Development of Aerobic Microbial Granules to Enhance the Performance of Activated Sludge Technology for Wastewater Treatment Application

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Abstract. Batik industry is one of textile industries in Indonesia generally in small and medium scale and has not good management of by-products in the form of wastewater. Wastewater from batik industry consist of complex and toxic pollutants hence need to be treated in order to support the development of environmentally friendly sustainable industry. Some researches have treated batik wastewater using conventional biological treatment such as anaerobic and activated sludge but optimal results have not been obtained. This research aims to develop a compact aerobic microbial granule with good endurance, which also rich in carbon and nutrient oxidizer bacteria to treat batik wastewater. Sequencing Batch Reactor (SBR) with volume of 8 L fed with Acetate (COD = 900-1000 mg/L), then aerated for 180 minutes. Settling time variation was from 20 to 3 minutes, with 50% liquid withdrawal. In the 4 weeks operation there is increasing of MLVSS reached on 4760 mg/L with COD removal reach on 91.94%. The depletion of dissolved oxygen take effect on decreasing of MLVSS and COD removal.

Keywords: batik industry, wastewater, aerobic granule

1. Background
Industry is one of the main national development sectors in Indonesia, but in the other side it has negative effect to the environment because of the discharge of its waste. Batik industry is a kind of textile industry potentially pollute environment by toxic and complex pollutant in wastewater. Some methods have been developed in treating batik wastewater chemically as well as biologically. Rustiana et al. [1] have tried to treat batik wastewater using coagulation-flocculation process, subsequently treating batik wastewater using anaerobic-activated sludge system [2] has also been conducted and all of them have not gotten optimal result.

Biological system in wastewater treatment still become a choice because it is environmentally friendly without produce dangerous and toxic byproduct. The development of aerobic granulation is not well studied and not yet widely applied in wastewater treatment technology compared with anaerobic granulation technology. Aerobic wastewater treatment technology still relies mostly on conventional Activated Sludge (AS) technology, which has many drawbacks i.e: massive sludge production, gigantic
reactor requirement, loading rate fluctuation and also relatively low in volumetric conversion capacity [3]. To address those drawbacks, aerobic microbial granule is proposed.

Compared with conventional activated sludge technology, aerobic microbial granules have shorter settling time, higher pollutant loading strength and better in dealing with shock loading [4,5,6]. Beside the ability of removing pollutant, aerobic microbial granules can be inactivated and be stored for some period of time without aeration, then later can be re-activated to be used as seed [7,8]. Aerobic granule have been developed and successfully treated brewery and wine industry wastewater even phenolic wastewater [9,10,11]. These advantages make aerobic microbial granules can be low-cost alternative for full scale application of biological wastewater treatment technology. This research aims to develop a compact aerobic microbial granule with good endurance, which also rich in carbon and nitrogen oxidizer bacteria.

2. Research Methodology
Batik wastewater derived from Sanggar Batik Semarang 16 in Semarang, Indonesia and then analyzed based on quality standar of textile wastewater according to Central Java Province regional regulation No. 05/2012.

Sequencing Batch Reactor (SBR) with volume of 8 L was used. An aeration unit with diffusers were inserted inside the SBR. SBR was initially filled with sludge seed generated from bakery industry activated sludge system. Macronutrients were added in the ratio of C:N: P= 100:5:1. Micronutrients such as buffer phosphate, FeCl$_3$ and Mg(SO$_4$)$_2$ were added. SBR was aerated continuously until reactor was ready to be used.

SBR (filled with sludge seed) was feed with Acetate (COD = 900-1000 mg/L) until volume reach at 8 Liters then aerated for 180 minutes. Afterwards, aeration was stopped and let the sludge settle, then 50% of the liquid was withdrew. SBR was feeding with acetate again until volume reached 8 L again (which means 4 L liquid was added). This cycle was running twice per day. Starvation period (no feed, just aeration) was keeping for 18 hours.

Settling time was varied from 20 to 3 minutes, running for a week at every settling time. Observation parameters were Dissolved Oxygen (DO), Mixed Liquor Volatile Suspended Solid (MLVSS), and Chemical Oxygen Demand (COD).

3. Results and Discussion

1. Batik Wastewater Characteristic
Batik wastewater consists of dye (natural and azo) and also wax, therefore categorized as toxic and complex pollutant wastewater. Characteristic of batik wastewater collected from equalization tank has been analyzed and presented in Table 1.
Table 1. Batik wastewater characteristic.

| Parameter       | unit | Wastewater analysis result | Standard of Central Java province regional regulation No. 05/2012. |
|-----------------|------|---------------------------|---------------------------------------------------------------|
| I. physical     |      |                           |                                                               |
| Temperature     | °C   | 29                        | 38                                                            |
| Total suspended solid | mg/L | 2461                      | 50                                                            |
| II. chemical    |      |                           |                                                               |
| BOD\textsubscript{5} | mg/L | 1105                      | 60                                                            |
| COD             | mg/L | 7858                      | 150                                                           |
| Total Phenol    | mg/L | 0.058                     | 0.5                                                           |
| Total Chrom     | mg/L | <0.010                    | 1.0                                                           |
| Total Amonia    | mg/L | 1.725                     | 8.0                                                           |
| Sulfide         | mg/L | 5.030                     | 0.3                                                           |
| Oil and grease  | mg/L | 2.50                      | 3.0                                                           |
| pH              | mg/L | 9.1                       |                                                               |
| MBAS            | mg/L | 0.383                     | 0.185                                                         |

According to Table 1, can be seen that for the most part of parameters are far beyond the quality standard mainly in BOD\textsubscript{5}, COD and sulfide parameter, hence batik wastewater need to be treated before discharged to the environment.

2. Effect of dissolved oxygen in MLVSS concentration

The development of the granule in the operation process can be detected by measuring MLVSS (mixed liquor volatile suspended solid) that present the number of organic material (microbe). It was reported that the process of granulation was influenced by various factors there were microbial seeds, substrate composition, organic loading rate, feeding strategy, reactor design and hydrodynamic, settling time, intensity of aeration and exchange ratio [12-17]. In this research observed that, development of granule influenced by concentration of dissolved oxygen. Can be seen in figure 1, depletion of dissolved oxygen causes the decline of MLVSS. The highest concentration MLVSS is 4760 mg/L occurred in week 2 when concentration of dissolved oxygen is between 4.49-4.32 mg/L, then getting lower in to 1800 mg/L with the decreasing of dissolved oxygen in 0.29 mg/L. Some research results revealed that dissolved oxygen in the aerobic granulation process can be given with a low concentration of 0.7-1 mg/L, as well as with high concentrations of 2-6 mg/L [6], but in this experiment with the low concentration of dissolved oxygen performs decreasing of MLVSS concentration.

3. Degradation of organic material

In the process of development granule observed the degradation of organic carbon (acetate) as single source of carbon. In this research, the removal of organic carbon reach on 91.94% with concentration of COD influent was 966.4 mg/L, which is achieved on week 2, and afterwards the performance of removal COD getting lower in to 54.64% in week 4. The trend of organic material degradation presented in figure 2.
Figure 1. Dissolved oxygen vs MLVSS

Figure 2. Degradation of organic carbon
In this experiment, can be observed the relationship between dissolved oxygen, MLVSS and removal of organic carbon. The depletion of dissolved oxygen decreases concentration of MLVSS, and the removal of organic carbon getting lower with the decreasing of MLVSS concentration. It is understandable that the lower MLVSS concentration, the less microorganism that consume organic carbon, hence the removal of COD also decrease. The relationship between MLVSS and removal organic carbon presented in Figure 3.

4. Visual characteristic of the granule
Some researchers stated that granule with high physical strength would withstand high abrasion and shear. The physical strength of granule expressed as integrity coefficient, for the aerobic granule grown on glucose and acetate possess integrity coefficient higher than 95% [18], smaller size granules tend to be denser than larger aerobic granule [19,20]. In this research visual appearance of the granule can be seen in figure 4. In the start period, the sludge is still in floc form, then after 1 week operation granule begin to be formed in conjunction with the increasing of MLVSS. In week 2 and 3 observed that form of granules are getting broken with the decreasing of MLVSS and dissolved oxygen, and finally in week 4 the granule is not visible anymore.

The dense granule has not been formed in this research, it may be caused the decreasing of dissolved oxygen concentration. The depletion of dissolved oxygen concentration in operation process can be caused by inhibition of continuous aeration, therefore in the next research intermittent aeration is suggested.
Waste water from batik industry consist of pollutant hence need to be treated before discharged to the environment. In the development granule, the depletion of dissolved oxygen cause the decreasing of MLVSS. Removal of organic carbon are getting lower with the decreasing of MLVSS. The highest MLVSS concentration and removal pollutant are 4760 mg/L and 91.94% respectively after 2 week operation. The dense granule has not been formed in this research predicted because of the depletion of dissolved oxygen in the operation process. Continuous aeration is predicted cause depletion oxygen concentration, hence intermitten aeration or idle time is needed to hold on oxygen concentration in the aerobic granule system.

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