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Sunlight And UV-Assisted Photocatalytic Degradation of Auramine-O and Metanil Yellow Using $NiFe_2O_4$ Nanocatalyst

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Article Details

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ABSTRACT

The removal of synthetic dyes from industrial wastewater is crucial for environmental sustainability this study investigate the photocatlytic degradation of Auramine-O(AO) and metanil yellow (MY) using $NiFeO_4$ nanocatalyst under sunlight and UV irradiation $NiFeO_4$ was synthesized via sol-gel method and characterized using SEM and EDX confirming nanoscale morphology and elemental composition . operational parameters including PH,catalyst dose, irradiation time and initial dye concentration were optimized. The catalyst achived 95% degradation for AO and 93% for MY under UV light at pH 4 and pH 6. Reusability test confirmed catalyst stability over three cycles. These result demonstrate the potentials of $NiFeO_4$ for practical wastewater treatment applications.

DOI: Availability

INTRODUCTION

Water pollution particularly from industrial dye effluents poses a severe threat to aquatic ecosystem and human health .dyes like Auramine-O Metanil yellow are highly stable toxic and resistant to conventional treatment method . advanced oxidation process particularly photocatalyst using nanostructured semiconductors offer an eco- friendly approach to degrade such pollutants.[1]Water is most likely a unique universal solvent that is absent from the other planet. From now on, its quality will directly affect life on Earth. Water pollution is one of the general problems.[2]. The degradation of water quality is referenced by the term "water contamination." Water quality and its biological condition can be altered by natural or man-made cycles, but in any case, it cannot be considered an impurity unless it is used inappropriately for a particular purpose.[3]. The usage of water for various purposes expanded as a result of industrialization and population growth. [4]. Modern activities and domestic use in developed countries generate vast amounts of waste water, which subsequently find their way into regular waterways and pose a serious risk of pollution. In any event, the shade generation in water is a serious issue. [5]. The presence of humic matter or artificial wonders like color waste can be used to determine the water's quality. [6]. Contamination of colors from the material industry Light is essential to aquatic life's healthy development. As a result, large amounts of colored materials prevent sunlight from entering the water, making them a major source of ecological contamination. [7]. These effluents are unquestionably hazardous, non-biodegradable, and resistant to destruction by physicochemical treatment methods. [8]. The rust foreign substance that is visible in wastewater is called shading. Removing color from waste is usually more important than removing other natural elements since the presence of small amounts of color (less than 1 ppm) is clearly visible and drastically alters the water's climate.[9]

CHARACTERIZATION TECHNIQUES

The synthesized catalyst was characterized through different spectroscopic techniques and classical methods. Scanning electron microscopy of nanocatalyst was carried out with a JSM-6700F. EDX was applied for the elemental analysis of synthesized photocatalyst.From the getting results the Point of zero charge PZC and surface area of the catalyst were determined through the calculations.

EXPERIMENTAL

CHEMICALS AND REAGENTS

Salts of Iron ($FeCl_3$) and Nickel($NiCl_2$), buffer solution, potassium hydrogen phthalate (KHP), Ammonium hydroxide (NH4OH), Ammonium chloride (NH4Cl), water, AO were purchased from Merck Germany.

INSTRUMENTS AND EQUIPMENTS

UV-visible spectrophotometer, Digital pH-meter, Digital balance, Oven, Magnetic stirrer, Centrifuge and Furnace .

SYNTHESIS AND CALCINATION OF $NIFE_2O_4$ NANOCATALYST

$NiFe_2O_4$ nanoparticles were synthesized via the sol-gel method using aqueous solutions of $FeCl_3$ (0.4 M) and $NiCl_2$ (0.2 M). The mixture was stirred at 70 °C, pH was raised to 12 using NH_4OH, and the resulting precipitate was filtered and dried. Calcination was carried out at 500 °C for 6 hours. The catalyst was cooled and stored for photocatalytic applications.

PREPARATION OF SOLUTIONS AND CALIBRATION CURVES

A 50 ppm AO stock solution was prepared, and standard solutions (1–6 ppm) were obtained by serial dilution. A buffer solution was prepared using KHP. The maximum absorption wavelengths (λmax) for AO and MY were determined by UV-Vis scanning from 450 to 750 nm. Calibration curves were plotted using absorbance values at λmax, and the Beer-Lambert law was applied for dye concentration estimation.

PHOTOCATALYTIC DEGRADATION PROCEDURE

Dye solutions (AO and MY) were treated with known amounts of $NiFe_2O_4$ catalyst under UV and sunlight exposure. Samples were withdrawn at defined intervals, centrifuged, and absorbance was measured to calculate degradation percentage. Each analysis was done in triplicate for accuracy.

OPTIMIZATION OF EXPERIMENTAL PARAMETERS

The effects of various factors, including radiation type, initial dye concentration (5–50 ppm), catalyst dosage (0.05–3 g), reaction time (5–50 min), and pH, were systematically studied while keeping other variables constant.

RESULT AND DISCUSSION

SEM & EDX ANALYSIS

SEM analysis (Fig. 3.1) revealed porous, variable-sized particles ranging from nanometers to micrometers, confirming nanoscale morphology. EDX spectrum (Fig. 3.2) confirmed the presence of Ni and Fe elements, validating the successful synthesis of $NiFe_2O_4$ nanocatalyst.

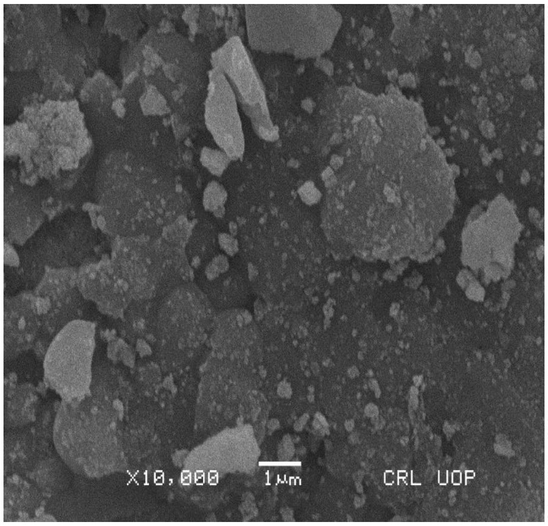


FIGURE3.1 SEM IMAGE OF NIFE2O4 X10,000 1µM

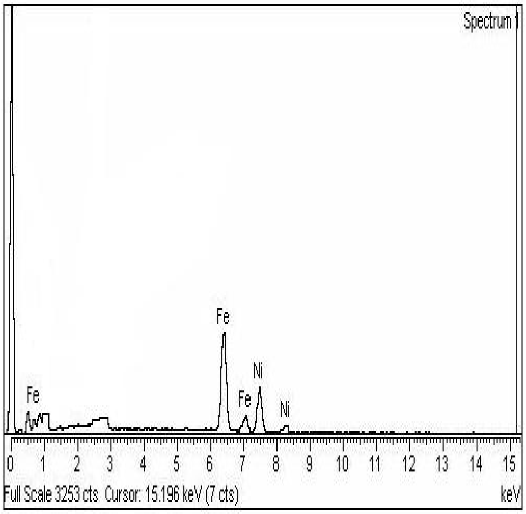


FIG 3.2 EDX SPECTRUM OF NIFE2O4 PHOTOCATALYST

SURFACE AREA AND POINT OF ZERO CHARGE (PZC)

BET surface area was found to be 193.827 m^2/g. PZC was determined to be pH 6, as the point where no net charge interaction occurred between dye molecules and the catalyst surface (Fig. 4.3, Tables 3.1 & 3.2).

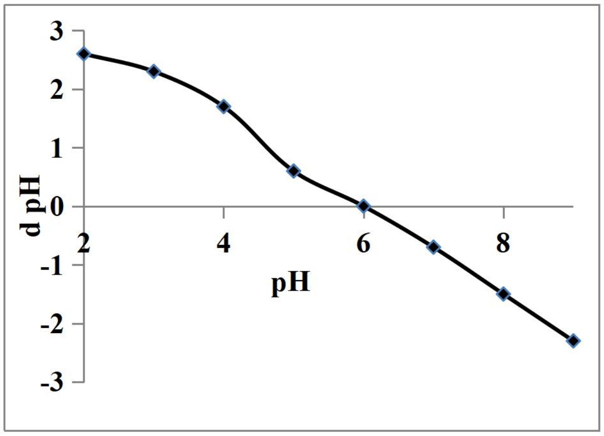
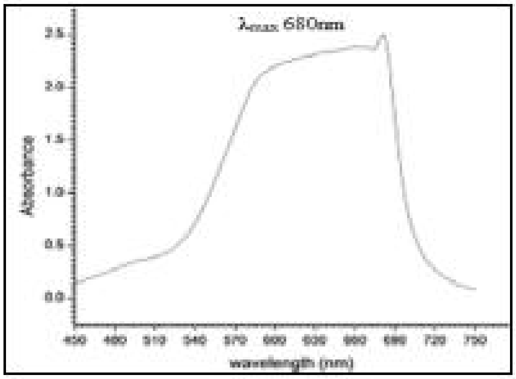


FIG3.3: PZC OF THE NANOCATALYST

SPECTROPHOTOMETRIC ANALYSIS OF DYES

DETERMINATION OF ΛMAX AND CALIBRATION

UV–Vis spectra showed maximum absorbance at 680 nm for AO and 620 nm for MY (Figs. 3.4 & 3.5). Calibration curves were prepared for both dyes (Tables 3.3 & 3.4, Figs. 3.6 & 3.7), which were used to quantify degradation and calculate % removal.



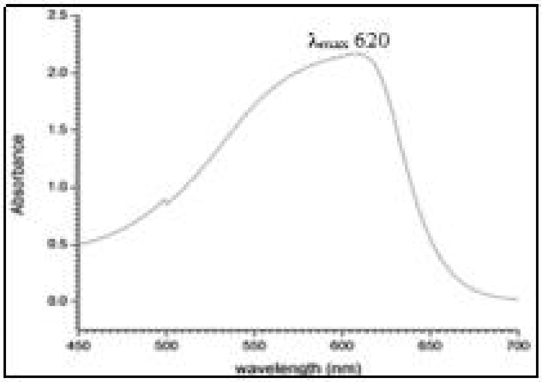
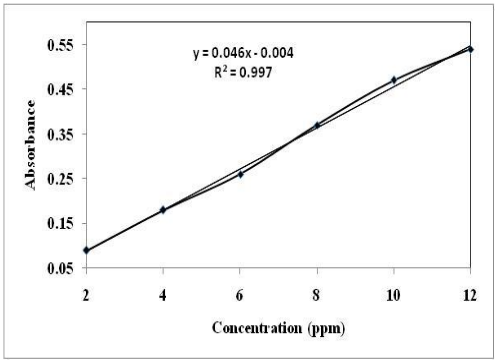


FIGURE 3.4 MAXIMUM WAVELENGTH OF AO

FIGURE 3.5 MAXIMUM WAVELENGTH OF MY



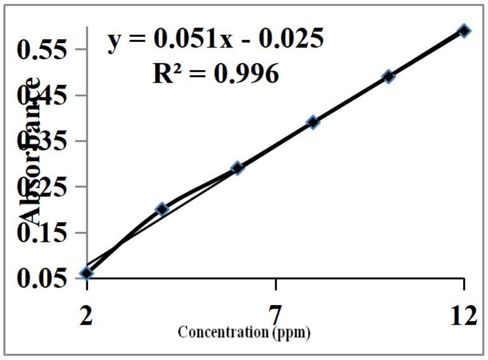


FIGURE 3.6 CALIBRATION CURVE OF AO

FIGURE 3.7 CALIBRATION CURVE OF MY

The photocatalytic degradation of Acridine Orange (AO) and Methylene Yellow (MY) dyes was studied using $NiFe_2O_4$ catalyst. Maximum degradation occurred at 30 minutes for AO (95%) and 25 minutes for MY (92%) under UV light. UV light showed higher efficiency than sunlight. Optimal catalyst doses were 0.1 g for AO and 0.15 g for MY; higher amounts led to reduced performance due to particle aggregation. Best degradation occurred at dye concentrations of 30 ppm (AO) and 35 ppm (MY). AO degraded most at pH 4, and MY at pH 6. Kinetic analysis followed pseudo-first-order, showing surface adsorption and ROS-driven oxidation.

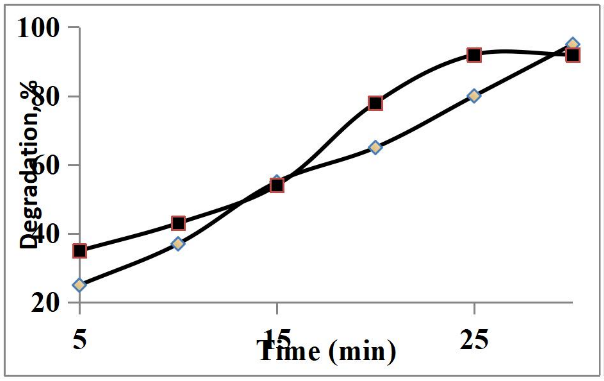


FIGURE 3.8 EFFECT OF SULIGHT ON AO AND MY

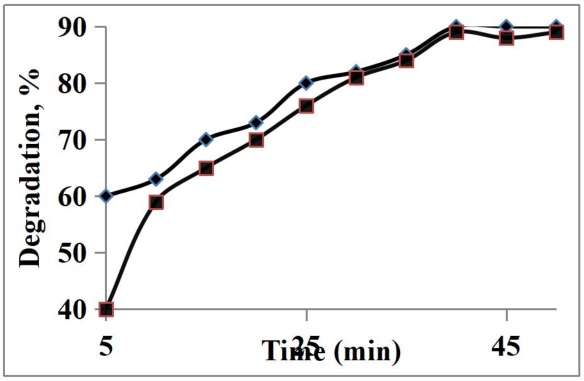
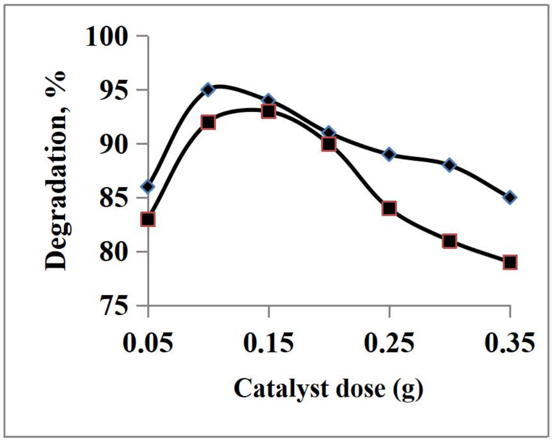
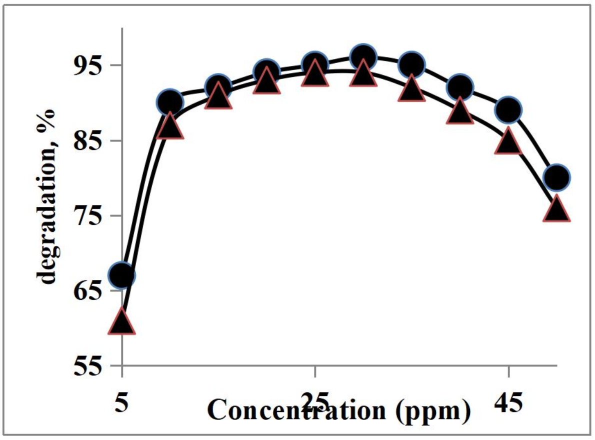


FIGURE 3.9 EFFECT OF TIME ON AO AND MY



EFFECT OF CATALYST DOSE ON AO AND MY



EFFECT OF DYES CONCENTRATION

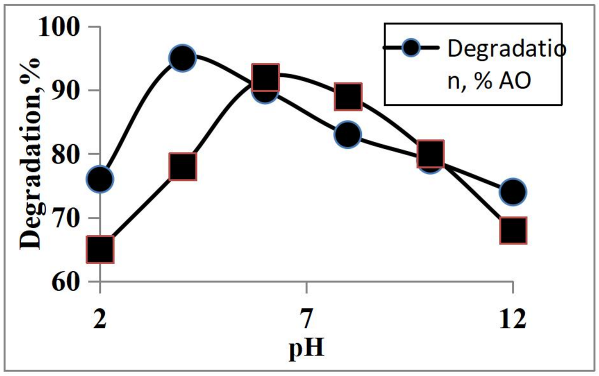


FIGURE 3.12 EFFECT OF PH

The kinetics of AO and MY dye degradation using $NiFe_2O_4$ catalyst were studied. For AO, the pseudo-first-order model gave poor fit ($R^2 = 0.831$), while the pseudo-second-order model matched well ($R^2 = 0.971$) with a rate constant of 0.013845, showing it follows second-order kinetics.For MY, the pseudo-first-order model had moderate fit ($R^2 = 0.924$), but pseudo-second-order showed better correlation, confirming that both dyes degrade through pseudo-second-order kinetics.The $NiFe_2O_4$ catalyst was reused in three cycles, maintaining over 90% efficiency, proving good reusability and stability.

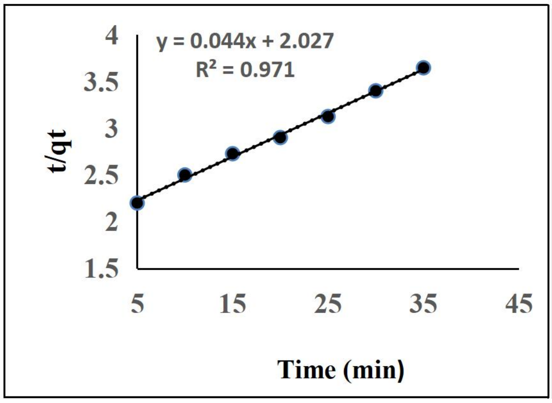


FIGURE 3.15 PSEUDO 2ND ORDER KINETICS

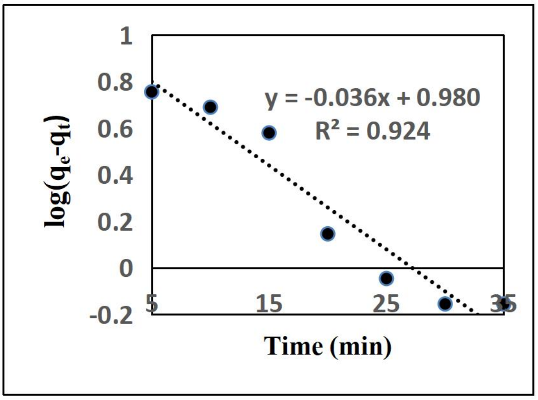


FIG 3.16:FIRST ORDER KINETIC MODEL OF MY DEGRADATION

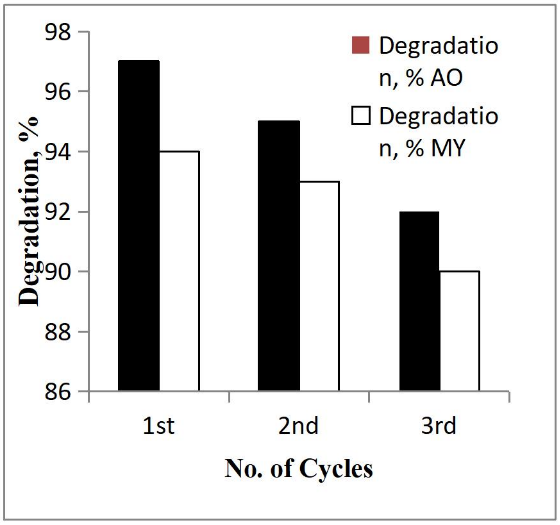


FIG. 3.17:CATALYST REGENERATION FOR AO AND MY DYE DEGRADATION

After three reuse cycles NiFe2O4 maintained over 90% degradation efficiency indicating good stability however minor activity decline may result from surface fouling or active warranting further strcutral analysis .

CONCLUSION

NiFe2O4 nanocatalyst demonstrated effective photocatalytic degradation of AO and MY dyes under UV and sunlight irradiation with optimal degradation achieved at specific PH catalyst dose, and irradiation time..The maximum percent degradation 97% were obtained for AO using 0.1g NiFe2O4 catalyst, 30min UV irradiation, pH 4 and 30ppm of the dye. While optimum conditions for high degradation 95% were obtained for 35ppm MY dye solution using 0.15g catalyst, 35min irradiation at pH6. the catalyst exhibited stability over three cycles highlighting its potential for sustainable.

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