ORIGINAL ARTICLE

Green synthesis of zinc oxide and evaluation of its photocatalytic activity against methylene blue

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Abstract

Aim: The aim of the study was to synthesize zinc oxide (ZnO) using the bio reduction method and test its photocatalytic degradation potential against methylene blue (MB) dye. **Materials and Methods:** Zinc nitrate salt was utilized as a precursor for synthesis creation of ZnO nanoparticles. After bio reduction of zinc nitrate, off white cream precipitates were formed, indicating the formation of ZnO. The produced ZnO was characterized using Fourier transform infrared (FTIR) spectroscopy, X-ray diffraction (XRD) analysis, and zeta potential measurements. **Results and Discussion:** FTIR peaks below 1000 cm^{-1} confirmed the formation of ZnO, while XRD studies showed that the average grain size of ZnO particles was 92 nm and these particles were crystalline in nature. Further, the average zeta potential value (-7.38 mV) of these NPs indicated that these particles were stable in nature. MB dye was used to examine the photocatalytic activity of the produced ZnO nanoparticles. According to our findings, ZnO nanoparticles have the capacity to degrade the MB dye. **Conclusion:** Overall, the findings revealed that ZnO synthesized through onion peel extract might be employed in dye-contaminated wastewater bioremediation.

Key words: Zinc oxide, green synthesis, photocatalytic, methylene blue, onion peel

INTRODUCTION

Metals are essential components that humans require; iron, copper, chromium, magnesium, and zinc that are all involved in physiological processes in the human body.[1] Metal and metal oxide nanoparticle creation has piqued interest in the physical, chemical, biological, medicinal, optical, mechanical, and engineering sciences, where novel approaches to probe and manipulate single atoms and molecules are being created. Metal and metal oxide nanoparticles have a large surface area and a high atom fraction, which explains their intriguing features such as antibacterial, magnetic, electrical, and catalytic activity. Nanoparticle characteristics are mostly determined by their size, shape, content, morphology, and crystalline phase.[2] Green synthesis methods produce useful and environmentally favorable metal oxide nanoparticles.[3] For the synthesis of NPs, green techniques have recently been regarded a significant field of nanotechnology. Metallic NPs synthesized with plant extracts have been extensively studied due to their unique physico-chemical properties and potential medical applications. Biological approaches for nanoparticle synthesis are clean, non-toxic, and biocompatible, allowing for formation of nanoparticles with a diverse variety of forms, sizes, compositions, and physiochemical properties. Plant extracts also have a larger reduction potential than microbial culture media, which means nanoparticle synthesis takes less time. However, factors such as the nature of the plant extract, its concentration, salt concentration, pH, temperature, and reaction duration affect the speed, quality, and other characteristics of the nanoparticles produced using plant extracts.[4] Green synthesis is the process of making nanoparticles using natural reducing agents such as plants, enzymes, and proteins. The shape of NPs is influenced by these reducing agents. Green synthesis is environmentally friendly because no harmful chemicals

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are used.[5,6] Green nanotechnology is a good alternative to chemical nanoparticle synthesis. In this technique, plant, fruit, and other waste materials are employed in the synthesis, effectively reducing the use and manufacturing of dangerous chemicals. Green synthesis strategies produce useful and environmentally friendly metal oxide NPs.[3] Green strategy is eco-friendly, cost-effective, biocompatible, and secure. This method produces nanoparticles with higher catalytic activity while reducing the usage of costly and harmful chemicals.[7] Hence, rationale of this study was to synthesize zinc oxide (ZnO) nanoparticles using onion peel extract.

MATERIALS AND METHODS

Materials

Onion peels were acquired from the local area of Solan and were authenticated at Dr. YS Parmar, University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh.

Chemicals used for experimental work

Zinc nitrate (Loba chemie, India), Sodium hydroxide (Loba chemie, India), ethanol (Jiangsu, China), methanol (Loba chemie, India) and methylene blue (Loba chemie, India).

Methods

Preparation of plant extract

30 g of dry onion peels were cut and washed properly first with tap water then with distilled water. The cut peels were then boiled in 150 ml distilled water at a temperature of 80°C for 2 h. The boiled extract was filtered using a Whatman filter paper and the filtrate was stored at 4°C for further use.

Synthesis of ZnO nanoparticles

10 ml of 0.1 M zinc nitrate solution was taken and onion peel extract was added into it at 60°C, and stirred. The pH of the solution was kept at 12 and the reduction was confirmed by the development of cream precipitates. Precipitates were centrifuged at 7000 RPM for 10 min, and the resulting pellet was washed 3 times with distilled water and twice with methanol. This pellet was dried overnight in an oven at 80°C and next dried pellet was crushed using a mortar pestle. Synthesis process is depicted in Figure 1. Different analytical techniques such as ultraviolet (UV) spectroscopy, Fourier transform infrared (FTIR) spectroscopy, and X-ray diffraction (XRD) were used to characterize synthesized ZnO. Further, the photocatalytic degradation of MB dye was evaluated using synthesized ZnO.

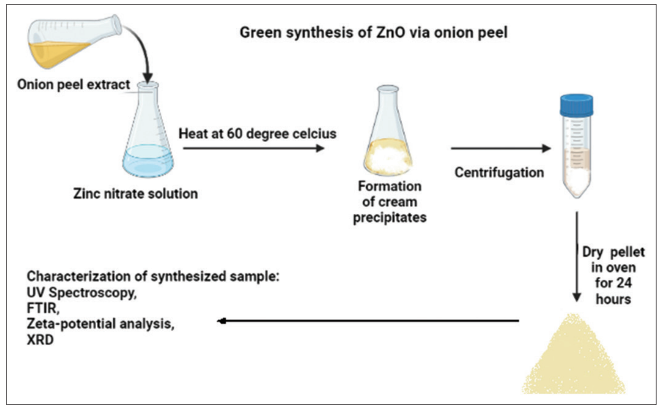

Figure 1: Green synthesis of zinc oxide through onion peel

Characterization of synthesized sample

The optical properties of ZnO NPs were studied by UV-visible spectroscopy with the wavelength ranging from 200 nm to 800 nm. UV-visible spectroscopy was carried out using UV spectrophotometer (Make: Perkin Elmer) at room temperature with methanol as blank. In addition, samples were analyzed to determine effects of plant metabolites on ZnO using FTIR spectrometer (Make: Bruker). Further samples were submitted to SAIF/CIL, Punjab University, Chandigarh for XRD analysis using X-ray diffractometer (Xpert Pro).

Photocatalytic Studies

Preparation of dye solution

Dye solution was prepared by dissolving 10 mg MB dye powder in 1000 ml distilled water.

Photocatalysis of MB

In a heterogeneous photocatalysis approach, the potential applicability of ZnO nanoparticles for dye removal from wastewaters was explored. The photocatalytic efficacy of ZnO nanoparticles was tested using MB. In the presence of sunlight, the photocatalytic activity of ZnO was investigated for the breakdown of methyl blue dye. In this procedure, ZnO (20 mg) was added to a 100 mL aqueous methyl blue dye solution at room temperature. Before UV light illumination, the suspension was magnetically agitated in the dark for 30 min to ensure appropriate homogeneity and achieve the absorption equilibrium. After reaching equilibrium, dye with ZnO solution was exposed to sun radiations for photo degradation.

RESULTS AND DISCUSSION

UV-visible Spectroscopy

Absorption peaks in the region of 250–400 nm can be found in the absorption spectra of ZnO. The UV-visible spectrum of ZnO exhibited peak at 378 nm [Figure 2], this absorption maxima could be attributed to ZnO indicating that the Zinc nitrate has been converted into ZnO.[8]

FTIR Spectroscopy

The spectrum of FTIR [Figure 3] showed peaks at 3317 cm^{-1} and 1637 cm^{-1}. The O-H stretching vibration of alcohol and phenols contained in onion peel extract can be attributed to the peaks at 3317 cm^{-1} and 1637 cm^{-1}. The vibrations of ZnO could be responsible for the peaks found below 1000 cm^{-1}.[9]

XRD Spectra of ZnO

XRD tests confirmed the production of ZnO synthesized through onion peel extract. XRD spectrum of synthesized compound [Figure 4] revealed 10 unique diffraction peaks. Using XRD data, Scherrer's equation ($d = 0.89\lambda/\beta \cos\theta$) was utilized to calculate the size of the produced nanoparticles. Only crystallite sizes up to 200 nm may be measured using this equation. The average grain size of ZnO was determined to be 92 nm, as per Scherrer's equation.[10] The crystalline nature of produced nanoparticles was confirmed by strong peaks at 31°, 34°, and 36°.[11]

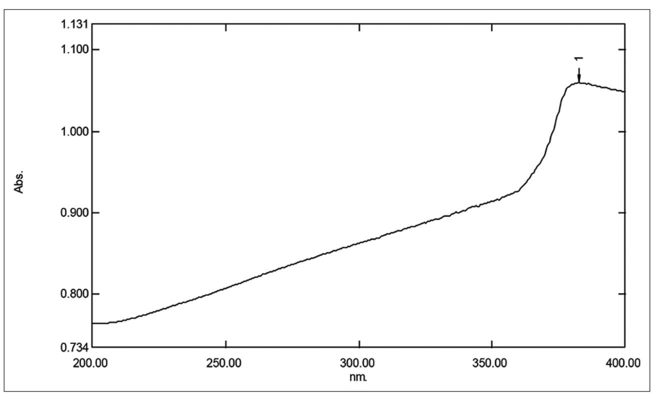

Figure 2: Ultraviolet-visible spectrum of zinc oxide

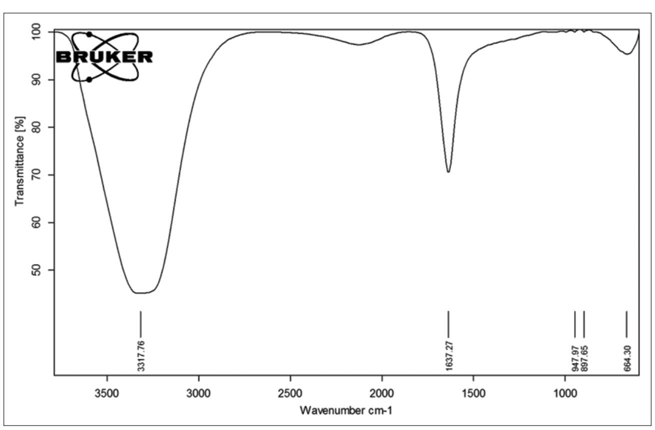

Figure 3: Fourier transform infrared spectrum of zinc oxide

Zeta Potential

The electrical potential created at the solid–liquid interface as a result of the relative mobility of the nanoparticle and the solvent is known as zeta-potential. The produced nanoparticles were distributed in double distilled water to examine the zeta potential. The electrical potential and the surface charge are critical for nanoparticle stability, so knowing them is crucial. The surface potential of a charged particle rises as the zeta potential rises.[12] As shown in Figure 5, the zeta potential of the produced nanoparticle was found to be −7.38 mV, indicating that the synthesized nanoparticles were reasonably stable and well-dispersed.

Photocatalytic Activity

Figure 6 depicts the breakdown of MB dye in the presence of ZnO on exposure to sunshine. After incubating ZnO

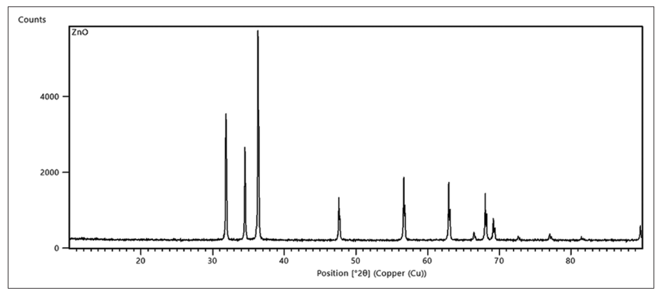

Figure 4: X-ray diffraction spectrum of zinc oxide

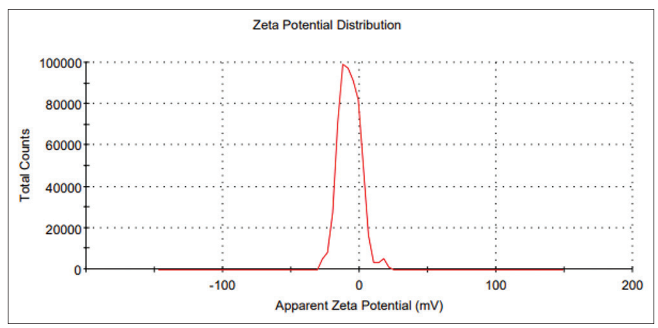

Figure 5: Zeta-potential of zinc oxide nanoparticles

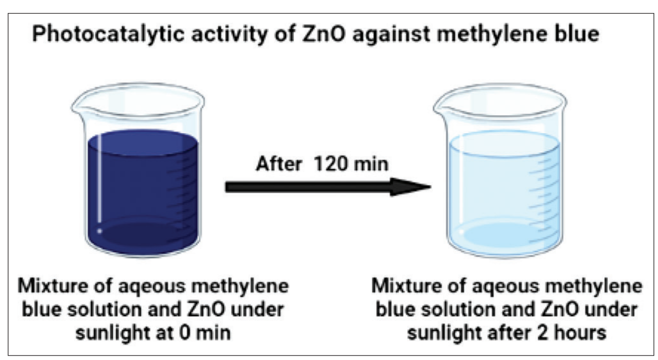

Figure 6: Photocatalytic degradation of methylene blue through zinc oxide NPs

nanoparticles with aqueous MB solution in the presence of sunshine for 120 min, the blue colored solution changed to colorless, indicating that ZnO nanoparticles are acting as a photo catalyst in dye degradation. However, more studies are required in detail to decipher the potential of ZnO to act as catalyst in degradation of dye.

CONCLUSION

The green production of ZnO was successfully done in this study using onion peel extract. The precursor for the synthesis of ZnO was zinc nitrate. Different techniques were used to characterize the synthesized compound, including UV spectroscopy, FTIR spectroscopy, XRD, and zeta potential analysis. As per UV spectroscopy study, the absorption maxima of ZnO was found at 378 nm. While the FTIR peaks at 3317 cm^{-1} and 1637 cm^{-1} verified the presence of hydroxyl functional groups on the surface of ZnO NPs. The FTIR peaks found below 1000 cm^{-1} could be attributed to the ZnO vibrational photon, indicating the formation of ZnO. Moreover, the XRD results revealed crystalline nature of ZnO with average grain size of 92 nm. In addition, the average zeta potential value (−7.38 mV) of synthesized ZnO indicated that synthesized particles were stable in nature. Furthermore, ZnO particles have the capability to act as catalyst in photo-degradation of MB dye, as blue color of MB dye changed to transparent after 120 min when the mixture of ZnO and aqueous MB was exposed to sunlight. Overall the results of this study suggested that this investigation should be continued in the future to decipher mechanisms behind the degradation of various MB dye using ZnO as catalyst.

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REFERENCES

1. Sengupta J, Ghosh S, Datta P, Gomes A, Gomes A. Physiologically important metal nanoparticles and their toxicity. J Nanosci Nanotechnol 2014;14:990-1006.
2. Sundrarajan M, Gowri S. Green synthesis of titanium dioxide nanoparticles by *Nyctanthes arbor-tristis* leaves extract. Chalcogenide Lett 2011;8:447-51.
3. Khandel P, Yadaw RK, Soni DK, Kanwar L, Shahi SK. Biogenesis of metal nanoparticles and their pharmacological applications: Present status and application prospects. J Nanostructure Chem 2018;8:217-54.
4. Jha AK, Prasad K, Kumar V, Prasad K. Biosynthesis of silver nanoparticles using Eclipta leaf. Biotechnology Prog 2009;25:1476-9.
5. Ahmed S, Annu, Chaudhry SA, Ikram S. A review on biogenic synthesis of ZnO nanoparticles using plant extracts and microbes: A prospect towards green chemistry. J Photochem Photobiol B 2017;166:272-84.
6. Saratale RG, Saratale GD, Shin HS, Jacob JM, Pugazhendhi A, Bhaisare M, Kumar G. New insights on the green synthesis of metallic nanoparticles using plant and waste biomaterials: Current knowledge, their agricultural and environmental applications. Environ Sci Pollut Res 2018;25:10164-83.
7. Gupta N, Singh HP, Sharma RK. Metal nanoparticles with high catalytic activity in degradation of methyl orange: an electron relay effect. J Mol Catal A: Chem 2011;335:248-52.
8. Samanta PK, Saha A, Kamilya T. Morphological and optical property of spherical ZnO nanoparticles. Optik 2015;126:1740-3.
9. Shoeb M, Singh BR, Khan JA, Khan W, Singh BN, Singh HB, *et al.* ROS-dependent anticandidal activity of zinc oxide nanoparticles synthesized by using egg albumen as a biotemplate. Adv Nat Sci Nanosci Nanotechnol 2013;4:035015.
10. Muniz FT, Miranda MR, Morilla dos Santos C, Sasaki JM. The scherrer equation and the dynamical theory of X-ray diffraction. Acta Crystallogr Sect A Found Adv 2016;72:385-90.
11. Vijayakumar S, Krishnakumar C, Arulmozhi P, Mahadevan S, Parameswari N. Biosynthesis, characterization and antimicrobial activities of zinc oxide nanoparticles from leaf extract of *Glycosmis pentaphylla* (Retz.) DC. Microb Pathog 2018;116:44-8.
12. Reicha FM, Sarhan A, Abdel-Hamid MI, El-Sherbiny IM. Preparation of silver nanoparticles in the presence of chitosan by electrochemical method. Carbohydr Polym 2012;89:236-44.

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