SEWAGE TREATMENT PERFORMANCE OF CONSTRUCTED WETLANDS USING *VETIVERIA ZIZANIOIDES*

Noraziah Ahmad, Johan Sohaili, Nur Atikah Abdul Salim, Noorul Hudai Abdullah

Abstract

Constructed wetlands are one of the alternative treatments for treating domestic wastewater since they are low-energy, low-maintenance and environmentally friendly. The purpose of this research was to see if the *vetiveria zizaniodes* plant could be used to eliminate pollution from a created wetland. Two alternative flow systems were used in the study, a 5-day retention period and no retention time flow system. In each cell of the constructed wetlands, *vetiveria zizanoides* were planted in different populations. The systems' effectiveness in minimising oil and grease (O&G) concentrations, total suspended solid (TSS), and biochemical oxygen demand (BOD) was measured by means of dissolved oxygen (DO) and pH, respectively. The analysis indicates that using *vetiveria zizanioides* in the artificial wetland may minimise near to 53.08 % BOD and 50.75 % O&G for 60 days of treatment for a 5-day retention duration. Meanwhile, the wetland was possible to reduce 61.92 % TSS on day 60 at zero hydraulic retention time (HRT) in that same 60 days of treatment. The *vetiveria zizanioides* plant was discovered to play a substantial role in eliminating BOD, TSS, and O&G during HRT as a result of the findings.

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Introduction

The zone where terrestrial and aquatic habitats meet is represented by wetlands. Using wetlands to remediate industrial wastewater is a promising substitute. Wetlands have been demonstrated in numerous studies to be good nutrient sinks, and to be capable of removing both organic and inorganic contaminants (Almuktar et al., 2019). Although the standard treatment methods have been used and applied for a long time and are adequate and practical, they can still be achieved by focusing on nutrients, organic and inorganic substances removal, and a technique to polish sewage treatment plant outflow before being discharged. Artificial wetlands for treating wastewater are now commonly recognised and becoming more popularly demanded as a treatment alternative. Constructed wetlands were initially utilised to effectively filter nutrients from household and septic systems, surface and fertiliser runoff.

Wetlands are divided into two types: natural and constructed wetlands. Most of the country has employed constructed wetlands as a secondary treatment following sewage treatment plants. A constructed wetland can be classified into various types (Wu et al., 2015) and are based on wetland hydrology; constructed wetland may be simply classified into two basic types, i.e. free water surface flow (FWS) and subsurface flow (SSF). These systems are commonly used for sewage treatment and have been classified as the Best Management Practices (BMPs) for flood control and small urban drainage systems. Constructed wetlands, according to Olson and Mitsch (1992), have been considered an appealing economical approach for managing water contamination from both point and non-point sources. According to Krzeminski et al. (2019), most countries have employed artificial wetlands as a secondary treatment following sewage treatment plants, and they have also been used for industrial purposes. Treatment of wastewater has been shown to be a viable option. Wetlands have also been reported to have the ability to prevent contaminated groundwater, by prohibiting it from infiltrating the wetland (Kadlec et al., 2000). Wetlands, according to Olson (1992), can help to reduce the nitrogen levels in sewage, therefore enhancing water quality. Constructed wetlands, on the other hand, are used to rehabilitate or recover diverse watersheds, including waterways basins, particularly during periods of drought (Nairn and Mitsch, 2000; Mitsch et al., 2005; Mitsch and Day, 2006). Constructed wetlands treat wastewater using various physical, chemical and biological features, whereas the traditional system depends on compact resources activities with limited residence durations. Wetlands, on the other hand, are huge passive systems with extensive detention periods.

Constructed wetlands offer a larger potential in sewage treatment than other wastewater treatment systems, as it can maintain a greater organic loading rate (OLR), while maintaining a shorter hydraulic retention time (HRT). These can then improve the effluent characteristics discharged (Chongrak and Lim, 1998). The goal of this study was to demonstrate how a design process may be used to improve the effectiveness of a constructed wetland using *vetiveria zizanioides* for sewage treatment in varying HRTs.

Methodology

The research was carried out in three (3) cells, each with a varying amount of *vetiveria zizaniodes*, with Cell A containing 60 plants, Cell B containing 30 plants and Cell C containing no plants serving as a controller. Two types of experiments were conducted, i.e. the experiments are conducted without flow rate, namely no retention time, and with flow rate of hydraulic retention time 5 days, namely 5-days retention time. The 5-days retention time is carried out with Q of 3.125 x 10^{-6} m^3/s. The three (3) cells used for the study shown in Figure 1, were designed with a concrete impermeable to water, located at the Environmental Engineering Laboratory, Universiti Teknologi Malaysia (UTM), Faculty of Civil Engineering, Skudai Johor, Malaysia. Every cell had the same width, length and depth (0.5m x 4.0m x 0.5m), as well as a

1% bed gradient. The support media includes large gravel (2 cm in diameter) on the bottom, medium gravel (1 cm in diameter) and sand on the top layer, with a total depth of 15cm. Gravel was preferred over other soil media because of its excellent hydraulic conductivity, durability and specification stability, which allows for improved performance predictability. Sand is used as a filter as well as a way to block any settled particles from flowing through the gravels.

The studies were conducted in an open, well-ventilated area with a glass roof. The inflow pipeline and nozzle to the sewage storage tank were connected to three built wetland cells. From the top of the medium, the sewage depth is kept at 0.3 m. The discharge pipe is around 20 cm under the water surface, i.e. at the bottom point of the unit. The *vetiveria zizaniodes* were put on top of the media in Cell A and B with different populations, as previously described. As a consequence, the roots were immersed in sewage for about 10 cm. Sewage was obtained from an active oxidation pond and fed continuously into each cell for one week to acclimatise the soil microorganisms and assist the development of the *vetiveria zizaniodes* plants in Cell A and B. The treatment began immediately after acclimatisation, with each cell being regularly fed raw sewage for 60 days. Both the pond's inflow and exit were kept at the same flow rate. The pond's inflow and outflow were both maintained simultaneously.

Individually, the 5-day retention time experiment and the no retention time experiment were performed. On days 15, 33, 39 and 51 of the study, samples were tested. Each cell's effluents were taken from the cell outflow, and tested for pH, DO and BOD using conventional procedures (APHA, 2005). The data were statistically analysed to see if there were any significant pollution removals between different cell systems and varied hydraulic retention times. Table 1 summarises the results of the study's parameter analysis.

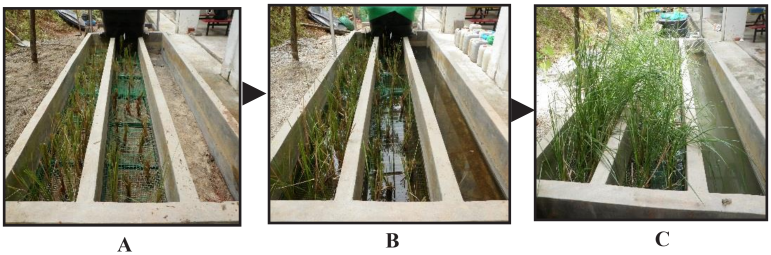

Figure 1: Development of artificial wetlands for sewage treatment with *vetiveria zizaniodes* from day 1 (A), throughout treatment (B) and after 60 days treatment (C)

Table 1: The parameters and the standards utilised.

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

Result and Discussion

The experiment was conducted for 60 days. The treatments were compared using statistical analysis. The proportion of pollutants removed and the time it takes to remove them are assessed in this study. Table 2 illustrates the primary concentrations of contaminants in raw sewage prior to treatment.

Table 2: Pre-treatment analysis of raw sewage

Parameter	Unit	Concentrations
DO	mg/L	4.86 ± 0.45
pH	-	7.36 ± 0.26
BOD	mg/L	185.22 ± 0.25
TSS	mg/L	54.03 ± 0.15
O&G	mg/L	52.55 ± 0.21

Table 3 summarises the elimination percentages for Cells A, B and C for a 5-day retention period of sewage treatment, while Table 4 shows the removal under no retention time. It reveals that the number of plants played a significant role in reducing sewage pollution. Pollutants were removed from all cells throughout the no retention time treatment.

Table 3: The elimination for different parameters at 5-day retention period over 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 elimination for different parameters at no retention time after 60 days of sewage treatment.

Parameter (%)	**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

Total Suspended solid

Total Suspended solids (TSS) are one of the most significant components of freshwater ecosystems, because they serve as a medium for nutrients to interact (Sandström et al., 2020; Nasrabadi et al., 2019). Mason (1998), and Boulton and Brock (1999) reported that all those substances inside the water could block light from reaching water plants, lowering photosynthetic activity, lowering water level owing to sediment development and increasing the amount of heat absorbed. The water's dissolved oxygen content will decline, making pathogens and disease development easier, and the water's ammonia potency will rise. Figures 2 (A) and 2 (B) indicate the proportion of TSS removed for both HRTs (B).

The zero-retention time method performed better than the 5-day retention time system in terms of lowering TSS, removal percentages at day 21 were 61.92% for no retention time and 32.28% for 5-day retention period, respectively. Day 21 was determined because the percentage of TSS eliminated on this day was practically constant. According to the results, there was a wide variation between no retention time and 5-day retention time for the cell with more plants (p 0.05). Since the TSS in the sewage is not disturbed, it settles quickly due to gravity, leaving clean water throughout the study, resulting in improved TSS elimination in no retention time. Long retention durations are probably constructed into the cells to allow the sedimentation of dissolved particles and other substances. Some particles remained suspended and did not settle in the system due to the flow rate.

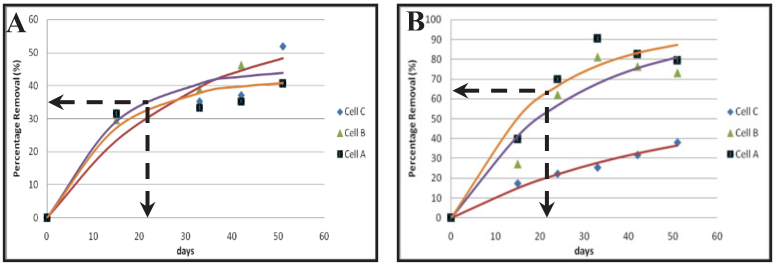

Figure 2: The TSS removal for the system at (A) a 5-day and (B) zero-retention time.

Figure 3 shows that the cells containing plants (Cells A and B) had a better discharge than the control cell (Cell C). Effluent from the Cell C was clearer than Cell B because it had more *vetiveria zizanioides*. In addition, the combination of *vetiveria zizanioides* and higher HRT lowered the elimination percentage in both cells, but higher in the control cell. These data show that a higher flow rate disturbs suspended and settled particles, making it more difficult to settle and resulting in a lower TSS removal percentage. Moreover, suspended solids are an important part of aquatic ecosystems and their nutrient concentrations can reflect the water quality (Lindstrom et al., 1999). The percentage of TSS removed is improved as the population of *vetiveria zizanioides* increased, according to the findings. Since more plants are used, the removal will increase even more. Too many plants, on the other hand, can help to improve the nutrition levels, mainly as the plants start to decay.

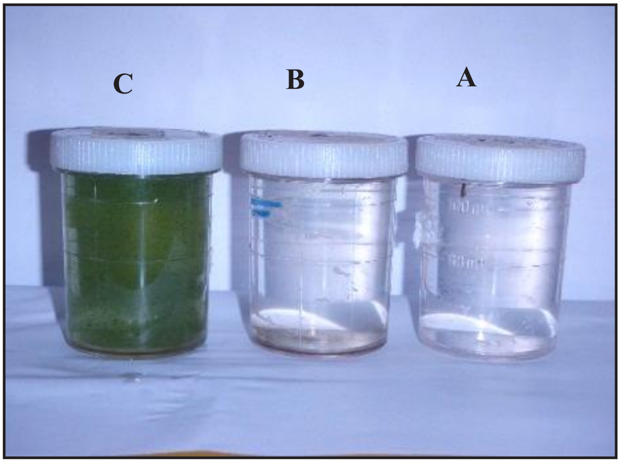

Figure 3: Cells A, B and C discharge cleanliness.

Biochemical Oxygen Demand (BOD)

BOD is a measure of how much oxygen microbes are consumed when organic and inorganic compounds are oxidised. The BOD_5 test is typically performed for 5 days to find out how much dissolved organic matter is in the effluent. Figure 4 shows the percentages of BOD removed.

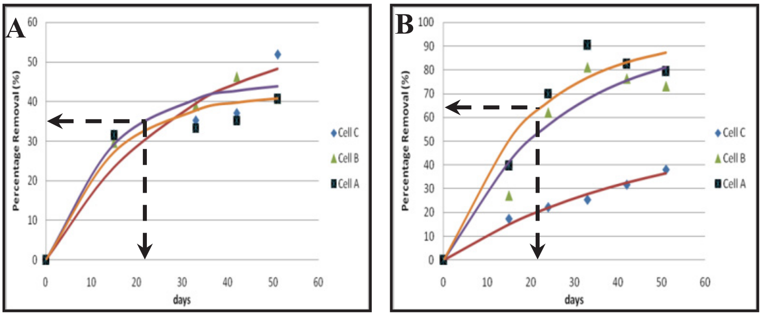

Figure 4: The BOD removal in the systems with (A) a 5-day and (B) no retention time.

The greatest number of eliminations at day 17 was 61.06% for a 5-day retention period and 32% for a no retention period, respectively. At day 21, the proportions of cells having plants eliminated were 53.08 % and 16.60 % for 5-day and no retention time, respectively. The BOD can be eliminated by settling particles and using a degradable carbon compound during the metabolic process. Since *vetiveria zizanioides* decomposes organic matter at a faster rate, it removes more BOD. As a result, CO_2 and acid were produced, ultimately lowering a measure of the effluent's pH (refer to Table 1, where initial pH was 7.36). The pH values of all cells are increased after the treatments, as seen in Tables 2 and 3. There was a substantial variation in retention length between zero and 5 days for cell A (p 0.05). As said by Sartaj et al. (2000), the wetland approach can significantly minimise BOD levels.

Oil & Grease (O&G)

The ability of the marsh to absorb nutrients varies depending on the season, on the species, sewage quality, size and root depths. The growth of the root system is similar to the available oxygen capacity of wetland plants on the soil and root roles of water conduction (Liu et al., 2007). The proportion of O&G that has been removed after 21 days of treatment with 5-days retention time in control cell, cell with less plant and cell with more plant is 15.43%, 40.05% and 50.75%, respectively, while the percentage of O&G removal after no retention time is 6.20%, 11.16% and 16.60%. Figure 5 shows the elimination percentage for retention times of 5 days and zero days. The massive root hairs of *vetiveria zizaniodes* trapped oil and grease, primarily in moving sewage systems compared to a non-flowing sewage system.

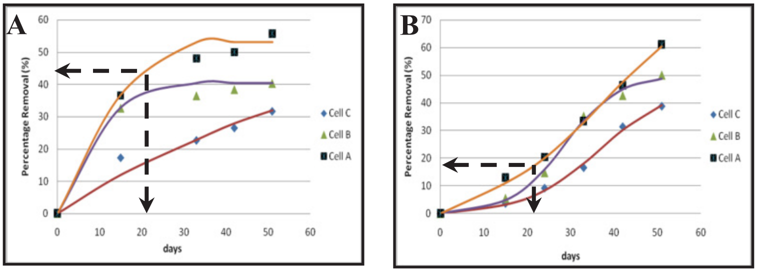

Figure 5: The O&G removal for (A) 5-day retention and (B) no retention time systems.

Compared to the no retention time method, when it came to extracting O&G from sewage, the 5-day retention time approach performed better. There was a significant difference (p 0.05) between Cell A in the 5-day and no retention time systems. In a no retention time system, the large amount of O&G is caught by the roots of *vetiveria zizanioides*. When sewage was circulated through the cell and media for a 5-day retention time system, the O&G was trapped by roots and media. When O&G was suspended on top of undisturbed sewage, Cell A had a higher percentage of removal than Cell B and Control. The elimination of O&G was compared at day 21 for both 5-day retention time and 0% retention time. The statistics show that the elimination rate for all cells was substantially greater for the 5-day retention time system than for the no retention time approach. As said by Panja et al. (2018), the *vetiver* subsoil has a diameter of 0.5–1.0 mm and is able to clean up any contaminants that pass through it in the sewage.

Conclusion

The *vetiveria zizanioides* used to treat sewage in this study's artificial wetland can be determined to be a promising alternative approach. TSS, BOD, and O&G were removed with the help of *vetiveria zizanioides*. In this investigation, the built wetland performed as expected in terms of water removal efficiency. The finest treatment day was day 21. When *vetiveria zizanioides* is present, HRT plays a role in the artificial wetland's ability to filter contaminants from sewage. The developed wetland with a 5-day retention time system reduced pollution more efficiently than the no retention time treatment, as stated in the data.

The study was designed to determine the change between zero and 5-day retention periods for all cells, with a p-value of 0.05. Unlike the percentage of elimination for no retention time, which increases continuously even after 21 days of treatment, the percentage of elimination per each factor for the 5-day retention period acclimates by day 21.

More detailed investigations, including the use of additional species of plants, HRT and the total of plants used in the study, are needed in the future. An extended study time is needed to assess the effectiveness of the developed wetlands' open water surface flow to remove contaminants to the fullest extent possible.

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References

Almuktar, S.A.A.A.N., Abed, S.N., & Scholz. M. (2018). Wetlands form wastewater treatment and subsequent recycling of treated effluent: a review. *EnvironmentaScience and Pollution Research International*. Vol. 25 No. 24. pp 23595-23623.

APHA (2002), *Standard methods for Examination of Water and Wastewater*. 21st edition. Washington: American Public Health Association.

Boulton, A.J. & Brock, M.A. (1999). *Australian Freshwater Ecology: process and Management*. Cooperative Research Centre for Freshwater Ecology and Gleneagles Publishing: SA.

Chongrak, P. & Lim, P.E., (1998). *Constructed Wetland for Wastewater Treatment and Resource Recovery*. Thailand: Environmental Systems Information Center.

Dunbabin, J.S. & Bowmer, K.H. (1992). Potential Use of Constructed Wetlands for Treatment of Industrial Sewages Cointaining Metals. *The Science of The Total Environment*. Vol. 2, No.3, pp 151-168.

Fulazzaky, M., Abdullah, N., Mohd Yusoff, A., & Paul, E. (2015). Conditioning the alternating aerobic–anoxic process to enhance the removal of inorganic nitrogen pollution from a municipal wastewater in France. *Journal of Cleaner Production*. 3, pp 1-7.

Krzeminski, P., Tomei, M.C., Karaolia, P., Langehoff, A., Almieda, C.M.R., Felis, E., Gritten, F., Andersen, H.R., Fernandes, T., Manaia, C.M., Rizzo, L., & Kassionos, D.F. (2019) Performance of secondary wastewater treatment methods for the removal of contaminants of emerging concern implicated in crop uptake and antibiotic resistance spread: A review. *Science of The Total Environment*. Vol. 648, pp 1052-1081.

Kadlec, R.H., Knight, R.L., Vymazal, J., Brix, H., Cooper, P., & Haberl, R. (2017). Constructed Wetlands for Pollution Control; Processes, Performances, Design and Operation". *Scientific and Technical Report* No. 8, IWA Publishing, London, England, 2000. 10. E. Maxwell, E. W. Peterson, and C. M. O'Reilly. Enhanced Nitrate Reduction within a Constrycted Wetland System: Nitrate Removal within Groundwater Flow. Wetland. Vol. 37 No.3, pp 413-422.

Lindström, M., Håkanson, L., Abrahamsson, O., & Johansson, H. (1999) An empirical model for prediction of lake water suspended particulate matter. *Ecol. Model*. 121, 185–198.

Maucieri, C., Barbera, A., Vymazal, J., & Borin, M. (2017) A review on the main affecting factors of greenhouse gases emission in constructed wetlands. *Agricultural and Forest Meteorology*. Vol. 236, pp175-195.

Mitsch, W.J., (1992). Landscape Design and the Role of Created, Restored, and Natural Riparian Wetlands in Controlling Nonpoint Source Pollution. *Ecological Engineering*. Vol. 12, pp 27-47.

Mitsch, W.J., Day, J.W., Zhang, L., & Lane, R.R. (2005). Nitrate-nitrogen Retention in Wetlands in the Mississippi River Basin. *Ecological Engineering*. Vol. 24, pp 267-327.

Mitsch, W.J. & Day, J.W. (2017). Restoration of Wetlands in The Mississippi-Ohio-Missouri (MOM) River Basin: Experiences and Needed Research. Ecological Engineering. Vol. 26, pp 55-69, 2006. 14. P. Champagne, L. Liu, and M. Howell. Aerobic in Cold-Climate Countries. *Current Development. Biotechnology and Bioengineering*. pp 161-201.

Nairn, R.W. & Mitsch, W.J. (2000). Phosphorus Removal in Created Wetland Ponds Receiving River Overflow. *Ecological Engineering*. Vol. 14, pp 107-126.

Nasrabadi, T., Ruegner, H., Sirdari, Z.Z., Schiwientek, M., & Grathwohl, P. (2016). Using total suspended solids (TSS) and turbidity as proxies for evaluation of metal transport in river water. *Appl. Geochem*. 68, 1–9.

Olson, R.K. (1992). Evaluating the Role of Created and Natural Wetlands in Controlling Non-Point Source Pollution. *Ecological Engineering*. 12:10-15.

Rezania, S., Ponraj, M., Talaiekhozani, A., Mohamad, S.E., Din, M.F.M., Taib, S.M., Sabbagh, F., & Sairin, F.M. (2015). Perspective of phytoremediation using water hyacinth for removal of heavy metals, organic and inorganic pollutants in wastewater. *Journal of Environmental Management*. Vol. 163, pp 125-133.

Sandström, S., Futter, M.N., Kyllmar, K., Bishop, K., O'Connell, D.W., & Djodjic, F. (2020). Particulate phosphorus and suspended solids losses from small agricultural catchments: Links to stream and catchment characteristics. *Sci. Total Environ*. 711, 1–12

Turcios, A.E. & Papenbrock, J. (2014). Sustainable Treatment of Aquaculture Effluent-what can learn from the past for the future? *Sustainability*. Vol. 6, pp 836-856, 2014.

Wu, H., Zhang, J., Ngo, H.H., Guo, W., Hu, Z., Liang, Z.S., Fan, J., & Liu, H. (2015). A review on sustainability of constructed wetlands for wastewater treatment: Design and operation. *Bioresource Technology*. Vol. 175, pp 594-601.

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