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Ultrasound enhancement of the reduction of the Basic Green dye in wastewater by cast iron

SHEN Zhuang-zhi, SHEN Jian-zhong

(Institute of Acoustics, Chinese Academy of Sciences, Beijing 100080, China. E-mail: szz6@163.com)

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Dyes in wastewater are of particular environmental concern since they give an undesirable color to the waters, dye and their derivatives are harmful to human health and the environment (Annadurai *et al.*, 2002). Due to their biological persistency, conventional biological treat-ment processes such as activated sludge process are ineffective for their removal(Shaul *et al.*, 1991). There is a need to develop effective methods for the degradation of such persistent organic pollutants, either to less harmful compounds or, more desirable, to their complete mineralization.

Ultrasound(for short US) is successfully used in wastewater treatment in China(Qi *et al.*, 1996; Shen *et al.*, 2005; Wu *et al.*, 2004; Xu *et al.*, 2004). Microelectrolysis(using cast iron) has been employed for dyestuff wastewater(Liu *et al.*, 1995; Cao *et al.*, 1999; Sun *et al.*, 2001), and higher decolourization ratios are obtained(Zhang and Wang, 2004), but the removal ratio of COD_{Cr} becomes lower(Zhang, 2000). In this paper, ultrasound treatment is proposed to enhance the removal ratio of COD_{Cr} of dyes wastewater using Basic Green as a model compound.

Iron scrap was dipped in 2% HCl for 10 min, and then rinsed with distilled water. Stock solution of Basic Green(Beijing Dyestuff Co. Ltd.) was prepared in distilled water. HCl or NaOH was used to adjust the pH of the dye solution to 8—9. The stock solution was fed into a stainless steel reactor(diameter 210 mm, height 132 mm and wall 1.5 mm) with ultrasonic transducer(ϕ70 mm) at the bottom of the tank. Then the pretreated cast iron was added into the reactor, and the ultrasonic generator(250 W) was started. After 10 min, the supernatant solution was analysed for COD_{Cr} by oxidation of the organic compound with $K_2Cr_2O_7$ (M-05 Model) and color with colorimeters(CM-06 Model) (Beijing Shuanghui Jingcheng Electronic Product Co. Ltd.), respectively. In all cases, 100 W of electric power was used, and 1000 ml of solution are treated.

As shown in Fig.1, the removal rate of COD_{Cr} reached 75.82% in the coupled US/cast iron system after 10 min treatment, while only 36.73% of removal rate was achieved with US, where cast iron has 22.66% of removal ratio. The decolorization efficiency reached 97% after 10 min treatment by US/cast iron, while only 65% of decolourization efficiency was achieved with cast iron, where ultrasound had no effect on the decolourization(the data of decolourization ratio is not shown in Fig.1). In all combined experimental cases, the decolorization ratio of Basic Green is more than 95%, so, in the paper, our aim is to study removal ratio of COD_{Cr} of Basic Green.

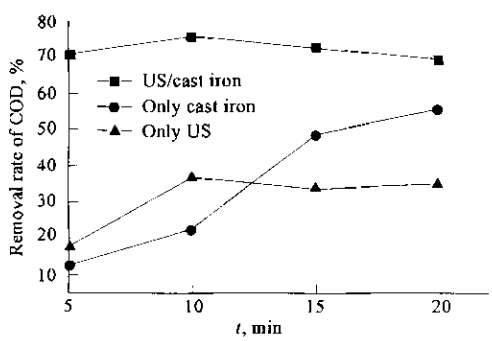

Fig.1 COD_{Cr} removal rate of Basic Green by cast iron with/without sonolysis
C_0=369.70 mg/L, pH=5.8, cast iron= 20 g/L

In the presence of ultrasound irradiation, transient cavitation results in turbulent flow conditions within the reactor that enhance overall mass transport. Ultrasound causes pitting and cracking of the metal surface thus increasing the degradation reaction rates. Moreover cavitation bubble collapse near the cast iron surface in aqueous phase will cause microjets to hit the surface and produce a nonsymmetrical shock wave. The latter leads to cleaning action of ultrasound. As a result of these events, more reactant surface area is readily formed for further surface

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reactions(Hung *et al.*, 2000). Therefore, compared to the cast iron alone, higher decolourization efficiency and removal ratio of COD_{Cr} in the couple US/cast iron system was achieved which can be attributed to the indirect chemical effects associated with the continuous ultrasonic cleaning and activation of the cast iron surface, the enhancement of mass transfer resulting from the turbulent effects of cavitation(Hung *et al.*, 2000).

Fig.2 illustrates the degradation ratio of Basic Green in the combined US/cast iron system at different pH. It shows that the removal rate of COD_{Cr} increased with the decrease of pH. When pH is 3.2, the removal rate of COD_{Cr} reached 82.61% after 10 min treatment. However, when pH is 6.8, the removal rate of COD_{Cr} dropped to only 57.36% . This is because that effective collision between dye molecule and elemental iron happens. Elemental Fe, as an electron donor, loses electrons, and the dye molecule, as an electron acceptor, accepts electrons, combines with H^+ and turns into the transitional product. This product gets electrons from elemental iron and combines with H^+ again, and then it turns into terminal products(Zhang *et al.*, 2005). As a consequence, pH would strongly affect the reduction of Basic Green, i. e., the reaction rate increases with increasing acidity.

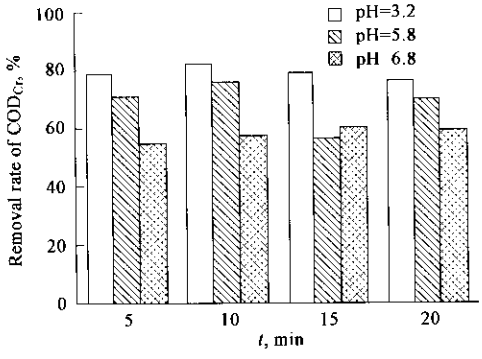

Fig.2 Effect of pH on the removal ratio of COD_{Cr}
C_0= 369.7 mg/L, cast iron is 20 g

As degradation of Basic Green by US/cast iron occurs at the cast iron and H_2O interface, cast iron surface area would affect degradation rate. The more cast iron loading, the more is the cast iron surface area. Therefore, as shown in Fig.3, the removal rate of COD_{Cr} increases with the increasing cast iron loading.

Fig.4 indicates that the removal rate of COD_{Cr} of Basic Green decreases with an increase of the initial dye concentration. When the initial dye concentration C_0 is 369.7 mg/L, the removal rate of COD_{Cr} reaches 85.67% in 10 min. When C_0 rises to 778.62 mg/L, the removal rate of COD_{Cr} drops to only 66.90% in 10

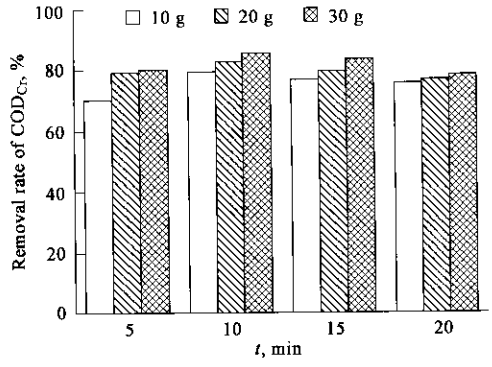

Fig.3 Effect of cast iron loading on the removal ratio of COD_{Cr}
C_0=369.7 mg/L, pH=3.2

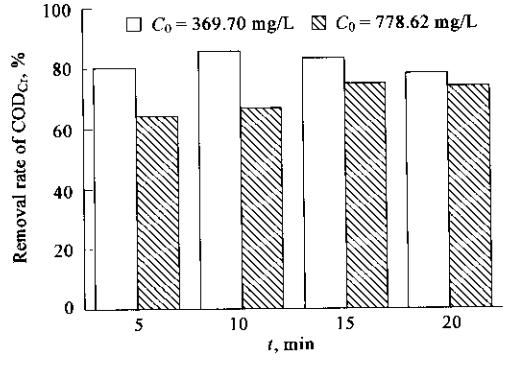

Fig.4 Effect of initial dye concentration on the removal ratio of COD_{Cr}
Cast iron is 30 g, pH=3.2

min. This mainly involves the adsorption of dye onto the cast iron surface and the sequent surface reaction. The adsorption capacity of cast iron is limited when the amount of cast iron is fixed. The adsorption of dye molecules onto the cast iron surface would hinder other dye molecules in the bulk solution to be adsorbed and reduced on the cast iron surface.

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