

Evaluation of UV/H₂O₂ advanced oxidation process (AOP) for the degradation of acid orange 7 and basic violet 14 dye in aqueous solution

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Abstract: The photochemical decolorization of Acid orange 7 dye (AO7) and Basic violet 14 dye (BV14) by the UV/H₂O₂ process was studied using a batch photoreactor with UV lamps emitting at 254 nm. The effects of experimental variables, such as initial pH, initial concentration of H₂O₂ and initial dye concentration were studied. The highest decolorization (98.2% for AO7 & 97.5% for BV14) rates were realized at a peroxide concentration in range from 10 to 30 m mol/L. The decolorization was more efficient in neutral pH values than the acidic or basic pH. Similarly positive removal efficiency was observed on the lower initial dye concentration (100 ppm) than the higher dye concentration (500 ppm).

Keywords: Acid orange; Basic Majenta; UV/H₂O₂ process; decolorization; pH;

I. Introduction

Extensive usage of dyestuffs and its disposal are the important sources for the today's environmental contamination. Different types of chemical and physical processes such as chemical coagulation, activated carbon adsorption are used for pollutant removal in the textile industrial wastewater, but they just transfer contaminants from one phase to another that needs further and ultimate disposal eventually (Slokar & Marechal, 1998, Pagga U & Brown D, 1986, Sheng HL & Chi ML, 1993 and Shu HY, et al, 1994). Many researchers have reported that non-biodegradable including azo dye can be mineralized successfully and completely by the advanced oxidation processes (AOPs) (Galindo et al., 2000; Kusvuran et al., 2004; Muruganandham and Swaminathan, 2006; Arslan-Alaton et al., 2008). AOPs are the processes that involve highly reactive species, specifically hydroxyl radicals (oxidation potential 2.8V). Among the several methods for generating hydroxyl radicals, combining UV and hydrogen peroxide (UV/H₂O₂) is one of feasible AOPs for dye wastewater treatment.

UV/H₂O₂ process is able to destroy totally the chromophore structure of azo dyes and the reaction rate of azo dyes depends on the basic structure of the molecule and on the nature of auxiliary groups attached to the aromatic nuclei of dyes (Galindo and Kalt, 1999). UV irradiation in the presence of H₂O₂ leads to complete decolorization and mineralization of sulphonated azo and anthraquinone dyes (Colonna et al., 1999). The mechanism of dye destruction in AOPs is based on the formation of a very reactive hydroxyl radical (OH) that, with an oxidation potential of 2.80 V (Legrini O et al., 1997 and Kang SF et al., 1999), can oxidize a broad range of organic compounds. Such a process implies relatively simple reactions, such as UV photolysis of H₂O₂. Furthermore, the UV/H₂O₂ process has the additional advantage of preventing any sludge formation during the different stages of the treatment. It can be carried out under ambient conditions and may lead to complete mineralization of organic carbon into CO₂ (Galindo C, et al., 1999). In spite of all its intrinsic advantages, to render AOP competitive with other processes, it is essential that its application represents a low cost operation, which basically implies a careful and continuous control of H₂O₂ concentration.

II. Experimental

A. Materials

The Acid orange 7 (AO7) and Basic violet 14 (BV14) are commercially available dyes and used without further purification. (Fig.1 & Table.1) The hydrogen peroxide solution (30%) of analytical grade, NaOH with 95% concentration, and HNO₃ with 70% concentration were used for reaction and to adjust the desired initial pH values of reaction mixtures.

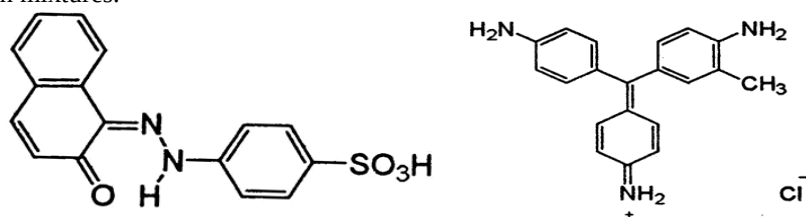


Fig.1. Chemical structure of Acid orange 7 and Basic violet 14

Table 1: Characteristics of the Dye used

Colour Index	AO7	BV14
Name of the Dye	Acid orange 7	Basic violet 14
Chemical Formula	$C_{16}H_{11}N_2NaO_4S$	$C_{20}H_{20}ClN_3$
Molecular mass (g/mol)	350.33	337.85
CAS Registry Number	633-96-5	632-99-5
λ_{max}	484 nm	547

B. Apparatus

Oxidation experiments were carried out in the 200 ml-capacity photo-reactor shown in Fig.2 (UV Photo Reactor System HEBER model : HPSLIV16254), which was operated in batch mode. The reactor is provided with a water jacket, made of quartz, and is equipped with a medium pressure mercury vapor lamp emitting in the 254 nm range (power of 16W UV lamp - Philips). Constant stirring of the solution was ensured using magnetic stirrers. A Digital desktop pH meter ((ELICO - LI 120) was used to measure the solution pH during the reaction. The spectrum was taken with ELICO make UV-VIS Spectrophotometer (ELICO-BL198 double-beam biospectrophotometer).

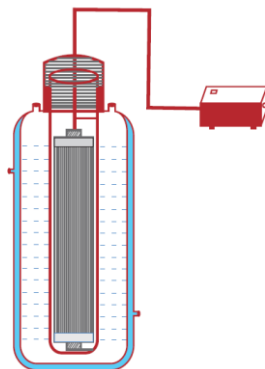


Fig.2. Immersion type UV - Photo reactor (HEBER : HPSLIV16254)

C. Experimental Procedure

The photodegradation experiments were carried out in a batch mode photoreactor at 298 K. The UV reactor was loaded with a synthetic reaction mixture consisting of 100, 200,300, 400 and 500 ppm of initial concentration of dye solution and varying concentration of H_2O_2 (0, 10, 15, 20, 25 and 30 mmol/l) at varying pH (3, 5, 7, 9 and 11) in order to find out the optimal removal efficiency. All experimental studies are carried out in the presence and absence of UV irradiation and the removal efficiency was recorded using double beam UV visible spectrophotometer with time.

The percentage of decolorization of dye was calculated as,

$$\text{Colour removal (\%)} = \left(\frac{C_0 - C_t}{C_0} \right) \times 100$$

Where C_0 is the initial concentration of the dye solution and C_t the concentration of the dye after the time interval t .

III. RESULT AND DISCUSSION

A. Effect of H_2O_2 Concentration

The solution initial concentration of the AO7 dye 100 ppm at the pH 7 was irradiated in the absence and presence of H_2O_2 as shown in the Fig. 3. The dye solution in the absence of H_2O_2 was slow and resulted in less than 10% degradation in 60 minutes which was in agreement with the literature (N.H. Ince, et al., 1997).

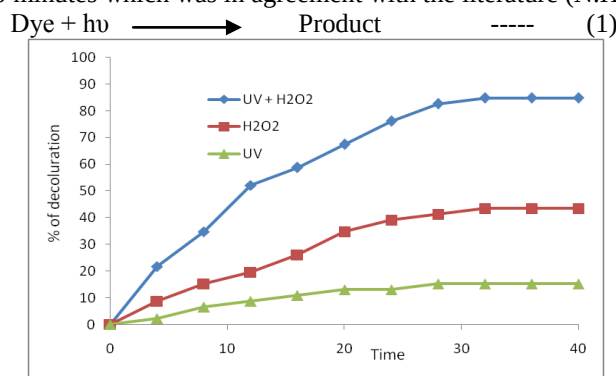


Fig.3. Effect of Photo degradation of Acid orange in the presence and absence of H_2O_2 (initial concentration = 100 ppm and pH = 3)

As shown by Fig.4, decomposition of both the dyes increases with increase in H_2O_2 concentration, at a constant UV intensity, due to the formation of more hydroxyl radicals. Similar trends of the H_2O_2 effect were also reported by Aleboyeh (2003), Daneshvar *et al.* (2004).



But in the higher concentration of H_2O_2 (25 & 30 mmol) shows nearly same trend in the dye removal efficiency compare to the lower concentration of H_2O_2 (10,15 & 20 mmol). This can be explained by (Fig. 4a & 4b) the fact that hydroxyl radicals formed are consumed by excess of H_2O_2 to form hydroperoxyl radical that have lower oxidation capability:



The same trend was observed for both AO7 and BV14 dyes.

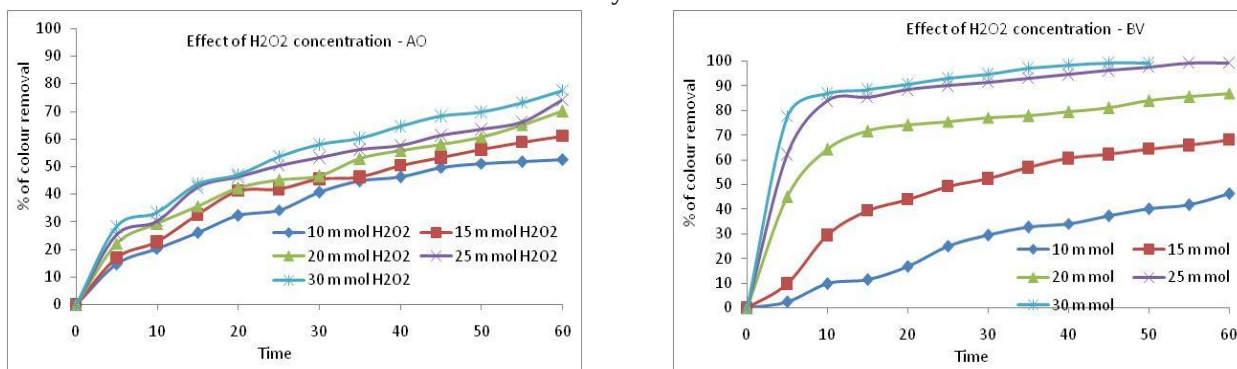


Fig.4a & 4b. Effect of H_2O_2 concentration on Photo degradation of AO7 & BV14 dye (Initial concentration = 500 ppm, pH = 7)

B. Effect of initial dye concentration

In order to investigate the effect of initial dye concentration on the dye degradation rate, initial dye concentration were varied from 100 to 500 mg/L and kept the other parameters constant. As shown by Fig.5a & 5b, the removal efficiency decreases when the initial dye concentration from 100 to 500 mg/L. Too high dye concentration could be unfavourable to the UV light penetration and thus decreases the reaction rate. Behnajady *et al.* (2004) also reported that the photo-oxidation efficiency decreased as the initial dye concentration increased because the solution became more and more impermeable to UV radiation.

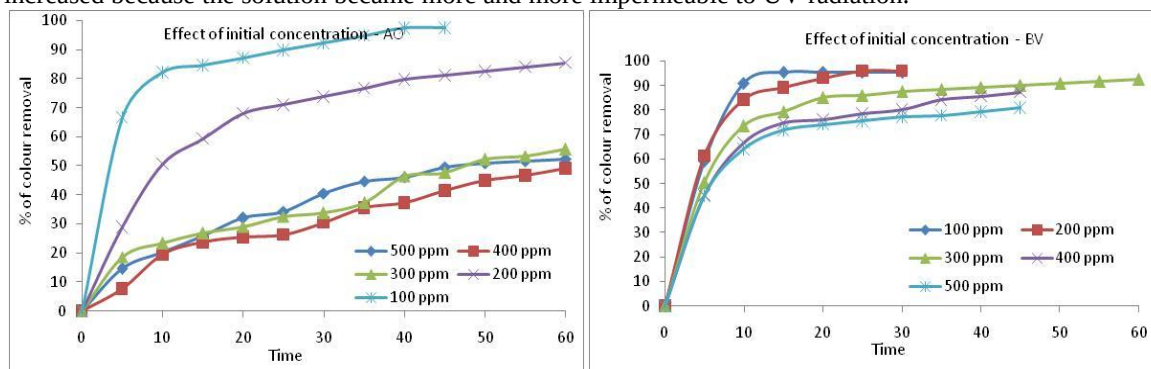
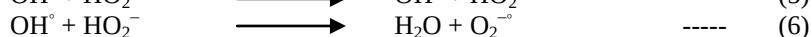
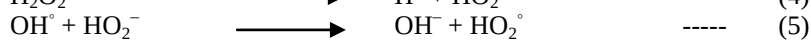
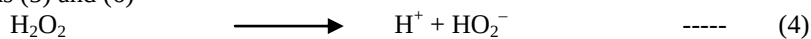


Fig.5a.& 5b. Effect of initial dye concentration on Photo degradation of AO7 & BV14 dye (H_2O_2 = 10 mmol/l, pH = 7)

C. Effect of pH

A series of experiments were carried out by varying initial pHs for 3 to 11. As shown by Fig.6a. & 6b. the initial reaction rates in the acidic and neutral mediums are only slightly influenced by the solution pH, but the initial reaction rate significantly decays in the alkaline medium. Similar trend of the pH effect was also reported by Aleboyeh *et al.* (2005). This is because hydrogen peroxide will dissociate to hydroperoxy anion in the alkaline medium as shown by reaction (4) and the dissociated hydroperoxy anion will consume the hydroxyl radicals as shown by reactions (5) and (6)



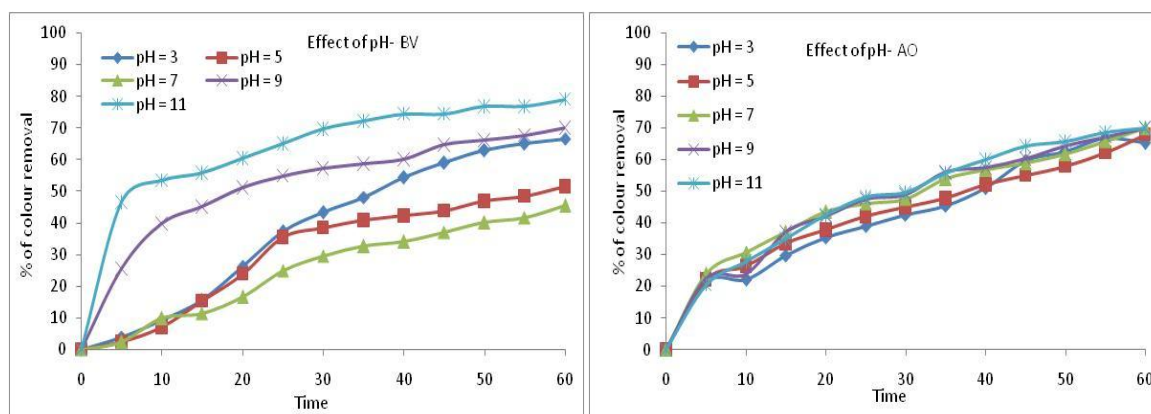


Fig.6a.&6b. Effect of pH on Photo degradation of AO7 & BV14 dye (Initial dye concentration = 500 ppm and H_2O_2 = 10 mmol/l)

IV. Conclusion

The experimental data demonstrated that both H_2O_2 and H_2O_2 /UV are promising techniques for the degradation of dyes from aqueous solution. Using UV radiation as a continuous source for the production of OH radicals and led to 98.2% for AO7 & 97.5% for BV14% degradation of the dyes. Among the different processes contributing to the removal of dye, the increasing order of dye decolorization was: H_2O_2 /UV > H_2O_2 > UV.

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