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Performance of Constructed Wetlands Using *Vetiveria Zizanioides* for Sewage Treatment

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ABSTRACT

Constructed wetlands is the one of the alternatives treatment to treating domestic wastewater due to low-energy, less maintenance, and green technique treatment. Even though the application of constructed wetlands have been widely used to treating the domestic wastewater, the treatment of domestic wastewater through the constructed wetland using Vetiveria zizanioides plant is still not yet fully understood. The aim of this research to assess the performance of the Vetiveria zizanioides plant to remove the pollutants through the constructed wetland. Experimental system was carried out using two different flow systems, which are 5-day retention time a zero retention time. The design of constructed wetland plants divided by cell, for each cell was planted with Vetiveria zizanioides in different populations. The performance of treatment systems was conducted to remove the concentration of oil and grease (O&G), biochemical oxygen demand (BOD), and total suspended solids (TSS) supported with dissolved oxygen (DO), and pH, respectively. The results showed that using Vetiveria zizanioides in the constructed wetland can reduce up to 53.08% of BOD and 50.75% O&G after 60 days of treatment for 5-day retention time. Conversely, for the same 60 days of treatment, the wetland was able to remove 61.92% TSS on Day 60 at zero hydraulic retention time (HRT). From the result, the Vetiveria zizanioides plant posed a great role in removing BOD, TSS, and O&G under HRT.

Key words: Sewage; Hydraulic retention time; Constructed wetland; Vetiveria zizanioides.

1. INTRODUCTION

Wetlands represent the transition zone between terrestrial and aquatic environments. It can be categorised into natural and constructed wetlands. The constructed wetlands have been used in most countries as the secondary treatment after the sewage treatment plant, and its application for industrial wastewater treatment has been proved to be a promising alternative [1]. Many studies have shown that wetlands provide effective nutrient sinks, and it can remove organic and inorganic pollutants [2]. Although the commonly used and practised conventional treatment method is suitable and efficient, it still has room for improvement. The emphasised can be given more to improve organic and inorganic nutrients removal and polishing of effluent quality from the sewage treatment plant prior to discharge [3]. The construction of artificial wetlands for wastewater treatment is now widely accepted and increasingly demanded as an alternative treatment [4]. Initially, wetland was constructed to remove nutrients from residential and municipal sewage, storm water, and agricultural runoff with a wide range of removal efficiencies.

There are two types of constructed wetlands, namely surface flow wetland (SFW) and subsurface flow wetland (SSF). Both methods are used to treat sewage and identified as the best management practice (BMP) for flood management and small urban drainage system [5]. Olson [6] and Mitsch [7] stated that constructed wetlands have been used as an attractive low-cost method to control water pollution from point and non-point sources. Dunbabin and Bowmer [8] also reported a better performance of the constructed wetland in the removal of metals from industrial effluents. In addition, wetlands can prevent groundwater contamination [9],[10] and reduce nutrient (phosphate and nitrogen) [6]; thus, improving the water quality. Besides the mentioned functions, the constructed wetlands are also used to improve or restore some water bodies such as rivers and water basins [11]-[13], especially during the drought season. Compared to conventional system which relies on the compact energy-intensive operations with short retention time, constructed wetlands offer wastewater treatment through various physical, chemical and biological processes as large passive systems with long retention times [14].

Among the aquatic treatment systems, constructed wetlands have a greater potential in sewage treatment because they can tolerate higher organic loading rate (OLR) with shorter hydraulic retention time (HRT) [15] and improve the characteristics of the discharged effluent [16]-[18]. Hence, this study was conducted to demonstrate a conceptual design that can be used to optimise the performance of the constructed wetland using Vetiveria zizanioides to treat sewage under different HRTs.

2. MATERIALS AND METHOD

Three cells were prepared with different populations of Vetiveria zizanioides: (1) 60 plants for Cell A, (2) 30 plants for Cell B, and (3) no plant for Cell C (control unit). The experiments were conducted at zero retention time (without flow rate) and 5-day retention time (flow rate of HRT). The flow rate used for the 5-day retention time was 3.125×10^{-6} m^3/s. Prior to use, the cells were constructed with an impervious concrete (Figure 1) at the Environmental Engineering Laboratory, School of Civil Engineering, Faculty of Engineering, Universiti Teknologi Malaysia (UTM). Each cell was constructed with the same dimension of 0.5 × 4.0 × 0.5 m (width × length × depth), and a bed slope of 1%. The support media of the cells consisted of large gravel (2 cm in diameter) at the bottom, followed by medium gravel (1 cm in diameter), and sand on the top layer with total depth of 15 cm. The gravel was selected because of its high hydraulic conductivity, ease of maintenance, and consistency of specification, which allow for greater predictability of performance than other soil media. Meanwhile, sand was used to filter any settled particle from passing through the gravels.

The experiment was carried out under a well-ventilated open space with transparent roof. The three constructed wetland cells were set up together with the inlet pipe and valve connected to the sewage storage tank. The sewage depth was maintained at 0.3 m high from the top of the media. The outlet pipe was placed at approximately 20 cm below water surface, i.e. at the lowest level of the cell. The Vetiveria zizanioides were attached on top of the media in Cells A and B with different populations as mentioned earlier. Thus, approximately 10 cm of the roots were submerged in the sewage. The sewage was collected from the operating oxidation pond and fed into each cell continuously for one week to acclimatise the soil microbes and support the growth of Vetiveria zizanioides plants in Cells A and B. The treatment was immediately started after the acclimatisation by feeding each cell continuously with fresh sewage for two months. The inlet and outlet of the pond were maintained with the same flow rate.

The experiments of 5-day retention time and zero retention time were carried out separately. The samples were taken on Day 15, 33, 39, and 51 of the experiment. The effluents from each cell were sampled from cell outlet and analysed for pH, oil and grease (O&G), dissolved oxygen (DO), biochemical oxygen demand (BOD), and total suspended solid (TSS) according to the standard method (APHA, 2005). The collected data were statistically analysed to determine any significant pollutants removal among different cell systems and under different HRTs. The analysed parameters and standards used to run each analysis are tabulated in Table 1.

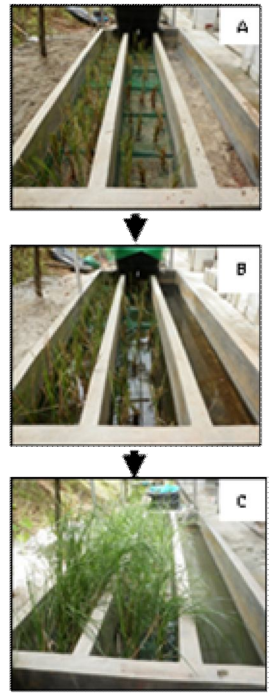

Figure 1: Development of the constructed wetlands using *Vetiveria zizanioides* for sewage treatment for (A) Day 1, (B) during treatment, and (C) after 60 days of treatment

Table 1: The parameter observed and standards used

Parameter	Units	Methods
pH	-	APHA 4500-H+ B
Dissolved Oxygen	mg/L	APHA 4500-O G
BOD@5 days	mg/L	APHA 5210 B
Total Suspended Solid	mg/L	APHA 2540 D
Oil & grease	mg/L	APHA 3114 C

3. RESULTS AND DISCUSSION

The experiment was carried out for 60 days. Statistical analysis was used to compare the treatments. The analysis evaluate the percentage of removal and time efficiency to remove the pollutants. Table 2 shows the initial pollutants concentrations in the raw sewage before treatment.

Table 2: Analysis of raw sewage before treatment

Parameter	Concentrations
Dissolve Oxygen (DO), mg/L	4.86 ± 0.45
pH	7.36 ± 0.26
Biochemical Oxygen Demand (BOD), mg/L	185.22 ± 0.25
Total Suspended Solid (TSS), mg/L	54.03 ± 0.15
Oil and Grease, mg/L	52.55 ± 0.21

The percentage of removal for Cells A, B, and C for 5-days retention time of sewage treatment is summarised in Table 3, while the removal under zero retention time is presented in Table 4. It shows that the number of plants had major contribution in reducing pollutants in the sewage. The removal of pollutants also occurred for zero retention time treatment for all cells.

Table 3: The percentage of removal for selected parameters at 5-days retention time for 60 days of sewage treatment

Parameter	Unit	Cell A	Cell B	Cell C
DO	mg/L	1.47 ± 0.21	1.73 ± 0.25	1.70 ± 0.04
pH	-	7.26 ± 0.12	7.27 ± 0.22	7.29 ± 0.01
BOD	mg/L	60.00 ± 0.15	44.86 ± 0.02	21.08 ± 0.25
TSS	mg/L	40.74 ± 0.05	40.74± 0.17	51.85 ± 0.21
O&G	mg/L	55.77 ± 0.29	40.38 ± 0.21	31.70 ± 0.08

Table 4: The percentage of removal for selected parameters at zero retention time for 60 days of sewage treatment

Paramete r	Unit	Cell A (%)	Cell B (%)	Cell C (%)
DO	mg/L	1.25 ± 0.01	1.27 ± 0.11	1.31 ± 0.14
pH	-	7.14 ± 0.23	7.28 ± 0.20	7.25 ± 0.22
BOD	mg/L	32.00 ± 0.11	28.57 ± 0.22	22.29 ± 0.1
TSS	mg/L	79.37 ± 0.10	73.02 ± 0.10	38.10 ± 0.11
O&G	mg/L	61.11 ± 0.19	50.00 ± 0.18	38.89 ± 0.28

3.1 Total Suspended Solid

Total suspended solid (TSS) are particles suspended in sewage that cannot pass through filter. Mason [19] and Boulton and Brock [20] reported that too much particles in the water can block the light penetration in water, and caused the reduction of photosynthesis by water plants, decrease water depth due to the build-up sediment, and increase the heat absorbed by the water. These conditions will lower the dissolved oxygen, facilitate parasite and disease growth, and increase the toxicity of ammonia in the water. Figure 2 (A) and (B) show the percentage of TSS removal for both HRTs.

The performance of zero retention time system in reducing TSS was higher than the 5-day retention time with the percentage of removal at Day 21 was 61.92% and 32.28% for zero retention time and 5-day retention time, respectively. Day 21 was chosen because the percentage of TSS removal for this day was almost constant. From the analysis, there was a significant difference between zero retention time and 5-day retention time for the cell with more plants ($p < 0.05$). The higher TSS removal in zero retention time is caused by the undisturbed TSS in the sewage, causing it to settle easily due to gravity force; leaving clean water throughout the experiment. The cells are typically designed to support long retention times to allow the suspended solids and other particles to settle. For the system with flow rate, the flow caused some particles to remain suspended and did not settle**.**

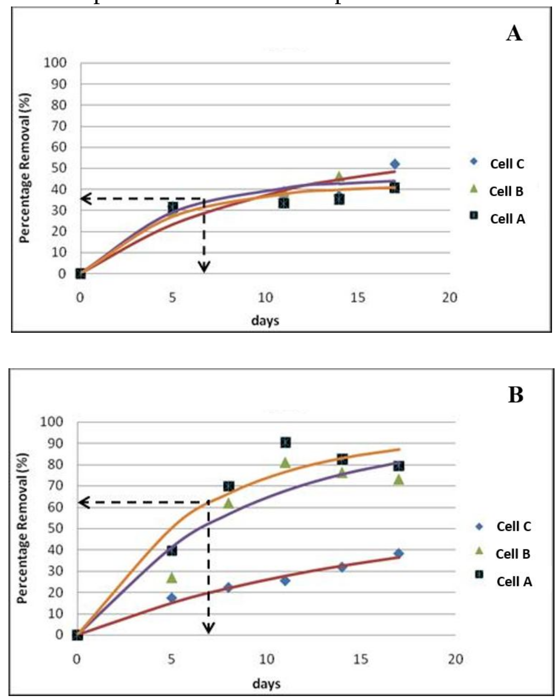

Figure 2: The percentage of TSS removal for system at (A) 5-day retention time and (B) zero retention time

Figure 3 shows that cells with plants (Cells A and B) gave a clearer effluent compared to the control cell (Cell C). Having more Vetiveria zizanioides gave a clearer effluent of Cell A than Cell B. Besides that, the presence of Vetiveria zizanioides and the increasing HRT decreased the removal percentage for both cells, but increased for the control cell. These results revealed that higher flow rate increased the disturbance to the suspended and settled particles make it difficult for the particles to settle, thus results in lower percentage of TSS removal. The results also show that the percentage of TSS removal increased with the increased of Vetiveria zizanioides population. The removal will further increase if more plants are used. However, too many plants may also lead to the increase of nutrients, especially when the plants die and rot.

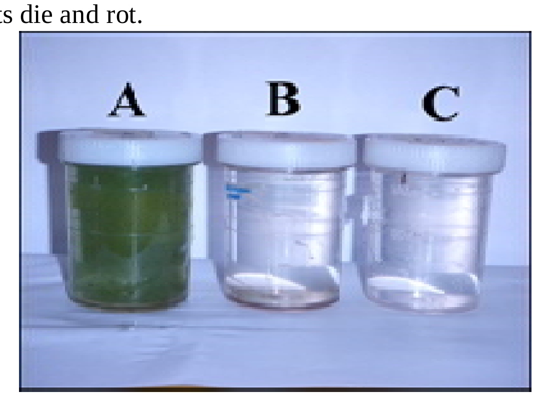

Figure 3: The quality of effluent for Cells A, B, and C.

3.2 Biochemical Oxygen Demand

BOD is a measurement of the oxygen consumed by microorganisms during the oxidation of organic and inorganic materials. The test is usually carried out for 5 days (BOD5) to indicate the amount of the readily degradable organic matter in the sewage. The percentages of BOD removal for both systems are shown in Figure 4.

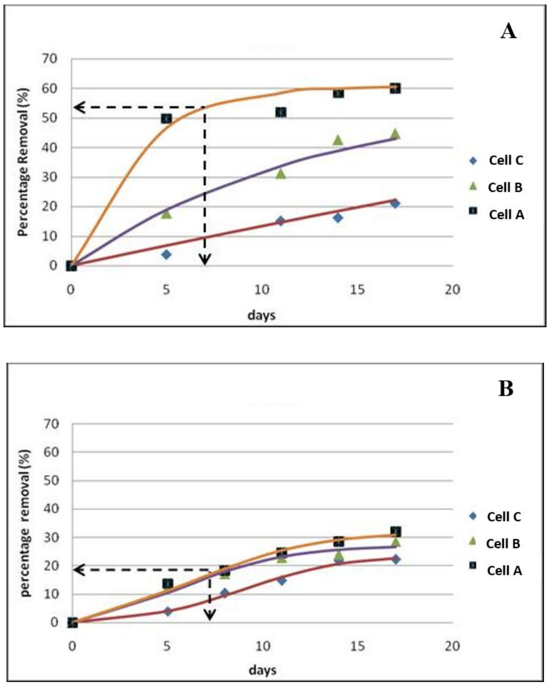

Figure 4: The percentage of BOD removal for (A) 5-day retention time, and (B) zero retention time systems

The highest percentage of removal for 5-day retention time and zero retention time at Day 17 was 61.06% and 32%, respectively. At Day 21, the percentage removals for cells with plants were 53.08% and 16.60% for 5-day retention time and zero retention time, respectively. The element of BOD could be removed by settling the particulates and during metabolic process where the utilizing the degradable carbon compound. The higher removal of BOD due to the higher organic decomposition rate by the Vetiveria zizanioides. Hence, it resulted in the CO_2 and acid production, which finally lower the pH value of the effluent (refer to Table 1, where initial pH was 7.36). Tables 2 and 3 also show that the pH values were increased for all cells after the treatment. There was a significant difference between zero retention time and 5-day retention time for cell A ($p < 0.05$). According to Sartaj et al. [21], wetland systems can significantly reduce the BOD content.

3.3 Oil & Grease

The potential of wetland plants to uptake nutrients have a few factors, which are the sewage quality, species of plants, the growth, and the depth of roots. Wetland plants on the soil with oxygen carrying the nutrients and root functions of water conduction are related to the development of root system [22]. Fig. 5 illustrates the removal percentage for 5-day retention time and zero retention time systems. The percentage of O&G removals after 21 days for 5-day retention time system in Cells A, B, and C were 15.43%, 40.05%, and 50.75%, respectively; while the zero retention time system gave 6.20%, 11.16%, and 16.60% for Cells A, B, and C, respectively. The O&G was trapped by the Vetiveria zizanioides massive roots, especially in the flowing system compared to the system without flowing sewage.

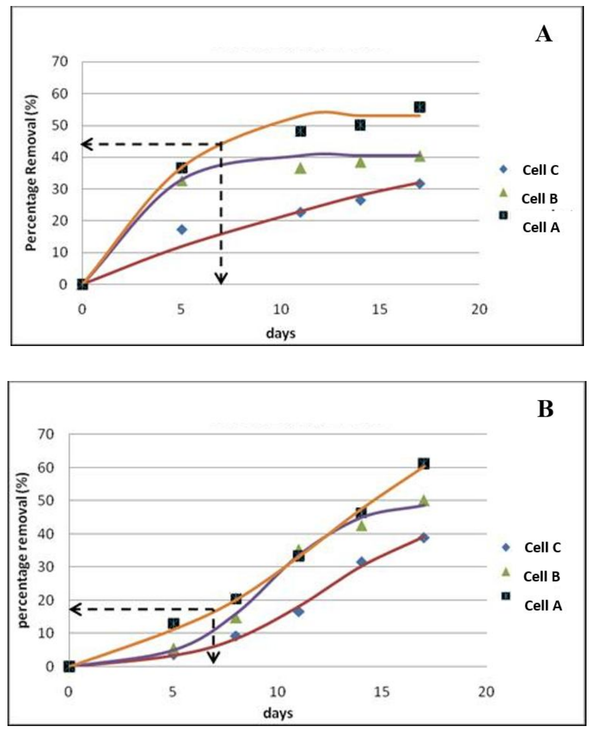

Fig. 5: The O&G removal percentage for (A) 5-day retention time, and (B) zero retention time systems

The ability of the 5-day retention time system to remove O&G in the sewage was higher compared to zero retention time system. Cell A in 5-day retention time and zero retention time systems showed a significant difference ($p < 0.05$). Majority of O&G trapped by the Vetiveria zizanioides roots in zero retention time system. For 5-day retention time system, the O&G was trapped at roots and media when the sewage was flowed through the cell and media. While O&G suspended on top of the undisturbed sewage, the percentage of the removal was higher for Cell A compared to Cell B and Control. A comparison was made on the O&G removal for both 5-day retention time and zero retention time at Day 21. The results show that the removal for 5-day retention time system was much higher compared to zero retention time system for all cells. The vetivers' root system are very good system with diameter of 0.5–1.0 mm and ready to remove any pollutants in the wastewater that passes through the root system [23].

4. CONCLUSIONS

It can be concluded that the *Vetiveria zizanioides* used in the constructed wetland to treat sewage in this study is an potential alternative technology. *Vetiveria zizanioides* contributed in the removal of nutrient, TSS, BOD, and O&G. The benefit of constructed wetland technology which are good treatment effect, low operation cost, low construction cost, ecological restoration function, and building ecological landscape compared to the chemical and biological sewage treatment [24],[25]. The removal efficiency of the constructed wetland in this study showed an effective performance as predicted. The best treatment day was at Day 21. HRT is also an element that contributes to the ability of constructed wetland with *Vetiveria zizanioides* to reduce contaminants in the sewage. From the study, the results show that the constructed wetland at 5-day retention time system reduced the pollution better than zero retention time system.

The analysis shows that there was a significant difference between zero retention time and 5-day retention time for all cells with $p < 0.05$. The percentage of removal for every parameter for 5-day retention time was acclimatised at Day 21 compared to the percentage of removal for zero retention time which was gradually increased even after 21 days of treatment**.**

For future research, more extensive studies need to be carried out including the implementation of other types of plant, HRT, and the number of plant population used in the experiment. A longer period of experiment is necessary to determine the capacity of the free water surface flow for the constructed wetlands to the fullest in terms of pollutant removal.

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