

Sonochemical degradation of Basic Blue 41 dye assisted by nanoTiO₂ and H₂O₂

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Abstract

The sonolysis of Basic Blue 41 dye in aqueous solution was performed at 35 kHz using ultrasonic power of 160 W and aqueous temperature of 25 ± 1 °C within 180 min. The TiO₂ nanoparticles were used as a catalyst to assist the sonication process. The effect of experimental parameters such as pH, H₂O₂ concentration and initial dye concentration on the reaction were investigated. It was recognized that in lower pH values the dye removal rate decreased. However, dye removal increased via increase in H₂O₂ concentration and lowering the initial dye concentration. All intermediate compounds were detected by integrated gas chromatography–mass spectrometry (GC/MS) and also ion chromatograph (IC). During the decolorization, all nitrogen atoms and aromatic groups of Basic Blue 41 were converted to urea, nitrate, formic acid, acetic acid and oxalic acid, etc. Kinetic studies revealed that the degradation process followed pseudo-first order mechanism with the correlation coefficient (*R*²) of 0.9918 under experimental conditions. The results showed that power ultrasound can be regarded as an appropriate tool for degradation of azo dyes to non-toxic end products.

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1. Introduction

There are many different classes of dyes, such as azo, anthraquinone, metal complex, azo metal complex and phthalocyanine, reflecting the chromosphere structures of their constituent molecules [1]. Azo dyes are the most important group of the synthetic colorants (60–70%) [2]. The azo group (–N=N–) characterizes them, in association with aromatic systems and auxochromes (–OH, –SO₃, etc.). These chemical groups are combined variously in dye molecules and in that way their bio-elimination from effluents has become an intricate matter. The diverse processes used for decolorization of dyes are based on physical or chemical methods. They include membrane filtration [3–5], electrochemical technology [6–8] and advance oxidation process (AOP) such as photochemical oxidation [9], photocatalysis [10–12] and ultrasonic wave [13–16].

The chemical and biological effects of ultrasonic were reported by Loomis in 1927 [17]. Ultrasonic wave spans the

frequencies of roughly 18 kHz–10 MHz with associated acoustic wavelengths of 10–0.01 cm. The chemical effects of high intensity ultrasound arise from acoustic cavitations of liquids: this rapid formation, growth and implosive collapse of gas vacuoles generates short-lived (–ns), localized “hot spots” whose peak temperatures and pressures have been measured at 5000 K and 1000 atm, confirming earlier calculations (Fig. 1) [18,19].

Interior of collapsing gas bubbles (i.e., the core) in which very high temperatures and pressures exist. Under these conditions the solvent vapor inside the bubble undergoes pyrolysis reactions at the interface between the collapsing bubble and the bulk solvent, where high temperature and pressure gradients exist.

In aqueous solutions, the relative efficiency of non-volatile solutes to decompose thermally or scavenge radicals formed in the hot spot depends on their ability to accumulate at the gas/solution interface of the growing micro bubble and bulk solution at ambient temperature. Free radicals formed in the hot regions may diffuse to the bulk solution and react to yield products similar to those found in aqueous radiation chemistry.

Substrates such as phenol [20], chlorinated hydrocarbons [21], various aromatics [22,23] and dyes [1,24–26] are trans-

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