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WATER POLLUTION AND TREATMENT TECHNOLOGIES - PAST AND PRESENT

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ABSTRACT

Wastewater is any water that has been adversely contaminated by different sources such as organic pollutants, bacteria and microorganisms, industrial effluent or any compound that has deterioted its initial quality. Current water and wastewater treatment technologies and infrastructure are reaching their limit for providing adequate water quality to meet human and environmental needs. The OECD Environmental Outlook to 2030[2] highlights i) water scarcity, ii) poor groundwater quality and iii) agricultural use of water and pollution of water as three environmental issues which are either not well managed, or are in a bad or worsening state requiring urgent attention. Presently Nanotechnology is gaining greater use in water control systems. It is envisaged as being particularly efficient for three key purposes: treatment and remediation, sensing and detection, and pollution prevention.

KEYWORDS: sources, water pollution, water treatment, nanotechnology.

I. INTRODUCTION

Water is the most essential substance for all life on earth and a precious resource for human civilization. Reliable access to clean and affordable water is considered one of the most basic humanitarian goals and remains a major global challenge for the 21st century.

Our current water supply faces enormous challenges, both old and new. Worldwide, some 780 million people still lack access to improved drinking water sources.[1] It is urgent to implement basic water treatment in the affected areas (mainly in developing countries) where water and wastewater infrastructure are often non-existent. In both developing and industrialized countries, human activities play an ever-greater role in exacerbating water scarcity by contaminating natural water sources.

Even in the developed world, water shortages is showing impact, not only on health, but on industries such as agriculture, manufacturing, and power production

Many factors contribute to water scarcity: imbalances in water availability and demand, inadequate management of resources (minimal re-use of wastewater recycling and non-potable water), cost, poor quality of some groundwater and surface water, competition between sectors such as industry, agriculture and the domestic water consumer, is compounded by declining freshwater quality.

The OECD Environmental Outlook to 2030[2] highlights *i)* water scarcity, *ii)* poor groundwater quality and *iii)* agricultural use of water and pollution of water as three environmental issues which are either not well managed, or are in a bad or worsening state requiring urgent attention.

The pollutants existing in the waters thus can be classified into following category[3]:

1. Toxic compounds which result in the inhibition or destruction of biological activity in the water.Most of these materials originate from industrial discharges and would include heavy metals from metal finishing &plating operations, moth repellants, herbicides and pesticides etc.
2. Anything which may affect the oxygen balance of the water, including substances, which hinder oxygen transfer across the air-water interface. Oils and detergents can form protective films at the interface which reduce the rate of oxygen transfer and may amplify the effects of oxygen –consuming substances.
3. Thermal pollution which can upset the dissolved oxygen balance (DO) because the saturation DO concentration reduces with increasing temperature.
4. Inert, suspended or dissolved solids in high concentrations can cause problems.

II. Characteristics of Wastewater

The physical quality of wastewater is generally reported in terms of its temperature, colour and turbidity. The temperature of waste water is slightly higher than that of the water supply. This is an important parameter because of its effect upon aquatic life and the solubility of gases.

The colour of wastewater is usually indicative of its age. Fresh water is usually gray, septic wastewater imparts a black appearance. Odours in wastewater are caused by the decomposition of organic matter that produces offensive smelling gases such as hydrogen sulphide. Waste water odour also provide a relative indication of its condition. Turbidity in wastewater is caused by a wide variety of suspended solids. Chemical characteristics of wastewater are expressed in terms organic and inorganic constituents.

The principal groups of organic matter found in municipal wastewaters are proteins, carbohydrates and fats and oils. In addition, wastewater may also contain small fraction of synthetic detergents, phenolic compounds, pesticides and herbicides. These compounds depending on their concentration may create problems such as non-biodegrability, foaming or carcinogenicity. The inorganic compounds mostly found in wastewater are chloride, hydrogen ions, alkalinity-causing compounds, nitrogen, phosophorus and sulphur compounds and heavy metals.

The increasingly stringent water quality standards, compounded by emerging contaminants, have brought new scrutiny to the existing water treatment and distribution systems widely established in developed countries. Furthermore, current water and wastewater treatment technologies and infrastructure are reaching their limit for providing adequate water quality to meet human and environmental needs.

The innovation of new technologies to increase the availability of clean water commenced 40 years ago (1960s) with establishment of three membrane separation processes reverse osmosis (RO), ultrafiltration (UF) and microfiltration(MF). During the 1970s and 1980s, nanofiltration membranes (Loose RO) were developed as an intermediate filtration material between ultra filtration and reverse osmosis.[4]

“Nanotechnology is a generic and evolving term that encompasses the development of a wide range of materials and products. It is the deliberate exploitation of particles or structures that are measured on the nanometer scale. A nanometer is one billionth of a meter; by comparison, a human hair is 80 000 nm thick. There are three types of nanoparticles[5]:

1. Natural: such as tiny particles from volcanic eruptions.
2. Incidental: such as emissions from engine combustion.
3. Engineered: purposely manufactured.

Engineered nanoparticles are usually developed by scaling down commonly used materials (*e.g.* carbon, metal oxide and precious metal) from large particles to small. Others are built atom by atom to create completely new compounds that have no large size counterpart. Some are fixed (embedded material); others are free and could be released into the environment." Nanotechnology for water and wastewater treatment is gaining momentum globally. The unique properties of nanomaterials and their convergence with current treatment technologies present great opportunities to revolutionize water and wastewater treatment.

Nanotechnology is being applied in the production of water purification membrane. The following water filtration membranes produced from nanomaterials

1. nanostructured membranes from nanomaterials such as carbon nanotubes ,nanoparticles and dendrimeres
2. nanoreactive membranes from metal nanoparticles and other nano materials.

The application of nanotechnology in the cleanup of contaminated water could be summarized as

1. Nanoscale filtration techniques
2. The adsorption of pollutants on nanoparticles
3. The breakdown of contaminants by nanoparticle catalysts.

Nanotechnologies have made great improvements for handling water contamination problems and will clearly make further advancements in future. Nanotechnology based treatment has offered very effective, efficient, durable and eco friendly approaches. These methods are more cost-effective, less time and energy consuming with very less waste generations than conventional bulk materials based methods.[6]

III. Technologies for water treatment and resource management

Water resource management is an important element in the conservation of water and in optimizing its use. Methods for identifying the amount of contamination in water and determining its suitability for use, as well as those for ascertaining how much water is needed and where, aid good water management. Nanotechnology is gaining greater use in water systems. It is envisaged as being particularly efficient for three key purposes: treatment and remediation, sensing and detection, and pollution prevention. Established techniques for water treatment can have drawbacks which nanotechnology may help to address.

Water treatment technologies

Conventional technology	Nanotechnology technology
1.Membrane filtration 1.1)Integrated systems 1.2)Bioreactors 1.3)Turbidity removal	1.Membrane filtration 1.1)Integrated systems 1.2)Bioreactors 1.3)Turbidity removal nanofiltration
2.Chemical treatment,including: 2.1) Coagulation and flocculation	2.Chemical treatment,including: 2.1)Disinfection eg.using nanometallic particles
3.Heat and UV disinfection	3.Catalysis enhanced Heat and UV disinfection

Technologies which are in use for water filtration include: ceramics to filter out suspended matter (turbidity), coliforms, faecal contaminants, E. coli, asbestos and iron; biosand, composed of gravel and sand particles, to remove faecal coliform, protozoa, suspended sediments, zinc, copper and lead; charcoal and activated carbon for filtration of solids, organics and some metals which form organic complexes; granular media such as sand for the removal of turbidity, enteric bacteria and parasites; and fibers and fabrics to filter solid particles and large microorganisms (>20 μm).Chemical treatments include coagulation and flocculation, independently and with chemical disinfection, for the purification of water containing turbidity, microbes, viruses, heavy metals and pathogens. These methods often require skill and can result in waste products, unpleasant tastes and odours. Reverse osmosis is used for some industrial, medical and domestic applications and more than 50% of desalination technologies are based on reverse osmosis. Distillation may be used to remove salts and heavy metals. Heat and ultraviolet radiation (*e.g.* solar disinfection, UV lamps) can neutralize vegetative and coliform bacteria and enteric pathogens.[6]

Current and potential applications of nanotechnology in water and wastewater treatment

Applications	Representative Nanomaterials	Desirable nanomaterials properties	Enabled technologies
1.Adsorption	1.1) Carbon nanotubes 1.2) Nanoscale metal oxide 1.3) Nanofibres	High specific surface area,highly Assesssable adsorption sites, Diverse contaminant-CNT Interactions High specific surface area,more adsorption sites, Easy reuse Tailored shell surface chemistry for selective adsorption	Contaminant detections Adsorptive media filters, slurry reactors Reactive nono-adsorbtents
2.Membranes	2.1) Nano -	Molecular sieve,hydrophilicity	High permeability thin film

and membrane processes	zeolites		nanocomposite membranes
	2.2) Nano-Ag	Strong and wide spectrum antimicrobial acttivity, low toxicity to humans	Anti –biofouling membranes
	2.3) Carbon nanotubes	Antimicrobial activity,high mechanical and chemical stability	Aligned carbon nanotube membranes
	2.4) Aquaporin	High permeability and selectivity	Aquaporin membranes
	2.5) Nano-TiO_2	Photocatylitic activity,hydrophilicity, high chemical stability	Reactive membranes,high performance thin film nanocomposite membranes
	2.6) Nano-magnetite	Tunable surface chemistry,superparamagnetic	Forwad osmosis
3.Photocatalysis	3.1) Nano-TiO_2	Photocatalytic activity in UV-Visible range, low human toxicity High stability,low cost	Photocatalytic reactors, Solar disinfection systems
	3.2)Fullerene derivaties	Photocatalytic activity in solar spectrum, high selectivity	Photocatalytic reactors, Solar disinfection systems
4.Disinfection and microbial control	4.1) Nano-Ag	Strong and wide spectrum antimicrobial acttivity, low toxicity to Humans,ease of use	Water disinfection, anti-biofouling surface
	4.2) Carbon nanotubes	Antimicrobial activity,fibre shape conductivity	Water disinfection, anti-biofouling surface
	4.3) Nano-TiO_2	Photocatylitic ROS generation,high chemical stability ,low human toxicity and cost	Full scale disinfection and decontamination
Applications	**Representative Nanomaterials**	**Desirable nanomaterials properties**	**Enabled technologies**
5.Sensing and monitoring	5.1) Quantum dots	Broad adsorption spectrum ,narrow,bright and stable emission which Scales with the particle size and chemical component	Optical detection
	5.2) Noble metal nanoparticles	Enhanced localized surface resonances,high conductivity	Optical and electrochemical detection
	5.3) Dye-doped silica nanoparticles	High sensitivity and stability ,rich silica chemistry for easy conjugation	Optical detection
	5.4) Carbon nanotubes	Large surface area,high mechanical strength and chemical stability, Excellent electronic properties	Electrochemical detection ,sample preconcentration

India and water-related nanotechnologies

In recent years due to industrialization and urbanization in India, this problem has become gigantic.

India's enormous and growing population is also putting great stress on the country's natural resources and particularly on water resources. Although access to drinking water has improved, the World Bank estimates that 21% of communicable diseases in India are related to unsafe water. In India, diarrhea alone causes more than 1 600 deaths daily.[7]

Regarding the water issue, finding solutions to improve citizen's access to safe water has become a major concern for policy makers in India. The Indian Water Portal.[8] shows the wide range of initiatives that have been taken to address this problem. Much is also being done to share water management knowledge amongst practitioners and the general public.

In addition to other projects, India has invested significantly in novel technology research for water treatment. Many initiatives have been launched to significantly enhance nanotechnology research in India. In 2007, the Indian government started a five year national project to make the country a global hub for nanoscience and nanotechnology with an investment of around 254 million. In this plan a particular emphasis have been given to research in novel water-related nanotechnology for water purifying, to eliminate bacteria and viruses, etc.[9]

CONCLUSION

The multidisciplinary field of nanotechnology's application for discovering new molecules and manipulating those available naturally could be dazzling in its potential to improve waste water treatment.

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