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Nano Technology and Waste Water Treatment: Opportunities and Challenges

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Abstract: *Water is most important need of human life. Water contamination is among one of the major issues faced by the whole world today. Water contamination not only effect environment and human health, but it also has greater effects on economic and social costs. There are numerous ways that are used commercially as well as non- commercially to solve this problem which is advancing day by day due to unprecedented technological growth. Nanotechnology has great prospective in advancement of waste water purification to get better treatment efficiency by which humans can be provided the quality water supply. The high surface areas of nanomaterials, upgraded membrane technologies and the catalytic properties of some nanomaterials have potential for removing toxic metal ions, disease causing microbes, inorganic and organic solutes from waste water. This study aims to include modern development in nanotechnology for wastewater treatment. It covers details about various nanotechniques like Nanosensors, Nanosorbents, Nanofilteration and Reverse Osmosis etc. The Positive and negative effects of Nanotechnology have also been discussed. Nanotechnology has led to various efficient ways for treatment of waste water in a more precise and accurate way on both small and large scale. Nanotechnology is able to treat water for daily use and industrial purposes which is the high-priority of eco-friendly system.*

Keywords: Nanotechnology; Nanoparticles; Nanosorbents; Nanocatalyst; Nano-filtration; Pollutants; Water contamination; Water treatment.

1. Introduction

The main challenge of Today's world is to provide clean and affordable water for human beings. Presently the human society is facing a very heavy pollution in ground water and surface water. The available supplies of fresh water are decreasing rapidly due to population growth, extended droughts. Nanotechnologies might help remove wastewater problems by removing water contaminants, including pathogenic bacteria, viruses, harmful chemicals arsenic, mercury, pesticides, insecticides etc. The presence in the environment of large quantities of toxic metals such as mercury, lead, cadmium, zinc or others, poses serious health risks to humans, and this threat puts the scientific community under pressure to develop new methods to detect and eliminate toxic contaminants from wastewaters in efficient and economically viable ways. Utilizing nanotechnology for wastewater treatment would certainly help the human being, our environment as well as industry too as it has shown amazing results in every fields [1].

Most conventional techniques like as extraction, adsorption and chemical oxidation are generally effective but they often prove to be very expensive. The capability to decrease toxic substances to safe levels effectively and at a reasonable cost is consequently very important. In this respect, nanotechnologies can play an important role [2]. Due to their unique properties like extremely high surface area, high absorbing, interacting and reacting capabilities due to their extremely small size, that builds them faster, lighter, stronger and more efficient as well as creating new classes of materials. Nanomaterials can offer a wide range of applications such as catalytic membranes, nanosorbents, bioactive nanoparticles and metal nanoparticles such as iron, silver, titanium oxides and many others. In water research, nanotechnology is applied to develop more cost-effective and high performance waste water treatment systems, as well as to provide instant and continuous ways to monitor water quality [3].

2. Methodology

In terms of wastewater treatment, nanotechnology is appropriate in discovery and removal of various pollutants. Heavy metal contamination poses as a serious threat to environment because it is toxic to living organisms, including humans, and not biodegradable [4]. Since water treatment by using nanoparticles has high technology demand, its usage cost should be managed according to existing competition in market *(Crane et al., 2012)5*. Various methods are used to resolve or greatly diminish problems involving water quality in natural environment [6].

2.1. Nanosensors

Nanosensors are any biological, chemical, or surgical sensory points used to convey information about nanoparticles to the macroscopic world. Sensors based on nanoparticles' optical properties have been used to develop sensitive and selective detectors for pollutants. Nanosensors can detect single cells or even atoms, making them far more sensitive than with larger components. Nanosensors for the detection of contaminants and pathogens can improve health, maintain a safe food and water supply and allow for the use of otherwise unusable water sources [3]. Various Nano-materials like carbon nanotubes, gold nanoparticles, quantum dots and magnetic nanoparticles have potential as sensor components due to their unique physical, chemical and electrical properties. Such sensors may prove valuable for water quality monitoring.

2.2. Nanosorbents

Nanosorbents have very high and specific capacity having wide application in water purification, re-mediation and treatment process. Nanosorbents are nanoscale particles from organic or inorganic materials that have a high affinity to absorb substances. One of the most prominent examples of a conventional sorbent for environmental application is activated carbon. Carbon based nanosorbents have high specific surface area, excellent chemical resistance, mechanical strength and good adsorption capacity which treats water containing nickel ions. Re-generable polymeric Nano-sorbents treat organic and inorganic contaminants in waste water. Nanosorbents eventually present a potent alternative to conventional treatment methods [3].

2.3. Nanocatalysts

Nanocatalysts are particles with catalytic properties that can chemically break down pollutants. Nano-catalysts increases catalytic activity at the surface due to its special properties with high surface area. It enhances the reactivity and degradation of contaminants [7]. Their use mitigates the extensive cost of transporting them elsewhere. This, in turn, has the potential for treating contaminants at very low levels, especially where the current treatment techniques are ineffective or very expensive. The commonly used catalyst nanoparticles are semiconductor materials, zero-valence metal and bi-metallic nanoparticles for degradation of environmental contaminants [8, 9].

2.4. Reverse Osmosis

Reverse osmosis (RO) is a water purification technology that uses a semi permeable membrane to remove larger particles from drinking water. Reverse osmosis can remove many types of molecules and ions from solutions, including bacteria, heavy metals, organic pollutants, viruses, and other dissolved contaminants. It is used in both industrial processes and the production of potable water. RO is a physical process that uses osmosis phenomenon, i.e. the osmotic pressure difference

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between the salt water and the pure water to remove salts from water. In this process , a pressure greater than the osmotic pressure is applied on salt water to reverse the flow , which results in fresh water passing through the synthetic membrane pores separated from the salt and a concentrated salt solution is retained for the disposal[10].

2.5. Nanofiltration

Nanofiltration (NF) is a pressure related process, during which separation takes place, based on molecule size. Membranes bring about the separation. The technique is mainly applied for the removal of organic substances, such as micro pollutants and multivalent ions. The NF membrane is the relatively newly introduced technology in wastewater treatment system. The size of pores in NF membranes (nominally ∼ 1 nm) is such that even small uncharged solutes are highly rejected while the surface electrostatic properties allow monovalent ions to be reasonably well transmitted with multivalent ions mostly retained [11]. NF membrane works similar to reverse osmosis except that with NF, less pressure if needed because of larger membrane pore size. NF has replaced reverse osmosis (RO) membranes in many applications due to lower energy consumption and higher flux rates. NF can remove some total dissolved solids, but is often used to partially soften water and is successful at removing solids, as well as dissolved organic carbons [3].

3. EFFECTS OF NANOTECHNOLOGY

Like any other technology Nanotechnology also has positive as well as negative effects [12].

3.1. Positive Effects Of Nanotechnology

- **Increased effectiveness** – Contaminants could be more effectively removed, even at low concentrations, due to the increased specificity of nanotechnology and the development of "smart" filters tailored for specific uses.
- **Removal of new contaminants** – Contaminants that were previously impossible to remove could now be removed. This will be achieved through novel reactions at the nanoscale due to the increased number of surface atoms.
- **Simplification**: Nanotechnology could radically reduce the number of steps, materials and energy needed to purify water, making it easier to implement widely in rural communities.
- **Reduced cost**: Substantial initial investment would be needed to incorporate or switch to nanotechnology based water treatments. However, once adopted, these techniques could considerably lower water treatment costs over the long term.
- **Less waste on raw materials**: Large sample testing will be done on a smaller scale and simultaneously use of raw materials will become more efficiency. Nanoscale chemical reagents or catalysts increase the reaction rate and other efficiency of chemical reactions.
- **Environmental monitoring and protection:** Utilizing advanced nanotechnology, a detector was made to detect a nuclear leak faster and more accurate at the Fukushima Daiichi Nuclear Power Plant. This is one of the best radiation detector in Washington and can sense the faintest amount of radiation.
- **Biological applications**: Developing ultra-small probes on planetary surfaces for agricultural applications and control of soil, air, and water contamination. This includes the medical diagnostic and treatments.

3.2. Potential Negative Effects of Nanotechnology

There are few considerations of potential risks that are needed to be considered using nanotechnology:

- **Risks to Human Health**: Although the benefits of using nanotechnology for removing contaminants from water have been widely discussed, more research needs to be conducted in order to assess its potential negative impact on the environment and on human health. A few of the studies conducted on this issue indicate that certain unique properties of nanomaterials such as their shape and size may cause them to be toxic.[13] They may also be responsible for the interaction with biological macromolecules within the human body, leading to the development of diseases and clinical disorders.[13] However till date, water purification from nanotechnology has not led to any ascertained health or environmental problems.[14]

- **Availability**: Another major challenge is the availability of suppliers of nanomaterials [14]. As mentioned earlier, nanomaterials are known for their high surface area to mass ratio and can therefore perform their function at a more affordable price. However, if suppliers of these materials are not readily available, it could seriously undermine the potential advantages of using this technology.
- **Risk Assesment**: Information of the chemical structure is a critical factor to determine how toxic material is, and minor changes of on human health and environmental impact need to be evaluated at all stages of nanotechnology. The risk assessment should include the exposure risk and its probability of exposure, toxicological analysis, transport risk, persistence risk, transformation risk and ability to recycle.
- Environmental implications of other life cycle stages also not clear.
- High energy requirements for synthesizing nanoparticles causing high energy demand.
- Lack of trained engineers and workers causing further concerns.

4. Conclusion :

Nanotechnology for wastewater treatment is gaining momentum globally. Although many Nanotechnologies highlighted in this review are still in the laboratory research stage, some have made their way to pilot testing or even commercialization. On the basis of study we have concluded that the impact and applications of nanotechnology is quite addressing for the treatment of waste water. Although nanotechnology enabled wastewater treatment processes have shown great promise in laboratory studies, their readiness for commercialization varies widely. Some are already on the market, while others require significant research before they can be considered for full scale applications. Their future development and commercialization face a variety of challenges including technical hurdles, cost-effectiveness, and potential environmental and human risk.

There are two major research needs for full scale applications of nanotechnology in wastewater treatment. First, the performance of various nanotechnologies in treating waste waters needs to be tested. Future studies need to be done under more realistic conditions to assess the applicability and efficiency of different nanotechnologies as well as to validate nanomaterial enabled sensing technologies. Secondly, the long-term efficacy of these nanotechnologies is largely unknown as most lab studies were conducted for relatively short period of time. Research addressing the long term performance of wastewater treatment nanotechnologies is in great need. As a result, side-by-side comparison of nanotechnology enabled systems and existing technologies is challenging.

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