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ROLE OF NANOTECHNOLOGY IN REDUCING POLLUTION

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**Abstract:-**

*Looking at the Nano scale has stimulated the development and use of novel and costeffective technologies for remediation, pollution detection, catalysis and others. Nanotechnology is defined as the creation of functional materials, devices and systems through control of matter on the nanometer (1-100 nm) length scale and the exploitation of novel properties and phenomena developed at that scale. Environmental nanotechnology is considered to play a key role in the shaping of current environmental engineering and science. Nanotechnology is an upcoming technology that can provide solution for combating pollution by controlling shape and size of materials at the Nano scale. This review provides comprehensive information regarding the role of nanotechnology in pollution control at three different steps viz. Source reduction or pollution prevention, remediation or degradation of pollutants and sensing of pollutants. Due to its large surface area and high surface energy, the nanoparticles have the ability to absorb large amount of pollutants or catalyze reactions at a much faster rate, thus reducing energy consumption during degradation or helps in preventing release of contaminants. Pollution prevention by nanotechnology refers on the one hand to a reduction in the use of raw materials, water or other resources and the elimination or reduction of waste and on the other hand to more efficient use of energy or involvement in energy production. The Nano size of the particles also make it possible to reach otherwise inaccessible areas and hence promote in-situ remediation rather than ex-situ remediation. The ability of the nanoparticles to be coated with various ligands and control of surface area to volume ratio by changing the shape of the nanoparticle Nanotechnology and the environment – is it therefore a Janus-faced relationship. There is the huge hope that Nano technological applications and products will lead to a cleaner and healthier environmentrticles enables the design of sensors with high selectivity, sensitivity and specificity.*

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**INTRODUCTION**

Applications utilizing nanotechnology includes manufacturing various products, measuring, imaging and manipulating matter on the Nano scale (Roco *et al.*, 2011; Sateesh, 2012). Nanotechnology utilizes the unique properties of nanomaterial’s which has at least one dimensional size of a material between 1 nm to 100 nm to produce Nano scale devices, components, and systems. Nanotechnology is of considerable interest by scientists in the fields of Nano composites, bio composites, and optical, biomedical, electronic manufacturing and environment friendly compounds. Environmental nanotechnology (E-nano) products can be developed for a wide array of urgently needed environmental remediation. The nanoparticles / nanostructures made by mechanical and /or microbial action with fundamental building blocks are among the smallest human made objects and exhibit novel physical, chemical and biological properties (Figure 1); which has wider application for pollution prevention, detection, monitoring and remediation of pollutants. The significance of environmental factors to the health and well-being of human populations is increasingly apparent. Environment pollution is a worldwide problem and its potential to influence the health of human populations is great. Pollution reaches its most serious proportions in the densely settled urban-industrial centers of the more developed countries and developing countries. Over the last three decades there has been increasing global concern over the public health impacts attributed to environmental pollution. Environmental scientists and engineers are already working with Nano scale structure to manipulate matter of the atomic or molecular scale that has cut across discipline of chemistry, physics, biology, and even engineering (Khan & Ghouri, 2011). Environmental nanotechnology would be the new innovation to remediate and treat the contaminants to acceptable levels.

 **Figure 1. Types of nanoparticles existing in the environments**.



Nanotechnology offers the potential for significant environmental benefits (Quester *et al.,* 2013), including:

* Cleaner, more efficient industrial processes
* Improved ability to detect and eliminate pollution by improving air, water, and soil quality
* High precision manufacturing by reducing amount of waste
* Clean abundant power via more efficient solar cells
* Removal of greenhouse gases and other pollutants from the atmosphere
* Decreased need for large industrial plants
* Remediating environmental damages.

# Nanotechnology and pollution control:

Nanotechnology plays a vital role in air and water pollution control (Mittal *et al.*, 2013).

Pollution results from resource production and consumption, which in their current state are very wasteful. Nanofabrication holds much potential for effective pollution control, but it currently faces many problems that prevent it from mass commercialization particularly its high cost.

# Nanotechnology and Air Pollution:

Another approach uses nanostructured membranes that have pores small enough to separate methane or carbon dioxide from exhaust. John Zhu of the University of Queensland is researching carbon nanotubes (CNT) for trapping greenhouse gas emissions caused by coal mining and power generation. CNT can trap gases up to a hundred times faster than other methods, allowing integration into large-scale industrial plants and power stations. This new technology both processes and separates large volumes of gas effectively, unlike conventional membranes that can only do one or the other effectively.

The WHO estimates that air pollution is responsible for 3 million premature deaths each year (Zhao *et al.*, 2016). This pathologic link has particular implications for low-income and middle-income countries with rapidly developing economies in which air pollution concentrations are continuing to rise. Air pollution can be remediated using nanotechnology in several ways. One is through the use of Nano-catalysts with increased surface area for gaseous reactions. Catalysts work by speeding up chemical reactions that transform harmful vapors from cars and industrial plants into harmless gases. Catalysts currently in use include a Nano fiber catalyst made of manganese oxide that removes volatile organic compounds from industrial smokestacks. Other methods are still in development (Pope *et al.,* 1995).

# Nanotechnology and Water Pollution:

The world is facing formidable challenges in meeting the rising demands of potable water as the available supplies of freshwater are decreasing due to extended droughts, population growth, more stringent health-based regulations, and competing demands from a variety of users. There are about 1 billion people in the world, mostly in developing countries, which have no access to potable water and a further 2.6 billion people lack access to adequate sanitation. Nanotechnology offers a low-cost and effective solution to the challenge of access to clean and safe water for millions of people in the developing world (Lakshmeesha *et al.,* 2014; Theron *et al.,* 2008). The technology holds the potential to radically reduce the number of steps, materials and energy needed to purify water. As with air pollution, harmful pollutants in water can be converted into harmless chemicals through chemical reactions. Trichloroethene, a dangerous pollutant commonly found in industrial wastewater, can be catalyzed and treated by nanoparticles. Studies have shown that these materials should be highly suitable as hydrodehalogenation and reduction catalysts for the remediation of various organic and inorganic groundwater contaminants. Nanotechnology eases the water cleansing process because inserting nanoparticles into underground water sources is cheaper and more efficient than pumping water for treatment.

The deionization method of using Nano-sized fibers as electrodes are not only cheaper, but also more energy efficient. Traditional water filtering systems use semi-permeable membranes for electro dialysis or reverse osmosis. Decreasing the pore size of the membrane to the nanometer range would increase the selectivity of the molecules allowed to pass through. Membranes that can even filter out viruses are now available.

Also widely used in separation, purification, and decontamination processes are ion exchange resins, which are organic polymer substrate with Nano-sized pores on the surface where ions are trapped and exchanged for other ions. Ion exchange resins are mostly used for water softening and water purification. In water, poisonous elements like heavy metals are replaced by sodium or potassium. However, ion exchange resins are easily damaged or contaminated by iron, organic matter, bacteria and chlorine.

These nanowires form a mesh that absorbs up to twenty times its weight in hydrophobic liquids while rejecting water with its water repelling coating. Recent developments of Nanowires made of potassium manganese oxide can clean up oil and other organic pollutants while making oil recovery possible. Since the potassium manganese oxide is very stable even at high temperatures, the oil can be boiled off the nanowires and both the oil and the nanowires can then be reused (Khan *et al.,* 2014).

**Nanotechnology and Removal of Pollutants:**

However, their applications have been restricted by many factors, such as processing efficiency, operational method, energy requirements, and economic benefit. Recently, nanomaterial’s (NMs) have been suggested as efficient, cost-effective and environmental friendly alternative to existing treatment materials, from the standpoints of both resource conservation and environmental remediation. In an effort to combat the problem of water pollution, rapid and significant progresses in wastewater treatment have been made, including photo catalytic oxidation, adsorption/separation processing and bioremediation.

The nanoparticles have been investigated as adsorbent for removal of organic and inorganic contaminants. The nano size metal oxides and natural Nano sized clays have been investigated for the removal of metals and inorganic ions. Besides oxidized and hydrooxylated CNTs are good absorbers for metals such as Cu, Ni, Cd and Pb. Pristine multiwalled CNTs has been found to be stronger adsorbed materials for organometallic compounds.

CNTs has also been found as a powerful adsorbent for a wide variety of organic compounds from aquatic environment, which include: dioxin, polynuclear aromatic hydrocarbons (PAHs), DDT and its metabolites, PBDEs, chlorobenzenes and chlorophenoles, trihalomethanes, bisphenol A and nonyphenol, phthalate easters, dyes, pesticides, and herbicides such as sulfuron derivatives, atrazine and dicamba. Nanoporous polymers which has cross linked and copolymerized with fuctionalized CNTs have been demonstrated for a high sorption capacity for a variety of organic compounds such as p- nitrophenol and trichloroethylene (Sepeur, 2008).

# TiO2 and ZnO:

There are now used in a variety of products such as self-cleaning glass, disinfectant tiles, and filters for air purification. The semiconductor-TiO2 nanoparticles have been extensively studied for oxidative transformation of organic and inorganic contaminants. TiO2 electrodes have the capacity to determine the chemical oxygen demand of water and are used as sensors for monitoring contaminated water. TiO2 nanoparticles can be immobilized on different supports which are used for the solar detoxification of water and air. These engineered nanoparticles are known for their interaction with organic, inorganic and biological contaminants such as heavy metals, organ chlorine pesticide, arsenic and phosphates in water, induced by ultraviolet light.

TiO2 leads to pollutant degradation through two everyday chemical reactions: reduction and oxidation. Once excited by UV and TiO2 electron-hole pairs develop. These electrons have sufficient oxidizing potential to oxidize pollutants in wastewater15. Interestingly, the combination of UV and TiO2 generates bactericidal activity, which attacks several types of bacteria. This approach thus provides a comprehensive treatment procedure since chemical species and pathogens can be removed from wastewater simultaneously.

TiO2, is potentially more attractive for environmental applications than other oxidative nanoparticles (Rai & Duran, 2011).Other nanoparticles with semiconducting properties, such as ZnO, ZnS, F2O3 and CdS can be used for photo catalysis oxidation. TiO2 is biologically and chemically inert and has demonstrated great resistance to corrosion along with the capacity to be used repetitively without substantial loss of catalytic activity and it is therefore inexpensive to use. In light of these properties,

# Iron nanoparticles:

The basis for the reaction is the corrosion of zerovalent iron in the environment. Contaminants such as tetrachloroethene can readily accept the electros from iron oxidation and be reduced to ethane. Laboratory research has established that Nano scale metallic iron is very effective in destroying a wide variety of common contaminants such as chlorinated methanes, brominated methanes, trihalomethanes, chlorinated ethenes, chlorinated benzenes, other polychlorinated hydrocarbons, pesticides and dyes.

# Nanotechnology and Hazardous waste clean-ups:

Thousands of chemical compounds in varying concentrations and compositions have contaminated a wide range of habitats.Xenobiotic and other toxic compounds from industrial activities are presently being accumulated in the ecosystems at an unsustainable rate. From an anthropocentric point of view such contamination is unsustainable because it threatens basic ecosystem functions and services that are necessary to maintain food security and provision of potable ground water. Most Nano remediation research projects undertaken by the department of defense are focused on cleaning up ground water contaminated by chlorinated solvents like trichloroethylene. Furthermore natural habitats for plants and animals are threatened. Nano scale materials can make a huge difference in the clean-up of hazardous waste. There are two reasons for the optimism: firstly, the size of nano materials lets them penetrate otherwise impossible- to-reach ground water or soil and secondly, their engineered coatings allow them to stay suspended in groundwater, a major asset in clean- ups. If practically feasible, nanomaterials could slash clean-up prices by avoiding the extraordinary costs and risks of hauling waste away for burning or burial.

Scientists are trying coatings that might enable nanoparticles to travel. They are also trying to learn how to make the Nano iron react only with target contaminants as well as to get it to selfdestruct after it has done its job. Such ―smarter nanomaterial’s will ultimately make the technology would not be a silver bullet for clean ups because most contaminated sites are fouled by more than a single contaminant and a phased approach will be needed (Fuente & Grazu, 2012).

Research shows that results have been promising in most demonstrations with most of the contaminant being destroyed – a finding that has been replicated by researchers elsewhere. However, there are complications. For one, iron also reacts with non-targeted materials, making it to degrade too quickly, before remediation is completed and nanoparticles clump after their release, making it difficult for them to travel beyond where they are injected.

# Nanoparticles in Waste Water:

During the course of the studies, it was discovered that coating these nanoparticles with a commercial surfactant enabled their separation from the water together with other waste particles. The environmental management of nanoparticle waste could greatly improve following a new study into substances found in wastewater. Researchers from several scientific institutions around the world collaborated on the study have focused on the behavior of potentially hazardous nanoparticles in sewage treatment plants, particularly silica-shelled nanoparticles. The scientists say that if the nanoparticles were allowed to settle out in this way, then they could be stopped from passing on to the subsequent stage of the waste treatment process, which would help prevent industrial accidents (Brar *et al.,* 2010).

# Remediation technologies to clean up Environmental Pollutants

The ability to catalyze the destruction of a wide variety of organic chemicals and complete oxidation of organics to CO2 and dilute mineral acids in many cases, lack of inherent toxicity and resistance to photo degradation at low cost render this process highly suitable for environmental remediation (Masciangioli & Zhang *et al,* 2003).The spread of a wide range of contaminants in surface water and groundwater has become a critical issue worldwide, due to population growth, rapid development of industrialization and long-term droughts. It is thus of necessity to control the harmful effects of contaminants and improve the human living environment. Contaminants persisting in wastewater include heavy metals, inorganic compounds, organic pollutants, and many other complex compounds. Environmental clean-up has promoted the development of highly efficient photo-catalysts that can participate in detoxification reactions. Environmental remediation by photo-catalysts comes with several advantages: direct conversion of pollutants to non-toxic by products without the necessity for any other associated disposal steps; use of oxygen as oxidant and elimination of expensive oxidizing chemicals; potential for using free and abundant solar energy; self-regeneration and recycling of photo-catalyst, etc. A significant amount of research on semiconductor catalyzed photo oxidation of organic chemicals has been carried out during the past 15 years.

Environmental protection and pollution issues are frequently discussed worldwide as topics that need to be addressed sooner rather than later. Nanotechnology can strive to provide and fundamentally restructure the technologies currently used in environmental detection, sensing, and remediation and pollution removal. Some nanotechnology applications are near commercialization: Nano sensors and Nano scale coatings to replace thicker, more wasteful polymer coating that prevent corrosion, Nano sensors for detection of aquatic toxins, Nano scale biopolymers for improved decontamination and recycling of heavy metals, nanostructured metals that break down hazardous organics at room temperature, smart particles for environmental monitoring and purification, nanoparticles as novel photo catalyst for environmental clean-up (Xu *et al.,* 2012).

**Conclusion:**

Engineering ethics need to be defined before the commercial use of nanotechnology. Risk assessment on new nanomaterial based application is important to evaluate potential risk to our environment when the products are in use. Full life cycle evaluation and analysis for all difference applications should be conducted with constant attention. It appears that polluted environment is global an issue and world community would bear worst results more as they already faced. As effective response to pollution is largely based on human appraisal of the problem and pollution control program evolves as a nationwide fixed costsharing effort relying upon voluntary participation. There is no doubt that nanotechnology will continue to be develop, be a benefit to society and improve the environment in various ways. Nano scale materials will make the products better in terms of functionality, weight savings, less energy consumption and a cleaner environment. Shortcomings always exist when new unproven technology is released. Nanomaterial may help clean certain environmental wastes, but contaminate environment in other ways. Choosing the right Nano scale materials is one of the key parameters for the future direction of nanotechnology.

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