PERFORMANCE OF CONTINUOUS PILOT SUBSURFACE SYSTEM IN PHYTOREMEDIATION OF COD, COLOUR AND SUSPENDED SOLID IN RECYCLED PULP AND PAPER EFFLUENT

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ABSTRACT

This work focused on the performance of a pilot subsurface flow (SSF) system of constructed wetlands in removing COD, colour and suspended solids from recycled pulp and paper mill under 5-day HRT. In this study, there were two tanks based on the SSF system; one tank planted with Malaysian native bulrush, Scirpus grossus and another tank without plants acting as a control. This pilot SSF system was constructed in Malaysia Newsprint Industry, Temerloh, Pahang operated at 5-day HRT for 72 days. It was found that the SSF system with S. grossus was much better compared to the SSF control. Throughout the 72 day-exposure, the planted SSF system have achieved removals of 66.1, 55.8 and 87.2% respectively for COD, colour and suspended solid (SS). However, the control SSF system without plants has lower performance for all three parameters (62.4% COD, 44.4% colour and 84.8% SS), giving evidence that constructed wetlands is an efficient technology to phytoremediate COD, colour and SS from recycled pulp and paper effluent.

Keywords: Constructed wetlands, phytoremedition, recycled pulp and paper industry, subsurface flow, *Scirpus grossus*

INTRODUCTION

Pulp and paper mill is already renowned as one of the heaviest water users in the world after the chemical and metal industries. High consumption of fresh water is needed in the three main processes in pulping, that is mechanical pulping, chemical pulping and combination of mechanical and chemical pulping that leads to the generation of wastewater. Each tone of paper produced will generates 60 m^3 of wastewater that potentially contain toxic chlorinated compounds and also high chemical oxygen demand (COD), biochemical oxygen demand (BOD), suspended solid and colour [1] and about 11 tonnes of waste are produced yearly that can contribute a significant number of toxic compounds [2]. Pulp and paper mill is responsible for a major source of environmental problem around the world such as in New Zealand [3], China [4], India [5], Canada [6], United State [7], Europe and South East Asia. A lot of studies have been conducted revealing that effluent from pulp and paper mill contain such as heavy metals (Cd, Cu, Pb, Ni), organic materials (such as lignin), biochemical oxygen demand (BOD), chemical oxygen demand (COD), absorbable organic halogen (AOX), phyto-sterols, phosphorous and extractives [8 – 12]. However due to high content of pollutants in its wastewater and huge production of wastewater, advanced and high capacity treatment system is required for the treatment. In recent, pulp and paper mill wastewater treatment uses technologies such as membrane filtration, adsorption and ozonation for the treatment of final discharge, but there are still some pollutants that are hardly degraded due to their persistence and diligence [13]. As a result, and it has caused the effluent from this industry not satisfying compliance level set by local authorities. For this study, constructed wetland, one of sustainable technologies, is proposed to further polish the final discharged effluent from a recycled pulp and paper mill. Therefore, the aim of this study is to evaluate the performance of a pilot subsurface constructed wetland, planted with Malaysian native bulrush, *Scirpus grossus* operated continuously at HRT of 5 days for 95 days and then compare with those unplanted constructed wetland.

MATERIALS AND METHOD

Constructed Wetland Design and Operation

A pilot constructed wetland system with subsurface flow system (SSF) was constructed in Malaysia Newsprint Industry (MNI), a recycled paper mill that uses 100% used paper as fibre raw material, situated in Temerloh, Pahang at the central of Peninsular Malaysia. In this study, two identical beds made from fibreglass tanks of 2 m (L) X 1 m (H) X 1 m (W) were used. Figure 1 below illustrate the size and arrangement of media for subsurface flow system, where each of tank sequentially filled with layer of gravels of different sizes and a layer of fine sand [14]. There were two tanks, each was filled with gravels to a thickness of 10 cm (Figure 1) from the bottom of fibreglass tanks. The inlet and outlet of the constructed wetland were at 40 cm and 10 cm from the bottom level. Another 30 cm was filled with sand above the gravel medium. The sand acted as media in the system to support the native plants, *Scirpus grossuss* obtained from Tasik Chini in one of the tanks (SSF SG). Another tank acting as a control tank (SSF Control) was left without plants to compare the effect of the plant presence in removing COD, colour and SS. The flow rate for subsurface system was maintained at 0.033 L/min calculated based on a continuous flow mode operation at a HRT of 5 days.

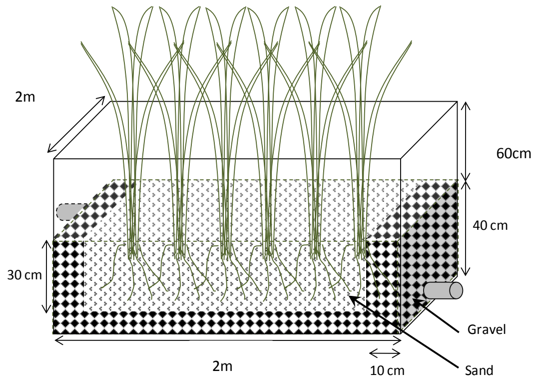

Figure 1. Size and arrangement of gravel and sand in subsurface flow with *Scirpus grossuss*

Figure 2. The pilot subsurface flow constructed wetlands developed in MNI

Wastewater source and characterisation

Real wastewater used in the constructed wetlands was channelled from the secondary clarifier pond, one of the treatment units in MNI, to the two constructed wetland. It was occasionally characterised within the exposure period from 1st December 2016 until 1st March 2017 with its characteristics are as listed in Table 1. The influent and effluent of the constructed wetlands were sampled and collected once for every ten day for the first month and every 15 day for the second month and third month for about 95 day. The samples were kept in refrigerator at 4^{o} C for further use.

Table 1. Characteristics of Malaysia Newsprint Industries secondary clarifier wastewater effluent

Parameter	Unit	Value
COD	mg/L	109.9± 21.5
BOD	mg/L	26.6 ± 10.3
Color	ADMI	132.7 ± 12.9
SS	mg/L	43.9 ± 33.1
Ammonia	mg/L	0.9 ± 1.9
pH	-	8.26 ±33.1
Temperature	°C	27-29

Physichochemical measurement of wastewater

Physicochemical analysis of the wastewater were performed in accordance with the standard Methods and were conducted within allowable holding times according to the standard methods (APHA, 2004). Two main parameters of COD and colour (ADMI) were determined using spectrometer (HACH DR6000, USA) after the filtration with 0.45 µm Whatman-type cellulose nitrate membrane filters. For suspended solid, sample were determined using gravimetric method in the Standard Method for the Examination of Water and Wastewater (APHA 2004).

RESULTS

The ability of the phytoremediation technology in treating COD, colour and SS removal from pulp and paper mill effluent over a 95- day period was analysed and shown in Figure 3, 4 and 5 respectively comparing the subsurface control (without *S. grossus*) with the ones with *S. grossus*.

Removal of chemical oxygen demand

Throughout 95-day period as shown in Figure 3, the COD concentration was reduced from 109.9 to 38.9 mg/L with 66.1% removal for SSF with *S. grossus*. Whilst for SSF control, the average removal efficiency obtained was only 62.4% with the COD reduced from 110 to 42.3 mg/L throughout the 95-day exposure. During the first month, SSF control and SSF SG show no significant difference in COD removal, but both manage to comply with the standard limits set by Malaysia legislation. For the second month until the day 95, there is a significant difference in the pattern of COD removal between SSF control and SSF SG, where SSF SG show a better removal than SSF control.

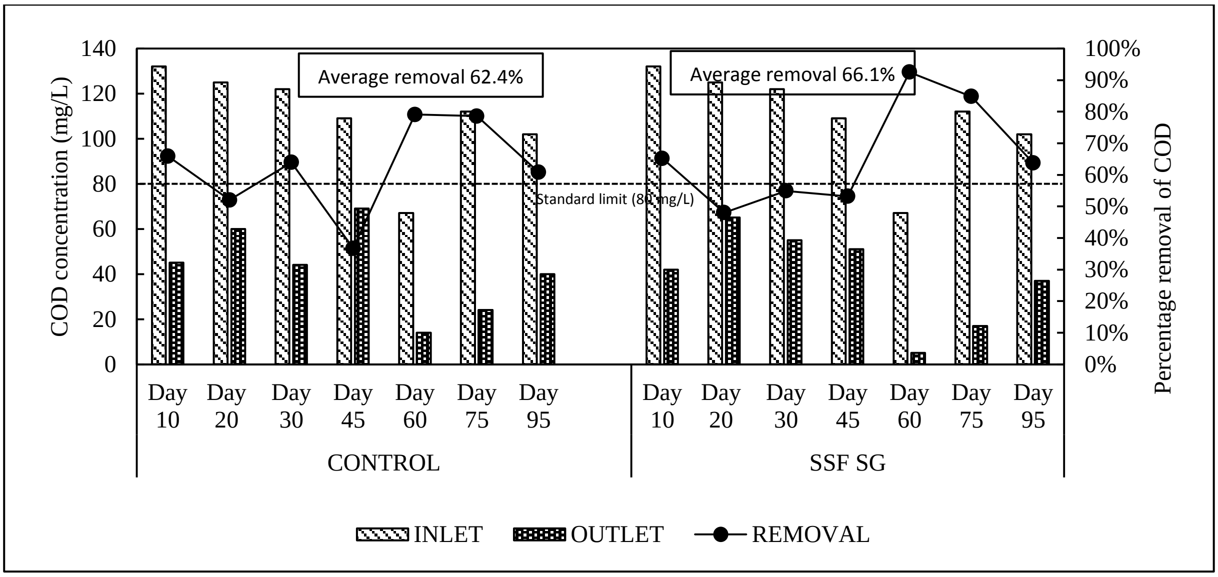

Figure 3. Variation of COD between subsurface control and subsurface *S. grossuss*

Removal of colour

In the 95-day period, the SSF planted *S. grossus* showed a better colour removal compared to the control with the average colour concentration of 59 ADMI in the effluent from 132 ADMI in the influent (Figure 4). The system with S. *grossus*, had removed colour for 55.8% compared with only 44.4% in the control bed with the average colour concentration in the effluent of 74.6 ADMI throughout 95 day. The colour concentration in the effluent was already below the limit of Environmental Quality Acts (Industrial Effluent) 2009 in the planted SSF until the end of study. The performance of the SSF control for the colour removal was not consistent and fluctuated.

Removal of suspended solids

The SS concentration of SS in the influent fluctuated throughout the exposure as shown in Figure 5. Both SSF without or with S. *grossus*, show higher removal of SS with the average 87.2% and 84.8% respectively for the planted SSF and SSF control. The removal of suspended solids were filtered by the gravel and sands inside the beds, was enhanced further by the rooting system in the planted bed.

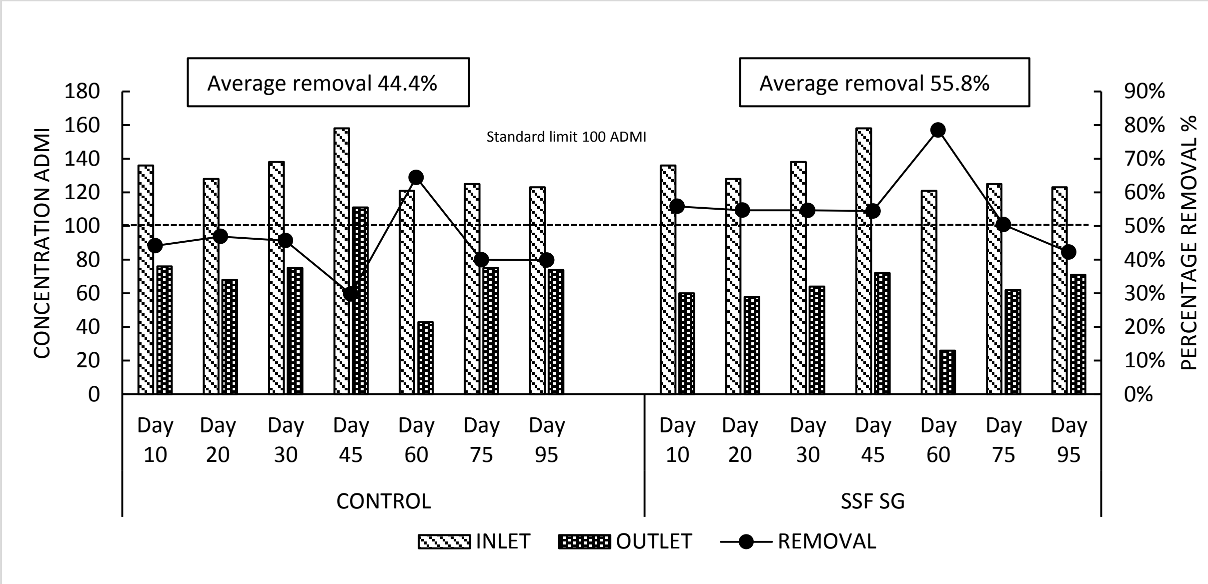

Figure 4. Variation of colour between subsurface control and subsurface *S. grossus*

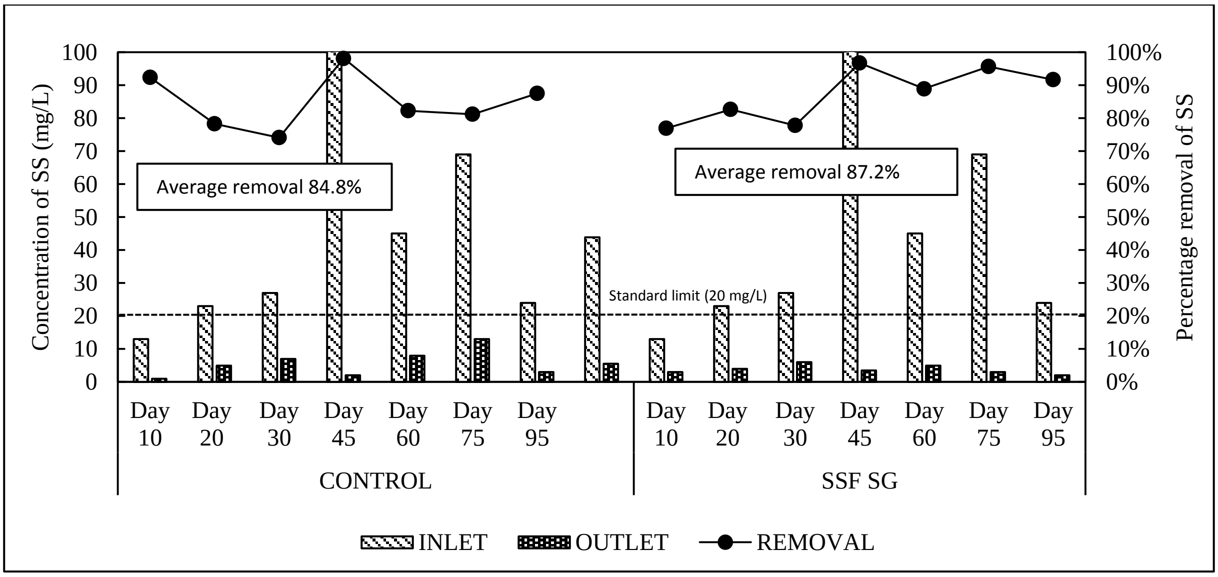

Figure 5. Variation of suspended solids between subsurface control and subsurface *S. grossus*

DISCUSSION

The results listed in Table 2 compares all of the average removal for each parameter of COD, colour and SS across the 95 day with HRT of 5 days between the planted SSF (SSF SG) and SSF control. As shown in Table 2, COD removal by SSF SG as recorded is not significantly different from the SSF control. This might due to the constraint faced by any phytoremediation process that requires longer time for full contaminant removal [15]. However, the result obtained here could be compared with [16] study, which the same result have been recorded in removal rates of COD, in which his study also found that COD removal between unplanted bed and planted bed only showed a small different, but the planted bed had consistent removal. [17] in their experiment found that *S. grosssus* started to wither on day 7 after being exposed with pulp and paper mill effluent. However at day 28, the plant reduced 100% COD giving evidence that *S. grossus* required more time to perform complete remediation process when it is operated in the continuous system. The results in Figure 3 shows that the COD had reached the standard limit starting for the first 10 days until the end of the study.

Throughout the 95 day of experiment, the SSF SG had acquired effective colour reduction compared to the SSF control with 55.8 and 44.4% colour removal respectively. Based on the [17] study, they found that *S. grossus* is one of potential tropical native plants in remediation of pulp and paper mill wastewater, with 50.28% reduction of colour. *S. grossus* showed big potential in decolourising MB dye at 1000 mg/L concentration with 38% of removal [18].

For the suspended solids that is sum of the organic and inorganic solids concentration, result show that there is slightly different between constructed wetland SSF control and SSF SG which is 84.8 and 87.3% respectively. The treated effluent complied with the standard limit for industrial effluent guidelines in Malaysia.

Table 2. Comparison of the COD, colour and SS between Subsurface control and subsurface with *S. grossus* along with effluent guideline standard level for Malaysian

Parameter	Unit	Influent	SSF Control		SSF SG		*Environmental Quality Acts (Industrial Effluent) 2009 in Malaysia
			Effluent	Removal	Effluent	Removal	Standard A
COD	Mg/L	109.9± 21.5	42.3±19.1	62.4%	38.9± 21.3	66.1%	80
Colour	ADMI	132.7± 12.9	74.6± 19.9	44.4%	59± 15.5	55.8%	100
SS	Mg/L	43.9± 33.1	5.6± 4.2	84.8%	3.8± 1.3	87.3%	20

Source from [19]

CONCLUSIONS

After 95 day of exposure, the results showed that with the presence of *S. grossus* in a pilot subsurface flow system, reductions of 66.1, 55.8 and 87.3% respectively were achieved for COD, colour and SS higher compared with only 62.4, 44.4, 84.8% respectively for COD, colour and SS in the unplanted bed, giving evidence that *S. grossus* has a significant role in removing the pollutants. In the next studied, developed reed bed system will be considered operated in HRT 3 day and HRT 4 day. Other than that, different aquatic plant may also to be use in further research using the same developed reed bed system.

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