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Nano-Bioremediation for Environmental Pollutions – A Review

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Abstract: Water and soil play significant roles in the everyday existence of humankind. It is important to keep up with them beneficial to avoid contaminants. The difficult task of this century is to tidy up the contaminants blended with the environment through eco-accommodating, maintainable, and financially adoptable advancements. Nano-bioremediation is one of the new rising techniques for remediation of contaminations utilizing green synthesized nanoparticles. Nano-bioremediation is yet another territory, however, quickly pulling in much intrigue among researchers. Such a significant number of biogenic nanoparticles have been tried and yielded excellent outcomes. The biosynthetic green incorporated nanoparticles could develop as a superior and more secure option in contrast to traditional strategies. This review covers the effective use of green synthesized nanoparticles in the remediation of the environment.

Keywords: nano-bioremediation; green synthesis; pollution; heavy metal removal; dyes.

1. Introduction

Nanotechnology is a quickly developing logical field that has attracted extraordinary interest throughout the past couple of years due to its plentiful applications [1-5]. The green procedures for the union of different nanoparticles have advanced into a significant part of nanotechnology and made generous interest in the territories of concoction, electronic, and organic sciences. The biogenic courses could be named green as these do not include using exceptionally poisonous synthetic compounds or raised vitality contributions during the union. The advancement of safe eco-accommodating strategies for biogenetic creation is currently of more enthusiasm because of the effortlessness of the methods and adaptability [6]. Green nanotechnology presents various potential ecological advantages, for example, creating a research zone, filling in as a significant strategy that underscores making the technique spotless, non-dangerous, and particularly earth benevolent, conversely with substance and physical strategies as now utilized for nano synthesis. Because of their amiability to organic functionalization, natural nanoparticles are finding significant applications in medication. The antimicrobial capability of metal-based nanoparticles has prompted its fuse in buyers, well-being-related, and mechanical items [7].

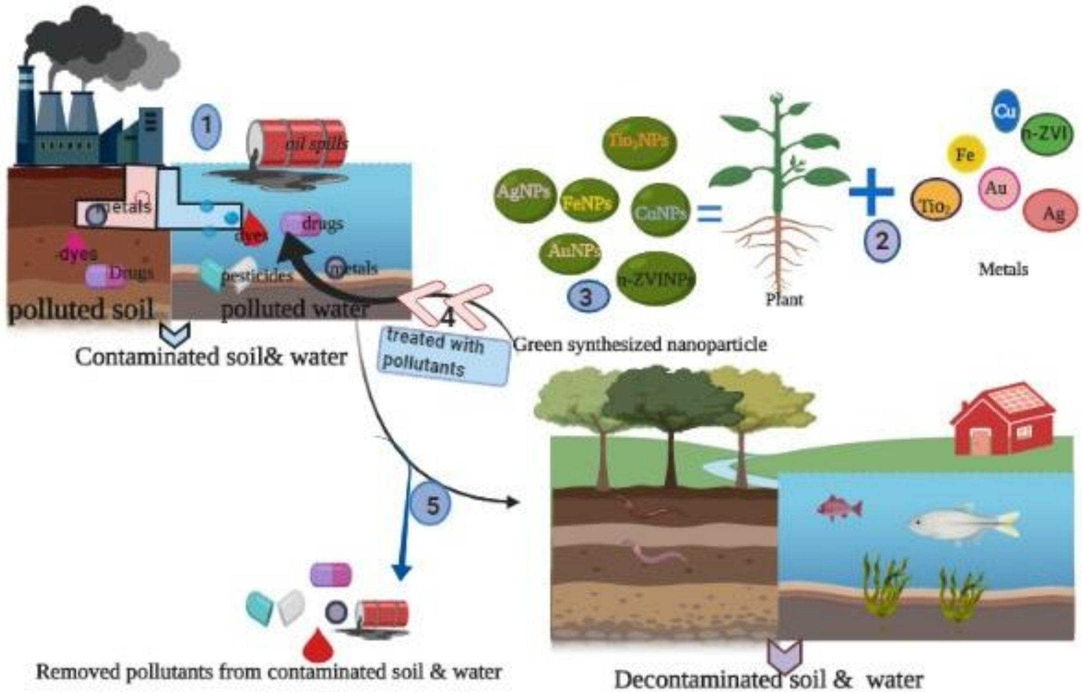

Figure 1. Schematic diagram of removal of contaminants from soil and water**.**

Due to fast industrialization, numerous contaminants enter earthly and aquatic environments daily, which deserves genuine natural concerns [8]. Land and water are valuable characteristic sources that depend on the manageability of agriculture and the civilization of humankind [9]. The contamination incorporates effluents, and substantial metal squanders from mining and purifying vehicle weariness, pesticides, bug sprays, and natural salts that were blended in with water and soil and causing critical dangers to nature.

Utilization of bug sprays/pesticides, removal of mechanical and city squanders in farming, and over-the-top utilization of composts may make greater dangers in nature. All the heavy metals at high concentrations have solid harmful impacts and are viewed as natural toxins [9,10]. Various endeavors have been embraced recently to discover techniques for expelling heavy metals from the soil, water, and different environments using green synthesized nanoparticles, such as phytoremediation. Plant vegetation plays an inexorably significant biological and sterile job for artificially contaminated terrains. Proper management of plants in such territories may add to reestablishing the regular habitat. Phytoremediation is a cost-effective, innovative technology for environmental cleaning. This review is intended to compose the ongoing nano-phytoremediation examinations for reestablishing the natural environments.

1.1 Green synthesis of nanoparticles.

The usage of plant frameworks has been viewed as a green course and a dependable technique for the biosynthesis of nanoparticles inferable from its amicable ecological nature. Utilizing biological material as reducing agents for the creation of metallic NPs is currently the subject of different investigations. Nature has formulated different procedures for the blend of nano and small scale length scaled inorganic materials, which have added to the advancement of relatively new and, to a great extent, unexplored regions of exploration dependent on the biosynthesis of nanomaterials. Synthesis using bio-organisms is compatible with green science standards. "Green synthesis" of nanoparticles utilizes eco-friendly, non-toxic, and safe reagents [9,11]. The green amalgamation of nanoparticles was associated with different steps. To reduce metal particles, 5 ml of plant extract was included dropwise into 1 mM metal solution made with metals like Ag, Au, Cu, Pt, etc. While adding the plant concentrate to the metal arrangement, the response blend transformed into a shaded arrangement demonstrating nanoparticle formation. At long last, the sample was centrifuged for 20 minutes, and the pellets were lyophilized and stored at 4° C for additional utilization.

1.2. Characterization of nanoparticles.

Different techniques were used for the measurement of the nanoparticles. Morphology like size, shape, and size distribution of the nanoparticles was measured using TEM (Transmission electron microscopy), SEM (Scanning electron microscopy), XRD (X-ray diffraction), PCS (Photon correlation spectroscopy), UV-viz spectrum, DLS (Dynamic light scattering) [12,13].

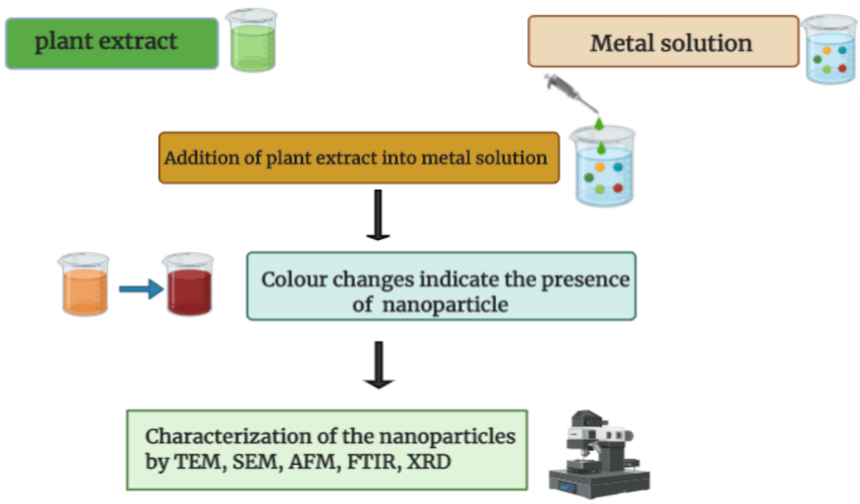

Figure 2. Schematic diagram of green synthesis of nanoparticles from plant extracts.

2. Soil Pollution

Soil is one of the precious natural sources that rely on the sustainability of civilization and the agriculture of mankind. Therefore, contaminated soils are a major priority environmental issue in many countries around the world. Industrial wastes containing hazardous chemicals, toxic substances, and heavy metals are exposed and deposited on the soil surface, leading to higher environmental risk. So, it is important to develop remediation technology to clean contaminated soil efficiently and effectively.

2.1. Degradation of dyes from contaminated soil.

2.1.1. Removal of crystal violet dyes using novel soil - Ag nanocomposite in soil.

Crystal violet dye is carcinogenic and highly toxic, leading to a significant environmental risk. Satapathy *et al*. [11,14] synthesized silver nanoparticles by green synthesis method using the leaf extract of *Azadirachta indica*. For this purpose, the removal efficiency and adsorption capacity was evaluated. The time cycle for degrading dyes using AgNPs nanocomposite shows a removal efficiency of 97.2%. Satapathy *et al*. repeated the same experiment using the same plant and nanoparticles but did different methods to eradicate the crystal violet dye in soil effluents. Surface methodology and desirability function in response surface methodology (RSM) were used to eradicate the crystal violet dye in soil. For optimization, the two-level three factors (2^3) factorial center composite design (CCD) was used to evaluate the parameters, effects, and certain factors. For this purpose, the pH, time requirement, and agitation speed were calculated. The results show that the removal efficiency in optimum conditions was 99.995% under certain factors at o4.68 pH level, agitation speed 106, and time contact of 30 min to remove the maximum crystal violet in the soil surface. These results show that green nanoparticle synthesis is effective against the degradation of crystal violet dye in soil using the surface methodology.

2.1.2. Removal of turquoise blue dye in soil using AgNPs nanocomposite

Turquoise blue is a reactive dye widely used in the textile industry to natural color fibers. This dye has hazardous chemicals and toxic agents that are deposited and contaminate the soil, leading to a significant environmental risk. Satapathy *et al*. [11,14] synthesized silver nanoparticles by green synthesis method using the leaf extract of *Ocimum tenuiflorum* (Black Tulsi) to investigate the degradation of turquoise blue dye from effluent soil. The bioreduction process was carried out to eradicate the dye from contaminated soil. The results show that the green synthesized nanoparticles express 96.8% removal efficiency against the contaminated soil sample. These results show that using the bio-reduction process, the green synthesized silver nanoparticles (AgNPs) are effective against degrading reactive turquoise blue dyes in soil effluents.

2.1.3. Degradation of gentian violet dye using AgNPs for soil effluents.

Gentian violet dye is an antiseptic dye. It can be used to assist a variety of fungal infections. The overexposure of gentian violet dye to soil can cause environmental defects. Sharma *et al*. [15-17] synthesized silver nanoparticles by green synthesis method using two different plant sources, such as neem leaf (*Azadirachta indica)* and basil leaf extract (*Ocimum sanctum*), to degrade the dyes in contaminated soil. Various experiments were carried out to eradicate the gentian violet dyes by green synthesized silver nanocomposite. Thermodynamics, kinetics, and absorption isotherms were also evaluated. The results explain that the silver nanocomposite from basil leaf provided 99.4% removal efficiency of gentian violet dye, and 98.1% were recovered for neem leaf extract. These results confirmed that the silver nanocomposite from different sources of plants was effective against the degradation of gentian violet dye from the soil effluents.

2.1.4. Removal of poly aromatic hydrocarbons in soil using iron hexacyanoferrate.

Polycyclic aromatic hydrocarbons (PAHs) are a class of persistent organic compounds released into the environment due to natural and anthropogenic activities. PAHs are toxic agents with persistent increases in molecular weight that lead to environmental risk. Shanker *et al*. [18] investigated how green synthesized nanoparticles are used to degrade the poly aromatic hydrocarbons (PAH) in the contaminated soil. For this purpose, iron hexacyanoferrate (FeHCF) nanoparticles are synthesized using the leaf extract of *sapindus - mukorossi* by the green synthesis method. Synthesized nanoparticles were exposed against the soil containing hazardous PAHs, namely BaP, chrysene, fluorene, phenanthrene, and anthracene; this adsorption was observed by molecular weight. GCMS calculated the higher efficiency of FeHCFs nanoparticles towards contaminated soil (under optimized conditions) after 48 hours. These results denote that the FeHCFs nanoparticles reduce the effectiveness of PAHs in soil effluents. These results confirmed that the green synthesized FeHCFs nanoparticles are effective against PAH degradation in soil effluents.

2.2. Elimination of heavy metals from contaminated soil.

Nowadays, many industrial wastes are blended with soil containing heavy metals that are toxic to the environment. Overcome this problem, which was rectified by various methods to remove the heavy metals from the soil. Immobilization is a method that inhibits or exchanges substrate in the medium [19,20].

2.2.1. Stabilization and immobilization of Arsenic in soil by green synthesized FeNPs.

Binglin Su *et al*. [19] worked on the stabilization and transformation of Arsenic (As) (Toxic substance) in soil by using green synthesized Fe nanoparticles from *Euphorbia cochinchinensis*. The composition of green synthesized Fe nanoparticles were Fe, O, C. Arsenic changes in the contaminated soil were monitored by X-ray photoelectron spectroscopy (XPS). On the other hand, Arsenic was extracted in five fractional stages, namely F_1 (non-specifically adsorbed soil), F_2(specifically-bounded), F_3(amorphous hydrous oxide-bounded soil), F_4(crystalline hydrous oxide bounded soil), F_5 (residual phases). Through this method, In F_1 0.25, F_2 0.76, F_3 6.45, F_4 4.37, and F_5 4.67, Arsenic mg/kg were found. The extracted arsenic from various stages was treated with green synthesized FeNps in different incubation periods such as 30, 60, and 120 days. After incubation of 120 days, the results found that Arsenic (III) and (V) had more stabilized while releasing and recrystallizing FeNPs. X-ray fluorescence (XRF) seasoned, progressing of green synthesized Fe has a salient procedure because it had a high stabilization effect during the Arsenic transformation in soil [30]. Then Arsenic (III) had more toxic than Arsenic(V). Both of the toxic levels are reduced by green synthesized Fe nanoparticles. These results confirmed that green synthesized Fe nanoparticles have an excellent immobilization of Arsenic in contaminated soil [19].

2.2.2. Removal of Nickel from soil based on green chemistry.

Nickel (Ni) is one of the most dangerous metals to the environment, and the dispersive solid-liquid phase microextraction (DSLME) method was used to remove Ni [20]. This technique was high-speed and novel because MNPs- olive oil act as a sorbent. Es' haghi *et al*. [20] investigated the removal of nickel (Ni) from the soil using magnetic iron nanoparticles coated with olive oil on a green chemistry basis. The collected soil samples were treated with an acid mixture that contains HNO_3 and HCl and heated for 5h at 100°C. Again 10 ml of the acid mixture and 20 ml of deionized water were added after the evaporation of the previous stage [20]. The filtered samples were maintained at a pH of 8 by adding NaOH. The absorption of Nickel was confirmed by UV-Vis spectrophotometry. The results were found by using this advantageous DSLME technique for extracting Ni from soil rapidly, following that effective ionic strength, adsorption time, desorption time, and types of disperser solvent were optimized. These results indicated that the green synthesized magnetic iron nanoparticles reduce nickel toxicity in the contaminated soil [20].

2.2.3. Immobilization of lead in soil by nano zero-valent iron impregnated with magnetic green tea biochar.

According to Mandal *et al*. [31], lead (Pb) is toxic to the soil, which leads to a significant risk to the environment. It was immobilized by nano zero-valent iron (nZVI) saturated with magnetic green tea biochar (nZVI@GTBC). The collected soil sample was designed to lead spilled soil (386 mg/kg) [19]. Green tea biochar (GTBC) was developed, and it was pyrolyzed at different temperatures (150-650°C). The polluted soil was mixed with GTBC, original nZVI, and magnetic nZVI@GTBC and incubated for 15 and 30 days. The immobilization of lead in soil was analyzed by the leaching procedure. Lead accumulation in soil was found after examining Pb with nZVI and nZVI@GTBC. It was analyzed by sequential extraction procedures (SEP). After the incubation of 30 days, the results show that nZVI expresses high stability when introduced to the green tea matrix was confirmed by mobility and colloidal stability studies. The immobilization of Pb is based on naturally obtaining acidic and alkaline PH present in the soil. These results show the nZVI@GTBC is most efficient for immobilizing lead in contaminated soil.[31]

2.2.4. Removal of chromium from the soil by synthesized Bentonite - nanoscale zerovalent iron impregnated with green tea extract.

Chromium is one of the most toxic heavy metals in the environment; the trivalent of Cr(III) and hexavalent of Cr(VI) were removed by green synthesized nanoparticles. Soliemanzadeh, M.; Fekri [32] reported that the green synthesized Bentonite - nanoscale zerovalent iron nanoparticles reduce the toxicity of chromium in contaminated soil. (B-nZVI), which contains polyphenols and carbon molecules that have good potential to reduce heavy metal activity. The Bentonite - nanoscale zerovalent iron (B-nZVI) was prepared with green tea extract and Bentonite [32], compared with Cr(III), Cr(Vl) had high environmental toxicity. The collected soil samples were incubated with Bentonite and synthesized (B-nZVI) for 5 months at 25°C. This mixture was taken in different tests, such as adsorption of Cr (VI) at different PH values, ionic strength, initial Cr(VI) conversation, contact times, and adsorbent dosage. The experimental result showed that (B-nZVI)NPs have a greater potential for adsorption of Cr (VI) than Bentonite, and this adsorption of Cr(VI) was highly dependent on PH 2-6. The (B-nZVI)NPs adsorption was chemisorption based on Langmuir and pseudo-second-order. At last, (B-nZVI)NPs have higher adsorption of Cr(VI), and it decreases the release of Cr(VI). Then Fe-Mn oxide-bound (ox) and residual (RS) fractions were increased, and exchange fraction (EX) was reduced by B-ZVI application (2-4%).

Chrysochoou *et al*. [33] worked on the removal of hexavalent chromium from contaminated soil were performed by using two reducing agents such as calcium polysulfide (CPS) and nanoscale zero-valent iron impregnated with green tea extract (GT - nZVI). In these, the CPS was injected 12 x times into the contaminated soil with chromium ions; the stoichiometric requirement resulted in the Cr(VI) removal was carried out up to 195 days, reducing the efficiency upto >99% (<2 mg/kg) at pH 7-9 this was analyzed by micro XANES method. This CPS contributes only a slow release of Cr(VI) from the soil matrix. This CPS caused a short-term release of sulfur in higher concentrations. So it quickly returned to background values. On the other hand, the zero-valent (GT- nZVI) was injected 12x and 24x stoichiometric result, that the Cr(VI) removal was carried out up to 45 days. It will be stable for the next equivalent of 3 years. It reduced efficiency up to 30 to 66% on the soil's surface, at pH increased to 4.5 and rebounded to 4.5. These results confirmed that the comparing of removal of chromium by CPS and (GT - nZVI), that (GT - nZVI) had 30% to 66% removing capacity because of the presence of 63% of Fe in (GT - nZVI) according to [33].

2.3. Eradications of oil spills from contaminated soil.

2.3.1. Removal of TPHs from contaminated soil.

Total petroleum hydrocarbons (TPHs) are a family of hundreds of chemical compounds mainly from crude oil. These hydrocarbons are embedded and make a group of persistent organic contaminants that causes defects in the environments, such as air, soil, water, and sediments. Murgueitio *et al*. [34] synthesized iron nanoparticles by the green synthesis method to evaluate the removal of total petroleum hydrocarbons (TPHs) from the soil. A series of 10g soil samples were added in 250 ml of amber borosilicate glass bottles. Then the petroleum completely dissolved in hexane was added to the soil sample bottles. The samples were mixed for 2 hours and kept outside for evaporation. After the distribution of petroleum in the soil, the vZVI (zero-valent iron nanoparticles) was added to the mixture containing petroleum-spiked soil. The samples were sonicated for 20 minutes and shaken for 64 hours. The aqueous portion was decanted and treated with dichloromethane. The extracted filtration was analyzed by gas chromatography for TPHs. The result shows that 24% of vZVI removed 81.90% of TPHs from the soil sample after 32 hours of treatment. This study suggests that the vZVI NPs might act on TPHs to clean contaminated soil [34].

2.4. Deletion of antibiotic contamination from contaminated soil.

2.4.1. Remediation of soil contaminated with ibuprofen by green synthesized zero-valent iron nanoparticles.

Ibuprofen is an anti-inflammatory drug that poses a significant risk to the environment. Machado *et al*. developed green synthesized zero-valent iron nanoparticles using extracts of grape marc, black tea leaves, and vine leaves to investigate the degradation of ibuprofen in contaminated sandy soil. The test results show that soil degradation efficiency is slower than in the aquatic system. The extracted nanoparticles from vine leaves show 62% of the highest degradation efficiency, and extracted nanoparticles from black tea leaves show 36% of the lowest degradation efficiency. The results suggest that at lower pH values, the nZVIs produced with vine leaf extract have the capacity to degrade ibuprofen in contaminated soil [35].

2.4.2. Phytoremediation of soil contaminated with fipronil.

Fipronil is a soil insect and broad-spectrum foliar in forestry, agricultural, and pastoral fields. So the deposition of fipronil in soil may increase environmental pollution. Ali *et al*. [36] investigated the degradation of fipronil by green synthesized silver nanoparticles (AgNPs) in soil contaminated with fipronil. The nanoparticles were synthesized using various medicinal plant extracts such as *Brassica alba*, *Plantago major*, *Ipomoea carnea*, and *Camellia sinensis.* Pot–culture experiments were conducted to remediate the contaminated soil. The test results show that the contribution of Plantago-AgNPs, Brassica-AgNPs, Camellia-AgNPs, and Ipomoea-AgNPs to the degradation of fipronil in the contaminated soil were 54.64, 68.8, 30.99 and 43.75% respectively. The removal efficiency of *B. alba* shows higher but only 10.1% recorded in 6 days of treatment with NPs. The *P. Major* extracted nanoparticles show 10.14% of degradation efficiency in 6 days of treatment. Those results show that the AgNPs synthesized from P. major plant extract plays a significant role in the remediation of soil contaminated by fipronil [36] (Table:1).

3. Water Pollution

Water pollution is a key issue that threats ecosystems, Food products, and biodiversity. There were many studies dealing with water contamination. The decontamination of the aquatic environment by green synthesized nanoparticles is covered in his review.

3.1. Degradation of dyes from contaminated water by using green synthesized nanoparticles.

Waste water is a major source of water pollution. Those water are mainly polluted by dyes such as methylene blue, methyl orange, bromophenol blue, bromocresol green, reactive dye, crystal violet, malachite green, Alizarin Yellow R (AYR), congo red, remazol yellow RR, eosin yellow, rhodamine B dye, etc. Nowadays, contaminated water is treated by various green synthesized nanoparticles using nanotechnology. Those are promising and effective methods to treat waste water. Further challenges and issues are also discussed clearly [25-28].

3.1.1. Removal of reactive blue dye by synthesized nanoparticles.

Bibi *et al*. [37] synthesized iron oxide nanoparticles (Fe_2O_3NPs) through the green synthesis route using pomegranate seed (*Punica granatum*) extract to remove the dyes in contaminated water. The synthesized nanoparticles are excellent in photocatalytic activity against the reactive blue 4 dye under UV light irradiation. The results show that the degradation capacity of the nanoparticles was achieved up to 95.08% with 56 minutes of UV irradiation. Thus revealed that *Punica granatum* seed extract was a potential biomolecule, and FeNPs are environmentally friendly for dye degradation in wastewater treatment. The results show that the green synthesized iron oxide nanoparticle is effective against degrading textile dyes in wastewater [37].

3.1.2. Removal of alizarin yellow R (AYR) dye using green synthesized nanoparticles in the wastewater.

The AYR dye is highly noxious and carcinogenic, which is released with industrial waste into water and causes water pollution. Ahmed *et al*. [38] synthesized the nanosized irons (FeNPs) from fruit extract of *Actinidia chinensis* act as a reducing and stabilizing agent used to remove the toxic dye from industrial waste water. The FeNPs were effective photocatalysts and showed photocatalytic activity against the alizarin yellow R (AYR) dye under sunlight irradiation. For this purpose, Ahmed and coworkers did batch experiments to analyze the nanoparticle's removal efficiency, temperature, pH, and dosage. The results show that 93.7% of the dye was degraded under different reaction conditions in 42 hrs of sunlight irradiation. This shows that the photo degradation and their photostability and reusability were evaluated for five-time cycles, which shows a slight loss of degradation efficiency of toxic dye. This result shows that the FeNPs are effective against toxic AYR dye to remediate industrial waste water [38].

Usman *et al*. [39] synthesized copper nanoparticle (CuNPs) by green synthesis method using the fruit extract of *Ficus carica,* and it acts as a photocatalytic agent to degrade the toxic organic dye in wastewater. The test results revealed at the end of the four-time cycle, the efficiency was achieved up to 89.71% under solar irradiation at optimized conditions. These results confirmed that the green synthesized CuNPs are an excellent photodegradation agent in the removal of AYR dye in wastewater by its photocatalytic activity [39].

3.1.3. Removal of malachite green dye using the green synthesis of nanoparticles method.

Brindhadevi *et al*. [40] developed green synthesized zinc oxide (ZnO) nanoparticle using the extract of *Vitis rotundifolia* (Hybrid grape pulp) for the investigation of the degradation capacity of malachite green dye in textile industries. The extraction of hybrid grape with $ZnCl_2$ and catalyzed by NaOH. In this way, the ZnO nanoparticle were synthesized. These green synthesized NPs were taken to determine antioxidant properties and eradicate the malachite green dye. The results explained that the complete reduction of MG dye occurred at 150 min of incubation under dark conditions [40]. Comparatively, the complete reduction of MG dye occurs when using graphene oxide nanoparticles after 6 hrs of incubation. The above results confirmed that the green synthesized nanoparticles are effective against the degradation of MG dye in wastewater using photocatalytic activity.

Prasad *et al*. [7,41] developed a green synthesized Ni/Fe_3O_4 magnetic nanoparticles using the leaf extract of *Moringa oleifera;* it acts as a reducing and capping agent to eradicate the organic dye in wastewater. The synthesized NPs were effective photocatalysts and possessed photocatalytic activity at room temperature. The test results revealed that Ni/Fe_3O_4 acts as a strong catalytic activity towards malachite green dye degradation. These results confirmed that the synthesized Ni/Fe3O4 is an efficient catalyst in removing dyes, and its adsorption rate for the degradation of malachite green dye from contaminated water was measured using the bioinspired green route method [7,41]. Zhang *et al*. [30] synthesized Fe-Cu oxides by the green synthesized method using the leaf extract of *Parthenocissus quinquefolia* (Virginia creeper) in the presence of oxalic acid.

Table 1. Nanoparticles and their applications in soil pollution.

S.No	Name of the plant/part	Nanoparticle	Characterization of nanoparticle	Morphology of nanoparticle	Results shown	Applications	References
1	Green tea extract	Zero valent iron	TEM		Removal of Chromium (Cr) metal ions in contaminated soil	Purification of metal ions in contaminated soil	[10]
2	*Azadirachta indica*	Silver (Ag)	SEM, XRD, and FTIR	Size:457 nm SHAPE: Spherical	Removal of Crystal Violet dye in soil. The removal efficiency was 97.2%	Purification of dyes in contaminated soil	[11]
3	*Ocimum sanctum(*Basil)/Leaf	Silver (Ag)	SEM, TEM, and FTIR	Size:435 nm SHAPE: Spherical, Oval, Irregular polygonal	Removal of gentian violet dye in contaminated soil. The removal efficiency was 99.4%	Purification of dyes in contaminated soil	[15-17]
4	*Azadirachta indica* (neem*)*/leaf	Silver (Ag)	SEM, TEM, and FTIR	Size:422 nm SHAPE: Spherical	Removal of gentian violet dye in contaminated soil. The removal efficiency was 98.1%	Purification of dyes in contaminated soil	[15-17]
5	*Sapindus mukorossi*	Iron hexacyano ferrate (FeHCF)	TEM	Size:10-60 nm SHAPE: Hexagonal, Rod, Spherical	Removal of polycyclic aromatic hydrocarbons (PAHs) in contaminated soil	Reduce the higher degradation and helps in Purification of dyes in contaminated soil	[18]
6	*Euphorbia cochinchinensis*	Iron oxide (Fe2O3)	SEM, EDS	-	Removal of Arsenic (As) metal ions in contaminated soil	Purification of metal ions in contaminated soil	[19]
7	Green chemistry (Olive oil)	Magnetic iron	SEM, FTIR	SIZE: 37.8-77.6 nm	Removal of Nickel ions in contaminated soil	Purification of metal ions in contaminated soil	[20]
8	Green tea biochar	Zero valent iron	XRD, FTIR, TEM and SEM	-	Removal of immobilized lead(Pb) in contaminated soil	Purification of metal ions in contaminated soil	[31]
9	Green tea extract	Bentonite zero valent iron(B-ZVI)	TEM	-	Removal of Chromium(Cr) metal ions in contaminated soil	Purification of metal ions in contaminated soil	[32]
10	Green tea extract	Zero valent iron	X-Ray adsorption	-	Removal of hexavalent chromium metal ions in contaminated soil	Purification of metal ions in contaminated soil	[33]
11	*Vaccinium floribundum/*Leaf part	Iron (Fe)	TEM, XRD, and FTIR	SIZE:5-10nm SHAPE: Spherical	Removal of Petroleum oil spills in contaminated soil. The degradation value was 81.90%	Purification of oil in contaminated soil	[34]
12	Grape Marc, Black tea, Vine leaf/ Leaf part	Zero valent iron	TEM	SIZE: 15-45nm	Degradation of Ibuprofen in Contaminated soil. The black tea leaf removes up to 62%, and the black tea leaf removes up to 36%	Purification of antibiotics in contaminated soil	[35]
13	*Brassica Alba, Plantago major, Ipomoea carnea, Camellia sinensis/* Leaf part	Ag (Silver)	UV- VIS spectra	WAVELENGTH: 200-800nm	Degradation of Fipronil in Contaminated soil	Purification of antibiotics in contaminated soil	[36]
14	*Ocimum tenuiflorum(*Black Tulsi) / leaf	Silver (Ag)	SEM and TEM	Size:425 nm SHAPE: Spherical	Degradation of Turquoise blue dye in soil. The removal efficiency was96.8%	Purification of dyes in contaminated soil	[61]

These synthesized NPs were used to eradicate the malachite green dye in the industrial wastewater. The test results show that the synthesized NPs had the potential to eradicate the dye in wastewater. These results revealed that the synthesized NPs are efficient for the purification of dye-laden wastewater and remediate other pollutants in water using the green synthesis method.

3.1.4. Removal of methylene blue from contaminated water by green synthesis method.

Sackey *et al*. [42] investigated the degradation of methylene blue dye using a novel-biosynthesis of highly crystalline cubic MgO NPs from the aqueous extract of *date pits* to eradicate the MB dye in the wastewater. For this purpose, the removal efficiency, removal kinetic of MB, and photocatalytic activity of MgO were evaluated. The test results show that the synthesized MgO NPs from date pits could potentially remove the dye from wastewater; the photocatalytic degradation efficiency was calculated as 64 and 52% for MgO NPs at 500 and 700°c under visible irradiation. These results confirmed that the synthesized nanoparticles could potentially eradicate the dye in wastewater using photocatalytic activity [42].

Das *et al*. [43] selected an efficient and eco-friendly route to develop green synthesized cupric oxide nanoparticles using the plant extract of *Madhuca longifolia* to eradicate methylene blue dye in wastewater. Thus synthesized NPs act as a non-toxic reducing agent. The results revealed that the synthesized NPs show excellent photocatalytic activity for degrading methylene blue dye in the presence of visible light irradiation in wastewater treatment. This result shows that the green synthesized nanoparticles are a promising material to remediate the organic dye in wastewater treatment [43].

Gan *et al*. [44] developed green synthesized graphene oxide nanoparticles (GONPs) using the sugarcane bagasse to investigate the degradation of methylene blue dye in the wastewater. The synthesized NPs act as a promising adsorbent to remove MB dye in wastewater. For this purpose, gan and his co-workers developed a simple and efficient method for the green reduction of GO to reduced graphene oxide(rGO) using the bagasse extract. This test showed that the malachite green dye adsorption using bagasse extract synthesized rGO was efficient and reusable. Furthermore, these results show that the synthesized NPs could dispose of dye in wastewater [44].

Karthigadevi *et al*. [45] developed green synthesized silver nanocomposite hydrogel using the plant extract of *Mukia maderaspatna* to investigate the removal of methylene blue dye in industrial wastewater. This plant extract act as a reducing agent. These test results confirmed that the synthesized NPs were efficient in removing the MB dye in the wastewater. These results demonstrate that the green synthesized nanoparticles are able to eradicate the toxic dye in industrial wastewater [45].

Vinothkannan *et al*. [46] developed green synthesized reduced graphene oxide(rGO/Fe3O4) nanocomposite using the plant leaf extract of *Solanum trilobatum* to investigate the degradation of methylene blue dye in wastewater treatment. The synthesized NPs act as a photocatalytic and electrostatic interactive agent to eradicate dyes in wastewater. The test results confirmed that the removal efficiency was achieved up to 95.9% in 12 minutes under optimum conditions. These results revealed that the synthesized NPs had an excellent recyclable catalyst to eradicate dyes in contaminated water using the green synthesis method [46].

3.1.5. Removal of organic pollutant dyes in wastewater by green synthesis method.

Ebrahimzadeh *et al*. [47] synthesized silver nanoparticles (AgNPs) by the green synthesis method using the fruit extract of *Crataegus pentagyna* as a reducing and capping agent to degrade the organic contaminant dyes in wastewater. Different parameters were carried out to eradicate the organic dyes by green synthesized silver nanoparticles. The test results show that the CP-AgNPs eradicate the organic contaminant dyes such as rhodamine b (Rhb), eosin (EY), and methylene blue with degradation efficiency of 85, 70, and 78%, respectively, in the presence of sunlight. These results confirmed that the CP-AgNPs have an excellent potential to degrade organic pollutants using photocatalytic activity [47].

3.1.6. Removal of pollutant dyes in Contaminated water using the green synthesis method.

Sherin *et al*. [48] investigated the degradation of organic pollutant dyes in Contaminated waters by green synthesized biogenic silver nanoparticles using kernel extract of *Terminaliabellericain*. An artificial network method was conducted to remediate the contaminated waters. This network is used to gain a catalytic behavior of K-AgNPs towards the reduction of wastewater contaminated with organic pollutants. The synthesized silver nanoparticles are efficient in the catalytic reduction of organic pollutants such as 4 - nitrophenol, methylene blue, eosin yellow, and methyl Orange. The test results revealed that 4 - nitrophenol exhibited a higher reduction of dyes among all the pollutants. These results confirmed that the nanosilver Tb-AgNPs have the potential to eradicate the pollutant dyes in anthropogenic water pollutants [48].

3.1.7. Removal of remazol yellow RR dye by green synthesized NPs.

Bhuiyan *et al*. [49] synthesized iron oxide nanoparticles from ferric chloride with a green synthesis method using papaya leaf extract (*Carica papaya*) to eradicate the remazol yellow RR dye in wastewater. For this purpose, the removal efficiency and certain parameters, such as catalyst dosage, pH, and dye concentrations, were evaluated. The test results show that the removal efficiency of green synthesized iron oxide nanoparticles in the presence of sunlight expressed about 76.6% in 6 hours with 0.8mg/L of dosage at 2 pH to remove the toxic dye in wastewater. These results revealed that synthesized iron oxide nanoparticles act as excellent photocatalytic agents against the toxic remazol yellow RR dye in waste water treatment using the green synthesis method [49].

3.1.8. Removal of RhB dye from wastewater using the green synthesis method.

Rafique *et al*. [50] developed green synthesized copper oxide nanoparticles using the leaf extract of *Citrofortunella microcarpa* (calamondin) for the investigation of the degradation of rhodamine B (RhB) dye in textile wastewater. The synthesized NPs were environmentally friendly and acted as reducing and capping agents. The test results revealed that the synthesized NPs using the green method effectively removed the rhodamine dye in textile wastewater at a removal efficiency of 98.31% under UV light exposure. Also, the CuONPs showed first-order kinetics value at 93.88% stability as catalysts. Therefore, the synthesized CuO nano photocatalyst was an efficient and stable catalyst for eradicating RhB dye. The above reports confirmed that the green synthesis of CuO NPs has the potential to remediate RhB dye in textile wastewater [50].

Ebrahimian *et al*. [51] synthesized SnO_2 NPs by green synthesis method using the fruit extract of Vitex agnus-castus as a reducing and stabilizing agent to remove the toxic dye in the wastewater. The synthesized NPs were effective photocatalysts and photocatalytic activity against Rhodamine B dye under UV irradiation. The test results show that the degradation of dyes achieved up to 91.7% at 298 K within 190 minutes under UV irradiation. These results confirmed that the synthesized NPs had the potential to remediate the Rhodamine B dye in wastewater using the green synthesis method.

Sharma *et al*. [13,15-17] synthesized magnetic nanoparticle (MNPs) using plant-derived potato extract to eradicate the rhodamine B dye under solar irradiation, and H_2O_2 act as an antioxidant agent in the wastewater. These synthesized NPs act as reducing and stabilizing agents. The test results show the efficient degradation of RhB using MNPs and H_2O_2 to remediate the rhodamine B dye in wastewater. These results confirmed that the synthesized NPs had the potential to remediate the toxic dye in wastewater using the green synthesized method. Sharma *et al*. [15-17] synthesized cerium dioxide NPs (CeO_2 NPs) by green synthesis method using the leaf extract of *Azadirachta indica* act as a reducing agent for the photocatalytic process. The test results show that the degradation efficiency was achieved up to 96% at 130°C within 120 minutes under light illumination to eradicate the rhodamine B (RhB) dye in the wastewater. These results confirmed that the green synthesized NPs act as a promising catalyst for dye degradation in wastewater using photocatalytic activity in the presence and absence of CeO_2 NPs.

3.1.9. Removal of toxic dye in anthropogenic water.

Baruah *et al*. [52] synthesized gold nanoparticles through a green route using an aqueous extract of *Alpinia nigra* leaves to remove the toxic dye in the anthropogenic wastewater. These synthesized AuNPs act as reducing and capping agents. The test results show that the AuNPs eradicate the toxic dyes such as Rhodamine B and methyl orange, expressing degradation efficiency of 87.64% and 83.25%, respectively, in the presence of sunlight. These results confirmed that *Alpinia nigra* is a potential bioresource for synthesizing AuNPs to remediate the toxic dye in anthropogenic wastewater.

3.1.10. Removal of CR and MG dye in water using the green synthesis method.

Chauhan *et al*. [53] developed green synthesized zinc oxide nanoparticles using the leaf extract of *Eucalyptus spp* to investigate the cationic and anionic dyes in aqueous water. These green synthesized NPs were taken to determine photostability and reusability efficiency to eradicate the crystal violet and malachite green dye in contaminated water. These results explained the complete reduction of CR dye at 87.3% in distilled water and MG dye at 92.5% in tap water. These results confirmed that using the green synthesis method, the synthesized ZnO NPs are economically effective and sustainable absorbents that can eradicate dye effluents in various industries.

3.1.11. Removal of congo red dye in wastewater using green synthesized NPs.

Debnath *et al*. [54] synthesized zinc oxide nanoparticles through the green route using the leaf extract of Hibiscus Rosa- sinensis to remove the congo red dye in the wastewater. Various experiments were carried out to eradicate congo red dye by green synthesis of ZnONPs. Thermodynamics, kinetics, and absorption isotherms were also evaluated. The results explain that the ZnO NPs removed up to 60.75% of congo red dye in wastewater at optimum conditions such as concentration (4mg/L), adsorbent dosage (0.05g), and contact time (20 min) was calculated. These results confirmed the synthesis of nanoparticles is effective against the degradation of congo red dye in wastewater using the green synthesis method.

Prasad *et al*. [55], a green route was synthesized Fe_3O_4 magnetic nanoparticles using an aqueous extract of pomegranate leaves to investigate the degradation of congo red dye in the wastewater. These synthesized NPs act as reducing and capping agents. These test results show that the synthesized NPs used to dispose of congo red dye in wastewater have adsorptive properties and effective photocatalytic activity. These results demonstrate that the green synthesized NPs are a promising material to remediate the congo red dye in wastewater using the green synthesis method.

Vidya *et al*. [56] developed green synthesized ZnO NPs using the leaf extract of *Artocarpus heterophyllusto* to investigate the usefulness of biosynthesized ZnO NPs in the degradation of dye in hazardous wastewater. These synthesized NPs act as an effective photocatalytic agent in the degradation of congo red dye under UV light at room temperature. The test results revealed that the efficiency was greater than 90% towards the degradation of 20 ppm in 1 hour at 9 pH under UV light at room temperature. These results demonstrate that the green synthesized NPs are very effective in the photo-degradation of congo red dye in hazardous wastewater using photocatalytic activity.

3.1.12. Removal of Bismarck brown R dye from wastewater using green synthesis method.

Fatima *et al*. [57] synthesized cadmium tungstate (CdWO4) through a green synthesis route using *Brassica rapa* leaf extract to eradicate the Bismarck brown R dye in wastewater. The synthesized NPs act as a photocatalytic agent for dye degradation in the presence of sunlight. These results revealed that the dye was removed up to 82.70% in 50 mL solution, 20 mgL-1 of dye concentration with $1.5gL^{-1}$ dosage of $CdWO_4$ in 15 minutes in the presence of sunlight. These results confirmed that biogenic $CdWO_4$ is efficient in eradicating the bismarck brown R dye in industrial wastewater using the green synthesis method.

3.1.13. Degradation of hazardous dye in wastewater using green synthesized NPs.

Goswami *et al*. [58] synthesized silver nanoparticles by green synthesis method using the cellulose extract of *Hibiscus sabdariffa* act as a catalytic activity to degrade the hazardous dye in wastewater. The test results show that the synthesized NPs efficiently removed organic dyes such as methylene blue, methyl orange, bromophenol blue, eosin Y, and orange G dye within 60 minutes of the reaction and was recycled for several times without loss of its catalytic activity. These results confirmed that the synthesized NPs are effective against the degradation of hazardous dye in wastewater using the green synthesis method.

3.1.14. Removal of various dyes in water using the green synthesis method.

Khodadadi *et al*. [59] synthesized silver nanoparticles by green synthesis method using the extract of *Achilla milleofolium* L, which acts as a reducing and stabilizing agent were used to evaluate the catalytic reduction of various dyes in water. The synthesized NPs are effective photocatalysts and photocatalytic activity at room temperature. The rest results show that AgNPs/peach kernel shell can be recovered and reused for several cycles to reduce methylene blue, methyl orange, and 4- nitrophenol with almost no loss of its catalytic activity. These results confirmed that the synthesis of nanoparticles is a highly active catalyst in reducing various dyes in water using the green route method.

3.1.15. Removal of textile dyes in wastewater green synthesized NPs.

Li *et al*. [60] developed green synthesized AgNPs using rhizome extract of Alpinia officinarum to investigate the usefulness of biosynthesized AgNPs in the degradation of dyes from textiles and other chemical industries. The synthesized AO/AgNPs act as effective in photocatalytic activity in the degradation of methylene blue and malachite green dye under UV and visible irradiation. The test results revealed that the degradation of dyes achieved up to 91% after 2 hours of UV radiation. Furthermore, methylene blue dye was degraded by up to 80% after 2 hours of visible irradiation. These results confirmed that the biosynthesized AgNPs are catalytically active, giving promising results in the photocatalysis of organic dye in textile and other chemical industries.

3.1.16. Removal of toxic dyes in wastewater using green synthesis method.

Banerjee *et al*. [12] worked on removing toxic dyes in wastewater by green synthesized AgNPs using the leaf extract of *Ocimum tenuiflorum* (black tulsi) act as a reducing and capping agent used to remove the turquoise blue dye in wastewater. The test results show 96.8% removal efficiency was carried out for 2 hrs at room temperature. These results demonstrate that using the green synthesis method, the synthesized NPs effectively removed the turquoise blue dye in textile wastewater.

3.1.17. Removal of organic pollutant dyes in wastewater using green synthesis method.

Choudhary *et al*. [61] successfully synthesized the gold nanoparticles (AuNPs) by the green synthesis method using the plant extract of Lagerstroemia speciosa acts as a strong photocatalyst in the reduction of dyes in wastewater. These synthesized NPs were used to remove the reduction of dyes such as methylene blue, methyl orange, bromophenol blue, bromocresol green, and 4- nitrophenol in the textile wastewater. This test results confirmed the photocatalytic degradation of organic pollutants such as methylene blue, methyl orange, bromophenol blue, bromocresol green, and 4- nitrophenol dyes with reduction efficiency of > 90% under visible light in the presence of $NaBH_4$. These results confirmed that the synthesized NPs are strong and stable photocatalysts that remove organic pollutant dyes in textile wastewater using the green route method.

3.1.18. Removal of dyes in contaminated water using the green route method.

Xin *et al*. [62] synthesized iron nanoparticles using green tea extract of Tieguanyin by green synthesis method to remediate the dyes from contaminated water. Thus synthesized NPs act as a reducing and capping agent to prolong the catalyst's lifetime. The test results show that the degradation of bromophenol blue dye achieved up to more than 90% within 15 min at ambient temperature. The results revealed that the synthesized NPs could potentially remove the bromophenol blue dye in wastewater by green synthesized nanoparticles.

3.1.19. Removal of decolorized dyes in wastewater using green synthesized nanoparticles.

Muthukumar *et al*. [63] developed green synthesized Iron oxide nanoparticles (FeONPs) using the leaf extract of *Amaranthus spinosus* to investigate the decolorization of dyes in wastewater. These synthesized NPs act as an antioxidant and reducing agents to remediate the dyes in wastewater. The test results revealed that the FeONPs eradicate the contaminant dyes such as methylene orange and methylene blue with a percent decolorization of 75 and 69%, respectively. The antioxidant efficiency was observed at 93% in the presence of sunlight. These results confirmed that the synthesized NPs are efficient in photocatalytic and antioxidant capacity to eradicate the dyes in waste water treatment using the green synthesis method.

3.1.20. Removal of synthetic dyes in wastewater by green synthesis method

Jassal *et al*. [64] synthesized potassium zinc hexacyano ferrate nanocubes by green synthesis method using the natural surfactant of *Sapindus mukorossi* to eradicate two synthetic dyes in wastewater. These synthesized NPs act as a photocatalyst under optimized conditions. For this purpose, the removal efficiency and certain parameters such as pH, temperature, dosage, and concentration of dyes were evaluated. The test results show that synthetic dyes' removal efficiency achieved up to 94.15% for malachite green and 76.13% for eriochrome black T dye at a pH of 7.0. These results confirmed that the synthesized nanoparticles are catalytically active and give promising results in the photocatalysis of organic dye in wastewater treatment.

3.1.21. Removal of methyl red dye in wastewater using the green route method.

Sinha *et al*. [65] used the green synthesis method to synthesize copper nanoparticles (CuNPs) using the peel extract of *citrus grandis* to investigate the degradation of methyl red dye in wastewater. This plant extract act as a reducing and stabilizing agent in the synthesis of CuNPs. The test results show that the removal efficiency achieved 96% under solar irradiation. These results demonstrate that the green synthesized NPs could remediate the methyl red dye in wastewater using photocatalytic activity. Fu *et al*. [66] investigated the degradation of toxic dye by green synthesized zinc oxide nanoparticles (ZnONPs) in water contaminated with dyes. The NPs were synthesized using the *Plectranthus amboinicus*, which acts as a photocatalyst and reducing agent. The test results confirmed that the biosynthesized ZnO NPs remain at more than 85% of degradation in 4 cycles at 80°C in 5 hours under UV light irradiation. These results confirmed that the biosynthesized NPs determined the performance of photocatalytic activity as highly effective when compared to the chemically synthesized ZnO NPs. This shows the photocatalyst had excellent stability in remediating methyl red dye in wastewater treatment.

3.1.22. Removal of organic dye in wastewater using the green synthesis method.

Najafinejad *et al*. [67] synthesized the Fe_3O_4@polythiophen - Ag magnetic nanocatalyst by green synthesis method using the grapefruit peel extract to act as a photocatalytic activity in the reduction of organic dye in the wastewater. These synthesized NPs were prepared by a coating of polythiophene with magnetic particles. The test results show that the synthesized catalyst can be used many times without losing its catalytic activity, and the rate of constant in the catalytic reaction was ordered in (105 and 104) of MO and MB, respectively. These results demonstrate that the synthesized NPs had the potential to remediate azo dyes in wastewater without loss of its catalytic activity using the green synthesis method.

3.1.23. Removal of azo dyes in wastewater using green synthesized NPs.

Rasheed *et al*. [68] developed green synthesized silver nanoparticles (AgNPs) using the plant extract of *Convolvulus arvensis*. It acts as a reducing agent in the presence of $NaBH_4$. The synthesized NPs had a potential efficiency for degrading organic pollutant dyes in wastewater. The test results show that the green synthesized NPs provided efficient results in degrading dye compared to the chemical and physical methods. For this purpose, the catalytic activity of the biogenic NPs was analyzed by UV- visible spectra for three different dyes such as RB-5, MO, and DY-142, respectively. These results confirmed that the synthesized NPs had the potential to remediate the azo dyes in wastewater using the green synthesis method.

3.1.24. Removal of dyes in wastewater using green synthesis method.

Sankar *et al*. [69] successfully synthesized the copper oxide nanoparticle treated with 5mM cupric sulfate using *Carica papaya* leaf extract; it shows photocatalytic activity against the degradation of coomassie brilliant blue R-250 dye in the wastewater. These test results show that the synthesized NPs act as an efficient photocatalyst under natural sunlight to remediate the coomassie brilliant blue R- 250 dye in wastewater within 2 hours. These results demonstrated that the green synthesized NPs had the potential to remediate the pollutant dyes in wastewater using photocatalytic activity.

3.1.25. Removal of concentrated dye in wastewater using green synthesized NPs.

Truskeurycz *et al*. [70] synthesized iron nanoparticles (FeNPs) by green synthesis method using the extract of green tea; it acts as a Fenton-like degradation of a concentrated dye in the textile wastewater. The test results revealed that the efficiency rate of concentrated azo(DR80) and anthraquinone(RBR-R) dye was achieved up to 99% with 0.53 ppm at 90°C after 191 minutes. These results confirmed that the synthesized NPs could potentially increase the dye degradation rates in the bioremediation process, it also acts as a promising material to remediate the dye in textile wastewater using the green synthesis method.

3.1.26. Removal of toxic dye in wastewater using green synthesized NPs.

Stan *et al*. [71] developed green synthesized Fe_3O_4 NPs using with and without fruit extract from avocado (*Persea americana*) and watermelon (*Citrullus lanatus*) to investigate the degradation of optilan blue dye in the contaminated wastewater. These synthesized NPs act as an effective adsorbent catalyst to eradicate the toxic dye in wastewater. Thermodynamics, dye adsorption, and kinetic studies were evaluated. The test results show that the removal efficiency occurred between 72 and 89% in the 298-318K temperature range under optimized conditions. These results confirmed that the degradation of optilan blue(OB) dye in textile wastewater is achieved by green synthesized nanoparticles.

3.1.27 Removal of various dyes in wastewater by green synthesis method

Sharma *et al*. [15-17] developed green synthesized AgNPs using the aqueous extract of *allium cepa* (Onion) to eradicate various dyes in wastewater. These synthesized NPs act as reducing and capping agents. The test results revealed that the catalytic degradation of various dyes such as methylene blue, methyl red, eosin yellow, safranin, and direct dye and reactive dyes were visualized under UV and visible spectroscopy. These results confirmed that green synthesized NPs are an excellent catalyst for reducing hazardous and toxic dyes in wastewater using photocatalytic activity.

4. Elimination of Heavy Metals from Contaminated Water

The advantage of Industrial development in metals is the result of the human population as well as the outbreak of that development is pollution. To rectify this outbreak, impregnated green synthesized nanoparticles are used [20-24,28-29].

4.1. Removal of hexavalent chromium in groundwater.

Chromium is a chemical element widely used in pigment production, Leather tanning, metal plating, and wood preservation industries. The untreated chromium is contaminated with water and leads to environmental pollution [27]. Zhu, F. *et al*. [72] synthesized zero valent iron/Cu nanoparticles using green tea extracts by green synthesis method to remediate hexavalent chromium Cr(VI)) from contaminated groundwater. Batch experiments were conducted to evaluate the removal efficiency of zero-valent iron/Cu nanoparticles in the groundwater sample contaminated with Cr (VI). The test results showed that the GT-nZV Fe/Cu actively worked against the Cr(VI) in contaminated groundwater with 94.7% removal efficiency at the temperature of 303k and 5 PH with the dosage of 0.4 g/L. These results represent that the green synthesized zero valent Fe/ Cu NPs can potentially remove Cr(VI) from contaminated groundwater.

4.2. Removal of chromium (VI) from aqueous solutions.

Mehdi *et al*. [73] synthesized iron nanoparticles (FeNPs) by green synthesis method using three different plant extracts such as *Rosa damascene* (RD), *Thymus vulgaris* (TV), and *Urtica dioica* (UD). The green synthesized iron nanoparticles (nZVI) were supposed to react against the wastewater contaminated with Cr(VI). Batch adsorption experiments were conducted to detect the removal efficiency of green synthesized NPs. The test results show 90% removal efficiency at 10 minutes of contact time by applying 0.2g/L of adsorption dosage. Among these, the nanoparticles extracted from *Thymus vulgaris* showed high removal efficiency. The results demonstrate that the synthesized NPs from different plant extracts were effectively removed even at high concentrations of hexavalent chromium.

4.3. Removal of Cr(VI) from contaminated water.

Rong *et al*. [74] developed green synthesized iron nanoparticles using Korla fragrent pear peel extract to remediate the water contaminated with hexavalent chromium Cr(VI). Iron in the KP-FeNPs mainly occurred as zero-valent iron (Fe°), di-valent iron (Fe(II)), and tri-valent iron (Fe(III)) oxides and coated with flavonoids, polyphenols, and other natural organic compounds in the peel extracts. The maximum Cr(VI) removal efficiency of KP-FeNPs in contaminated water was recorded at 46.62 mg/g at 55°C and a pH of 5.0. These results revealed that the green synthesized iron nanoparticles were actively involved in the remediation of water contaminated with hexavalent chromium.

4.4. Removal of nitrate in aqueous solution.

Nitrate is a polyatomic ion. Water contamination by nitrate may cause serious threats to aquatic ecosystems and eventually lead to eutrophication. Furthermore, drinking water with nitrate contamination can lead to toxic and carcinogenic effects on humans and animals. [75-76] worked on the removal of nitrate in the contaminated aqueous solution by green synthesized iron nanoparticles (FeNPs) using green tea extract (GT-Fe) and eucalyptus leaf extracts (EL-Fe). Batch experiments were performed to calculate the removal efficiency of the iron nanoparticles. The test results showed 59.7% removal efficiency of GT-Fe (Fe nanoparticles synthesized from green tea extract) and 41.45 removal efficiency of EL-Fe (Fe nanoparticles synthesized from eucalyptus leaf extract). These results demonstrate that the green synthesized Fe nanoparticles effectively removed the nitrate in the contaminated water and can be used for large-scale eutrophic wastewater treatment.

4.5. Removal of heavy metals from contaminated water.

Sebastin *et al*. [77] synthesized iron oxide nanoparticles by green synthesis method using coconut husk extract to remediate the water contaminated with heavy metals. These nanoparticles efficiently adsorb Ca (Calcium) and Cd (Cadmium) from aqueous media. The kinetic studies revealed that the adsorption was a combined effect of both physical and chemical processes. Equilibrium studies show that the nanoparticles' maximum adsorption efficiency is 13.7 mg g^{-1} against calcium and 9.6 mg m^{-1} against cadmium. The maximum adsorption pH was recorded at 6.0 and a temperature of 30.3°C for both Ca and Cd. These results revealed that the green synthesized iron oxide nanoparticles express a high potential to remediate the water.

4.6. Removal of lead from contaminated water.

Kumar *et al*. [78] developed green synthesized zero-valent iron nanoparticles using *Emblica Officinalis* leaf extract to remediate the water contaminated with lead. Batch experiments were conducted to remediate the lead in wastewater. These GZVINPs show the potential to remediate Pb^{2+} in aqueous medium recorded at 10, 20, 30, and 100 ppm in 24 hours with 20 ml 1^{-1} concentration. Overall the test results showed that the synthesized FeNPs have a high potential to remove lead from contaminated water.

5. Eradication of Oil Spills from Contaminated Water

5.1. Removal of petroleum oil from contaminated water.

Murgueitio *et al*. [34] synthesized iron nanoparticles by green synthesis method using *Vaccinium floribundum* to remove the petroleum and oils from contaminated water. Batch experiments were performed to remove TPHs (Total petroleum hydrocarbons) using vZVI nanoparticles. After treatment with NPs, the water contaminated with TPHs in two concentrations such as 9.32 mg/L and 94.20 mg/L, showed removal efficiency of 85.94% and 88.34%, respectively. Those results indicate that adding vZVI NPs produces strong reducing conditions against the wastewater to remediate TPHs.

6. Expulsion of Antibiotic Components from Contaminated Water

A variety of pharmaceutical wastes are blended with the aquatic environment. It leads to severe toxicity to the environment and causes water pollution [19].

6.1. Green synthesized nanoparticles act as an adsorbent of amoxicillin in polluted water.

Ali, I. *et al*. [79] developed activated carbon (Ac) from pomegranate peel, and it was coated with zero-valent iron nanoparticles (Ac-nZVI). These synthesized nanoparticles act as an adsorbent for removing amoxicillin from an aqueous medium. The result confirmed that the Langmuir monolayer isotherm model and pseudo-first-order kinetics were fitted to the adsorption equilibrium and for kinetic data (Imran Ali *et al* 2020.,). The synthesized activated carbon-nZVI (AC- nZVI) acted as a promising adsorbent on amoxicillin from polluted water.

6.2. Removal of Ibuprofen from aqueous solution using green synthesized nanoparticles.

Ali, I. *et al*. [80] worked on removing ibuprofen drug residue from the aquatic environment by using iron nanoparticles synthesized from black tea. HPLC was used to analyze the presence of ibuprofen residual in the water. This experiment was observed in different parameters such as various concentrations, pH, contact time, temperature, and adsorbent amount. The result confirmed that adsorption and exothermic sorption values were more convenient, which was confirmed by thermodynamic parameters [80]. According to the result, these adsorption processes followed the Freundlich, Temkin, Langmuir, and Dubinin-Radushkevich model then pseudo-first order was fitted to the adsorption process. The result confirmed that the ibuprofen was adsorbed by nano adsorbent (green synthesized FeNPs) with highly effective 92%, then nano adsorbent also favorable to removing ibuprofen from any other water bodies.

Machado *et al*. [35] developed a zero-valent iron nanoparticle in the 15 to 45 nm range using three leaf extracts (black tea, grape mare, and vine leaves). Nanoscale zero-valent iron nanoparticle (n-ZVI) has good potential to degrade the contaminants in water. The synthesized n-ZVI nanoparticles were employed to clean up the ibuprofen-containing water. Comparing the three leaf extracts shows that black tea leaf and vine leaf used n-ZVI iron gave excellent results at pH 7 and 3. Therefore this work explored 50 to 65% of ibuprofen degraded in an aqueous solution by green synthesized n-ZVI nanoparticles. But the cleanup process achieved 95% while using n-ZVI with n-ZVI catalyzed Fenton-like reaction, which supplements the cleanup process.

6.3. Removal of Rifampicin from aqueous solution using green synthesized nanoparticles.

Cai, W. *et al*. [81] synthesized magnetic Fe_3O_4 nanoparticles using *Excoecaria cochinchinensis* leaf extract. The green synthesized magnetic Fe_3O_4 nanoparticles are effective in removing rifampicin antibiotic drugs from an aqueous solution. The experimental result shows that the effective adsorption of rifampicin was achieved at 98.4%, and it had an 84.8mg/g adsorption capacity [81]. Kinetic studies fitted to the pseudo-second-order and isothermal adsorption were stuck to Longmuir isotherm; these all processes indicated by adsorption study. According to the result, the synthesized magnetic Fe_3O_4 nanoparticles effectively eliminated rifampicin from water.

Lin, Z. *et al*. [82] used tea extract to synthesize iron nanoparticles. Further, it was employed to remove the rifampicin antibiotic from an aqueous solution. The tea extract contains caffeine and polyphenols, which act as reducing and blocking agents during FeNPs preparation. The result reported that the synthesized FeNPs positively interacted with removing rifampicin in water, and 91.6% of rifampicin was removed from the aqueous medium [82]. The result confirmed that synthesized FeNPs act as an efficient adsorbent for removing rifampicin from wastewater. Pseudo-second orders kinetic shows efficient adsorption of rifampicin from wastewater by synthesized FeNPs.

6.4. Removal of antibiotic mixtures from water by green synthesized nanoparticles.

Stan, M. *et al*. [83] synthesized three types of magnetite iron oxide nanoparticles (Fe_3o_4 NPs) using three agro waste (peels) for the removal of various antibiotic mixtures, namely erythromycin (ERY), piperacillin (PIP), sulfamethoxazole (SUL), trimethoprim (TRI), ampicillin (AMP), tazobactam (TAZ) and tetracycline (TET). The nanoparticles were synthesized using three agro wastes, such as cucumber, lemon, and black grapes, and characterized by various techniques. The result shows that the removal of the antibiotic mixture was identified by the optimum technique based on the Box-Behnken design approach. On the other hand, antibiotics adsorption was done by synthesized Fe_3O_4NPs, and it was confirmed by Langmuir, Freundlich, and Temkin adsorption isotherm models through kinetic study. Therefore the result confirmed that synthesized nanoparticles have>90% of antibiotic removal efficiency except for sulfamethoxazole (SUL), trimethoprim (TRI) [83]. However, compared with the three peel extracts, cucumber peel extract gave excellent removal efficacy and good adsorption capacity, demonstrated by a kinetic study.

7. Ejection of Chemical Composites from Contaminated Water

Some high concentrations of chemicals are released from industries and cause contamination of the aquatic region. This contamination can cause high toxicity to the aquatic environment, and it causes water pollution. Green synthesized nanoparticles are used to degrade the chemical contaminants to overcome this problem.

7.1. Remove various chemical pollutants from water by the green synthesized nanoparticle.

Devatha *et al*. [84] worked on removing chemical components from domestic wastewater in different parameters such as (phosphate, chemical oxygen demands, and ammonia nitrogen) by Iron nanoparticle, which was synthesized from different leaf extracts due to the presence of polyphenols: the leaves, namely *Azadiracta indica, Magnolia champaca, Mangifera indica*, *Murraya Koenigii*. The result showed, among the various synthesized nanoparticles, the iron nanoparticle synthesized from *Azadiractaindica* (AI-FeNPs) had 98.08% efficiency in removing phosphate, 82.35% efficiency in removing chemical oxygen demands, and 84.32% efficiency in removing ammonia nitrogen from the water. All over, the AI-FeNPs shows good result.

Luo, F. *et al*. [8] synthesized iron nanoparticles using grape leaf extract, and agarose gel was added to the synthesized iron nanoparticle. At last, the green synthesized agarose-FeNPs hydrogel was formed. The synthesized agarose-FeNPs hydrogel was used to remove various contaminants in water, particularly trichloroethylene (TCE). The result shows 97.2% of TCE were removed from contaminated water while treated with synthesized agarose-FeNPs hydrogel. X-ray photoelectron spectroscopy(XPS) showed that synthesized agarose-FeNPs hydrogel acts as a chemical reductant, and FTIR result indicates that the synthesized nanoparticles were involved in the removal of TCE due to the presence of functional groups. Overall the work, the kinetic study helps with the removal mechanism [76]. According to the result, this work had an efficient reference for the removal of organic and inorganic contaminants in water by green synthesized FeNPs-hydrose gel [8]

7.2. Removal of nitrate from aqueous solution using green synthesized nanoparticles.

Wang, T. *et al*. [75] developed green synthesized iron nanoparticles using eucalyptus (EL-FeNPs) and green tea leaf extracts (GT-FeNPs). These FeNPs are used to eliminate nitrate in contaminated water and treated for eutrophication. The synthesized FeNPs are capable of capping and stabilizing the nitrate, analyzed by XRD and FTIR. When compared to the nano-zero valent iron nanoparticle (nZVI) and Fe_3O_4, the result shows that GT-FeNPs removed 59.7% of nitrate, and 41.4% of nitrate was removed by EL-FeNPs. Meanwhile, the nZVI reactions would sometimes decrease, but the synthesized GT-FeNPs and EL- FeNPs remain constant. According to the result, 13.06 mg/g of nitrate was removed by GT-FeNPs, and EL-FeNPs removed 9.698mg/g of nitrate. The removal mechanism is suitable forpseudo–second–order adsorption, which was suggested by kinetic studies [75].

In another study, Peternela *et al*. [85] synthesized copper oxide (CuO) nanoparticles using pomegranate leaf extract impregnated with vegetal activated carbon (VAC), which involved the removal of contaminants from water. SEM and XRD analyzed the synthesized copper oxide nanoparticle size between 40 and 78nm. The result shows that 1.5% of Cu for 24 hours was impregnated with carbon, which shows excellent removal potential of organic contaminants and water pollutants. According to the result, impregnated synthesized CuO nanoparticles acted as good nitrate remover activated carbon and gave good reducing and stabilizing effects on nitrate in contaminated water. Vegetal activated carbon (VAC) has good pollutant removal potential [85].

Katata-Seru, L. *et al*. [86] investigated the removal of nitrate from contaminated water by synthesized iron nanoparticles using *Moringaoleifera* leaf and seed extracts. The plant had coagulation properties for water treatment because of the presence of water-soluble substances, which comprise edible oil [7]. The synthesized FeNPs using *Moringaoleifera* leaf (MOL) and *Moringaoleifera* seed (MOS) were treated with nitrogen-containing water [41]. The result shows that the removal of nitrogen percentage increased and decreased with the pH. The nitrate removal percentage was varied between (MOL) and (MOS) using FeNPs. According to the results, the MOL and MOS-FeNPs acted as major reducing and capping agents for removing nitrate from water. The synthesized FeNps was an effective alternative to removing nitrate and having coagulation properties [86].

8. Deletion of Pesticides from Contaminated Water

Toxic pesticide chemicals spread to the water, leading to more danger to the aquatic environment and species. This pesticide-contaminated water can cause some health issues for humans.

8.1. Degradation of organochlorine pesticides by green synthesized nanoparticles in water.

EI-Said *et al*. [87] utilized two types of green tea extraction to synthesize mesoporous silica nanoparticles/iron oxide nanoparticles in 30nm. The green tea extract act as a good reducing and capping agent. These synthesized nanoparticles are used to remove organochlorine pesticides, specifically lindane, in the aquatic environment. Using an external magnetic field, the developed nanoparticles can efficiently remove chlorinated compounds (organochlorine). This removal process was monitored by UV-VIS spectrophotometry. The result shows, (99%) of organochlorine pesticides were removed while using 90mg of synthesized mesoporous silica nanoparticles/iron oxide nanoparticles, which was confirmed by FTIR, HPLC, and gas chromatography [87].

8.2. Removal of fipronil insecticide by green synthesized nanoparticles in water.

Rani, M.; Shanker, U [88] prepared silver nanoparticles (AgNPs) using various plants, namely Ipomoea, Plantago, camellia, and brassica. These green synthesized AgNPs are used to remove Fipronil insecticides from water. The synthesized AgNPs were treated with fipronil-contaminated water for 2 days. After the treatment, the results were confirmed that 63.48% of fipronil was reduced by Plantago- (AgNPs), Ipomoea reduced 90.15% of fipronil-(AgNPs), 95.45% of fipronil was reduced by *brassica*-(AgNPs) and 63.65% of fipronil were reduced by *camellia*-AgNPs [88].

8.3. Elimination of chlorfenapyr using green synthesized nanoparticles.

In a recent study, Romeh, A.A.; Saber, R.A.I. [89] synthesized three nanoparticles using three plants such as Brassica, Ficus, and Ipomoea. The synthesized nanoparticles were shortly called brassica-silver nanoparticles (Br-Ag^o) sizes of 6.05 to 15.02nm, ficus iron nanoparticles (F-Fe^o) (2.46-11.49 nm), and ipomoea silver nanoparticles (IP-Ag^o) (6.27-21.23nm). These synthesized nanoparticles were impregnated with activated charcoal (Ach), identified as (Br-Ag^o Ach, F-Fe^o Ach, and IP-Ag^o Ach) which was utilized for the degradation of chlorfenapyr insecticide in contaminated water. These synthesized (Br-Ag^o Ach, F-Fe^o Ach, and IP-Ag^o Ach) were treated with chlorfenapyr-contaminated water for 24hrs. Therefore, after the 24hours of treatment, Br-Ago Ach eliminates 92.92%, F-Feo Ach eliminates 93.7%, and IP-Ag^o Ach eliminates 91.30% of chlorfenapyr in contaminated water [89].

9. Future Outlook

Environmental pollution is a major problem in today's environment. The water and soil are polluted due to dyes, medicinal wastes, metal ions, oil spills, and in many ways. Green nanotechnology is mainly used to eradicate environmental pollution due to its fewer side effects and low cost. This technology is an emerging research method that is highly effective, cost-effective, and reusable. In the future, producing industrial products prepared using green nanotechnology can avoid environmental issues and is a preventive measure to avoid environmental pollution.

10. Conclusions

Nanotechnology is an exciting new area in science, with many possible applications in various fields. This article seeks to outline the role of green nanotechnology. In green nanotechnology, synthesized nanoparticles are an emerging research trend. This method is less toxic or non-toxic, eco-friendly, cost-effective, and efficient compared to physical and chemical methods. Various biological agents prepare these green synthesized NPs. But nowadays, plant synthesized nanoparticle is highly efficient and effective against pollution. Green nanotechnology rapidly removes emerging pollutants in organic and inorganic contaminants such as dyes, heavy metal ions, chemical pesticides, oil spills, and medical wastes from water and soil. In upcoming future, the green synthesized NPs can easily separate and reuse because of their efficiency and high stability.

Moreover, the green synthesis of NPs in water and soil treatment is an eco-friendly and promising technology to fulfill the zero effluent discharge in wastewater treatment and soil effluents. So, green nanotechnology focuses on improving treatment methods by increasing the efficiency of the process, and reusability can save the cost of operation in the plant or processes in water treatment as well as soil. Thus, the green synthesized NPs are essential components used to remediate the water and soil pollution in the environment.

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Conflicts of Interest

The authors declare no conflict of interest.

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