

## Degradation of Basic Red 46 Dye From Color Wastewater Using Cold Atmospheric Plasma

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### ABSTRACT

Contamination of groundwater with colored and toxic wastewater causes many environmental problems and adversely affects human health. In this study, Basic Red 46, the decolorization of textile dye, Basic Red 46, was studied using advanced oxidation processes (AOPs) in a non-thermal plasma reactor. The reactor uses a high voltage AC power source and airflow based on pin-to-water high-voltage corona discharge. The rate of the dye removal for 100 ml of this solution was investigated. The results showed that the corona discharge exhibited 85 % degradation efficiency for 50 mg/l of basic Red 46 within 30 min of treatment time.

**Keywords:** Corona Discharge, Basic Red 46 Dye, Degradation.

### I. Introductions

Due to the water crisis, developing creative and clean advanced oxidation processes for decomposing harmful organic compounds in wastewater has become a significant challenge for many research teams. The textile industry is one of the factors involved in producing high concentrations of liquid pollutants.

The industry produces waste that contains complex molecules of a variety of organic compounds that make the waste dye toxic and resistant to conventional treatment. Azo dyes are the most used (60–70 %) in the textile industry and are

characterized by their typical  $-N=N-$  nature [1]. Azo dyes cause various human disorders in addition to being harmful pollutants to our environment [2] and are carcinogenic, mutagenic, and allergenic [1]. Therefore, urgent requests have been aroused for the treatment of effluents containing azo dyes to be disposed of or converted into useful and safe products. Several physical or chemical processes such as flocculation, precipitation, ion exchange, membrane filtration, electrochemical destruction, and ozonation are used to treat dye wastewater. However, these

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processes are costly and lead to the generation of sludge with higher concentrations of stable pollution [3].

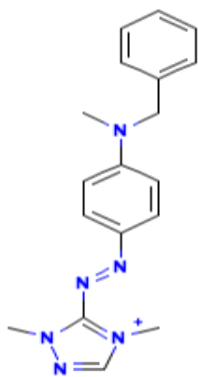
Cold discharge plasma is one of the most widely studied and developed processes due to its low energy cost and easy operation [4,5]. Gas plasma is ionized gas produced by an electrical discharge, generating UV light and many reactive species such as free electrons, radicals (i.e., OH $\cdot$ , H $\cdot$ , O $\cdot$ ), negative and positive ions (i.e., OH $^-$ , H $_2$ O $^+$ , H $^+$ , H $_2$ O $_2^-$ ), and neutrals (H $_2$ O $_2$ , O $_3$ ). The detailed formation mechanism for these species can be followed in ref. [6].

In recent years the use of discharge plasma to eliminate pharmaceutical products, synthetic dyes, and pathogenic bacteria in wastewater has received increasing attention and development [7-9].

In this research, corona discharge has been adopted for decolorization of Basic Red 46 dye from an aqueous solution, which is not removed by conventional methods such as electrocoagulation.

## II. Materials and Methods

The Basic dye used as a textile dye in the present study is C.I. Basic Red 46 (Mr = 357.5), purchased from Isfahan Paksh Novin Chemical Company. The Basic Red 46 molecular structure and its properties are shown in figure 1 and table 1, respectively.



**Fig. 1.** Basic Red 46 chemical structure [10].

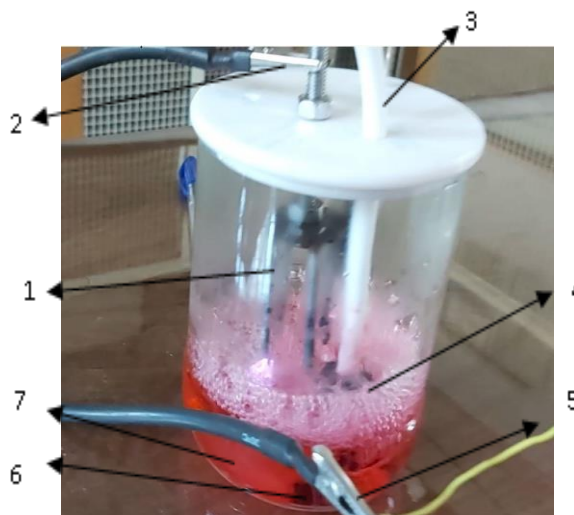
**Table 1.** Properties of Basic Red 46.

Color index	Basic Red 46
Type	Cationic
Molecular Formula*	C $_{18}$ N $_6$ H $_{21}$
Molecular Weight	357.5 (g mol $^{-1}$ )
$\lambda_{\max}$	530 (nm)
pH range	2-12

\*Associated counter ions are not included.

Typically, textile industry-processing effluents contain dyes of 10 and 200 mg/l. Most textile dyes are clearly visible at a low concentration of even < 1 mg/l [11]. Here, the dye solution was prepared at a concentration of 50 mg/L. A 100 mL Basic Red 46 aqueous solution was used as a treated sample volume.

The reactor made of a cylindrical glass container consists of four tungsten pins diameter of 3 mm. (figure 2). By injecting air, it is possible to form plasma on all pins. The air was dispersed into the wastewater by pumice stone. The high voltage AC power supply (~15 kV) was used to ignite the plasma plume between the pins and the aqueous surface in the reactor. The ground electrode is placed inside the reactor (inside the solution).



**Fig. 2.** Pin-to-water corona discharge reactor. 1-Tungsten pin, 2- High voltage connection, 3- Air inlet, 4- pumice stone, 5- Grounded connection, 6- Grounded electrode, 7- Dye solution.

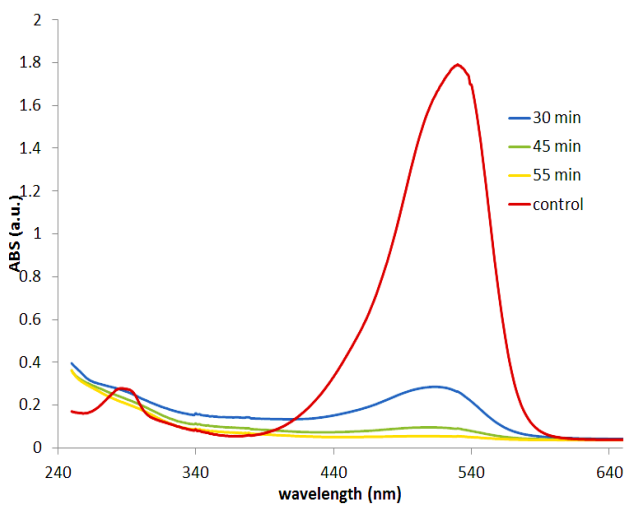
## II. Experimental Results and Discussion

The dye was treated with a corona array, and its degradation was monitored by UV-vis absorption spectroscopy. Time-dependent absorption spectra of plasma treated Basic Red dye are given in Figure 3, from which it is understood that Basic Red 46 dye exhibits a maximum absorption peak at 530 nm, which can be used to monitor the degradation process.

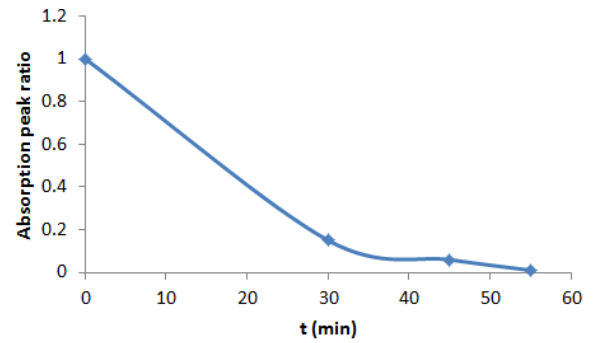
Figure 4 shows the absorption peak ratio ( $A/A_0$ ) of the tested dye solutions throughout the experiment (55 min). Where  $A_0$  was the absorbance of wastewater before treatment, and  $A$  was the absorbance of wastewater after treatment.

The decolorization rate of Basic Red was higher at the beginning (up to 30 min), and then it increased at a lower rate from 30 to 55 min.

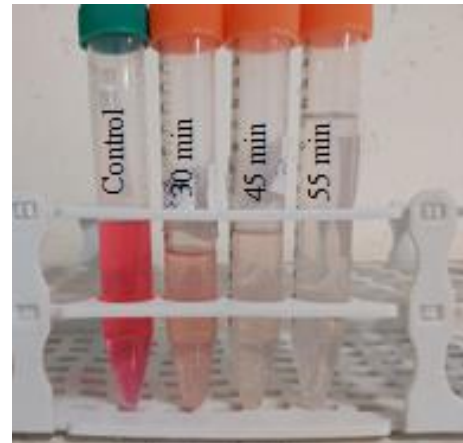
Figure 5 shows the Basic Red 46 solution color variation with treatment time at a discharge voltage of 15 kV. The increase in treatment time results in better decolorization. The color of the water solution is almost completely decolorized after 55 min treatment.



**Fig. 3.** Absorbance of Basic Red 46 dye solution without (control) and with (30, 45, 55 minutes) plasma treatment.

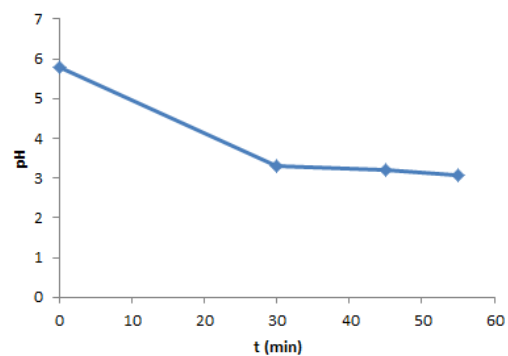


**Fig. 4.** Time variation of decreased concentration.



**Fig. 5.** The variation of Basic Red 46 solution color with the processing time.

The pH value of the solution is monitored with labCHEM-pH-TPS. Figure 6 shows the pH value of the solution during the treatment process. pH dropped drastically in the early part of the process from the initial 5.8. After 30 min, the pH decreased to 3.32. It shows that acidic solutions are generated when plasma is discharge in air-liquid interface. The acidity is due to the nitrates and nitrites forming in the solution.



**Fig. 6.** pH of Basic Red 46 solution during the corona oxidation with the processing time.

The chemical oxygen demand (COD) for the control sample and after 55 min plasma treatment was measured with standard method-5220 B [12]. The value of COD was reduced from 40 ppm down to 31 ppm. The efficiency of plasma treatment in reducing COD is low. It was mainly because of an organic species produced due to the destruction of the molecular structure of azo dye by ozone and other reactive species in cold plasma. As treatment time increases, these organic species are also degraded, and COD decreases.

### III. Conclusions

The corona plasma array discharge reactor system has been designed and tested for degradation of Basic Red 46 textile dyes in an aqueous solution. The maximum decolorization rate (85%) was found in the first 30 minutes. In general, chemical and physical discoloration methods have been used to remove dye from effluents, such as coagulation and flocculation processes, mainly used to treat textile wastewater. But these methods transfer dyes from liquid to solid. The phase that causes secondary pollution (i.e. sludge) requires further treatment. On the one hand, textile wastewater has a high pH value i.e. 10 [13]. Other hand Plasma treatment decreases pH value. Thus, the alkalinity of the effluent can be expected to be reduced to neutral conditions. Plasma treatment of dye solution reduced the COD concentration. 22.5% COD reduction occurred in 55 min of treatment time. It can be concluded that a non-thermal plasma reactor is more effective for the decolorization of typical concentrations of dye in textile wastewater.

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