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Performance of Pilot-scale Constructed Wetland for Treating Stormwater
(Potensi Pembinaan Wetland Bersaiz Kecil Untuk Merawat Air Sisa)

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ABSTRACT

Water scarcity and storm water management are two major challenges that effect the ecosystem and urban environment. In hot and humid country such as Malaysia, wastewater reuse should be encouraging whenever it is safe and economically feasible. Constructed wetlands (CW) have been recognized as one of the environmentally friendly technologies and successfully used for treating a diverse range of wastewaters. Constructed wetland can also be suitable habitat for native wetland plants and associated fauna. In an urban setting such as a university campus, a constructed wetland can also be landscaped as an educational and attractive green space, providing service learning and teaching opportunities for campus and surround community members. This study examines the performance of pilot-scale constructed wetlands as a sustainable wastewater treatment in Universiti Pertahanan Nasional Malaysia (UPNM) campus for treating and reusing the stormwater in the mini-reservoir. The pilot-scale of constructed wetlands have been designed and constructed in the laboratory using native wetland plant, the Cat-tail Typha Angustifolia. The pilot-scale of CW with vertical subsurface flow (VSF) system was able to remove all parameters better than horizontal subsurface flow (HSF) system. The highest percentage of removal of all parameters was at hydraulic retention time (HRT) of 5 hours and percentage of removal increased with an increase in HRT. The percentage of removal for total suspended solid (TSS), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), and Dissolved Oxygen (DO) approximately 84%, 71%, 68%, and 25%. Thus, the constructed wetland had the potential to increase the water quality level of stromwater in UPNM campus in order to support the sustainability and Green Campus environment campaign.

Keywords: Waste water; pembinaan wetland; waste water management; sustainablity; green campus campaign

ABSTRAK

Kekurangan air dan pengurusan air sisa dari hujan adalah dua cabaran utama yang boleh mempengaruhi ekosistem dan persekitaran di kawasan bandar. Di negara yang panas dan lembap seperti Malaysia, penggunaan semula air sisa semestinya menggalakkan apabila ianya melepasi tahap selamat untuk digunakan oleh pengguna dan dapat dilaksanakan dari segi ekonomi. Pembinaan Wetland (CW) telah diakui sebagai salah satu teknologi mesra alam dan boleh digunakan untuk merawat pelbagai jenis air sisa. CW yang dibina juga boleh menjadi habitat yang sesuai bagi flora dan fauna yang berkaitan. Dalam suasana bandar seperti universiti kampus, CW yang dibina juga dapat dilanskap sebagai ruang hijau yang menarik dan boleh menyediakan peluang untuk pembelajaran dan pengajaran di kampus dan masyarakat komuniti sekitar. Kajian ini mengkaji prestasi CW yang dibina berskala kecil sebagai rawatan air sisa di kampus Universiti Pertahanan Nasional Malaysia (UPNM) untuk merawat dan menggunakan semula air sisa dari hujan di takungan mini. CW berskala kecil yang telah dibina di makmal dengan menggunakan tanaman tanah asli, dan tanaman jenis Cat-tail Typha Angustifolia. CW dengan sistem aliran bawah permukaan menegak (VSF) mampu mengeluarkan semua parameter dengan lebih baik berbanding sistem aliran bawah permukaan mendatar (HSF). Peratusan penyingkiran tertinggi dari semua parameter adalah pada masa pengekalan hidraulik (HRT) 5 jam dan peratusan *penyingkiran meningkat dengan peningkatan HRT. Peratusan penyingkiran bagi pepejal terampai (TSS), permintaan oksigen kimia (COD), permintaan oksigen biologi (BOD), dan oksigen terlarut (DO) kira-kira 84%, 71%, 68%, dan 25%. Oleh itu, system CW yang dibina berpotensi untuk meningkatkan tahap kualiti air sisa dari hujan di kampus UPNM.*

Kata kunci: Air sisa; pengurusan air sisa; kelestarian; kempen kampus hijau

INTRODUCTION

Constructed Wetland (CW) is an environmentally artificial treatment facility planned and constructed for the treatment of waste water using natural processes. In the CW, the wastewater is transported by filtering media and the substances are primarily removed by physical mechanisms such as filtration, sedimentation, and biochemical interactions (i.e., microbial degradation). This connection refers to the natural processes used to extract wastewater pollutants (Vymazal 2005).

The CW are a sustainable, cost-effective and require limited installation and maintenance to treat wastewater (Sample et al. 2020). Additionally, CW has given green spaces and has the ability to increase the quality of the environment. A study reviewed by Ingrao et al. (2020) agreed that CW system can cause less greenhouse gas (GHG) emissions and less environmental impact than conventional waste water treatment plant hence contribute to sustainable enhancement on the global ecosystem on the waste water treatment.

The free water surface system and subsurface flow system are widely used in CW design (Wu et al. 2015). The subsurface flow system consists of horizontal subsurface flow (HSF) and vertical subsurface flow (VSF). In the HSF system, the wastewater remains below the media surface and flows horizontally across the bed before reaching the outlet (Kadlec & Wallace 2009). Later, the hybrid CW is the combination of HSF and VSF was designed to produce a good quality of effluent removal (Vymazal 2005). In wastewater management, both of these types of CW play an important role in emphasizing ecosystem regeneration and environmental conservation.

The significant aspect in wetland system is the selection of plants (Kalff 2002). A detailed analysis on the role of plants in horizontal subsurface CW was addressed by Vymazal (2013). CW plants serve as storage sites for carbon and nutrients. Oxygen is transferred from the air into the root zone and soil. In CW system, different types of plant can be included such as Typha, Scripus, Phragmites, and Juncus (De Sousa et al. 2003; Vymazal 2013). The efficiency of CW on plants depends on many aspects such as type of CW (e.g., vertical, horizontal, surface, subsurface, hybrid), quality and quantity of the wastewater loads, plant species and their combination, climate, medium type, and plant management. Various studies have revealed that aquatic plants play important roles in hydraulic and treatment performance of CW (Vymazal 2011, 2013; Guo et al. 2017). Othman et al. (2020) discussed the performance of small-scale of CW to treat waste water in campus.

The goal of this study was to assess the potential of pilot-scale capability of constructed wetlands using VSF and HSF system with the native wetland plant, Cat-tail Typha Angustifolia for stormwater management in the UPNM campus.

METHODOLOGY

A pilot study was carried out at UPNM to determine the efficiency of nutrient removal using VSF and HSF system with native wetland plant, the Cat-tail Typha Angustifolia species. Two plastic tanks with size of 790 mm (length) x 540 mm (width) and 520 mm (height), respectively, were installed in the laboratory. The tank system (Figure 1) was built using VSF and HSF CW system. These tanks were fitted with a piping scheme that included inlet pipe, outlet taps, and overflow holes. They were filled with soil, sand, and gravel to avoid clogging.

FIGURE 1. The pilot-scale of constructed wetland using HSF and VSF with Typha Angustifolia

The section was split into three within the HSF system. The lower layer of the middle segment, consisted of coarse aggregate (20 mm sizes) of thickness 150 mm and covered the surface with a cover soil thickness of 200 mm thickness above it. To ensure a consistent distribution of stormwater in the tank, a 200 mm thickness aggregate was provided at both sides of tank. The bottom layer of the VSF system, consisted of coarse aggregate (20 mm sizes) of thickness 10 mm and cover soil with 200 mm thickness above it. On the top, a 100 mm thickness aggregate was provided. The plants were permitted to set up for four weeks prior to the loading of the stromwater. Each unit was planted with eight plants in two rows at equal intervals. The spacing between the plants was 100 mm in length and 150 mm in width.

In these pilot-scale of CWs, water samples were analysed weekly for COD, BOD, ammonia nitrogen (AN), TSS, DO, temperature, and pH value. In these pilot-scale of CWs, water quality was monitored from October 2017 until April 2018 in monthly basis. Samples of water were obtained from the outlet. Water samples were collected from outlet.

RESULT AND DISCUSSION

The percentage of removal is used to determine the performance of stormwater pollutant removal through pilot-scale of constructed wetland. The percentage of removal on each sampling was determined using Equation (1):

$$\% = \frac{C_{in} - C_{out}}{C_{in}} x\ 100 \qquad (1)$$

WATER QUALITY PARAMETER ON MINI RESERVOIR IN UPNM CAMPUS

The water quality of the mini reservoir in UPNM campus was recorded to evaluate the performance of the pilot-scale of CW. The variations in the temperature, DO, BOD, COD, and TSS are shown in Table 1. The pH of water samples ranged in between 5 and 6.5. The in-situ temperature of water samples ranged in between 23 and 26. The normal appropriate temperature for plant-microbe growth and interaction is 20-30^{o}C in temperate region (El-Sheikh et al. 2010).

TABLE 1. Water quality parameters for mini reservoir samples in UPNM campus

Sample	TSS (mg/L)	DO (mg/L)	BOD (mg/L)	COD (mg/L)
Water Sampling	18.2	6	2.2	12

PERFORMANCE OF CONSTRUCTED WETLAND WITHOUT VEGETATION

The pilot-scale of CW were evaluated without plants to estimate the potential of the reactor as a natural filter without any plants and as a control. The characteristic parameters of stormwater treated without plants with both HSF and VSF at a HRT of 8 hours is shown in Figure 2. It can be observed that the TSS removal was high and DO removal was low. It can be concluded that the reactor acted as a filter medium.

FIGURE 2. The percentage of removal parameters from water with pilot-scale of CW without plants

where C_{in} and C_{out} are the concentration of influent and effluent of the cell.

PERFORMANCE OF HORIZONTAL AND VERTICAL SUBSURFACE FLOW CONSTRUCTED WETLAND WITH THYPHA ANGUSTIFOLIA

The pilot-scale of CW using HSF and VSF was planted with Typha Angustifolia supplied with stormwater at four different HRTs. The percentage of removal efficiencies of BOD, COD, TS, TSS, and TDS are presented in Figure 3 and 4.

The assessment of water quality in stormwater shown an improvement through the pilot-scale of CW. The maximum removal of BOD occurred at HRT of 5 hours. The percentage of removal on BOD is higher compared to COD for both HSF and VSF systems. During the experiment, the average concentration of COD in CWs were in between 12 to 40.3 mg/L. In addition, the COD percentage of removal in the C_{ws} ranged between 40% to 85% as can be seen in Figure 3 and 4. The developing anaerobic conditions and high organic loading rate can be the other reasons for reduction in the percentage of removal (El-Sheikh et al. 2010).

The TSS percentage of removal ranged in between 30% to 85% as shown in Figure 3. Based on the sampling HRT of 5 hours, the results showed high average of removal of TSS (85%) and BOD (82%). The high removal of these pollutants (TSS and BOD) from the stormwater were due to mechanism occurring in the CW substrate, physically by filtration and sedimentation, chemically by adsorption and precipitation and biologically by biodegradation and plant assimilation (Ji et al. 2007). From the results, the percentage of removal for TSS with VSF is higher compared to HSF.

The measured DO behaved similarly and the values showed small significant differences (Figure 3 and 4). In wetland system, DO has lower solubility at higher temperatures. The microorgamism play an important role in the transformation and mineralization of nutrient and organic pollutants, thus leading to depression in DO (Kouki et al. 2009).

The highest percentage of removal of all parameters was at HRT of 5 hours. Longer HRT allows for more biological activity to take place rather than mere action as a filter media. The results also show that the pilot-scale of CW with VSF system was able to remove all parameters better than HSF system. The dominant activities of root zones in the vertical flow reactor as a filter bed compared to horizontal flow reactor.

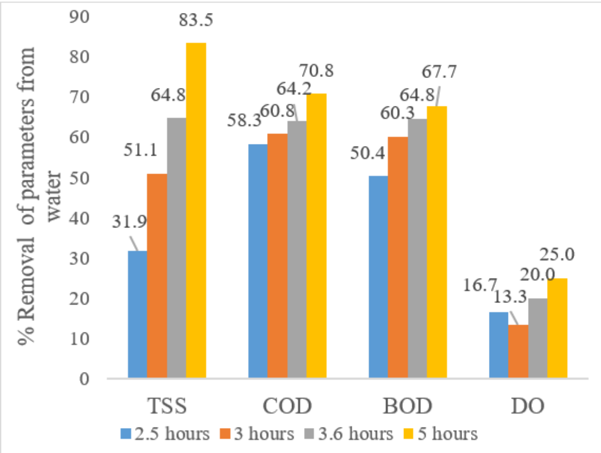

FIGURE 3. The percentage removal of TSS, COD, BOD, and DO from water for HSF with Typha Angustifolia

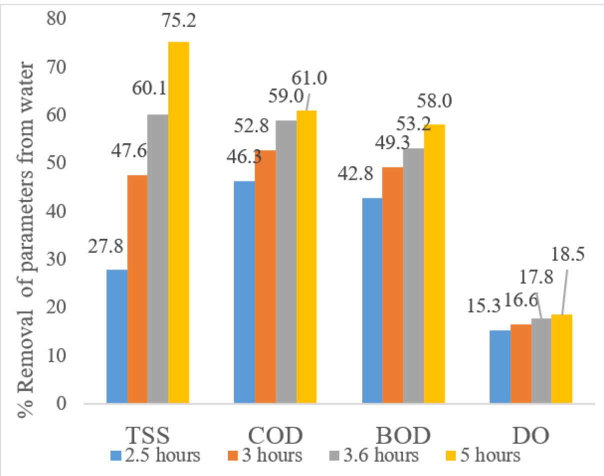

FIGURE 4. The percentage removal of TSS, COD, BOD, and DO from water for VSF with Typha Angustifolia

The hydrologic characteristic such as hydraulic retention time and velocity influence the increasing of water quality level in CW. The study reported by Stottmeister (2003) shows the HRT was strongly affected by the pollutant removal when higher removal was shown in the small event of rainfall compared to large event of rainfall. Every species of macrophyte may have different characteristics which will influence the HRT in order the suspended solid being settled and trapped in CW and also the uptake of ammonia-nitrogen (Mangangka 2013).

CONCLUSION

In this study, the pilot-scale of constructed wetland had the potential to increase the water quality level of stromwater in UPNM campus. The highest percentage of removal of all parameters was at HRT of 5 hours and percentage of removal increased with an increase in HRT. The pilot-scale of CW with VSF system was able to remove all parameters better that HSF system. The percentage of removal for TSS, COD, BOD, and DO approximately 84%, 71%, 68%, and 25%. Constructed wetland can effectively function as stormwater treatment based on the results in this study.

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DECLARATION OF COMPETING INTEREST

None

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