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RESEARCH PAPER

Photocatalytic Degradation of Fast Green Dye Using Nickel Oxide Nanoparticles for Removal Industrial and Environmental Pollutants

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ABSTRACT

The increasing requirements for paints and chemicals in industry have necessitated the use of several techniques to reduce pollution, including a combined chemical precipitation(Co-precipitate) approach to prepare NiO nanoparticles in the form of NPs nanoparticles, where structural and morphological analyzes revealed the formation of nanostructures, such as the scattering of X-rays (XRD) , Fourier transform Infrared spectroscopy(FTIR) a technique used to analyze the interaction between matter and infrared radiation by measuring the absorption, emission, or reflection of infrared light, and dispersive energy X-ray spectroscopy (EDX) analytical techniques used in scientific research, , Electron scanning microscopy ,and Thermal gravimetric analysis (TGA). The second part includes the study of the photo catalytic activity of prepared nanocomposite, using a fast green dye. The rate of the photocatalytic degradation process was affected by different parameters such as the concentration of dye, effect of a mass of catalyst, and the effect of temperature. The experiments were performed under optimum conditions from (0.15 g / 100 mL) of NiO nanocomposite, with an air Rate of flow of 10 mL/min. The best removal amount of Fast green dye was (91.45%). The effect of dye concentration has been used to study the optimum value of Fast green dye (10mg/L) dye. The activation energy for the photo degradation process calculated using the Arrhenius equation was equal to (31.67. ±1 kJ.mol^{-1}).

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INTRODUCTION

Numerous investigations into photocatalysis have been carried out in recent years. An electron-hole pair is created vi Oxidation or reduction occurs on the surface of the catalyst, at light energies below its Intensity. An organic substance pollutant can be oxidized containing the presence of a photocatalyst either directly by A photo-generated hole can be formed directly or indirectly through an interaction with various reactive ROS groups, such as the hydroxyl radical, formed in a solution. For example, dyes in wastewater are growing explosively due to the widespread use of clothing and goods by modern society and is one of the major concerns worldwide [1,2]. Since they are toxic and have the potential of mutagenic and carcinogenic changes it is of high concern about the synthesis of NiO based on morphologically enabled features that have been crucially important since they are connected with the specific surface area

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that's led should be make more accurate at NiO as NPS. Nickel consider its one semiconductor material. A p-type NiO with band gap (3.6 eV) is one of the most highly explored semiconductor photocatalysts capable of degrading harmful wastewater components due to its easy synthesis, excellent stability, low price, abundance in nature, and excellent physico-chemical properties. These transitional semiconductor elements enter into heterogeneous reactions that have the ability to decompose organic materials and transform them by photocatalytic action of CO_2 and H_2O.

Three dimensional (3D) porous NiO nanostructures have become eminent in recent years due to their efficient charge transfer properties and large surface area [3]. Kim et al., studied three different morphologies of NiO, such as nanoparticles, nanoflowers, and nanoslices, that were developed by means of the sol-gel synthesis method and examined their supercapacitor properties. The 3D flower shaped nanosized NiO with the greatest pore volume gained the superlative properties. The excellent performance of the 3D nanoporous flowers could be attributed to several pores, which offered easier interaction and electrolyte migration that formed NiO nanochannels, providing an extended pathway of electrons. showed the hybrid three dimensional NiO along with graphene material for supercapacitor applications. There are several studies that demonstrate the UV light degradation of organic dye pollutants since NiO is unable to absorb visible light.The mechanism of formation (electron-hole) pairs as follows:

$$NiO + hv \rightarrow e^- + h^+ \quad (1)$$

$$h^+ + H_2O \rightarrow H^+ + OH^\bullet \quad (2)$$

$$e^- + O_2 \rightarrow O_2^{\bullet -} \quad (3)$$

the co-precipitation method ensures an easy, fast, and industrially scalable synthesis. In addition, the obtained materials have gained much attention due to their high efficiency in absorption, electron hole pair generation, and high efficiency when used for wastewater treatment and other applications. in some cases, the dye removal efficiency is not significant due to the rapid regeneration of electron-hole pair in a photocatalytic process. Hence, the photocatalytic activity of these materials was improved by doping with metals. The photocatalysis is green and clean photochemical method of water purification. In

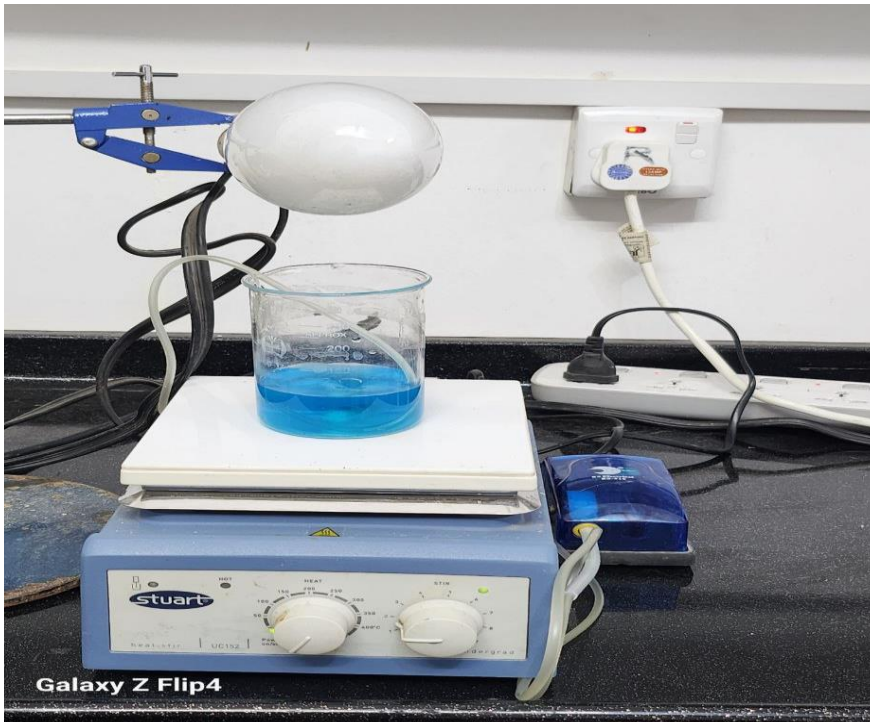

Fig. 1. Optical photo for main parts of the Photocatalytic degradation system

the photocatalytic process, the semiconductor converts photon energy into chemical oxidation/ reduction process which will further degrade the contaminants in water through the free radical formation. As a result, the chemical contaminants are degraded by photochemical oxidation/ reduction [4-6].

MATERIALS AND METHODS

Chemicals

Nickel nitrite hexahydrate [$Ni(NO_3)_2 \bullet 6H_2O$], provided by Fluka AG, Fast green dye, supplied by sigma – Aldrich, Sodium hydroxide , supplied by Fluka**,** Hydrochloric acid, supplied Authored by Fluka. All compounds were used without further purification.

Photocatalytic Reactor Set up

Fig. 1 shows the photocatalytic degradation system that was used to carry out all experiments.

Photocatalytic degradation experimen

The experiment on photocatalytic degradation was conducted. with to use of photocatalytic reactor system, which included all of the major components illustrated in Fig. 1 Photocatalysis has activity of the NiO that was created nanomateral was studied using dye. Under solar light, Photocatalytic of dye in an aqueous solution was completed using NiO NPs as a photo catalyst. There are two pieces to a photo reactor. The first was employed to cool the suspension solution with the help of the cooling water that passed through it. The second component contains a suspension solution with a capacity of (100 mL) for degrading the dye. Using distilled water, a (100mg/L) stock solution of dye solutions was created. Stirring produced a suspension solution combination for concentrating dye. The suspension mixture was generated by introducing 0.15 g of NiO nano (NPS) into 100 mL of dye and stirring. A desktop solar light source was utilized to expose the corresponding suspension solution to radiation. mixture. In Every 10 minutes, about (2-3) mL of sample was taken with a syringe The sample was subjected to centrifugation at a speed of 3000 revolutions per minute (rpm) for a duration of 10 minutes. , after which dye absorbance was measured with a UV–

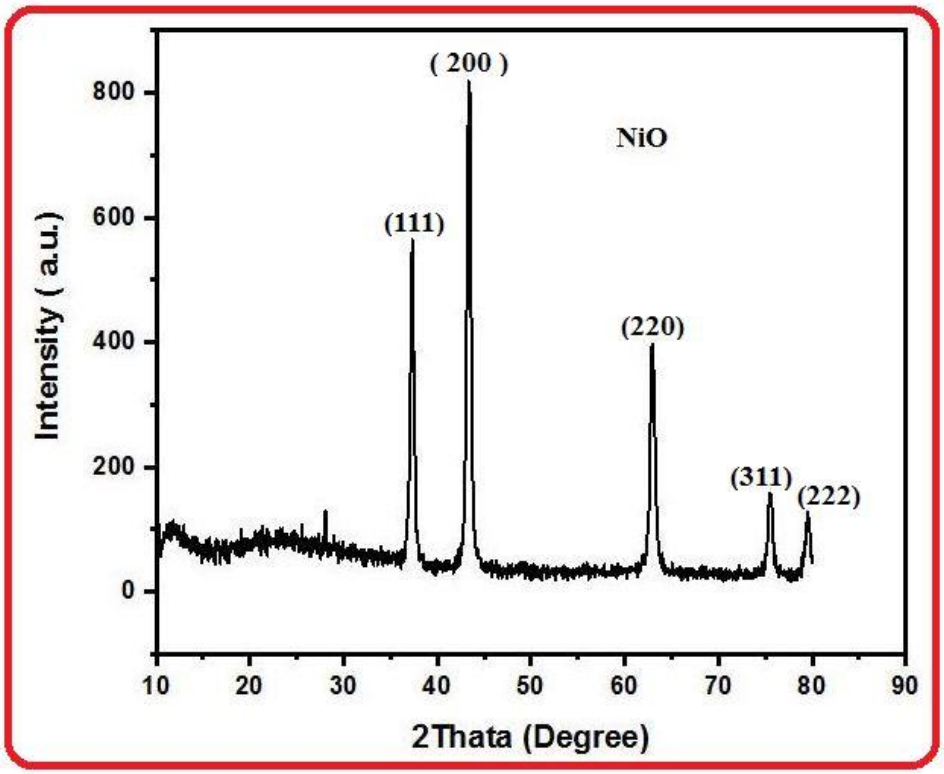

Fig. 2. XRD patterns of NiO

Vis spectrophotometer.

Preparation of NiO NPs Using The co-precipitation technique

The NiO nano was fabricated by the homogeneous co-precipitation process. The synthesis started by preparing a solution containing Ni, in 100 mL of deionized water. The nickel salt was utilized in a quantity of 6.22 g, Ultimately, mixture was dried. NiO (NPs) was pulverized to achieve finely ground powders, which were next subjected to annealing at a temperature of 600 ◦C for a duration of 2 hours.

RESULTS AND DISCUSSION

Characterization refers to the process of describing and developing the traits, qualities, and attributes of a character in a literary work. The Nano consisting of NiO was subjected for X-ray diffraction analysis at a wavelength. The sample was examined using (X-ray) diffraction. method, and asize of the produced catalyst particles was measured. All a measurement has been performed using XRD6000, Shimadzu is a company based in Japan. The measurement conditions were configured using 45 The radiation used is Cu-Kα with a wavelength of (λ = 1.54056 Å) at 40kV, 30mA with a rate of 5deg / min and ran at the 2θ range (3-90˚). In Fig. 2 the peaks positions of NiO - nano appearing at 2θ (37.6856 ˚, 43.4265˚, 63.0019 ˚, 75.5144 ˚, and 79.4791 ˚) can be readily indexed as (111), (200), (220), (311), and (222), crystal planes of the NiO, which agrees with the typical statistical methods of standard data of Nickel oxide (JCPDS card no. 47-1049).

For the NiO/ZnO nanocomposite consists of the peaks at (432.39,470.75,952.45,1489.16 , and 2349.50). The band located at 2922 cm^{-1} represents (CO_2) groups. The band located at 1482 cm^{-1} represents (C=O) symmetric groups. The peak at 952 cm^{-1} cans be attributed to the (Ni-O) bond and 470 cm^{-1} (Ni-O)). All results are shown in Fig. 3.

Electron microscopy with scanning technique was employed examine the Morphology describes the study of the structure and form of words and how they are formed of NiO NPS, yielding valuable insights into the synthesized structure. NiO NPS by using SEM, Zeiss, Germany. SEM images, Gaussian and histogram of NiO nano partical are depicted in Fig. 4 The SEM micrograph examination revealed

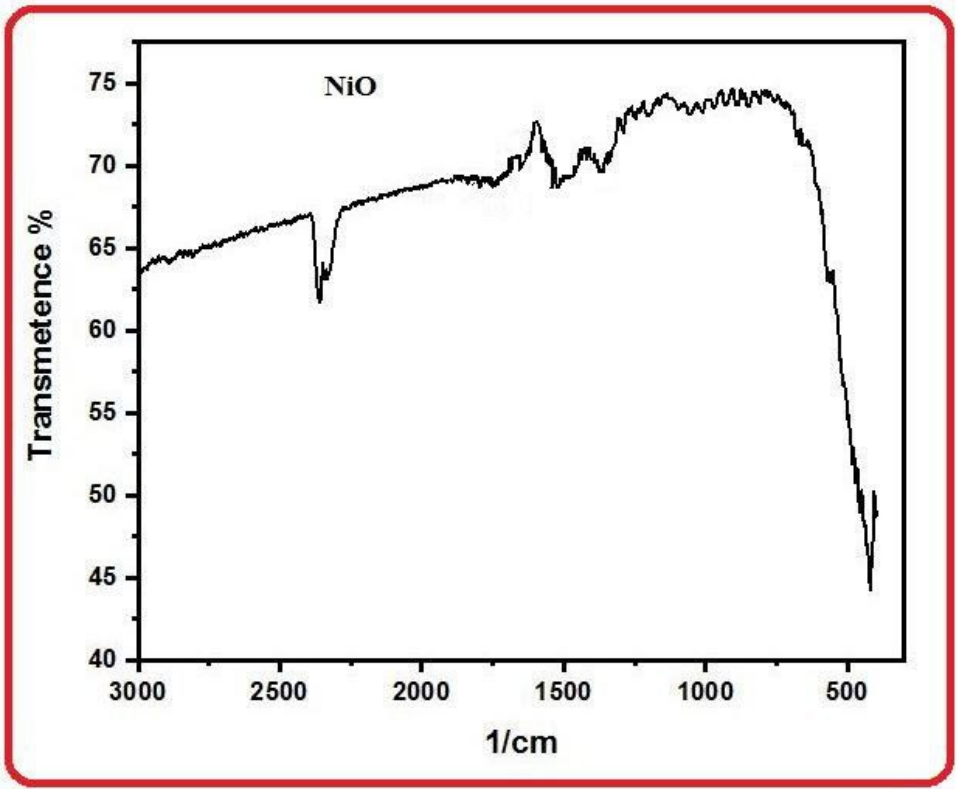

Fig. 3. FTIR NiO NPs

irregularly dispersed aggregates with an aspherical form. The grain size was equal to (17.50 nm) from Gaussian [7].

Energy Dispersive X-ray spectroscopy (EDX)

Is a technique for science. used to analyze the chemical composition of a material by measuring the energy of X-rays emitted by the material. of NiO. An Energy Dispersive X-ray Spectroscopy (EDX) examination was conducted to ascertain the composition of the prepared NiO nano partical. The EDX spectrum in Fig. 5 indicates that the particles in the synthesized NiO nano particale consisting of (O, and Ni) elements confirmed the

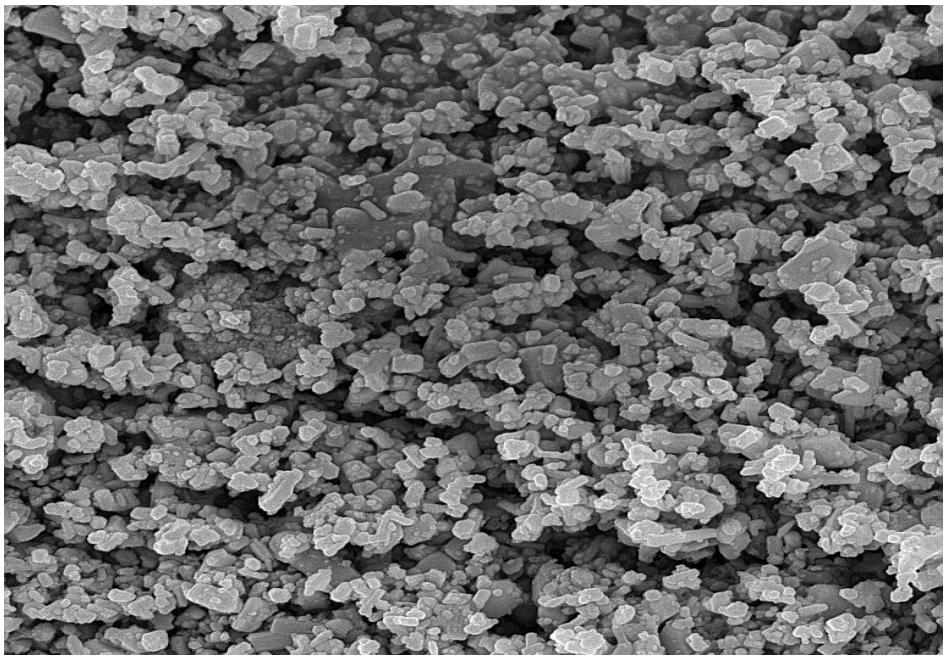

Fig. 4. FESM Scan electron microscopy pattern of the Nano particle of NiO

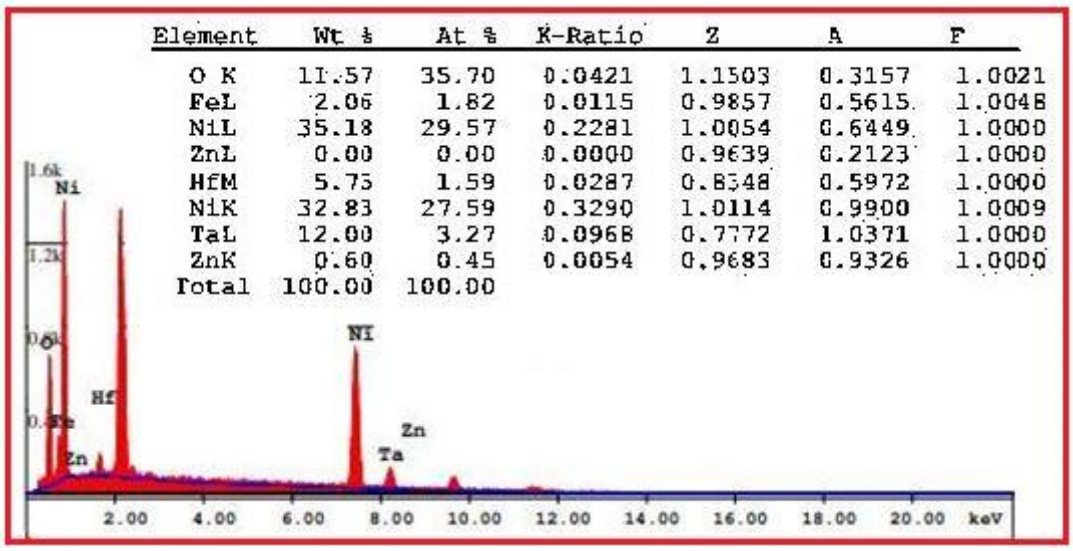

Fig. 5. EDX spectrum of ZnO

success in preparing the nanoparticles of NiO. The atomic percentage of O (k) is (11.57%), Ni (L) is (35.18 %) and Ni (k) (32.83%), respectively [8, 9].

The impact of the mass of the NiO nanopartical on the photo catalytic degradation of the substance is being studied Fast green dyes

The Impact of mass of NiO NPs on the process of Photocatalytic decomposition is being investigated. The process of dyeing was examined utilizing (10 mg/L) of the dyes, air The volumetric flow rate is 10 mL/min, and the parameter being referred to is temperature. of (25°C). When the masses of NiO NPs increase reaching (0.15g/100 mL) photo catalytic Fast green dye degradation, gradually increases and photocatalytic Efficiency of deterioration (91.07%) , then gradually diminishing. When the weight of NiO-NPs

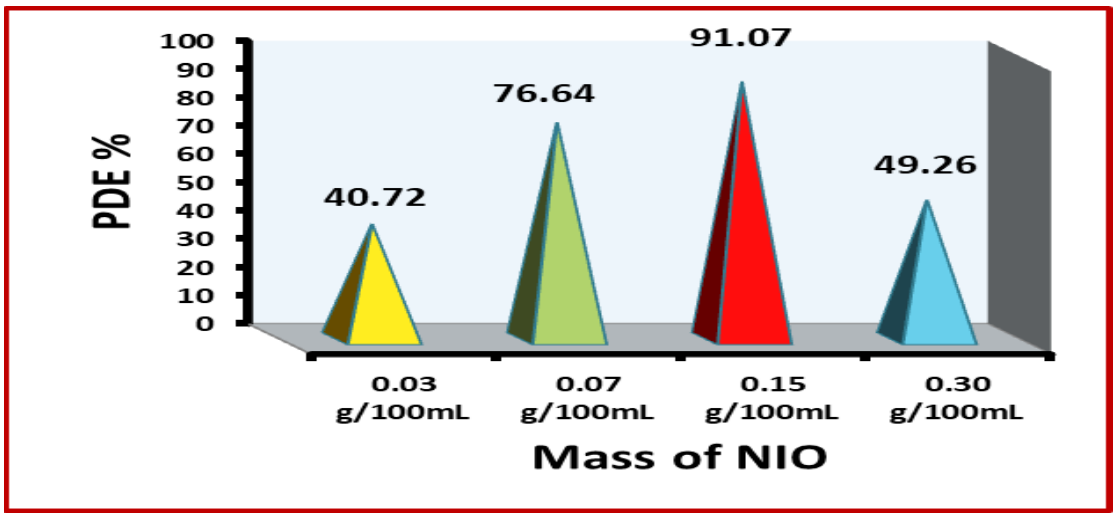

Fig. 6. Photocatalytic degradation efficiency using (10mg/L) of Fast green dye against mass of NiO (0.03,0.07,0.15,0.30)

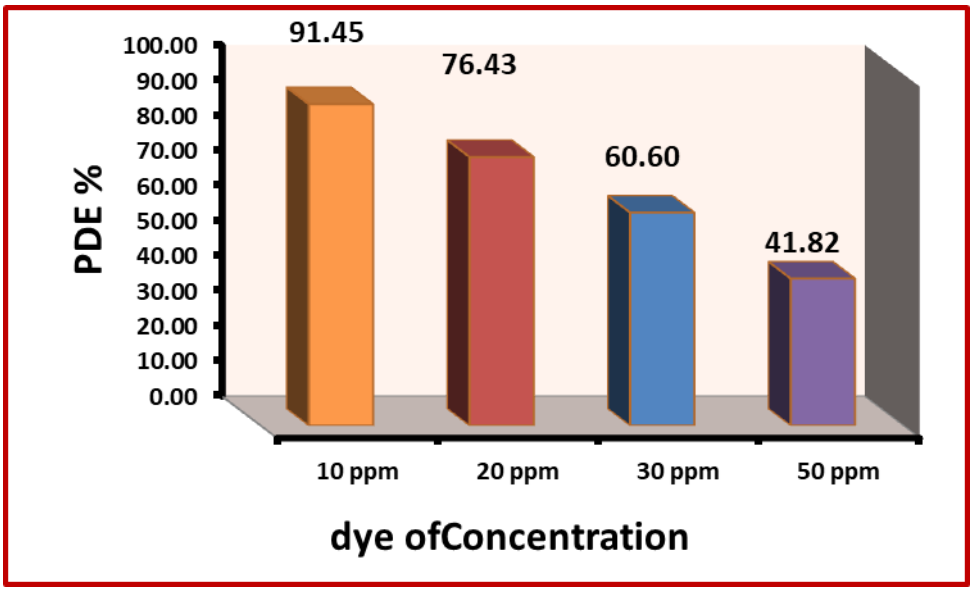

Fig. 7. Photocatalytic degradation efficiency using (0.15 g / 100 mL) NiO NPs against different concentration of Fast green dye .

(0.15g/100mL) is greatest, the semiconductor provides the greatest light absorption. The decline in photodegradation effectiveness at NiO nano concentrations more than (0.15 g/100 mL) due to light absorption is restricted to the initial layers of Fast green dye; The photons are not transmitted to the other layers of the solution. In addition, light scattering at high NiO nano loading causes a reduction in photon intensity. As illustrated in Fig. 6, the significant absorption of light by the initial Successive layers of the solution prevents illumination originating from penetrating all

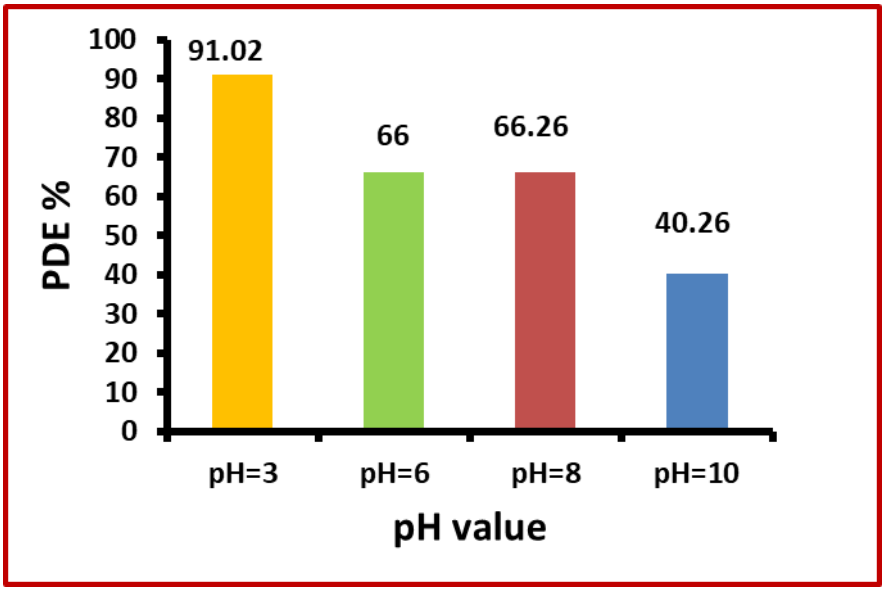

Fig. 8. Photocatalytic degradation efficiency using (0.15g / 100 mL) NiO NPS and (10 mg/L) of Fast green dye for different initial pH.

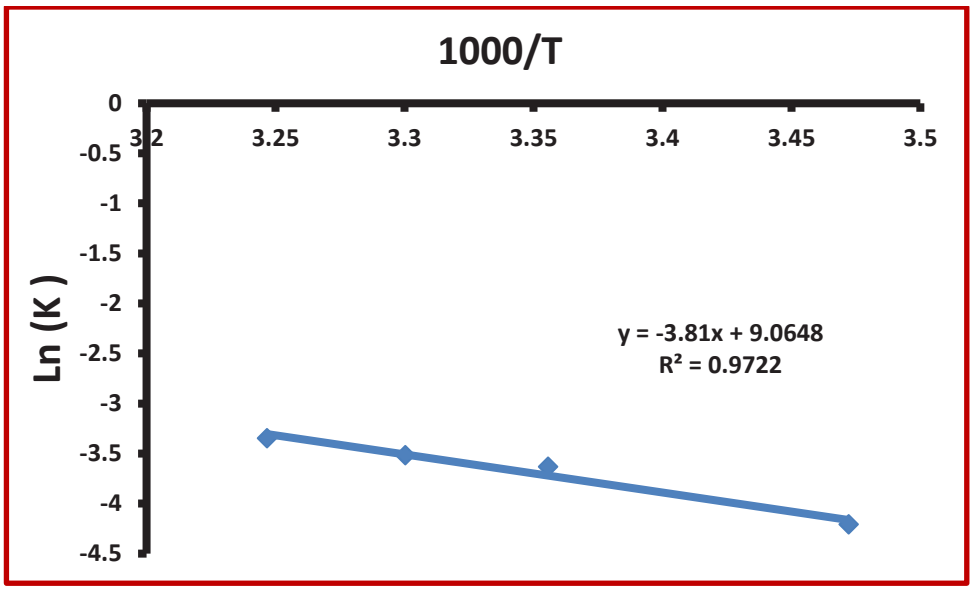

Fig. 9. Arrhenius plot of Fast green dye.

other Multiple strata within the reaction vessel. Many researchers have explored this impact, At the loading mass of NiO nano below the optimal value (0.15 g/100 mL), the speed at which photos degrade of Fast green dyes was also decreased because of a decrease in the surface area in NiO Nano material, which resulted in a decrease in the light absorption of light by NiO nano, which in turn caused a decrease in the photo degradation rate of Fast green dye [10,11].

Effect of Fast green Minimum concentration of the dye undergoing photocatalytic degradation

Effect of the concentration of "Fast green dye" solution in the photocatalytic degradation processes range of (10 to 50) (mg/L) was tested by leaving all other experimental conditions unchanged at (25°C), an airflow rate of (10mL/min), and mass of NiO NPs (0.15g/100mL). The outcomes are graphically shown. at Fig. 7. These The findings suggest a correlation between the rate of deterioration by photocatalysis was reduced as the level rises "initial dye concentration". Photocatalytic degradation efficiency (91.45%). As the initial Fast green Concentration of dye decreases, the distance traveled by the photon when it enters the solution. increases. Therefore, the quantity of photons that reach the surface of the catalyst increases hence the rate at which of formation of hydroxyl radicals and best oxide ions also increased thereby increasing the rate of degradation [12].

Impact of initial pH

Set of experiments was performed to investigate the impact of initial pH on photocatalytic degradation of suspension solution Fast green dye using (0.15 g /100mL) of NiO nanocomposite, (10mg/L) of "Fast green dye concentration", (10 mL/Min) "flow rate" of an Air bubble at (25 °C). These practical experiments were carried out under different pH solutions (3, 6, 8 and 10). As Shown in Fig. 8 the optimum value of degradation dye, was determined at (pH=3). At pH in the acidic medium. The outer layer of the catalyst becomes acidic, which lead to an increase in the attractive force of dye molecules with catalyst of surface, hence increasing photocatalytic degradation efficiency [13]. Meanwhile a higher pH function in the fundamental medium increased the repulsion force between the molecular dye and catalyst surface hence, decreasing the photocatalytic degradation efficiency [14].

Effect of Temperature

Set of experiments were conducted to determine the effect of temperature on the "photocatalytic degradation" of "Fast green dye" in range (285 – 311) kelvin. Other experimental conditions have been constant at initial Fast green dye concentration of (10 mg/L), prepared NiO catalyst dosage was (0.15 g /100mL), (10 mL/min) flow rate of an air bubble and (pH =3). Photocatalytic degradation process to dye progressively increased in tandem with the temperature rise. This may be due to the increased reactive hydroxyl radical obstetrics [15]. The activation energy associated with the photodegrdation of the dye was calculated according to the Arrhenius equation. By plotting ln k versus 1/T. Shown in Fig .9. the activation energy found was 31.67 ±1 kJ.mol^{-1}.

CONCLUSION

- NiO nanoparticle was prepared using the Co-precipitate method.
- The photocatalytic degradation processes of Fast green dye depended on the amount of catalyst dosage and the optimum value was equal to (0.15 g / 100 mL) of NiO NPs.
- The effect of dye concentration has been used to study the optimum value of Fast green dye (10mg/L); Photocatalytic processes of the fast green dye decreased with an increase the concentration of the dye
- Activation energy calculated when using the Fast green dye was = 31.67. ±1 kJ.mol^{-1}.

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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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