Textile wastewater treatment: colour and COD removal of reactive black-5 by ozonation

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Abstract. Textile industries produced a large amount of highly coloured wastewater containing variety of dyes in different concentrations. Due to the high concentration of organics in the effluents and the higher stability of modern synthetic dyes, the conventional biological treatment methods are ineffective for the complete colour removal and degradation of organics and dyes. On the other hand, physical-chemical treatment are not destructive, mainly just concentrate and separate the pollutants phases. This research paper investigates the removal of colour and chemical oxygen demand/COD from textile wastewater using ozone treatment. Varied ozone dosages of 1.16; 3.81; 18.79; and 40.88 mg/minute were used in the experiment. Varied wastewater containing Reactive Black 5 (RB-5) concentrations of 40 mg/L, 100 mg/L were also applied. Research result showed the highest colour removal efficiency of 96.9% was achieved after 5 hours incubation time, while the highest COD removal efficiency of 77.5% was achieved after 2 hours incubation time.

Keywords: COD, dye, ozonation, RB-5

1. Introduction

Indonesia is ranked among the top ten largest textile producing countries in the world and second largest in South East Asia with more than 4,500 companies [1]. The textile and garment industry is one of Indonesia's oldest industries and being labor intensive as a large source for jobs. The Indonesian government targets to increase the nation's value of exported textiles and garments to USD $75 billion by the year 2030, implying that this industry would contribute around 5 percent to global exports. Although, the textile sector is the flourishing sector in economics but the most important problem is the side impact of these industries. The textile manufacturing process is characterized by the high consumption of resources like water, fuel and a variety of chemicals in a long process sequence that generates a significant amount of waste. The common practices of low process efficiency result in substantial wastage of resources and a severe damage to the environment. The main environmental problems associated with textile industry are typically those associated with water body pollution caused by the discharge of untreated effluents.

During production process, different type of chemicals are used such as strong acids, strong alkalis, inorganic chlorinated compounds, hypochlorite of sodium, organic compound such as dye stuff, bleaching agent, finishing chemicals, starch, thickening agent, surface active chemicals, wetting and
dispensing agents and salts of metals. Various dyes are used during dyeing stage for colouring purposes; multi colours are used to improve best of products [2]. The textile industry consumes large quantities of water and produces large volumes of wastewater from different steps in the dyeing and finishing processes. Wastewater from printing and dyeing units is often rich in colour, containing residues of reactive dyes and chemicals, such as complex components, many aerosols, high COD and BOD concentration as well as much more hard-to-degrade materials [3]. Dye wastewater effluent may lead to environmental problem such as eutrophication in receiving water bodies, and environmental concerns about the possible toxicity and carcinogenicity of some organic dyes. Dyes also decrease light penetration and photosynthetic activity, causing low dissolved oxygen in water bodies [4, 5, 6].

Many methods have been used such as biological, physical and chemical treatment of dye containing wastewater. Among these treatment technique, activated sludge, flocculation, and adsorption are the most commonly applied methods in Indonesia. Biological treatment processes are frequently used to treat textile effluents. However, colour is not readily removed from microbial-based treatment processes. Therefore, due to environmental implications and limitations of each of the above treatment methods, research on combining one of the biological treatment methods with other techniques such as chemical oxidation is needed to ensure a cost-effective and best approach technology for hard-to-degrade dyes/chemicals pollution treatment and control. Biologically treatment organics in textile wastewater must be accomplished via certain methods that enhance the biological degradability of organics, such as ozonation [7], [8].

2. Research Method

2.1. Materials
Azo-reactive black-5 (RB-5) dye was obtained from Bratachem. Dye solutions were prepared by dissolving the dye in distilled water to certain concentration to simulate loaded textile wastewater. Ozone was produced by a corona discharge type ozone generator (Resun RSO25) with dry air used as the feed gas. The ozone was fed into the reactor through a porous glass diffuser located at the bottom of the reactor to produce fine bubbles. The excess ozone leaving the reactor was destroyed by sequential 20 % KI traps incorporated to the reactor set-up as shown in Figure 1. In this study, experiments were conducted at room temperature and no reactor cooling was provided.

![Figure 1. Illustration of the experimental apparatus used for the ozonation.](image)

2.2. Experimental procedure and analysis
The volume of bench scale reactor is 2 L. O₃ is produced from dried air with O₃ output of 1.16; 3.81; 18.79; and 40.88 mg/minute and flow rate of the gas stream of 0.6; 1.4; 2; 4 LPM. Determination of ozone dosage is measured by iodometry method [9]. RB-5 initial concentration used in this study was 40 mg/L, and 100 mg/L. Starch was added to simulate the organic content of textile wastewater. During the experiments, a sample was taken from the sampling port in the batch system at regular time intervals for COD and colour measurements according to the standard methods for the examination of water and wastewater.
3. Results and Discussion

3.1. Colour removal

The changes in dye concentration and colour of RB-5 initial concentration of 40 mg/L after ozonation, are shown in Figure 2 (upper). Colour removal was quite rapid during the first 60 min except for doses 1.16 mg/min and the initial decolourization rate was higher for higher ozone doses. The treatment time of 15 min; colour removal was about 40% for the ozone doses of 1.16 and 3.81 mg/min, and over 60% for the ozone doses of 18.79 and 40.88 mg/min. Similar result was obtained by [10] with 50 mg/L RB-5 initial concentration and 10 g/h dosage of ozone resulting percentage of decolourization was approximately 31.8% after 60 min of reaction time.

The changes in dye concentration and colour removal of RB-5 initial concentration of 100 mg/L after ozonation, are shown in Figure 2 (lower). With ozone doses of 40.88 mg/min, the best efficiency for the removal of colour is 96.9% at 300 min incubation time. Whilst the treatment with the lowest colour removal efficiency corresponded to the ozone doses of 1.16 mg/min with 87.5%. The decolourization efficiency increased with increasing in ozone dosage.

![Figure 2](image_url)  
Figure 2. Colour removal efficiency of 40 mg/L (upper) and 100 mg/L (lower) initial concentration of RB-5 as the function of ozonation duration.

Results obtained in this study showed that colour disappears almost completely for 60 min (40 mg/L RB-5 initial conc.) and 150 min (100 mg/L RB-5 initial conc.) of ozonation, making it promising used as raw water for cleaner production application. Analysis from UV–Vis absorption spectrum (data not shown) of initial RB-5 and treated RB-5 showed that chemical structure breakdown was occurred during the process. However, generated by-products require further treatment for complete degradation [10,11]. The absorbance decay in the UV region is considered evidence of degradation for
the aromatic fragments of the dye molecules and oxidation of their intermediates. Similar result was reported by [12] using photocatalytic reaction in treating Acid Red-4.

![Image](image.png)

**Figure 3.** Visual image of colour gradation of RB-5 (upper: 40 mg/L and lower: 100 mg/L initial concentration) as the function of ozonation treatment with dosage of 40.88 mg/min.

The treatment of simulated textile wastewater was conducted by adding 100 mg/L RB-5 with 1 g/L starch into the reactor and ozonated for 120 minute incubation time. After the incubation period, the rate of colour degradation is slower compared to RB-5 without addition of starch. Organic presence in the wastewater makes the rate of colour removal efficiency decrease from 90% to 75% (Figure 4).

![Image](image.png)

**Figure 4.** Colour removal efficiency of simulated textile wastewater by adding 100 mg/L RB5 with 1 g/L starch.

### 3.2. COD removal

Chemical oxygen demand is a common used parameter for the characterization of organic matter present in textile wastewaters; it depends on the dyes used in the production process. COD removal was observed in all ozonation treatment cases. COD reduction observed from 73.5% to 77.5% (40 mg/L RB-5 initial concentrations) was achieved after 120 minutes of treatment process. Similar COD reduction was found from 70.1% to 77.1% (100 mg/L RB-5 initial concentrations) was achieved after 300 minutes of treatment process. Different result occured in the simulated textile wastewater experiments, where COD reduction efficiency decrease to about 43 – 50% after 120 min incubation time indicating that organics breakdown still in the form of intermediate products (see Table 1).
Table 1. COD removal efficiency.

| Ozone dose mg/min | Removal Efficiency, % |
|-------------------|------------------------|
|                   | 40 mg/L RB-5 | 100 mg/L RB-5 | 100 mg/L RB-5 + 1 g/L starch |
| 1.16              | 77.5         | 77.1          | 43.8                     |
| 3.81              | 65.0         | 73.6          | 50.7                     |
| 18.79             | 70.9         | 64.5          | 44.9                     |
| 40.88             | 73.5         | 70.1          | 46.4                     |

3.3. Biodegradability

The biodegradability of the dye was performed for the simulated wastewater containing RB-5 dye and organics. Although the transformation products were not identified, the degradation of RB-5 into other by products was monitored by the change in the degree of oxidation. Research results showed that \( \text{BOD}_5/\text{COD} \) values of RB-5 mixture are increased after ozonation treatments as can be seen in Figure 5. This indicated that partial breakdown of complex into simpler compound is occured after ozonation process, making it more readily or suitable for biological process treatment.

![Figure 5. Change of biodegradability index (BOD$_5$/COD) during the ozonation of RB5.](image-url)

4. Conclusion

The presented lab-scale ozonation treatment of RB-5 dye was designed to evaluate treatment efficiencies for colour and COD removal system. The results indicated that ozonation shows a promising efficiency in removing both colour and COD. Since ozone system represents a significant cost, instead of ultimate degradation to complete mineralisation of organic compounds, a partial breakdown to more readily biodegradable compounds is more preferable. After partial oxidation by ozone, biological process that utilize microorganisms can be used in a post-treatment process for complete mineralization of dye and organics in the wastewater. Therefore, the use of ozonation combined with biological degradation process may provide more economical and effective process in the treatment of highly coloured wastewater.

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