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Decolourization of remazol black-5 textile dyes using moving bed bio-film reactor

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Abstract. The desizing and dyeing processes in the textile industries produces wastewaster containing high concentration of organic matter and colour, so it needs treatment before released to environment. In this research, removal of azo dye (Remazol Black 5/RB 5) and organic as COD was performed using Moving Bed Biofilm Reactor (MBBR). MBBR is biological treatment process with attached growth media system that can increase removal of organic matter in textile wastewater. The effectiveness of ozonation as pre-treatment process to increase the removal efficiency in MBBR was studied. The results showed that in MBBR batch system with detention time of 1 hour, pre-treatment with ozonation prior to MBBR process able to increase the colour removal efficiency of up to 86.74%. While on the reactor without ozone pre-treatment, the colour removal efficiency of up to 68.6% was achieved. From the continuous reactor experiments found that both colour and COD removal efficiency depends on time detention of RB-5 dyes in the system. The higher of detention time, the higher of colour and COD removal efficiency. It was found that optimum removal of colour and COD was achieved in 24 hour detention time with its efficiency of 96.9% and 89.13%, respectively.

Keywords: decolourization, textile, dye, MBBR, ozonation, RB-5,

1. Introduction
The production processes in textile industry not only utilizes large quantity of water and energy but also generates large amount of waste products. Desizing and dyeing processes can generate high organic and dyes pollutants in the textile industry. The effluent generated by the textile industry is an important issue to be treated. Unfortunately, Indonesian government standard for textile wastewater for colour parameter is not regulated so far (The Indonesian Ministry of Environment and Forestry Decree No. 5 Year 2014) [1], [2]. Generally, the synthetic dyes are widely used for dyeing process of textile products in Indonesia. Among of those, azo dyes are the most used ones [1] and estimated that they represent about 60 to 70 % of all dyes commonly used [2]. Azo dyes are characterized by the presence of –N=N- bonds, linked to aromatic groups [3]. About 10 to 15% of the dyes used in dyeing processes is not incorporated into the fabric or product, and therefore, is released in the effluent. Likewise in the desizing process, it can generate high organic pollutants and be a significant environmental pollution source. The concentration of BOD from textile waste is about 80-6,000 mg/L,
while the concentration of COD is about 150-12,000 mg/L and the ratio of COD and BOD is about 1.5: 1 to 3:1 [4].

In recent years, studies are focusing on hydraulic systems combining the advantages of suspended growth and the biofilm system. The Moving Bed Biofilm Reactor (MBBR) has been developed as one of the most attractive hydraulic systems [5]. Moving bed biofilm reactor (MBBR) is a type of biological treatment using attached growth processes in media. MBBR process has the advantages of both activated sludge and bio-film systems. MBBR can be operated similar to activated sludge process with the addition of freely moving carrier media. Carrier elements provide a surface for bacterial growth. Carrier elements have lighter density than water so they continuously move along with water stream inside the reactor [6]. This technology has the removal efficiency almost similar to activated sludge system for treating organic matter, but the advantages of this MBBR system is just requires a smaller reactor tank [7]. Other advantages for MBBR like smaller size, no sludge bulking, high concentration of biomass, tolerance to loading impact, high COD loading, no need of periodic backwashing [8]. Despite the widespread use of cost-effective biological processes for the treatment of several types of municipal and industrial wastewaters, studies have shown that aerobic biological processes are not capable of effective decomposition of azo dyes [9]. It is because the textile waste has low BOD/COD ratio (less biodegradable), hence it is necessary to give a pre-treatment before biological process [6]. Studies have shown that the processes of chemical oxidation appeared as suitable alternative for the pretreatment of textile waste containing organic dyes due to their capability of high colour removal. Among the processes of oxidation, the ozonation process is preferably for certain applications, such as dye colour removal. Ozone can rapidly break the azo bond, and remove colour in short time intervals [10]. Meanwhile, ozonation can increase the biodegradability of dyes, enable the use of a subsequent biological process.

In this study, RB-5 dyes will be treated using ozonation as pre-treatment and then using biological treatment by moving bed biofilm reactor (MBBR). The purpose of oxidation using ozone is to increase the biodegradability of RB-5 prior to biological degradation.

2. Research Method

2.1. Materials

Azo Reactive Black-5 (RB-5) dye and starch as carbon were obtained from environmental laboratory, Indonesian center for textile, Bandung. The ozone generator type RSO-25 was used with O₃ output of 400 mg/hour. An artificial wastewater was prepared in the laboratory by mixing ozonated or non-ozonated dye solution with the following compounds: Azo Reactive Black-5 (RB-5) as the main colour source of 100 mg/L and starch as the main carbon source to reach 1,000 mg/L of COD. The concentration of colour is about 100 mg/L and the organic is about 1000 mg/L represented the characteristic of dye and organic in the real condition based on study literature. The media used for MBBR is Kaldness K1 with volume to reactor ratio (V_media/V_reactor) of 20%. The cylindrical-shape MBBR carrier was made of polyethylene with a density of 0.123 g/mL and a diameter of 10 mm with cross inside. The carrier materials are shown in Figure 1.

| Specification | Value          |
|---------------|----------------|
| Material      | Plastic (PE)   |
| Diameter      | 10 mm          |
| Thickness     | 0.5-0.8 mm     |
| Shape         | cylinder       |
| Density       | 0.123 gr/mL    |
| Surface area  | 500 m²/m³      |
A laboratory scale acrylic reactor with a total volume of 5 L was used for this study (diameter x height of 14 x 32 cm, respectively). Aeration was provided by a porous air diffuser connected to a compressed air line, located at the bottom of the reactors. The function of aerator is to mobilize the media contained in the reactor and provide dissolved oxygen to keep the system in aerobic conditions (with a minimum dissolved oxygen concentration of 4 mg/L). The microorganism used is a mixed culture obtained from the Textile Wastewater Treatment Installation in Bandung City.

2.2. Experimental procedure and analysis
RB-5 dyes are difficult to treat by biological process only, hence it is necessary to give a pre-treatment before biological process. The purpose of oxidation using ozone is to increase waste biodegradability, make it easier to enter biological process. The ozonation process aims to increase the ratio of BOD/COD to 0.5. While In other set of experiments, the other reactor directly processed using MBBR without ozone oxidation pretreatment.

2.2.1. Ozone pre-treatment. Ozonation was performed in a 2 L glass column. Ozone was generated from a commercial ozone generator (Resun RSO-25) and continuously introduced through a porous diffuser to the system. The applied ozone dose was set at 0.4 g O₃/hour, with airflow of 1.4 L/min. The applied ozone time detention was set for 120 minutes. The ozone concentration and detention time used were obtained based on previous research using the same dye, ozone generator and reactor. No pH adjustment was carried out during the ozonation tests.

2.2.2. Analytical method. The main parameters measured are colour and COD. The COD measurement method is based on 5220D (APHA, 2005) standard method. While the colour absorbance of RB-5 was measured at maximum wavelength (590 nm) using a spectrophotometer JENWAY 6305 type.

3. Results and Discussion
Azo dyes are difficult to treat by biological treatment only. Then, the ozonation process is introduced as pre-treatment before MBBR. The results show that ozonation can remove the organic content from 993 mg/L COD decreased to 397.20 mg/L. Ozone is able to oxidize the organic compounds contained in the carbon source i.e. starch. In addition, it is known that oxidation using ozone can enhance biodegradability of RB5. The process of ozonation can reduce the concentration of COD, so it enhances the ratio of BOD/COD. The obtained ratio of BOD/COD is 0.23 enhanced to 0.42. The ozonation process remove RB-5 dyes with an initial concentration of 121.8 mg/L decreased to 59.1 mg/L. The oxidation using ozone causes the primary degradation process with the changes in the structural of RB-5 compound. Therefore, the biodegradability of RB-5 dye is enhanced [11].

Each MBBR was filled with Kaldness k1 carrier by 20% (v/v). Before receiving dye wastewater, microorganisms were attached to the Kaldness K1 carrier using activated sludge collected from a Textile Wastewater Treatment Installation in Bandung City. COD and colour removal from RB-5 dye were tested on a lab-scale reactor to investigate the decolourisation on both variation used.

![Figure 1. (a) Kaldness 1 media (K1); (b) Biofilm attached on K1 media.](image)
3.1. COD removal

In this research, the initial concentration of COD is 928 mg/L. Ozonation process has removed the concentration of COD about 76.90%. It decreases from 928 mg/L to 214.4 mg/L. The COD removal in both reactors is shown in Figure 2. The result shows that MBBR system can decrease COD in the both reactors. Biological treatment is able to treat organic compounds sourced from starch (less degradable with the ratio of BOD/COD 0.23). While the other reactor with ozone pre-treatment, the ratio of BOD/COD is increased to 0.42. The result shows that the COD removal efficiency in both reactors is different. R1 is more efficient to remove organic compound than R2. The removal efficiency of R1 is 59.31%, and R2 is 72.07%. It is because the ozonation process is able to oxidize organic compounds, and increase the COD removal. The result also shows that the efficiency of COD removal and time have a linear relation. The maximum of removal efficiency in both reactors occur at 48 hours. The removal efficiency of COD during contact time for 48 hours on R1 and R2 are 87.59% and 85.86%, respectively.

![Figure 2. Removal of COD in both MBBR reactors.](image)

3.2. Colour removal

The initial concentration of colour in the batch system is 131.07 mg/L. Ozonation process removes the colour concentration of RB-5 down to 100.59 mg/L. Ozone acts as the powerful oxidising agent because it can easily decompose azo bond on the dyes that causes the colour to disappear. Oxidation in specific compounds is characterized by the occurrence of primary degradation, which there is a structural change in the main compound [11]. The results show that the significant colour removal in both reactors occurs at the first hour. The efficiency of colour removal in R1 and R2 is 86.74% and 68.6%, respectively. However, after 6 hours of incubation time, the concentration of colour was increasing (Figure 3).

![Figure 3. Decrease of colour on RB-5 dyes in both reactors.](image)

This result suggests that biosorption process took places in the first hours of colour removal whereas the RB-5 dye was adsorbed by biomass in the MBBR reactor. The removal of colour is constant after 24 hours indicated by no significant colour change. The visual of colour removal is shown in Figure 4.
3.3. Biological process on continuous system
The application of MBBR on continuous system aims to conduct similar condition with the existing condition. The hydraulic retention time (HRT) was varied to investigate the shock loading resistance of both reactors. The determination of HRT is obtained from the batch system result. Variation of HRTs used is 24 hours, 18 hours, 12 hours and 6 hours.

3.3.1. COD removal. The process of COD removal on the continuous system depends on HRT. The greater the HRT, the smaller the organic loading rate (OLR). The result shows that the COD removal changes significantly in both reactors as the HRT decreases from 24 to 18 h. By further decrease of HRT, the COD removal declined apparently. Reactor with ozone pre-treatment is more efficient compared to reactor without ozone pre-treatment. The average COD removal on both reactors is shown Table 2. The result indicates that the MBBR had a strong resistance to shock loading. The longer duration was beneficial for microorganism to degrade pollutants.

| HRT (hour) | R1 (+ Ozone + MBBR) | R2 (− Ozone + MBBR) |
|------------|---------------------|---------------------|
|            | COD  | Colour | COD  | Colour |
| 24         | 89.13% | 96.95% | 83.63% | 81.21% |
| 18         | 67.98% | 85.68% | 61.06% | 76.89% |
| 12         | 62.56% | 82.89% | 49.97% | 76.37% |
| 6          | 51.08% | 78.83% | 37.55% | 75.74% |

3.3.2. Colour removal. Decolourization of colour in the continuous system utilizes the activity of microorganisms. The result shows that R1 (reactor with ozone pre-treatment) has higher efficiency than R2 (reactor without ozone pre-treatment). The colour removal changes significantly in R1 reactor when HRT was also reduced. The average of colour removal in R1 reactor was 96.95%, 85.68%, 82.89% and 78.83% at 24, 18, 12, and 6 h HRT, respectively. While in the R2, the colour removal is still constant and not affected by HRT. The average of colour removal on the both reactor is shown in Table 2. In the continuous systems, the colour removal process is caused by aerobic bacteria. The microorganism uses carbon from dyes solution as their carbon source to support their growth.
4. Conclusion
A lab scale Moving Bed Biofilm Reactor (MBBR) system was operated to treat RB-5 dye. Biological treatment process was conducted in batch system to treat RB-5 dyes by ozone pre-treatment and without ozone pre-treatment. The pre-treatment process aims to examine the effectiveness of ozone in the removal of COD and colour in MBBR system. The results show that in the batch system, MBBR can decrease COD and colour in both reactors. Significant removal of colour in both reactors occurs at the first hour, but R1 (with ozone) has higher removal efficiency of colour than R2 (without ozone). The removal efficiency of colour in the both reactor was 86.74% and 68.6% respectively. While the result of COD removal shows that R1 is more efficient to remove organic compound than R2. The removal efficiency of R1 and R2 is 59.31%, and 72.07%, respectively. While in the continuous system, pretreated reactor with ozone pre-treatment is more efficient than without ozone pre-treatment. The average removal of colour and COD at 24 h in R1 reactor was 96.95% and 89.13%, while in R2 reactor was 81.21% and 83.63%, respectively. It is known from continuous system that the removal of COD and colour are affected by HRT.

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References
[1] The Indonesian Ministry of Environment and Forestry, Wastewater effluent standard for industries, Decree No. 5, 2014.
[2] Ghaly A E, Ananthashankar R, Alhattab M, and Ramakrishnan V V. 2014. Production, characterization and treatment of textile effluents: a critical review. J. Chem. Eng. Process Technol. 51:18.
[3] Wang C, Yediler A, Lienert D, Wang Z, and Kettrup A. 2003. Ozonation of an azo dye C.I. Remazol black 5 and toxicological assessment of its oxidation products. Chemosphere. 52:1225–32
[4] Azbar N, Yonar T, and Kestioglu K. 2004. Comparison of various advanced oxidation processes and chemical treatment methods for COD and colour removal from polyester and acetate fiber dying effluent. Chemosphere. 55:81-6.
[5] Shin D H, Shin W S, Kim Y H, Han M H, and Choi S J. 2006. Application of a combined process of moving-bed biofilm reactor (MBBR) and chemical coagulation for dyeing wastewater treatment. Water Sci. Technol. 54:181-9.
[6] Francis A, and Sasomony K J. 2015. Treatment of pre-treated textile wastewater using Moving bed bio-film reactor. Procedia Technology. 24:248 - 55.
[7] Esmaeiliard N, Borghesi S M, and Vosoughi M. 2015. Kinetic of ethylene glycol biodegradation in a sequencing moving bed biofilm reactor. Journal of Civil Engineering and Environment Science. 1:2-7.
[8] Borkar R, Gulhane M, and Kotangale A. 2013. Moving Bed Biofilm Reactor - A New perspective in Wastewater Treatment. IOSR Journal of Environmental Science, Toxicology and Food Technology. 6:15-21.
[9] Forgacs E, Cserháti T, and Oros G. 2004. Removal of synthetic dyes from wastewaters: a review. Environ Int. 30:953–71.
[10] Castro F D, Bassin J P, and dezotti M. 2011. Treatment of a simulated textile wastewater the Reactive Orange 16 azo dye by a combination of ozonation and moving-bed biofilm reactor:evaluating the performance, toxicity, and oxidation by-product. Environ Sci Pollut Res Int. 24:6307-16.
[11] Tchobanougous G, Burton F L, and Stensel H D. 2003. Wastewater engineering: treatment and reuse, New York: McGraw-Hill.