Journal of Ultrafine Grained and Nanostructured Materials
https://jufgnsm.ut.ac.ir
Vol. 56, No.1, June 2023, pp. 75-83
Print ISSN: 2423-6845 Online ISSN: 2423-6837
DOI: 10.22059/jufgnsm.2023.01.08

Study of the Single Step Green Synthesis of MgO Nanoparticles Using Peanut Shell Extract for the Evaluation of in Vitro Antibacterial and Photocatalytic Properties

Waseem Ahmad*[*,1], Pushpa Biswas[2]

[1]Department of Chemistry, Graphic Era Deemed to be University, Dehradun, India;
[2]Department of Chemistry, Uttaranchal University, Dehradun, India.

Recieved: 7 December 2022; Accepted: 16 April 2023

**Corresponding author email: waseemahmad8@gmail.com*

ABSTRACT

Among the various available nanoparticles 'inorganic nanoparticles' are more promising due to their wide range of application. MgO Nanoparticles (MgO NPs) is a very important inorganic metal oxide nanoparticle due to their diverse field of applications. There are so many physical and chemical methods are available to fabricate potentially useful MgO NPs. The proposed research work highlighted a novel green synthesis method for the fabrication of MgO NPs by using waste material peanut shell as a precursor. The green synthesized MgO NPs are characterize by the techniques like XRD, SEM, FTIR, UV-Vis Spectroscopy. The green synthesized MgO NPs are crystalline in nature & the tetragonal structure of MgO NPs was determined by XRD, various functional groups present on the surface of the synthesized nanoparticles was determined by FTIR and average particle size of green synthesized MgO NPs is 25-30 nm, found as result by SEM and XRD analysis. Two important applications photocatalytic activity and antibacterial activity of the synthesized nanoparticles was investigated in the proposed research work. The green synthesized MgO NPs show remarkable photo catalytic activity against the Indigo Ceramine and Rhodamine dyes and approximately after 60 min the photocatalyst completely remove the dyes from the solution. The Green synthesized MgO NPs show highest antibacterial activity against the *pseudomonas aeruginosa* (19 mm) bacteria.

Keywords: *Antibacterial Activity, Green Synthesis, MgO Nanoparticles, Photocatalysis.*

1. Introduction

Inorganic metal oxide nanoparticles received much attention due to its chemical and thermal stability unique electrical catalytic and magnetic properties [1]. Nowadays, inorganic metal oxide nanoparticles received remarkable amount of awareness and tremendous research is carried out in this area to develop new techniques for the fabrication of nanoparticles and to explore their different biological and photocatalytical applications [2-3]. At present different physical and chemical methods are involved in the fabrication of nanoparticles these methods have unintentional effects like environmental pollution, a large amount of energy required, and health issues [4,5]. Among the biological alternatives, plants or plant extracts seem to be the best option. The nanoparticles developed by utilizing different plant extract are more stable and the rate of the reaction of this synthesis is much faster as compare to the synthesis involve in the development of nanoparticles by utilizing microorganism [6,7]. The plant produces many phytochemicals which play a significant role in the biological synthesis of ceramic nanoparticles. Nanoparticle production using microbes and plants by green production technology is safe, low-cost,

and eco-friendly [8]. Metal-oxide nanoparticles show an important role in numerous fields of technology with sensing, catalysis, storage of energy, changing and electroceramics, etc. This is predictable that they could show new properties at the nanoscale [9].

An inclusive range of metal oxide nanoparticles has been synthesized using metal targets with nickel (Ni), cobalt (Co), magnesium (Mg), iron (Fe), aluminum(Al), copper (Cu), cerium (Ce), bismuth (Bi), yttrium (Y). Metal oxide NPs are among maximum used nanomaterials. e.g., aluminum and iron oxides and titanium dioxide (TiO_2) have been used for many years, but presently, nano-sized forms that arrived on the market are being used in dissimilar consumer products [10-12]. Zinc oxide (ZnO), and titanium dioxide (TiO_2) are widely broken due to their photolytic properties. Semiconductor nanoparticles such as zinc oxide nanomaterials have a large surface area and thermal stability and antimicrobial properties. These metal oxide nanomaterials are chemically fixed and are used in a kind of various applications [13].

The use of ceramic and semiconductor nanoparticles as nano photocatalysts in the decontamination of polluted water contaminated with the organic pollutant like organic dyes, and pharmaceutical and agricultural waste is becoming one of the major thrust areas of research during the last few decades [14,15]. In this heterogeneous photocatalytic degradation of dye in presence of metal and ceramic nanoparticles, different kinds of reactive intermediates are produced [16]. When the ceramic nanoparticles are irradiated with light having energy equal or larger than the band gap of valence band and conduction band then the electron and hole pair is produced on the surface of these nano photocatalysts and on the surface of the catalyst they participate in the redox reaction and generated highly reactive reaction species like superoxide radical anion and hydroxyl free radical species [17-19]. These reactive species interact with the organic pollutants and converted them into non-toxic products [20].

Among the various available inorganic metal oxide nanoparticles MgO NPs received much attention due to their unique biocompatibility and chemical stability [21]. MgO NPs are used in the manufacturing of crucibles, refractory materials, and as coating materials [22]. MgO NPs can be applied in electronic devices, as an antimicrobial agent, as an additive in catalysis, in ceramics, and several other fields [23]. The MgO NPs have a large surface area for better adsorption, a large band gap, and notable thermodynamic stability. It has also a low refractive index and low dielectric constant. All these properties make MgO NPs a suitable candidate For the photodegradation of organic pollutants [24]. Conventional methods available for the fabrication of MgO NPs require lots of toxic chemicals and these methods generated different kinds of toxic byproducts which create serious environmental and biological threats [25]. To overcome these obstacles present in the chemical generation of nanoparticles, green synthesis of ceramic and semiconductor nanoparticles provides a clean safe and ecologically responsible method for the manufacturing of ceramic and semiconductor nanoparticles. Biofabrication of MgO NPs is still an unexplored area of research and has lots of research possibilities.

Accordingly in the present research work, we are trying to elaborate a facile green synthesis method for the fabrication of MgO nanoparticles and their potential application in wastewater treatment and as a potential antibacterial agent.

2. Materials and method

2.1. Reagents and chemicals

The different kinds of starting materials like $MgNO_3$, ethanol, NaOH, Indigo Carmine, and Rhodamine were purchased from High Purity Laboratory Chemicals Pvt. Ltd India. The reagent and chemicals involve in this study were of analytical grade.

2.2. Isolation of peanut shell extract

Peanut shell extract was prepared by using the Soxhlet extraction technique, this apparatus has a thimble containing a sample, at the top condenser is present and at the bottom heating mental contains a round bottom flask with the suitable solvent in the present case water is used as a solvent. Now, first peanut shell was collected from Dehradun's area, then it was crushed, and this crushed shell measured about 25 g filled carefully in a thimble and in the round bottom flask 250 mL water. The extraction is a continuous process for 3-4 h till the color of the solvent present in RBF is changed. The extraction solvent was unceasingly cycled through the medium by boiling and condensation, with the sample being collected in the hot solvent (Fig.1) [26].

2.3. Bio fabrication of MgO NPs

For the fabrication of MgO NPs, a 50 mL aqueous magnesium nitrate solution (1 mM) was added carefully to the 5 mL isolated peanut Shell extract. These reaction mixtures were kept on magnetic stirring at 4000 rpm and the temperature of the test solution was maintained at 60^{0}C when the desired temperature was reached and added drop by drop NaOH solution to the reaction mixture. After approximately 20 min of continuous stirring there is slight modification in the color of the test solution from light brown color to dark brown.These color changes initially indicate the formation of MgO nanoparticles. The prepared reaction mixtures were then centrifuged at 12000 rpm for about 15 min and collected the prepared nanoparticles. The fabricated nanoparticles were washed thoroughly with distilled water. The resulting products (nanoparticles) were calcined at 400^{0}C in a muffle furnace for about 20 min to acquire fine MgO nanoparticles (Fig. 2) [27].

Fig. 1- Isolated leaf extract by soxhlet extraction techniques.

2.4. Characterization of MgO NPs

Biosynthesized MgO NPs nanoparticles were structurally analyzed by using a different technique such as X-ray diffraction (XRD) which has been achieved using a Rigaku diffractometer. UV-Visible absorbance spectra of the developed nanoparticles were evaluated by using a systonic UV spectrometer. FTIR (Fourier transform infrared spectroscopy) has been passed out by using a thermo scientific FTIR spectrophotometer. The SEM (scanning electron microscopy) images of synthesized nanoparticles have been achieved on Zeiss-evo-18 SEM.

2.5. Photocatalytic Activity

Organic dyes are widely used in many industries and approximately 10-15% of these dyes are released into near water bodies. These discharges in near water bodies create a serious environmental threat to human beings and aquatic animals. MgO NPs can degrade the solution of different dyes in various conditions of temperature and light. In the proposed research work two different dyes namely Indigo carmine and Rhodamine are used.

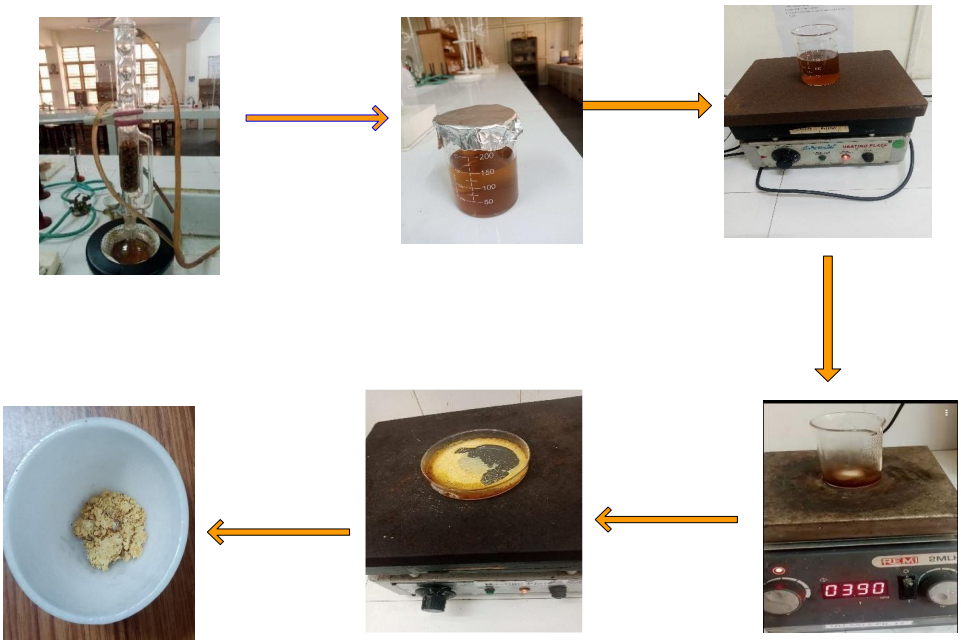


Fig. 2- Bio fabrication of MgO NPs using peanut shell extract.

First, we prepared 50 mL 1 ppm aqueous solution of both dyes, and 0.2 g/L of green synthesized nanocatalyst was added into the solution of both dyes these solutions are now placed in a sonicator for about 10-15 min so that the nanoparticles are properly dissolved in a dye solution. These prepared solutions of dyes are placed under natural solar light and observe the color variation of the dye solution. The photocatalytic activities of the prepared nanoparticles were evaluated by measuring the absorbance of the 2 mL centrifuged aliquot of dye solution at regular intervals of 10 min in a UV spectrophotometer [28].

2.6. Antibacterial activity

Nanotechnology proposes a way to develop advance new inorganic antibacterial agent. In this work, we use three bacterial strains to examine the antibacterial property of the developed MgO NPs. For this purpose first the three clean Petridis were taken and the three different bacterial strains were spread through all these three Petridis. Filter disc loaded with different concentration (20%, 30%, and 40%) of the developed nanoparticles and a standard antibacterial agent was kept on the surface of the plate. The plate was kept for overnight in an incubator and next day examine the zone of inhibition to report the antibacterial activity [29].

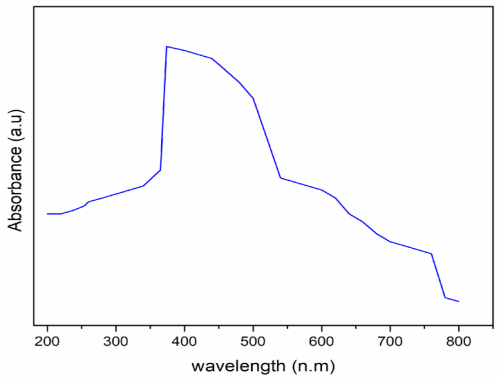


Fig. 3- UV Visible spectrum of Green Synthesized MgO NPs.

3. Results and discussions

3.1. Characterization

3.1.1. UV-Visible analysis

The optical properties of the developed nanoparticles were evaluated by using UV visible spectroscopic analysis. The optical properties was largely depends upon the shape, size and the interaction of the other particles were present on the green synthesized nanoparticles surface. UV-Visible absorbance spectra of prepared NPs have been shown in fig.3. The graph depicts the absorption spectra of MgO NPs in a range of 200-800 nm. The strong peak that exists at 350 nm explains about the surface properties of the created magnesium oxide nanoparticles (Fig.3).The nanoparticles have been detected to be dark brown in color. The Similar observations are recorded by other authors [30]

3.1.2. SEM (Scanning electron microscope) analysis Of MgO

The SEM micrograph of the developed MgO NPs were used to analyze the surface morphology of the developed MgO NPs. Fig. 4 reveals an image obtained as a result of SEM describing the morphological structure having a tetragonal shape of MgO NPs with small amount of the gathering due to this gathering formations it was difficult to describe the clear structural shape of these nanoparticles therefore there is different shape and size shown in the image.The average particle size of the developed nanoparticles were found in the range of 25-30 nm. The SEM images of the

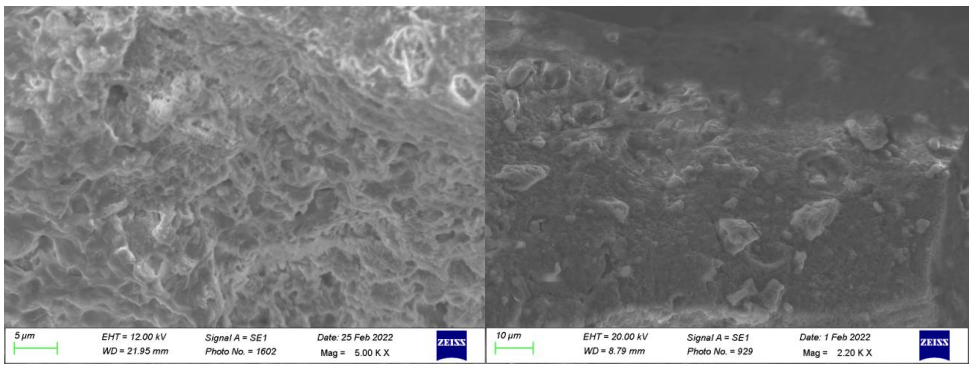


Fig. 4- SEM micrograph of the developed MgO NPs.

developed MgO NPs showed that the prepared powders contained a mixture of fine and large grains including irregular size, although others had apparent bulk particles along with irregular shapes [31,32].

3.1.3. XRD analysis

Fig. 5 shows the XRD pattern of the developed MgO NPs obtained by utilizing the peanut shell extract. The XRD spectra of the synthesized nanoparticles show the peaks at diffraction angles 36.97, 42.93, 62.32, 74.71, and 78.61 which correspond to the lattice planes at (111), (200), (220), (311), and (222) of a tetragonal structure of magnesium respectively and clear that the MgO NPs are crystalline in nature. Similar XRD analysis for the bio fabricated MgO NPs reported by other authors [33]. Based on the XRD result of the fabricated nanoparticles, the average crystallite size of the developed MgO NPs was evaluated by utilizing the Debye–Scherrer equation.

$$d=k\lambda/\beta \cos \Theta \quad (1)$$

This equation indicates that as the width of the diffraction peak (β) and diffraction angle (Θ) increases the crystallite size (d) of the fabricated nanoparticles decreases. The average crystallite size of the fabricated nanoparticles found to be 26 nm.

3.1.4. FTIR analysis

FTIR spectroscopic analysis of the developed nanoparticles reveals the presence of different functional group present on the surface of the developed nanoparticles. The absorption spectra of manufactured MgO NPs can be seen in fig. 6. The analysis is done in the range of 500-4000 cm^{-1}. The peak at 1366 cm^{-1} shows the stretching vibration of the aromatic C=C bond [34]. The peak observed at 1635 cm^{-1} is due to the C=C stretching vibration of Alkyne [35]. The intense peak appears at 1527 cm^{-1} indicating the bending vibration of N-H bond of aromatic amine. The peak appears at 3605 cm^{-1} indicating the presence of a phenolic hydroxyl group [36]. The band appears at 2396 cm^{-1} and corresponds to the C-H stretching vibration of the CH2 group present in phytochemicals. The peaks that appear at 1007 cm^{-1} and 824 cm^{-1} are basically due to the C–O and C–O–C diagnostic bonds, respectively. The peak detected at 825 cm-1 shows the stretching vibration of the Mg-O-Mg bond [37].

3.2. Photocatalytic Activity

Fig. 7 & 8 show the photodegradation behavior of the two well-known dyes Indigo carmine and Rhodamine in presence of the green synthesized MgO NPs. The decrease in the absorbance of the given Dyes (Indigo carmine and Rhodamine) in the time interval of 60 min in presence of MgO NPs Photocatalysts indicates the photodegradation of dyes. Fig. 9 indicates the probable mechanism of the photodegradation of dyes in presence of the nano photocatalysts. When the solar light is irradiated on the dye solution containing nano photocatalyst absorbs the solar light irradiation and the hole and electron pairs are generated [38].

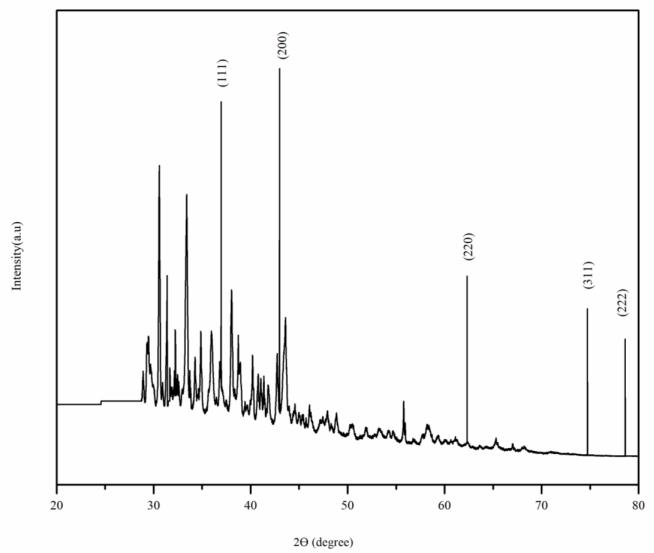


Fig. 5- XRD analysis of Green synthesized MgO NPs 2Θ (degree).

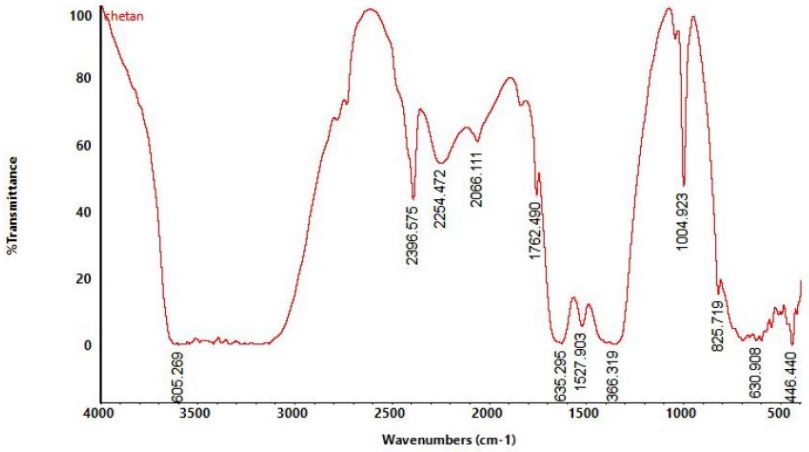


Fig. 6- Functional group analysis of the synthesized MgO NPs.

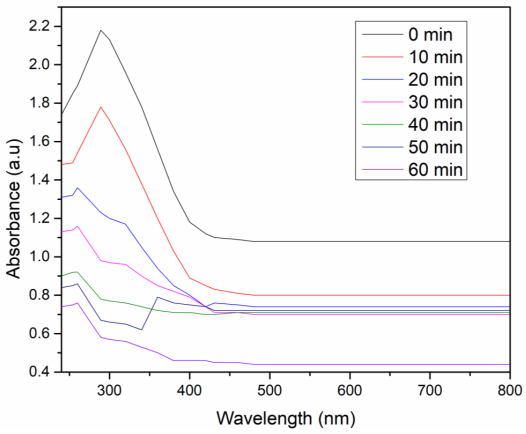


Fig. 7- Photocatalytic activity of the green synthesized MgO NPs against Indigo Ceramine conditions: pH=5.5; 0.2g/L of catalyst.

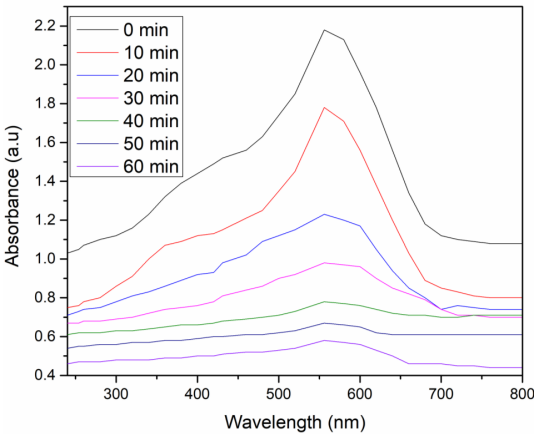


Fig. 8- Photocatalytic activity of the green synthesized MgO NPs against Rhodamine conditions: pH=5.5; 0.2 g/L of catalyst.

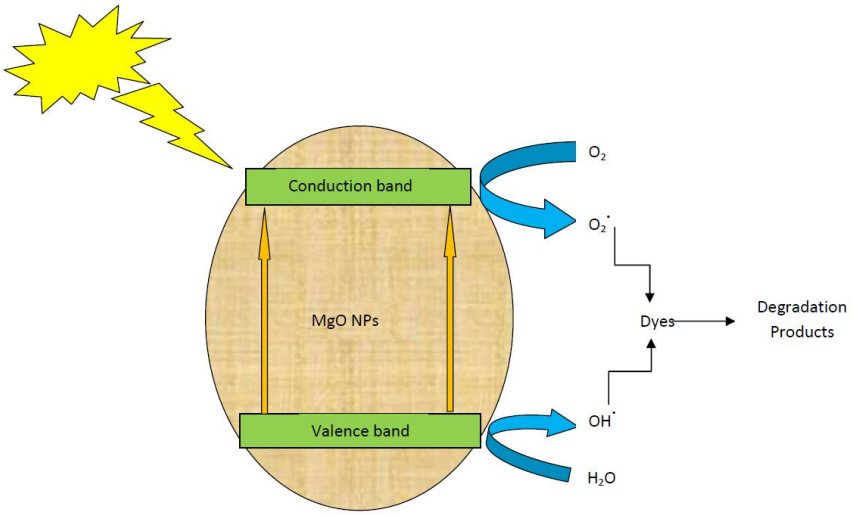


Fig. 9- Photocatalytic Mechanism of Synthesized nanoparticles in the degradation of dye.

These holes and free radicals interact with oxygen and water molecule to generate two highly reactive reaction species like superoxide radical anion and hydroxyl free radicals these reactive species in the next step interact with selected dyes and converted it into non toxic products.

3.3. Antibacterial activity

The agar distribution assay is used to evaluate the efficiency of the developed MgO nanoparticles. The antimicrobial potential of the MgO NPs is investigated against the strains of pseudomonas aeruginosa (PA), staphylococcus aureus (S. aureus is a gram-positive bacteria) and esherichia coli (E. coli) by utilizing the disc diffusion methodology. The Escherichia coli (E. coli) has a zone of inhibition 11 mm at a concentration of 20 %, 12 mm at a concentration of 30 %, and 14 mm at a concentration of 40 %. Bacteria staphylococcus aureus shows a zone of inhibition of 10 mm at a concentration of 20%, 12 mm at a concentration of 30, and 17 mm at a concentration of 40 % respectively. The pseudomonas aeruginosa shows a zone of inhibition of 11 mm at a concentration of 20 % and 13 mm at a concentration of 30 at a concentration of 40 % showing a 19 mm zone of inhibition (Table-1). Antibacterial activity has been described through tables and images, obtain as a result. On exposure to the light the nanoparticles generate different reactive oxygen species these reactive oxygen species causes the damage of cellular membrane and also destroy other cellular organism which ultimately causes the death of the bacterial pathogen (Fig.10).

4. Conclusion

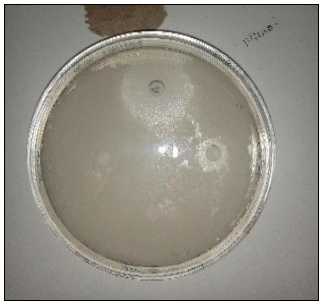
The present study evaluates the biosynthesis of MgO NPs using peanut shell extract with a broad range of useful properties. The proposed research established a novel eco-friendly approach for synthesis of MgO NPs. The penut Shell extract act as reducing and stabilizing agent in

Table 1- Antibacterial potential of the green synthesized MgO NPs

S.NO.	Name of Micro-organism	Zone of Inhibition in mm at various concentration			
		Control	20 mg/mL	30 mg/mL	40 mg/mL
1.	pseudomonas aeruginosa	24 mm	11 mm	13 mm	19 mm
2.	staphylococcus aureus	22 mm	10 mm	12 mm	17 mm
3.	E. coli	23 mm	11mm	12 mm	14 mm

(a) *staphylococcus aureus*

(b) *E. coli*



(c) *pseudomonas aeruginosa*

Fig. 10- Images shows antibacterial activity of the synthesized MgO NPs against, (a) staphylococcus aureus, (b) E. coli, (c) pseudomonas aeruginosa.

the development of nanoparticles. Successfully synthesized MgO nanoparticles have particle size in the range of 25-30 nm. The particle sizes of the nanoparticles were determined by using XRD diffraction pattern and SEM images of developed nanoparticles. The developed nanoparticles show excellent antibacterial agent against different bacterial pathogen. The findings of the present study suggested that the developed nanoparticles were show remarkable photocatalytic activity in the degradation dyes. It seems that green synthesized MgO nanoparticles were excellent candidate for the treatment of waste water contaminated with the organic pollutants and for development of new potential antibiotics.

References

1. Hussain I, Singh NB, Singh A, Singh H, Singh SC. Green synthesis of nanoparticles and its potential application. Biotechnology Letters. 2015;38(4):545-60.
2. Rao C, Liao D, Pan Y, Zhong Y, Zhang W, Ouyang Q, et al. Novel formulations of metal-organic frameworks for controlled drug delivery. Expert Opinion on Drug Delivery. 2022;19(10):1183-202.
3. Nasiri-Ardali M, Nezamzadeh-Ejhieh A. A comprehensive study on the kinetics and thermodynamic aspects of batch and column removal of Pb(II) by the clinoptilolite–glycine adsorbent. Materials Chemistry and Physics. 2020;240:122142.
4. Mirsalari SA, Nezamzadeh-Ejhieh A, Massah AR. A designed experiment for CdS-AgBr photocatalyst toward methylene blue. Environmental Science and Pollution Research. 2022;29(22):33013-32.
5. Ahmad W, Kumar Jaiswal K, Amjad M. Euphorbia herita leaf extract as a reducing agent in a facile green synthesis of iron oxide nanoparticles and antimicrobial activity evaluation. Inorganic and Nano-Metal Chemistry. 2020:1-8.
6. Ahmad W, Chandra Bhatt S, Verma M, Kumar V, Kim H. A review on current trends in the green synthesis of nickel oxide nanoparticles, characterizations, and their applications. Environmental Nanotechnology, Monitoring & Management. 2022;18:100674.
7. Ahmad W, Pandey A, Rajput V, Kumar V, Verma M, Kim H. Plant extract mediated cost-effective tin oxide nanoparticles: A review on synthesis, properties, and potential applications. Current Research in Green and Sustainable Chemistry. 2021;4:100211.
8. Omrani N, Nezamzadeh-Ejhieh A. A comprehensive study on the enhanced photocatalytic activity of Cu2O/BiVO4/WO3 nanoparticles. Journal of Photochemistry and Photobiology A: Chemistry. 2020;389:112223.
9. Derikvandi H, Nezamzadeh-Ejhieh A. Increased photocatalytic activity of NiO and ZnO in photodegradation of a model drug aqueous solution: Effect of coupling, supporting, particles size and calcination temperature. Journal of Hazardous Materials. 2017;321:629-38.
10. Nezamzadeh-Ejhieh A, Zabihi-Mobarakeh H. Heterogeneous photodecolorization of mixture of methylene blue and bromophenol blue using CuO-nano-clinoptilolite. Journal of Industrial and Engineering Chemistry. 2014;20(4):1421-31.
11. Sabouri Z, Akbari A, Hosseini HA, Khatami M, Darroudi M. Green-based bio-synthesis of nickel oxide nanoparticles in Arabic gum and examination of their cytotoxicity, photocatalytic and antibacterial effects. Green Chemistry Letters and Reviews. 2021;14(2):404-14.
12. Ahmad W, Kamboj A, Banerjee I, Jaiswal KK. Pomegranate peels mediated synthesis of calcium oxide (CaO) nanoparticles, characterization, and antimicrobial applications. Inorganic and Nano-Metal Chemistry. 2022:1-8.
13. Ying S, Guan Z, Ofoegbu PC, Clubb P, Rico C, He F, et al. Green synthesis of nanoparticles: Current developments and limitations. Environmental Technology & Innovation. 2022;26:102336.
14. Jaiswal KK, Dutta S, Pohrmen CB, Banerjee I, Das HT, Jha N, et al. Bio-fabrication of selenium nanoparticles/micro-rods using cabbage leaves extract for photocatalytic dye degradation under natural sunlight irradiation. International Journal of Environmental Analytical Chemistry. 2021:1-18.
15. Nezamzadeh-Ejhieh A, Shahriari E. Photocatalytic decolorization of methyl green using Fe(II)-o-phenanthroline as supported onto zeolite Y. Journal of Industrial and Engineering Chemistry. 2014;20(5):2719-26.
16. Noruozi A, Nezamzadeh-Ejhieh A. Preparation, characterization, and investigation of the catalytic property of α-Fe2O3-ZnO nanoparticles in the photodegradation and mineralization of methylene blue. Chemical Physics Letters. 2020;752:137587.
17. Mehrali-Afjani M, Nezamzadeh-Ejhieh A, Aghaei H. A brief study on the kinetic aspect of the photodegradation and mineralization of BiOI-Ag3PO4 towards sodium diclofenac. Chemical Physics Letters. 2020;759:137873.
18. Ahmad W, Singh V, Ahmed S, Nur-e-Alam M. A comprehensive study on antibacterial antioxidant and photocatalytic activity of achyranthes aspera mediated biosynthesized Fe2O3 nanoparticles. Results in Engineering, 14 (2022) 100450.
19. Al-Tamimi SA. Biogenic green synthesis of metal oxide nanoparticles using oat biomass for ultrasensitive modified polymeric sensors. Green Chemistry Letters and Reviews. 2021;14(2):166-79.
20. Baig N, Kammakakam I, Falath W. Nanomaterials: a review of synthesis methods, properties, recent progress, and challenges. Materials Advances. 2021;2(6):1821-71.
21. Ahmad W, Jaiswal K K , Amjad M. Euphorbia herita leaf extract as a reducing agent in a facile green synthesis of iron oxide nanoparticles and antimicrobial activity evaluation, Inorganic and Nano-Metal chemistry, 2020, 51, 1147-1154.
22. Kaur S, Singh J, Rawat R, Kumar S, Kaur H, Venkateswara Rao K, et al. A smart LPG sensor based on chemo-bio synthesized MgO nanostructure. Journal of Materials Science: Materials in Electronics. 2018;29(14):11679-87.
23. Moorthy SK, Ashok CH, Rao KV, Viswanathan C. Synthesis and Characterization of Mgo Nanoparticles by Neem Leaves through Green Method. Materials Today: Proceedings. 2015;2(9):4360-8.
24. Awwad AM, Ahmad AL. Biosynthesis, characterization, and optical properties of magnesium hydroxide and oxide nanoflakes using Citrus limon leaf extract. Arab J Phys Chem. 2014;1(2):66.
25. Das B, Moumita S, Ghosh S, Khan MI, Indira D, Jayabalan R, et al. Biosynthesis of magnesium oxide (MgO) nanoflakes by using leaf extract of Bauhinia purpurea and evaluation of its antibacterial property against Staphylococcus aureus. Materials Science and Engineering: C. 2018;91:436-44.
26. Preliminary phytochemical, antimicrobial and photochemical study of Calotropis gigantea leaf extract. Current

Chemistry Letters. 2020:105-12.
27. Ammulu MA, Vinay Viswanath K, Giduturi AK, Vemuri PK, Mangamuri U, Poda S. Phytoassisted synthesis of magnesium oxide nanoparticles from Pterocarpus marsupium rox.b heartwood extract and its biomedical applications. J Genet Eng Biotechnol. 2021;19(1):21-.
28. Ghattavi S, Nezamzadeh-Ejhieh A. A visible light driven AgBr/g-C3N4 photocatalyst composite in methyl orange photodegradation: Focus on photoluminescence, mole ratio, synthesis method of g-C3N4 and scavengers. Composites Part B: Engineering. 2020;183:107712.
29. Vergheese M, Vishal SK. Green synthesis of magnesium oxide nanoparticles using Trigonella foenum-graecum leaf extract and its antibacterial activity. Journal of pharmacognosy and phytochemistry. 2018;7(3):1193-200.
30. Dobrucka R. Synthesis of MgO Nanoparticles Using Artemisia abrotanum Herba Extract and Their Antioxidant and Photocatalytic Properties. Iranian Journal of Science and Technology, Transactions A: Science. 2016;42(2):547-55.
31. Ahmad W, Kamboj A, Banerjee I, Jaiswal K K. Pomegranate peels mediated synthesis of calcium oxide (CaO) nanoparticles, characterization, and antimicrobial applications. Inorganic and Nano-Metal Chemistry, 2022, DOI: 10.1080/24701556.2021.2025080.
32. Khan MI, Akhtar MN, Ashraf N, Najeeb J, Munir H, Awan TI, et al. Green synthesis of magnesium oxide nanoparticles using Dalbergia sissoo extract for photocatalytic activity and antibacterial efficacy. Applied Nanoscience. 2020;10(7):2351-64.
33. Sharma G, Soni R, Jasuja ND. Phytoassisted synthesis of magnesium oxide nanoparticles with Swertia chirayaita. Journal of Taibah University for Science. 2017;11(3):471-7.
34. Suresh J, Pradheesh G, Alexramani V, Sundrarajan M, Hong SI. Green synthesis and characterization of hexagonal shaped MgO nanoparticles using insulin plant (Costus pictus D. Don) leave extract and its antimicrobial as well as anticancer activity. Advanced Powder Technology. 2018;29(7):1685-94.
35. Vergheese M, Vishal SK. Green synthesis of magnesium oxide nanoparticles using Trigonella foenum-graecum leaf extract and its antibacterial activity. Journal of pharmacognosy and phytochemistry. 2018;7(3):1193-200.
36. Sugirtha P, Divya R, Yedhukrishnan R, Suganthi KS, Anusha N, Ponnusami V, et al. Green Synthesis of Magnesium Oxide Nanoparticles Using Brassica oleracea and Punica granatum Peels and their Anticancer and Photocatalytic Activity. Asian Journal of Chemistry. 2015;27(7):2513-7.
37. Vijayakumar S, Nilavukkarasi M, Praseetha PK. Synthesis of MgO nanoparticles through green method and evaluation of its antimicrobial activities. Vegetos. 2021 Sep;34:719-24.
38. Nezamzadeh-Ejhieh A, Karimi-Shamsabadi M. Decolorization of a binary azo dyes mixture using CuO incorporated nanozeolite-X as a heterogeneous catalyst and solar irradiation. Chemical Engineering Journal. 2013;228:631-41.