Single probes of Fe₃O₄ Nanorods on textile dye degradation in waste-water treatment

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Abstract

The process of removing cancer-causing colours from modern effluents before releasing them into water sources such as rivers, lakes, and groundwater has become standard. Traditional waste-water treatment systems have such great difficulties in eliminating these contaminants. The current one is a unique flavonoids synthesis employing Fe_3O_4 nanorods that have been utilized as photocatalytic to degrade material color in the watery stage using noticeable light illumination. Flavonoids@ Fe_3O_4 nanorods were blended by green methodology. The vanishing of the ultra-violet (UV) retention top that appeared at 581 nm affirmed the evacuation of the Methyl violet color. Following 60 minutes of duration, the dramatic color elimination by Fe_3O_4 nanorod was noticed to be 97 percent. The findings demonstrate that the Fe_3O_4 nanorods made using the green approach are immensely beneficial in the photocatalytic destruction of hazardous pollutants.

1. Introduction

In this materialistic world, the most poisonous modern pollutants are amalgamated in the materials with great extent used in food, cosmetics, leather, paper and plastic industries for aesthetic purposes. The vast majority of them are possibly dangerous, representing an extraordinary hazard to the current state of the ecosystem. The colors were also utilized generally in pigment production [1] and upon the intravenous mixture that causes serious mutagenic and cancer-causing ailments[2]. Generally, there are different physicochemical techniques such as coagulation/flocculation, adsorption on activated carbon and layer filtration. In frontier, attractive iron oxide nanoparticles (Fe_3O_4 NRs) have been applied in differing fields, like recognition and detachment of proteins to improve the affectability of magnetic resonance imaging (MRI), immunoassay and targeted drug delivery [3–4]. In addition to this, the nanoparticles are also applied in a great deal with the consideration in the field of Catalysis [5], proton exchange membrane and biosensor[6].

Similarly, some iron oxides and their composite have been demonstrated as a powerful tool for color corruption by adsorption [7–8] because of their high surface area to the volume ratio and various nanostructures. So far, various methodologies have been utilized for the synthesis of Fe_3O_4 NRs like hydrothermal, sonochemical, micro-emulsion, electrochemical, sol-gel and co-precipitation etc. [9, 10]. However, the present work has used a novel way for the first time; it concentrates on integrating and utilizing flavonoid @ Fe_3O_4 NRs and revealing their photocatalytic inspection, synergist action upon methyl violet (MV) dye expulsion in a watery medium.

2. Experimental

2.1 Experimental

The predetermined chemicals were utilized in De-ionized water and without further sanitization.

2.2 Isolation of Functionalization Agent (FA)

The dissolvable extraction of 5g CRL powder was treated with 60% methanol and 37% HCl in the Soxhlet extractor. The obtained methanolic extracts were neutralized by 0.4mol Na₂CO₃ arrangements and isolated the arrangements petroleum ether and ethyl acetate was emptied threefold, and the surface layer vanished. To fractionalize Catharanthus leaf extract (CRL), the inclination elution Gathered part volume was 30ml and 6 divisions were fractionalized by column chromatography. The obtained Flavonoids separates were assessed by including 0.5ml hydroxide, and extricated tests were blended at temperature. The yellow color was seen, which affirms flavonoids present inside the CRL separate [11]

2.3 Architecture of recyclable Fe₃O₄ nanocatalyst

Fe₃O₄ MNRs were synthesized via a simple and eco-accommodating methodology. In typical protocol has used slightly modified [12]. The architecture of 2g of FeCl₃·6H₂O and 6.56 g of sodium acetate were included as functionalization agents (flavonoid 50ml) was mixed enthusiastically for two hours at 70 °C. The uniform mixture becomes black color, and accordingly, the block product was acquired and isolate.

2.4 Photo catalysis inspections (PCI)

Flavonoid@Fe₃O₄ NRs on textile dye removal has inspected by photo catalysis platform. Fire the experiment, 50 ml of 0.1M of MV dye was mixed of 10mg of Fe₃O₄ NRs was subjected to UV illumination. A control (MV) set was also used in the absence of a catalyst. The reaction mixture was to ensure desorption equilibrium to illuminate periodically. Later, the chromphoric group was decomposing under UV illumination in presence of a catalyst (mercury lamp 120w) with different time exposure [13]. Decomposition of dye was observed in terms of the drastic decrease in the absorbance peak at ($\lambda_{\max}$ = 581nm) has shown in Fig- 5 (a).

3. Results And Discussion

Electronic absorption spectra of incorporated Fe₃O₄ NRs were obviously two shoulder bands, such as band I (Flavonoid) at 248nm. The spectra for phenolic compounds and flavonoids typically lie in the range of 210–290 nm, and band II (Fe-O) at 402 nm was immobilized flavonoid @ Fe₃O₄ NRs was shown in Fig-1 (a). Similarly, were also evidenced [14– 15]. This is due to the formation of Fe₃O₄ NRs depends upon the nucleation growth mechanism [16]. In this connection, this is an outcome of obviously characterized that the carbonyl gathering flavonoid group were in solid coordination bond appear in strongly proved by Fourier transform infrared [FT IR] spectrum. Fig-1 (b) insitu the energy gap of Fe₃O₄ NRs elucidates from Tauc's relations.

$$\alpha h\nu = C(h\nu - E_g)^2 \text{ ————— (1)}$$

The band gap of flavonoid@Fe₃O₄ NRs was found to be 4.2 eV, which were strong plasmonic effect and high electrode potential + 33eV

Fig – 2 shows that FTIR characteristic peak was assigned in 3421, 2925, 1626, 1407, 1234 and 1067 cm⁻¹ to expanded significantly for Fe₃O₄ nanorods. Strikingly, other bands at 590 & 622 cm⁻¹ credit to the characteristic extending vibrations of Fe-O bond [17]. Subsequently; the FTIR profile demonstrates the crucial part of the flavonoid group in secondary metabolites that reduce Fe³⁺/Fe²⁺ metal ions and adjustment of Flavonoid @ Fe₃O₄NRs

The crystallite structure of Fe₃O₄ NRs was studied by using the powder X-ray diffraction (XRD) study. Figure 3 **(a)** represents the XRD profile of Fe₃O₄ NRs acquired utilizing the flavonoid extract (CRL). The XRD patterns of the Fe₃O₄ NRs shows that six relatively strong reflection peaks were located at (111), (200), (220), (311), (400), and (440) are well indexed to the cubic inverse spinal system of Fe₃O₄ NRs (JCPDS # 76 – 045) which affirms the fabrication of Fe₃O₄ NRs. The crystallite size was estimated by the Scherrer equation [17, 18].

$$D = K\lambda / \beta \cos\theta \text{ —————(2)}$$

The calculated Fe₃O₄ NRs average crystallite size is 57.7 nm and Micro strain of Fe₃O₄ NRs was calculated by using the equation

$$\epsilon = \beta \cos\theta/4 \text{ (3)}$$

Dis-location density is derived this equation

$$\delta = 1/D^2 \text{ (4)}$$

the microstrain of Fe₃O₄ NRs was found to be 0.807 ε × 10⁻³, and also dislocation density was 8.75×10¹⁵. From the results, we can conclude that the potentially active dislocation density of crystallite size and crystal field distract also helped to as dye removal process [19].

The size and surface morphology of the Fe₃O₄ NRs were confirmed to be wire, rod-shaped through the scanning electron microscopy (SEM), and transmission electron microscopy (TEM) evaluation. Figure 4**(a) and (b)** represent various magnifications of the SEM images of the Fe₃O₄ NRs, which clearly indicate wire-like shapes **Fig. 4(c)** illustrates TEM image of synthesized Fe₃O₄ NRs, which clearly depicted rod-like structure. The mean size of the nanorods has been observed 15 to 20nm. The rod like structure of Fe₃O₄ nanoparticles was induced strong ROS radicals that help of with photocatalytic activity [20, 21]. The EDS evaluation of the Fe₃O₄ is shown in **Fig. 4(d)**, which clearly indicates the presence of Fe and O in the resulting material.

The kinetic behavior of Fe₃O₄ nanorods on methyl violet dye was inspected by photocatalytic method (PCI) and Langmuir hinshelwood mechanism was followed:

$$\ln (C/C_0) = K_{app} t \text{ —————(5)}$$

The plot of the graph $\ln(C/C_0)$ vs time for the Fe_3O_4 NRs gives rate constant which was found to be 0.0789 min^{-1} and also the pseudo-first-order kinetic model was shown in **Fig-5 (b)**[22]

Once the light is incident on the material, the excitation of electrons occurs from VB to CB, and forming the electron-holes in the VB. Furthermore, the separation of charge and movement of produced charge carriers to the surface of Fe_3O_4 layer can led to the redox process. The reactive oxygen (ROS) species of (h+) (VB) in Flavonoid@ Fe_3O_4 nanorods is the oxidation of MV to responsive intermediates radicals (*OH) that can convert into the decomposition of water. [13, 21]. Fig-5(c) showed that the reusability and stability of flavonoid@ Fe_3O_4 NRs were highly stable were evaluated for five cycles with strong, and effective nature [2]

4. Conclusion

By the overview, the flavonoid @ Fe_3O_4 NRs were successfully achieved by greener way using CR leaf extract. Thus, the recyclable and photostability of Fe_3O_4 NRs were derived from various analytical characterizations subsequently. Furthermore, the effective dye removal of flavonoid @ Fe_3O_4 NRs was observed to be 97 % @ 60 minutes time duration, which is due to strong dis-location density is 8.75×10^{15} , crystal field attraction and reactive oxygen species (ROS) mechanism was also helped to as fast reaction rate and easy to achieve rapid in the decolorization process. The flavonoid @ Fe_3O_4 NRs can be used as promising for contaminated water treatments and MRI, Biosensors, etc.

Declarations

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Figures

Figure 1

(a) Electronic absorption spectra for Flavonoids @ Fe₃O₄ NRs using green route (b) Insitu of energy gap of Flavonoids @ Fe₃O₄ NRs

Figure 2

Functional group analysis of flavonoids containing Fe_3O_4 NRs by FTIR spectrum

Figure 3

(a) Crystallite structure identification by powder X-ray analysis. (b) Williamsons Hall plot of Fe_3O_4 NRs

Figure 4

(a) and (b) various magnification of Fe_3O_4 nanowire by SEM (c) HR-TEM image of Fe_3O_4 nanorods (d) Elemental composition spectrum

Figure 5

(a) Different time exposure of methyl violet dye degradation curve via photocatalysis method