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Decolorization and decomposition of organic pollutants for reactive and disperse dyes using electron beam technology: Effect of the concentrations of pollutants and irradiation dose

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ABSTRACT

Dyeing wastewater was known to have strong color and refractory organic pollutants. In this study irradiation alone was used for dyes wastewater treatment. This paper studies the effect of the concentrations of pollutants to its removal at various dosages using electron beam technology. Irradiation was effective in removing the highly colored and refractory organic compounds. The color removal for initial concentrations of 255 CU, 520 CU, 990 CU and 1900 CU treated using irradiation at 0.5 kGy were 61%, 48%, 28% and 16%, respectively. However, at the dose of 108 kGy and higher, the color removal between 87% and 96% were recorded with no apparent trend. COD removal also reported similar trend but at relatively lower removal percentage. The COD removal at 0.5 kGy for initial COD concentrations of 57 mg/l and 515 mg/l were 10% and 0%, respectively. At irradiation dose of 108 kGy, the removal for initial COD concentrations of 57 mg/l and 515 mg/l were 37% and 13%, respectively. This showed that concentrations of pollutants and dose of irradiation applied to remove color and COD were dependent to each other.

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1. Introduction

Textile industry consumes high volume of water. Subsequently, the water discharged resulting from the textile dyeing also is high. Dyeing wastewater requires to be treated because it is significant pollution sources that contain organic dyestuffs, surfactants and additives. Therefore, dyeing wastewater has high concentrations of refractory organic compounds and highly colored (Al-Momani et al., 2002). If not treated properly, effluent will deteriorate the aquatic life of receiving waters. They are hardly biodegradable and their removal using physical treatment, biological treatment or biofilters alone usually is not very effective. Low biodegradability of dyeing wastewater usually restricted the biological treatment processes or the conventional methods.

Radiation technology has been recognized as effective method to treat refractory organic wastewater. Refractory or hazardous organic wastewater is commonly present in industrial wastewater. It is becoming a concern of many countries because industrial wastewater is the major contributors to the declining qualities of freshwater resources. Numerous researches have been conducted on the application of radiation technology for industrial wastewater treatment. The approaches used were combination of radiation technology with conventional methods to remove color and COD. The use of electron beam irradiation with addition of H_2O_2 (Wang et al., 2006) and addition of Fe(III) (Kurucz et al., 1998) to the sample have shown reduction of color and COD of dyeing wastewater. Barrera-Diaz et al. (2003) has reported improvement result when combined electrochemical and gamma-irradiation treatment was applied in sequence to remove color and COD of industrial wastewater. Han et al. (2002) has used the combined electron beam technology and biological treatment for dyeing wastewater treatment. Relatively higher COD reduction is observed using combined electron beam and biological treatment compare to without applying the electron beam irradiation. The effects of air, N_2 and N_2O introduced to sample and followed by gamma irradiation have resulted degradation and decolorization of textile dye (Solpan et al., 2003). Duarte et al. (2000) has used combined electron beam technology with conventional (existing treatment facility) methods to treat industrial wastewater, which showed removal of trihalomethanes, PCE, TCE and others. However, Duarte et al. (2000) did not find significant reduction of COD after irradiation. Combination method of electron beam technology and conventional methods such as coagulation, flocculation, and sedimentation were used by Shin et al. (2002) to remove the color of paper mill wastewater. Paper mill wastewater has similar characteristic to textile wastewater that consists of highly color and refractory organic compounds. Although color and COD of the paper mill wastewater and others showed reduction, they were resulted from

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combination treatments which were not contributed from electron beam technology alone in reducing the color and COD.

As described above, there were numerous scientific research works reporting the combination of radiation technology and conventional method to remove color and COD. This study, however would examine the effects of the concentrations of pollutants and dose applied for color and COD removal of dyeing wastewater using electron beam technology. The objective of this study was to investigate the contribution of electron beam technology alone in removing the color and COD present in dyeing wastewater at various concentrations of raw wastewater.

2. Experimental

2.1. Sampling and sample preparation

Wastewater used in this study was obtained from textile industries situated in Rawang Integrated Industrial Park (RIIP), Malaysia. The compositions of raw dyeing wastewaters were from the mixture of reactive dyes (80–90%) and disperse dyes (10–20%). The pH of collected raw dyeing wastewater was alkaline (Table 1). Prior to irradiation, the raw dyeing wastewater was diluted using distilled water to targeted concentration of color at 255 CU (abs = 0.072), 520 CU (abs = 0.147), 990 CU (abs = 0.280) and 1,900 CU (abs = 0.539). COD was analyzed for samples with color concentration of 255 CU and 1900 CU.

2.2. Irradiation

Experiment was conducted by irradiating the samples which were filled in the petri dishes. The petri dishes filled with samples were placed on the trolley and transported to the irradiation chamber to be irradiated by electron beam. Dosages of the irradiation required were adjusted according to speed of the conveyor and current (mA) of the electron beam applied. This was illustrated in Fig. 1. All samples treatments were conducted at room temperature. PH adjustment was not carried out on the samples prior irradiation. Thus only pH of the actual raw dyeing wastewater collected from the field was conducted in this study. Although the pH of the sample at acidic or neutral might influence the removal of pollutants treated using irradiation, the authors predicted that the removal of the pollutants will displayed similar trend. The samples were analyzed before and after irradiation. Irradiation of sample was conducted using Nissin, 3 MeV and 30 mA in a batch system. The speed of the conveyor used was ranged 0–20 m/min, the current used was varied from 5 mA to 20 mA with energy of 1 MeV and sample thickness was 3.0 mm. Dosimetry was performed using CTA film (FTR-125, Fuji Photo Film Co.). The samples were irradiated using following doses: 0.5 kGy, 2.4 kGy, 8 kGy, 18 kGy, 41 kGy, 53 kGy, 108 kGy and 215 kGy.

2.3. Sample analysis

Analysis of chemical oxygen demand (COD), pH and total suspended solid (TSS) were conducted according to APHA et al. (2005). COD was determined by Hach-2400 spectrophotometer

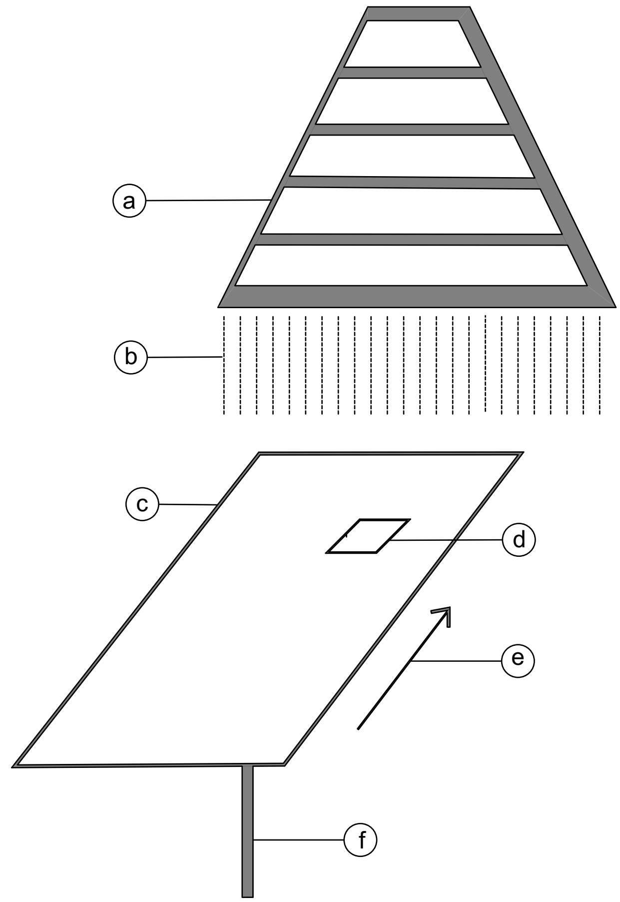

Fig. 1. Schematic diagram of sample irradiation [(a) beam scanner; (b) electron beam; (c) upper part of trolley to put sample; (d) sample filled in petri dish; (e) direction of trolley moving under beam scanner; (f) trolley connected to conveyor].

using dichromate solution for digestion in Hach reactor. pH of the water sample was analyzed using pH meter (WTW Multi 340i). Color measurement was carried out using Shimadzu Spectrophotometer at wavelengths of 456 nm. The color determination was followed according to Method 2120C in APHA et al. (2005). pH was measured according APHA et al. (2005). The analysis of sample was done with duplicate samples.

2.4. Calculation of decolorization and COD removal

The color and COD removal was calculated as follows:

Color removal = $(CU_0 - CU_i)/CU_0 \times 100\%$. CU_0 and CU_i were color unit (CU) before and after irradiation.
COD removal = $(COD_0 - COD_i)/COD_0 \times 100\%$. COD_0 and COD_i were the COD concentration before and after irradiation.

3. Results and discussion

3.1. Effects of substrate concentrations

The highest color removal was recorded for the concentration of color at 255 CU. As the concentrations of color increased, the color removal was decreased. The accumulated color removal (%) for the concentrations of color at 255 CU, 520 CU, 990 CU and 1900 CU were 616%, 598%, 546% and 460%, respectively (Fig. 2). It was expected that the accumulated color removal (%) would further reduce if higher concentration of color than 1900 CU was applied.

Table 1
Characterization of textile wastewater at RIIP

Parameters	Value
pH	10.35–10.45
COD	515 mg/l
Color	1900 CU
Total suspended solid	250 mg/l

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