

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

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2 Abilities of stratified filter and wetland to reduce TDS and TSS in blackwater domestic waste

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Abstract. This study aimed to devise a new design of domestic waste treatment which can produce an output of class IV water (irrigation water) based on measurement of TDS (Total Dissolved Solid) and TSS (Total Suspended Solid) parameters. The physical model tested in this research was a stratified filter consisting of compositions from coarse to fine materials namely gravel, charcoal and sand. Furthermore, filtering blackwater waste was refined by remediation with Cattail (*Typha Angustifolia*) and Vetiver (*Vetiveria Zizanoides*). The physical model of WWTP was set to 1:25 added by a stratified filter in the upstream section. Observations were done by measuring blackwater TDS levels prior to treatment, after going through a stratified filter, and after going through a remediation process with aquatic plants. The results showed that stratified filters and wetland can reduce TDS levels in blackwater until it reached the standard for irrigation water.

1. Introduction

The impact of population growth is an increase in the amount of clean water use and waste which will be generated. This is often not supported by the provision of balanced environmental sanitation infrastructure. Wastewater requires adequate handling as it can have serious impacts on the environment and human being. The impacts include pollution in raw water sources for clean water needs [1]. The most polluting wastewater in the river is that from household activities (domestic). Approximately, 50-75% of the organic load in the river comes from domestic waste [2].

One type of wastewater which requires serious processing is blackwater. Blackwater originates from human waste and contains pathogenic bacteria, so it must be processed first before disposing it to the river. Generally, blackwater is stored in septic tanks or directly channeled to sewage system for next processing in Domestic Wastewater Treatment Plant (WWTP).

Constructed wetland is an artificial wetland managed and controlled by humans as a solution of wastewater treatment by using plants, microbial activities and other natural processes [3]. A previous

study conducted by Mthembu et al. [4] showed that the wetland system can achieve high efficiency and effectiveness to reduce the content of organic and inorganic materials and other pathogens when managed properly and efficiently. Thus, wetland can be a useful solution in the management and conservation of scarce water resources.

In this study, processing blackwater is performed through two stages, namely filtering with a filter continued by using aquatic plants. A study conducted by Sodamage and Pearse [5] revealed that using a sandstone filter with 800mm-thickness is effective to lower Fe and Mn levels. The use of filters can reduce Fe and Mn content up to 0.02 and 0.1 mg/L so that the resulting output meets the quality standard. Gravel can be used as a waste filter, in which the gravel (0.5-2.0 cm diameter) can lower lipid and detergent levels and neutralize pH [6]. Meanwhile, charcoal has an active carbon content, enabling to eliminate chemical pollutants [7].

To improve the quality of filter results, then wetland is used with aquatic plants namely Vetiver (*Vetiveria zizanioides*) and Cattail (*Typha angustifolia*). Both are types of water plants (submerged/amphibious plants) which can be used for artificial wetlands. Aquatic plants simultaneously play a major role in wastewater purification. The use of aquatic plants has advantages such as low operational costs and simple technology [8]. Beside a bioremediation agent, Vetiver grass also has high resistance to pollutants [9]. Meanwhile, Cattail has been recognized to improve the quality of wastewater indicator significantly with an effectiveness value more than 80% toward BOD, COD and TKN parameters [10].

The study aimed to increase the effectiveness of domestic waste treatment from communal WWTP, particularly related to TDS (Total Dissolved Solids) and TSS (Total Suspended Solid) parameters. The design of model used a stratified filter and wetland expected to improve the waste quality effectively and efficiently so it can be used to water rice fields or agriculture.

2. Method

2.1 Planning the Wastewater Treatment Plant and Filters

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



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

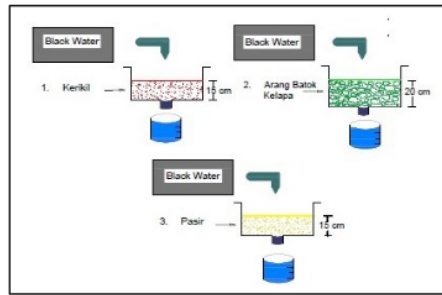


Figure 2. A single filter



Figure 3. A stratified filter

2.2 Composing Wetland

This research used two types of aquatic plants for remediation agents in processing the household wastewater (Blackwater), namely Cattail (*Typha angustifolia*) and Vetiver (*Vetiveria zizanioides*). Those were made as wetlands to reduce TDS and TSS in domestic waste.

2.3 Measuring parameters of wastewater quality

Blackwater samples were observed 3 times: at 2-day, 4-day and 6-day observation intervals. Samples of wastewater were obtained from a *septic tank*/communal tank in Tlogomas subdistrict of Malang, and 120 liters were taken to be tested with a combination of stratified filters and wetland. Measuring TDS and TSS parameters were performed in the laboratory by standard methods of laboratory measuring instruments, as described in the following Table 1:

Table 1. Measurement method of wastewater quality parameter

Parameters	Unit	Method
TDS	mg/l	Horiba water quality
TSS	mg/l	Suspended Solids Analyzer

2.4 Data analysis

The data of this research were analyzed using descriptive method to determine the decrease in TDS and TSS level and the best treatment combination that can improve the quality of wastewater. The final TDS and TSS level were then compared with the standard of water quality of agricultural water (grade IV) regulated in the Government Regulation of the Republic of Indonesia No.82 of 2001 on the *Management of Water Quality and Water Pollution Control*.

3. Results and discussion

3.1 Vetiver Grass

The Table 2 show the observations related to TDS and TSS parameters onvetiver grass:

Table 2. Summary of TDS results on theWetland with Vetiver Grass

Sand Thickness (cm)	Initial TDS / Blackwater (mg/L)	TDS on Filter (mg/L)	TDS level (mg/L) ofblackwater In wetland (mg/L)			Standard (mg/L)
			2-day	4-day	6-day	
15	629.67	3200	1238	1235	1210	2000
20	629.67	590	1300	1210	1000	
25	629.67	6620	900	800	790	

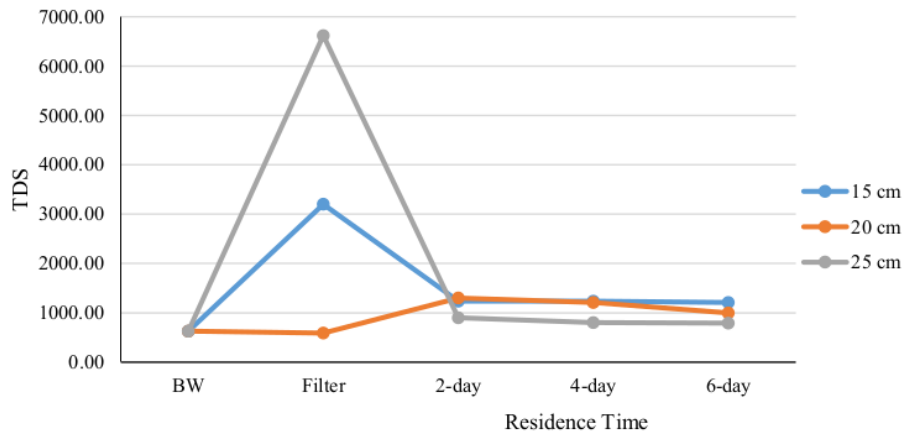


Figure 4. Graph of TDS levels at each processing stage

Figure 4 showed the significant increase from black water to TDS whose value was improved. It was due to compounds existed in the filter being dissolved along with blackwater. However, when regarding the color, it was clearer than the initial conditions as well as the turbidity. In the next graph, under filter treatments 1 (15 cm sand thickness), 2 (20 cm sand thickness) and 3 (25 cm sand thickness), TDS value of blackwater decreased from the initial condition. The filtration process with the residence time in the filter media for 25 minutes and wetland for 6 days resulted in the lowest TDS levels. Treatment 3 with 25 cm sand thickness and wetland 6 days showed the lowest TDS, i.e. 790 mg/L. The total of obtained dissolved solids was much better than the standard of irrigation water from Government regulation [11], i.e. 2000 mg/L. It could be due to the mud or soil washing in the wetland tube during the process of water flowing through the outflow hole.

The result showed that the level of TDS of blackwater was increased significantly after being processed with stratified filter. The average initial TDS was 629.67 and then increased to 3200 mg/L (treatment 1 with 15 cm of sand thickness), and 6620 mg/L (treatment 3 with 25 cm of sand thickness). This is due to the input of various dissolved solids from the filter material which dissolved with the blackwater during the filtration process. TDS levels have decreased again after going through the remediation process with the wetland. The best treatment combination obtained was sand thickness of 25 cm with residence time of 6 days, where the final TDS content was 790 mg/L. However, the overall outcome has met the class IV water standard of 2000 mg/L [11], therefore the output of wastewater treatment was feasible for agricultural purposes.

Furthermore, observations of TSS levels of blackwater processed with stratified filter and wetland were observed. The results are summarized in the following Tables 3 and graphs:

Table 3. Summary of TSS results on the Wetland with Vetiver Grass

Sand Thickness (cm)	Initial TSS / Blackwater (mg/L)	TSS on Filter (mg/L)	TSS level (mg/L) of blackwater In wetland (mg/L)			Standard (mg/L)
			2-day	4-day	6-day	
15 cm	766.67	110	60	58	50	400
20 cm	766.67	110	45	40	35	
25 cm	766.67	110	30	20	9	

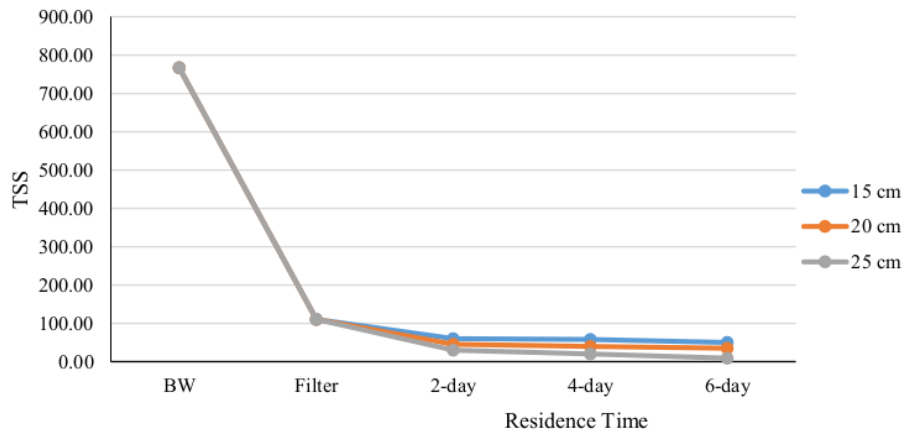


Figure 5. Graph of TSS levels at each processing stage

In Figure 5 with the initial treatment, blackwater showed much higher number. Then, after being filled with the combination filter consisting of gravel, charcoal, and sand, it showed a significant decrease as seen in the graph above. It showed better water quality improvement particularly TSS which was greatly reduced.

The result of treatment 1 (sand thickness 15 cm); 2 (sand thickness 20 cm); and 3 (25 cm thickness of sand) demonstrated the decrease of suspended solids in all residence times of blackwater in wetland tube. The best result was obtained from treatment combination 3, namely sand thickness of 25 cm and residence time of 6 days (9 mg/L). Overall, the water output obtained from all treatment combinations have been feasible to dispose of into rivers and met the standard of grade IV water for agricultural purposes.

The findings support previous studies in which TDS and TSS levels can be reduced by using stratified filter and wetland, especially with Vetiver grass. The previous study obtained by Dyamanagowdru and Lokeshappa [12] proved that *Vetiveria zizanioides* can improve the quality of wastewater by decreasing TDS levels to 29% and TSS levels to 65%. In agreement with Yeboah et al. [13], *Vetiveria zizanioides* is able to eliminate pollutants presented in the waste. Measurements of TSS parameters showed an end rate of 16 mg/l, previously from 330 mg/l. Thus, the obtained result was the effectiveness in TSS content reduction which was equal to 95,15%. In TDS parameter, the final content obtained was 1570 mg/l, previously from 2560 mg/L. Hence, the decrease in TDS levels through the use of *Vetiveria zizanioides* plant was 38.67%.

3.2 Cattail Plants

The Table 4 data showed observations related to TDS and TSS parameters on the Cattail:

Table 4. Summary of TDS results on the Wetland with Cattail plants

Sand Thickness (cm)	Initial TDS / Blackwater (mg/L)	TDS on Filter (mg/L)	TDS level (mg/L) of blackwater In wetland (mg/L)			Standard (mg/L)
			2-day	4-day	6-day	
15	629.67	3200	1120	1110	1100	2000
20	629.67	590	1100	825	800	
25	629.67	6620	800	750	700	

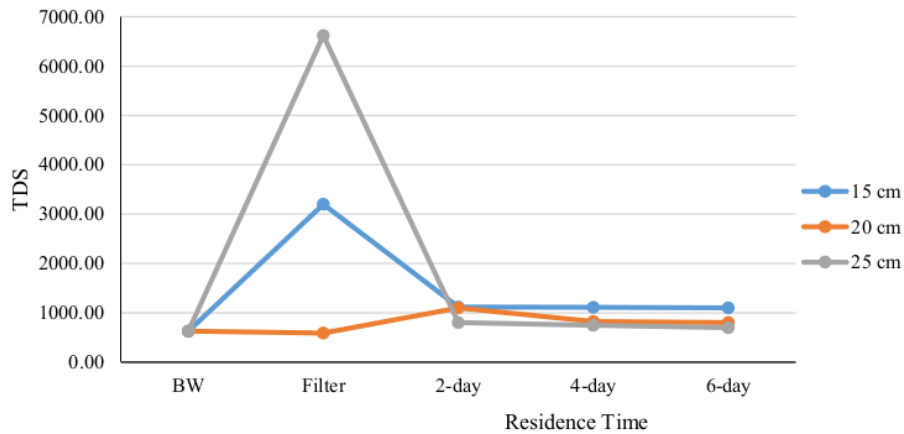


Figure 6. Graph of TDS levels at each processing stage

In Figure 6, it can be seen that the quality of blackwater has increased significantly after going through the filtration process, especially on the treatment 1 (15 cm sand thickness) and 3 (25 cm sand thickness). This is due to the input of the dissolved solids from the filter materials itself. TDS levels eventually reduced after going through the remediation process with wetland. This can be seen directly from 2 days of residence time in wetland. The best result was obtained from treatment 3 (sand thickness 25 cm) with final TDS content of 700 mg/L, compared with treatment 1 (1100 mg/L) and treatment 2 (800 mg/L). However, it can be said that all TDS levels of the output have met the standard of grade IV water, therefore the wastewater can be used for agricultural activities. The result of TSS measurement of processed blackwater is presented in the following table 5 and graph:

Table 5. Summary of TSS results on the Wetland with Cattail Plants

Sand Thickness (cm)	Initial TSS / Blackwater (mg/L)	TSS on Filter (mg/L)	TSS level (mg/L) of blackwater In wetland (mg/L)			Standard (mg/L)
			2-day	4-day	6-day	
15	766.67	110	56	55	50	400
20	766.67	110	40	35	30	
25	766.67	110	25	20	0	

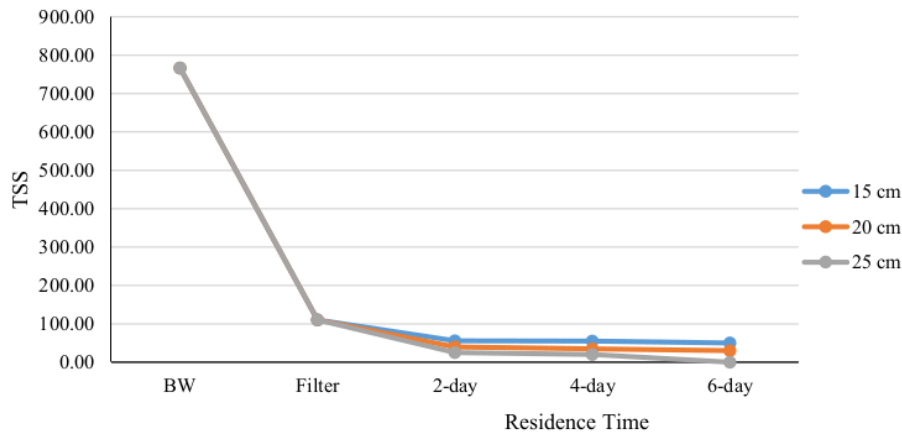


Figure 7. Graph of TSS levels at each processing stage

In line with result of TDS parameter, blackwater treatment using stratified filter and wetland planted with Cattail (*Typha angustifolia*) also showed significant decreases in TSS levels. The average of initial TSS level was 766.67 mg/L and has decreased to 110 mg/L after being processed with stratified filter. Furthermore, TSS levels continued to decline during the remediation process with wetland. This applied to all treatments. The final result of blackwater treatment using 25 cm of sand thickness and 6-day residence time even reached 0 mg/L, in other words, there suspended solids were entirely removed. Therefore, the combination treatment 3, was considered as the best treatment for removing the suspended solids of blackwater. Compared to the standard of class IV water, it was clear that TSS levels have met the standard for agricultural use, even far below the required level (400 mg/L).

Blackwater treatment using stratified filter and wetland with Cattail plant (*Typha angustifolia*) has resulted in output water with improved quality, both from TDS and TSS parameters. The results of this study confirm the findings in some previous researches. Zhang et al. [14] found that the use of artificial wetland with combined aquatic plants is able to reduce TSS content very efficiently up to 93.82%, in which one of the plants used as remediation agent of wastewater is Cattail. In addition, Arivoli and Mohanraj [15] revealed that *Typha angustifolia* plant is able to decrease TDS level up to 84.66% after 36 hours hydraulic retention time (HRT). While in artificial wetlands without *Typha angustifolia* plant, the decrease of TDS level is equal to 67.26%. Thus, it can be said that the use of *Typha angustifolia* plants is able to improve the effectiveness of waste water treatment. Suhendrayatna et al. [16] also showed similar results in which the use of aquatic plants (*Typha latifolia* and *Saccharum spontaneum*) proved to be potent and effective in reducing TSS levels of waste water. The *Typha saccharum* plant was able to decrease the TSS level up to 88.83%, in which in the observation for 9 days obtained the decrease of TSS level namely 58.6 mg/L, 31.1 mg/L, 14.7 mg/L, 13.5 mg/L, 13.0 mg/L, 12.9 mg/L, 12.6 mg/L, and 12.2 mg/L.

4. Conclusion and recommendation

4.1 Conclusion

This research has been proved that Vetiver grass (*Vetiveria zizanioides*) and Cattail (*Typha angustifolia*) are able to improve the quality of wastewater, both from the decrease in TDS and TSS. The final level of both parameters exceeded the standard for class IV water (agricultural water). Evenmore, the treatment of stratified filter and wetland using Cattail plant (*Typha angustifolia*) was able to thoroughly eliminate the suspended solids up to 0 mg/L.

4.2 Suggestions

Filter materials are better to be rinsed before used for wastewater treatment. In addition, it is recommended to apply the longer residence time to reach the new saturation point and then blackwater flowed into wetland. This process can then be calibrated by backwashing before the next usage. The combination of Vetiver grass and Cattail in wetland might allow better results of wastewater treatment, hence it can be used as a study for the future research.

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