

# PROSPECTS OF GREEN SYNTHESIZED NANOMATERIALS FOR THE ENVIRONMENTAL REMEDICATION

## Abstract

Worldwide disintegration of water, soil, and climate by the appearance of harmful synthetic substances from the consistent anthropogenic activities is transforming into a significant issue all through the world. This postures different issues pertinent to the environment and human prosperity that increase the application difficulties of conventional treatment innovations. Nanotechnology gives novel treatment approaches and makes developments with better advantages compared to conventional techniques. Cutting-edge technologies for the green synthesis of nanomaterials (NMs) and nanoparticles (NPs) can transform their properties for future applications by changing their size and shape. The influence of recent advancements in nanotechnology research, together with the new horizon of prospects and possibilities for improvement, has prompted the affirmation of these materials for use in environmental remediation. This paper highlights the beneficial nanomaterial applications in air, soil, and water, as well as a brief overview of the pros and cons of bioremediation, in light of the remarkable advances in nanotechnology and the urgent need to develop green, powerful, and cost-effective approaches for environmental remediation.

**Keywords:** Bioremediation, nanoparticles, air, water, soil, contamination, nanotechnology, nanomaterials.

## Authors

### Varsha Verma

School of Sciences  
MATS University  
Raipur, Chhattisgarh, India  
Varsha987verma@gmail.com

### Piyush Kumar Thakur

Faculty of Science and Technology  
ICFAI University  
Raipur, Chhattisgarh, India  
piyush.thakur25@gmail.com

## I. INTRODUCTION

As the earth's human populace has increased, natural ecosystems have declined and modifications inside the balance of natural cycles have harmed each people and exclusive dwelling systems [1]. The industrial expansion that happened during the nineteenth and twentieth century's modified into many economic and technological advancements that have essentially changed the direction of mankind. The use of correct diligence entry into the environment and connected to excessive recycling, distribution, and disposal of materials in the environment without proper safeguards have been made due to technology advancements across many techniques and goods. As a result of these factors, the protection of public health and the environment has become a recurring topic in policymaking and the enactment of new regulations, resulting in considerable investments in contaminated site cleanup [2]. Multiple severe infectious issues have been produced by the generation and non-diligent disposal of substances, posing a threat to the world's environmental, social, and economic systems. To address these challenges, effective management approaches must be implemented to achieve environmental sustainability. Sustainable remediation solutions have risen in importance in recent years, with the primary goal of reducing pollutants concentrations by lowering the risk level, as well as removing the global environmental impacts caused by greenhouse gas emissions. The bio-based strategy has already had a significant impact on environmental security. In this way, bioremediation is eminently a spotless, green, and supportable answer for the cure of tainted substances and is overall considered 'ecologically fitting'. Be that as it may, bio-based techniques are tedious and at higher pollutant fixations harmful to the creatures included for the reason.

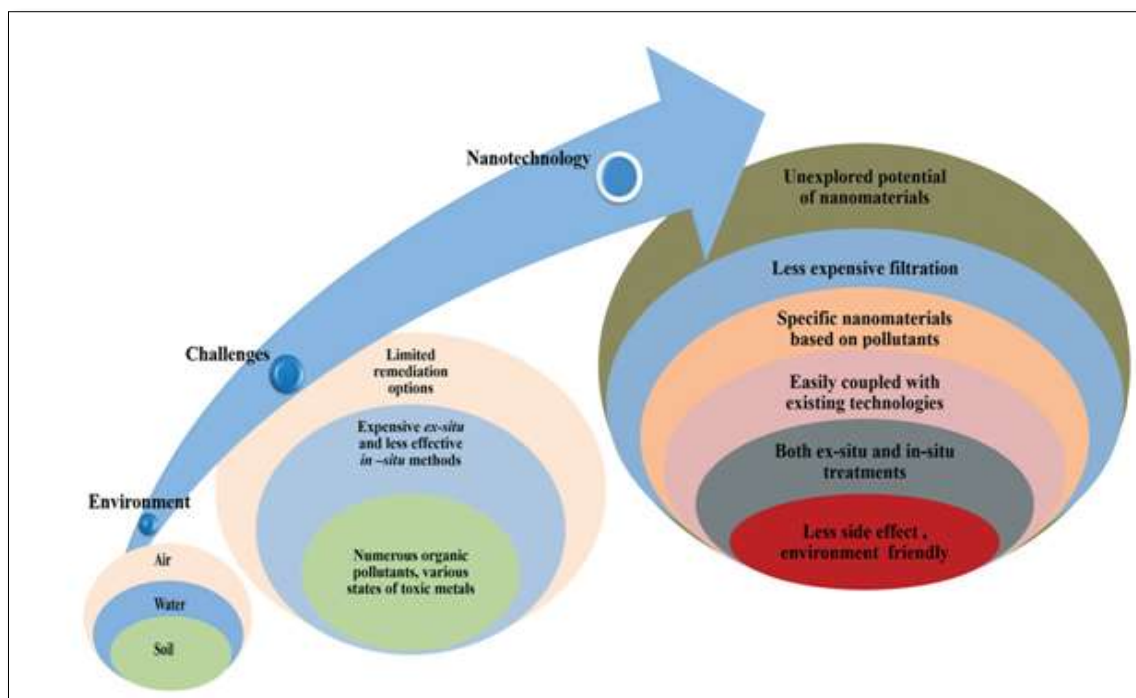
The recent rise of bio-mimetic nanotechnology has piqued academics' interest in delving deeper into this unexplored path. Nanobiotechnology encompasses all forms of living organisms and incorporates information from all branches of science and technology [3]. Because contaminants are usually identified as mixes, technology that can monitor, recognize, and treat such a tiny number of contaminants in the air, water, and soil is required. In this setting, technology that can detect, mitigate, prevent, and treat environmental pollution is required. Nano bioremediation (NBR) is the use of nanoparticles/nanomaterial framed by plants, growths, and miniature living organisms with the use of nanotechnology to remove environmental toxins (such as heavy metals, organic and inorganic pollutants) from contaminated areas. NBR is a new approach for removing contaminants from the environment for natural cleaning. Synthetic and actual remediation, cremation, and bioremediation are some of the most recent breakthroughs in decontaminated site restoration. With recent advancements, bioremediation now offers a naturally beautiful and financially viable option for removing toxins from the environment [4-5].

As of late, supportable remediation has acquired importance, which targets diminishing the focuses to chance-based levels as well as limiting the auxiliary ecological impacts comprehensive of ozone harming substance discharges, squander age, and normal asset utilization, among others [6]. Bio-based strategies comprehensive of bioremediation have demonstrated to have a magnificent capacity to be green and supportable procedures to manage sullied destinations. Nonetheless, bioremediation requires an extensive cure time, and it can now at this point don't be compelling if unnecessary pollutant fixations which can be poisonous to microorganisms exist. The combination of nanomaterials and bioremediation has a magnificent capacity to be viable, productive, and maintainable.

The following are some justifications for using NMs in bioremediation:

1. When the substance is reduced to the nanoscale, the surface area is stable while the material's unit mass increases; as a result, more of the substance may interact with the environment, which alters its reactivity.
2. NMs show a quantum impact; thus, significantly less actuation energy is expected to make the substance responses doable.
3. Surface Plasmon reverberation is another wonder displayed through NPs which might be utilized for the location of poisonous materials.

In terms of shape and size, a variety of metallic and nonmetallic NMs in a variety of shapes and sizes can be utilized to clean up the environment. It is possible to employ different single metallic, bimetallic or carbon based NMs and other materials because NPs may penetrate directly into a contaminated zone where micro particles can't reach and they have superior reactivity to redox-amenable pollutants [7]. In this review article, we're looking to compare different types of bioremediation and Nano bioremediation processes, in addition to specific bionanomaterials which remove respective pollutants from the specific medium. We additionally deal with factor which impacts the removal of pollutant in water, air, and soil.



**Figure 1:** Illustration of environmental remediation's difficulties and the benefits of using nanotechnology in environmental biotechnology [8].

**Source:** Das et al., (2018) Environ. Sci.: Nano, 5, 2784–2808.

## II. TYPES OF BIOREMEDIATION

The process of biologically decomposing organic wastes under controlled circumstances to a risk-free state or levels below concentration limits specified by regulatory authorities is known as bioremediation. Microorganisms are ideally adapted to the task of eradicating contamination because they have the necessary genetic components to ingest natural contaminants. By giving them the proper nutrients and chemical elements they require to break down and detoxify toxins that are damaging to the environment and living things, bioremediation aims to encourage them to work [9,10]. Depending on the application site, bioremediation procedures can be classed as *ex situ* or *in situ*. Some of the factors that are likely to be taken into account when choosing a bioremediation approach include the nature of the contaminant, its intensity and degree of contamination, the kind of environment, location, cost, and environmental regulations [11].

- 1. In-Situ Bioremediation:** There is no need to excavate or remove soils or water when using *in-situ* bioremediation. The pollutants are eliminated as soon as feasible in the location where they occur or at the source of contamination, resulting in lower costs, less dust, and the ability to treat a large volume of soil with minimal discharge of contaminants. *In-situ* biodegradation includes feeding naturally occurring microorganisms that break down organic pollutants with oxygen and nutrients by flowing aqueous solutions through polluted soils. It is appropriate for both groundwater and soil [12].

There are two types of *in-situ* bioremediation. Intrinsic bioremediation and designed *in-situ* bioremediation are the two types. The *in-situ* bioremediation technique involves feeding nutrients and oxygen to indigenous or naturally occurring microbial populations to increase their metabolic interest, whereas the engineered *in-situ* bioremediation technique involves the introduction of specific microorganisms to the contamination site. When site conditions aren't ideal, designed frameworks must be familiar with that particular location. Designed *in situ* bioremediation accelerates the decontamination process by increasing the physicochemical conditions that encourage the growth of microorganisms. Microbial development is aided by oxygen, electron acceptors, and supplements (nitrogen and phosphorus) [13]. This strategy has numerous potential benefits since it doesn't need unearthing of the defiled soil and therefore ends up being practical, there might be least site interruption, so the amount of soil made is substantially less, and concurrent cure of soil and groundwater is conceivable. It represents a couple of negative angles moreover because the procedure is tedious when contrasted with the other healing techniques, occasional variety of the microbial movement because of direct openness to adjustments in natural factors that can't be overseen, and hazardous use of treatment added substances [14].

- 2. Ex-Situ Bioremediation:** This process requires the excavation of contaminated soil or the pumping of groundwater to promote microbial decomposition. This methodology has more drawbacks than advantages. Starting at the earliest stage, *ex-situ* bioremediation treatments include the uncovering or termination of contaminated soil. *Ex-situ* bioremediation is divided into solid-phase and slurry segment systems, depending on the state of the contamination to be removed. These methods include removing toxins from contaminated areas and transporting them to another location for treatment [15–16].

### III. ROLE OF NPs IN BIOREMEDIATION

Nanoparticles are described as a collection of materials with at least one dimension less than 100 nanometers. A nanometer is one-millionth of a millimeter – about a millionth of a millimeter – roughly the size of a human hair [17]. Because of the quantum effect of NMs, chemical processes can occur with a lot less activation energy. Surface plasmon resonance (SPR) is a further observable fact seen by NPs that may be used to identify dangerous chemicals. Taking everything into account, different metallic and nonmetallic NMs of various shapes and sizes could be used to clean up the environment [18].

**Table 1: Bio-Synthesized Nanomaterials Applied For Bioremediation of Air, Water, And Soil.**

Types of nanomaterials	Used biological Entities	Chemical presentation	System is applied	Target pollutants	Reference
Nanoparticle	<i>Pantoeaananatis strain RNT4</i> (Microorganism)	FeO (19 - 40 nm)	Soil	Cd compounds	[19]
Nanoparticle	<i>Yerba mate extracts</i> (Plant extract)	Fe (15 - 100 nm)	Water	100 % removal capacity of Cr(VI)	[20]
Nanocrystals	Enzymatic degradation	ZnS	Water	P-nitrophenol and acid orange 7	[21]
Nanomembranes	A biological extract of <i>Cynomoriumcoccineum L.</i>	Thin-film composite polyamide	Industrial wastewater	Cyanide compounds	[22]
Nano sponge	Two organo-clays ( <i>Dellite 67G and Dellite 43 B</i> )	Cyclodextrin-based, highly cross-linked polymers	Soil	Triclopyr (3,5,6-Trichloro-2-pyridinyloxyacetic acid)	[23]

Nanorods	Desulfuromonas acetoxidans	Zno (zinc oxide)	wastewater	organic pollutant (Rhodamine B)	[24]
nano-plates and porous nano-sheet	<i>Azadirachta indica</i>	Zno (zinc oxide)	wastewater	heavy metal Cu (II)	[25]
<b>Nano-filter</b>	Gelatin	Nanofibers	Air	particle matter and toxic chemicals (e.g. HCHO and CO)	[26]
nano-silica	Maize and wheat	Ferroussulfate	Soil	As, Cd and Pb	[27]
Nano zero-valentiron gel	Rice ( <i>Oryza sativa</i> ) seedlings	carbon/alginate composite	wastewater	Cr(VI)	[28]
Mesoporous activated carbon	cellulosebased aerogel ( <i>aerocellulose</i> ) monoliths	carbonization	Ambient air	excellent adsorption properties toward CO <sub>2</sub>	[29]
nanocage	<i>Sphingomonas sp.</i>	Zn <sub>12</sub> O <sub>12</sub>	Air	Carbon disulfide (CS <sub>2</sub> )	[30]
Nanotubes	enzyme organophosphate hydrolase	Unzipped carbon nanotube (CNT)	Water and Soil	Organophosphates and heavy metals	[31]
nanotubes	<i>Dracaena trifasciata</i>	Carbon	Air	Nitrogen (N <sub>2</sub> ), methane (CH <sub>4</sub> ), carbon monoxide (CO), carbon dioxide (CO <sub>2</sub> )	[32]
Nanopowders	microorganisms	FeO nanopowder	water	Azodye direct red	[33]

Nanoparticles have distinct subordinate properties that can be dominantly due to their exorbitant surface-to-volume proportion and may prompt extremely delicate discovery, and their mass material engages them to remediate the defilement at a rapid rate with a reduced proportion of dangerous side effects. Nanosized metals or metal oxides, on the other hand, produce extreme surface areas and explicit coupling. Metal oxides, on the other hand, have the least natural effect, minimal dissolvability, and little auxiliary pollution, and have been used as sorbents to remove significant metals from contaminated areas [34]. The utilization of nanoparticles in enzyme-mediated remediation innovation is slowly making strides because of the reality they give a biocompatible and idle microenvironment that least meddling with the local properties of the catalysts and takes into account holding their natural activities [35]. A merged method comprehensive of nanotechnology and biotechnology might need to beat this imperative: complex regular blends would be sullied into less confounded blends by nano-exemplified synthetic compounds, which hence would be immediately adulterated by the joint activities of microorganisms and plants [36].

Nature has contrived various methodologies for the union of nano-and miniature length scaled inorganic materials which have added to the advancement of generally new and in huge part neglected spaces of examination dependent on the biosynthesis of nanomaterials [37]. There are approaches for nanoparticle union, the hierarchical and base up. Hierarchical methodologies looking for to make nanoscale objects by utilizing bigger, remotely controlled minuscule gadgets to coordinate their get together, while granular perspectives attempt sub-atomic parts that are built up into more unpredictable congregations. The hierarchical strategy regularly utilizes microfabrication strategies where remotely controlled instruments are utilized to cut, factory, and shape materials into the ideal shape and size. Micropatterning procedures, which incorporate photolithography and inkjet printing are generally known instances of the hierarchical methodology. Then again, granular perspectives utilize oneself collected properties of single particles for some valuable conformity [38, 39].

The fundamental response occurring during the base-up biosynthesis of nanoparticles is reduction/oxidation. The breakdown of metallic combinations into their nanoparticles is frequently attributed to microbial proteins or plant phytochemicals with cell strengthening or decreasing capabilities. The creation of nanomaterials is as of now assessed to be in the large numbers of tons worldwide and is relied upon to increment significantly soon [40]. The benefit of the utilization of plants for the combination of nanoparticles is that they're effectively accessible, protected to deal with, and have a wide fluctuation of metabolites which could support a decrease. An assortment of plants is and by being researched for their part in the blend of nanoparticles. While growths and microorganisms require a nearly longer brooding time for the decrease of metal particles, water-solvent phytochemicals do this in a lot lesser time. Along these lines, in contrast with microorganisms and organisms, plants are a better possibility for the union of nanoparticles. Taking utilization of plant tissue custom strategies and downstream handling systems, it's far practical to combine metallic just as oxide nanoparticles on a modern scale once issues including the metabolic status of the plant are appropriately tended to. It is obvious from accumulated data that the impact of nanoparticles shifts from one plant to another and relies upon their method of utilization, size, and focus [41]. Nanoparticles might conceivably be utilized for the remediation of soil and groundwater. Nanoparticles, having high assimilation, association, and response abilities can act as colloids by blending in with watery suspensions, and they likewise can show quantum

size impacts. They can infiltrate further and subsequently can treat water/wastewater, which is typically impractical by customary advances [42- 44].

**1. Nano-Bioremediation for Air:** A dangerous atmospheric deviation is an air issue that changes land, water sources, and the environment. Ozone-depleting substances (GHGs) (IPCC, 2014)–CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, and fluorinated gases – can remain in the environment for a long time. Air contamination can be made up and treated by different strategies that utilize nanomaterials as adsorbents [45]. Air quality has an impact on human health and can result in a variety of deaths (cancer, respiratory and cardiovascular). Because of their considerable monitoring qualities, enhanced nanosensors, and reduced pollution by substituting harmful compounds with other safe materials, nanomaterials can be used in a variety of sectors. The benefits of nanotechnology in combating air pollution can generally be divided into three categories: recovery and treatment, recognition and examination, and contamination avoidance [46].

Nanoscale adsorbents can solve or vastly enhance a variety of problems, including air quality. Because of the typical pore width, pore-volume, surface region, and surface region action, carbon nanostructures are adsorbents with excellent selectivity, like, and limit [47].

New ways for adding metal oxide nanocatalysts can help to reduce and possibly eliminate air pollution. Ag, Fe, Au, and MnO nanofibers can be used to control the environment for the capacity of unpredictable natural combinations from current smoky energizes and have beneficial effects, such as removing CO and dissolving trichloroethylene (TCE). The ZnO photocatalyst is a concept that is being developed. At 400 ppb, which is a typical value for indoor air quality, the bismuth oxybromide microspheres impetus (BiOBr) of nanoplate microspheres was used to reduce NO impacted by noticeable light [48]. Self-cleaning coatings made of titanium dioxide (TiO<sub>2</sub>) nanoparticles with photocatalytic characteristics are capable of neutralizing atmospheric pollution (nitrogen oxides, VOCs, and other pollutants for less hazardous species) [49].

Expanding energy interest and the need to diminish ozone-harming substance outflows will prompt the utilization of energy from inexhaustible sources and the change of CO<sub>2</sub> and water into fuel utilizing sun-oriented fuel [50]. Nanotechnologies had fostered a few new carbon nanomaterials used to catch CO<sub>2</sub>, and nanocatalysts are liable for synergist transformation of CO<sub>2</sub> and H<sub>2</sub>O into fuels, decreasing industrial CO<sub>2</sub> emanations, diminishing Earth's warming, and producing extra fuel sources. The wide scope of nanotechnologies' applications affirms that nanotechnologies likewise represent a danger of nanoparticles being transmitted, which requires a comprehension of their versatility, bioavailability, and circulation across the natural pecking order, sway on the environment and wellbeing [51].

Air contamination can be controlled utilizing semiconductor photocatalytic recuperation materials. The dynamic surface is a significant piece of the impetus where the response happens. As the size of the impetus diminishes, its dynamic surface expands, which prompts expanded response productivity. Nanotechnology further develops molecule size and atomic design of new nanocatalysts with the expanded surface region performs fast and particular synthetic changes with amazing item yield combined with



catalyst reduction capability [52]. Nanostructured membranes with small enough pores to isolate poisons from exhaust and residue are another technique to deal with air pollution control. Antimicrobial elements such as silver nanoparticles and copper nanoparticles are commonly used in air filtration technologies to expel bioaerosols through air cooling procedures [53].

- 2. Nano-Bioremediation for Water:** Nanotechnology, as we probably are aware in its advanced and post-present day structures, is the youthful part of information however humanity has experimentally utilized it for millennia. As aforementioned, coordination of traditional bioremediation and nano-biotechnological approach or direct nano-remediation procedures could be the practical alternative that could immerse the contamination from the climate. In another examination, silver nanoparticles at nanostructure incubated with Congo red containing *Aspergillusniger* extract showed over 85.8% decolorization within 24 hours [54]. Because of the fast energy and high adsorption limit of metal and metal oxide nanoparticles, numerous studies on contaminant evacuation have been dedicated to the expulsion of heavy metals and organochlorine chemicals from water. In watery conditions, nanoparticles can be used for both in situ and ex-situ purposes [55].

Titanium oxide (IV) nanoparticles are used in water purification, air refinements, self-cleaning of surfaces, and as an impetus for water treatment because of their low cost, non-toxicity, semiconductor, photocatalytic, electronic, gas affectability, and energy-changing capacity [56].

Water treatment and sunscreen are just two of the applications for polymer nanoparticles. Polymeric nanoparticles exhibit amphiphilic characteristics, with hydrophobic and hydrophilic sections in each particle, according to the same comparative rule as surfactant micelles. Crosslinking occurs before the collecting of particles in polymer nanoparticles, ensuring that their solidity is maintained. As a remediation expert, amphiphilic polyurethane (APU) nanoparticles offer a lot of potential [57, 58]. Because of the customizable capabilities and amazing features of NMs, nanotechnology has emerged as a powerful and effective breakthrough in wastewater treatment that overcomes the limitations of existing cycles. The ability of nanotechnology to destroy some types of refractory materials almost completely is critical for the advancement of this field [59].

The three fundamental applications are

- Because of a very high explicit surface region, more open sorption destinations, and lower intraparticle diffusion, nano-adsorbents, which are made of either carbon-based or metal-based NMs, have a high efficacy on adsorption of natural contaminants, and for metal expulsion [60].
- membrane frameworks made of nanofibers or nanocomposites, which have the potential to improve membrane penetrability, fouling resistance, mechanical and thermal stability, and provide new roles for pollutant degradation [61].
- nanocatalysts, with a focus on photocatalysts such as  $\text{TiO}_2$  [62].

This wastewater treatment application allows for the rapid and efficient removal of metals, as well as a variety of natural contaminants such as hydrocarbons, perfluorooctanoic corrosive, medicines, personal care items, and antibiotic-resistant bacteria and genes [63-65].

Besides, staying away from unseen side-effects on indigenous habitats is the principal issue for the successful selection of this innovation. Truth be told, the utilization of nanotechnology will prompt the arrival of ENMs in water and in sludge, from where they will probably enter regular environments [66].

Alternatively, bioremediation processes provide promising outcomes for the evacuation of metals, in any event, when present in exceptionally low focuses where physicochemical expulsion techniques neglect to work. Moreover, this is an eco-viable and economically feasible option. The bioremediation procedure depends on the high metal binding capacity of natural specialists, which can eliminate substantial metals from defiled destinations with high effectiveness. In such a manner, microorganisms can be considered a natural device for metal evacuation since they can be utilized to concentrate, eliminate, and recuperate heavy metals from tainted oceanic conditions [67-68].

Marine algae have great metal biosorption abilities because of the presence of active functional groups on the outside of their phone walls. The use of marine *macroalgae* as activated carbon materials enjoys various benefits including minimal expense, broad accessibility, and high metal restricting proficiency [69-70]. A range of human waste operations, result in heavy metals being present in the soil, aqueous solution, or streams. When discovered in high concentrations in soil, all heavy metals have a harmful effect and must be removed or changed. Microorganisms can be used as cation sorbents to remove heavy metal cations from industrial effluent and recover metals from their solutions [71].

- 3. Nano-Bioremediation for Soil:** Heavy metals defiled in the soil can aggregate and endure for long periods and might be harmful to fundamental cycles associated with microbial supplement cycling [72]. Heavy metals can assume a part as micronutrients, however, they can likewise be poisonous to people, e.g., Hg, Pb, Cd, Cu, Ni, and Co, contingent upon the exposure levels [73]. Because of their toxic nature, most heavy metals cause a few medical issues like kidney harm, cerebrum work issues, and sensory system decays. Their toxic side effects are sleep deprivation, crabbiness, iron deficiency, unsteadiness, and muscle shortcoming [74].

Mining and refining metals, using nonrenewable energy sources, using composts and pesticides in agriculture, manufacturing batteries and other metal goods in businesses, sewage muck, and civil waste removal are all examples of these activities [75].

Natural methodology (bioremediation) on the other hand energizes the foundation/restoration of plants on dirtied soils. It is harmless to the ecosystem approach since it is accomplished through natural cycles. Alternately, heavy metals might change soil properties particularly soil organic properties. [76-77].

Furthermore, heavy metals' harmful impact on the development and activities of soil tiny organic entities may have an impact on plant growth. A decline in beneficial soil microorganisms brought on by high metal concentrations, for example, could lead to a drop in natural matter breakdown, resulting in a loss in soil nutrients. Interference of heavy metals on soil microbial activity may also stymie important enzyme activities for plant metabolism. These negative consequences (both direct and indirect) result in a reduction in plant development, which occasionally results in plant death [78]. Rice plants growing on soil contaminated with 1mgHg/kg showed a significant drop in height, according to Kibra. At this level of Hg in the soil, tiller and panicle development were similarly reduced. When Cd levels in the soil solution were as low as 5mg/L, wheat plants showed a reduction in shoot and root growth [79].

Heavy metals cannot be destroyed during bioremediation; instead, they must be converted from one organic component to another. Heavy metals' oxidation states can be modified to make them less toxic, easily and less water dissolvable [80]. *B. subtilis* converted selenite to the less toxic elemental Se, according to Garbisu et al. [81].

Phytoremediation is a type of bioremediation that involves the use of plants to treat contaminated soils. Phytoremediation of heavy metal-contaminated soils can be achieved using a variety of methods. Phytoextraction, phytostabilization, and phytovolatilization are among these components. Reeves and Baker described a few plants that can accumulate high levels of heavy metals and, as a result, can be used in remediation plans. *Haumaniastrumrobertii*, *Aeollanthussubacaulis*, *Maytenus bureaviana*, *Minuartia Verna*, and *Agrostis tenuis*, and *Dichapetalum gelonioides*, *Thlaspitatrense*, and *Thlaspi caerulescens* are some of these plants [82]. Raskin and Ensley discovered that there are no plant species that can hyper-accumulate Hg. As a result, genetically modified plants are commonly used in phytovolatilization. *Nicotianatabacum*, *Arabidopsis thaliana*, and *Liriodendron tulipifera* are examples of transgenic plants that have been used to phytovolatilize Hg-polluted soils [83]. Phytovolatilization is commonly used to treat soils that have been contaminated with mercury [84]. Phytovolatilization can also be used to clean up soils that have been contaminated by Se. *Brassica juncea* and *Brassica napus* have both been successfully used for phytovolatilization of Se-contaminated soils [85, 86].

Biochar is an organic substance that is now being researched for use in the management of heavy metal contaminated soils. Because biochar, unlike most other natural additions, has the ability to raise soil pH, it may have boosted the sorption of these metals, lowering their bioavailability for plant uptake [87]. When polluted soil was modified with biochar, Namgay et al. found that the availability of heavy metals decreased, which lowered plant absorption of the metals [88, 89].

#### IV. THE ADVANTAGE OF BIOREMEDIATION

It takes a brief period, as a worthy waste treatment measure for polluted material like soil. Microorganisms can debase the impurity and expansion in numbers when the toxin is available. At the point when the pollutant is debased, the biodegradative populace becomes decays. The residues for the treatment are generally innocuous products including water carbon dioxide and cell biomass.

1. It requires next to no exertion and can frequently be done nearby, regularly without causing a significant disturbance to typical activities. This also avoids the need to carry large volumes of garbage off-site and the potential risks.
2. It is administered at a reasonable cost since it costs less than the other common methods used to clean up hazardous waste. a crucial method for cleaning up oil-contaminated locations.
3. This function reduces the risk of potential responsibility connected with the handling and removal of contaminated material and aids in the elimination of pollutants. Several dangerous substances can be converted into harmless products.
4. It does not utilize any hazardous chemicals. Nutrients mainly fertilizers added to make active and rapid microbial growth. Frequently, used on lawns and gardens. Due to their natural role in the environment, they are effortless, labor-intensive, and inexpensive.
5. Contaminants are eliminated rather than simply being transported to various environmental media.
6. Non-intrusive, allowing for continuous use of the site.
7. Implementation is relatively simple.
8. Effective methods for removing contaminants from the natural ecosystem that are also environmentally acceptable [90].

## **V. THE DISADVANTAGE OF BIOREMEDIATION**

1. It's only allowed to use biodegradable substances.
2. There are some fears that biodegradation products will be more determined or toxic than the original substance.
3. Biological cycles are frequently made quite clear. The availability of metabolically capable microbial populations, acceptable natural development conditions, and appropriate levels of supplements and contaminants are all important site elements for success.
4. Research is expected to create and construct bioremediation innovations that are suitable for destinations with complex combinations of toxins that are not evenly distributed in the climate.
5. Adequate performance standards for bioremediation remain a source of regulatory uncertainty. Because there is no universally accepted definition of "clean" evaluating bioremediation exhibits is difficult [91].

## **VI. RECOMMENDATIONS**

To execute the viable utilization of nanotechnology, a careful eco-safe prescient evaluation approach ought to be performed tending to the accompanying key angles:

1. Estimate the behavior of NMs in the media to be remediated, with a specific spotlight on the physical/chemical alterations instigated by natural components, which may influence their reactivity and destiny;
2. Think about the nature of the contaminants and the qualities of the contaminated media/region and its environmental elements;
3. Recognize conceivable toxicological targets of NMs and give a mechanism-based assessment of ecotoxicity in various species and more significant at the environment level.

Ecotoxicology can provide the necessary instruments to select environmentally benign and feasible NMs for ecological rehabilitation. In addition to the administrative requirements, the lack of reliable, hazard testing methodologies for NMs is now limiting the risk assessment for those projected to be used in natural applications such as nanoremediation [92]. As a result, there is a pressing need to offer comprehensive guidelines, including the best technique to conduct ecotoxicological testing of NMs to solve present constraints and issues, as well as administrative and natural strategies to support them. Regulators hope to make choices on the maximum amount of NMs that can be given in the climate, which is primarily required by stakeholders and industries. While standardized, specially created ecotoxicity bioassays can be used as screening tools to choose the most environmentally friendly plan of remediation for NMs, any risk related to their fate, behavior, or collaboration with organic parts of the media under remediation should be thoroughly investigated using a more biological system-scale approach. To maximize a remediation interaction, all plausible fate scenarios should be taken into account, from the entrance of NM into a contaminated site to their removal or degradation with the eradication of the target pollutants. NM transport models are helpful tools in the planning and selection of a nanoremediation system for a particular contaminated region, despite the absence of methodologies for in-situ evaluation of NM speciation, maturation, and agglomeration state [98]. While a few NMs revealed in the literature show exceptional performances, as far as cleaning effectiveness of water and soil, the potential security disadvantages identified with their utilization in biological systems, related to conceivable bioaccumulation [93].

## VII. RECOMMENDED STEPS IN RESEARCH

We have to research the following areas to improve the evaluation of bioremediation:

- 1. Evaluation Protocols:** Protocols should be created for incorporating the three-section assessment system. Thought ought to be given to assessing the scope of chemical pollutants and site qualities. These conventions ought to be field tried through coordinated endeavors including government, industry, and the scholarly world and ought to be liable to logical and peer audit [94].
- 2. Innovative Site Characterization Techniques:** Quick, reliable, and inexpensive site portrayal methods would fundamentally affect the ease of assessing bioremediation. Instances of important site estimations incorporate the distribution of hydraulic conductivities, contaminant concentrations related to solid or other nonaqueous stages, native biodegradation potential, and abundance of various microbial populaces. Strategies to quantify physicochemical attributes in situ are being created and could reform the capacity to handle evaluations [95].
- 3. Improved Models:** Upgrades in mathematical models are fundamental since models connect comprehension of chemical, physical, and biological phenomena. One especially encouraging progression is the utilization of demonstrating as a key part or further developed means for on location the executives, which requires an enthusiasm of the dynamic interactions among the many phenomena. As field testing turns out to be more quick and exact, an on-site decision will be restricted more by the capacity to comprehend the powerful connections than by turnover times among examining and examination [96].

## VIII. CONCLUSION

Natural pollution is a global danger that is growing every day as a result of urbanization, heavy industrialization, and people's changing lifestyles. Given this, providing people with clean air and water, as well as a sanitary environment, is a difficult undertaking. The advancement of nanotechnology has opened up a world of possibilities and opportunities for the development of desired nanomaterials with large surface-to-volume ratios and unique functions for the treatment of contaminants. Nanomaterials are used for a variety of reasons in environmental rehabilitation, including the management of natural waterways, soils, residue, industrial and domestic wastewater, mine tailings, and contaminated air. Different kinds of nanoparticles are being used because they work on some bioremediation activities that would otherwise slow down the process and impose kinetic limits on the system, resulting in the beneficial microbial debasement of environmental contaminants. Natural poisons can be chemically altered or directly adsorbent using nanoparticles (NPs). They can also help with microbial impurity remediation by immobilizing contaminants or inducing the production of remediating microbial catalysts.

In batch experiments, the synergy between nanoparticles and microorganisms for the degradation of some impurities has been demonstrated. It should be mentioned that, as far as we are aware, there are no published safety data on the long-term usage of NPs with microorganisms. In comparison to metallic nanoparticles, bio nanoparticles have benefits including biodegradability, which has a smaller environmental impact. Nanotechnologies may be employed in cleaning methods for soil, air, or water, however more affordable development methods are required. A major issue with the usage of these materials is the regulatory environment.

Finally, because it is less expensive than other technologies and has positive effects on the environment, nanobioremediation has the potential to significantly contribute to sustainability. Additionally, the variety of uses for NMs has shown significant activity in the degradation of pollutants when paired with biological therapies, opening up new approaches for dealing with environmental problems. The state-of-the-art in bioremediation technology still has to be updated due to the quickly developing science of nanotechnology. However, because these nanoparticles might affect the living biota, including human health, it is vital to evaluate the ecological risk and repercussions of their use.

## DECLARATIONS

Ethical Approval: Not Applicable

Consent to Publish: Not Applicable

Author's Contributions: Conceptualization and writing- Dr. Varsha Verma Review and editing-Dr. Piyush Kumar Thakur. We both read and approved the final manuscript.

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