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Degradation of some azo dyes by Fenton process

An overview

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Abstract
Dyes are used in various industries as colouring agents. Synthetic dyes released in wastewater pose a threat to environmental safety. Several methods have been used for the removal of dyes from water bodies. The advanced oxidation processes (AOPs) have been proven to be effective technologies for dyes degradation. In this review, different types of Fenton processes such as electro-Fenton, photo-Fenton and sono-Fenton were chosen to study the degradation of some azo dyes.

Keywords: azo dyes, electro-Fenton, photo-Fenton, sono-Fenton

1. INTRODUCTION

Textile wastewater causes serious environmental problems because of its toxicity and persistence. As the most common synthetic dyes released into the environment, azo dyes pose a serious threat. Their chemical structure is characterized by one or more azo groups (-N=N-) [1]. These dyes and their biodegradation products, exhibit toxicity to

aquatic organisms and are mutagenic and carcinogenic to humans. Consequently, it is crucial to remove these dyes from wastewaters before their discharge into the environment [2].

Several methods have been applied for the elimination of organic pollutants from wastewaters, including biological treatment, coagulation, chemical oxidation, electrochemical treatment, ozonation, adsorption, etc. [3]. The oxidation by Fenton's reagent has shown great effectiveness in eliminating a wide range of organic pollutants present in wastewater [4].

Different variants of Fenton processes are available for utilization, including electro-Fenton, photo-Fenton, photo-electro Fenton, sono-Fenton, sono-electro Fenton, and sono-photo Fenton processes [5].

This review describes the degradation of some azo dyes such as Acid Orange 7, Ponceau S, Sunset Yellow FCF, Reactive Brilliant Orange X-GN, Direct Red 81, Amaranth, Acid Red 1, Chocolate Brown HT, Eriochrome Black by Fenton process such as: electro-Fenton, photo-Fenton, sono-Fenton [1-4, 6-9] (figure 1).

a. Electro-Fenton Process

In a study conducted by T. X. H. Le et al., the Electro-Fenton process was investigated for the degradation of Acid Orange 7 azo dye in an acidic medium with a pH of 3 [1]. The carbon-felt cathode was employed in this study. The optimal operating conditions for achieving maximum degradation were determined as –8.3 mA cm^{-2} for the applied current density and 0.2 mM for the catalyst concentration. Under these conditions, the mineralization of 200 mL of Acid Orange 7 reached 96.2 % after 8 hours of treatment (Table 1).

H. S. El-Desoky et al. studied the oxidation of Ponceau S azo-dye in aqueous solutions using electro-generated Fenton's reagent [2]. The experiments were performed at a pH of 2.5, using a reactor equipped with a reticulated vitreous carbon (RVC) cathode and a platinum gauze anode. The results demonstrated that complete colour removal of 0.05, 0.1, and 0.3 mM Ponceau S could be achieved by electro-Fenton oxidation within 30, 60, and 90 minutes, respectively (Table 1).

M. M. Ghoneim et al. investigated the oxidation of Sunset Yellow FCF azo dye [3]. The experiments were carried out at room temperature using an undivided electrochemical reactor with an RVC cathode and a platinum gauze anode. Optimizing operational parameters (by using a 0.05 M Na_2SO_4 aqueous solution with a pH = 3, containing 0.1 mM $FeSO_4$, and controlling the applied potential of the RVC cathode at -1.0 V vs. SCE), the researchers achieved complete decolourization (100 %) of Sunset Yellow FCF azo dye through electro-Fenton oxidation. The treatment duration required to achieve this complete decolourization was 120 minutes (Table 1).

In a study published by M. O. A. Pacheco-Alvarez et al., they investigated the electrochemical degradation of various azo dyes, including Chocolate Brown HT and Eriochrome Black [9]. The Boron-doped Diamond electrode was used as cathode. The researchers conducted electrolysis with a current density of 20 mA cm^{-2}, treating a solution containing 150 mg/L of each dye at a pH range of 2.8–3.0. Under these conditions, the decolourization efficiency for Chocolate Brown HT dye, after 60 minutes, was 92 %. On the other hand, the use of Eriochrome Black dye led to nearly complete decolourization, approaching 100 % within the same timeframe (Table 1).

b. Photo-Fenton Process

Q. Chen et al. conducted a study where they prepared a heterogeneous photo-Fenton catalyst using iron pillared vermiculite (Fe-VT) [4]. In their experiment, they used a solution containing 100 mg/L of Reactive Brilliant Orange X-GN dye. A pH value of 3 and a hydrogen peroxide concentration of 3.92 mM were used. Additionally, a dosage of 0.5 g/L of Fe-VT catalyst was employed. With a UV irradiation time of 75 minutes, the results demonstrated that the system achieved an impressive decolouration efficiency of 98.7 % (Table 1).

In a study conducted by L. Wang et al., a Z-scheme heterogeneous system comprising flower-like Fe_2O_3 and nanosheet-like g-C_3N_4 was used for the photo-Fenton degradation of Amaranth dye [7]. By optimizing the experimental parameters such as pH value, H_2O_2 dosage, Fe_2O_3 loaded amount, the authors found that an 8 % Fe_2O_3/g-C_3N_4 catalyst exhibited excellent photocatalytic degradation activity

towards Amaranth dye. Remarkably, within 10 minutes of reaction time, the system achieved an impressive degradation efficiency of 97.6 % (as shown in Table 1).

C.-E. Tan et al. developed a mixed organic ligand composed of 2-methylimidazole and fumaric acid to enhance the photo-Fenton decomposition of Acid Red 1 azo dye [8]. The researchers demonstrated that the prepared catalysts exhibited remarkable adsorption capacity and photocatalytic efficiency. Specifically, in the presence of trace amounts of hydrogen peroxide, a 100 % removal of Acid Red 1 dye was achieved after only 45 minutes of irradiation. This impressive performance is highlighted in Table 1.

c. *Sono-Fenton Process*

G. Harichandran et al. conducted a study on the degradation of a reactive azo dye, Direct Red 81, using the Fenton process and in combination with sonolysis (Sono-Fenton) [6]. Through their investigation, they identified the following optimum conditions for decolourization: a pH value of 3.0, a ferrous ion concentration ($[Fe^{2+}]$) of 0.2 g/L, a hydrogen peroxide concentration ($[H_2O_2]$) of 5.1×10^{-3} mol/L, and ultrasonic parameters including a frequency of 120 kHz and a power of 60 W.

Under these optimized conditions, the system achieved an impressive decolourization rate of 99 % for Direct Red 81 within a total treatment time of 75 minutes [6]. The obtained results are summarized in Table 1.

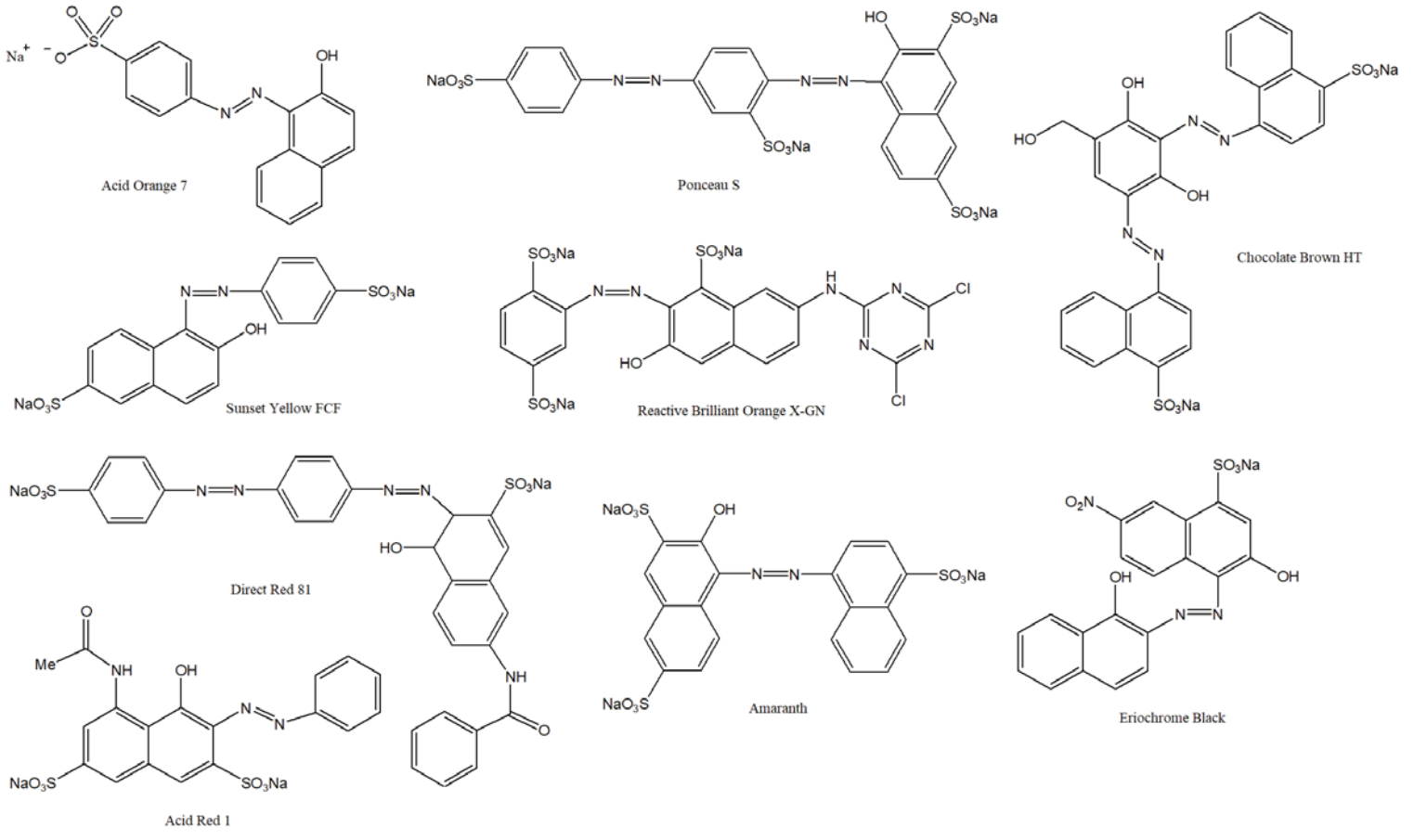

Figure 1 Chemical structures of studied azo

Table 2. Discoloration of various azo dyes by Fenton reagent

No	Name of dye	Degradation method	Λ_{max} (nm)	pH	Azo dye concentration	Discoloration time (min)	Discoloration (%)	Ref
1	Acid Orange 7	Electro-Fenton	485	3	0.1 mM	120	90	[1]
2	Ponceau S	Electro-Fenton	515	2.5	0.1 mM	180	100	[2]
3	Sunset Yellow FCF	Electro-Fenton	480	3	0.2 mM	120	100	[3]
4	Reactive Brilliant Orange X-GN	Photo-Fenton	479	3	100 mg/L	75	98.7	[4]
5	Direct Red 81	Sono-Fenton	523	3	50 mg/L	75	99	[6]
6	Amaranth	Photo-Fenton	522	3	0.03 mM	10	97.6	[7]
7	Acid Red 1	Photo-Fenton	532	-	100 mg/L	45	100	[8
8	Chocolate Brown HT	Electro-Fenton	424	3	150 mg/L	60	92	[9
9	Eriochrome Black	Electro-Fenton	580	3	150 mg/L	60	100	[10]

4. CONCLUSION

This study describes the degradation of some azo dyes by electro-Fenton, photo-Fenton and sono-Fenton processes, respectively. Under the optimized conditions, the decolourization rates were ≥ 90 % for Acid Orange 7, Ponceau S, Sunset Yellow FCF, Reactive Brilliant Orange X-GN, Direct Red 81, Amaranth, Acid Red 1, Chocolate Brown HT and Eriochrome Black after 120 min (for Acid Orange 7 and Sunset Yellow FCF), 180 min (for Ponceau S), 75 min (for Reactive Brilliant Orange X-GN and Direct Red 81), 10 min (for Amaranth), 45 min (for Acid Red 1) and 60 min, respectively of treatment (for Chocolate Brown HT and Eriochrome Black).

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