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Enhancement of wastewater effluent quality by using multi-layer materials constructed wetlands (MLCWs)

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ABSTRACT

This study aims to determine the efficiency of *Phragmites australis* in multi-layer materials constructed wetland (MLCW) to treat effluent from secondary treated sewage treatment plant. MLCW was consisting of waste cement, gravel, peat soil with plantation of common Reed (*Phragmites australis*). Effluent of treated sewage was collected from the sewage treatment plant in the Universiti Tun Hussein Onn (UTHM) campus. The removal of Biochemical oxygen demand (BOD), Chemical oxygen demand (COD), Total suspended solids (TSS) and Turbidity by MLCW were up to 73.2%, 87.8%, 68.7%, and 79.2%, respectively. The pH also reduced from 8.5-9.0 to 6.5-6.5. Therefore, it shows that multilayer (waste cement, gravel, peat soil) with common reed (*Phragmites australis*) can enhance the quality of primary treated sewage effluent of domestic wastewater. Being economical and low-technology systems, MLCWs are potential alternative or supplementary systems to achieve sewage treatment efficiency.

Key words: *Domestic wastewater, Multi-layer materials constructed wetland (MLCW), Peat, Phragmites australis*

Introduction

Malaysia, as a developing country, is confronting with this issue which led to the escalation of wastewater in urban areas. Domestic wastewater is generated from residential, institutional, commercial, and industrial establishments that are disposed via drainage and sewers (Gani *et al.*, 2017; Ibrahim *et al.*, 2017). A lot of wastewater is generated with organic and inorganic pollutants (Wu *et al.*, 2015; Yanqoritha *et al.*, 2018; Yunardi *et al.*, 2019). Previously, common treatment systems including constructed wetlands have developed in prevalence for wastewater treatment since the mid-1980s (Wu *et al.*, 2015). The possibility to use the utilization of constructed wetlands to the wastewater treatment is relevant until today because it seems to be environmentally sustainable and ecologically sound for the treatment of numerous pollutants and cost savings (Mara, 2003). There are different alternatives to treat domestic wastewater which the identification of the preferred option in specific circumstance of the cost; both working and capital cost and the restriction force on the quality and amount of release. Up until this point, many advanced techniques, conventional and experiences have been aggregated in the field of domestic wastewater treatment. However, the common wastewater treatments are expensive and require high energy input (Abou-Elela *et al.*, 2019). The aim of this study is to produce a better solution for domestic wastewater after the treatment from secondary treated sewage.

Materials and Methods

Plant species of common reed, *Phragmites australis* were taken from a swamp area at Bestari Residential College, UTHM, and harvested in wet soil with natural condition. Constructed wetland used as a primary technology. Three different samples were collected from sewage treatment plant at Universiti Tun Hussein Onn Malaysia. The samples were collected once a week, around 9.00 a.m. to 10.00 a.m. (morning peak flow) for four weeks. The 5 liters of samples were kept using Polyethylene Terephthalate plastic container in the chiller room at 4°C to minimize microbial activity (APHA, 2012).

Fig. 1 illustrates the schematic diagram and filling materials of the multi-layer constructed wetland. The multi-layer constructed wetland is designed of 130 cm height, which includes gravel stone layer with 60 cm thickness of (10-20) mm (Wu *et al.*, 2015), waste cement which results from demolitions and construction of buildings layer with 30 cm thickness of (20mm) (Tang *et al.*, 2017), and peat soil layer with 40 cm thickness (Almuktar *et al.*, 2018) total of 130 cm thickness for filling materials multi-layer constructed wetland around the sedimentation basin which receives excess treated wastewater (over flow) from the multi-layer constructed wetland after completion of the biological treatment which result from wetland plants and microorganisms. Since the height of constructed wetland tank is 1.3m, hydraulic loading rate (HLR) is 0.34 m^3/m^2 day while hydraulic retention time (HRT) is 4 days.

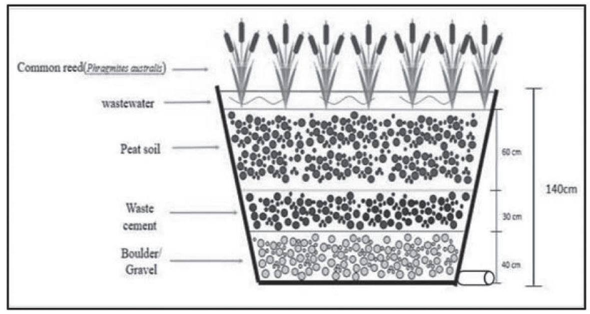

Fig. 1. Filling materials in multi-layer constructed wetland

There were 5 parameters (BOD_5, COD, pH, turbidity, total suspended solid) tested to characterize the effluent of domestic wastewater (sewage treatment plant) for sample A, B and C. Triplicates experiment were conducted to minimize error. The chosen parameters were compared to standard sewage effluent (Standard B, in Environmental Quality Act, EQA 1974 by Department of Environment Malaysia, DOE, 2010) since the effluent from sewage treatment plant (STP) is downstream from the water intake point.

Results and Discussion

Table 1 shows the range values of BOD_5, COD, pH, turbidity, total suspended solid for the domestic wastewater effluent. It is indicated that COD and BOD_5 concentrations in sample A, B, and C showed acceptable concentration, ranging from 71.5 to 83.8 mg/L and 21.8 to 29.3 mg/L compared to the effluent standard B, indicated that the wastewater is well treated from the secondary treatment process by STP. These concentrations are slightly higher than the values reported by Abunama and Othman

Table 1. Mean ± standard deviation characteristics of the Sewage Treatment Plant (STP) effluent compared with Standard B

Chemical Parameter	Sample			Standard B
	Sample A	Sample B	Sample C	
COD (mg/L)	83.8 ± 4.4	71.5 ± 4.0	82.0 ± 3.4	200
BOD_5 (mg/L)	29.3 ± 2.8	24.0 ± 1.8	21.8 ± 1.7	50
Physical Parameter	Source			Standard B
	Sample A	Sample B	Sample C	
pH	8.5	9.0	8.7	5.5-9.0
Turbidity (NTU)	43	36	32	n.s.
Suspended Solids (mg/L)	67	74	69	100

* n.s. = not stated

(2017), which obtained COD (23.2 mg/L) and BOD_5 (18.8 mg/L) from secondary treatment sewage treatment plant. Meanwhile, for pH value 8.5-9.0 for all samples were in the range of the standard permissible. In the present study, the value of turbidity and total suspended solid was in the range of 32 to 43 NTU and 67 to 74 mg/L and under acceptable standard B. Turbidity was related with suspended solid contaminant in wastewater. The higher of turbidity produced the higher suspended solid (Hannouche *et al.,* 2011). It is noted from the experiments that the water quality effluent was improved after treatment with MLCW.

The efficiency of MLCW was tested for domestic wastewater effluent to enhance the safe disposal. The removal efficiency of COD for sample A, B and C was successfully removed more than 85.7 % of the remaining concentration as shown in Table 2. The MLCW treatment system in the present study was found to be effective similar with the study by Srivastava *et al.,* (2015), which COD was successfully removed more than 85% in synthetic domestic wastewater. Moreover, the use of *Phragmites australis* as the filtration media of three layers constructed wetland in certain thickness standard was able to maximize the treatment efficiency of wastewater effluent compared to the study reported by Saeed *et al.,* (2011) which only removed 60.3% of COD in domestic wastewater with gravel as the filtration material. The MLCW is more effective to reduce the pollutant in domestic wastewater rather than biofiltration. Based on Purwatiningrum (2018), the biofiltration only removed 15% of COD and 12% of BOD. Different results are shown by Ningrum (2018), the combination of aeration and sand filtration successfully removed more than 65%.

The use of *Phragmites australis* in BOD_5removal is presented in Table 3. The reduction of BOD_5 in each sample was recorded more than 72% is might due to the ability of *Phragmites Australis* to produce oxygen in creating an environment essential in terms of sustaining aerobic microorganisms as stated by Wu *et al.,* (2015), which is beneficial in completely to reduce BOD_5 in effluent. BOD_5 could highly remove since COD value was removing efficiently in this study since while COD indicates all oxidizable materials; BOD_5 allocates the amount of biodegradable matter of effluent to enhance effluent quality (Abdalla and Hammam, 2014). This finding can be supported by Adeola *et al*. (2009) where he also planted *Phragmites australis* in subsurface gravel filled flow constructed wetland for airport water runoff treatment and able to remove 70.8% of BOD_5 concentration within 7 days. It appeared that MLCW system with *Phragmites australis* plantation has great potential in removing contaminant especially BOD_5 from wastewater.

The performance of MLCW in removing the total suspended solids (TSS) is shown in Table 4. TSS concentration percentage removal achieved more than 62 – 68% by each sample. This result also indicated lower than the result of previous study by Manios *et al.* (2003) where they planted *Typha latifolia* with several combination of topsoil, gravel and river sand performed almost above 95% TSS removal. This situation is due to the peat soil usage in this study which did not improve the hydraulic conductivity of the soil-based substrate

Table 2. The Efficiency of MLCW on COD removal

Sample	Initial concentration (mg/L)	Final concentration (mg/L)	Removal efficiency (%)
Sample A	83.8 ± 4.4	12 ± 1.2	85.7
Sample B	71.5 ± 4.0	9 ± 0.7	87.4
Sample C	82.0 ± 3.4	10 ± 0.5	87.8

Table 3. The Efficiency of MLCW on BOD removal

Sample	Initial Concentration (mg/L)	Final Concentration (mg/L)	Removal efficiency (%)
Sample A	29.3 ± 2.8	7.9 ± 0.3	73.0
Sample B	24.0 ± 1.8	6.1 ± 0.9	74.6
Sample C	21.8 ± 1.7	6.1 ± 0.6	72.0

(Rezaheznad *et al.,* 2016). The results also indicated that MLCW in the present study has different effect and efficiency due to different plantation, material compares to various studies (Wu *et al.,* 2015).

Turbidity is a combination of suspended matter and it can be divided into two categories of organic and inorganic matter. Turbidity also is a part enormous problem in wastewater treatment. Turbidity removal efficiency in this MLCW experiment are between 62.5 to 69.4% as it can be seen in the Table 5 which is better effluent quality compared to raw water.

The use of constructed wetland is recognized as an effective remediation technology for a wide range of polluting effluents. The performance of constructed wetland treating acidic- alkaline water sources has long established in several of studies (Rozema *et al.,* 2016). Fig. 2 shows the different pH value before and after MLCW treatment process. The pH value was in the alkaline to neutral state which under allowable standard of discharge in Standard B (5.5-9.0). However, the result shows that MLCW in the present study was gradually decreased from 9 to 6.7 in Sample B, 8.5 -8.7 to 6.6 in Sample A and C. These results are supported by Jin *et al.* (2017) which is the MLCW with peat soil can contribute to the reduction in the pH levels since the peat soil were mainly consisting of humic and fulvic acids and quickly release under alkaline conditions in aqueous environments.

Conclusion

The present study reveals the quality of the primary treated sewage treatment plant were differed based

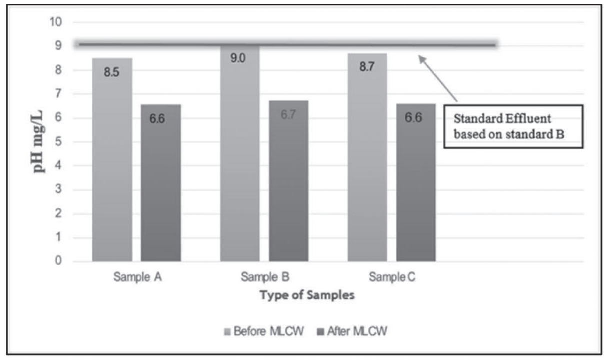

Fig. 2. Different of pH between before MLCW and after MLCW

on the location. According to DOE (2010) standard B, the effluent of primary treated sewage treatment plant characteristics should follow the standard. As for BOD5, COD, TSS, and pH, the value must be below 50 mg/L, 100 mg/L, 100 mg/L and 5.5 to 9.

The performance of MLCW was based on the characteristic of the material used. It was required to consider the characteristics of the material used such as *Phragmites Australis*, gravel, waste cement, and peat soil. Based on the obtained results, the highest removal efficiencies of COD, BOD5, Turbidity and TSS was 87.8%, 73.2%, 79.2%, and 68.7%. Based on this data, it showed the efficiency of MLCW method in improving the water quality compared with the standard effluent.

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Table 4. The efficiency of MLCW on TSS removal

Sample	Initial Concentration (mg/L)	Final Concentration (mg/L)	Removal efficiency (%)
Sample A	67	21	68.7
Sample B	74	28	62.2
Sample C	69	22	68.1

Table 5. The efficiency of MLCW on turbidity removal

Sample	Initial Concentration (mg/L)	Final Concentration (mg/L)	Removal efficiency (%)
Sample A	43	14	67.4
Sample B	36	11	69.4
Sample C	32	12	62.5

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