Photocatalytic degradation of Reactive Red 141 dye by photo-Fenton process

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Abstract

Photocatalytic bleaching using AOPs is a field of interest for the researchers as it offers an interesting approach for colour removal and reduction to simple inorganic compounds. It was found that treatment with Fenton Reagent was also effective for the colour removal and convert into smaller pollutants. Photocatylitical degradation of Reactive Red 141 was studied in detail using H_2O_2/Fe^{3+}. The experimental results showed that photocatalytic degradation depends on the dye concentration, catalyst concentration, H_2O_2 concentration, pH and light intensity. Photodegradation optimized for these parameters. This photodegradation follows pseudo first order kinetics. Experimental results shows effectiveness of photocatalytical degradation of RR 141 using Fenton system.

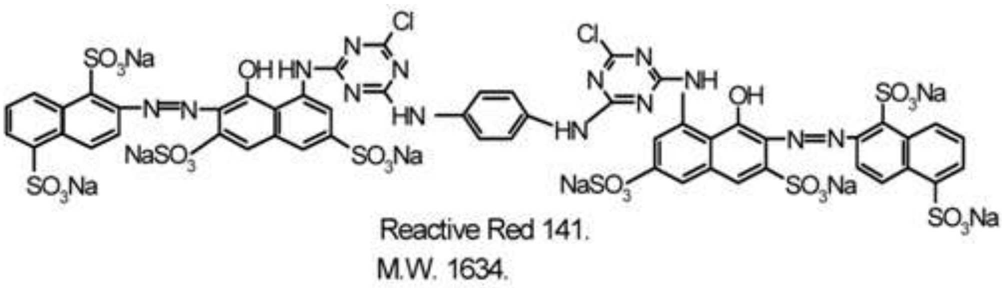
Keywords:, RR 141, photo-Fenton, Photodegradation, Bleaching, Advance oxidation process.

Introduction

Water pollutants of industrial and domestic waste is big issue for both developed and developing nations. These nations are dealing with issues like organic water contamination, heavy metals, biological contamination, and intensive nutrients.Recently the synthetic dyes are largely used in textile, leather, paper, pulp, furniture and plastic industry.In the dyes degradation process large molecule of dyes get oxidised into smaller molecules like water, CO2, and other mineral by products. Advance oxidation processes (AOPs) are very powerful method for degradation of dyes. AOPs like photo catalytic, sonophotocatalytic, photo -Fenton, photo - ozonolysis etc are extensively used. These all generate powerful oxidising agent hydroxyl radical ($E^o = 2.80$ V *versus* Normal

Hydrogen Electrode).

The structure of reactive red 141 is



It is a diazo dye and has C.I. number 61931. It is mainly used for cotton, hemp, viscose fibre, cotton and polyester print/stick blended fabric dyeing.The direct release of wastewater containing Reactive Red 141 causes serious environmental problems due to its dark color and toxicity.

Literature Review

Water pollution with toxic and non-degradable chemicals such as heavy metals, artificial dyes, and organic micropollutants threatens the physical and environmental health of billions of people[1,2]. The estimated usage of dyes is around one million tons per year, widely employed in the production stages of food items, paper, cosmetics, and textiles[3]. The effluents from these industries contain significant amounts of colorants, leading to long-term environmental pollution, reduced light penetration, decreased dissolved oxygen (DO), increased chemical oxygen demand (COD) in receiving waters, and contamination of groundwater, due to discharge into the environment, even with low concentrations of dyes[4].

According to the World Bank research report, textile dyeing and treatment constitute 17–20 percent of industrial water pollution[5]. Approximately, 2000 different chemical substances are used in the textile industry as dyes, and around 15% of these utilized dyes enter the ecosystem along with wastewater[6]. Dyes have diverse effects on human health, including allergies, dermatitis, digestive disorders, and eye irritation[7]. Moreover, dyes are recognized as potential carcinogens that can induce genetic abnormalities. Therefore, the removal of dyes is essential to prevent pollution[8].

Photocatalytic degradation of organic dyes under visible light on N-doped TiO2 photocatalysts was done by Sannino et.al[9]. Decolorization of mordant red 73 azo dye in water using H2O2/UV photo Fenton treatment was done by Bary et.al.[10]. Degradation of Reactive Red 194 and reactive yellow 145 azo dyes by O3 and H2O2/UV-C process was done by Gul et.al.[11] Photocatalytic degradation of reactive black-5 dye using TiO2 impregnated ZSM5 was done by patil et.al.[12] Photo-catalytic degradation of two commercial dyes in aqueous phase using photo catalyst TiO2 was done by Sharma et.al.[13] Use of nanomaterials in waste water treatment done by Vyas et.al.[14] Photocatalytic degradation of Malachite Green using Undoped and Carbon – Doped Calcium Molybdate catalysts was done by Ameta et.al. [15]

Experimental

In this study RR 141, anhydrous $FeCl_3$ and H_2O_2 (30% v/v) was employed. Photochemical degradation of RR 141was investigated using Fe^{3+} ion as a catalyst, $H_2O_2$and visible light. A stock solution of RR 141 and ferric ion was prepared in demineralised water. For photobleaching of dye diluted solution of stock solution is used. Measurement of pH done using pH meter and absorbance was measured using spectrophotometer.

Results and Discussion

Control experiments (without photocatalyst and light) verified that photocatalyst with light alone are needed in order to follow the photocatalytic pathway for dye photobleaching. We observed that RR 141at its λmax = 532 nm and went under photochemical degradation. Table 1 as well as Figure 2 do provide results for a typical run. Solution optical density (OD) diminishes as irradiation time increases. This suggests that RR 141 is degraded with photolight, and the plot of absorbance versus time was linear.

Effect of pH

Photobleaching of dye depend on pH value; therefore, the photodegradation experiment was conducted with a range of pH values from 2.0 to 4.8 (Figure 3). The results showed that the rates of photobleaching of Dye Disperse Blue 73 increase as the pH increases up to 3.4, and decrease as the pH increases above 3.4. The optimum pH 3.4 was set for bleaching of dye.

Effect of Dye (Reactive Red 141) Concentration

The rate of photochemical degradation increased with increasing concentrations of RR 141 up to 3.0×10^{-5} M (Figure 4), and then decreased at higher concentrations, perhaps because more molecules of RR 141 are present for degradation or because an excess of RR 141 may serve as a filter that reduces the amount of light incident on the dye molecule in solution.

Effect of Ferric Ion Concentration

With all other variables being held constant, the effect of varying catalyst concentration was studied by changing the amount of catalyst present in the reaction mixture to observe how it affects the photochemical degradation rate. Figure 5 shows that the photobleaching dye rate increases as Fe^{3+} ions increase up to 3.71 x10^{-4} M. This concentration of ferric ion was set as optimum value for bleaching of dye.

Effect of H_2O_2 Concentration

As shown in Figure 6, the rate of photobleaching of dye increases with increasing concentration of H_2O_2 upto a maximum at about 2.5 mL, and then remains unchanged as more H_2O_2 is added. 2.5 mL was set as optimum value for bleaching of dye.

Effect of Light Intensity

Figure 7 illustrates how the rate constant changed linearly with light intensity, meaning that a decrease in light intensity results in a slower rate of reaction. This could be because every photon interacts with Fe^{3+} ions, and as the number of photons rises, the rate of reaction rises as well because there are more hydroxyl radicals.

Table 1: A TYPICAL RUN

[Reactive Red 141] = 3.0×10^{-5} M H_2O_2 = 2.5 mL [Fe^{3+}] = 3.71×10^{-4} M
Light intensity = 80.0 mW cm^{-2} pH =3.4

Time (min.)	2 + log O.D.
0	1.807
5	1.659
10	1.511
15	1.363
20	1.215
25	1.067
30	0.919

$$k = 11.361 \times 10^{-4}\ s^{-1}$$

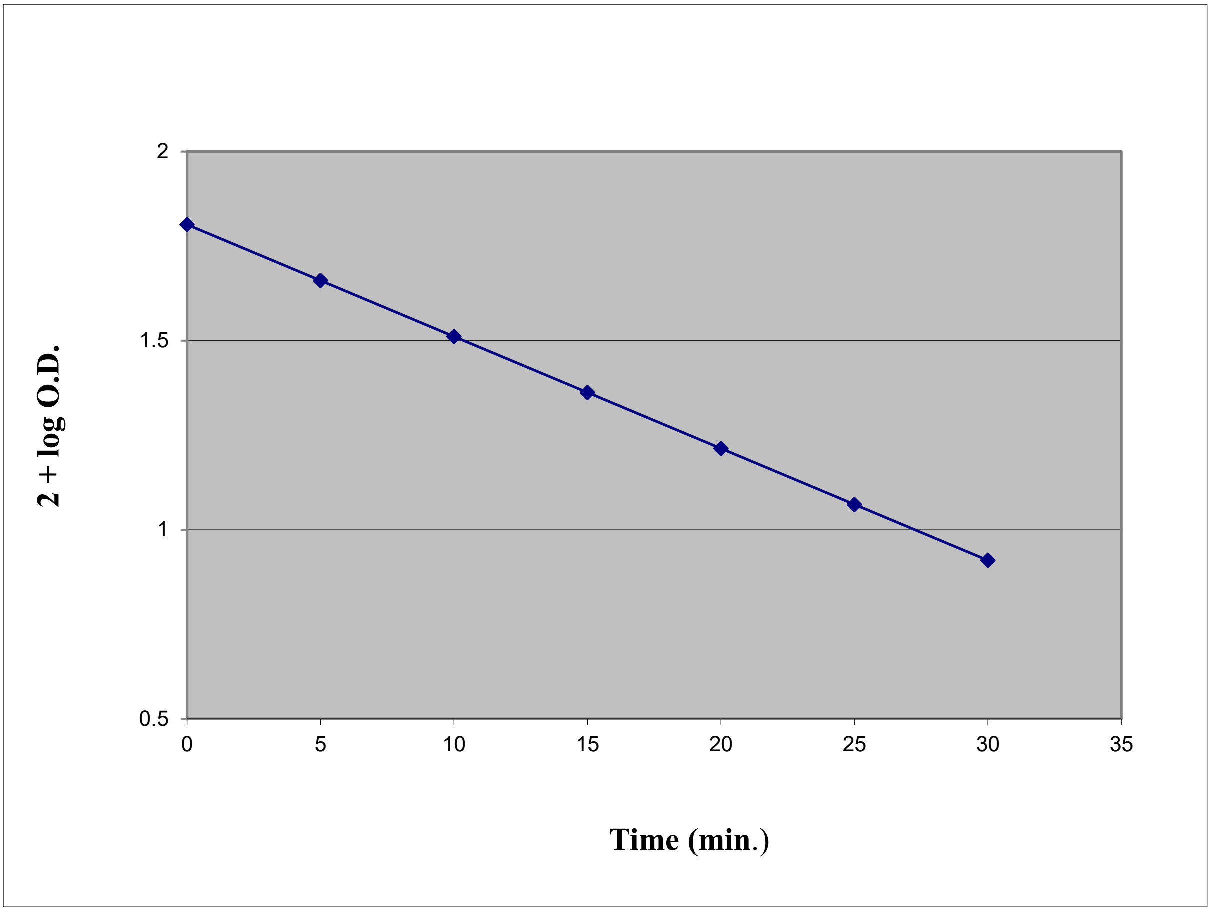


Figure 2: A Typical Run

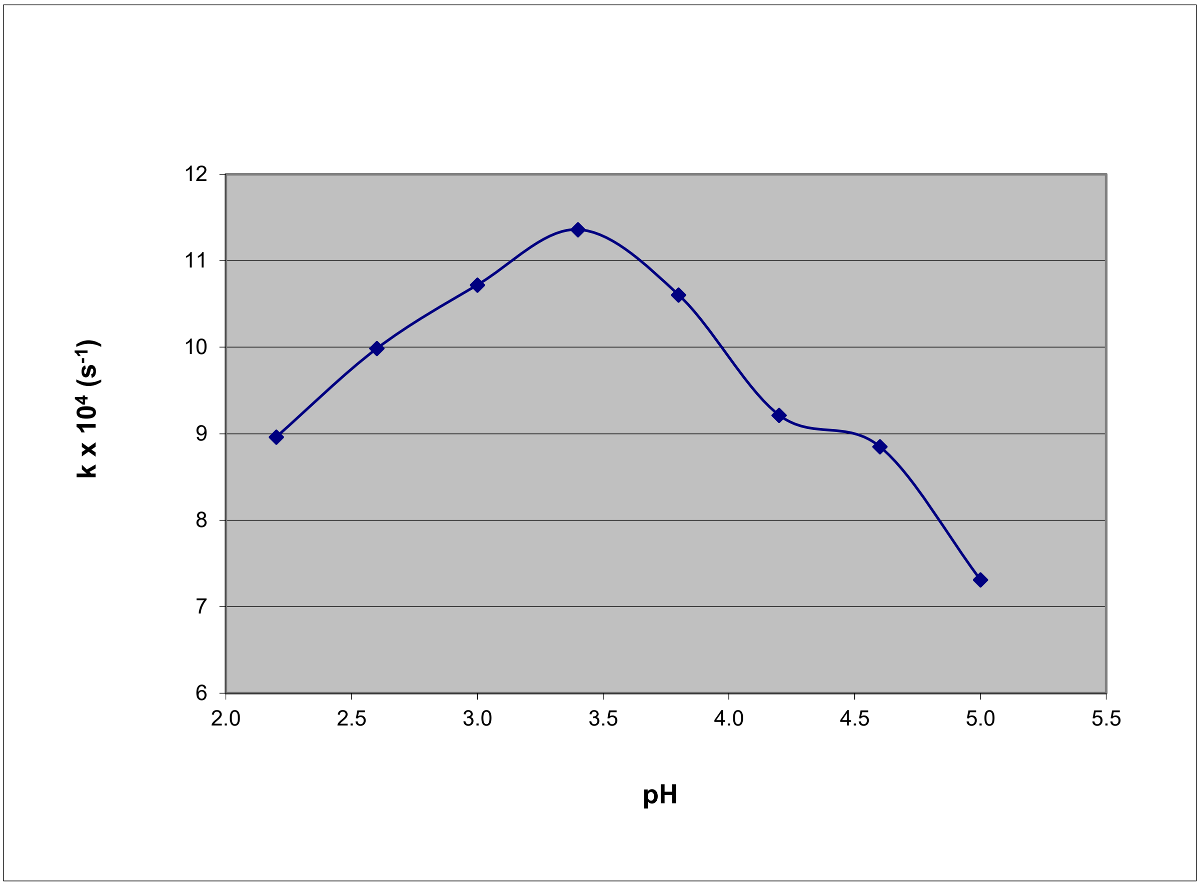


Figure 3: Effect of pH

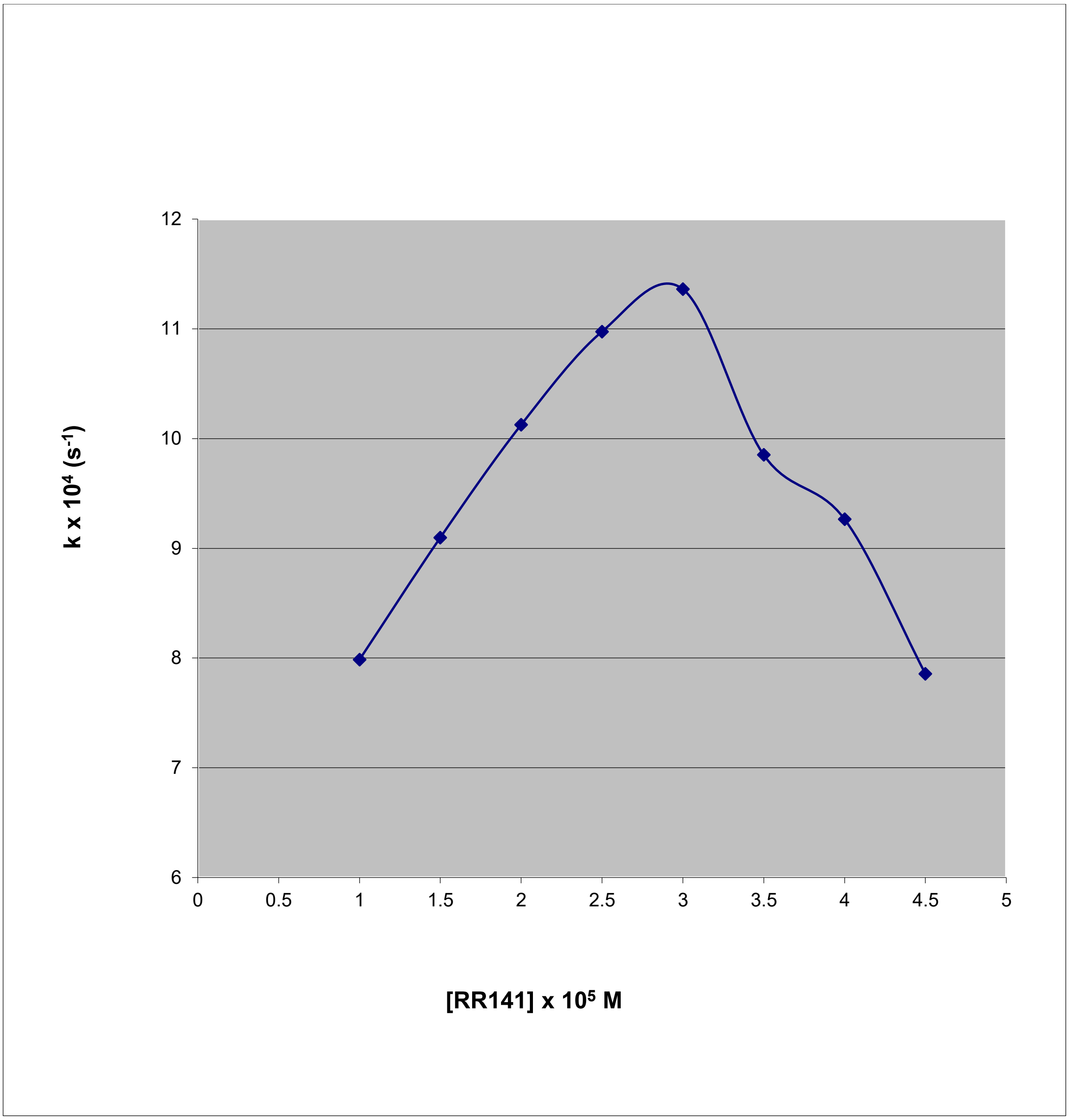


Figure 4: Effect of Dye Concentration

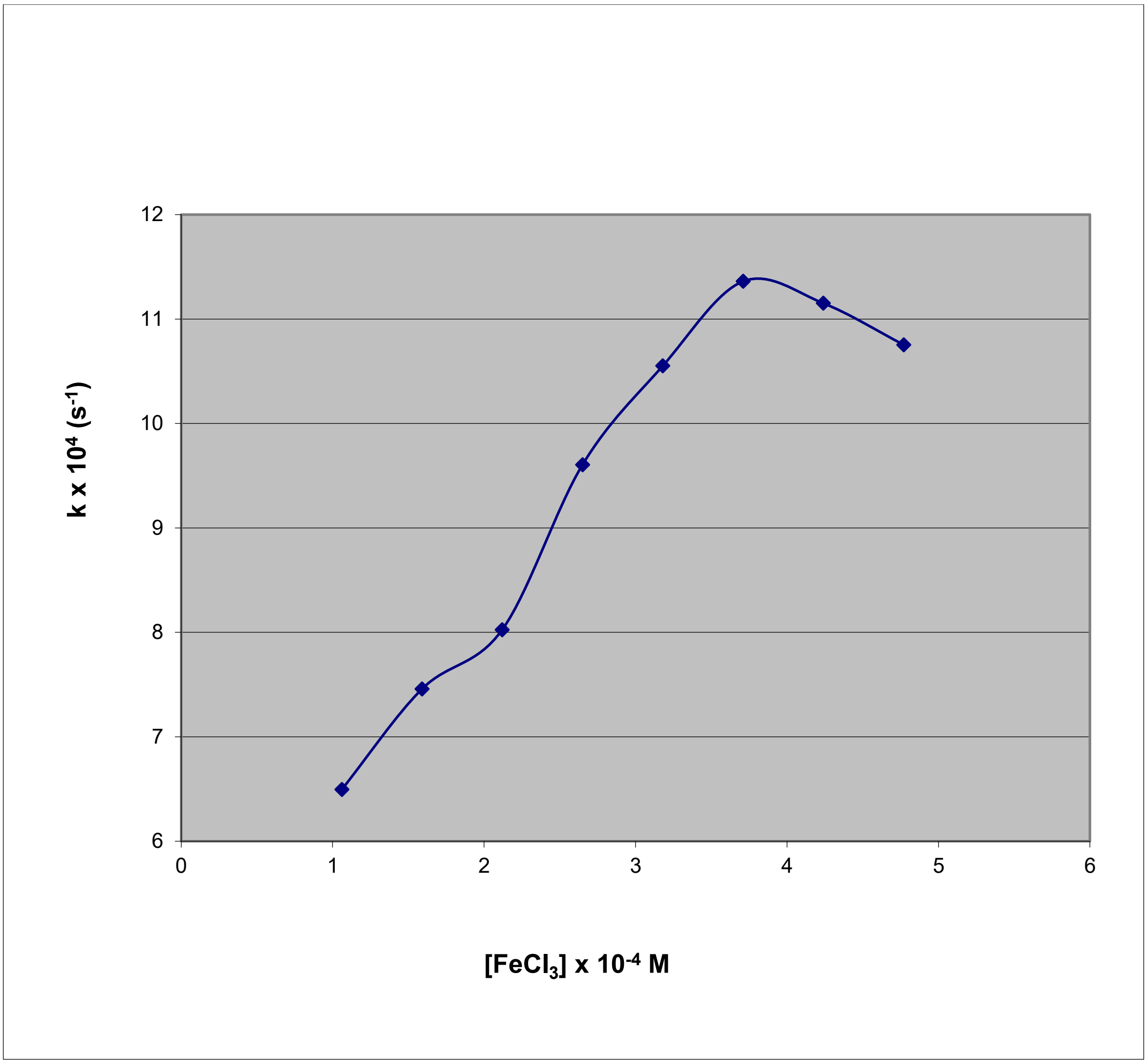


Figure 5: Effect of Fe^{3+} Ion Concentration

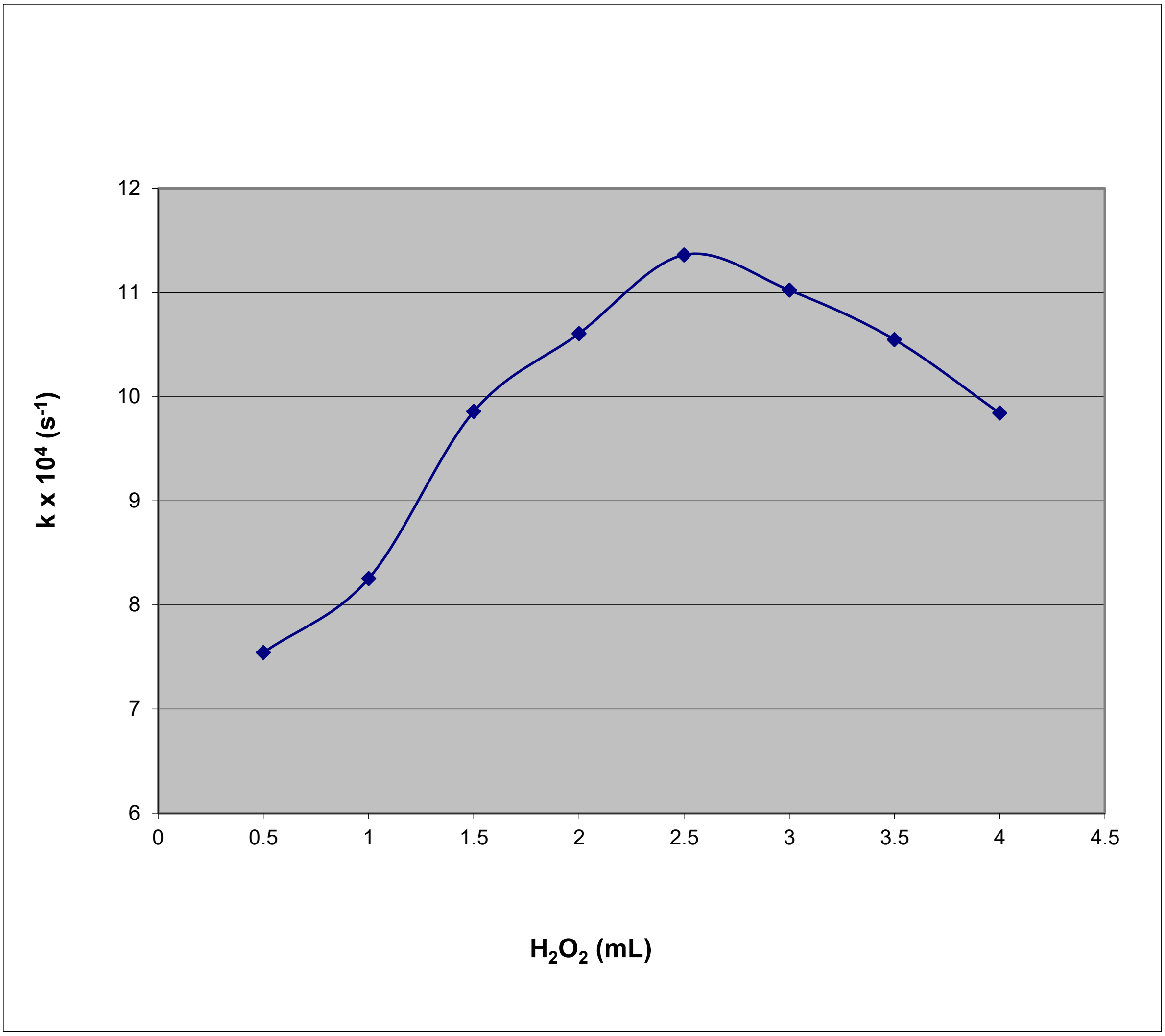


Figure 6: Effect of H_2O_2 Concentration

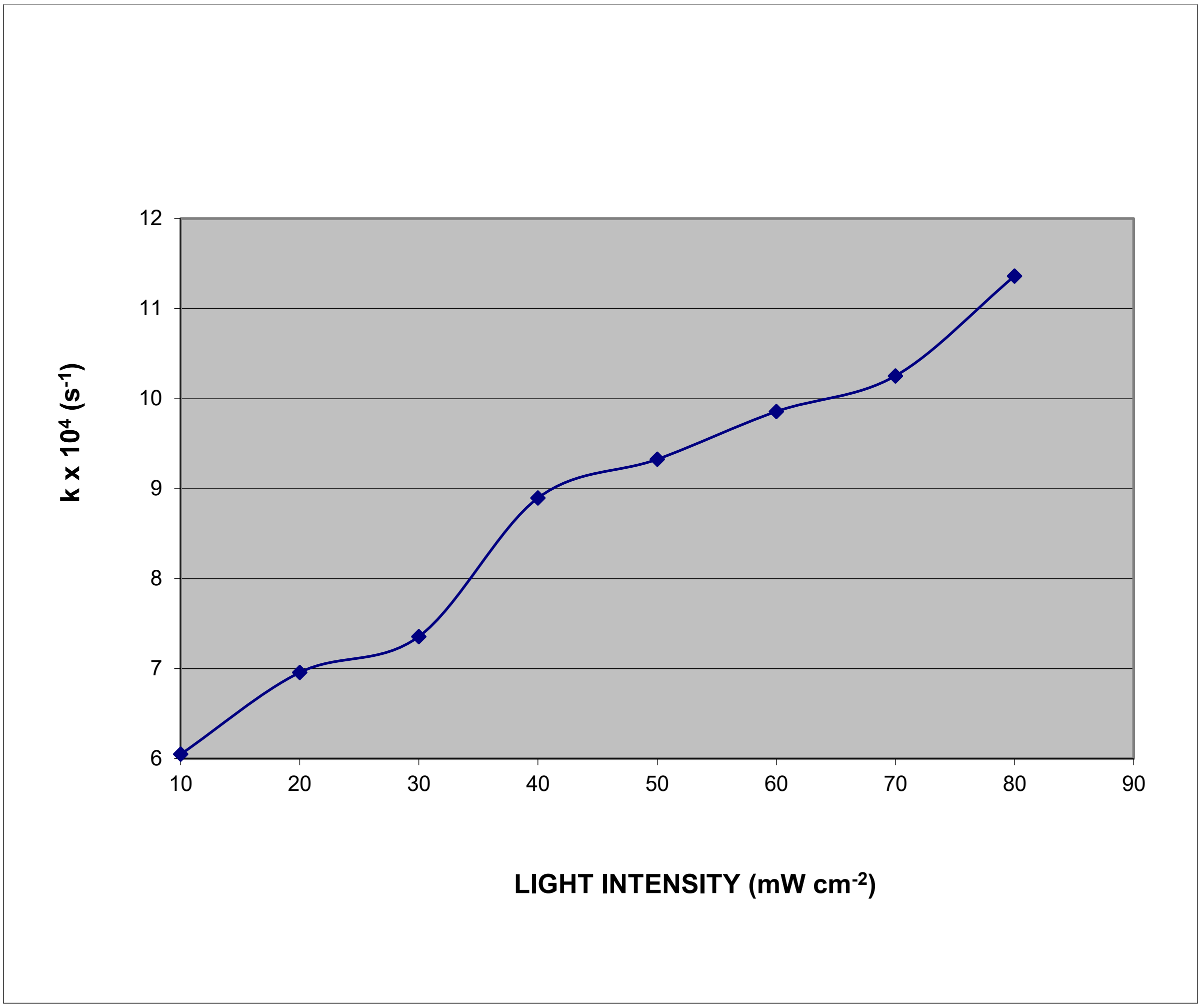


Figure 7: Effect of Light Intensity

Conclusion

Photobleaching of RR 141 was investigated using photo Fenton (H_2O_2/Fe^{3+}) as a catalyst. Various parameters such as dye concentration ,H_2O_2 concentration, ferric ion concentration, pH values, light intensity were tested. This work shows that photocatalysis is very effective technology for bleaching of RR 141. Photo Fenton reagent produce hydroxyl radicals in suitable amount for bleaching of dye.

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