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Nanotechnological Methodology for Treatment of Waste water

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Abstract: Water plays an important role in the world economy, as it functions as a solvent for a wide variety of chemical substances and facilitates industrial cooling and heating operations. Exclusively to people in developing countries scarcity of water, in terms of both quantity and quality, poses a significant threat to the current and future well-being of people worldwide, but. Sustainable water management is a critical aspect of addressing poverty, equity, and related issues. Science and technology has a role to play in contributing to the development of new systems, tools, and techniques to solve specific water quality and quantity problems. Projects that meet economic, social, and environmental criteria can contribute to sustainable management of water resources and improve access to clean water for poor people in developing countries. This review paper provides an outline of water treatment devices that combine nanotechnology; some of these are already on the market while others are still in development and then explores potential environmental and health risks, risk governance issues, and socio-economic issues regarding the potential use of nanotechnology to improve access to clean water and basic sanitation.In particular, this paper describes nano-filtration membrane technologies used to clean water. It then describes socio-economic issues and potential environmental and human health risks of using nanotechnology to clean water.
Keywords: waste water, nanotechnology, nano-filtrations, nano-catalyst.

1.0 Introduction

Water containing unwanted substances which adversely affect its quality and thus making it unsuitable for use is termed as wastewater. Wastewater is generated from various sources such as residential areas, commercial/industrial properties, agriculture etc. composition of wastewater varies widely and depends upon the source from which it is generated. Common constituents of wastewater are pathogenic and non-pathogenic microorganisms, organic substances such as excreta, plants material, food protein and inorganic substances like meal particles, ammonia along with gases[1]. When left untreated these constituents may pose threat to living beings and the environment, which makes it essential to treat wastewater before disposal various physical, chemical and biological treatment processes are used for wastewater treatment. Among these methods, currently nanotechnology has been extensively studied by researchers as it offers potential advantages like low cost, reuse and highly efficient in removing and recovering the pollutants.

In terms of wastewater treatment, nanotechnology is applicable in detection and removal of various pollutants. Heavy metal pollution poses as a serious threat to environment because it is toxic to living organisms, including humans and not biodegradable. Various methods such as Photolysis, Nano filtration, Adsorption and Electrochemical oxidation involve the use of Tio2,Zno, ceramic membranes, nanowire membranes, polymer membranes, carbon nanotubes, submicron Nano power, metal oxides, magnetic nanoparticles , nanostructured boran doped diamond are used to resolve or greatly diminish problems involving water quality in natural environment[2].

2.0 Water Pollution and Nano filtration

Water that does not meet drinking water standards should be treated to ensure that the health of the consumer or community is not compromised through exposure to toxic pollutants. Polluted water is often treated by conventional or pressure-driven membrane processes to make it comply with drinking water standards. The conventional water treatment process consists of several stages. These include pre-treatment, coagulation, flocculation, sedimentation, disinfection, aeration, and filtration. The pre-treatment stage removes suspended solids. Coagulation and flocculation are carried out to precipitate dissolved impurities through sedimentation. The water is then filtered to remove any suspended particles. One of the disadvantages of the conventional water treatment method is that it cannot remove dissolved salts and some soluble inorganic and organic substances.

Pressure-driven membrane technology is an ideal method for the treatment of water to any desired quality. The integral part of the technology is the membrane. The membrane is a barrier that separates two homogenous phases. It allows some solutes to pass through but rejects the permeation of others. It achieves the separation of solutes of a fluid mixture when a driving force is applied. The force could be a pressure difference (Æp), concentration gradient (Æc), temperature difference (ÆT), or electrical potential difference (ÆE).The basic principle of operation is illustrated in Figure 1. Phases 1 and 2 are generally the feed water and the product water or permeate, respectively[3]. The basis of separation is that each membrane has unique characteristics for the selective permeation and rejection of different

3.0 Desalination

Desalination is the removal of dissolved salts from raw or untreated water by either thermal or membrane processes. A thermal process uses heat to evaporate water, which is then collected by condensation. In a membrane process, pressure is applied to force the raw water through a membrane that retains the dissolved salts. Reverse osmosis (RO) membranes can retain all the salt, whereas other membrane processes, such as nanofiltration (NF), selectively retain some salts. Desalination is carried out for various reasons, including limited freshwater, increasing demand, global warming, regulation, cost effectiveness, and politics. A reverse osmosis (RO) desalination plant consists of the following sequence of stages: feed water intake system, pre-treatment facility, high-pressure feed pumps, RO membrane, and desalinated water conditioning system. A pressure of 40 – 80 bars is required for the permeation of water through the RO membrane for the desalination of seawater. Two membrane sheets are glued together and spirally wound around a perforated central tube. The product water exits through this tube. Nanotechnology is used in Israel for the desalination of saline waters[4]. The Grand Water Research Institute of the Israel Institute of Technology is working with corporate and other partners to treat salt water and create fresh sources for drinking water and irrigation.

4.0 Suitability of the Nano membrane Technologies

There are merits and demerits of nano-membrane technologies (e.g., nanofiltration and reverse osmosis) over conventional filtration technologies. The conventional sand filter does not retain some microbes and dissolved salts (e.g., arsenate). Nanofiltration (NF) and reverse osmosis (RO) membranes remove all multivalent ions and bacteria. The conventional carbon filter, biological sand, and biological carbon filters do not remove some bacteria and dissolved salts (e.g., calcium). Calcium is readily removed by the nanomembrane processes. However, NF membranes have a low rejection coefficient (R) for monovalent ions. Thus, they are not well suited for the removal of nitrate and fluoride ions from water, which could be an advantage in cases where fluoride ion levels are suitable for the healthy development of teeth[5].

The only additional equipment required for NF membrane filtration, compared to conventional filtration, is cartridge filters. These serve as a pre-treatment for the removal of particulate matter before membrane filtration. Their cost is insignificant. One of the setbacks of nanomembrane technology is cost. The cost of a full-scale conventional filtration plant is about 70% of a nanomembrane plant. The durability of a nanomembrane plant is comparable to that of a conventional filter plant and is determined by the nanomembrane whose life span ranges between five and six years. The life span can be further prolonged by using an effective pre-treatment.

Nanomembrane filtration technologies are suitable for developing countries. Nanomembrane plants can be built as portable units, which can be assembled in the major urban centers and then transported to the outlying areas (i.e., rural and peri-urban) where they are needed. By building the plants as portable units, the initial capital required for the construction can be lowered[6].

The paper demonstrates that nanotechnology research is being conducted in a broad spectrum of areas relevant to water treatment – filters, catalysts, magnetic nanoparticles, and sensors. However, the maturity of research and development efforts is uneven across these areas, with nanofiltration currently appearing as the most mature. Interest in the application of nanotechnology to water treatment devices appears to be driven by several factors including, but not limited to, reduced costs, improved ability to selectively remove contaminants, durability, and size of device. While the current generation of nanofilters may be relatively simple, many researchers believe that future generations of nano-based water treatment devices will capitalize on the new properties of nanoscale materials. Advances through nanotechnology, therefore, may prove to be of significant interest to both developed and developing countries.

Nanotechnology can impact water purification applications in various ways:

4.1 Nano filtration membranes

These act as a physical barrier and selectively reject substances smaller than their pores, and so remove harmful pollutants and retain useful nutrients present in water. Currently, many water treatments include micro– and nanoscale processes, but are not considered as nanotechnology as they are produced conventionally, and considered as "older generation" nanotechnology. When produced via nanotechnology–driven approaches, all aspects of the membrane can be refined and optimised, such as having smaller and more uniform sized pores as well as making the membrane more reactive. The filters and membranes are made from a variety of nanomaterials including carbon nanotubes, nanoporous ceramics (clays), dendrimers, zeolites, nanofibres and nanosponges. Multi–tasking filtration systems could be developed to detect, separate out, and/or detoxify a contaminant. It is anticipated that in time such membranes and filters will become commonplace in detecting and removing viruses from water as the current research in this direction indicates[7,8].

4.2 Nano catalysts and magnetic nanoparticles

Nanocatalysts are particles with catalytic properties that can chemically break down pollutants. 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. Magnetic nanoparticles have large surface areas relative to their mass and easily bind with chemicals. Their ability to bind with contaminants, such as arsenic or oil, which can be easily removed using a magnet, makes them an appealing solution for water treatment[9].

4.3 Sensing and detection

Nanotechnology is being used to develop small and portable sensors with enhanced capabilities for detecting biological and chemical contaminants at very low concentration levels in the environment, including in water. Ultimately, nanotechnology has the potential to contribute towards

4.4 Increasing Potable Water Supplies

The development of low–cost portable filters, purifiers and other techniques could positively impact rural communities and informal settlements located close to industrial areas, where the accessible water is heavily contaminated.

4.5 Desalination of sea water

By removing the salt from seawater, another large sustainable source of potable water could be provided significantly more cheaply than existing techniques.

5.0 Safety of industrial effluent

New, more efficient and cost-effective techniques could be applied to protect the environment alongside industrial practices. For example, nanotechnology may be used by the mining industry to prevent the contamination of groundwater from inactive mines by cleaning of acid mine drainage sources.

Benefits of using 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.

Regulation of nanotechnology

At present, there are no nanotechnology specific regulations in South Africa mainly due to the relative infancy of this emerging technology, and due to the lack of evidence and scientific data to demonstrate the impact of products already in use. This also accounts for the relatively “loose” regulations that have been developed around the world (Canada, the USA, Japan and the European Union). It is likely that these regulations will be modified and “tightened” accordingly as new data becomes available[10-12].

It is important that nanotechnology is developed in a safe, responsible, acceptable, and sustainable manner. For this to happen, the entire life cycle of nanoparticles needs to be carefully considered from production to disposal, to allow an informed assessment of the potential human health and environmental impacts[13]. This will mitigate the challenges faced by other technologies such as asbestos, DDT, and GMOs. Risk assessment of nanotechnology is currently starting at several universities and science councils throughout the world and is expected to become an integral part of the nanotechnology research in this country[14].

In summary, some key issues to be considered with regard to water and nanotechnology include.

Technology transfer

Developed water treatment technologies need to be transferred to specific target communities and must be relevant to the community needs, technical capability, and available infrastructure. The receiving communities have to take ownership both in skill and perceived benefit of the technology to be able to sustain it once there is no longer technical support.

Public understanding of nanotechnology

As with any emerging technology, public awareness and understanding of the technology and related issues are an integral component of responsible application. It is essential that factually based, credible information is communicated and that the public and other key audiences are engaged in relevant topics to ensure community preparedness for this technology.

“Buy–in” of the water sector –

Since significant capital investment will be required to make the switch to nanotechnology-based water treatment, the involvement of the water sector, at all levels, is crucial.

Nanotechnology risk assessment –

Long term acceptance of nanotechnology–based products and industrial applications by society is strongly dependent on the way risk concerns (real and perceived) will be investigated, communicated to the public, and managed[15].

6.0 Conclusion:

Industrialization and population are the main reasons for increase in amount wastewater. These are also the main areas which require regular supply of clean water. Several methods are employed to ensure a sustained supply of water for the requisite purposes. Nanotechnology is also being looked upon to provide an economical, convenient and eco-friendly means of wastewater remediation. Different types of nanoparticles such as nano-sized metals, metal oxides, zero valent ions, nano-filtration membranes have proven effective in detection, removal and /or destruction of contaminates.

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