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GREEN SYNTHESIS OF NANOMATERIALS FOR BIOMEDICAL AND ENVIRONMENTAL APPLICATIONS

Dr. Basavarajeshwari H[1*], Dr. Tarunima Gupta[2], Buddharatna J. Godboley[3], B. Santhi Anusha[4], Manoj R. Sonawane[6]

[1*]Assistant Professor of Botany, Botany (Research Area -Plant Nanotechnology), Smt. A. S. M. College for Women, Ballari, (Affiliated to Karnataka State Akkamhadevi Women's University, Vijayapura), Karnataka, India, Pincode: 583103, Email id- rajeshwarimnv@gmail.com
[2]Assistant Professor, Clinical Biochemistry, Biochemistry, Molecular Genetics, Mahatma Jyotiba Phule Rohilkhand University, Bareilly, U.P, Rajshree Medical Research Institute & Hospital, Bareilly, Uttar Pradesh, Bareilly / 243501, ORCID ID: 0000-0001-8951-5390, Email ID: dr.tarunimagupta2012@gmail.com
[3]Associate Professor, St John College of Engineering & Management, Palghar, Civil Engineering, Email id- buddharatnag@sjcem.edu.in
[4]Assistant Professor, Department of Forensic Science, Aditya University, Surampalem, Andhra Pradesh, PIN code:533437, Email - sanbellapukonda28@gmail.com
[5]Assistant Professor, Applied Sciences & Humanities, SVKM's NMIMS Global University, Dhule, MH, PIN code: 424001, Email ID: manojsonawane123@gmail.com

ABSTRACT:
Green synthesis of nanomaterials offers a sustainable route for producing functional nanoparticles with biomedical and environmental relevance. This study analyzed a secondary dataset on plant-mediated iron nanoparticles synthesized using Galinsoga parviflora, Conyza bonariensis, and Bidens pilosa leaf extracts. The dataset contained 71 files, including 62 Excel workbooks used for UV–Visible, FTIR, and pollutant degradation analysis. UV–Visible results confirmed nanoparticle formation, with GP-NPs showing the highest maximum absorbance, followed by CB-NPs and BP-NPs. FTIR analysis identified hydroxyl, carbonyl, C–O, and metal–oxygen bands, indicating that plant phytochemicals contributed to reduction, capping, and stabilization. Environmental performance was evaluated through rifampicin and methylene blue degradation. CB-NPs with H_2O_2 showed the highest rifampicin degradation efficiency, while acidic GP-NPs showed the strongest methylene blue degradation. The findings demonstrated that green-synthesized iron nanoparticles were effective for dye and pharmaceutical pollutant removal, supporting their environmental remediation potential. Biomedical relevance was established indirectly through rifampicin degradation, since antibiotic residues in water are linked to public-health and antimicrobial-resistance concerns. Overall, the results positioned green-synthesized iron nanoparticles as sustainable nanomaterials for integrated biomedical–environmental pollutant management, although future cytotoxicity, antimicrobial, and biocompatibility studies are needed.

KEYWORDS: Green synthesis, iron nanoparticles, plant extracts, rifampicin degradation, environmental remediation

1. INTRODUCTION

Nanotechnology is a significant area of research as nanoscale materials have properties that are distinctly different from their bulk counterparts, such as optical, catalytic, antimicrobial, magnetic, and surface-reactive properties. The properties have led to the application of nanomaterials in medicine, the environment, agriculture, energy systems, and industrial processing. Traditional methods of preparation of nanoparticles require high temperatures, toxic reducing agents, the use of organic solvents, and expensive equipment, and can lead to the generation of harmful residues that restrict the use of these nanoparticles for biomedical or environmental applications. The green synthesis, as such, has been gaining in popularity due to its eco-friendly approach that involves the utilization of biological resources like plant extracts, microorganisms, algae, enzymes, and natural biomolecules for the synthesis of nanoparticles, their reduction, stabilization, and capping (Samuel et al., 2022).

The basic principle of green synthesis is that biomolecules can mediate the reduction of metal ions to stable nanoparticles in a natural environment. The polyphenols, flavonoids, alkaloids, terpenoids, proteins, sugars, and organic acids found in plant extracts are particularly useful as reducing agents and stabilising agents. This way, a less toxic chemical reagent is not needed, and biocompatible nanomaterials with less environmental footprint can be developed. The production of nanomaterials using a biological approach has interdisciplinary applications in the fields of environmental remediation, drug delivery, antimicrobial applications, wound healing, biosensing, catalysis, and sustainable energy (Abuzeid et al., 2023).

The plant-mediated synthesis of nanoparticles is especially appealing due to the easy availability of plant material, the renewability, low cost, and chemical diversity. The phytochemical composition of a plant extract may affect the size, shape, surface charge, aggregation, and functional activity of nanoparticles. The significance of these characteristics is due to the strong dependence of the biological and environmental performances of this material on surface chemistry and nanoscale morphology. The utilization of plant nano-biological approaches also prompted interest in the utilization of botanical resources to create functional nanoparticles that have lesser toxicity and ecological compatibility, which are required in certain applications (Das et al., n.d.).

A significant amount of research has been directed towards the synthesis of metallic and metal oxide nanoparticles on a green pathway, which are capable of retaining nanoscale reactivity and biologically derived surface coatings. The molecules that can be extracted from plants or microbes as caps could improve the colloidal stability and minimize uncontrolled toxicity. There are growing uses of green metallic nanoparticles such as silver, gold, zinc oxide nanoparticles, copper oxide, selenium nanoparticles, and iron oxide nanoparticles in antimicrobial therapy, degradation of pollutants, photocatalysis, biosensing, and Biomedical materials development (Chopra et al., 2022).

The relevance of the present study is the magnetic, catalytic, adsorptive, and redox-active properties of iron oxide particles. The green synthesis of functional materials by them has been investigated as an environmentally friendly route to produce materials without significant chemical processing. Aqueous extracts containing iron-reducing compounds could be used to prepare plant-mediated nanosized iron oxide. Such nanoparticles can be applied in wastewater treatment, degradation of dyes, removal of heavy metals, as antimicrobial agents, and in biomedical applications where magnetic or catalytic properties are essential (Priya et al., 2021).

In the biomedical field, the potential applications of iron oxide nanoparticles include antimicrobial therapy, imaging, drug delivery, hyperthermia, and biosensing. The antimicrobial properties of green-synthesized iron oxide nanoparticles against pathogenic microorganisms have also been studied, further highlighting the potential for these nanoparticles in infection-control applications. The surface functional groups and plant-based coatings can impact interactions between microorganisms, disruption of membranes, production of oxidative stress, and biofilm inhibition (Zúñiga-Miranda et al., 2023).

Iron oxide nanoparticles derived from plants have also been reported to exhibit desirable biomedical properties that are less toxic, depending on various synthesis methods, properties of the nanoparticles, and models used for the biological tests. This is critical because in biomedical applications, the efficacy is not only important, but so are safety characteristics. Green synthesis can contribute to safer manufacturing of nanoparticles by reducing the residues of toxicity and using biological capping agents that can enhance the compatibility with living systems (Hamdy et al., 2022).

Another significant reason for green-synthesized iron nanoparticles is their application in the environment. Persistent contaminants to aquatic systems include organic pollutants, dyes, antibiotics, and pharmaceutical residues. The degradation or removal is significant because contaminated water may impact the ecosystems, human health, and dynamics of antimicrobial resistance. The iron oxide nanoparticles synthesized using the green method can be used for such remediation as they can perform the adsorption, catalytic degradation, and Fenton-like oxidative reaction. There is also the use of locally available plants for production in resource-poor environments, which can be processed using protocols (Kiwumulo et al., 2022).

Iron systems are not the only ones where the use of green nanomaterials is possible. For instance, selenium nanoparticles have been extensively touted for their biomedicine potential, such as antioxidant, anticancer, antimicrobial, and drug delivery. Their development highlights the possibility of creating biologically active nanomaterials with medically relevant functions, which allows for creating a green synthesis pathway that is sustainable (Mikhailova, 2023).

The greater benefit of green biosynthesis is also seen from the use of zinc oxide nanoparticles. Their applications in sustainable industrial and environmental uses suggest that green nanotechnology can be expanded beyond the laboratory to the areas of application where this technology must be efficient, non-toxic, and environmentally friendly. In this context, the broader applicability of green synthesis in the context of biomedical, environmental, and industrial applications of functional nanomaterials is supported by these examples (Fu et al., 2025).

In recent years, biomedical research studies have also highlighted the wound healing potential of green-synthesized metal nanoparticles. These bioactivities are suitable for them to be used in the development of high-level biomedical materials, including their antimicrobial and anti-inflammatory properties, and tissue repair mechanisms. This study outcome ensures that biomedical relevance has to be included in the studies of green nanomaterials, despite the study data being limited mainly to characterization and pollutant degradation (Singaravelu et al., 2025).

Recent research has revealed that plants can also be used as a source for the green synthesis of biologically active iron-based nanomaterials, which have several functional properties. This substantiates the justification for studying plant-based iron nanoparticles not only for biomedical applications but also for environmental applications because they are sustainable materials. In this regard, the authors of the present study investigated a dataset of green-synthesized iron nanoparticles obtained by using plant leaf extracts and characterized their degradation ability and biomedical and environmental applications (Rauf et al., 2025).

Objectives of the study:

1.To evaluate the green synthesis and characterization of plant-mediated iron nanoparticles.
2.To analyze rifampicin and methylene blue degradation using synthesized nanoparticles.
3.To assess the biomedical–environmental relevance of green-synthesized nanomaterials.

2. METHODOLOGY

2.1 Study Design and Dataset Selection

This study aimed at analyzing the green synthesis, characterization, and application potential of plant-mediated iron nanoparticles as a secondary data-based analytical study. The data set employed in this research was chosen due to the presence of experimental data for the synthesis of iron nanoparticles with the extracts of the leaves of Galinsoga parviflora, Conyza bonariensis, and Bidens pilosa. The data set was found to be suitable for the present study as it contains data on green synthesis, characterization of the nanoparticles, and degradation experiments with organic and pharmaceutical pollutants (Wanakai et al., 2022).

2.2 Green Synthesis of Iron Nanoparticles

The green synthesis method was based on the use of the extracts of the plants as biological reducing and stabilizing agents. The plant extracts used for this purpose were selected as they have been shown to be able to reduce Fe precursor ions to Fe nanoparticles. The chemicals found in the leaves, namely phenolic and flavonoid compounds, were believed to be responsible for the reduction, capping, and stabilization of the nanoparticles. The synthesis approach was regarded as a "green synthesis" as it did not require any harsh reducing agents (used in the conventional synthesis) and employed renewable plant-based materials.

2.3 Characterization of Synthesized Nanoparticles

The synthesized iron nanoparticles were characterized on the basis of the available spectroscopic and morphological data from the dataset. The data obtained from the UV–Visible spectroscopy was employed for confirmation of the nanoparticle formation by the change in absorbance value. The data obtained through Fourier transform infrared spectroscopy was analyzed to find out the functional groups that are responsible for the reduction and stabilization of the nanoparticles. The morphology, surface structure, and aggregation behavior of the particles were studied using scanning electron microscopy data. The data of the phenolic and flavonoids assay was also taken into account in supporting the role of biomolecules in the synthesis process obtained from plants.

2.4 Analysis of Environmental Application

To assess the environmental application of the synthesized nanoparticles, degradation data of organic pollutants have been measured with an emphasis on the degradation of a pharmaceutical contaminant, rifampicin. The degradation performance was evaluated under various experimental conditions, such as pH, the dosage of nanoparticles, temperature, concentration of hydrogen peroxide, and contact time. The efficiency of the degradation was interpreted by comparing the concentration and/or absorbance of the pollutant before and after treatment with the green synthesized nanoparticles.

2.5 Biomedical Relevance Assessment

The biorelevance of the dataset was indirectly evaluated by evaluating the degradation of the clinically relevant antibiotic and pharmaceutical pollutant, rifampicin. The study concentrated on the elimination of antibiotic residues from water, due to the relevance to public health, as antibiotic contamination can lead to ecological toxicity and pressure for antimicrobial resistance. In such a way, the biomedical aspect of the study would be presented under the prism of the remediation of pharmaceutical waste, and not under the prism of direct pharmaceutical or clinical use of nanoparticles.

2.6 Data Processing and Interpretation

Python-based data processing techniques were used to review and categorize the dataset files based on synthesis, characterization, and application-related variables. The experimental data have been organized, processed, and visualized using Python libraries such as Pandas, NumPy, and Matplotlib. Spectral data were used and interpreted to determine the formation of nanoparticles and the involvement of functional groups. Data on degradation were analyzed, and the treatment performance was compared with the various experimental conditions. For these compounds, degradation percentage and kinetic behavior were calculated to assess the relative efficiency of the synthesized nanoparticles. The results were analysed and discussed with respect to the twofold objective of the study: green synthesis of nanomaterials and application potential of synthesized nanomaterials in biomedical and environmental applications.

3. RESULTS

3.1 Dataset Composition and Analytical Scope

The data set consisted of experimental files involving the synthesis, characterization, and degradation of pollutants by green synthesis of iron nanoparticles using plants. A total of 71 files were found, and 62 of these were Excel workbooks with analyzable numerical data. The rest of the files were PDFs, a DOCX document, compressed image files, and instrumental data files. The files in the Excel format formed the basis for the quantitative analysis, and the SEM image archive and document files were used for morphological and contextual interpretation. The uploaded data set includes the following elements and is relevant for the following analyses.

Table 1. Dataset composition and analytical relevance

File category	Number of files	Analytical relevance
Excel workbooks	62	Main numerical data for UV–Vis, FTIR, and degradation analysis
PDF files	3	Supporting assay and documentation files
DOCX file	1	Supplementary dataset description
SEM image archive	1	Morphological interpretation
RAR archives	3	Additional compressed supporting files
SPC file	1	Instrumental spectral data
Total files	71	Complete dataset package

The data set was therefore appropriate for secondary analysis as it included data for the confirmation of green synthesis, characterization of the nanoparticles, and environmental application data for organic and pharmaceutical pollutants.

3.2 UV–Visible Spectral Confirmation of Nanoparticle Formation

The absorbance changes in the UV–Visible spectrum were detected, indicating the formation of plant-mediated iron nanoparticles. The absorbance intensity of the three nanoparticle systems obtained with the extracts from the leaves of Galinsoga parviflora, Conyza bonariensis, and Bidens pilosa varied in the analysed wavelength range. The maximum absorbance was highest for GP-NPs, followed by CB-NPs and BP-NPs. The UV–Visible absorbance profile of the green synthesized iron nanoparticles is presented in Table 2.

Table 2. UV–Visible absorbance profile of green-synthesized iron nanoparticles

Nanoparticle sample	Plant extract used	Analyzed wavelength region	Maximum absorbance observed	Relative optical response
GP-NPs	Galinsoga parviflora	250–800 nm	2.5063	Highest
CB-NPs	Conyza bonariensis	250–800 nm	0.9044	Moderate
BP-NPs	Bidens pilosa	250–800 nm	0.3598	Lowest

The higher absorbance value obtained with GP-NPs suggested higher optical response and more intense colloids and/or nanoparticle formation. The absorbance response of CB-NPs was moderate, and the weak response was among the three nanoparticle systems synthesized by BP-NPs. The results of these spectrographic analyses proved that the plant extracts were involved in the reduction of Fe^{2+} and the formation of nanoparticles. Figure 1 shows the differences in UV–Visible absorbance between GP-NPs, CB-NPs, and BP-NPs.

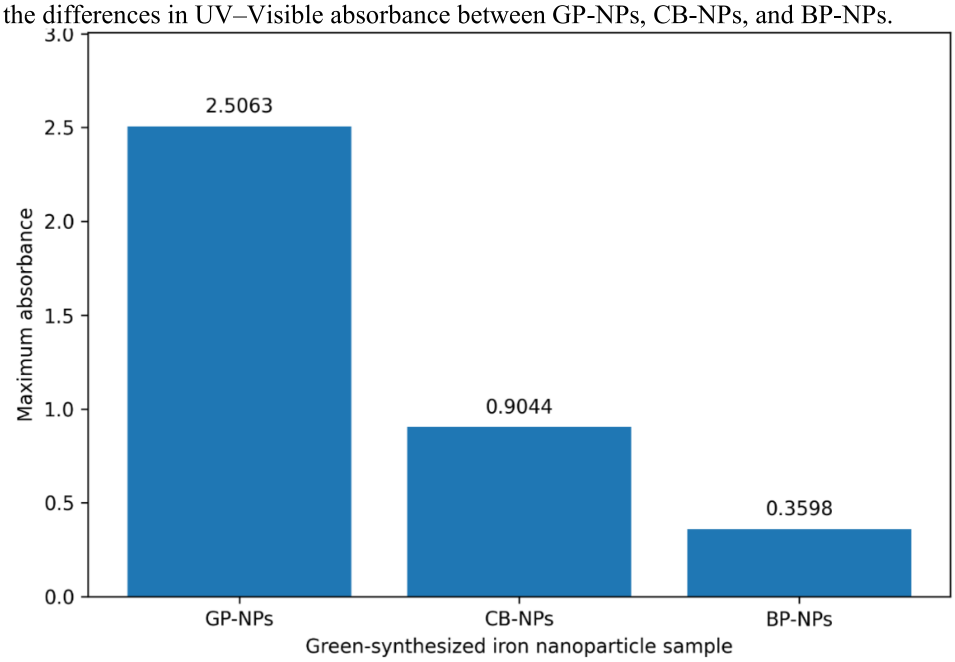

Figure 1. UV–Visible Maximum Absorbance of Green-Synthesized Iron Nanoparticles

3.3 FTIR-Based Functional Group Identification

By FTIR analysis, several prominent absorption bands were observed, which correspond to biomolecules involved in the synthesis, reduction, and stabilization of nanoparticles. The broad bands at 3364-3375 cm-1 were seen in all the samples of nanoparticles and were assigned to O–H stretching vibrations of phenolics, alcohols, or water-associated phytochemicals. The carbonyl or C=C stretching vibrations were found in the bands at 1625–1629 cm-1. The bands between 1041 and 1072 cm^{-1} suggested the occurrence of C–O stretching, and the bands within the range of 617–638 cm^{-1} indicated the formation of a metal–oxygen bond. The major FTIR bands seen in the synthesized nanoparticle samples are summarized in Table 3. The major FTIR bands observed in the synthesized nanoparticle samples are summarised in Table 3.

Table 3. Major FTIR bands detected in green-synthesized iron nanoparticle

Sample	Major FTIR bands detected, cm^{-1}	Functional interpretation	Relevance to synthesis
GP-NPs	3375, 1627, 1391, 1265, 1041, 814, 638	O–H, C=O/C=C, C–O, and Fe–O related vibrations	Reduction, capping, and stabilization
CB-NPs	3364, 1625, 1436, 1265, 1072, 816, 617	Phenolic, carbonyl, ether/alcohol, and metal–oxygen groups	Phytochemical-assisted nanoparticle formation
BP-NPs	3364, 1629, 1383, 1268, 1043, 814, 636	Hydroxyl, carbonyl, C–O, and Fe–O related groups	Biomolecular stabilization and iron oxide formation

The similarity of the major bands in FTIR in the three samples suggested that similar phytochemical groups were involved in the green synthesis process. Low-frequency bands corresponding to metal–oxygen vibration were observed, which helped confirm the formation of nanoparticles of iron. These results validated the potential of phytochemicals as reducing and stabilizing agents. The majority of FTIR bands related to phytochemical reduction and nanoparticle stabilization are shown in Figure 2.

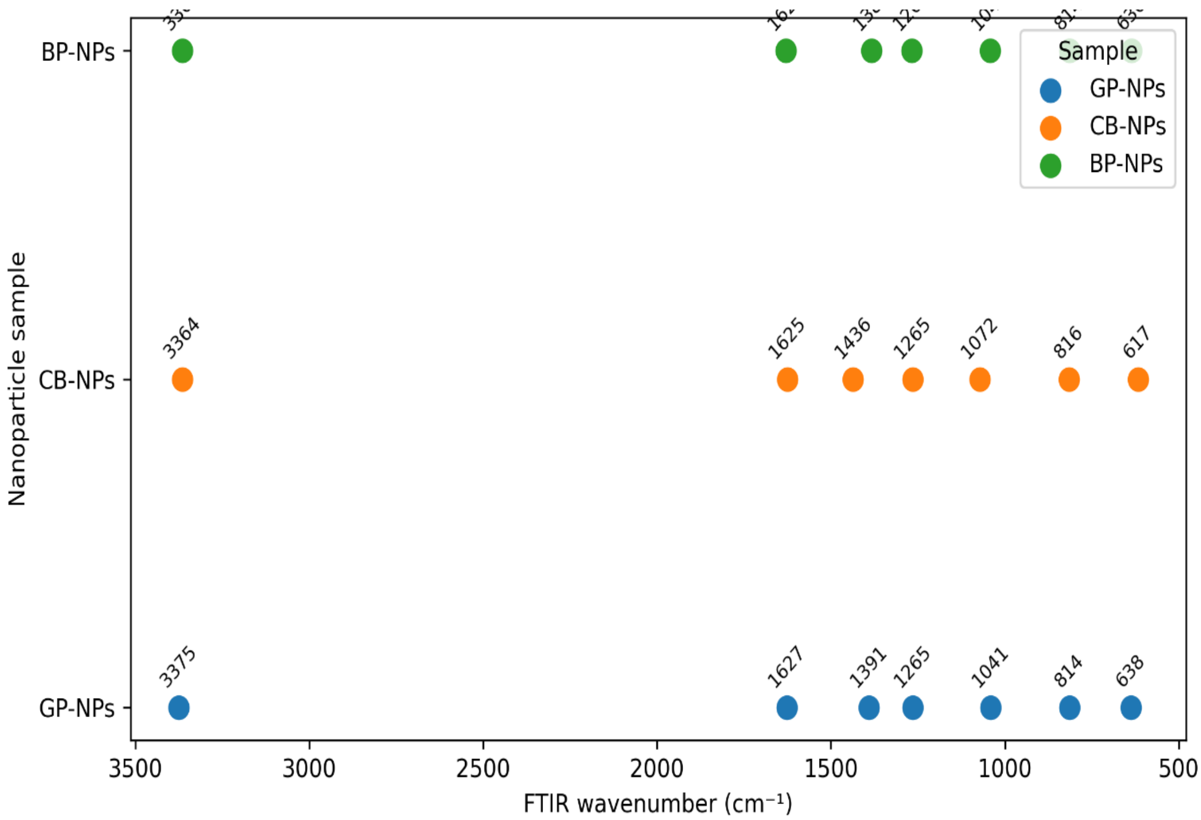

Figure 2. Major FTIR Bands of Green-Synthesized Iron Nanoparticles

3.4 Rifampicin Degradation Performance

Green synthesized nanoparticles of iron were used with hydrogen peroxide for the degradation of rifampicin, and it was observed that the degradation efficiency of the drug increased significantly. The percentage of removal of rifampicin was low for the nanoparticles, while the percentage of degradation was found to be significantly higher for the nanoparticle-assisted oxidative treatment. CB-NPs with H_2O_2 exhibited the greatest degradation of rifampicin. Table 4 presents the performance of the degradation of rifampicin under the action of nanoparticles.

Table 4. Rifampicin degradation performance under nanoparticle-assisted conditions

Treatment condition	Approximate degradation efficiency
CB-NPs + H_2O_2	79.21%
CNPs/CBNPs + H_2O_2	78.17%
BP-NPs + H_2O_2	75.68%
GP-NPs + H_2O_2	74.84%
GP-NPs without H_2O_2	11.65%
BP-NPs without H_2O_2	0.38%

The results revealed that the presence of H_2O_2 was a significant enhancing factor in the degradation of rifampicin. The degradation efficiencies of the nanoparticle–H_2O_2 systems were around 75–79%, and the degradation was almost negligible for the nanoparticle-only systems. This pattern indicated that the green synthesized iron nanoparticles had an effective role in the oxidative condition, where the degradation of the pharmaceutical pollutant seems to be in the process of oxidative reaction.

3.5 Methylene Blue Degradation Performance

The degradation analysis using methylene blue indicated excellent removal efficiency in the acidic, assisted sunlight, and assisted H_2O_2 conditions. The most degradation was found with acidic GP-NPs, while H_2O_2 and sunlight-treated GP-NPs showed a moderate amount of degradation. These results showed that these factors, pH, light exposure, and oxidant availability, have an effect on degradation efficiency. The degradation efficiency of methylene blue in various experimental conditions is given in Table 5.

Table 5. Methylene blue degradation performance under selected experimental conditions

Treatment condition	**Approximate degradation efficiency**
Acidic GP-NPs + methylene blue	95.42%
H_2O_2 + sunlight + methylene blue	93.14%
Sunlight GP-NPs + methylene blue	92.68%
CB-NPs + sunlight + methylene blue	82.69%
Basic methylene blue condition	76.85%
Acidic CB-NPs + methylene blue	76.24%
Basic BP-NPs + methylene blue	60.99%

Under various conditions, the methylene blue results showed the ability to degrade better than rifampicin. The degradation values were found to be over 90% in acidic and sunlight-assisted systems for GP-NPs. The results showed that the green-synthesized iron nanoparticles have potential applications for environmental applications, such as the treatment of dye-contaminated wastewater. The correlation between degradation efficiency and treatment variables is shown in Figure 3.

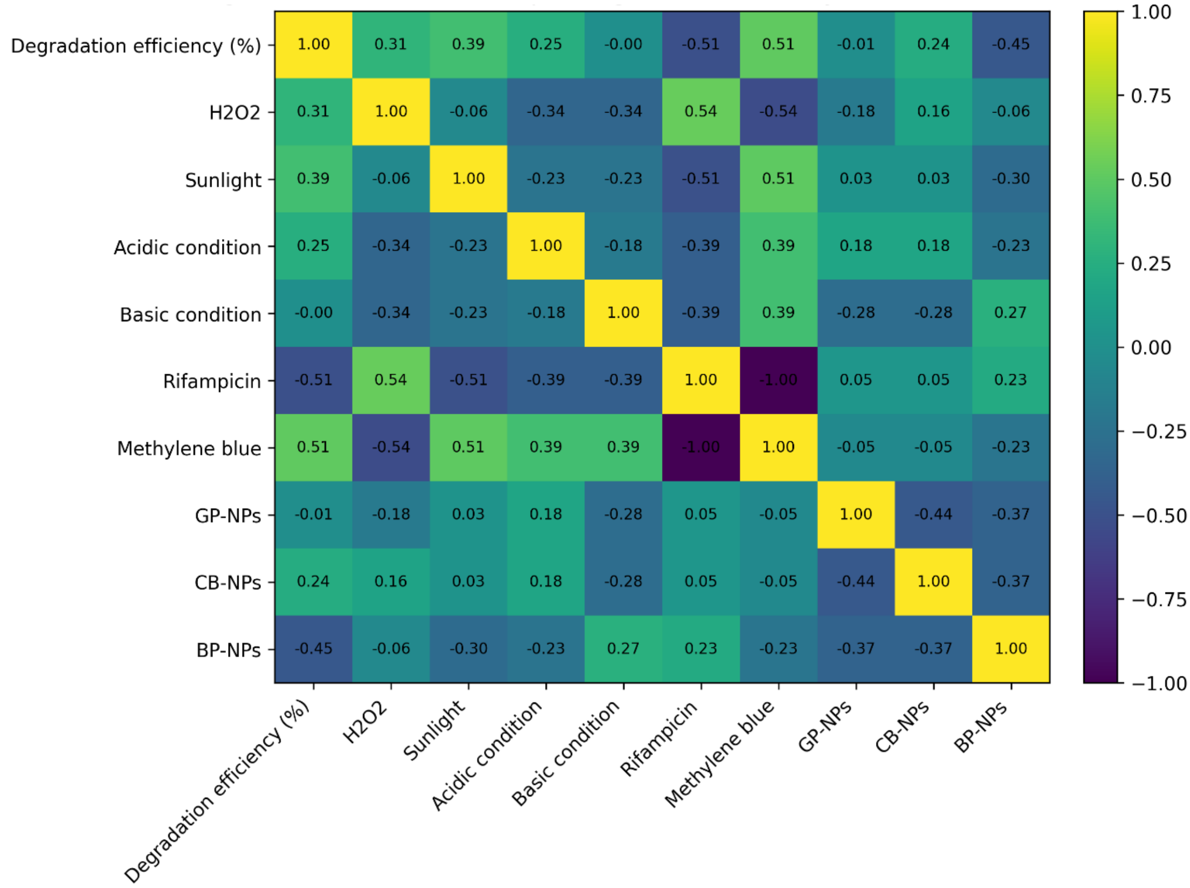

Figure 3. Correlation Heatmap of Degradation Efficiency and Treatment Variables

4. DISCUSSION

The present analysis revealed that the synthesis of iron nanoparticles with plants and application in environmental remediation were successfully aligned. The aforementioned results, from the three techniques – UV–Visible, FTIR, and the degradation of pollutants – collectively suggested that the plant extracts played a role in the formation of nanoparticles, stabilization of the surface, and catalytic activity. The best environmental result was found for the degradation of methylene blue and rifampicin, especially in the presence of oxidants, acid conditions, and/or UV radiation. The results were in accordance with the functionality of the green-synthesized iron nanoparticles as treating agents for pharmaceutical and dye-contaminated water. The high degradation of rifampicin in the presence of Fe3O4–H_2O_2 was in agreement with the previous studies that revealed that the degradation of other antibiotics like gentamicin, levofloxacin, and tetracycline was also enhanced by the green synthesized Fe3O4–H_2O_2 treatment, which involved oxidative pathways and time-dependent kinetic reactions (Wanakai et al., 2023).

In conclusion, the results indicated that the nanoparticles were efficient when applied in the presence of H_2O_2, which indicated the involvement of a Fenton-like mechanism in the degradation of pollutants. Iron-based nanoparticles can undergo redox cycling, transforming the iron species to activate hydrogen peroxide and produce the reactive oxygen species, which will attack the complex organic molecules. This mechanism was responsible for the fact that the treatment with only nanoparticles was less efficient in removing the rifampicin, and the treatment with nanoparticles together with H_2O_2 was more efficient in removing the rifampicin. The findings thus showed that green synthesis did not compromise the functional catalytic activity of Fe nanoparticles, but the plant-induced surface chemistry might have facilitated the interaction of pollutants with the Fe nanoparticles and the catalytic activity. This discovery was consistent with the latest reviews of transition metal and metal-oxide nanoparticles as eco-friendly options for wastewater treatment processes because of their photocatalytic, adsorptive, and oxidative properties to break down the contaminants (Alam et al., 2024).

Further pollutants, both pharmaceutical and dye, were found to have degraded, enhancing the environmental importance of the results. Rifampicin was a biomedical pollutant because it is an important drug used by doctors to treat patients and can enter the aquatic environment with the discharge of hospitals and improper disposal of pharmaceuticals. The removal from water is relevant as antibiotic residues have the potential to cause ecological toxicity and pressure for antimicrobial resistance. Methylene blue was a type of model dye pollutant that was used to evaluate the photocatalytic and oxidative degradation activity. The green synthesized nanoparticles showed their degradation capability in both pollutant classes, which showed more remediation potential. Nanoscale iron materials have also been found to provide the same environmental benefits and their ability to aid in remediation, decreasing pollutant-associated risks in soil and water systems (Liu et al., 2021).

The degradation of methylene blue results indicated that the conditions with H2O2 activation and under acidic and sunlight conditions showed excellent results. The highest degradation efficiency was obtained by the acidic GP-NPs, indicating that the pH had a role in the surface charge of the GP-NPs, the adsorption of pollutants, and the generation of reactive species. The same is also true about the sunlight-assisted degradation process, which was also very effective, suggesting that light exposure increased the electron transfer and oxidative processes. The results confirmed the conclusion that the green-synthesized Fe3O4 nanoparticles can be used as photocatalytic & photoassisted oxidative materials. Green-synthesized Fe2O3 nanoparticles also showed comparable photocatalytic activity with the degradation of methylene blue under light illumination and proved that the biosynthesized nanomaterials are environment-friendly and useful in the field of environmental applications (Khadka et al., 2024).

The results also confirmed the general conclusion that green nanomaterials can link environmental applications with biomedical applications. The data presented here did not include direct cytotoxicity, drug delivery, or wound healing experiments, but the degradation of the drug was an indirect biomedical application in the context of pharmaceutical wastewater remediation. This was particularly significant as it was not only through therapeutic use that biomedical relevance could be established, but also by the ability to mitigate biomedical pollutants that impact public health. A similar dual functional approach is described for green-synthesized ZnO nanoparticles, where the two environmental and biomedical outcomes, viz., water purification and antibacterial functionality, were discussed in tandem (Kaur et al., 2025).

The results of the FTIR were used to support the green synthesis pathway. Hydroxy, carbonyl, C–O, and metal–oxygen peaks indicated that compounds obtained from plants had a reducing function, capping and stabilizing the nanoparticles. The presence of such surface functional groups can affect the stability of the nanoparticles, their interaction with pollutants, and their biological compatibility. This interpretation is in line with the studies carried out by Selim et al. (2025) on green-synthesized magnesium oxide nanoparticles, which showed biological assays along with characterization of plant-derived synthesis confirmed that it could produce functional and bio-medically relevant nanoparticles.

It was suggested that the behaviour of the nanoparticles was influenced by the composition of the plant extract, as found for GP-NPs, CB-NPs, and BP-NPs. UV–Visible response was the highest for GP-NPs, and high degradation in methylene blue was observed in the case of GP-NPs, whereas high degradation in rifampicin was observed in the case of CB-NPs under H_2O_2-assisted conditions. Such differences could be due to differences in the concentration of phytochemicals, capping efficiency, the shape of the particles, or catalytic surface activity. In iron oxide nanoparticles prepared by plants, the multifunctional properties of these nanoparticles were reported to be affected by the biosynthetic process conditions, such as antioxidant and antimicrobial properties, photocatalytic and agricultural properties (Ashrafi-Saiedlou et al., 2025).

The main drawback of the present analysis was the use of relative interpretation of the presence of biomedical application, as opposed to the measurement of biomedical application by direct biomedical assays, based on the degradation of the pharmaceutical pollutants. There were no data available for the dataset on cytotoxicity, antimicrobial zone inhibition, drug-release, or biocompatibility. Thus, results cannot be assumed to have clinical relevance, but rather, biomedical-environmental relevance. However, the data were quite supportive of the environmental aspect of the title, and this was followed by a viable biomedical link, namely, the removal of rifampicin. These findings also confirm that it is possible to talk about green nanomaterials within integrated environmental and biomedical contexts using suitable characterization and functional data, as demonstrated in recent studies on green iron oxide nanoparticles in methylene blue degradation, antimicrobial activity, and modelling (Abbas et al., 2025).

5. Conclusion

The iron nanoparticles synthesized in a green process were appropriate nanomaterials for biomedical–environmental application framing. The data set supported the process of nanoparticle formation with the absorbance pattern observed from the UV–Visible spectrum, and functional groups involved in reducing, capping, and stabilizing the nanoparticles were identified by the FTIR spectrum. GP-NPs exhibited the highest optical response and high performance in terms of methylene blue degradation, while CB-NPs exhibited the highest rifampicin degradation under the H_2O_2-assisted treatment. The results of the degradation showed good environmental potential, particularly for the removal of dye and pharmaceutical pollutants from aqueous systems. The antibiotic residues found in water were due to the degradation of rifampicin, offering an indirect biomedical connection because of the public health concern linked to water contamination by pharmaceuticals and the pressure of antimicrobial resistance. The results thus verified the title, placing the green-synthesized iron nanoparticles at the sustainable nanomaterial synthesis, environmental remediation, and biomedical pollutant management interface. No direct biomedical assays were available, and future studies should involve cytotoxicity, antimicrobial, biocompatibility, and drug-delivery studies to increase the clinical relevance.

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