies to the environment is the ability of nanoscience to create new nanostructured materials with specific properties to serve specific functions [16]. We will focus on environmental nanotechnology applications in water treatment.

II. PROPERITES OF NANO MATERIALS

Nanotechnology involves designing and producing substances or structures at a very small or nano scale, 100 nanometres (100 millionth of a millimetre) or less to form nanomaterials. Nanomaterials are one of the important products of nanotechnologies such as nano-scale particles, tubes, rods, fibres etc. Nanoparticles are normally defined as being smaller than 100 nanometres in at least one dimension. Important features of nanomaterials include the average size of the particle, size of the individual particles, surface area, structure etc. Nanomaterials have manifold possible commercial and technological applications.

A. Physical Properties

- Size, shape and ratio of width and height
- Specific surface area
- Property to stick together (agglomeration process)
- Nature of the surface (smooth or rough)
- Structure of the nanomaterial (crystal structure and any crystal defects)
- Solubility.

B. Chemical properties

- Structure of the nano material (molecular)
- Composition of the nano material, including purity, additives and known impurities.
- Physical state (solid, liquid or gas).
- Surface chemistry of the nano material.
- Molecular interaction of the nano material with different solvents

III. WATER TREATMENT

Water is a mythical substance whose material existence is secondary compared to the symbolic value as it is manifested in our mind as the symbol of life. Sustainable supplies of clean water are vital to the world's health, environment and economy. Currently the human society is facing a tremendous crunch in meeting rising demands of potable water as the available supplies of freshwater are decreasing due to extended droughts, population growth, decline in water quality particularly of groundwater due to increasing groundwater and surface water pollution, unabated flooding and increasing demands from a variety of competing users. Water being a prime natural resource, a basic human need and a precious national asset, its use needs appropriate planning, development and management.

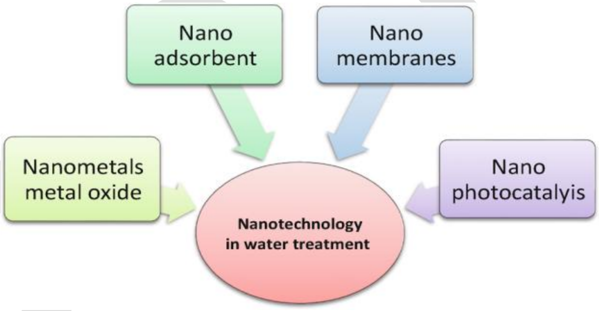

Fig .2 Nano technology Water treatment Process

Increasing population coupled with overexploitation of surface and groundwater over the past few decades has resulted in water scarcity in various parts of the world. Wastewater is increasing significantly and in the absence of proper measures for treatment and management, the existing freshwater reserves are being polluted. Increased urbanization is driving an increase in per capita water consumption in towns and cities. Hence there is a need to recognize the requirement to manage existing water reserves in order to avoid future water strain.

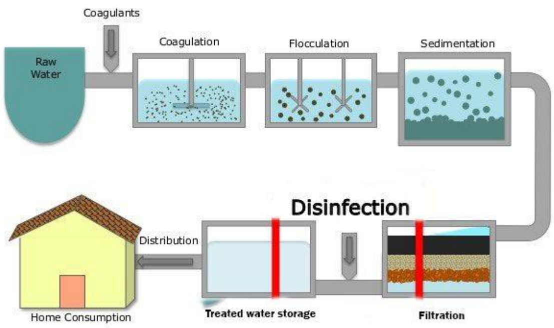

Fig 3 Water Treatment Process

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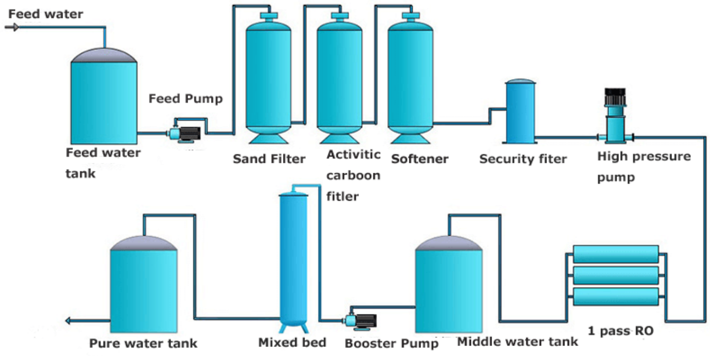

Fig 4 RO Water treatment Process

Today availability of safe drinking water is a concern. For almost all the water needs of the country, groundwater is by far the most important water resource. Worldwide, according to a United Nations Environment Programmed (UNEP) study over 2 billion people depend on aquifers for their drinking water.40 percent of the world's food is produced by irrigated agriculture that relies largely on groundwater. Groundwater constitutes about 95 per cent of the freshwater on our planet (discounting that locked in the polar ice caps), making it fundamental to human life and economic development. However the ever increasing scarcity of groundwater coupled with diminishing water quality has posed a serious threat to the population especially the rural community and has forced everyone to look at treatment of groundwater because clean water is fast becoming an endangered commodity. The unabated use has taken a serious toll on the availability of groundwater resources and as such the world is facing a severe crunch in the availability of groundwater. So we have no other option to move from "groundwater development" to "groundwater management" which means that we have to move towards optimal usage of groundwater which would be sustainable in the long run.

IV. Role of Nanomaterials in Water Treatment

Nanomaterials are fast emerging as potent candidates for water treatment in place of conventional technologies which, notwithstanding their efficacy, are often very expensive and time consuming. This would be in particular, immensely beneficial for developing nations where cost of implementation of any new removal process could become an important criterion in determining its success. Qualitatively speaking nanomaterials can be substituted for conventional materials that require more raw materials, are more energy intensive to produce or are known to be environmentally harmful. Employing green chemistry principles for the production of nanoparticles can lead to a great reduction in waste generation, less hazardous chemical syntheses, and an inherently safer chemistry in general.

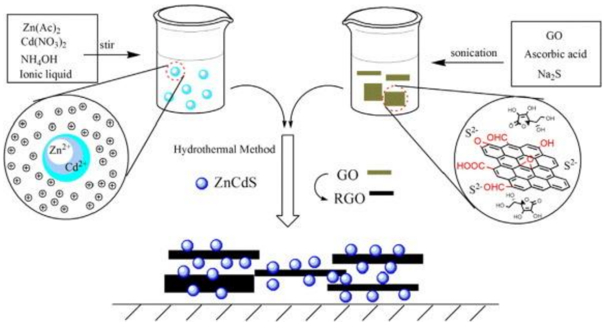

Fig 5 Role of Nano materials in Water treatment

However, to substantiate these claims more quantitative data is required and whether replacing traditional materials with nanoparticles does indeed result in lower energy and material consumption and prevention of unwanted or unanticipated side effects is still open to debate. There is also a wide debate about the safety of nanoparticles and their potential impact on the environment.

A.Nano Filration

Membrane processes such as nano filtration (NF) are emerging as key contributors to water purification. Nano filtration membranes (NF membranes) are widely used in water treatment for drinking water or wastewater treatment. It is a low pressure membrane process that separates materials in the 0.001-0.1 micrometer size. NF membranes are pressure-driven membranes with properties between those of reverse osmosis and ultra filtration membranes and have pore sizes between 0.2 and 4 nm. NF membranes have been shown to remove turbidity, microorganisms and inorganic ions such as Ca and Na. They are used for softening of groundwater (reduction in water hardness), for removal of dissolved organic matter and trace pollutants from surface water, for wastewater treatment (removal of organic and inorganic pollutants and organic carbon) and for pretreatment in seawater desalination.

B.Magnetic Nanoparticles & Ferritin

Magnetic nanoparticles offer advantages over non-magnetic nanoparticles because they can easily be separated from water using a magnetic field. Separation using magnetic gradients, the so-called high magnetic gradient separation (HGMS), is a process widely used in medicine and ore processing. This technique allows one to design processes where the particles not only remove compounds from water but also can easily be removed again and then be recycled or regenerated. This approach has been proposed with magnetite (Fe3O4), maghemite (g-Fe2O3) and jacobsite (MnFe2O4) nanoparticles for removal of chromium(VI) from wastewater.

C. Polymer Nanoparticles

Polymer nanoparticles have various uses, including water treatment and sunscreen. Using a similar principle as surfactant micelles, polymeric nanoparticles have amphiphilic properties, where each molecule has hydrophobic and hydrophilic parts. When water is available, the polymer will form a polymer cell with a diameter of

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several nanometers inside the hydrophobic part, while the hydrophilic part is outside. On polymer nanoparticles, crosslink occurs prior to the aggregation of particles so that their stability is maintained.

D. Bioactive Nanoparticles for Water Disinfection

Nanotechnology provides an alternative solution to clean germs in water, a problem that has been getting worse due to the population explosion, growing need for clean water and emergence of additional pollutants. One of the alternatives offered is antimicrobial nanotechnology stated that several nano materials showed strong antimicrobial properties through diverse mechanisms, such as photo catalytic production of reactive oxygen species that damage cell components and viruses (e.g. TiO2, ZnO and fullerol),(2) compromising the bacterial cell envelope (e.g. peptides, chitosan, carboxy fullerene, CNTs, ZnO and silver nanoparticles),(3) interruption of energy transduction (e.g. Ag and aqueous fullerene nanoparticles) and (4) inhibition of enzyme activity and DNA synthesis (e.g. chitosan).

E. Nanoscale Zerovalent Iron (nZVI)

Iron nanoparticles are quite useful component for nanoremediation. Iron at the nano scale was synthesized from Fe (II) and Fe (III), using boro hydride as the reductant. The size of the nano scale zero-valent iron particles are 10-100 nm. in diameter. They have a typical core shell structure. The core consists primarily of zero-valent or metallic iron whereas the mixed valent [i.e., Fe (II) and Fe (III)] oxide shell is formed as a result of oxidation of the metallic iron. Nano scale Zerovalent Iron (nZVI) is generally preferred for nanoremediation because of large surface area of nanoparticles and more number of reactive sites than microsized particles and it possess dual properties of adsorption and reduction.

$$2Fe0 + 4H^+ + O_2 \rightarrow 2Fe^{++} + 2H_2O$$
$$Fe0 + 2H_2O \rightarrow Fe^{++} + H_2 + 2OH^-$$

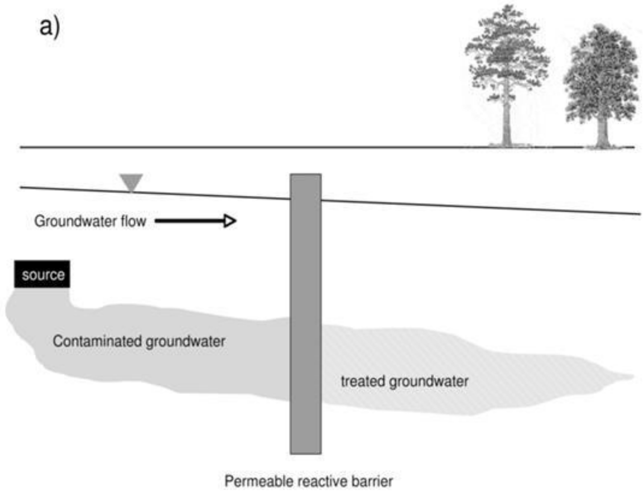

Fig 6 Conventional reactive barrier using granular ZVI

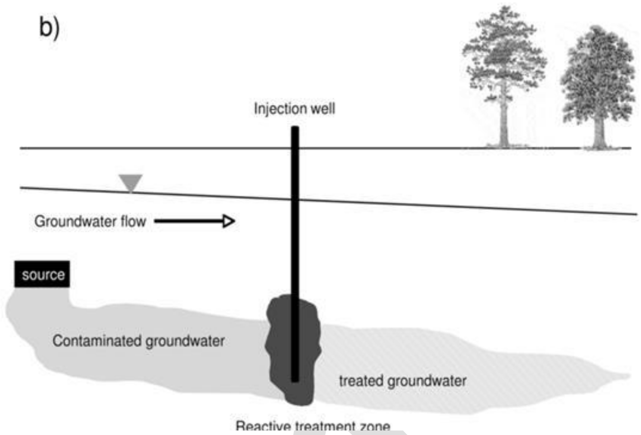

Fig 7 Injection of nZVI to form an immobile reaction zone

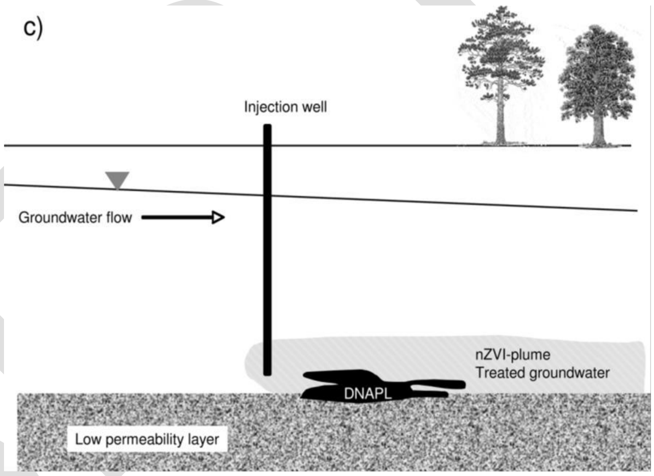

Fig 8 Injection of mobile nZVI

F. Porous Graphene Material

Wastewater remediation, the process of removing the contaminants from water, becomes a critical issue. It is drawing much attention in developing functional materials that are able to effectively adsorb, remove, and transfer contamination, such as oil spills, heavy metal ions, and organic contaminants, from the water. Generally, the performance of materials for water remediation is associated with their specifi c surface area and surface behaviors, which are mainly a function of geometrical structure and/or chemical composition. In addition, water remediation requires that functional materials can be collected easily after usage, even properly recycled and thus reused.

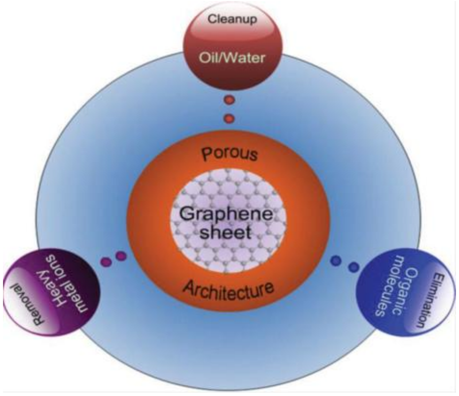

Fig 9 Schematic illustration of graphene sheets assembled into bulky porous architectures for water remediation.

G. Remove of Nanoparticles After Water Treatment

The use of nanoparticles in environmental applications will invariably lead to the release of nanoparticles into the environment. Assessing their potential risks in the environment requires an understanding of their mobility, bioavailability, toxicity and persistence. Little is known about the possible exposure of aquatic and terrestrial life to nanoparticles in water and soil. The rapidly growing use of engineered nanoparticles in a variety of industrial scenarios and their potential for wastewater purification and drinking water treatment raise the inevitable question how these nanoparticles can be removed in the urban water cycle. Traditional methods for the removal of particulate matter during wastewater treatment that have been in vogue include sedimentation and filtration.

Hence, this technique can also be used for the removal of nanoparticles. Most nanoparticles in technical applications today are functionalized in nature and therefore studies using virgin nanoparticles may not be relevant for assessing the behavior of the actually used particles. Fictionalization is often used to decrease agglomeration and therefore increase mobility of particles. Unfortunately little is known to date about the influence of fictionalization on the behavior of nanoparticles in the environment.

V. Environmental Risks

Generally, the source of human and animal exposure to nanoparticles will be through the food supply, through the air and water supply, and from medical application. The routes of exposure for nano particles include inhalation, dermal absorption, ingestion, and injection. Environmental exposure to nanoparticles will come from several sources: intentional release, for environmental remediation and unintentional release, and spillage or disposal of consumer products. As with human and animal routes of exposure, there is likelihood that soils, plants, water, and the atmosphere will uptake nanoparticles through various pathways.

There is already evidence of occupational and environmental exposures to engineered nanoparticles. Occupational exposure to nanoparticles usually comes from inhalation of airborne nanoparticles, though there is evidence that dermal exposure may be a significant route as well. Research is lacking on the current exposure levels of workers to engineered nanoparticles, though much exists on their exposure to ultra-fine particles (which include nanoparticles). Similarly, there only exists exposure data of non-engineered particles to the general public. Though it is difficult to predict the amounts, researchers predict there will eventually be measurable quantities in the environment.
Exposure to engineered nanoparticles is very difficult to measure. Even when the structure, size and properties (morphology and composition) of the particles are known their interaction with the environment varies greatly. As well, the traditional dose–response relationship does not apply. Once taken up into the body, nanoparticles act differently from larger particles of the same type. Though there is some variation, it seems that most current research shows that surface area of the particles will be much more important to dose response than mass concentration. What this means for exposure will vary by particle. The characteristics of the particular nanoparticle in question will be much more important for exposure estimation than has been the case in the past.

VI. Risk of Nano Technology

Although nanotechnology offers a broad range of potential uses and rapid advances, this technology may also have unintended effects on human health and the environment. Materials that are harmless in bulk forms can become highly toxic at the nanoscale, for example, if they enter and build up in drinking water supplies and the food chain, and do not biodegrade. The inhalation of airborne nanoparticles and the impact upon lung disease is a specific concern, with recent studies showing a similar response by the human body to some forms of CNTs as to asbestos particles, if inhaled in sufficient quantities. These concerns are exacerbated by the current poor understanding of the fate and behaviour of nanoparticles in humans and the environment. However, it is very early in the development of this technology, and the amount of testing has been relatively limited. Currently many international organizations, such as the Royal Commission on Environmental Pollution. Scientific authorities acknowledge this as a massive challenge, since monitoring the huge volume of diverse nanoparticles being produced and used and their consequent impact is very difficult to track. This strengthens our case for an increase in the amount and type of testing to assess whether these theoretical risks are real, and to monitor their behavior in the environment.

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