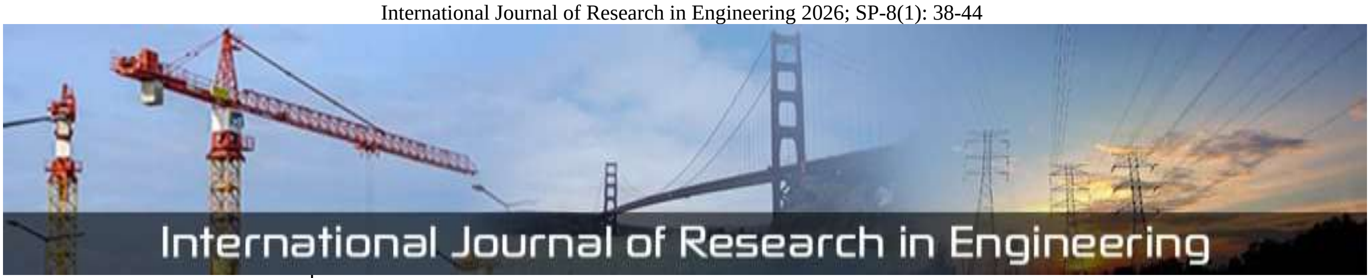

E-ISSN: 2664-8784
P-ISSN: 2664-8776
Impact Factor: RJIF 8.26
IJRE 2026; SP-8(1): 38-44

www.engineeringpaper.net
Received: 24-01-2026
Accepted: 27-02-2026

Dr. Reena
Department of Physical Science, D.P.G. Degree College, Gurugram, Haryana, India

Corresponding Author:
Dr. Reena
Department of Physical Science, D.P.G. Degree College, Gurugram, Haryana, India

Recent Advancement in Multidisciplinary innovation and research RAMIR-25

Role of green nanoparticles in wastewater treatment

Reena

DOI: https://www.doi.org/10.33545/26648776.2026.v8.i1a.177

Abstract
Nanotechnology is the inventive technology of the twenty-first century, and nanomaterials have attracted significant attention from researchers around the globe. Green synthesis of nanoparticles (NPs) is a promising exploration trend in green nanotechnology as this method is less toxic, environmentally friendly, robust, proficient, and inexpensive as compared to other conventional physical and chemical methods. It can create materials with peculiar and strange qualities that have never been known to mankind before. Many physicochemical techniques are often castoff to generate nanoparticles (NPs). Recent advances and challenges about this nanocatalyst and nanomaterials and their potential applications in wastewater treatment and water purification are highlighted, including toxicity and biosafety concerns. The present review outlines the developments and issues pertaining to the exploitation of these nanomaterials bestowed to wastewater treatment and photocatalytic activities from the last ten years. The knowledge of adsorption is discovered, and varieties of nano-adsorbents that are commonly used in the treatment of waste water have been carefully inspected. The types of contaminants that nano adsorbents may remove are also covered in the paper, with an emphasis on the nano adsorbent's renewal. Due to its beneficial environmental uses, including the removal of dangerous pollutants and the production of sustainable energy, photocatalysis has received a lot of attention.

Keywords: Nanomaterials; Metal oxides; Green synthesis; Photodegradation; Waste water treatment

Introduction
Nanoparticles define the measure of a particle, which is in between the scope of 01-100nm. The nanoscale atomic and subatomic properties of a metal can be used in medication delivery, biomedical engineering, and nanomedicine. The three main ways of generating these nanoparticles are chemical, physical and environmental methods. Bioproduction of nanoparticles can be more cost-effective and efficient with green synthesis that avoids the use of hazardous chemicals or extreme pressures or temperatures [13, 8]. Applications of Green Synthesized Nanomaterials

Fig 1: Plant-mediated synthesis of nanoparticles

The field of nanotechnology has advanced quickly and now offers a number of appealing options for treating water and wastewater. Nanomaterials are now recognized in the degradation and remediation of persistent toxic organic/inorganic pollutants due to their unique physicochemical properties, including their high catalytic activity, high physical, chemical, and thermal stability, large specific surface area, significant chemical reactivity, and strong electron transfer capacity, among others [17].

In the last several years, biosynthesis has become a crucial component of the manufacturing of metal oxide nanoparticles. It eliminates dangerous chemicals produced by chemical reactions as well as the organic solvent used in synthetic treatments. The present evaluation indicates that, when employed in physical and chemical processes, metal nanoparticles created from plants are safe, reliable, and environmentally friendly. Because of its inexpensive technology, plant extract nanoparticle synthesis is a novel and practical technique for large-scale manufacturing [1]. It has long been known that plants contain a variety of medicinal chemicals that were formerly employed as herbal therapies. Because of its vast variety of plant species, it is still being researched for a wide range of applications in industry, agriculture, and medicine, and as a result, it is being used as a resource for the creation of several nanoparticles. Recent findings have suggested that the presence of bioactive compounds found in plants, such tannins, phenols, alkaloids, terpenoids, flavonoids, quinines, and others, can be beneficial to the production of nanoparticles.

One of the most pressing problems facing the world today is water contamination from both organic and inorganic contaminants. Waste streams from several industries, such as paper, battery, metal smelting, textiles, mining, food, fertilizers, and pesticides. These sectors can have a significant negative impact on the environment and create a wide range of issues for living organisms [23, 3, 9, 6]. Nano materials have demonstrated their utility in a range of commercial domains, such as pharmaceuticals, water treatment, catalysis, and sensing. They differ from other typical materials in their basic mechanical, optical, magnetic, and electrical characteristics [62]. Many different kinds of nano-based materials have been successfully employed to remove inorganic anions, heavy metal ions, and dyes from water that are produced by microbial organisms. These materials include a wide range of nanocomposite materials, as well as metal and metal oxide nanoparticles and carbon nanotubes (CNTs) [15]. These can enter human organs via polluted food chains and drinking water [10] and lead to a variety of potentially fatal issues. Dyes are often used in the paper, textile, rubber, leather, pharmaceutical, food, and cosmetic industries. The wastewater from these businesses releases significant amounts of harmful synthetic dyes, which causes a variety of serious health issues for people as well as environmental issues. The metabolites of most dyes are just as hazardous and carcinogenic as the dyes themselves. Therefore, it's imperative to treat dye-containing water before releasing it into the environment to lessen toxicity, avoid water contamination, and protect the ecology [13].

Given these findings and in line with our research on nanomaterials [16], the goal of the current study is to summarize the recent progress in the removal and detection of harmful contaminants and aqueous pollutants using a variety of environmentally synthesized nanomaterials. The existing review article, however, concentrates more on the different methods for green preparation of nanoparticles.

2. Techniques for Creating Nanomaterials

Because of their significance in reducing environmental effect when proteins and/or peptides are utilized as green-reducing agents, the biosynthesis of nanoparticles has attracted increasing attention in recent years. The fabrication of nanomaterials typically relies on two fundamental strategies: top-down and bottom-up methodologies. The production of nanomaterials was covered in a number of studies.

Table 1: Various techniques for producing nanomaterials.

Sr. no	Nanomaterials	Synthesis method	Particle size (nm)
1	$CoFe_2O_4$	Microwave	55
2	$NiFe_2O_4$	Green method	17-29
3	MgZn Fe_2O_4	Sol-gel auto combustion	25.3-33.4
4	$CoNiFe_2O_4$ (Nd doped)	Combustion	12-21
5	$NiFe_2O_4$/rGO	Green method	3-5
6	$ZnFe_2O_4$ (Mg doped)	Sol-gel auto combustion	35.85
7	$CoFe_2O_4$ (Ag doped)	Combustion method	24-41
8	$CoFe_2O_4$	Combustion	15-21
9	$CoFe_2O_4$ (Zn doped)	Green method	18
10	$ZnFe_2O_4$	facile Molten Salt Method	50-90
11	$TiO_2/ZnFe_2O_4$	Sol-gel	10
12	$ZnFe_2O_4$/AgI composites	hydrothermal method	10
13	$NiFe_2O_4$@TiO_2	Wet chemical techniques	$12\text{-}14 \pm 2$
14	ZnO	Sol-gel	1-10
15	ZnO	Sonochemical synthesis	10
16	ZnO	Solid state reaction	15-20
17	ZnO	Microemulsion system	5-35
18	ZnO	Alcohothermal decomposition of copper acetate	3-9
19	ZnO	Sol-gel techniques	7-9
20	ZnO	Spinning disk reactor	20-30

2.1. Biological production

Because of its straightforward, rapid, environmentally friendly procedure, regulated toxicity, and capacity to modify size characteristics, our primary goal is to highlight the synthesis of nanoparticles using green extracts. Numerous natural sources, such as plants, yeast, fungi, and bacteria, are used to make nanoparticles. In addition, single-cell and multicultural organisms can produce extracellular and intracellular inorganic nanoparticles. Using green synthesis approaches, plant leaf extracts have been used by many scientists to create nanoparticles. The extraordinary ability of plant-derived biomolecules to convert metal salts into nanoparticles is one of its remarkable properties. For this reason, plant extract-based biosynthetic approaches are becoming more and more popular as a possible alternative to established, reliable, and inexpensive methods of nanoparticle manufacturing. Using Flacortia indica and Aloe vera as fuel, $CuFe_2O_4$ was produced, and its characteristics were studied [10]. Using Mangifera indica as biofuel, $NiFe_2O_4$ has been hydrothermally produced with average particle diameters under 45 nm. Ninety percent of the commercial dye methyl blue breaks down in 80 minutes when exposed to solar radiation [7].

Numerous publications describe the green synthesis and nanoparticle size control methods using various plant extracts for the manufacture of nano ferrites, including photocatalysis. The end result is the production of nanoparticles that are good for the environment. By utilizing biomolecules from plant extracts, metal ions can be converted into nanoparticles in a single step of the green process. This biogenic reduction of metal ion to base metal can be accelerated significantly at moderate temperature and pressure. The plant extract used as fuel has an impact on particle size. Particle size is a crucial characteristic of nanoparticles since a reduction in particle size enhances bioactivity. There has been recent interest in using plant extracts to create ferrite nanoparticles, and the public has access to a large number of scholars. The green-assisted method offers the additional benefits of using a widely available plant resource and incorporating synthetic chemicals that support the reduction process throughout the synthesis.

The synthesis may be carried out in a single step using bacteria, action bacteria, yeast, molds, algae, and plants or their byproducts. By lowering enzymes, proteins, phenolic chemicals, amines, alkaloids, pigments, and other molecules from plants and microorganisms, nanoparticles are created. Biological beings that naturally contain these chemicals are used in the environmentally friendly synthesis process to produce nanoparticles that are biocompatible. Since microorganisms develop quickly, have a low cultural cost, and are simple to manage and regulate the expanding environment, they are more adept at producing nanoparticles. Moreover, some bacteria have unique strategies to reduce the harmful effects of metals, particularly heavy metals. Microorganisms are chosen because they can produce nanoparticles both in-situ and ex-situ. Using metabolic processes and bacterial reducing agents such proteins and enzymes, metal ions can be reduced and precipitated to produce nanoparticles [16, 18]. Sundried *Cinnamomum camphora*, *Azardicta indica* leaf extract, and Geranium extract can be used to create gold and silver nanoparticles [22, 23]. Gold and silver ions, which are simultaneously present in solution and exposed to plant leaf extract, are cheaply reduced to create bimetallic silver and gold nanoparticles. Making silver nanoparticles using the latex of Plumeria rubra is also covered in the literature. The biosynthetization of gold nanoparticles using Mirabilis jalapa leaf extract was described. In prior years, the production of nanoparticles using bacteria has increased significantly due to its versatility. Researchers have shown that members of the Bacillus genus can both create metallic nanoparticles and lower the amount of silver in the body. Additionally, they have the ability to produce extracellular circulating nanoparticles [19]. Utilizing bacteria is another technique for creating gold nanoparticles. Full Marinobacterpelagius strains are advantageous for the consistent, monodisperse manufacture of gold nanoparticles, according to the literature [16]. According to [6], titanium nanoparticles were produced using Lactobacillus strains. At ambient temperature, the process is carried out. To determine the creation of Ti nanoparticles, X-ray and transmission electron microscopy analyses are carried out. There are many aggregates that are about spherical in shape and range in size from 40 to 60 nm, as well as individual nanoparticles.

The tolerance to toxicity, higher bioaccumulation, simplicity of synthesis, inexpensive cost, simple downstream processing, and biomass management are all factors that now govern the fungal bioproduction of nanoparticles. Through the extracellular synthesis of silver nanoparticles, Aspergillus niger [15], Fusarium solani [23], and Aspergillus oryzae [19] have all been found to produce silver nanocrystals. Moreover, Pleurotus sajorcaju was used to generate extracellular nanoparticles [25]. Trichoderma viride may create spherical nanoparticles [24]. When Fusarium oxysporum is exposed to silver ions, it generates stable Ag hydrosols [5].

The scientific community throughout the world has recently published a variety of reviews that discuss the biosynthesis of nanomaterials from different natural sources [13, 12], [25], [Fig. 2].

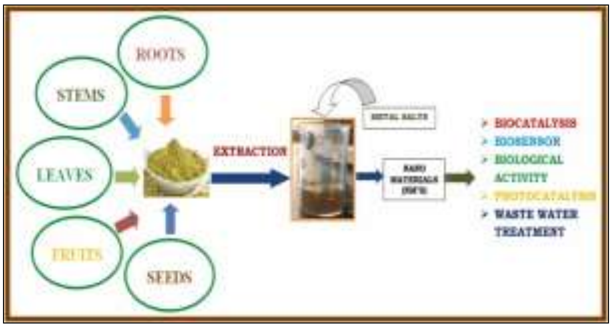

Fig 2: Applications of nanoparticles in wastewater treatment

In a more recent study, Nagesh *et al*. reported that an aqueous extract of Cissus quadrangularis L. was utilized to create Iron Oxide Nanoparticles (IO-NPs) from anhydrous ferric chloride. FT-IR, XRD, UV-Vis, PSA, Zeta potential, SEM, and EDX methods were used to describe the produced IO-NPs. At a concentration of 250 µg/mL, the antioxidant and anti-inflammatory effects of Cissus quadrangularis L. mediated IO-NPs showed the highest percentage inhibition of 75.65 ± 0.0027 and 76.48 ± 0.0027, respectively, with IC50 values of 162.55 and 148.40 µg/mL.

2.2. Treatment of wastewater using nanomaterials

Water is the most important and necessary component of every living thing on the planet. Nevertheless, as a result of industrialization and urbanization, dyes that are harmful to aquatic life have contaminated sources of clean water. Due to their photocatalytic characteristics, physicochemical equilibrium, high porosity, excellent carrier separation effectiveness, and paramagnetism, nanomaterials are readily recovered. Their band gap is, however, surprisingly narrow. In recent years, a variety of wastewater treatment techniques have been studied, but their application is limited by a number of factors, such as the use of hazardous chemicals, the production of disinfection byproducts (DBPs), and the time of application. As a gifted technology that has achieved remarkable accomplishments in a variety of areas, including wastewater treatment, nanotechnology holds promise as a method for manipulating matter at the atomic or molecular level to create innovative structures, techniques, and procedures with superior electrical, optical, magnetic, conductive, and mechanical properties. Nanomaterials' high surface-to-volume ratio, high sensitivity and reactivity, high adsorption capacity, and ease of functionalization make them ideal for use in wastewater treatment. The nanotechnology-based wastewater treatment methods that are now being developed, including adsorption and biosorption, nanofiltration, photocatalysis, disinfection, and sensing technology, are discussed in this article. The literature included numerous examples of the usage of nanomaterials in waste water treatment, [6]. In this article, we discuss the benefits and viewpoints of different nanomaterials over the past few years.

Wastewater, which is the liquid waste product of municipal garbage, contains pollutants such as hazardous heavy metals, microorganisms, organic matter, and inorganic soluble compounds. The biological, chemical, and physical characteristics of pristine water are changed by these pollutants [2]. There are many kinds of wastewater, including household waste, organic and inorganic substances, urine and feces from waste materials, as well as commercial and agricultural wastewater [4]. The contaminants in the wastewater are shown in Figure 3.

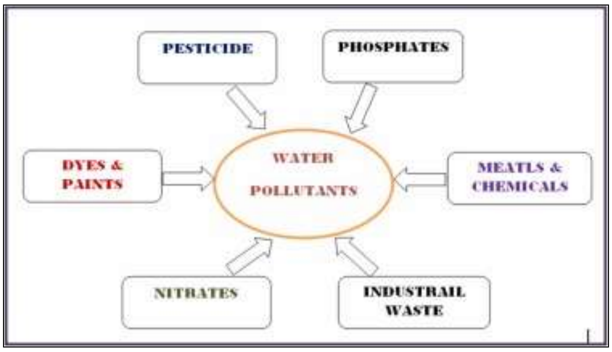

Fig 3: Represents the pollutants present in the wastewater.

When the energy of the light source is lower than the band gap energy, photodegradation occurs. Photocatalytic degradation is shown schematically in Figure 2. When the light source exceeds the band gap, negative electrons in the valence band gain energy and become excited to the conduction band. The process of photocatalytic degradation involves negatively charged electrons forming a positively charged gap in the valence band, followed by reduction and oxidation electrons. The photocatalytic dye degradation employing manufactured nanoparticles was assessed by examining the dye breakdown under UV or visible light at specified intervals. In the meantime, the solution is visualized using a spectrophotometer, and the experiment's photo reactivity is analyzed. The amount of dye used in the photocatalyst determines its rate of disintegration. It was emphasized that additional study requires the acquisition of a photocatalyst after multiple applications. Using a created nanoparticle, photo catalytic dye breakdown was monitored at specific intervals under UV, visible, or sunlight exposure. Photodegradation occurs as a result of the difference between the light energy and the band gap energy. Irradiation light that exceeds the band gap excites the valence band's negative electrons into the conduction band. Photocatalytic breakdown is demonstrated by the half-reactions of reduction and oxidation with electrons and holes, respectively. The photo reactivity of the experiment is evaluated at regular intervals, and a spectrometer is used to visualize the solution. For future study, the photocatalyst concentration was measured and reiterated. Wastewater contains dangerous substances like trace elements, radioactive elements, and bigger microbes like bacteria, viruses, and protozoa. Wastewater is also a significant factor in waterborne diseases, some of which can be deadly, such as typhoid fever and cholera. Due to polluted water, about 1.5 million children under the tender age of five perished in 2004 [9]. In 2011, Beak and An investigated the inhibitory effects of different nanomaterials on microbial pathogens. Sb2O3, NiO, CuO, and ZnO are the nanoparticles that were investigated [15]. Wastewater treatment may employ the physical, chemical, and biological processes to get rid of various pollutants from water [17]. Water that has been treated with wastewater includes organic, inorganic, and gaseous compounds. Organic pollutants consist of 50% proteins, 40% fats and oils, and 10% carbohydrates. Organic contaminants in wastewater include impurities and surfactants (Baek and J. 2011). Novel water treatment options using nanotechnology include adsorption, electrostatics, reactivity, hydrophilic and hydrophobic interactions, sensors, and high-aspect-ratio optical electronics. By being efficient, flexible, and modular, nanotechnology procedures deliver high-quality, low-cost water and wastewater solutions. Uncommon water sources may be treated and fixed more affordably using nanotechnology.

2.3. Utilizing nanomaterials to break down colorsphotocatalytically

Synthetic organic dyes are a common coloring ingredient in many sectors, including the textile and food industries. Although some organic colors have intriguing dyes and long-lasting effects, they can also induce harmful disruptions to human health and aquatic ecosystems [10], [6]; Muhammad 2024). We examine here the effectiveness of several nanomaterials and their nanocomposites in breaking down dyes. Around the world, it is estimated that there are 8,000 distinct dyes used by various industries right now. The majority of the colors used are hazardous to aquatic life and cause cancer. The release of dye into water is the primary contributor to water pollution, salt buildup, and disruption of aquatic ecosystems. The government has enacted laws restricting dye concentrations, and before being released into the water system, solvents that contain dyes must be treated. As a result, a significant amount of study is devoted to photodegradation tests carried out to lower the level of harmful dyes. Consequently, in order to lessen pollution and alleviate the burden on water resources, it is imperative that environmentally friendly technological solutions be implemented. Electro catalysis, photocatalysis and biocatalysis, have all been widely utilized recently to accomplish these objectives (Fig. 4).

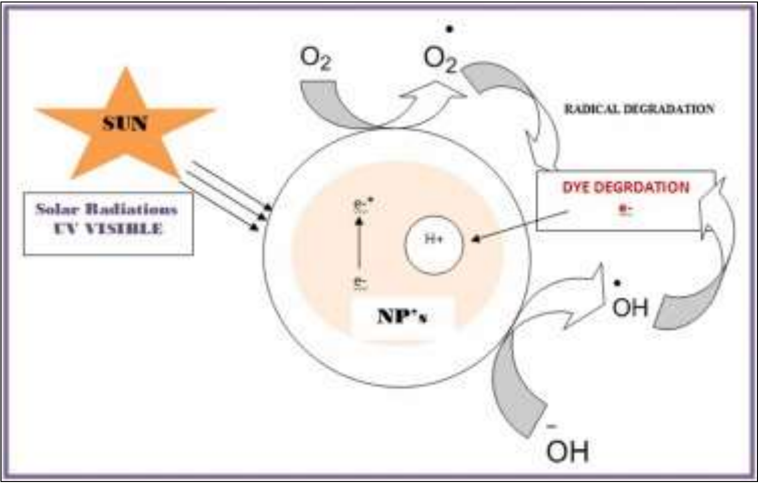

Fig 4: Schematic representation of photocatalytic degradation.

Table 2: Various nanomaterial degradation by various dyes.

Sr. No.	nanomaterials	Synthesis method	Dye used	Irradiation time
1	$BaTiO_3$	hydrothermal method	EBT	30 min
2	$BiFeO_3$	Sol-gel	MB	3 hours
3	$NiFe_2O_4$	Co-precipitation	MO	140 min
4	$ZnFe_2O_4$	combustion	MG	150 min
5	Mn-$ZnFe_2O_4$	Hydrothermal method.	AO−88	90 min
6	$NiFe_2O_4$	Sonochemical method	DY	90 min
7	$CaFe_2O_4$	Ultra-sonication	CR	120 min
8	$CoZnFe_2O_4$ (Ce & Ni doped)	Sol-gel auto-combustion	CR	60 min
9	$BaFe_2O_4$	Citrate-nitrate combustion	MO	120
10	Ce_2TiO_5	Hydrothermal method	MB	30 min
11	Fe_2TiO_5	Sol-gel method	MO	60 min
12	La_2O_3/Ag_3O_4	impregnation process	RhB	60 min
13	Ag_2O@Ag@$BiVO_4$	co-precipitation	RhB, MB	90 min
14	Ag, B, Eu tri-modified $BiVO_4$	sol-gel	MO	50 min
15	(GO/$BiVO_4$)	solvothermal method	methomyl	180 min
16	$ZnFe_2O_4$/AgI composites	hydrothermal method	Rh-B	40 min
17	$CoFe_2O_4$	microwave combustion method		180 min
18	$MnFe_2O_4$	Chemical method	(RR198)	200
19	$BiFeO_3$ (La +3 doped)	Sol gel auto-combustion	Phenol red	120 min
20	$AgCa_2Ni_2V_3O_{12}$	Pechini method	MB	300 min
21	Ag-rGO-$BiVO_4$	Sonication	Rh-B	10 h

(MB-Methylene blue, MO- methylene orange, MR-methylene red, EBT- erychrome Black-T, RR198-Reactive Red 198, MG-Malachite Green, AO88-Acid orange 88, DY-Drimarene yellow, CR-Congo red, RhB- Rhodamine B)

2.4. The use of nanocomposites as photocatalysts

Due to its roles in solar energy recovery and environmental cleanup in the presence of sunlight, photocatalysis with visible light has attracted a lot of attention. This method makes use of semiconductor photocatalysis since it produces hydroxyl and oxidative radicals, which are highly reactive and aid in the breakdown process.

A photocatalytic cell typically consists of an adsorbent, an adhesive, a substrate, and a photocatalyst. Overall, a photocatalytic cell is able to perform photocatalysis, which uses metal-oxide NPs, such titanium oxide, to remove heavy metals from wastewater [11]. The photocatalysis method employs both light and a catalyst concurrently to improve and enhance a chemical process that can break down organic pollutants. Several metal oxides and adsorbents have been used to investigate heterogeneous photocatalysis. Numerous nanomaterial adsorbents have been developed because they can enhance the efficiency and capacity of adsorption for removing pollutants from wastewater. Various membranes act as adsorbents in photocatalytic cells. The combination of metal oxide and adsorbent demonstrated a significant cooperative effect in removing the polluted water [16].

Photocatalytic wastewater treatment has employed metal oxide catalysts, such as zirconium dioxide (ZrO2), ZnO, TiO2, and silica, for decades. These metals, which are environmentally friendly, pricey, and effective at absorbing pollutants at low concentrations (ppb), have been proposed for the removal of dangerous contaminants, such as heavy metals like cadmium.It is well established that ZnO acts as a photocatalyst in the removal of heavy metals from water solutions [8, 9]. Heavy metals like Pb and Cd may be removed via photocatalysis using ZnO [24]. For example, Cd was removed from an aqueous solution using ZnO as a photocatalyst in an experimental-laboratory batch study. When the energy of the band gap is less than the energy of the light source, photodegradation occurs. Negative electrons in the valence band absorb energy and become excited to the conduction band when the light surpasses the band gap. Negative electrons create a positively charged hole in the valence band, which leads to electron-hole half-reactions of reduction and oxidation.

The most widely used metal oxide in photocatalysis is titanium dioxide (TiO2). TiO2 has a high refractive index, high stability, low cost, high surface activity, and excellent catalytic properties, among other unique features. TiO2 is a good photocatalyst because of its chemical stability and high reactivity with ultraviolet (UV) light having a wavelength of less than 390 nm. Photocatalysis operates on the fundamental principle of photo excitation of the catalyst, which generates holes (h+) and emits electrons (e-) through light (UV) irradiation in the conduction band. Because of its high photocatalytic activity and chemical stability, zinc oxide (ZnO) is advised for the removal of water pollutants, while TiO2 has lately been used in composites with adsorbents, such powder activated carbon (PAC) and TiO2, for the treatment of wastewater that contains heavy metals. The band gap of ZnO is 3.37 eV, and its exciton binding energy is high at room temperature. ZnO can exist in a variety of forms, including nanorods, nanowires, nanosheets, nanobelts, and complicated hybrids. Because of its electrochemical stability, rapid oxidation, and low toxicity, zinc oxide (ZnO) is a potential photocatalyst. ZnO is the oldest and most widely used metal oxide for heterogeneous photocatalysis [23]. In an environmentally friendly way that avoids the use of hazardous materials, Al-Qahtani showed the manufacturing of nanoparticles of zero valent silver using an extract of Ficus benjamina leaves. The efficacy of the manufactured silver nanoparticles in removing Cd2+ from the polluted solution was evaluated using a variety of variables, such as the heavy metal concentration, pH, adsorbent dose, swirling rate, and contact duration [10]. The Fe3O4-NPs utilized in the Pb adsorption experiments were biosynthesized and trapped in calcium alginate beads]. Using P. pavonica, alginate beads made of green synthetic Fe3O4-NPs Although L. Thivy's extraction capacity was 91%, S. acinarium L. Setchell 1933's was just 78% after 75 minutes [24].

Mystrioti *et al*. To create nano-iron suspensions that reduce Cr(VI), Mystrioti *et al*., tested five plant extracts and juices: red wine, pomegranate juice, spearmint, clove, and green tea. Plant and juice extracts containing polyphenols lower water iron levels and stabilize nanoparticles after oxidation and agglomeration. In a one-step, room-temperature biosynthetic process utilizing eucalyptus leaf (EL) extracts, the first spherical iron nanoparticles were created. Using XRD and FTIR, this study demonstrated that EL-Fe NPs capped/stabilized by poly phenols were evaluated for their reactivity in treating pig wastewater, with the removal of 84.5% COD, 30.4% P, and 71.7% N. CuO nanoparticles (NPs) were created using an extract of the green Madhuca longifolia plant. The average particle size of the well-distributed, spherical nanoparticles created by the two plant extracts was 120 and 130 nm. Different particle sizes give CuO NPs different band gaps and photoluminescence intensities. Methylene blue dye degradation was used to evaluate the NPs' photocatalytic capabilities, which suggests that photocatalysis can be used to treat wastewater [20].

To create nanocomposites, which have comparatively superior applications and utility, metal oxides are often supported or impregnated with large-sized porous materials, such carbon nanotubes (CNTs) or zeolites, because of their low mechanical strength. Nano-composites with Ag, CNTs, CeO2 [13], and γ-Mn2O3 [16] are produced using NMOs like ZnO [13], CdO [14], and TiO2 [15]. Utilizing the enhanced photocatalytic capabilities of these nanocomposites, the wastewater is treated to remove industrial textile effluents.

3. Conclusions

The green synthesized nanoparticles (NPs) are a promising technology for the resource-constrained world since they require little energy and money and can aid in achieving zero effluent discharge after wastewater treatment. Furthermore, it's a sustainable option for the environment. Due to green nanotechnology, organic dyes and heavy metal ions are being quickly removed from water and wastewater. In the future, the wastewater treatment industry will be greatly impacted by nanoparticles. However, expenditures related to running plants and processes may be decreased by enhancing the effectiveness of existing treatment methods and the reusability of nanomaterials. The research examines several strategies for producing nanomaterials, placing a strong emphasis on the benefits of environmentally friendly technology. Particle sizes, morphological concepts, and estimated surface area can all have an impact on the breakdown activity of a photocatalyst series. The nanoparticles' effective surface-based active sites demonstrate their potential as catalysts. Although metal oxide nanoparticles have a variety of uses similar to other nanoparticles, there are still some health hazards as a result of their unpredictable use and release into the environment. These problems must be addressed in order for nanoparticles to be utilized in a more effective and ecologically responsible manner. To commercialize the use of green synthesized NPs for wastewater treatment and pollutant removal, more research in this field is needed.

4. Potential results

Green manufactured NPs are nontoxic and environmentally friendly because they make use of a notable green chemistry technique and a plant extract that provides essential metabolites, which act as reducing/capping agents during NP synthesis. The treatment process has made good use of green synthetic nanoparticles (NPs) in removing contaminants from water and wastewater, resulting in zero-valent effluent discharge. The use of metal-oxide nanoparticles in 21st-century nanomedicine and other biological applications appears to be on the verge of becoming essential. These nanoparticles may be created artificially using a variety of techniques, and they can be utilized effectively in a wide range of biological and nonmedical applications. The creation of monodispersed nanoparticles is necessary for more research. However, the method by which these nanoparticles were produced is unknown at this time. Future research should thus focus on the process that determines the size and shape of nanoparticles. The need to reduce toxicity and expand the use of nanoparticles in therapeutic applications is another major challenge. The need to reduce toxicity and expand the use of nanoparticles in therapeutic applications is another significant obstacle [25]. However, before noble metal nanoparticles are widely employed, their effects on anthropological health aspects must be taken into account, even if developments in nanoscience are enabling novel applications of them to address these concerns. By [26], a comprehensive examination of the nascent nanotechnology-based strategies for treating organic and inorganic contaminants as well as pathogenic and nonpathogenic microorganisms in wastewater.

References

1. Abiraman T, Ramanathan E, Kavitha G, Rengasamy R, Balasubramanian S. Ultrasonics Sonochemistry. 2017;34:781-791.
2. Abou El-Nour KMM, Eftaiha A, Al-Warthan A, Ammar RAA. Synthesis and applications of silver nanoparticles. Arabian Journal of Chemistry. 2010;3(3):135-140.
3. Abu-Nada A, McKay G, Abdala A. Recent advances in applications of hybrid graphene materials for metals removal from wastewater. Nanomaterials. 2020;10:595-599.
4. Adams LK, Lyon DY, Alvarez PJJ. Comparative eco-toxicity of nanoscale TiO_2, SiO_2, and ZnO water suspensions. Water Research. 2006;40(19):3527-3532.
5. Ahmad A, Mukherjee P, Senapati S, Mandal D, Khan MI, Kumar R, Sastry M. Extracellular biosynthesis of silver nanoparticles using the fungus *Fusarium oxysporum*. Colloids and Surfaces B: Biointerfaces. 2003;28(4):313-318.
6. Alizad Oghyanous F. Nanoparticles in wastewater treatment. IntechOpen; 2022.
7. Al-Musawi TJ, Rajiv P, Mengelizadeh N, Arghavan FS, Balarak D. Photocatalytic efficiency of $CuNiFe_2O_4$ nanoparticles loaded on multi-walled carbon nanotubes as a novel photocatalyst for ampicillin degradation. Journal of Molecular Liquids. 2021;337.
8. Al-Radadi NS, Hussain T, Faisal S, Shah SAR. Novel biosynthesis, characterization and bio-catalytic potential of green algae (*Spirogyra hyalina*) mediated silver nanomaterials. Saudi Journal of Biological Sciences. 2022;29:411-419.
9. Al-Thabaiti SA, Al-Nowaiser FM, Obaid AY, Al-Youbi AO, Khan Z. Formation and characterization of surfactant stabilized silver nanoparticles: A kinetic study. Colloids and Surfaces B: Biointerfaces. 2008;67(2):230-237.
10. Al-Qahtani KM. Cadmium removal from aqueous solution by green synthesis zero valent silver nanoparticles with *Benjamina* leaves extract. Egyptian Journal of Aquatic Research. 2017;43(4):269-274.
11. Anjum M, Miandad R, Waqas M, Gehany F, Barakat MA. Remediation of wastewater using various nanomaterials. Arabian Journal of Chemistry. 2019;12(8):4897-4919.
12. Antunes Filho S, Dos Santos MS, Dos Santos OAL, Backx BP, Soran ML, Opriş O, *et al*. Biosynthesis of nanoparticles using plant extracts and essential oils. Molecules. 2023;28(7):3060.
13. Soran L, Opriş O, Lung I, Stegarescu A, Bououdina M. Biosynthesis of nanoparticles using plant extracts and essential oils. Molecules. 2023;28(7):3060.
14. Argueta-Figueroa L, Morales-Luckie RA, Scougall-Vilchis RJ, Olea-Mejía OF. Synthesis, characterization and antibacterial activity of copper, nickel and bimetallic Cu-Ni nanoparticles for potential use in dental materials. Progress in Natural Science: Materials International. 2014;24(4):321-328.
15. Boutra B, Güy N, Ozacar M, Trari M. Magnetically separable $MnFe_2O_4$/TA/ZnO nanocomposites for photocatalytic degradation of Congo Red under visible light. Journal of Magnetism and Magnetic Materials. 2020;497:165994.
16. Baek YW, An YJ. Microbial toxicity of metal oxide nanoparticles (CuO, NiO, ZnO, and Sb_2O_3) to *Escherichia coli*, *Bacillus subtilis*, and *Streptococcus aureus*. Science of the Total Environment. 2011;409(8):1603-1608.
17. Bahrudin NN, Nawi MA. Immobilized titanium dioxide/powdered activated carbon system for the photocatalytic adsorptive removal of phenol. Korean Journal of Chemical Engineering. 2018;35:1532-1541.
18. Bartram J, Balance R. Water quality monitoring: A practical guide to the design and implementation of freshwater quality studies and monitoring programmes. London: Taylor & Francis; 1996.
19. Bharathkumar S, Sakar M, Balakumar S. Egg white-mediated synthesis of $BiFeO_3$ cubes and their enhanced photocatalytic degradation properties under solar irradiation. Journal of Materials Science: Materials in Electronics. 2022;33(16):12638.
20. Binupriya AR, Sathishkumar M, Yun SI. Myco-crystallization of silver ions to nanosized particles by live and dead cell filtrates of *Aspergillus oryzae* var. *viridis* and its bactericidal activity toward *Staphylococcus aureus*. Industrial and Engineering Chemistry Research. 2010;49(2):852-858.
21. Bhukal S, Sharma R, Mor S, Singhal S. Mg-Co-Zn magnetic nanoferrites: Characterization and their use for remediation of textile wastewater. Superlattices and Microstructures. 2015;77:134-151.
22. Carnes CL, Stipp J, Klabunde KJ, Bonevich J. Synthesis, characterization, and adsorption studies of nanocrystalline copper oxide and nickel oxide. Langmuir. 2002;18(4):1352-1359.
23. Chandran SP, Chaudhary M, Pasricha R, Ahmad A, Sastry M. Synthesis of gold nanotriangles and silver nanoparticles using *Aloe vera* plant extract. Biotechnology Progress. 2006;22(2):577-583.
24. Chang MH, Liu HS, Tai CY. Preparation of copper oxide nanoparticles and its application in nanofluid. Powder Technology. 2011;207(1):378-386.
25. Lallianrawna, Biswas A, Selvaraj M, Changmai B, Rokhum SL. Green synthesis of silver nanoparticles using plant extracts and their antimicrobial activities: A review of recent literature. RSC Advances. 2021;11:2804-2837.
26. Chu S, Cui Y, Liu N. The path towards sustainable energy. Nature Materials. 2017;16(1):16-22.