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RESEARCH PAPER

Study the Photocatalytic Activity of Zinc Oxide Nanoparticles for Degradation of Malachite Green Dye

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ABSTRACT

This study looks at the photograph squalor of malachite green color with an artificial nanocomposite and UV radiation. Zinc oxide nanoparticles were produced by the sol-gel method. This work is divided into two primary portions. The first involves the fabrication of zinc oxide (ZnO) nanoparticles. The features of nanoparticles were studied using a sum of methods, as well as scanning electron microscopy (SEM), Fourier transform infrared spectroscopy (FTIR), and X-ray diffraction (XRD). According to the Scherer equation, the produced zinc oxide nanoparticles particle size is) 50.44 nm (. The second section focuses on the photo catalytic movement of produced zinc oxide NPs. For this reason, numerous tests were carried out, such as the influence of catalyst mass loaded and the optimal value (0.16 g/100 mL) of nanoparticles, the effect of dye concentration (30 mg/L) of aqueous suspension solutions of malachite green dye, and how light intensity affects things.

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INTRODUCTION

It is very crucial to propose a wastewater treatment solution because water contamination is one of the major issues of the current decade [1]. Both qualitative and quantitative wastewater generation rises as a result of population growth and industrialization.

Hazards to aquatic life, the environment, and public health may arise from the dumping of partially or untreated industrial effluent [2-4].

The textile industry uses a large number of dyes, and the non-bio-recalcitrant nature of their effluents has a number of negative effects on the environment [5].

These substances can be eliminated from water using a variety of techniques, including biological, mechanical, thermal, chemical, physical, and precipitation deposition, Advances in the full mineralization of organic molecules and non-biodegradable contaminants are provided by the photocatalytic treatment technique. Numerous nanoscale photo catalyst nanomaterials, including as (TiO_2, ZnO, CdS, SiO_2, WO_3, and others (, are used in the process [6–8]. Without producing secondary pollutants, photo catalysis efficiently breaks down organic dyes into) H_2O, CO_2, and mineral acid([9].

The little size and elevated surface-to-volume ratio of nanoparticles render them highly captivating. Nanoparticles have enhanced chemical stability, thermal conductivity, and catalytic reactivity [13].

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The particle sizes that nanotechnology works with range from (1 to 100 nm), depending on the unique uses. Recent years have seen an increase in interest in semiconductor materials' nanoparticles due to their distinct features, including as their huge surface area and electrical and optical properties, which set them apart from their bulk counterparts [14]. Because of its low cost, readily available nature, strong Zinc oxide (ZnO) is an excellent candidate for photocatalytic treatment methods because to its chemical and thermal stability, lack of toxicity, and environmental friendliness [10–12].

(ZnO (nanoparticles have been manufactured utilizing a variety of processes, including laser ablation, hydrothermal, sol-gel, electrochemical, thermal, chemical vapor, and combustion, as well as other ways investigated in the literature. Recently described approaches include electrophoretic deposition, microwave-assisted combustion, anodization, ultrasound, and two-step mechanical chemical thermal synthesis [15–17].

When compared to other metal oxides, zinc oxide (ZnO) possesses large photocatalytic efficiency for the elimination of organic contaminants because to its organic stability and lack of toxicity. Low cost, high excitation energy (60 meV), and eco-friendly species [18].

As a result, (ZnO) is now regarded a promising photo catalyst. Materials scientists created and produced zinc oxide nanoparticles as a kind of nanotechnology. (ZnO) NPs have unique optical, electrical, photocatalytic, and antibacterial characteristics that make them suitable for a variety of environmental and therapeutic uses.

(ZnO) NPs are effective Nan carriers for Due to their low toxicity and biodegradability, they can be used in a variety of medications.(ZnO) nanoparticles are chemically, electrically, and thermally stable due to their (60 meV) binding energy and (3.37 eV) energy bandgap [19].

The ability of the Advanced Oxidation Process (AOP) to directly transform contaminants into harmless chemicals in wastewater has drawn public attention. Advanced oxidation processes (AOPs) use atmospheric oxygen as an oxidant to convert organic pollutants into) CO_2, water, and mineral acids (for use as a semiconductor catalyst.

These processes produce a powerful oxidizing agent, such as the OH^- radical, which effectively removes contaminants from wastewater [20].

A carbon-based complex that is controversially utilized as a colorant and antibacterial in aquaculture. Malachite Green, sometimes called Victoria Green 4, is a green crystal powder with the chemical formula ($C_{23}H_{25}N_2Cl$). It has been utilized in the jute, cotton, silk, wool, and acrylic industries, as well as a culinary colorant. Malachite green is categorized as a trial methane dye in the dyestuff business and is utilized in pigment production. This chloride salt is formally called as malachite green [C_6H_5C (C_6H_4N $(CH_3)_2)_2$] Cl as shown in Fig. 1.

Consequently, the name Malachite green is a broad description that frequently refers just to the colored cation. The oxalate salt is easily accessible, and the anions have little effect on the color. The cation's vibrant green color was caused by a large absorption band at (621 nm) and an extinction value of (105 M^{-1} cm^{-1}) [21–23].

In this study, the particular goal is to look at how the produced and described (ZnO (NPs may be used to decolonize an aqueous solution that contains malachite green coloring.

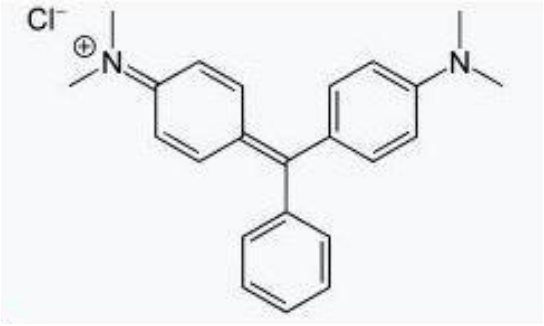

Fig. 1. Chemical structure of malachite green dye

MATERIALS AND METHODS

Chemicals

A. Zinc acetate dehydrate (Zn $(CH_3COO)_2 \cdot 2H_2O$), were provided by Fluke,

B. Sodium hydroxide (NaOH(, were provided by Fluke (Bucks, Switzerland).

C. Malachite green dye is manufactured by Sigma-Aldrich.

D. Ethanol (C_2H_5OH) was delivered by Fluke,

E. No additional purification was done before using any of the compounds.

Production of zinc oxide nanoparticles

ZnO photocatalytic nanoparticles were produced utilizing the cost-effective sol-gel technique. Ethanol (C_2H_5OH) was used as a reagent, with zinc acetate dehydrate as a precursor. Sodium hydroxide (NaOH) was employed as an oxygen foundation. A magnetic stirrer was used to combine and stir the liquid after zinc acetate dehydrate (0.2 M) had been dissolved in room temperature ethanol. The sol was transparent and clear with no precipitation or turbidity. The sol was stirred for (60 minutes) after a little addition of (0.02 M) (NaOH). They did not disturb the sol until the white precipitate had sunk to the bottom. Following precipitation, the precipitate was filtered and washed with more ethanol to remove any residual starting material. The material was then dried on a hot plate at (50°C for 15 minutes). To acquire the necessary crystallinity and characteristics, as well as to eliminate any potential impurities, this dry ZnO precipitate was annealed for (24 hours at 100°C) [24].

Zinc oxide nanoparticle-based photocatalytic degradation of malachite green dye

Zinc oxide (ZnO) nanoparticles were used as Malachite green dye in aqueous elucidation is broken down by a photo catalyst in photocatalytic degradation studies when exposed to UV light. Using a specially constructed photo reactor, the two-phase experiment was carried out. Cooling water was poured through the first one to chill the suspension solution. A (100 mL) suspension solution for the dye degradation is contained in the second component. A stock solution of malachite green dye solutions at a concentration of (100 parts per million) was made using distilled water. For every color concentration, a suspension solution combination was made by stirring. (0.16 g of ZnO(NPs were added to (100 mL) of each

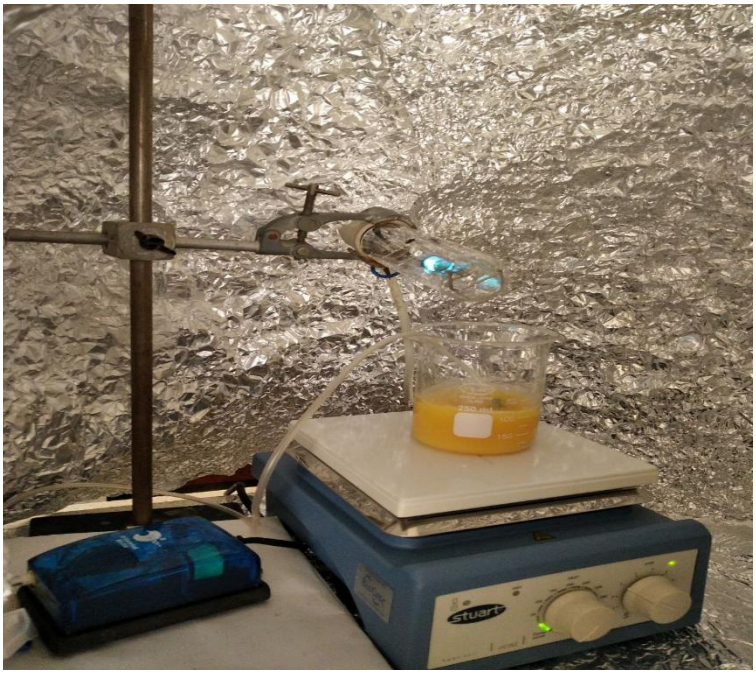

Fig. 2. Malachite green dye was photo catalytically degraded using the main components of the photocatalytic cell.

hue, and the mixture was then swirled. A tabletop light source has been used to expose the matching suspension solution combination to UV light as shown in Fig. 2.

A syringe was used to extract two to three milliliters of each sample every ten minutes.

The samples were then spun for ten minutes at (3000 rpm), and UV-Vis spectrophotometer was secondhand to quantity apiece section's absorbance.

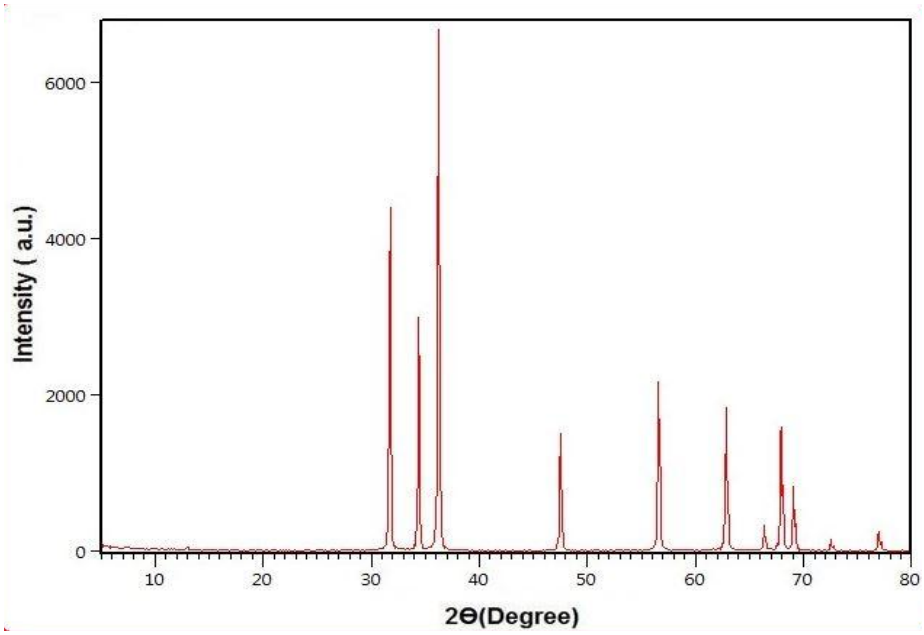

Fig. 3. XRD patterns of ZnO nanoparticles

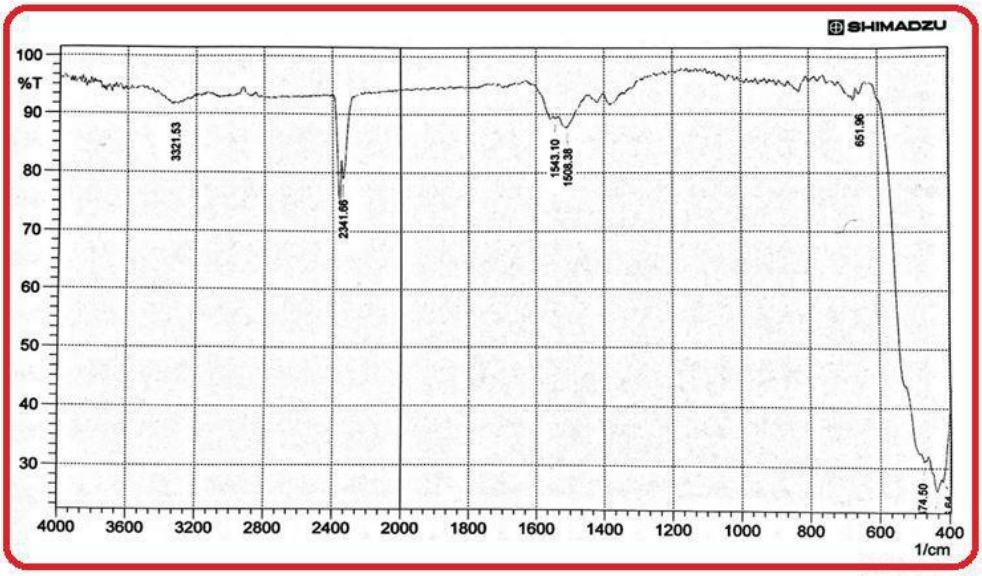

Fig. 4. FTIR patterns of synthesized ZnO nanoparticles.

RESULT AND DISCUSSION

Characterization of zinc oxide nanoparticles

ZnO nanoparticle X-ray diffraction analysis

X-ray diffraction was employed to analyze the crystallinity and particle size of the synthesized (ZnO) nanoparticles utilized as a catalyst. Using and XRD (6000) from Shimadzu, Japan, and the generated (ZnO) nanoparticles were examined using XRD. The measurement parameters were configured to operate at a rate of (5 dug/min, 40 kV, 30 mA, and 45) Cu Kα radiation (λ = 1·54056 Å) in the 2θ range (3-90˚).

The normal crystallite diameters of the generated (ZnO) nanoparticles were calculated using the Scherer calculation to be (50.44 nm).

As in Fig. 3: Zinc oxide nanoparticles could be indexed to the hexagonal (Ref. Pattern: zinc oxide, No. 98-002-9272), the diffraction peaks at (31.837˚, 34.502˚, 36.334˚, 47.650˚, 56.726˚, 63.012˚, 68.114˚, 69.254˚, and 89.860˚).

Fourier-transform infrared spectroscopy synthesized zinc oxide

The peaks at (444.02, 498.75, 546.84, 607.37, 825.45, 88018, 1029.43, 1111.52, 1172.86, 1376.88, 1430.76, 2370.23, 2921.64, 3350 cm^{-1}) correspond to the FTIR spectra of produced zinc oxide nanoparticles, as seen in Fig. 4. At (3333 cm^{-1}), the absorption peak emerged, signifying the extending vibrations of (OH) groups. The band at (2895 cm^{-1}) represents groups of carbon dioxide. The peak at (14340 cm^{-1}) is caused by the link between, ($^{\cdot}C$ and ^{-}H). The bands that may be practical at (1034, 622, and 501 cm^{-1}) are (C-OH), (C-C), and (Zn-O), respectively.

SEM scanning electron microscopy of ZnO nanoparticles obtained by synthesis

To get meaningful information on the structure of the created (ZnO) nanoparticles, the morphology of the particles was studied by means of scanning techniques. Techniques of scanning electron microscopy (SEM).

The (SEM), Gaussian, and histogram images of (ZnO) nanoparticles are shown in Fig. 5.

Aspherical shapes and irregularly distributed aggregates were seen in the SEM micrograph analysis.

Degradation of malachite green dye by photo catalytic reaction over ZnO NPs

ZnO NPs' loaded mass and its impact on the

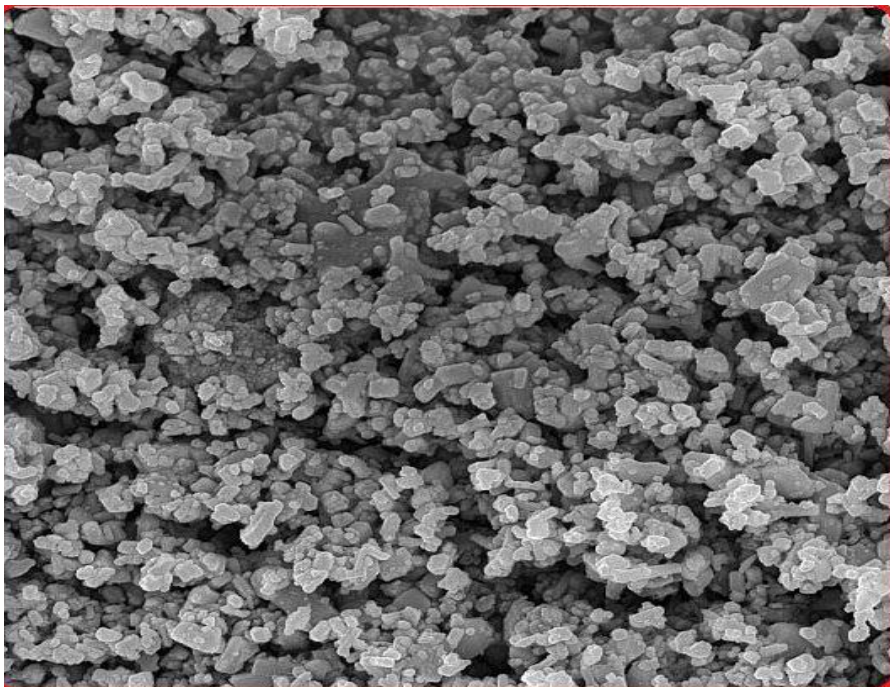

Fig. 5. SEM pattern of ZnO nanoparticles.

malachite green dye's photocatalytic degradation

The inspiration of ZnO nanoparticle mass (0.04, 0.08, 0.16, 0.25 g/100 ml) on the photocatalytic degradation of malachite green dye was examined utilizing a (30 ppm (dye concentration and an air flow rate of (10 mL/min) at chamber heat. Numerous researchers have examined this effect when ZnO NP loading mass falls below the optimal value of (0.16 g/100 ml (as shown in Fig. 6, the mass of ZnO NPs surface area decreases, reducing the aggregate of light that ZnO NPs can captivate resulting in a reduction of the photo-degradation rate of malachite green dye [25-27].

A photo degradation efficiency of (93.74%)

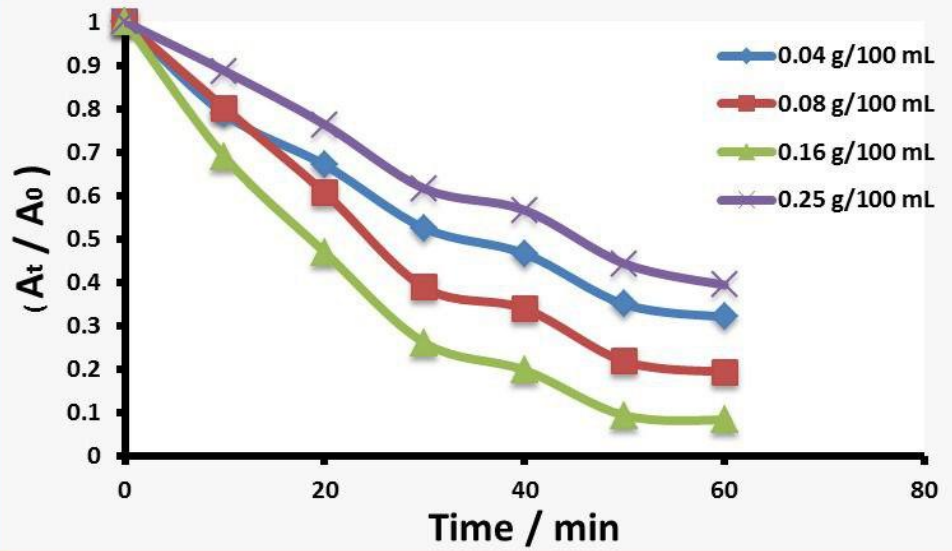

Fig.6. Difference in (A_t / A_o) with the irradiation time at (30 mg/L) of dye concentration.

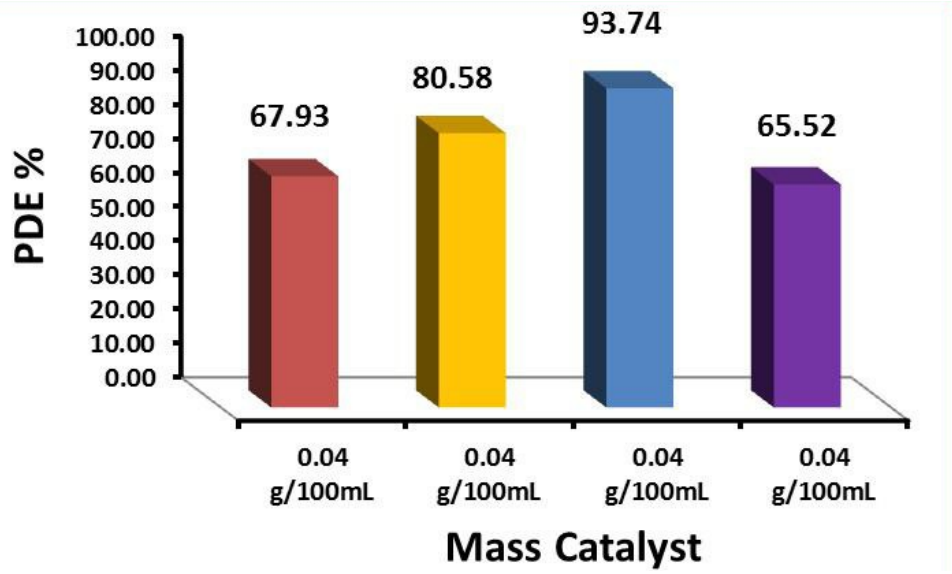

Fig. 7. Photocatalytic degradation efficiency using (0.16 g/100 ml) ZnO nanoparticles and (30 mg/L) malachite green dye.

was realized at an absorption of (30 mg/L) of malachite green. The efficiency of photocatalytic degradation was evaluated at different catalyst mass concentrations. Displayed in Fig. 7.

The effect of the original attention of malachite green dye on the photocatalytic degradation process

Throughout the remainder of the

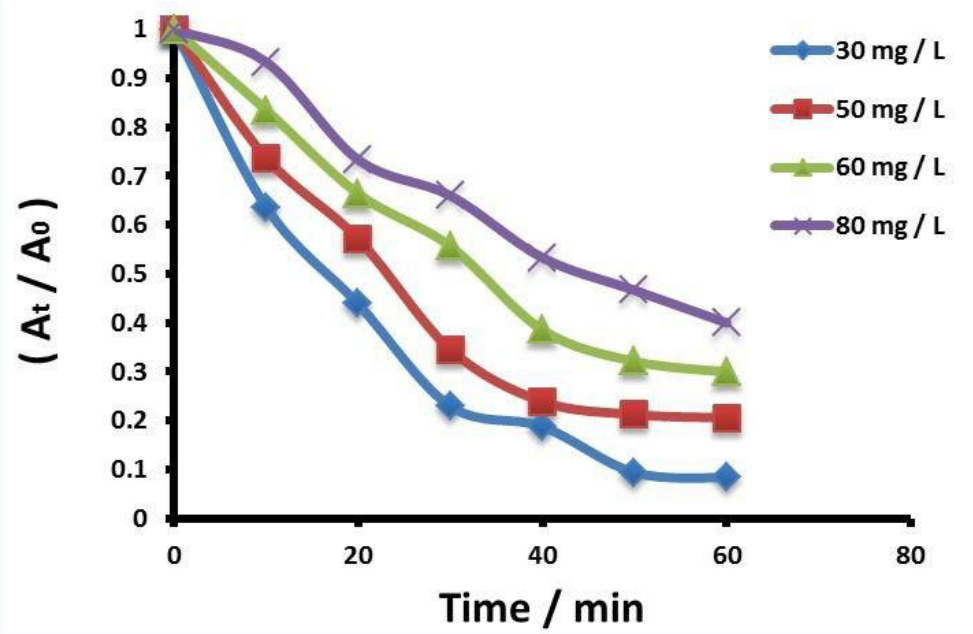

Fig. 8. Variations in (At/A_0) at different dye concentrations with irradiation duration.

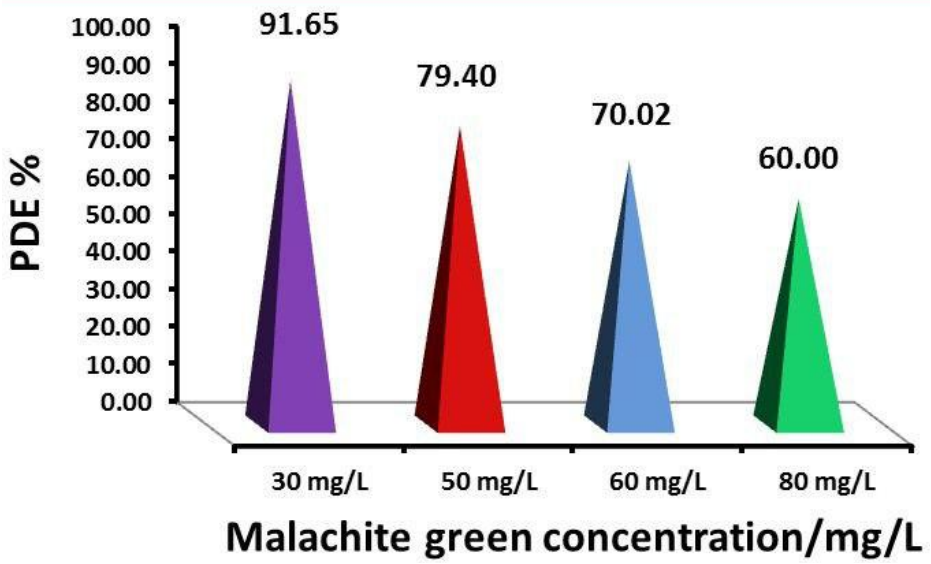

Fig. 9. Photocatalytic degradation efficiency using malachite green dye (30 mg/L) and ZnO nanoparticles (0.16 g/100 mL).

experiment, the effects of the malachite green dye concentration solution and the range of photocatalytic degradation processes (30-80 mg/L) were examined under the same conditions. Plotting the data in Fig. 8 demonstrates that the photocatalytic degradation rate dropped as the original dye attention rose. More photons arrive at the catalyst surface when the primary concentration of "malachite green" dye decreases because the photon's path lengthens as it enters

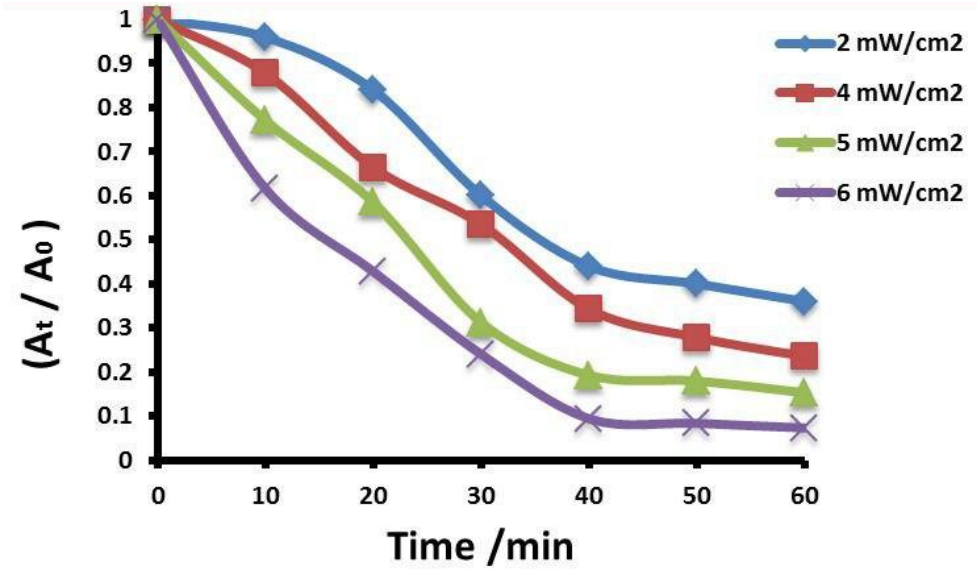

Fig. 10. Change in (At/A_0) throughout duration of irradiation at varying light intensities.

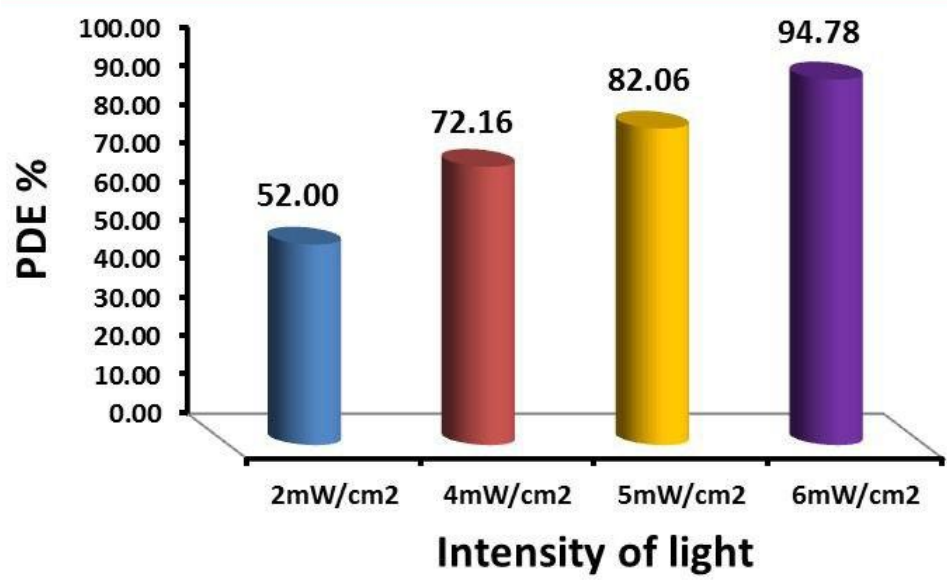

Fig. 11. Photocatalytic degradation efficiency using (0.16 g/100 ml) ZnO nanoparticles and (30 mg/L) of malachite green dye.

the solution.

This, in turn, increases the rate at which hydroxyl radicals and superoxide ions are formed, which in turn speeds up the degradation of materials [28-29].

The effectiveness of photocatalytic degradation, measured at different concentrations of malachite green, is shown in Fig. 9. (30 mg/L) has a high photo degradation efficiency of (91.65%).

The impact of light intensity on ZnO nanoparticle-induced photo degradation of malachite green dye

Multiple investigations were conducted within the range of (2–6 mW/cm²) to investigate the influence of light intensity on the photocatalytic degradation of malachite green dye. Other experimental conditions were upheld at an initial dosage of (30 mg/L) to optimize energy conservation.

At ambient temperature, the produced (ZnO) nanoparticles' catalyst dose was (0 mL 100/100 mL, 10 mL/min) flow rate of an air bubble. The results in Fig. 10 show that the dye's breakdown process progressively accelerated as light intensity increased [30-33]. This may be attributed to the increased photon output required for electrons in the catalyst to migrate between the conduction and valence bands.

At a light, the maximum photo degradation efficiency of (94.78%) is reached.

The photocatalytic degradation efficiency, which was measured at different light intensities, is shown by the high photo degradation efficiency (94.78%) in Fig. 11.

CONCLUSION

This work describes the sol-gel process for creating zinc oxide nanoparticles. The photocatalytic degradation of "malachite green" dye was regulated by the catalyst dose; the optimal amount was (0.16 g) of (ZnO) nanoparticles per (100 mL). The effects of dye concentration have been studied, and the optimal concentration of Malachite green dye has been determined to be (30 mg/L). The photocatalytic breakdown process is impeded by the increased malachite green dye because it reduces the adsorption of (OH^-) on the surface of the catalyst. With increased light intensity, the efficiency of photocatalytic degradation of malachite green dye rises to (94.78 %). The typical size of the crystallites produced (ZnO) nanoparticles was measured using the Scherer equation, and the result was (50.44 nm).

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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