NANOTECHNOLOGY A NEW APPROACH OF RECENT BIOREMEDIATION TECHNOLOGIES FOR TREATMENT OF EMERGING WATER POLLUTANTS

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ABSTRACT

Emerging pollution from various anthropogenic sources that are released in the environment is a great threat to the environment and human health. There is uncontrollable pollution being released into the environment as a result of increased rate of the industrialization these days. Bioremediation can help to solve many environmental related problems of the existing population. Nanotechnology has the potential to enhance the quality and viability of water through bioremediation processes. Use of nanotechnology for bioremediation of emerging water pollutants is creating a new economic, cleaner, cost-effective and healthier environment. Nanobioremediation is an emerging technology and can be used for remediation of various pollutants through these mechanisms including, materials based on carbon, like carbon nanotubes, dendrimers such as polymer-based material, zeolites that is silica-based materials and metal-based nanoparticles such as Zinc oxide, titanium dioxide, iron oxides, silver, copper nanoparticles etc. Nano-adsorbents, photocatalysts, nano-metals and nanoscale zero valent iron (nZVI), carbon nanotubes and nano-filtration are the techniques of nanobioremediation. Hazardous water pollutants such as heavy metals, dyes and other chemicals can remediate through advanced nanotechnology. In this study role of nanotechnology in combination with bioremediation in waste water treatment to control emerging pollutants is included.

Keywords: bioremediation; environmental; heavy metals; nanotechnology; waste water

1.INTRODUCTION

The main problem the world is facing these days is water contamination due to increase in industrialization. Water pollution is not only creating threats to human health and environment but also impacting social and economic costsFor industries and the environment to thrive sustainably, industrial effluents need to be treated in an economical manne.r The toxicity of wastewater effluents has been reduced and methods for making it sustainable have been developed [27]. Organic and inorganic pollutants are the main sources of water contamination [85].

The textile industry frequently uses synthetic and azo dyes, which also contribute to the increasing effluents [2]. These dyes cannot be removed using conventional methods or treatments, and theylast a very long time in the environment harming living things[68]. The results of using these dyes can be seen in both plants and human beings.These dyes harm the liver and kidneys and can irritate the skin and the digestive system in addition to producing nausea and vomiting and in plants dyes are inhibiting germination of seed and microbial activity and alteration in the plants' roots and shoots [63].

One of the numerous novels and effective new technologies for waste water treatment is nanotechnology.Nanotechnology has demonstrated a remarkable potential for wastewater clean-up and various environmental problems [28]. The nano-particles range from 1-100 nm having high absorbing and reacting surface. Treatment of waste water using nanotechnology has increased in so much demand because its custom costcan be managed accordingly [5].

Several nonmaterial including catalytic membranes, molecularly imprinted polymers (MIPs), nanosorbents, nanocatalysts, and hazardous microorganisms, are used to remove highly hazardous metals, harmful microbes, inorganic and organic solutes, and harmful microbes from water.Nanomaterials come in the shapes of nanowires, nanotubes, films, particles, quantum dots, and colloids.Nanotechnology is among the most sophisticated methods for treating wastewater.It has been divided into three primary groups based on the nanomaterial: Adsorbents, catalysts, and membranes at the nanoscale.On the surface of a nano-material, chemically active components with high adsorption efficiency can be combined to form nano-adsorbents[49]. Metal oxides, activated carbon, silica, clay materials, silica, and composites made of modified compounds are the materials used as nano-adsorbents [20].

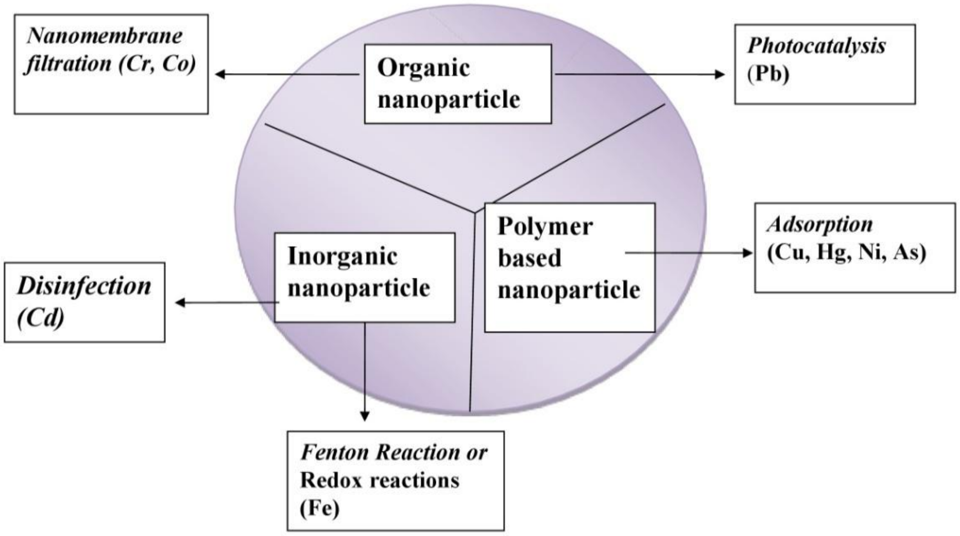

Figure 1: Nanotechnology used in water treatment.

In order to degrade waste water contaminants, many nanocatalysts are used, including electrocatalysts, [19] Fenton-based catalysts, [48] which increase the chemical oxidation of organic pollutants,and catalysts with antimicrobial effects [12]. Semiconductors and metal oxides are the non-materials that have attained interest in developing wastewater remediation technologies Nano-catalysts also help in improving degrading processes [15]. The removal of heavy metals from wastewater is also assisted by metal-organic frameworks (MOFs). By combining organic ligands with metal ion precursors, these MOFs are created Due to less steric hindrance from metals, MOFs with functional groups complementing metals can be more successful than those with organic ligands [18].

Nano-membranes are also employed in conjunction with nanomaterials in wastewater treatment methods. This method uses pressure-driven wastewater treatment. It has been shown to be excellent for enhancing desired water quality [77]. The nano-filtration (NF) is discovered to be utilised often in industries for the treatment of wastewater due to its smaller pore size, greater effectiveness, and higher efficiency [78].

In comparison to traditional approaches for environmental pollution, the surface modification chemistry with the nanomaterial's physical properties has notable advantages. An effective way to produce materials that can overcome the difficulties associated with the cleanup of contaminants is to combine nanotechnology with chemical and physical manipulation of the surface of the materials[74]. There are some key challenges for developing nanomaterials for environmental remediation such as target-specific, cost effective, green synthesis, non-toxicity, biodegradability and recyclability.Green synthesis of nanomaterials from microorganisms is contributing to environment friendly remediation of emerging pollutants[10].

Table 1: Nanoparticles used in remediation process.

Processes	**Target chemicals**	**Nanomaterials utilized**	**Novel characteristics**	**References**
Adsorbption	Organic substances, heavy metals such as chromium (IV), arsenic, phosphate mercury, DDT, PAHs, Dioxin	Iron oxides, Carbon nanotubes and Carbon-based nanomaterials like as dendrimers, polymetrs etc.	Specific surface area and adsorption sites, intra-particle diffusion distance was found to be short, concordant surface chemistry, easy to reuse	[9]
Photocatalysis	PAHs, Congo red dye, Azo dye, 4-chlorophenol, organic pollutants, and Orange II	ZnO, TiO_2, iron oxides	Solar spectrum photocatalytic activity, high stability and selectivity, cost-effectiveness, and low toxicity	[44]

Redox reactions	Nitrate, arsenate, oil, PAH, PCB. Halogenated organic compounds, metals	Nanoscale zero-valent iron (nZVI), nanoscale calcium peroxide	Transfers of electrons involved in metabolic processes, molecular signalling, photosynthesis, respiration, and the structure of their redox centres	[69]
Disinfection	Diamines, hydrogen peroxide, silver ions, halogens, phenols, formaldehyde, acridines, glutaraldehyde, and hydrogen peroxide	CNTs, titanium dioxide, and nanoscale silver	Strong antibacterial action, minimal toxicity, low cost, and high chemical stability	[5]
Membranes	Organic and halogenated organic solvents, polyethylene, 1,2-dichlorobenzene, inorganic solutes, and chlorinated chemicals	CNTs, NanoAg, and Zeolites with Magnetite	Relatively high stability, good mechanical stability, high permeability, strong photocatalytic activity, hydrophilicity, low toxicity	[5]

2. Bioremediation

A technique called bioremediation is used to remove and degrade contaminants such azo dyes, hydrocarbons, heavy metals, and pesticides into a less harmful form. It is accomplished with the aid of biological agents [40]. Bioremediation is extensively utilized to convert organic waste into less harmful chemicals. The size of the nanoparticles is very small that that permits their entry into the contaminated site and yields superior results to bioremediation techniques [23]. Bioremediation is utilized in conjunction with nanoparticles to increase the effectiveness of the process [79]. Over time, there has been a significant increase in interest in nanoparticles for the bioremediation of contaminants [11].

When the nanoparticles are used for remediation of environmental pollutants then it's being called as nano bioremediation [100]. Nano remediation is more effective and selective as compared to conventional methods.It can be utilized as sensors to assess environmental pollutants, heavy metals, and toxins [45]. Nanotechnology has many advantages as it helps in improving the already existing techniques of bioremediation [105] and this technique is much better than the existing ones, due to large surface-to-volume ratio of the nanoparticles and because of that it is capable of absorbing maximum amount of pollutants [30].

2.1. Nanoremediation of water

Nanomaterials have wide applications in waste water treatment processes as clean water is our necessity for sustainable life. Contaminated water is the main concern because of high risks to our ecosystem[86]. Heavy metals, ions, hydrocarbons, radioactive materials, pharmaceutical products and pesticides etc are the emerging pollutants in the water streams [106]. The need for water remediation research and development cannot be overstated.Many approaches based on nanoparticles have been used in the rehabilitation of water in recent years because of their characteristics, such as their selectivity to particular pollutants and their ability for absorption. The most common nanomaterials used in water remediation include carbon-derived materials, biopolymeric membranes, and metallic nanoparticles [82].

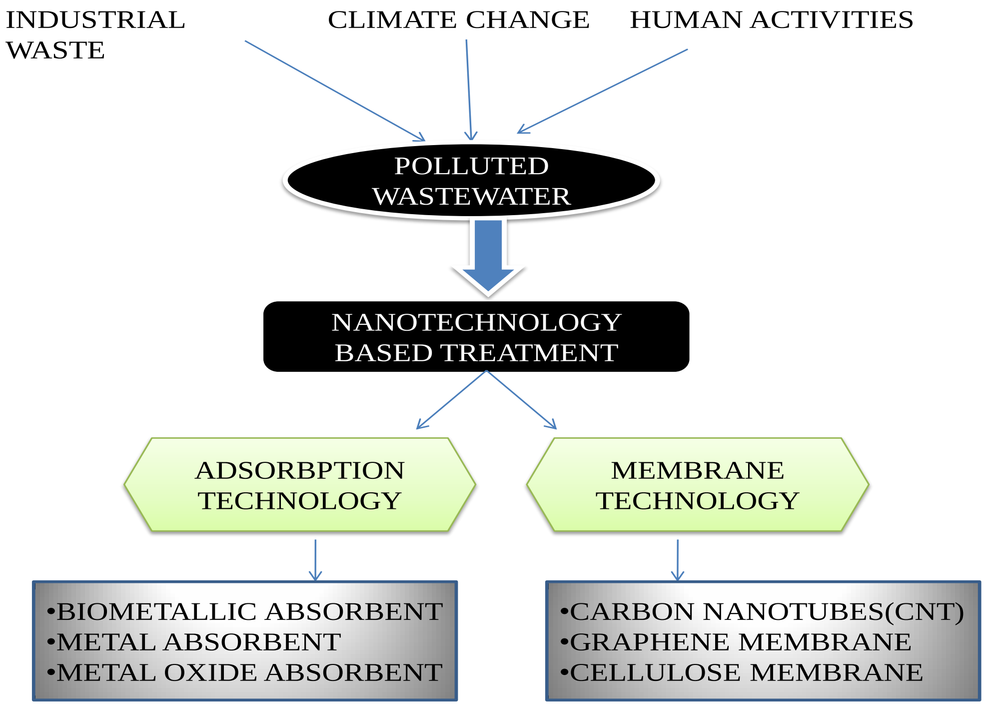

Figure 2: Waste water treatment through Nanotechnology.

3. METHODS FOR BIOREMEDIATION OF WATER USING NANOTECHNOLOGY

3.1) NANO-ADSORBENTS

Materials with nanoparticles have been investigated recently as adsorbents. The nanoparticles' reduced size enhances their chemical activity and ability to bind metal to their surfaces [26]. Nanoadsorbents exhibit a significantly higher rate of organic compound adsorption than granular or powdered activated carbon due to their high specific surface area. The adsorption process depends on the pollutant's recitation partitioning and adsorption coefficient Kd when equilibrium conditions exist, for instance when organic pollutants or heavy metals are prevalent[62]. In order to modify the ionic structure of inorganic contaminants that accumulate, redox reaction is preferred.For the heavy metal adsorption, the most often used nanoparticles include ferric oxides, manganese oxides, graphene, zinc oxides, magnesium oxide, activated carbon, and carbon nanotubes[28]. The two major characteristics of nano-adsorbents are both internal and external functionalization.Their physical, chemical, and material properties are also related to their extrinsic surface structure, apparent size, and intrinsic composition. The factors affecting the adsorption process in the aquatic environment include high surface area, adsorption activity, chemical activity, atom positioning on the surface, absence of internal diffusion resistance, and high surface binding energy[42]. Nano adsorbents alsoaids in the removal of hazardous textile dyes from the environment. Materials that are both inorganic and organic, comprising both metals and non-metals, can be utilized to manufacture it. The nano-adsorbent must be modified for effective dye molecule adsorption and breakdown into less toxic or non-toxic forms.

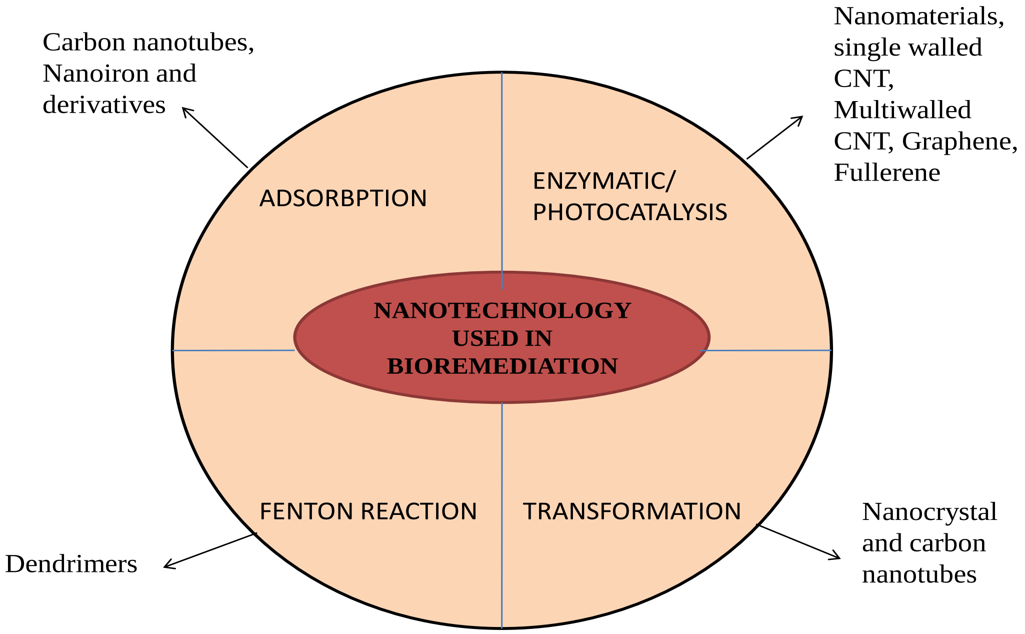

Figure 3: Methods of Nanobioremediation: A novel approach to remediate waste water through nanotechnology.

Currently, the following categories of nanoadsorbents are the main subject of research:

- carbon-based nanoadsorbents, such as carbon nanotubes (CNTs)
- polymeric nanoadsorbents: Dendrimers
- Silica based nanomaterials: zeolites
- Metal and Metal-based nanoadsorbents

Classification of nano-adsorbents

Based on adsorption process, nano-adsorbents are widely categorized into various types. It consists of metallic oxide NPs, mixed oxides with nanostructures, magnetic NPs, and metallic nanoparticles. In addition, carbon nanotubes, carbon nanoparticles, and carbon nanosheets were recently developed as carbonaceous nanomaterials (CNMs).Additionally, silicon nanoparticles, silicon nanosheets, and silicon nanotubes are also used as adsorbents in various forms Size, interface chemistry, agglomeration state, form and fractal dimension, chemical properties, crystalline structure, and solubility are the variables affecting a nanoadsorbent's characteristics [71]. When compared to other compounds like standard scale titanium dioxide and alumina, nanoparticles stand out due to their chemical activity and minute grain size[39]. Additionally, some reagents can be used to modify nanoparticles to improve their capabilities for metal ion pre-concentration [42].

3.1.1) Carbon based Nanomaterials: Carbon nanotubes (CNTs)

Carbon nanotubes are a prominent research compound with the ability to adsorb toxic metals and several organic contaminants from wastewater [80]. The two types of carbon nanotubes that have been identified are single-walled carbon nanotubes (SWCNTs) and multi-walled carbon nanotubes (MWCNTs) [46]. SWCNTs and MWCNTs are both distinct macromolecules with distinctive chemical characteristics, one-dimensional structures, and thermal stability[22]. In addition to successfully adsorbing PCBs by lowering their bioavailability from sediment, SWCNTs have antibacterial capabilities that break down bacterial cell walls by interfering with metabolic processes and/or inhibiting DNA synthesis [31]. MWCNTs also have the ability to remediate heavy metals through adsorption and antimicrobial action,lowering the risk of pollutants in soil [14].

CNT's total adsorption activity is increased via surface modification.Different researches have documented several surface modification strategies, such as acid pretreatment, [33] metals insemination, [109] and functional molecules/group grafts [13]. Acid treatment eliminates contaminants from the surface of carbon nanotubes. It also adds functional groups to the surface of the CNTs, improving their ability to absorb wastewater[28]. Grafting useful molecules or groups on the surface of CNTs is a different strategy for improving their surface properties. It can be done by using various methods such as by microwave technology, chemical alterations, and plasma technique [13]. However, the least energy-intensive and most environmentally friendly of these processes is the plasma method.He reported removing heavy metals from wastewater using modified CNTs mounted with various functional groups.The use of CNTs treated with metal or metal oxide, such as MnO_2, $Al2O_3$ and iron oxide to remove heavy metals from wastewater also show promising outcomes [89].

CNT and nanocrystals have a wide range of environmental applications, including all those sorbents, antimicrobials, and environmental sensors in the remediation of contaminants. They can be employed for the adsorption of pollutants in water used for drinking due to their attachment to a functional group, distinct adsorption capabilities, [59] mesoporous structure, and high ratio of surface to volume [84]. According to Yu [104] the methods CNT employs to absorb organic substances include hydrogen bonding, the hydrophobic effect, electrostatic interactions, and covalent bonding. They have reportedly been able to remove a variety of contaminants, including pathogenic bacteria from waste water and soil harmful organic chemicals, such as polychlorinated biphenyls and polycyclic aromatic hydrocarbons [73].

3.1.2) Polymer-Based Nanomaterials

Despite the fact that nanoparticles' high ratio of surface to volume results in stronger reactivity, better performance, the occurrence of agglomeration, non-specific, and poor stability, and the nanotechnologies' use may be constrained due to their dearth of functionality. Use of a host material, whose function is to serve as a framework or support for different kinds of materials such as nanoparticles is an alternate method to improve the stability of nanoscale materials [111]. Most commonly, polymers are used for the detection and removal of contaminated chemicals, gases, organic pollutants, pharmaceuticals, and a variety of biologics. Contaminant chemicals include manganese, nitrate, iron, arsenic, heavy metals, etc. Polymeric hosts, such as stabilizers, surfactants, and emulsifiers can agglomerate when there are polyvalent cations present [94].

Nanoparticles have a number of benefits but stilltheir limitation is particle stability. Multiple studies have demonstrated that, after synthesis, nanoparticles can assemble depending on a number of factors. Adsorption capability is decreased by particle aggregation. As alternative, polymeric NPs could be used. To prevent agglutination and increase the stability of pure nanoparticles, we need a matrix or backing material in this instance to hold the NPs in place. The polymeric host is composed of stabilizer, ligands for surface modification, emulsifiers, and surfactants.The term "polymeric NPs" refers to particles having a size between 1 and 1000 nm.To eliminate a wide range of contaminants, polymeric NPs are used [93]. These contaminants include heavy metals like Fe, Hg, Mn, and As, organic pollutants like pesticides, medications, volatile organic compounds, other aliphatic and aromatic compounds, gases like SO_2, CO_2, NO_2, and microbes like bacteria, viruses, and other pathogens.The most promising membrane technologies, according to the many notions put forth, are composites, self-assembled two-dimensional layer materials, aligned nanotube membranes, tightly packed nanoparticle and nanofiber membranes[103].

Dendrimers are nanoparticles that are typically manufactured from organic material; they do not contain carbon- or inorganic-based nanomaterials. They are branching nanoscale polymers, and their internal cavities can be utilized for medication delivery [67]. A dendrimer's surface has various chain ends that can be modified to carry out particular chemical tasks; this feature makes dendrimers effective as catalysts [24]. Highly organized macromolecules called dendrimers have a central core that is coupled to two or more repeating branching units.Dendrimers are monodispersing polymers with a particular size, solubility, porosity, high degree of molecular uniformity, and highly functional terminal groups on their surface[96].

Polymeric nanoadsorbents called dendrimers are useful for removing organic pollutants and heavy metals.While heavy metals can be absorbed by the specialized external branches, organic substances can be adsorbed by the internal hydrophobic shells [29]. Dendrimers were used into an ultrafiltration system to extract copper from water. Almost 80% of the copper ions were collected using this dendrimer and ultrafiltration technique combination. A simple pH adjustment is all that is needed to replenish the adsorbent. Sadeghi-Kiakhani[81] created a combination chitosan-dendrimer nanostructure to construct a very effective bioadsorbent for the elimination of anionic compounds, such as colour, from textile effluent. Biocompatible, non-toxic, and degradable describe the bioadsorbent. With some dyes, they can remove up to 99% of them.

3.1.3) Silica Based Nanomaterials

Due to their versatility, mesoporous silica materials have attracted interest for a variety of uses, including adsorption and catalysis. For environmental remediation applications, mesoporous silica materials have a number of advantageous properties, such as substantial pore volumes, pore sizes that can vary, a high specific surface area, and ease of surface modification [92]. The hydroxyl groups on the surface of silica materials are essential for further surface modification, gaseous adsorption, and other surface phenomena including wetting. Another well-known method for creating novel catalysts and adsorbents is to graft functional or organizational structures onto the porous walls [32]. The surface characteristics of mesoporous silica compounds and their use in adsorption processes are important.Since the early 1980s, zeolites and silver atoms have been used in combination[8]. Zeolite has an extremely porous structure that allows for the incorporation of nanoparticles like silver ions. Through exchange with other cations in solution, they are then expelled from the zeolite matrix there.When in contact with liquids, the metallic surface releases a small number of silver ions. Zeolites are effectively as a source of silver ions for a disinfectant or as an adsorbing substrate for silver nanoparticle as demonstrated in the Water Research Commission Report No KV 297/12.Zeolites can also be used as nanoparticles, [91] who developed nanozeolitesby fragmenting zeolite. Linde type A microparticles using a laser and applied nanozeolites to sequential batch reactors for the treatment of waste water.For instance, the Ag ion product line has a substance with antibacterial qualities that is created from zeolites and naturally occurring silver ions.

3.1.4)Metal and Metal-Based Nanomaterials

There are various kinds of metal oxide nanoparticles, including TiO_2, zinc oxides, and iron oxides.Because of their strong reactivity, photolytic qualities, and its adsorbent characteristics resulting from their large surface area and attraction to diverse functional or chemical groups, nanomaterials are used for water purification [7]. Because of high adsorption capability and good stability in suspension media, iron nanoparticles are utilized to neutralizecolours in polluted water from the industry sectors for textile, paint, and paper. These NPs were recently proven to be quite effective at adsorbing dyes like methyl orange and methylene blue, the most often used dyes in industries and ones that have the worst repercussions for both the environment and human health [61]. Analyzing effectiveness of magnetic iron oxide nanoparticles combined with carbon to remove methyl orange and phenol demonstrated that the interactions between the dye and the nanocomposites are higher, with the carbon concentration playing a crucial role in the NPs' adsorbent function [35]. Heavy metals are another important class of water contaminant in addition to dyes like as chromium (VI). Recent studies revealed that the inclusion of oxides of iron, zero-valent iron NPs, and organic acids could reduce the environmental harm posed by chromium (VI) [112]. TiO_2 nanoparticles (TNPs) are a popular photocatalysts for the removal of water micropollutants and a successful substitute for newly emerging contaminants like pharmaceuticals [58].

Heavy metal and chlorinated contaminants removal from water has been accomplished using metal-based nanoparticles. Metal and metal oxide nanoparticles are extremely effective adsorbents with benefits like quick kinetics and a large amount of adsorption capacity [83]. Since nanoparticles are extremely adaptable to both in situ and ex situ uses in aqueous environments, they are frequently employed for environmental cleanup [16].

a) Zero-Valent Iron (ZVI):

One of the most prevalent metals on earth is zero valent iron (ZVI) nanoparticles, which aid in environmental remediation [17]. Due to their excellent reduction potential for chlorinated pollutants, they have undergone extensive research. They also have a greater sorption capacity and reaction rates than bulk particles—roughly 25–30 times quicker [69].

b) Nanosized Zero-Valent Iron:

At the Fe0 oxidation, a number of iron oxides and hydroxide groups, including nZVI have FeOOH, FeO, Fe_2O_3, Fe_3O_4, and Fe $(OH)_3$, are present. To precipitate, and adsorb water, the Fe0 core oxohydroxide shell is required. H_2O_2 is created when Fe is oxidized in water. Reactionary radical hydroxyl (•OH) is produced during reaction with Fe_2^+[57]. A procedure or industrial activity may result in the degradation or diminishing quality of commodities, which adversely affects human health. However, scientists predict that degrading intermediates will have a substantial impact on issues related to the environment and public health.

The oxohydroxide layer precipitates water impurities in addition to the iron core. The nZVI becomes more reactive because to the redox-active environment, but the lifetime is still short due to spontaneous corrosion. It is frequently necessary to stabilizenZVI as pore carbon in polymer matrices. It has been demonstrated that nZVI can adsorb both organic and inorganic wastewater pollutants employing a range of stabilizers [91].

c) Nanosized Iron Oxide:

Due to their simplicity and abundance, iron oxide nanoparticles have recently gained attention. Maghemite (Fe_2O_3) is a nanosorbent that is both magnetic and nanomagnetic. Because nanosorbent materials are often small in size, it is challenging to separate and reclaim filthy water. As sorbent materials, they have demonstrated their efficacy in removing heavy metals from water systems L-glutathione (GSH), EDTA, Meso-2,3-dimercaptosuccinic acid (DMSA), and mercaptobutyric acid have been used to alter the adsorption properties.If they have many functional groups, the Fe_3O_4 nanoparticles can be successfully encapsulated in a flexible bonding shell. A polymer shell also increased the stability of the dispersion of nanostructures [4]. Molecules may become carriers of metal ions when they bind to those ions. Hematite has been presented as a durable, affordable sensor, catalyst, and environmental material. It has also been demonstrated that nanohematite is a superior absorber for removing ionized metal from tap water. Water treatment is now possible because to the development of microstructures that resemble flowers in 3D- Fe_2O_3. The porosity structure of Fe_2O_3 allows for effective clumping and access to contaminants via numerous active sites.

d) TiO_2 Nanoparticles:

In comparison to their bulk counterpart, because of their increased surface area per unit mass, nanoparticles offer unique traits including strong reactivity, wider reactivity, or targeting both organic and inorganic molecules, and a high surface-to-volume ratio that permits quantum effect for being take place [34]. They are the most ideal for cleaning up environmental pollutants due to their new qualities. TiO_2 has been investigated frequently as a metal-based nanoparticle with non-toxic, affordable, photocatalytic, and energy-converting properties for the remediation of environmental pollution [51].

TiO_2 has been shown to remove contaminants from water [51,70] remediate contaminants such as Cr (VI), Ag (I), Pt (II), chlorinated alkanes, benzenes, dioxins, and furans, among others [84],pesticides, dyes, and toxic compounds from waste water [76]. TiO_2 is therefore widely used in environmental remediation.

3.1.5) Oxide based nano-particles

Metal and non-metal combinations are frequently used to produce inorganic oxide-based nanoparticles.Nanoparticles are frequently employed to remove dangerous contaminants from wastewater.Other oxides include ferric oxides, zinc oxides, magnesium oxides, manganese oxides, titanium oxides, titanium oxide or dendrimers composites, and others.Greater BET surface area, lesser environmental effect, minimum solubility, and no secondary contaminants are characteristics of oxide-based nanoparticles [28].

a) Iron based nano-particles

Due to its natural occurrence and ease of management, ferric oxide is a cheap chemical for the adsorption of hazardous metals.It is an environmentally benign substance that can be utilized in hazardous areas without raising the risk of secondary contamination [52,53].Varying heavy metals are adsorbable to Fe_2O_3 nanoparticles at different rates depending on the pH, temperature, quantity of adsorbent, and incubation time. Various researchers modified the surface of Fe_2O_3 to boost its adsorption capability [95] According toPalimi[72] 3-aminopropyltrimethoxysilane was used to modify the Fe_2O_3 nanoparticles' surfaces. The alteration of these nanoadsorbents reveals a remarkable affinity for the efficient removal of a number of contaminants from wastewater [28].

b) Zinc oxide(ZnO) nano-particles

For the adsorption of heavy metals, zinc oxide (ZnO) has a porous nanostructure with a significant Braunauer-Emmett-Teller (BET) surface area. Numerous nano-adsorbents are utilized to remove heavy metals from wastewater, such as hierarchical ZnOnano-rods, nano assembly, nanoplates, and microspheres with nano-sheets [47]. The modified varieties of ZnOnanoadsorbent outperform commercial ZnO and exhibits remarkable heavy metal removal effectiveness.ZnO nanoplates and porous nanosheets were utilized[97] to remove Cu (II) from wastewater Compared to commercial ZnO, these modified ZnOnano-adsorbents exhibit high Cu (II) removal efficiency because of their distinctive micro/nanostructure.

c) Magnesium oxide (MgO) nano-particles

Several types of heavy metals are eliminated from contaminated water using magnesium oxide(MgO) MgO microsphere can increase the adsorption affinity for eliminating heavy metals [28]. Numerous changes were made to the NPs' form, which increased the MgO's ability to adsorb. The group includes nanorods, driven fishbone fractal nanostructures, nanobelts, [113], nanotubes, [102] nanocubes, [54] and 3-D objects. Mesoporous MgO, which resembles flowers, is an effective surface for the adsorption of Pb (II) and Cd (II) [52].

3.2)GRAPHENE BASED NANO-ADSORBENTS

One carbon allotrope with unique properties that make it particularly beneficial for a variety of environmental applications is graphene. When a graphite layer is chemically oxidized, a two-dimensional carbon nanomaterial known as graphene oxide (GO) is produced. The most common way for synthesizing graphene oxide is method known as Hummers method [56]. The adsorption of heavy metals is enhanced by the presence of the OH groups, carboxyl and hydroxyl in graphene oxide [50, 56]. GO is gaining increased attention as an adsorbent for the removal of heavy metals owing to its large surface area, superior mechanical qualities, lighter weight, elasticity, and chemical resistance[25]. Additionally, presence of OH or functional groups on the surface of graphene oxide has an impact on the adsorption process [107]. Furthermore, GO already has a hydrophilic functional group, thus it didn't require any additional acid treatment to increase its adsorption capacity [111].

3.3) NANOCATALYSTS

Nanocatalysts have a larger surface area and shape-dependent characteristics; they are also commonly utilized for the treatment of water because they enhance catalytic activity on the surface. Bimetallic nanoparticles, zero-valence metals, and semiconductor materials are frequently employed to degrade environmental pollutants such PCBs (polychlorinated biphenyls), azo dyes, halogenated aliphatic, organochlorine insecticides, and halogenated herbicides [99]. Using enhanced nanocatalytic activities, waste waters with specific pollutants, such as residues of selective biodegradation of halogenated organic compounds (HOCs) is possible.Fabric dyes and other organic pollutants found in wastewater can be degraded using nanocatalysts, which are powerful catalytic materials Ultraviolet (UV), visible, or fluorescent light sources are utilized for photocatalytic reduction and chemical oxidation degradation. The three main types of catalysts used for pollution remediation are electrocatalysts, photocatalysts, and nanocatalysts based on Fenton.Metallurgy and semiconductor variants of nanocatalystswere advantageous from inorganic sources for purifying water as well as removing pollutants. It possessed particular benefits including efficient cleanup, effective modification capacity, high photocatalytic activity, and selective to persistent contaminants. One of the best nanocatalysts for dye decolorization was zinc oxide (ZnO), which has a wide bandgap of 32 eV and antibacterial action against impurities equivalent to titanium dioxide (TiO_2).

According to multiple analytical investigations employing various Pd concentrations in ZnO nanoparticles, ZnO nanoparticles with palladium incorporation were discovered to have extremely great photocatalytic activity for eliminating E coli from water [43]. Palladium nanoparticles (PdNPs) have been explored for their potential to accelerate the conversion of Cr (VI) to Cr (III) during in situ remediation. Combining a catalyst with nanosorbents to bind and degrade pollutants simultaneouslyis another strategy for improving the effect. Water treatment has found nanocatalysis to be quite effective.For improving chemical oxidation of organic pollutants and antimicrobial effects, wastewater treatment processes include a variety of nano-catalysts, such as photocatalysts, electrocatalysts, and Fenton-based catalysts [48]. Because nanoparticles have a larger surface-to-volume ratio and smaller diameters than typical catalysts, they are more active, more selective, and more stable. Numerous studies are being conducted to produce nano-catalysts in an easy and eco-friendly manner[64].

3.4) NANO-MATERIALS AS PHOTOCATALYSTS

Nanoparticle photocatalytic reactions have extensive and powerful photocatalytic activity for a variety of pollutants which depends on metallic nanoparticles are of tremendous interest because of how light energy interacts with them [3]. Metal semiconductors are often used to generate these photocatalysts which are capable of degrading a number of volatile organic chemicals, pesticides, dyes, and other persistent organic pollutants in wastewater [55]. Additionally, under certain conditions, PCPPs, heavy metals, organic molecules with halogens and without halogens can all are decomposed very efficiently by semiconductor nano-catalysts [1]. Semiconductor nano-materials operate under reasonably benign conditions and perform well even at low concentrations. Basic principle behind how photocatalysis functions is an electron inside the catalyst is photoexcited.

In conduction band, UV light irradiation causes holes (h+) and ejected electrons (e) to generate Hydroxyl radicals (OH) are produced in an aqueous medium when water molecules capture holes (h+) [6]. Radicals are a powerful and ruthless oxidizing agent. These hydroxyl radicals transform the organic pollutants into liquid and gaseous breakdown products[3]. Because of its chemical stability and high UV reactivity, TiO_2 is one of the nano photocatalysts that have been produced up to this point that has been used the most in photocatalysis [3]. Similar to TiO2, ZnO too has a broad band gap and has been widely explored for its photocatalytic activity [55]. Their effectiveness is influenced by a variety of variables, including pH, particle size, dosage, and band gap energy.ZnO's photocatalytic degradation efficiency was reduced by excessive calcination temperature, which causes particle size rise because of agglomeration CdS is a widely used semiconductor with bandgap of 242 eV and an operating wavelength range of 387 nm. This is caused by the TiO_2-like broad band gap energy of 32 eV. As a result, additional catalyst modifications have been investigated to boost their activities for the breakdown of organic contaminants under visible light sources [19].

3.5)NANOFILTERS

Nanofiltration is a regulated pressure filtration technique that uses an organic membrane that is semi-permeable with incredibly small pores, typically between 0.1 and 10 nanometers and 1 nanometer [66]. At a pH of 7, surface charges on nanofiltration membranes are modest. This negative surface charge is vital to the separation qualities and transit mechanism. The pressure-driven cross-flow method known as nanofiltration is characterized by membrane pores with working pressures of 150-200 psi and molecular weight restrictions of 200-1000 Daltons [75].

Nanofiltration is the most effective and widely utilized method of wastewater treatment. Pollutants, both organic and inorganic, are removed using it. High adaptability, cheap cost, and easy manufacturing are just a few of the benefits of nanofiltration. The two types of nanofiltration membranes now in use are polymeric and ceramic membranes [37]. In recent studies, polyphenylsulfone nanofiltration membrane with carboxylated graphene oxide incorporation was employed to filter out heavy metals [87]. A nanofiltration membrane was created by layer-by-layer assembling sodium lignosulfonate, chromium, and copper on a polysulfone (PSf) membrane surface using cross-linking technology. Cadmium, zinc, lead and other heavy metal ions may be removed by this nanofilter membrane with an efficiency of over95%.

To increase permeability potential, catalyse reduction, and prevent membrane fouling, nanoparticles were used in the production of the majority of membranes. It has several advantages, including as simple manufacture, affordable manufacturing, minimal energy requirements, limited area requirements, and successful remediation [101].

4) APPLICATIONS

Water purification membranes are being manufactured using nanotechnology. Threonrecently reported the following nanomaterial-based water filtration membranes: nanostructured membranes made of nanomaterials like Carbon nanotubes, nanoparticles, and dendrimeres, as well as nanoreactive membranes made of metal nanoparticles and other nanomaterials [90]. Adsorption, on the other hand, is regarded as an effective, efficient, and cost-effective method of removing water contaminants [38]. Activated carbon, clay minerals and silicas, zeolites, metal oxides, and modified composites are all effective adsorbents [108].

Many scientific studies have demonstrated the effectiveness of TiO2-mediated photocatalyst in the decomposition of organic compounds in water as well as the disinfection of water under UV light [98]. Nanotechnology for water remediation would be essential for worldwide water security and, by extension, global food security. Smith summarised the applications of nanotechnology in the cleanup of contaminated water [88]

- Nanoscale filtration techniques;
- Pollutant adsorption on nanoparticles;

- Contaminant breakdown by nanoparticle catalysts.

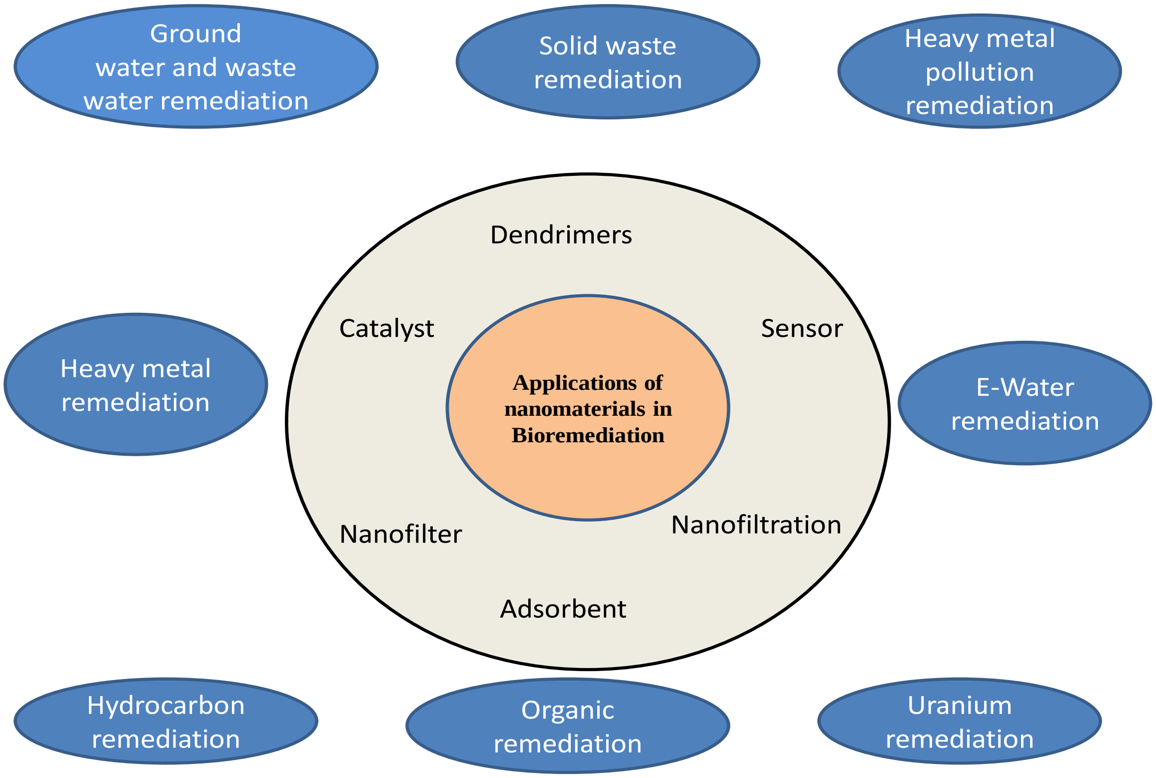

Figure 4: Applications of nanomaterials in Bioremediation.

5) CONCLUSION AND FUTURE PERSPECTIVE

Due to their small surface area and high adsorption and selectivity potential for wastewater treatment, there is a significant need for advanced water technologies in the current environment to ensure high water quality, eliminate chemical and biological pollutants, and intensify industrial wastewater production processesEach nanotechniqueshave advantages and unique ability to remove pollutants The nano-adsorbents are successfully filtering the wastewater to remove heavy metals as Cr, As, Hg, Zn, Cu, Ni, Pb, and VdUsing nano-particle photocatalysts, which have been modified to facilitate for the use of solar light in the visible spectrum rather than expensive artificial ultraviolet radiation, is an effective method for treating both harmful contaminants and heavy metals Nano membranes have been shown to be very successful at reducing foulants, heavy metals, dyes and other contaminants in wastewater treatment processesNanotechnology is crucial in the development of innovative goods that can replace current production processes with higher performance with low cost In addition, the development of production processes in a more environmentally friendly manner, eventually approaching zero emissions, is a potential benefit of nanotechnology Without endangering the environment, nanotechnology may offer environmentally beneficial alternatives for environmental management Nanotechnology has a bright future in the field of water treatment, but this future depends on the government and the scientific community maintaining a true and dedicated level of oversight To assess the possible ecotoxicity of each new nanoparticles change, further work and research are required

Finally, nanobioremediation has the potential to make a significant contribution to sustainability because it is inexpensive compared to other technologies and offers environmental benefits Furthermore, the variety of applications for nanomaterials combined with biological treatments have shown high efficacy in the degradation of contaminants, opening up new avenues for addressing environmental issues.

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