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Degradation of Azo Dye in Textile Wastewater using Cobalt Nanomaterial

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ABSTRACT
Cobalt oxide (Co_3O_4) nanoparticles have been synthesized by co – precipitation method. The synthesized Co_3O_4 nanoparticles were characterized using X-ray diffractometry (XRD). Our present study involves degradation of azo dyes using cobalt nanoparticles. The photocatalytic degradation of azo dye under visible light irradiation was tested, with Co_3O_4 showing a degradation efficiency of 87.94 %. These results highlight the potential of Co_3O_4 nanoparticles for environmental applications, particularly in wastewater treatment.

Keywords: **Cobalt oxide nanoparticles, Azo dyes degradation**

INTRODUCTION

Water purification becomes a focal point of research and scientific interest, employing various treatment methods like adsorption, electrolysis, membrane filtration, chemical precipitation, physisorption, chemisorption, electrokinetics, ion exchange, and coagulation, aiming to address the pressing issue of water pollution caused by the discharge of organic dyes from industries. [21]
Various Chemical and physical methods are currently under investigation to deal with dyes related pollution problems. [16] Nanomaterials used for the catalytic degradation of textile dyes can be synthesized by various processes such as physical, chemical and biological process. [7]
Multiple studies exploited the catalytical activity of nanomaterials against numerous toxic dyes such as Auramine O, Tymol Blue, Rhodamine B dye, congo red, Phloxine B, Methyl orange, etc. Up to 90 – 100% degradation was observed for various dyes through metallic nanomaterials. [28]
The present study provides easy and quick chemical method for the synthesis of cobalt nanomaterials, which were characterized for their morphological features such as shape, size and surface charge through XRD, SEM, TEM, etc. The synthesized cobalt nanomaterials were used further for azo dye degradation potential.

MATERIALS AND METHODS

Chemicals and Apparatus

All chemicals used in experiment were of analytical grade. The chemicals used in the synthesis were $Co(NO_3)_2.6H_2O$, $NaMoO_4$ and citric acid were purchased from Mysore Pure Chemicals, Mysuru, Karnataka. All the solutions were prepared in distilled water.

Synthesis of Nanomaterials by Co – precipitation Method

A stoichiometric amount of cobalt nitrate hexahydrate [$Co(NO_3)_2.6H_2O$] and sodium molybdate [Na_2MoO_4] was added in 160 ml DI water and stirred for a few minutes. Then, citric acid was added in the reaction mixture and stirred for 2 hours to form a homogeneous solution. Then the obtained mixture was transferred to crucible and placed in Muffle Furnace for 4 hr at 550^0C. Black colour Co_3O_4 nanoparticles were thus obtained.

Spectral Characterization

The crystal structures of the annealed samples were characterized by X-ray Diffraction (XRD) analysis. Morphology and structures were observed by scanning electron microscopy (SEM).

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Catalytic dye degradation using cobalt nanoparticles

Prior to the dye degradation experiment, dye solution was scanned between 400 nm and 700 nm to obtain λ_{max}. The absorbance of a solution at various wavelengths using a spectrophotometer was measured and then graph was plotted to identify the peak. The wavelength at which the absorbance is highest corresponds to λ_{max}.

The degradation of dyes in term of percentage was calculated as per the following equation:

$$Dye\ Degradation\ \% = \frac{A_0 - A_t}{A_0} \times 100$$

RESULTS AND DISCUSSION

XRD

XRD patterns of the prepared Co_3O_4 nanoparticles show amorphous. The samples were calcined at 550 °C for 4 hr. The XRD of the calcined Co_3O_4 nanoparticles is shown in Fig. 1. The peak positions (2θ = 7.5197, 9.4799, 12.7199, 16.6991, 18.6397, 21.0511, 23.4893, 24.5880, 26.9170, 28.1777, 29.0790, 30.8398, 33.5599, 36.7200, 38.4397, 41.4400, 44.5997, 48.0398, 51.8574, 54.7121, 59.2287, 65.2861, 71.6400, 77.9572, 81.8489) respectively.

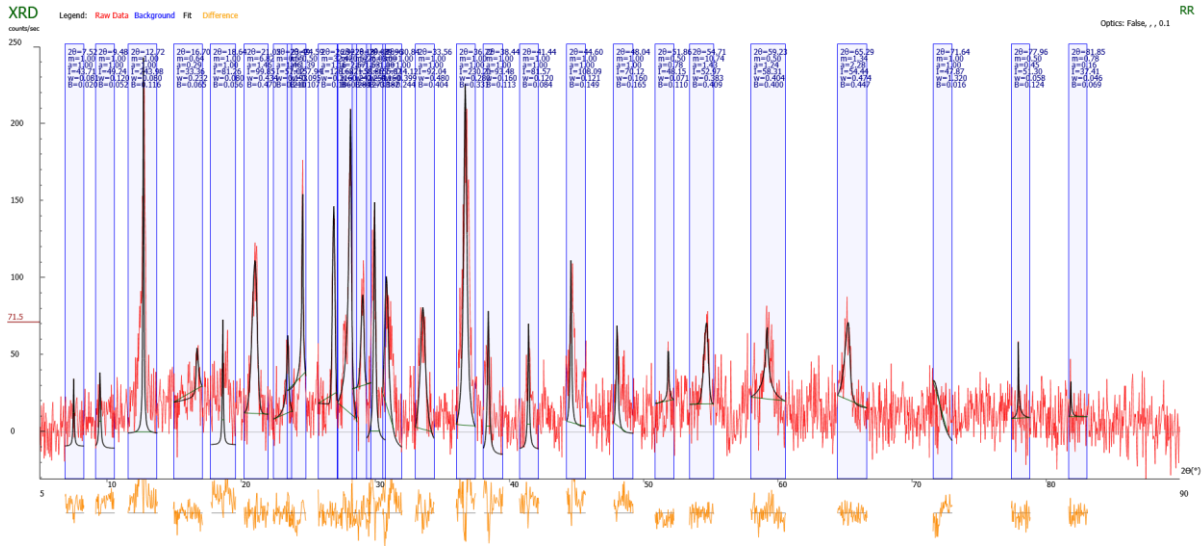

Fig 1: XRD of Cobalt Nanomaterial

Catalytic activity of cobalt nanomaterial

Fig 2. indicates maximum absorbance (λ_{max}) for pink dye (535 nm). All the degradation studies were examined at their maximum absorbance.

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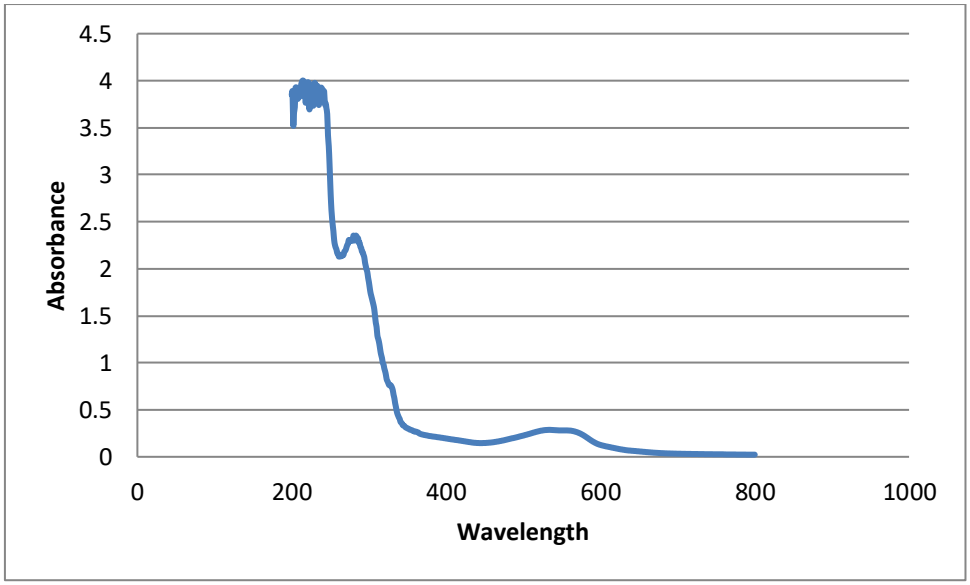

Fig 2: Maximum Absorbance to find λ_{max}

EXPERIMENT 1: Take the initial absorbance of 30 ml dye wastewater for the wavelength of 535 nm and incubate it for photocatalysis for 60 mins and then take the final absorbance. Then the degradation of dyes in term of percentage was calculated by

$$Dye\ Degradation\ \% = \frac{A_0 - A_t}{A_0} \times 100$$

Azo dye concentration (ml)	Initial Absorbance	Final Absorbance	Degradation (%)
30	0.509	0.472	7.26

EXPERIMENT 2: Take the initial absorbance of 30 ml dye wastewater for wavelength of 535 nm and add 2, 4, 6, 8 and 10 mg of cobalt nanomaterial. Incubate for photocatalysis for 60 mins and then take the final absorbance. Then the degradation of dyes in term of percentage was calculated.

Azo dye concentration (ml)	Cobalt Nanomaterial (mg)	Initial Absorbance	Final Absorbance	Degradation (%)
30	2	0.398	0.277	30.40
30	4	0.332	0.279	15.96
30	6	0.839	0.303	63.88
30	8	0.626	0.369	41.06
30	10	0.284	0.206	27.46

EXPERIMENT 3:Take the initial absorbance of 30 ml dye wastewater for wavelength of 535 nm and add 10 mg nanomaterial and 1, 2, 3, 4 and 5 mg sodium borohydride (reducing agent). Keep it for photocatalysis for 60 mins and then take the final absorbance. Then the degradation of dyes in term of percentage was calculated and represented in Table.

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Azo dye concentration (ml)	Cobalt Nanomaterial (mg)	Sodium Borohydride (mg)	Initial Absorbance	Final Absorbance	Degradation (%)
30	10	1	0.6645	0.3347	49.63
30	10	2	0.3758	0.2666	29.06
30	10	3	1.1799	0.1423	87.94
30	10	4	0.2702	0.0841	68.87
30	10	5	0.8758	0.3410	61.06

CONCLUSION

The azo dye under the experimental conditions showed only 7.26% degradation, whereas the experiments carried out with Co nano-particle showed greater degradation. Especially, the one with 6mg Co nano-particle exhibited 63.9% degradation. However, with 10 mg of Co nano-particle, addition of Sodium Borohydride gave a maximum degradation of 87.9% with 3 mg of Sodium Borohydride.

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