Photolytic Degradation of Rhodamine B in Water Using H_2O_2/UV System

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ABSTRACT

In this study Photolytic degradation of rhodamine b in wastewater with the application of Advanced Oxidation Process (AOP) based on H_2O_2/UV system was carried out. The optimum condition for treatment of rhodamine b was determined by experimenting on a synthetic rhodamine b solution prepared using the crystalline rhodamine b in water. Different parameters that affect the reaction rate were tested namely: initial rhodamine b concentration of 10 to 50 ppm, Reaction time 1 to 5 hrs and Catalyst dose from 1 ml to 5ml at fixed UV light intensity of 9 watt and fixed pH of 7.9. Photo catalytic experiments were carried out using laboratory photo reactor for degradation of rhodamine b from waste water. It is found that complete degradation of rhodamine b is possible in a reasonable time, 6 hrs when concentration of rhodamine b is 10 ppm. The results of the photo catalytic activity under UV radiation show maximum rhodamine b conversion up to 92.20%.

Keyword: Wastes processing; waste water; water purification; rhodamine b; H_2O_2/UV system

INTRODUCTION

A wide range of organic contaminants have been detected in industrial and municipal wastewater. Rhodamine b and rhodamine bic compounds are the important Organic contaminants which pose severe problems in biological treatment systems due to their resistance to biodegradation or/and toxic effects on microbial processes [1]. They are discharged to the environment from industries such as petroleum refining, coal tar, steel dye stuff, synthetic resins, coal gasification and liquefaction surface runoff from coalmines, by product of agriculture chemicals, paper and pulp mills, tanning, paint stripping and fibre board production operation. They are hard to decompose in waste water [2].

According to environmental protection rules (1992) of central pollution control board of India, the maximum discharge limit of total rhodamine b compounds in domestic water is 1mg/l and 5mg/l for the other water whereas the industrial effluent discharge contains a
higher percentage of such organic contaminants because of very low capacity of established effluent treatment plants. A survey report shows that only 10% of generated waste water is treated and rest is discharged to the water bodies [3]. Technological systems for the removal of organic pollutants have been recently developed. Among the heterogeneous photocatalysis is the Advanced Oxidation Process or AOP, which can be successfully used to oxidize many organic pollutants present in aqueous systems [4].

During the past two decades, the treatment of spent industrial wastewater by traditional methods has proven to not be effective for many wastewater treatment facilities. Conventional activated sludge treatment is the typical treatment used today, though activated sludge was not originally used for treatment of industrial wastes, particularly textile wastes containing dyes and surfactants [5]. Additional waste water treatment methods such as combination of biological, physical, and chemical methods including coagulation/flocculation, electrochemical oxidation and activated carbon adsorption, reverse osmosis, ozone and oxidative/reductive chemical processes are all techniques that can be used for treating industrial wastewater. The AOP consequently realizes complete treatment of such compounds, so advanced oxidation processes are being considered as emerging technology to handle large volumes of textile waste water.

The concept behind the AOP is exposure of a strong oxidizing agent to ultraviolet (UV) light generates hydroxyl free radicals, which are stronger than any other oxidants [6]. The hydroxyl radicals generated after activation have a higher oxidation potential (2.8 V) than hydrogen peroxide (1.78 V) and so rhodamine bic compounds treatment is feasible. Advanced oxidation is one of the potential alternatives to treat rhodamine bic compounds present in industrial and municipal wastewater. This process implies generation and subsequent reaction of hydroxyl radicals, which are the most powerful oxidizing species after fluorine [7].

In this study, the photolytic degradation of Rhodamine b carried out using H2O2/UV system and effect of process parameters on degradation efficiency was observed. To investigate the efficiency of UV/H2O2 process, three obvious variables of Photocatalytic process were chosen namely concentration of rhodamine bic solution (C), dose of photocatalyst H2O2, and reaction time (t).

MATERIALS AND METHODS

Materials
To carry out the Photocatalytic degradation experiment of synthetic solution of rhodamine b, a Photocatalytic system was used. It was a closed chamber of 3x2.5x2.5 feet. A UV Bulb of 9 watt was used to provide the UV light and a magnetic stirrer was used to provide the continuous stirring to solution. Analytical grade H2O2 (30% w/v) was used as oxidant and Rhodamine b, to prepare the synthetic solution of rhodamine b. All the solutions were prepared in distilled water. A spectrophotometer (spectronic 20) was used to measure the absorbance of treated solution of rhodamine b.

Experimental Procedures
The mineralization experiments were conducted according to advance oxidation method, applied in treatment of organics published elsewhere [3, 6]. A synthetic solution of rhodamine b was prepared in distilled water and a measured volume of photo catalyst Hydrogen peroxide (H2O2; 30%) was added in the rhodamine b solution as the source of hydroxyl radicals. Before treating the blank solution with UV light, Absorbance of solution was measured and then blank mixture was placed in photo-catalytic reactor to precede the
degradation reaction. During the experiments, sample of the reaction mixture were withdrawn at different reaction times to measure the absorbance of rhodamine b solution. Analysis of treated solution was carried out by the measurement of UV light absorbance with spectrophotometer.

RESULTS AND DISCUSSION
Effect of oxidant (H$_2$O$_2$) dose
The effect of H$_2$O$_2$ dosage (ranging from 1 cm$^3$ to 5 cm$^3$) on the degradation efficiency was investigated by altering the H$_2$O$_2$ doses with 50 ppm rhodamine b solution at 7.9 pH & room temperature. The effect of the H$_2$O$_2$ dose on the degradation efficiency is shown in Figure 1. It can be observed that the degradation efficiency increases with increasing hydrogen peroxide dose up to an optimum loading of 3-5ml. This is consistent with the available literature.

The initial rate value indicates that the degradation rate increased with an increase in catalyst dose up to 5ml. further increase in the catalyst dose showed no increase in % degradation. This may be attributed to the fact that as the dose of the catalyst increased, the number of organic molecules adsorbed was increased, owing to an increase in number of (OH) hydroxyl radicals, thereby enhancing the rate of photo degradation. Several studies have proposed different reaction mechanisms for this photolysis. It is widely accepted that the main interaction between H$_2$O$_2$ with UV radiation and free radicals are well represented by the following reactions [8].

Hydrogen peroxide is unstable as shown by the following equation:

$$\text{H}_2\text{O}_2 \rightarrow \text{H}_2\text{O} (l) + \frac{1}{2} \text{O}_2 (g) \quad (1)$$

The reaction from left to right is a spontaneous process and is accompanied by a decrease of free energy. Hydrogen peroxide is a weak acid. For the equilibrium,

$$\text{H}_2\text{O}_2 \rightarrow \text{H}^+ + \text{HO}_2^- \quad (2)$$

(Its dissociation constant is $1.5 \times 10^{-12}$ at 20 $^\circ$C)

Therefore, it is important to optimize the applied dose of hydrogen peroxide to maximize the performance of the UV/H$_2$O$_2$ process and minimize the treatment cost. The optimum dose for this experiment is 5 ml. Where the degradation efficiency reached 92.20%, the hydrogen peroxide concentration is an important parameter to adjust and control the degradation of rhodamine b in the UV/H$_2$O$_2$ reactor.

![Fig. 1. Effect of H$_2$O$_2$ concentration on the degradation efficiency of rhodamine b solution at 50 ppm](image)
Effect of concentration of rhodamine b
The photo catalytic degradation of rhodamine b at different concentration in the range 10-50 ppm was investigated under optimized conditions catalyst dose: 5 ml, pH 7.9 and varying the reaction time. Fig. 2 shows the degradation of rhodamine b as a function of time. The time required for complete degradation was between 3 to 6 hr. when the initial concentration of H$_2$O$_2$ was fixed at 5ml. A decrease in the degradation rate was observed with further increase in the initial concentration of rhodamine b. The results show that by increasing the initial rhodamine b concentration from 10 ppm to 50 ppm the degradation efficiency decreased from 92.20% to 65.50%.

A plausible explanation can be given that since, the hydroxyl radical is mainly responsible for rhodamine b degradation and its concentration remains constant for all rhodamine b concentrations. The increase in rhodamine b concentration increases the number of rhodamine b molecules and not the hydroxyl radical concentration and therefore the removal rate decreases [9].

![Fig. 2. Effect of concentration of rhodamine b at 5ml H$_2$O$_2$ dose](image)

Effect of Reaction time
The degradation percentage always increases with increase in reaction time as can be seen from figure 1 and figure 2. Reaction time was investigated from 1 hr to 5 hr at all combination of concentration of rhodamine b and catalyst dose. In all trial, increased percentage degradation was found. The reaction time reaches to its optimum at 6 hrs, thereafter no change in degradation efficiency was seen.

CONCLUSION
The experimental results presented in this work showed that the application of this new photochemical reactor for the treatment of waste waters containing rhodamine b was well succeeded. This reactor showed to be very promising for industrial applications because of its easy operational procedure and simple design. Furthermore, the use of UV lamp (violet light) results in an important advantage in the economical point of view in relation to usual UV radiation sources.

The studies of the effect of the catalyst dose suggest that degradation increases with increase in catalyst dose up to an optimum loading. Further increase in catalyst dose show
no effect. Also, the initial rate of photo degradation was high at low concentration of rhodamine b and it decreases with increase in initial concentration of rhodamine b. The degradation of rhodamine b was found to follow zero order kinetics. The apparent rate constant values obtained were found to decrease with increase in the initial concentration, it can be concluded that degradation efficiency reached 92.5% with 10 ppm rhodamine b conc. and 5 ml of H₂O₂ dose.

REFERENCES

Cite this article as: