Environmental Remediation by Nanomaterials: A Photocatalytic Approach

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Abstract

Environmental pollution is one of the main problems that today world is facing. Pollution contaminates air, water and soil also. Best solution to tackle this problem is to reduce or stop the use of methods and processes that causes increases in pollution. Novel methodologies which involve recent technologies are constantly being explored for the environmental remediation of air, water, and soil. Varieties of materials can be used in environmental remediation. Wide varieties of approaches can be exploited for this purpose. As compare to classical technologies nanotechnology has gained a lot of attention in recent decades due to the unique physical properties of nanoscale materials. Higher surface to volume ratio of nanomaterials enhances their reactivity compared to their bulkier counterparts. Among the many possible ways of water remediation are filtration, absorption, adsorption, chemical reactions and photocatalysis. Photocatalysis based water remediation can be carried out with the help of natural energy source, i.e., solar energy which removes the persistent organic pollutants in water using different photocatalysts.

This article has focused on recent advancements in the use of nanomaterials for the environmental remediation of a variety of water pollutants by photocatalysis.

Introduction

The rise in population increases the load on natural resources. The excessive use of natural resources and particularly of water by selective countries also of great concern. The extensive use of natural resources has threatened the ecosystem by continuous human interference and unplanned exploitation of resources. Climate

change is a major issue which is related to the depletion of these resources. In order to ensure the uninterrupted water supply requires novel and innovative technologies which also reduces global water pollution load. The long-term development of the global water situation is closely connected to the growth of the world population and global climate change. It is predicted that world population will be nearly 6.3 billion people in 2050. Tremendous increase in droughts also responsible for reduction in water sources. Chemical and biological weapon by terrorist attacks also adds loads on in water resources planning.

Several physical and chemical techniques are available like boiling of water, distillation, use of different derivatives of chlorine, ultraviolet light, low frequency ultrasonic irradiation, reverse osmosis, deionization etc. for the treatment of water.

During the past few decades, a lot of research were done to use different polymeric materials, natural and synthetic ion exchangers including zeolites and metal ions as bactericides for water disinfection.

Removal of most of the organic water pollutants and air matrices is still a great challenge where most of these conventional methods get failed. Hence techniques with nanomaterials are used in waste water treatment

1 Nanotechnology in environmental remediation

1.1 Environmental Remediation by conventional methods

To tackle environmental contamination in soil, wastewater andgroundwater many remediation technologies have been developed for treatment of contamination by various pollutants [1]. For reduction of contamination to a safe level various physical, chemical and biological technologies can be used individually or in combination with one another. To ensure proper selection, the design, and adjustment of the remediationtechnology is of prime importance [2]. Air stripping, carbon adsorption, biological reactors or chemical precipitation are typical conventional methods available for treatment of water trench, pump waters etc.

One of the drawbacks of these methods is production of highly contaminated waste which increase in operation cost.

1.2 Nanotechnology for waste water treatment

Varieties of nanomaterials are used for water purification process. Most commonly used are dendrimers, metal-containing nanoparticles, etc. These materials have a wide range of physico-chemical properties which increases their use in separation and reactive media for treatment of waste water.

Conventional techniques are already reported for water purification. These methods have their limitations, therefore more cost effective and robust methods should be used for water purification and for tackling environmental problems.

Varieties of nanomaterials are now available for use in environmental remediation. Recently phocatalysis by nanomaterials shows promising results in purification of water.

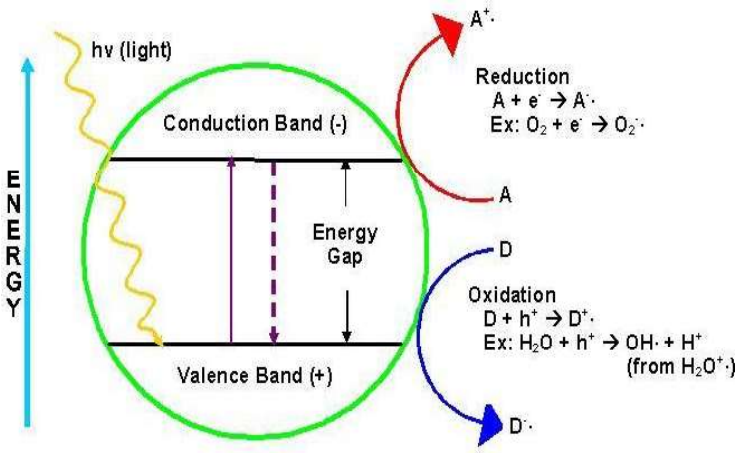
1.3 Photocatalysis

Photocatalytic is one of the several advanced methods which can be used to tackle these problems. Photocatalysis as a green technology has the potentialto bring the high-performance water detoxification at affordable rates using solar active advanced materials with sustainable approach. This method is a blend of natural processes and methods developed by human being. Photocatalytic oxidation processes generate highly reactive hydroxyl radicals and other strong oxidants, which are capable of mineralizing pollutants into harmless substances. This is a typical irradiation process where excitation ofcertain metal oxide semiconductors result in electron–hole pairs formation.Photocatalysis is effective in degradation of pollutants like synthetic dyes, biocides, and other chemicals. The technology is very promising not only for dye degradation but also for biological decontamination as well. It can purify the air by destroying pathogens, volatile organic compounds (VOCs), and odors.

This writ-up covers scientific and technical knowledge of photocatalysis and its

applications in treating wastewater containing different dyes. This also covers some general areas which need more research in the near future. **Photocatalysis** is the activity occurring when a light source interacts with the surface of semiconductor materials, the so called **photocatalysts.**

A typical photocatalysis mechanism is represented as follows.



Properties of Photocatalyst are depend on following factors

- **Physical and chemical properties** – morphology of catalyst, its size, energy level structure,etc.
- **Photoreactors design** – manual or automatic stirred reactors,source of light, etc.
- **Operational parameters-** pH, reaction time, frequency of light source, concentration of impurity are the other relevant parameters.

Advantages to use Photocatalysis for waste water remediation

- The oxidant used is atmospheric oxygen which reduces the consumption of expensive chemicals.
- This is cleaner process and not produces sludge.

- Photocatalytic reaction may be driven by sunlight
- Decompose of organic pollutants and bacteria

Steps involved in photocatalysis

Transfer of the reactants in photoreactor. It can also be spread on surface so that it can adsorb on surface.

- Photons are incident on surface or on solution so that it can be adsorbed on phase.
- Desorption of the products
- Removal of the products from the interface

1.4 Typical Semiconductor Metal Oxide Nanoparticles for Visible Light Photocatalysis

TiO2- TiO2 shows excellent photo activity under UV irradiation.

Solar Radiation contains only 2-4% UV light, rendering TiO2 inactive towards major portion of sunlight.

Various methods to improve the efficiency of TiO2 in visible light:

- Dye sensitization
- Metal & Non-metal doping
- Composite semiconductors
- Nano sized

Iron nanoparticle

- Zerovalent Iron nanoparticles in the range of 10-100 nm are nowadays use for nano remediation.

  Nanoscale iron particles shows high efficiency for the detoxification of varieties of organic pollutants like chlorinated organic solvents, chlorinated

organic pesticides and PCBs [1].

- Bimetallic nanoparticles are also another group used in nano remediation. Bimetallic of iron platinum (Pt), gold (Au), nickel (Ni), and palladium [3] are the potential nanomaterials used in waste water remediation. The combination of metals to form a nanoparticle increases the kinetics of oxidation reduction (redox) reaction, therefore catalyzing the reaction.
- Carbon nanotubes (CNT) - In recent years carbon nanotubes are used in waste water treatment industry.

1.5 Characteristics of nano photocatalyst

- Small Size
- High Surface area
- Adsorption potential
- Low cost to prepare and use
- High stability (Biologically and chemically inert)
- Non-toxic to the environment and humans
- High efficiency
- Effectively activated by sunlight

Photocatalytic Decomposition of pollutants

- Utilization of nanosized TiO_2 photocatalyst dispersed on substrates with high surface area
    - Spreading on ground to collect sunlight
    - UV light in sunlight is sufficiently strong to decompose them by TiO_2 photocatalysis
    - Nanoparticles are necessary for photocatalyst with high activity

1.6 Environmental risks of using nanomaterials

Despite their wide range of potential applications of nanomaterial's, dark side of these materials should be considered. Some of these materials are very toxic

hence toxicological risk assessment is required. Very less literature is available related to toxicity of nanomaterials [1]. In response to these concerns, various scientific communities are trying to gain more knowledge in exposing their toxicological effects on human [4] andecological health [5].

Conclusion

Contamination in soil, wastewater and groundwater is big problem we are facing nowadays. To tackle these problems many remediation technologies are developed but few conventional technologies are affordable and effective for removal of contaminants from water and wastewater. If we consider cost removal efficiency of certain pollutants like persistent organic pollutants these have many disadvantages. Therefore, environmental remediation by nanotechnology with conventional technologies gives appreciable results.

References

[1] Rao G.P., Lu C., Su F. *Separa. Purif. Technol*., 2007, **58**:224

[2] Khan F.I., Husain T., Hejazi R. *J. Envir. Manag.,* 2004, **71**:95

[3] Ottaviani, M.F., Favuzza P., Bigazzi M., Turro N.J., Jockusch S., Tomalia D.A. *Langmuir*, 2000, **19**:7368

[4] Doyle M.E. Nanotechnology: a brief literature Review. *Food Research Institut*., 2006 [41] Oberdörste G. *Intl. Arch. Occup. Environ. Health*, 2001, **74**:1

[5] Tratnyek P.G., Johnson R.L. *Nano Today*. 2007, **1:**44

Bio sketch Dr. Avinash V. Bharati

Dr. Avinash V. Bharati has done M. Sc. in 1991, and Ph. D. in January 2000, from PGTD of Chemistry, RTM Nagpur University, Nagpur. He is Associate Professor with 30 years of teaching experience. He is a registered guide in RTM, Nagpur University, Nagpur. Till date, 7 students have been awarded Doctoral Degree under his guidance. His area of interest is Synthetic Organic Chemistry, Nanotechnology and Environmental Sciences. He has published more than 25 research papers in reputed journals of high impact factor. He has authored five books on 'Engineering Chemistry', 'Material Chemistry' and 'Energy and Environment' for engineering students. He has delivered several guest lecturers in different seminars in many institutions and participated in seminars, workshops and symposia. Currently, he is BOS member in Applied Sciences and Humanities, RTMNU, Nagpur. He is also the Chairman of Indian Society of Analytical Scientists, Nagpur Chapter.