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Control of textile wastewater by electron beam irradiation in combination with biological treatment

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Abstract: Environmental pollution, especially water pollution, is of great concern nowadays. Textile wastewater treatment by electron beam irradiation (EB) shows the advantage of not using toxic additives and not creating secondary sludge. In this study, textile wastewater was treated by electron beam irradiation in a low absorbed dose range of 0.5-2 kGy in combination with biological treatment. Besides, a study on combining EB irradiation and H_2O_2 oxidizing agent was also carried out to reduce the absorbed dose. The results show that after EB irradiation in the presence of oxidizing agents H_2O_2 combined with biological treatment, the color indicator of wastewater is within the allowed range according to column B of the national technical regulation on the effluent of the textile industry (QCVN 13–MT/2015/BTNMT), which is eligible for discharge into the environment. Research on the treatment of textile wastewater by EB irradiation combined with biological methods has shown that it increases the ability to effectively treat textile wastewater, contributing to reducing the environmental pollution.

Keywords: *Textile wastewater, biological treatment, electron beam irradiation.*

I. INTRODUCTION

In recent years, environmental pollution is a leading problem globally. Population growth and industrial development have resulted in more and more toxic and harmful wastes released to nature. Most of these pollutants are relatively stable, hard to degrade, spread, and remain for a long time, causing diseases and increasing the earth's temperature [1].

In industry, though textile dyeing jobs for a large amount of labor, the main problem facing them is wastewater pollution, because the textile dyeing process carried out by the water solvent and generate large amounts of wastewater [2, 3]. 1 kg of fabric need about 70-150 liters of water for processing. There are many harmful factors to the environment and human health in textile wastewater, including suspended solids, chemicals, colorants, and odorants. The dyes in wastewater can cause several diseases such as hemorrhage, skin ulcers, nausea, etc … [4] In the wastewater, the dyes block sunlight from the water's surface and interfere with the photosynthesis of the plants and phytoplanktons. It reduces oxygen regeneration thereby hindering photosynthetic organisms' growth. Therefore, pollutants and harmful chemicals must be removed from textile wastewater before discharging to nature. Many methods have been applied to remove those substances. The physicochemical processes such as adsorption, flocculation, filtration, oxidation

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have been used to treat textile wastewater but have produced secondary sludge that needs further treatment [3]. The biological method using activated sludge for textile wastewater treatment can effectively reduce COD but cannot complete de-color and requires large treatment space [2, 5-7]. Using electron beam irradiation (EB) to handle decomposition of pollutants in wastewater, waste gas and sewage sludge is interested in current research. This method's main advantage is that the irradiation dissociation process generates the active free radical without the use of harmful chemicals, no secondary sludge generation, high processing speed, and processing at a normal temperature [8, 9]. However, to completely treat textile wastewater, a high absorbed dose of over 20 kGy is required. This issue will be difficult to compete with the current traditional methods. Meanwhile, the irradiated wastewater in the presence of 10 mM H_2O_2 showed an effective reduction in the color degree [10]. The efficiency of textile wastewater treatment by EB irradiation can enhance by combining hydrogen peroxide (H_2O_2) due to the increased concentration of $^{\cdot}OH$ during irradiation in the presence of H_2O_2 [11, 12]. In this study, low dose EB irradiation combined with biological treatment method to enhance color degradation in textile wastewater.

II. CONTENT

A. Materials and methods

1. Experiment

Wastewater was taken directly from the harmonic tank of the textile factory's dyeing department and determined the color concentration parameter. Sampling and sample's treatment were done according to TCVN 6663-1:2011. The wastewater was contained in a sealed plastic container and stored at 0°C-4°C, protected from direct sunlight for 24 hours. The wastewater was filtered through a sand and gravel filter column to remove suspended solids before proceeding to the next experiments.

Next, wastewater was put into the plastic boxes with lids, each with 4 liters and denoted PK-0K, PK-0.5K, PK-1K, PK-2K, PK-1K-OXH10. Particularly for sample PK-1K-OXH10, 10mM H_2O_2 solution was added to investigate the effect of color treatment with the presence of oxidizing agents. Then, samples PK-0.5K, PK-1K, PK-2K and PK-1K-OXH10 were irradiated by the electron beam accelerator UERL-10-15S2 at the Vinagamma center with absorbed doses of 0.5, 1, 2 and 1 kGy, respectively.

2. Aerobic biological treatment model (aeroten) of irradiated wastewater

This study was performed in a spherical glass reactor with a working volume of 4 liters (Fig. 1). Air was supplied by an air pump (ACO-003, Hailea, Taiwan) through the pumice stone at the reactor bottom to provide mixing at an airflow rate of 0.5 m^3/hour. The operational process was as follows: the irradiated wastewater was pumped into the aerobic model from the bottom up by a metering pump to ensure a maximum retention time of 7 days. During the process, the dissolved oxygen index (DO) ensured $\geq$ 2 mg/L for aeration condition [13], and mixed liquor suspended solids (MLSS) was about 4 g/L, equal to 3/8 of the reactor's working volume discharged. Poorly settling sludge was withdrawn periodically to maintain a stable mixed liquor suspended solids (MLSS) concentration in the reactors. At the same time, the pH value was in the range of 6.5 - 8.5. Wastewater was taken to check the color from the vertical valves and outlet in the model.

Fig. 1. Aeroten model

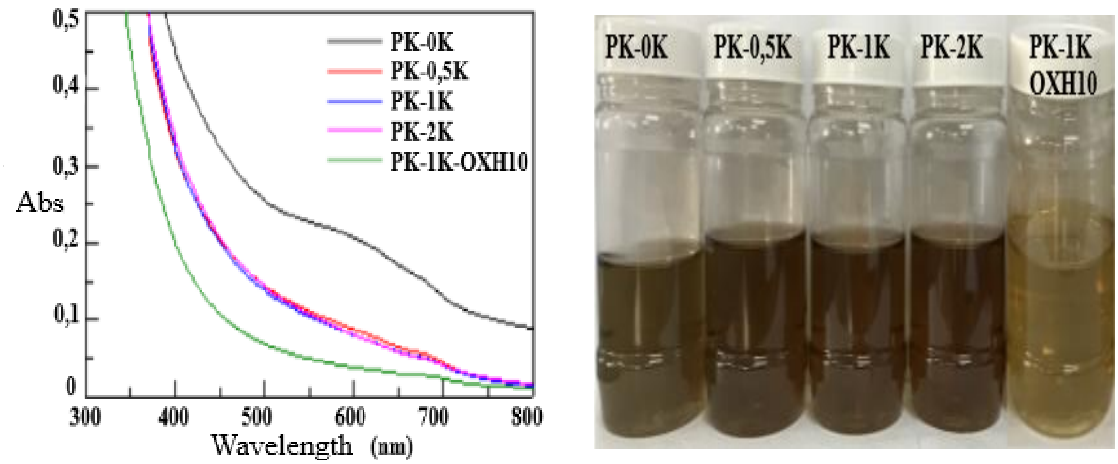
3. Analysis method

Before and after irradiation, the absorption spectra of wastewater samples were measured on a UV-Vis spectrophotometer (Shimadzu V-630) at a 200-1000 nm wavelength, a scanning speed of 400 nm/min. The wastewater sample was diluted 10 times.

The color degree of wastewater after irradiation and biological treatment was analyzed using the standard color-scale method in platinum-cobalt (Pt-Co) units, according to TCVN 6185-1:2008 (ISO 7887:1994) [14].

B. Results

1. Effects of irradiaion dose



(a) (b)

Fig. 2. UV-Vis spectrum (a) and photo (b) of wastewater according to the irradiation dose

In Fig. 2, the UV-Vis spectrum of the pre-irradiated textile wastewater shows an absorption peak at 600 nm. After irradiation, the optical absorption density decreased compared to baseline but found no significant difference in the range of 0.5-2 kGy dose. The optical absorption density of textile wastewater with 10mM H_2O_2, an irradiation dose of 1 kGy, decreased compared to samples without H_2O_2, an irradiation dose of 2 kGy. The color of irradiated wastewater and non-irradiated wastewater has also changed. However, there was no color difference between the 0.5-2kGy irradiation dose. The color of wastewater containing 10 mM H_2O_2 is lighter than that of samples without H_2O_2. It can be seen that the dye in textile wastewater is partially degraded when irradiated at a low dose of 0.5-2 kGy.

Table I. Effect of irradiation dose and H_2O_2 on wastewater color degree

Samples	Color degree (Pt-Co)
PK-0K	567,44 ± 28,37
PK-0,5K	515,90 ± 25,80
PK-1K	547,11 ± 27,36
PK-2K	580,49 ± 29,02
PK-1K-OXH10	303,02 ± 15,15

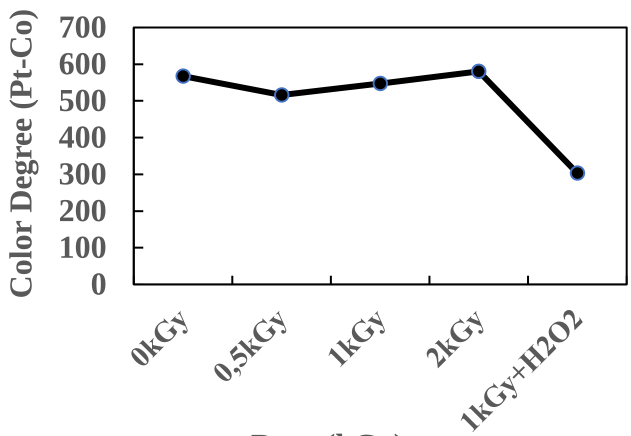


Fig. 3. Effect of irradiation dose and H_2O_2 on wastewater color degree

The effects of irradiation dose and H_2O_2 on wastewater color degree are presented in Table I . The color degree of pre-irradiation wastewater was 567.44 (Pt-Co). When irradiation dose of 0.5 kGy, the color degree of the wastewater decreased to 515.90 (Pt-Co), then it increased to 547.11, and 580.49 (Pt-Co) at the irradiation dose of 1 kGy and 2 kGy respectively. In the presence of 10mM H_2O_2, color degree of wastewater droped drastically to 303.02 (Pt-Co).

3.2. EB irradiation combined with biological treatment method

The results of the combination of EB irradiation and biological treatment method showed in Fig. 4. At the start of the biological process, the color degree in the wastewater range from 303 to 580 (Pt-Co). After 7 days, the sample PK-1K-OXH10 achieve the highest color reduction efficiency, only about 28.4 (Pt-Co) (about 90% compare to the original sample, achieving grade A QCVN 13 2015 [15]). Other wastewater samples also decreased color degree after biological treatment in the range of 70-76%.

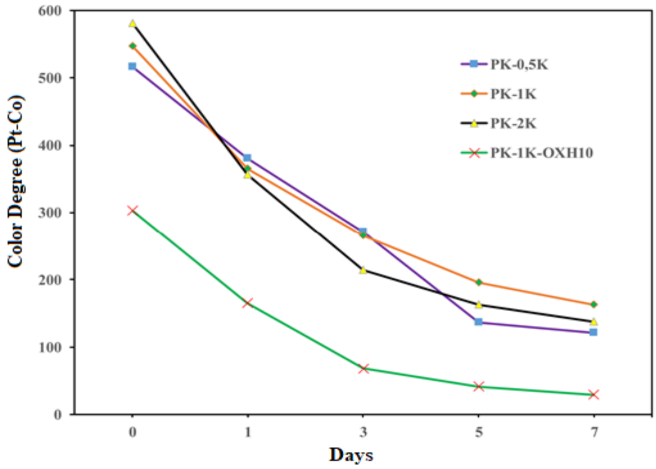


Fig. 4. Color degree of EB irradiated wastewater after biological treatment

C. Discussion

The optical absorption density and wastewater color did not differ between irradiation doses, but in the presence of 10 mM H_2O_2, the dye degradation efficiency at a low absorbed dose of 1 kGy increased significantly. This result was also consistent with the study of author Abdou et al. [8]. The presence of H_2O_2 increased the dye degradation process at any irradiation dose of radiation. Specifically, azo dye completely decomposed at a irradiation dose of 3 kGy in the presence of H_2O_2 and only decomposed 60% at the same irradiation dose in the absence of H_2O_2.

In the range of low irradiation dose of 0.5-2 kGy, the increased irradiation dose increased the color degree of wastewater. This might be since dye molecules decomposed only into segments that were suspended in the water, increased the turbidity of the wastewater. This result was also consistent with the study of Selambakkannu et al. [16]. The turbidity of the EB irradiated wastewater with the absorbed dose less than 10 kGy did not show any difference compared with the non-irradiated sample due to the initial decomposition of pigments in wastewater. When irradiated to 100 kGy, the effluent turbidity showed efficiency reduction due to the complete decomposition of pigments in wastewater.

In wastewater sample using 10 mM H_2O_2, color degree decreased sharply to 303.02 (Pt-Co). The presence of H_2O_2 increased the concentration of $^{\bullet}OH$, which facilitated the complete mineralization of a part of pigment molecule to CO_2 and H_2O, reduced the color degree of the wastewater (reaction 1-3) [8, 17].

$$e^-_{aq} + H_2O_2 \rightarrow OH^{\bullet} + OH^- \quad (1)$$

$$H^{\bullet} + H_2O_2 \rightarrow OH^{\bullet} + H_2O \quad (2)$$

$$Dye + OH^{\bullet} \rightarrow \text{degradation products} \rightarrow CO_2 + H_2O \quad (3)$$

As shown in Figure 4, all the samples were eliminated by activated sludge. Especially, PK-1K-OXH10 sample had reached over 90% in color removal efficiency as compared with around 70% of these other experiments. This finding could be explained by the synergistic of EB with H_2O_2 enhance the biodegradation of the dyes. The samples that did not have H_2O_2 had lower efficiency but, in general, the efficiency of them had little difference. This result was consistent with previous studies [18-20], which the treatment efficiency when adding H_2O_2 increased compared to experiments with only irradiation.

An integrated biological and electron beam would provide a viable alternative and could help remove color from textile wastewater (a hardly biodegradable recalcitrant organic matter). The biorefractory organic compounds were converted into more easily biodegradable compounds around 90% within 7 days (Figure 4). Therefore, to this day, most of the carbon in the organic compound has been converted. There is little food available for the bacteria to consume and the bacteria have formed flocculant to reach endogenous respiration phase [13]. These result consistent with the finding of other studies [21] who found that textile wastewater was effectively treated by the combined process of electron beam radiation and an activated sludge process.

III. CONCLUSIONS

Research on textile wastewater treatment using EB irradiation method combined with the biological method has been carried out. The optical absorption density at 600 nm and color of wastewater did not differ between investigated irradiation doses. Dye in textile wastewater was partially degraded by low irradiation doses of 0.5-2 kGy. Presence of 10 mM H_2O_2 showed to increase dye degradation efficiency at low irradiation doses of 1 kGy. Electronic beam irradiation with the presence of 10 mM H_2O_2 combined with biological treatment has reduced the color degree of wastewater by 90% after 7 days of implementation and achieved grade A QCVN 13 2015.

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