

Original Research

# Degradation of a Pigment Red 238 using UV, UV/H<sub>2</sub>O<sub>2</sub>, UV/H<sub>2</sub>O<sub>2</sub>/SnO<sub>2</sub> and Fenton Processes

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## Abstract

This study implicates the degradation of pigment red 238 (PR238) from aqueous solution employing photocatalytic processes. The procedure was carried out under UV radiation, SnO<sub>2</sub> and H<sub>2</sub>O<sub>2</sub> as well as Fenton process. The influence of process variables viz., pigment concentration (50-150 ppm), amount of catalyst (0.1-0.3 g/L), H<sub>2</sub>O<sub>2</sub> concentration (0.3-0.9 mL), UV irradiation time (30-60 min) and pH (3-9) were studied for the removal of PR238. The experiments were conducted by exposing aqueous solutions of PR238 having photocatalyst with UV light and effect of process variables such as pH, concentration of pigment, concentration of H<sub>2</sub>O<sub>2</sub> and amount of catalyst was investigated. The degradation of >90% was achieved with Fenton process, whereas H<sub>2</sub>O<sub>2</sub>/UV and UV/H<sub>2</sub>O<sub>2</sub>/SnO<sub>2</sub> furnished up to 78% and 89.6% PR238 removal, respectively. From results, it was concluded that the Fenton process is highly efficient for the removal of PR238, which can be employed for the removal of dyes form effluents

**Keywords:** dye degradation, industrial effluents, environmental remediation, UV radiation, photocatalyst, fenton process

## Introduction

Pigments are extensively used for plastics, leather, textiles, food, paper and cosmetic industry to paint products. Textile manufacturing which releases about

20% of the colorant in textile effluents is considered as major contributor for water pollution. Textile industries produce 100-170 colored dye effluent per kg of processed fabric that can be characterized by powerful odor, excessive COD & extensive range of pH [1-5]. The environmental contamination and other crucial problems are becoming gradually thoughtful with the fast development of population and the rising industrialization and expansion. The pollutants are

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released into water bodies, inevitable or unacceptable by all means, has been projected as the chief cause of environment contamination [6-9].

Many conventional methods of treatment are inefficient, non-destructive, shifting chemicals from water to additional stage and generating secondary pollution. Based on heterogeneous photocatalysis, advanced oxidation processes (AOPs) appear to be an effective procedure due to having a variety of important features. The favorable operating conditions or features

are mild functioning temperature, pressure, low energy production, maximum pollutant mineralization without subordinate pollutants and lower cost. Photocatalytic degradation is considered as one of the main advanced oxidation processes to destroy organic contaminants [10, 11].

Generally, the photocatalyst may include predictable metal oxides without pores e.g.,  $\text{SnO}_2$ ,  $\text{TiO}_2$ ,  $\text{ZnO}$ , etc. The production of energy charge carriers commonly called as electron-hole pairs shall begin on the light

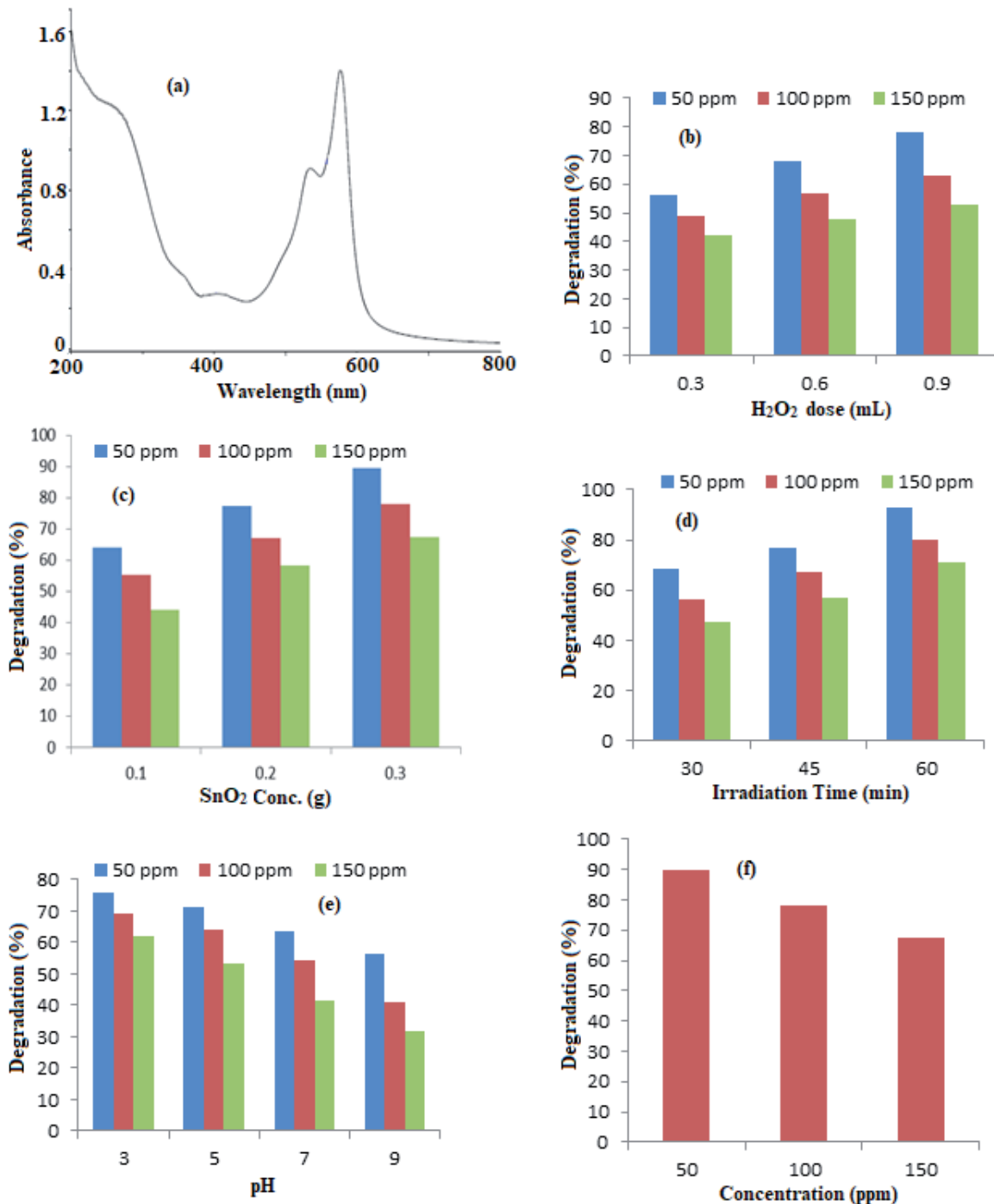


Fig. 1. Absorption spectra of Red 238 Pigment, (b-f) Effect of process variable on Red 238 Pigment percentage degradation, b)  $\text{H}_2\text{O}_2$ , c)  $\text{SnO}_2$ , d) reaction time, e) pH and f) pigment concentration.

impregnation having energy equivalent to the band gap energy of the catalyst. These electron-hole (e-h) pair produce radicals to participate in oxidation-reduction process. This surface phenomenon is helpful to attain the oxidation of organic pollutants [12, 13]. In process based on photocatalytic destruction, the contaminants are destructed by the action of reactive species. The species are prepared by multi-step process using photocatalyst, light source and oxidizing agent like  $\text{H}_2\text{O}_2$  [14, 15].

## Materials and Methods

Red 238 pigment was obtained from Harris dyes and chemicals, Faisalabad, Pakistan. All reagents and chemicals employed were acquired from Merck and Sigma Aldrich. HCl and NaOH (0.1 M) was used for pH adjustment. Pigment red 238 stock solution of 1000 ppm was made in a flask (1000 mL) by adding 1 g of pigment in 1L water. Further dilutions of this stock solution were made with distilled water to achieve a series of pigment solutions with different concentrations. The diluted solutions were exposed to UV radiations having wavelength of 254 nm and intensity of 144 watts. After time intervals (30, 45 and 60 min), the absorbance of the sample was measured (Perkin-Elmer spectrophotometer). The solution was placed in sample cell of spectrophotometer and it was then scanned for UV-Visible range (200-800 nm). The aqueous solution of pigment red 238 showed absorption peak ( $\lambda_{\text{max}}$ ) at 577 nm in visible region is shown in (Fig. 1). The change in sample absorption of each pigment solution was measured before and after each treatment by spectrophotometer (Perkin-Elmer). The absorbance of treated pigment sample was recorded at 577 ( $\lambda_{\text{max}}$ ), which was used for residual pigment concentration by employing relation (pigment removal (%)) = absorbance at 0 time/ absorbance at 0 time \* 100).

## Results and Discussion

The outcome of the initial  $\text{H}_2\text{O}_2$  amount on the discoloration of dye was investigated. The rate of degradation increased with increasing concentrations of  $\text{H}_2\text{O}_2$ . Under ultraviolet light,  $\text{H}_2\text{O}_2$  generates additional superoxide anion to increase treatment efficiency. It occurs through interaction of hydrogen peroxide with light [16].

It was observed that by increasing the  $\text{H}_2\text{O}_2$  concentration from 0.3-0.9 mL, the pigment removal efficiency was also increased, which is due to generation of hydroxyl radicals ( $\text{H}_2\text{O}_2 \rightarrow 2\cdot\text{OH}$ ) [17]. The  $\text{H}_2\text{O}_2$  act as an oxidant, which enhanced the pigment degradation by generation hydroxyl radical, which is a strong oxidizing agent and remove the pigment by oxidation-degradation mechanism [18]. The effectiveness of the process was also scrutinized in the occurrence of UV

and different concentrations of hydrogen peroxide and showed that increasing the amount of  $\text{H}_2\text{O}_2$  will raise the degradation of the red 238 pigment (Fig. 1). The catalytic loading on degradation of dye was examined by differing  $\text{SnO}_2$  dose from 0.1 to 0.3 g/L. Each pigment solution was treated by changing concentrations of  $\text{SnO}_2$  to elucidate the influence of  $\text{SnO}_2$  concentration. As the amount of catalyst was increased from 0.1 to 0.3 g/L, then degradation increased from 64.1 to 89.6% at 60 min irradiation time. Results showed that degradation of red 238 reaches a maximum of 0.3g/L. This stated that the active site obtained for substrate adsorption on the catalytic surface is restricted to a catalytic dose of 0.3g/L. The removal efficacy of pigment increases due to active sites on the catalyst surface (Fig. 1) [19, 20] [21].

The aqueous pigment solution was subjected to treatment by Fenton reagent ( $\text{Fe}^{2+}/\text{H}_2\text{O}_2$ ) in the occurrence of UV radiation while keeping other parameters constant. In fact, the Fenton process initiates with the generation of hydroxyl radicals. As a result,  $\text{Fe}^{2+}$  reacts with  $\text{H}_2\text{O}_2$ . All the ferrous ion and  $\text{H}_2\text{O}_2$  lead not only to formation of hydroxyl radicals but also to formation of scavengers of hydroxyl radicals. The ratio of  $[\text{Fe}^{2+}]/[\text{H}_2\text{O}_2]$  are expected to have an influence on the amounts of radical  $\cdot\text{OH}$  production and scavenging. It is therefore crucial to use the optimal  $[\text{Fe}^{2+}]/[\text{H}_2\text{O}_2]$  ratio [22, 23]. It was indicated the maximum degradation for pigment solution was 93.2% (Fig. 1). The pH of the mixture was varied by HCl and NaOH to the pigment solution. With rise of pH from acidic to basic, the rate of degradation has been found to decreases [24, 25]. The increase in the degradation rate at lower pH could be ascribed to the lesser recombination rate of  $\cdot\text{OH}$  radicals produced under these acidic conditions [26]. The concentration of pigment in the wastewaters originated form textile industry is in the range of 50 to 150 mg/L. Usually, the removal of pigment declines with increment in the initial concentration. At higher concentration, the production of  $\cdot\text{OH}$  on catalytic exterior is reduced because the active sites and the number of pigment molecules increases as compared to  $\cdot\text{OH}$  radical [27]. Consequently, the reaction among the catalyst and hydrogen peroxide was hindered, thereby reducing degradation efficiency [28, 29].

## Conclusion

In this study, red 238 pigment is degraded employing UV, UV/ $\text{H}_2\text{O}_2$ , UV/ $\text{H}_2\text{O}_2/\text{SnO}_2$  and Fenton processes. The effect of the key working parameters that influence the pigment removal including initial pigment concentration, contact time, medium pH and  $\text{H}_2\text{O}_2$  concentration were studied. The percentage of pigment degradation improved with an increase in catalyst loading and reduced with increase in pH, initial concentration of pigment. The pH 4 was found

to be appropriate for photocatalytic destruction of red 238. The maximum removal of red 238 with UV/H<sub>2</sub>O<sub>2</sub>, UV/H<sub>2</sub>O<sub>2</sub>/SnO<sub>2</sub> and Fenton process was 78%, 89.6% and 93.2%, respectively in 60 min. The results indicate that Fenton process is highly promising for the removal of Red 238 pigment versus other, which could be employed for the removal of Red 238 from effluents.

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### Conflict of Interest

The authors declare no conflict of interest.

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