

Degradation of basic and acid dyes in high-voltage pulsed discharge



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ABSTRACT

The degradation of monocomponent basic dyes (Basic Orange, Methylene Blue), acid dyes (Methyl Orange, Eosin Yellowish) and the mixture of basic and acid dyes was investigated in a gas–liquid series high-voltage pulsed discharge reactor. The decolourization efficiency of the reactor was higher; nearly complete bleaching was achieved in 21 min for all the monocomponent dyes and over 90% bleaching for the mixtures. The total organic carbon removal of the monocomponent was 32% for acid dyes and 22% for basic dyes; the mineralization of mixtures was lower than that of single dyes. On comparing with the single dyes, the energy yield significantly increased when this reactor was used to treat the mixtures. The initial pH and conductivities had significant effect on the degradation of both acid and basic dyes.

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1. Introduction

Effluent from textile and other dyestuff industries contain a large number of synthetic dyes, which have high toxicity to creatures [1,2]. Because they are designed for anti-oxidation, it is very difficult to mineralize them. Promising results have been achieved using advanced oxidation processes (AOPs), such as UV/O₃ [3], UV/H₂O₂ [4], photocatalysis [5], sonophotocatalysis [6], pulsed-discharge technology [7,8] and so on.

Pulsed discharge technology has higher energy efficiency compared with other AOPs [7], which has been also investigated as an efficient way to degrade drugs and toxins [9,10]. It has been demonstrated that various reactive species such as radicals ($\cdot\text{OH}$, $\cdot\text{O}$, $\cdot\text{HO}_2$) and molecular species (H₂O₂, O₃) could be generated in the pulsed discharge process [11–13]. Therefore there has been growing interest in the degradation of dye wastewater [14–16], and either acid or basic dyes have been discussed. The variation of concentrations, pH and conductivity were investigated for acid dyes in pulsed discharge [8,17], and the degradation mechanism of methylene blue (basic dye) was analyzed [18]. It is noteworthy that the chemical structure of dyes had a considerable effect on the degradation process [19,20]. The degradation of basic and acid dyes was compared via other methods, such as electrochemical treatment [21] and sorption [22,23]. So far, the degradation of

single component acid and basic dye mixtures by pulsed corona discharge was compared [24]. However, a few of literatures compared the degradation processes of two-component basic dye mixtures and acid dye mixtures by pulsed discharge treatment.

The present work focused on the degradation of basic dye mixtures (Basic Orange (BO) and Methylene Blue (MB)) and acid dye mixtures (Methyl Orange (MO) and Eosin Yellowish (EY)) in pulsed discharge. The degradation efficiency of basic and acid dye mixtures with different molecular structures was discussed and compared.

2. Materials and methods

2.1. Experimental equipment

Experiments were carried out in a gas–liquid series high-voltage pulsed discharge water treatment reactor, as illustrated in Fig. 1. The voltages of the power supply (DGM, Dalian Power Supply Technology Co. Ltd., China) range from 0 to 60 kV and the pulse frequencies are 0–300 Hz. The power supply has an output capacitance of 67 pF and a pulse rise time less than 100 ns. This reactor consists of a discharge unit (I), a ozone-aerated section (II), and a circulation system.

The discharge unit is a glass cylinder (inner diameter 45 mm, height 300 mm) including two electrodes made of porous titanium plates (diameter 40 mm, thickness 4 mm). The distance between the ground electrode and liquid surface was maintained at 5 mm by the control of a peristaltic pump (BT00-600M). The distance

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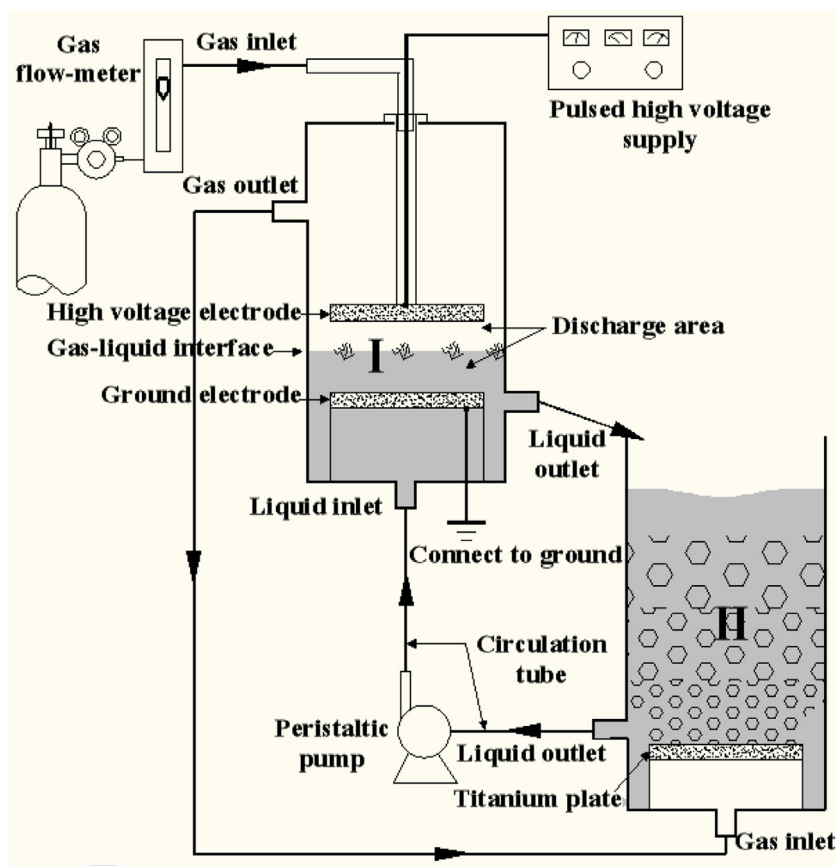


Fig. 1. Schematic of high-voltage pulsed discharge water treatment reactor.

between the high voltage electrode and the liquid surface, namely, the gas layer height was 3 mm. The power supply applied voltage to the high voltage electrode (pore size 100 μm) which was suspended in the gas phase and the ground electrode (pore size 20 μm) that was submerged in the liquid phase. The voltage and pulse frequency chosen in the experiments were 30 kV and 100 Hz, respectively. Electric discharge forms in the aqueous phase along the gas–liquid interface and the gas phase above the solution interface [16]. Oxygen was led into the air chamber through a gas flow-meter (flow rate 160 L/h) then passed through the high voltage electrode and entered the discharge region. Along with discharge, $\cdot\text{OH}$ and H_2O_2 were produced in the liquid phase and O_3 was generated in the gas phase. These reactive species react with the pollutant directly [25].

To make full use of ozone, which was formed by discharge, it was bubbled into the ozone-aerated section. A polyvinyl chloride (PVC) cylinder (inner diameter 50 mm, height 400 mm) with a porous titanium plate (pore size 20 μm) was placed at the bottom. The titanium plate was used to cut the ozone into bubbles (0.2–1.0 mm in diameter), so that these tiny bubbles could provide sufficient mixing of ozone in the liquid phase. As 400 mL of dye solution was injected into the PVC cylinder, circulation tube and peristaltic pump realized the circulation of solution in the discharge unit and the ozone-aerated section.

2.2. Materials

Basic dyes BO (Aladdin Chemistry Co. Ltd., China) and MB (Meilin Industry & Trade Co. Ltd., Tianjin, China) were chosen, which belong to the azo and heterocyclic classes, respectively. Acid dyes MO (Sinopharm Chemical Reagent Co. Ltd., China) and

EY (Kelong Chemical Reagent Factory Chengdu, China) were the same chemical structure as the above basic dyes. The characteristics of each dye are given in Table 1. The reagents in this experiment were analytical grade, and were used without any purification.

2.3. Analytical methods

All the experiments were carried out at atmospheric pressure and room temperature. The total volume of the four monocomponent solutions or the mixtures was 400 mL, and its concentration was 40 mg/L, which were prepared with deionized water. Absorbance was measured by UV-Vis spectrophotometer (UV-3000, MAPADA Co. Ltd., Shanghai) at the maximum absorption wavelength. The width of the quartz cell was 1 cm. The relationship between absorbance and concentration was proved to be linear for all the dyes tested, which was obtained by plotting standard curves. The decolorization efficiency (D) of the monocomponent solutions was expressed as:

$$D(\%) = \frac{(C_0 - C_t)}{C_0} \times 100 \quad (1)$$

where C_0 (mg/L) was the initial solution concentration and C_t (mg/L) was the solution concentration at time t (min).

In mixture systems of acid or basic dyes, as a correction, Eqs. (2) and (3) were applied to spectrophotometry of the residual concentration at the maximum absorption wavelength (Table 1) [26].

$$C_x = \frac{(\varepsilon_{2y}A_{\lambda 1} - \varepsilon_{1y}A_{\lambda 2})}{(\varepsilon_{1x}\varepsilon_{2y} - \varepsilon_{2x}\varepsilon_{1y})} \quad (2)$$

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