A Review of Nanobioremediation Technologies for Environmental Clean-up

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***Abstract*—Nanotechnology plays a pivotal role in the development of new products which substitutes existing bioremediation processes, with improved performance. The present treatment method caused several problems which make the bioremediation processes very complex and economical. This process is a long duration treatment method; this process was not effective if contaminant molecule exhibits in higher concentrations led toxic to microorganisms. The use of nanotechnology for bioremediation is an emerging field, that plays an important role in addressing environmental challenges.**

The use of nanomaterials in the bioremediation processes has resulted in cost-effective and more rapid than conventional methods of bioremediation, as nanomaterials have enhanced surface area, transport properties, and sequestration characteristics. bioremediation now become a successful tool for the treatment of pollutants due to their low economical cost and wide range of applications. The concept of nanotechnology was postulated in 1959 by Richard Feynman. Nanobioremediation is an advanced and emerging technologies for the bioremediation of pollutants. The removal of pollutants from contaminated sites using nanoparticles, mainly produced by plants or microbes, fungi or bacteria, with the help of nano-biotechnology is termed as nanobioremediation. The nanobioremediation is processes where nanoparticles and microorganisms or plants are used to remove contaminants from contaminated sites

Nanoparticles (NPs) can prepared by various physical and chemical methods Recent studies were shown that nanomaterials have been integrated with the biological processes like bioremediation to accelerate the removal of pollutants from the environmental sites.

Nowadays, it was attracting a major attention as a versatile technique for sustainable environmental clean-up.

***Index Terms*—Bioremediation, Nanobioremediation, Nanoparticles, Nanotechnology, Pollutants**

I. INTRODUCTION

Now-a-days the global requirement for domestic water, soil and air has been increasing day by day. making it impossible for industries to cope up with a better and more effective treatment of these environmental issues caused by heavy metals. [1]. Nanotechnology provides an eco-friendly alternative for the environmental safety by the natural way. Plants, fungi and bacteria are accumulating large concentrations of metals are called as hyper accumulators. Such plants, fungi and bacteria are useful for bioremediation of heavy metal pollution.

Nanomaterials can be used for removal of the environmental pollutants. Nanoparticles have obtained from such plants, fungi and bacteria, have had actual application in removing some heavy metals from polluted sites. Nanoparticles are obtained from plants, fungi and bacteria are useful for the detoxification and bioremediation of soil, water and in highly polluted conditions.

There are various methods for remediation has been designed by different industries. Due to increasing population these methods has become less efficient and costly. These methods include physiochemical methods like chemical precipitation of heavy metals, reduction in less toxic form, electrodialysis of heavy metals. [2] The field of nanotechnology and nanoremediation has vast applications in various areas like biomedicine and drug delivery, agriculture and food, cosmetics, textile, optical engineering and communication, defense metallurgy and energy sector.

Nanomaterials

Nanomaterials are that Materials which are classified as 1-100 nm in size are considered nanomaterials. They have exclusively visible properties in various applications due to its size in areas such as in

biomedicine, synergistic, and boosting of chemical reactions [3]. The structural properties of nanoparticles mainly high adsorption capacity and selectivity make them unique to be used for the elimination of pollutants from wastewater at lower concentrations [4]. Nanoparticles has atomic-level modifications that opens gateways to further novel approaches. [5].

Nanoparticles Produced by Fungi

Here the study mainly was focussed on the Fungi as they are an excellent source of many extracellular enzymes which could influences the nanoparticle synthesis. There fungi have been widely used for the biosynthesis of nanoparticles and the mechanistic aspects for governing the formation of nanoparticles.

As compared with bacteria, fungi could be used as a source for the production of larger amounts of nanoparticles because of fungi can able to secrete a larger of proteins which directs to higher productivity of nanoparticle formation [6].

The use of specific enzymes secreted by fungi in the synthesis of nanoparticles is promising tools.

Microbiological methods generate nanoparticles at a much slower rate than that of plant extracts are used. In the biosynthesis of metal nanoparticles by a fungus, enzymes are produced which are used to reduce a salt to its metallic solid nanoparticles through the catalytic effect [7].

In many industrial applications the fungi have certain properties which include high production of specific enzymes or metabolite, high growth rate, easy handling in large-scale production and low cost requirement for production technologies [8].

Fungi have an advantages over other microbes due to its wide diversity, easy culture methods, reducing time and increasing cost-effectiveness. Therefore, it has provided an eco-friendly approach for nanoparticle synthesis. Genetic engineering techniques can be employed to improve the particle properties in near future.

Soil and Groundwater Remediation with Nanoparticles

Nanoparticles can mainly use for the remediation of soil and groundwater. Environmental remediation methods are classified as adsorptive or reactive and as in-situ or ex-situ. The conventional remediation technologies include ex situ soil washing and pump and-treat operations, and in situ thermal treatment, chemical oxidation and used reactive barriers with iron [9,10]. The rapid and significant progresses in treatment of wastewater mainly including photocatalytic oxidation, adsorption, disinfection, membranes processing and bioremediation [11- 15].

There are many unique properties of nanomaterials, like high reactivity, strong sorption, are explored for application in water treatment based on their functions in unit operations [16].

Nanoparticles may have properties like high absorption, interaction, and reaction capabilities, can behave as colloid by mixing mixed with aqueous suspensions [17-18]. They have higher penetration power therefore can be treat polluted water which can generally not possible by conventional technologies [19].

Recent studies showed that Nanoscale calcium peroxide has been used for the clean-up of oil spills [20]. Nanoscale zero-valent iron for soil and groundwater remediation. Biopolymer-stabilized iron nanoparticles can degrade lindane [21].

Table 1: Examples of Nanoparticles /Nanomaterials used in Water remediation [22]

Nanoparticles / Nanomaterials	Pollutants
Nanocrystalline zeolites	Toluene, NO_2
Carbonaceous nanomaterials	Heavy metal ions
CeO_2-Carbon nanotubes (CNTs)	Benzene, toluene, ethylbenzene, xylene
Activated carbon fibres (ACFs)	p-nitrophenol benzene, toluene, dimethylbenzene
CNTs functionalized with polymers	Heavy metal ions
CNTs functionalized with Fe	Trihalomethanes (THMs)
Single-walled carbon nanotubes	Heavy metal ions
Multi-walled carbon nanotubes	THMs chlorophenols

	Herbicides Microcystin toxins
Self-assembled monolayer on mesoporous supports (SAMMS) Anion-SAMMS Thiol-SAMMS HOPO-SAMMS	Inorganic ions Heavy metal ions Actinides and lanthanides
Biopolymers	Heavy metal ions
Zero-valent iron nanoparticles (nZVI)	Polychlorinated biphenyls (PCBs) Inorganic ions Chlorinated organic compounds Heavy metal ions
Bimetallic nanoparticles Pd/Fe nanoparticles	PCBs Chlorinated ethane Chlorinated methanes
Ni/Fe nanoparticles Pd/Au nanoparticles	TCE and PCBs Dichlorophenol Trichlorobenzene Chlorinated ethane Brominated organic compounds (BOCs)
Nanocrystalline TiO_2 Nitrogen (N)-doped TiO_2 Fe (III)-doped TiO_2 Supported TiO_2 nanoparticles TiO_2 based p-n junction nanotubes	Heavy metal ions Azo dyes Phenol Aromatic pollutants Toluene

II. FUTURE PERSPECTIVES AND CHALLENGES

There is concern and more focus on greener and eco-friendly methods of remediation. The major challenges of nanotechnology included health and environmental risks due to unknown long-term effects of nanomaterials, the high cost and complexity of scaling up production. There is need for new regulations to govern it. and the societal and ethical concerns regarding its potential misuse and impact on privacy of peoples. In future, modification and adaptation of the nanotechnology will be extending the quality and length of bioremediation.

III. CONCLUSIONS

Nanotechnology has the potential to revolutionize existing technologies for pollution control. The nanotechnology has provided the potential to organize and develop production processes in a sustainable way. It has concluded from the literature that it has been focused on the development and potential benefits of nanomaterials in water treatment processes, concerns have also been raised regarding their potential human and environmental toxicity. Nanotechnology provide an effective solution for many pollutions, related problems such as heavy metal contamination, adverse effects of chemical pollutants, oil pollution.

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