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Reduction of BOD and COD of by using stratified filter and constructed wetland for blackwater treatment

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Abstract. Blackwater is a type of domestic wastewater that must be processed before discharge into the river. This study uses gravel, sand, and charcoal as filtration materials which arranged from coarse to fine, and also wetland system using Vetiver grass (*Vetiveria zizanioides*) and Cattail (*Typha angustifolia*). The treatment process is obtained by applying different treatments related to the sand thickness and blackwater residence time in the wetland. The focus of observation is emphasized on the measurement of BOD (Biological oxygen demand) and COD (Chemical oxygen demand). Both parameters measured and compared with the standard of water for agricultural purposes (Grade IV) regulated by Indonesian Government. The results showed that stratified filters can reduce the levels of BOD and COD effectively. The final results obtained after blackwater flowed through the wetland tube shows that BOD and COD levels have yet to meet the standard of grade IV water, although the overall result indicated the significant reduction of both parameters. This can be related to the input of organic matter from wetland itself, and it also can be considered an indication that blackwater treatment requires longer residence time.

1. Introduction

Various anthropogenic activities have an absolute potential to produce residues or waste. Wastewater is the most common domestic waste that pollutes rivers up to 50-70% [1]. Pollution may occur if the amount of wastewater discharged into the river has exceeded the natural capacity of self-purification. In other words, the amount of pollutant has exceeded the standard [2]. The increasing volume of wastewater is often not supported by the availability of environmental sanitation infrastructures. Wastewater requires adequate handling as it can generate environmental disturbances and serious health

problems for humans. These impacts begin when wastewater contaminate raw water sources used for daily basis [3].

As a crucial natural resource, water needs to be sustainably managed so that both the availability and quality are able to meet the standard for basic purposes [4]. Blackwater is a type of wastewater that must be processed before discharge into the river. This is due to the high pathogenic bacteria and other pollutants that come from human feces. Generally, blackwater is stored in a septic tank or directly channeled to the sewage system and then processed in the treatment plant.

Various solutions have been developed to improve the output quality of blackwater treatment, such as filtration method and wetland. Previous research has shown that the filter materials such as gravel and sand can be used for water purification [5]. In addition, charcoal can also be used as color and odor in water filter due to its activated carbon content [6]. Charcoal is a convenient filter material for water treatment since it can reduce various chemical and physical pollutants, and also cheap and easy to get [7].

Constructed wetland can be used to complement or refine the filtration treatment. Wetland can be made by utilizing potential plants for wastewater remediation such as *Vetiveria zizanioides* [8] [9] and Cattail (*Typha angustifolia*) [10] [11]. Both plants are known for having good resistance and they can reduce organic and inorganic pollutants. Constructed wetlands are always inundated with water that supports the life of aquatic plants, and consist of soil as a medium of growing plants [12].

In this study, blackwater treatment is performed by using the combination of stratified filter and constructed wetland. The observation is focused on the decrease in BOD (Biological oxygen demand) and COD (Chemical oxygen demand) level of blackwater during processing. BOD represents the oxygen need for the first stage decomposition of organic waste, which is played by microorganisms. Meanwhile, COD indicates the oxygen need for oxidation process of unstable inorganic materials from the first stage decomposition [13]. The output of blackwater treatment in this study is expected to meet the standard of grade IV water, ie water that can be used for irrigation or agricultural purposes.

2. Method

2.1 Planning of Blackwater Treatment Plant and Stratified Filter

The wastewater treatment plant in this study is planned with a scale of 1: 25, in which the model size was not the same as the field condition. Filters were arranged from coarse to fine material (reversed with a water filter), namely gravel, charcoal, and sand (Figure 2 and 3). This was based on the consideration that crude material (gravel) is able to filter suspended solids, then continued with charcoal to filter out dissolved solids and sand to filter slowly flowing sewage (Figure 1).

Figure 1. Materials for filter (Gravel 12.5 mm, 2 mm Charcoal and 2 mm Sand)

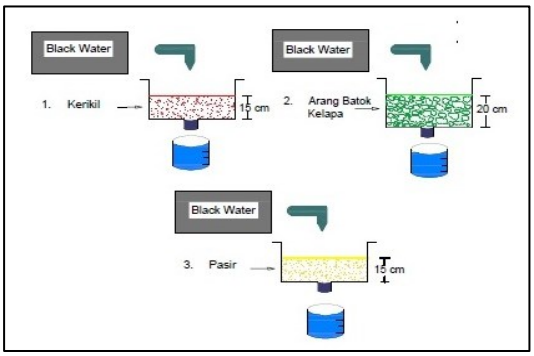

Figure 2. Single filter

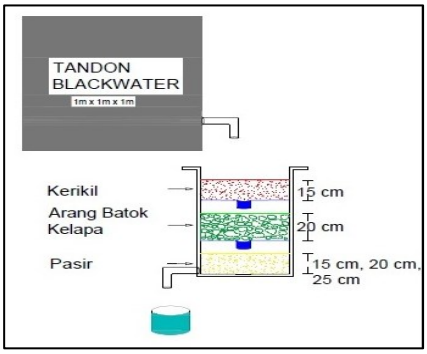

Figure 3. Stratified filter

2.2 Constructing the Wetland

This study used two types of aquatic plants for remediation agents in processing the domestic waste (blackwater), namely Vetiver grass (*Vetiveria zizanioides*) and Cattail (*Typha angustifolia*). Those plants were used as wetland plants in order to reduce BOD and COD of blackwater.

2.3 Measuring the Parameters

Blackwater samples were observed 3 times; at 2-day, 4-day and 6-day observation intervals. Wastewater samples were obtained from the communal septic tank in Tlogomas subdistrict of Malang, and 120 liters were taken to be tested with the combination method of the stratified filter and constructed wetland. The measurement of BOD and COD parameters were performed in the laboratory by using standard methods from the laboratory, as described in the Table 1 below:

Table 1. Measurement method of wastewater parameters

Parameter	Satuan	Metode
BOD	mg/l	Incubator, Buret
COD	mg/l	Reflux

2.4 Data Analysis

Research data were analyzed using descriptive analysis to know the decrease of BOD and COD levels during processing based on each treatment and then used to determine the best or most effective combination method in lowering pollutant levels. The output of wastewater treatment will be compared with the standard of water for agricultural purposes based on Government Regulation of Republic of Indonesia No.82 Year 2001.

3. Result and discussion

Wastewater is known to contain a high level of BOD and COD, therefore, it is treated using stratified filter and constructed wetland to enhance the quality. The output of the treatment is expected to meet the standard for agricultural activities based on Government Regulation no. 82 in 2001. In the grade IV water category, the maximum limits for BOD and COD in water are 12 mg/L and 100 mg/L, respectively [14]. The results obtained will demonstrate the ability of each treatment combination so that it can be concluded which treatment is the most effective in reducing BOD and COD of blackwater.

3.1 Vetiver Grass (Vetiveria zizanioides)

The following Table 2 presents the data of BOD level from each processing stage in accordance with sand thickness and residence time. The wetland plant was Vetiver grass (*Vetiveria zizanioides*):

Table 2. BOD level of blackwater on each treatment stage (Vetiver grass)

Sand Thickness (cm)	Initial BOD / *Blackwater* (mg/L)	BOD on Filter (mg/L)	BOD level (mg/L) of *blackwater* In *wetland* (mg/L)			Standard (mg/L)
			2-day	4-day	6-day	
15 cm	375.0	166	142	140	130	
20 cm	375.0	135	145	140	120	12
25 cm	375.0	119	110	100	91	

Table 2 showed that BOD level of blackwater from treatment 1 (sand thickness 15 cm); treatment 2 (sand thickness 20 cm); and treatment 3 (sand thickness 25 cm) were decreased from their initial condition. Combination treatment 3 with 25 cm sand thickness and 6 days residence time in wetland showed the lowest BOD level (91 mg/L). Overall, the final BOD levels were much lower than the initial levels, yet they have not met the standard of grade IV water required by the government. Figure 4 provides the graph of the data from table 2.

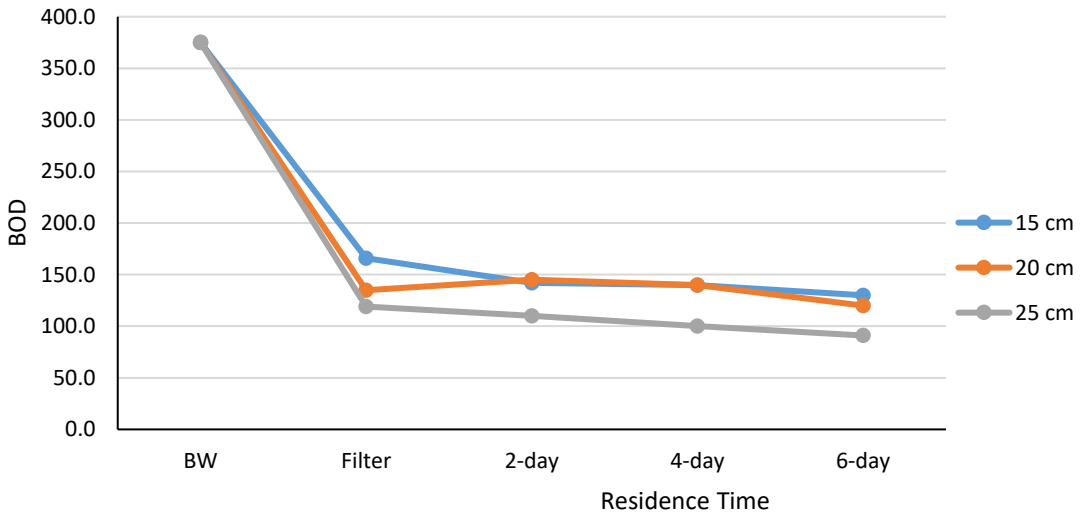

Figure 4. Graph of BOD reduction on each treatment stage (Vetiver grass)

The following Table 3 presents summary data of COD levels on each treatment stage of filtration and residence time in wetland planted with Vetiver grass.

Table 3. COD level of blackwater on each treatment stage (Vetiver grass)

Sand Thickness (cm)	Initial COD / *Blackwater* (mg/L)	COD on Filter (mg/L)	COD level (mg/L) of *blackwater* In *wetland* (mg/L)			Standard (mg/L)
			2-day	4-day	6-day	
15 cm	482	173	205	203	190	
20 cm	482	195	210	200	150	100
25 cm	482	175	140	125	105	

The overall wastewater quality has improved after the treatment, but the best final COD level resulted from the combination treatment 3 (25 cm sand thickness, 6 days of residence time). The results obtained from the treatment were 105 mg/L, which almost met the standard for agricultural purposes (100 mg/L).

Thus, the treatment can be expressed as the best treatment in lowering the COD level. For a clearer picture, the pattern of COD reduction can be seen in the following graph:

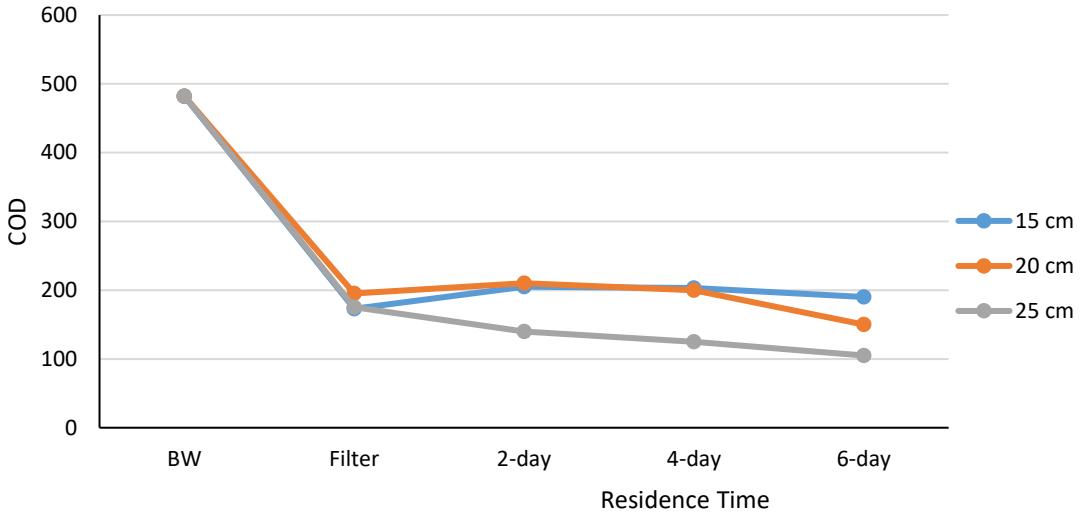

Figure 5. Graph of COD reduction on each treatment stage (Vetiver grass)

This study confirms the findings of previous studies that stratified filter can improve water quality by lowering BOD and COD levels. The study conducted by Bryant & Roberta [15] showed that gravel and charcoal can reduce BOD levels from the 29.3 mg/L to 22.9 mg/L, and also reduce COD level from 2925 mg/L to 453.7 mg/L, with a reduction effectiveness of 84.5%. Regarding the use of Vetiver grass, Dymanagowdru & Lokeshappa [16] found that Vetiver grass can reduce BOD level of wastewater up to 70% and COD up to 80%. In addition, Yeboah et al. [17] also found a reduction in BOD level up to 91.26% and COD up to 82.27%.

Vetiver grass has a complex root system characterized by the root length of 3 - 4 meters and forms a large volume coverage. This condition provides good habitat for bacteria and symbiotic fungus that simultaneously form a symbiotic ecological system to absorb pollutants. In addition, Vetiver plants have the ability to absorb large amounts of pollutants without affecting their growth rate [18]. Regarding the graph presented in figure 5, it appears that the decrease in BOD and COD levels is performed more by the stratified filter. Nevertheless, by looking at the final outcome, especially in combination treatment 3, the role of wetland system using Vetiver grass cannot be ruled out. Longer residence time might result in the better output.

3.2 Cattail Plant (Typha angustifolia)

Table 4 demonstrated the data of BOD levels on each treatment stage using stratified filter and wetland system planted with Cattail plant (*Typha angustifolia*):

Table 4. BOD level of blackwater on each treatment stage (*Cattail* plant)

Sand Thickness (cm)	Initial BOD / *Blackwater* (mg/L)	BOD on Filter (mg/L)	BOD level (mg/L) of *blackwater* In *wetland* (mg/L)			Standard (mg/L)
			2-day	4-day	6-day	
15	375.0	166	140	135	130	
20	375.0	135	180	175	160	12
25	375.0	119	150	100	57	

Based on table 4, the combination treatment 1 (15 cm thickness of sand), combination treatment 2 (sand thickness 20 cm), and combination treatment 3 (25 cm thickness of sand) can decrease the level of BOD in blackwater. Filtration process with 25 cm sand thickness with residence time for 6 days resulted in the lowest BOD level (57 mg/L). Combination treatment 3 with 25 cm sand thickness and 6 days of residence time on wetland resulted in the lowest level of BOD (57 mg/L). This level was much lower than the initial level of 375 mg/L. However, the final COD levels have not met the expected standard for agricultural purposes (grade IV). Figure 6 illustrates the reduction pattern of COD level on each treatment stage using Cattail plant.

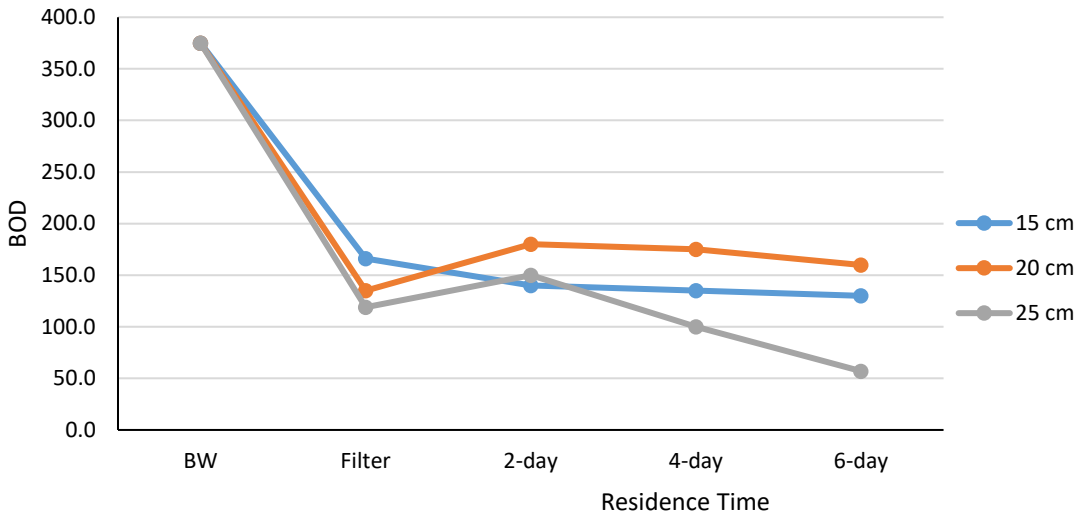

Figure 6. Graph of BOD reduction on each treatment stage (*Cattail*)

The blackwater treatment using stratified filter and wetland system planted with *Typha angustifolia* also showed the same result on the COD parameter. The initial COD level of blackwater waste was 482 mg/L and then reduced by filter materials in the filtration process ranging from 173 to 195 mg/L. However, COD levels were slightly increased in the initial stage of wetland residence time. This is allegedly caused by organic materials contained in wetland itself. The entire process indicated that overall COD levels have been decreased even though the final COD levels have not met the expected standard for agricultural water (Grade IV). The complete data is presented in the following Table 5:

Table 5. COD level of blackwater on each treatment stage (*Cattail* plant)

Sand Thickness (cm)	Initial COD / *Blackwater* (mg/L)	COD on Filter (mg/L)	COD level (mg/L) of *blackwater* In *wetland* (mg/L)			Standard (mg/L)
			2-day	4-day	6-day	
15	482	173	210	200	160	
20	482	195	240	231	200	100
25	482	175	180	120	96	

Table 4 showed that the best blackwater treatment was performed by the combination treatment 3 (sand thickness of 25 cm, 6 days of residence time), resulting in the lowest final COD level of 96 mg/L. This level is the only result that meets the standard of agricultural water. To provide a clearer picture, the following Figure 7 presents the reduction pattern of COD level:

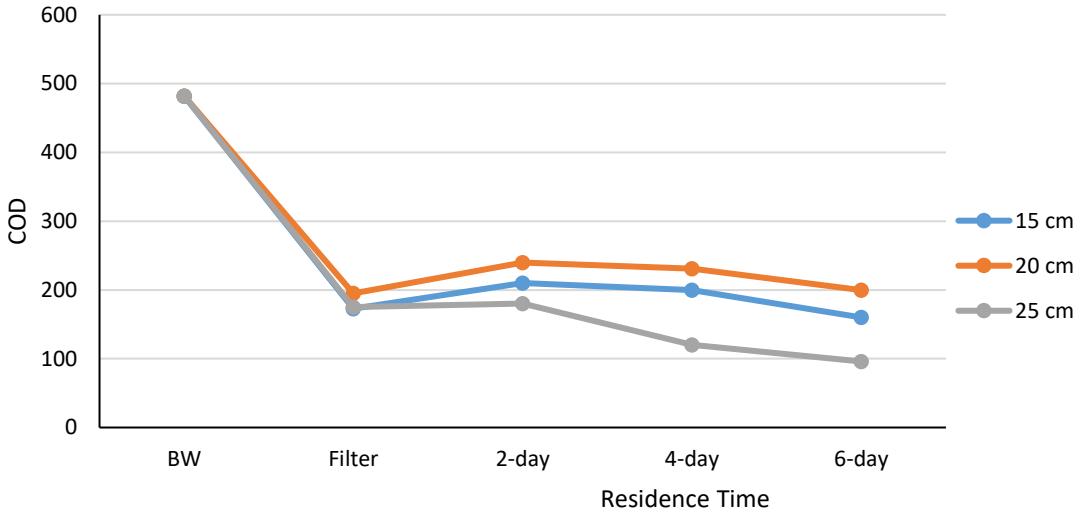

Figure 7. Graph of COD reduction on each treatment stage (*Cattail*)

Previous research obtained similar results where gravel, charcoal, and sand can reduce the level of BOD and COD [15]. As for the use of Cattail plant, the study from Arivoli & Mohanraj [19] showed that Cattail plants gave a major contribution to reduce organic pollutants. Initial BOD content of 157.20 mg/L was reduced to 30.74 mg/L, and the COD level was also reduced from 412.32 mg/L to 63.84 mg/L. The ability of Cattail plants to reduce organic pollutants is due to the high availability of decomposing microorganisms in the rhizosphere. In line with these findings, Suhendrayatna et al. [20] found that Cattail plants were able to reduce BOD and COD of domestic waste by 50.15% and 56.72%, respectively.

Cattail plant is known to have good resistance to pollutants. In morphology, Cattail has a dense fibrous root that supports the absorption of large contaminants. In addition, one of the advantages of using Cattail plant for remediation is the ease of obtaining it, as it grows in natural wetlands in Indonesia [21]. The results of this study, particularly in the combination treatment 3, at least confirmed the theory and results of previous studies.

4. Conclusions

This study showed that the lowest decrease in BOD and COD level (best result) was obtained in combination treatment 3 (25 cm of sand thickness and 6 days of residence time), both in wetland with Vetiver grass and Cattail plant. Overall, blackwater treatment in this study has been able to reduce BOD and COD levels, but the final results obtained have not met the standard of grade IV water. BOD and COD reduction was likely to be performed more by the stratified filter.

5. Recommendations

Future studies are suggested to consider the ratio of land area and wastewater discharge. In addition, the residence time of blackwater in the wetland can be enhanced in order to obtain better results and meet the standard for agricultural purposes.

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