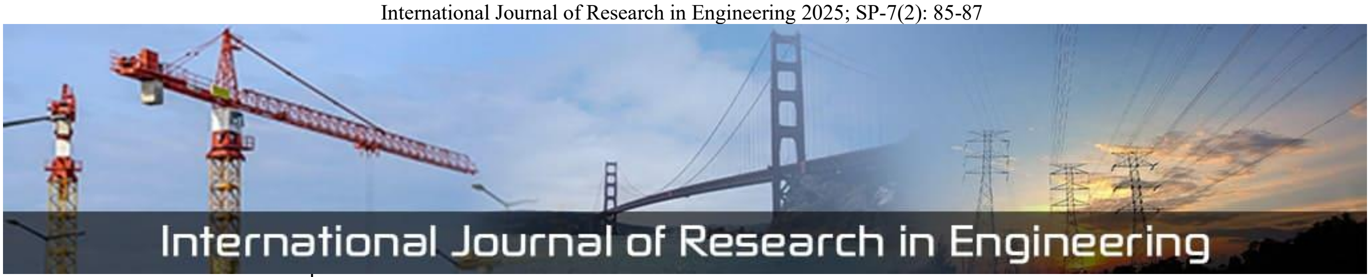

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Nanotechnology for environmental remediation

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Abstract
Environmental remediation primarily depends on the use of diverse technologies such as chemical reactions, adsorption, photocatalysis, absorption and filtration to remove toxins from different environmental media. In the field of environmental remediation, nanotechnology-based materials have the ability to remove pollutants and biological contaminants more efficiently due to their improved characteristics and effectiveness. In addition to this, nanoremediation is a sustainable alternative to eliminating emerging pollutants and a promising strategy defined as engineered materials used to clean up the environment. It is a cost-effective, fast, easy and efficient technology for dealing with chronic compounds including pesticides, chlorinated solvents, halogen-containing chemicals, or heavy metals. Nanotechnology is a rapidly developing area that encompasses a wide range of technologies that are currently being developed at the nanoscale. Nanoparticles demonstrated variety of applications in environmental biotechnology, including pollution reduction, remediation, water treatment, dye degradation, and water purification development. Nanomaterials show a better performance in environmental remediation than other conventional techniques because of their high surface area (surface-to-volume ratio) and their associated high reactivity. This review aims to discuss the applications of nanomaterials in the context of water, soil, and air treatment, presenting current studies and also gives an overview of the applications of nanomaterials in environmental remediation.

Keywords: Nanomaterials, environmental remediation, nanoremediation

Introduction

Recently, environmental engineering and research are anticipated to be significantly influenced by environmental nanotechnology. The development and applications of innovative and economical technologies for pollution treatment, monitoring, and detecting have been accelerated by the nanoscale [1]. Nanostructured materials are employed as biosensors to track and identify various substances. Because nanoparticles have a significantly higher surface area on a mass basis than conventional methods, using them may be more advantageous [2]. Some nanoparticles are adsorbent of contaminants due to their special structure and electrical characteristics. Depending on their size, many nanomaterials have adsorbent properties. Due to remarkably large surface area, chemically modified nanomaterials-particularly nanoporous materials, have also garnered a lot of interest [3, 4]. To achieve the environmental detoxification, many techniques such as adsorption, precipitation, ion exchange, reverse osmosis evaporation, oxidation and biosorption etc. are in use. But environmental detoxification with much better efficiency can be achieved with the help magnetic separation. Ethylenediamine-functionalized titanium dioxide was evaluated for its capacity to extract heavy metals from polluted groundwater [5]. Large volumes of water meant for municipal water supplies are typically treated using the most popular environmental remediation methods, such as carbon adsorption, air stripping, oxidation through ozonation or chlorination and incineration, ultrafilteration, and sedimentation [6, 7]. These methods are usually employed for the elimination of pollutants on large scale. Several techniques used in science and technology to reduce pollution in the environment are diverse and include multiple approaches for purifying soil, water, and air.Surface modified magnetic nanoparticles serve the purpose and can remove pollutants from the waste water of various industries. An adsorbent which has strong affinity to target, large surface area and more sites for binding is considered as a good adsorbent. In this context, nanotechnology offers some new adsorbents for efficient removal of these pollutants from waste water [8]. It includes nanoparticles, nanopowder and nanomembrane which can be used for the detection and removal of toxic chemical substances like dye and heavy and toxic metal ions [9]. However, the adsorption process is most popular among these because of its simplicity and high removal efficiency.

Removal of contaminants using nano-sized particles

Chlorinated methanes, brominated methanes, trihalomethanes, chlorinated benzenes, other polychlorinated hydrocarbons, pesticides, and dyes are just a few of the common contaminants that can be effectively destroyed by nanoscale metallic iron, according to laboratory research [10]. Tetrachloroethene is one of the pollutants that can readily absorb the electros from iron oxidation and undergo reduction to ethane. The inorganic anions nitrate, which is reduced to ammonia [11, 12], perchlorate (with chlorate or chlorite), and subsequently to chloride [13], selenite [14], arsenate [15], arsinite [16] and chromate [17, 18], can also be reduced by nanoscalezerovalent iron (nZVI), in addition to organic pollutants. Moreover, ZVI effectively extracts dissolved metals from solutions, such as Pb and Ni [19]. When compared to granulated iron, the absorption capability of nZVI is significantly larger and the reaction rates are at least 25–30 times faster [20]. Either the metals are surface complexed with the iron oxides that are produced during the reaction, or they undergo reduction to zerovalent metals or lover oxidation states, such as Cr (III). While some metals reduce reactivity, others can speed up the pace at which organics dechlorinate and produce less harmful byproducts. A great deal of nZVI research has concentrated on soil and groundwater remediation.

Surface modification will help to tune the properties of nanoparticles because surface properties determine the interaction among the components as well as solubility and agglomeration behavior. Y.F. Shen *et al* reported effect of size tailoring and structural distortion of Fe_3O_4 nanoparticles for the purification of contaminated water in 2009 [21]. The effect of particle size on the adsorption capacity was also studied and it was found that the decrease in the size of particles enhances the adsorption capacity. Further, it was observed that particle size mainly dependent upon the valence rather than the type of counter ion of the iron salts used in synthesis [22]. The surface of nanoparticles was modified with a layer of hydrophilic and biocompatible polymer and further these modified nanoparticles were used to remove the toxic ions from wastewater. It finally comes to the point that high distorted surface results extremely high adsorption capacity. The technique explained in this is found to be very effective and can be used for biosorption, separation and recovery of heavy metal ions in industrial wastewater.

Nanosized materials can have a significant impact on hazardous waste cleaning. The optimism stems from two factors: first, the size of nanomaterials allows them to reach soil or ground water that might otherwise be unattainable and second, their specially designed coatings enable them to remain suspended in groundwater, which is a significant advantage in removal of contaminants. By removing the exorbitant expenses and hazards of transporting garbage away for burning or burial, nanomaterials might, if technically possible, drastically reduce the cost of remediation. A recent investigation on chemicals detected in wastewater could significantly enhance the environmental treatment of nanoparticle waste. The investigation, which involved collaboration between researchers from several scientific institutions worldwide, emphasised on the behaviour of possibly toxic nanoparticles in sewage treatment plants, specifically silica-shelled nanoparticles.

Technologies for remediation to remove environmental pollutants

The development of extremely effective photocatalysts that may participate part in purification processes has been aided by environmental remediation. The simple conversion of contaminants to non-toxic byproducts without the need for additional disposal steps, the use of oxygen as an oxidant and the removal of costly oxidizing chemicals, the possibility of employing free and plentiful solar energy, the photocatalyst's self-regeneration and recycling, and other benefits are all benefits of utilization photocatalysts for environmental remediation [23]. This technique is ideal for environmental remediation since it can accelerate the destruction of a wide range of organic molecules and, in many circumstances, completely oxidise organics to CO_2 and diluted mineral acids. It is also inexpensive, resistant to photodegradation, and has no intrinsic toxicity. Globally, there is a lot of discussion on the importance of addressing pollution and concerns about the environment as quickly as possible. The technologies now employed in environmental detection, sensing, remediation, and pollution removal can be radically restructured and made available via nanotechnology [24]. Nanostructured metals that decompose potentially harmful biological material at room temperature, nanosensors and nanoscale coatings that substitute thicker, more wasteful polymer coatings to prevent corrosion, nanosensors for detecting aquatic toxins, nanoscale biopolymers for better heavy metal decontamination and recycling, smart particles for environmental monitoring and purification, and nanoparticles as innovative photocatalyst for environmental cleanup are some applications of nanotechnology that are almost ready for industrialization.

Conclusion

Challenges of using nanotechnology for environmental remediation have not yet been resolved, despite the fact that several studies have been conducted to examine its usage. Further research is required to completely comprehend how nanotechnology can significantly impact the remediation of environmental contaminants in real-world case scenarios, even though numerous studies do show efficacy in laboratory settings (e.g., the treatment of polluted water, soil, and air from industrial processes). Furthermore, although the methods by which the various nanotechnologies are employed are widely recognized is well known about what happens to these materials once they have been used for the removal or absorption of pollutants. Although certain materials have been advertised as being recyclable, it seems that their effectiveness eventually diminishes, rendering them useless. To prevent these products from becoming a cause of environmental pollution themselves, study is thus required to clarify their destiny after being released into the environment for remedial reasons. For optimal utilization of nanomaterials for applications in the environment, these challenges should be removed. However, there are several techniques that may be used to address environmental pollution due to nanotechnology.

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