Review

Effect of potassium monopersulfate (oxone) and operating parameters on sonochemical degradation of cationic dye in an aqueous solution

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ABSTRACT

In this study, removal of Cresol Red (CR), a cationic triphenylmethane dye, by 300 kHz ultrasound was investigated. The effect of additive such as potassium monopersulfate (oxone) was studied. Additionally, sonolytic degradation of CR was investigated at varying power and initial pH. RC can be readily eliminated by the ultrasound process. The obtained results showed that. Sonochemical degradation of CR was strongly affected by ultrasonic power and pH. The degradation rate of the dye increased substantially with increasing ultrasonic power in the range of 20–80 W. This improvement could be explained by the increase in the number of active cavitation bubbles. The significant degradation was achieved in acidic conditions (pH = 2) where the color removal was 99% higher than those observed in higher pH aqueous solutions. The ultrasonic degradation of dye was enhanced by potassium monopersulfate (oxone) addition. It was found that the degradation of the dye was accelerated with increased concentrations of oxone for a reaction time of 75 min.

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1. Introduction

The release of colored wastewaters from the textile industry is a current problem encountered by developed and under developed countries over the world. This release in natural environment, mainly in aqueous medium, is undesirable because of the potential transformation of these compounds to toxic and carcinogenic of species. Organic dyes represent one of the large groups of these effluents. However, several treatment processes are available for the removal of this type of pollutants.

For instance, several decontamination methods, such as precipitation, biological treatment [1], coagulation [2], adsorption on various supports [3]. Many advanced oxidation processes (AOPs) were

also used for the oxidation of dyes in water [4,5]. These techniques (AOPs), which involve an in situ generation of highly oxidizing agents such as ·OH radical, have emerged as an important class of technologies to accelerate the non-selective oxidation.

Sonochemical oxidation has been investigated as a viable AOP for the destruction of various pollutants in water. In this technique, the free radicals are generated through transient collapse of cavitation bubbles driven by an ultrasound wave. Ultrasonic irradiation induces the production of cavitation bubbles in the liquid through which it is transmitted. These microbubbles grow during the subsequent compression–rarefaction cycles until they reach a critical size. Further compression leads to the collapse of the bubbles, with the concomitant release of heat and production of chemically active species during the last phase of the bubble collapse [6–8]. This collapse induces localized extreme conditions. It has been reported that the gaseous contents of a collapsing cavity reach temperatures as high as 5200 K and pressures higher than 500 atm, and about 1900 K in the interfacial region between the solution and the collapsing bubble [9]. Under such conditions, molecules trapped in the bubble (water vapor, gases and vaporized solutes) can be brought to an excited-state and dissociate [8]. The radical species produced can recombine, react with other gaseous species present in the cavity, or diffuse out of the bubble into the bulk fluid medium where they are able to react with solute molecules.

In the present work, an cationic dye, Cresol Red (CR), was chosen as a model substrate for a systematic study of the sonochemical degradation process. The aim of this work was to investigate the influence of additive such as potassium monopersulfate (oxone) on the sonolytic degradation of CR. Additionally, the effects of some experimental parameters such as ultrasonic power and pH on the sonochemical degradation of dye was studied.

2. Materials and methods

2.1. Materials

The cationic acidic dye, Cresol Red sulfonate salt, (molecular formula $C_{21}H_{18}O_5S$), was obtained from Sigma–Aldrich and used without further purification (molecular weight: 382.43 g mol^{-1}) which is a highly water soluble, was used as a model solute. The structure CR is shown in Fig. 1. Elemental iron, monopersulfate (oxone), hydrogen peroxide were commercial products of the purest grade available. All solutions were prepared with distilled water.

2.2. Reactor

Sonolysis experiments were performed in a cylindrical water-jacketed glass reactor operating at 300 kHz. Ultrasonic waves introduced from the bottom of the solution through a plate Pyrex surface (diameter 5 cm) holding the piezoelectric disk (Saint-Gobain Quartz, France) with a diameter of 4 cm. The temperature of the solution was monitored using a thermocouple immersed in the reacting medium. The temperature inside the reactor was maintained at 25 ± 1 °C by circulating cooling water through a jacket surrounding the cell. Acoustic power dissipated in the reactor was estimated using standard calorimetric method [10,11]. The reactor was periodically sampled for analysis

2.3. Procedures

The initial concentration of CR solution was 6 10^{-5} M for all experiments. Various aqueous solutions of CR (6 10^{-5} M) contain-
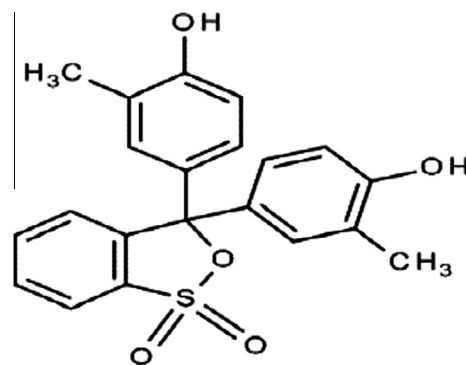

Fig. 1. Chemical structure of Cresol Red.

ing different additives were prepared by adding the required amount of these agents and stirring using a magnetic bar.

Sonolytic degradation of CR was carried out at 300 kHz under different conditions using constant solution volume of 300 mL. Ultrasonic power was adjusted at 20 W, excluding runs conducted to investigate the influence of power. The pH of the solution was adjusted using NaOH or HCl.

The efficiency of the proposed process was evaluated by monitoring CR degradation by measuring absorbance at 432 nm using a UV–visible spectrophotometer. The wavelength resolution and the bandwidth were, respectively, 1 and 0.5 nm. The length of the optical path in glass cell was 1 cm. The temperature of the sonicated solution was kept at 25 °C by circulating cooling water through a jacket surrounding the cell.

Therefore, the concentration of the CR in the reaction mixture at different reaction times was determined by measuring the absorption intensity at 432 nm and from a calibration curve. Prior to the measurement, a calibration curve was obtained by using the standard CR solution with known concentrations. In some cases, a proper dilution was necessary to obtain a well measurable absorption.

3. Results and discussion

3.1. Characterization of CR sonolysis

As shown in Fig. 2, the application of high frequency ultrasound (300 kHz and 20 W) to 300 mL of the aerated CR solution with initial dye concentration of 6 10^{-5} M reduced the initial substrate concentration. The CR concentration decreased exponentially with sonication time following apparent first-order kinetics (Fig. 2.in insertion). Besides the degradation process, the ultrasonic treatment resulted in the formation of hydrogen peroxide according to the Reactions (1)–(7), which can be used to estimate the amount of ·OH radicals released by the bubbles at determined sonochemical conditions.

OS: organic substrate

$$H_2O \rightarrow H^· + ·OH \qquad (1)$$

$$O_2 \rightarrow 2O \qquad (2)$$

$$H + O_2 \rightarrow HOO^· \qquad (3)$$

$$O + H_2O \rightarrow 2·OH \qquad (4)$$

$$·OH + OS \rightarrow HOOS^· \qquad (5)$$

$$2·OH \rightarrow HOOH \qquad (6)$$

$$2HOO^· \rightarrow HOOH + O_2 \qquad (7)$$