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Removal of Nutrients from Landfill Leachate Using Subsurface Flow Constructed Wetland Planted With *Limnocharis flava* and *Scirpus atrovirens*

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Abstract. This study focus on the efficiency of horizontal subsurface flow constructed wetland in the removal of nutrients (NH_3-N and PO_4-P) in landfill leachate. Where, it is also to compare the efficiency of two species which are *Limnocharis flava* and *Scirpus atrovirens* in removing nutrients in landfill leachate. The system comprises of two planted system and one control system. Each system consists of a wetland reactor, a feeding tank and settling tank. The systems operated identically at hydraulic retention times of 24 hours. The removal efficiency obtained from this study indicated that Planted system with *Limnocharis flava* and *Scirpus atrovirens* had the highest percentage of removal compared to unplanted control system. However, the percentage of nutrients uptake by *Limnocharis flava's* for NH_3-N is 61.3% and PO_4-P is 52%, while for *Scirpus atrovirens*, the percentage of NH_3-N uptake is 38.7% and PO_4-P is 48%, respectively. So that, it can be concluded that *Limnocharis flava's* is more suitable to be used for the treatment of landfill leachate which contain high nutrients compared to *Scirpus atrovirens*.

Keywords: Landfill Leachate, Nutrients Removal, Plant Uptake, Constructed Wetlands.

1. Introduction

Landfill leachate classified as problematic wastewaters and represents a dangerous source of pollution for the environment. It contained high concentration of organic matters, inorganic matters and heavy metals (Qasim and Chiang, 1994). Thus, landfill leachate must be treated before its being discharged into the waterways or lakes. Failure to treat the effluent from the landfill caused the content of organic and inorganic materials may migrate from the refuse and contaminate the surface water and groundwater. If not dealt properly its can affecting aquatic ecosystems, human health problems and effect the environment. There are various options to treat landfill leachate and constructed wetland is one of efficient method to treat this landfill leachate.

Constructed wetlands have become a very popular technology for removal of contaminants from domestic sewage (Hanna and Katarzyna, 1999). This system considered as low-cost alternative for wastewater treatment especially suitable for developing countries. They also have low operation and maintenance requirements. Treatment of wastewater in constructed wetland systems includes biological and biochemical processes (Wittgren and Maehlum, 1997). They have been proved to be efficient in reducing different undesired constituents, such as BOD, COD, NH_3–N, PO_4–P and heavy metals from wastewaters. Biochemical transformations, adsorptions, precipitations, volatilisation and plant uptake of pollutants are the main pollutant removal mechanism in a constructed wetlands system (Gui et. al, 2007). Constructed wetland is principally using the same natural degradation processes and nutrient uptake.

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The aims of this study are to assess the performance of horizontal subsurface flow (HSSF) constructed wetland system in the removal of nutrients (Ammonia Nitrogen, NH_3-N and Orthophosphate, PO_4-P) from landfill leachate. Where, it is also to compare the efficiency of *Limnocharis flav*a and *Scirpus atrovirens* in removing nutrients in leachate. This is done by measuring the amount of nutrients accumulated and retained in the plant's root and aerial part (stem and leaves).

2. Methodology

2.1. Experiment Set up

In this study, three laboratory scale horizontal subsurface flow (HSSF) constructed wetland systems have been constructed. Two systems comprises of two different planted system and one control system. The planted systems namely Reactor A was planted with *Limnocharis flava*, Reactor B was planted with *Scirpus atrovirens*, while the control systems namely Reactor C were left unplanted. Each system consists of a wetland reactor, a feeding tank and settling tank. The wetland reactor and operation characteristics are summarized in Table 1. The wetland reactors were constructed using acrylic with the dimension of 0.584 m length, 0.305 m wide, and 0.330 m depth. Each reactor has plantation area of 0.141 m^2 and similar construction which the outlets for each system are placed in a horizontal position with the inlet at 0.254 m from the bottom of the reactor.

Table 1: Reactor characteristics

Total reactor height	0.33 m
Total surface area	0.178 m^2
Total planting area	0.141 m^2
Weight of soil per reactor	33.02 kg
Flow rate	0.029 m^3/d
Hydraulic Retention Time (HRT) per cycle	24 hours

Ten (10) stems of each species are used in this experiment and the initial characteristic of plants had been done before planted in each reactor. After the transplantation, the wetland reactors were loaded with tap water to establish the emergent plant. The duration it takes for the acclimatization process was 14 days, where the readiness of the plant for the actual experimental procedure was illustrated by the healthy leaves and stem and also by the growth of new leaves and inflorescence.

2.2. Analysis of Plant Tissues

Analysis of the plant tissues were conducted initially before the treatment procedures begin and after the termination of the experiment. This analysis was conducted to determine the uptake of nutrients (NH_3-N and PO_4-P) by the plant tissues. The plant tissue samples were digested using the 11466 ISO standard methods (the aqua regia digestion method) where one sample from each plant reactors were selected and harvested. The plants samples were then placed in a porcelain crucible and ashed by heating it overnight in a furnace at 200°C and blended. The ash residue was then cooled and 3 g of each sample (leaf, stem, and root) was placed in a 100 mL round bottom flask with 21 mL of concentrated HCl (35%) and 7 mL concentrated HNO_3 (65%). The solution was kept at room temperature over night and solution heated to boiling for 2 hour. 25 mL of water was added before filtration of the mixture through using a Whatman No. 42 filter. The filtered residue was rinsed twice with 5 mL of water and the solution was made up to 100 mL (Tanja and Dermot, 2009).

3. Result and Discussion

This research discusses the performance of subsurface flow (SSF) constructed wetland system planted with *Limnocharis flava* and *Scirpus atrovirens* in treating landfill leachate (NH_3-N and PO_4-P) based on the laboratory scale reactors and laboratory analysis. In this study, landfill leachate with high NH_3-N and PO_4-P concentrations were treated by using constructed wetland systems operated in horizontal subsurface flow mode. The experiment was carried out during December 2010 until February 2011 including planting and acclimation periods.

Nitrogen transformation in wetlands occurs by five principal biological processes, ammonification, nitrification, denitrification, nitrogen fixation and nitrogen assimilation. Nitrogen removal is achieved not only by bacteria, but also by plant uptake and adsorption, where ionized ammonia reacts with the media in SSF constructed wetlands (Kadlec and Knight, 1996; Yang et. al, 2001; Al-Omari and Fayyad, 2003). Fig. 1 shows the initial concentration of NH_3-N in the landfill leachate was 138 mg/L, which was then reduced significantly to 11.35 mg/L, 13.28 mg/L, and 17.62 mg/L for Reactor A, B and C, respectively at the end of treatment. In this study, all of the reactors performed well in the removal of NH_3-N in the landfill leachate, as indicated by the overall treatment performance which does not differ greatly between each system with 91.8%, 90.4% and 87.2% for reactor A, B and C, respectively.

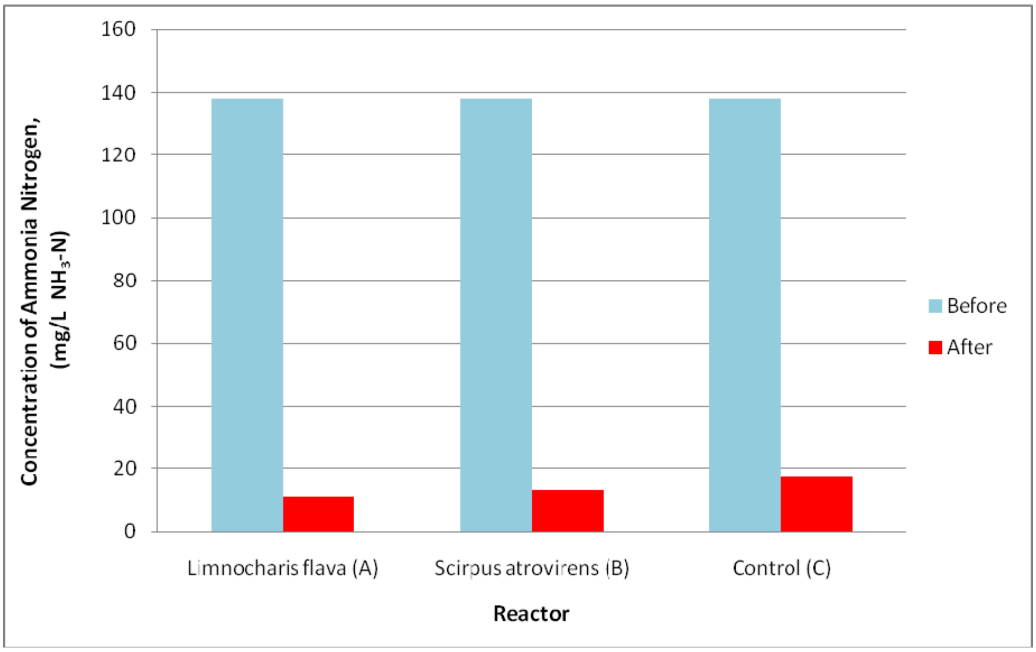

Fig. 1: Concentration of Ammonia Nitrogen (NH_3-N) before and after treatment

As shown in Fig. 1, the concentration of NH_3-N in leachate has been decreased. This is caused of soil effect because all soils have a power of holding nutrients and plant nutrient though there is a great different in the power according to the kind of soil and nutrient (Miyake et. al, 1923). NH_3-N in a constructed wetland is removed by volatilization, adsorption, plant uptake and nitrification (IWA, 2000). In this work, the pH in both wetland systems was found to be ranging from 6 to 8 throughout the treatment period. Therefore, NH_3-N loss through volatilization was negligible in this study because NH_3-N volatilization is generally insignificant at pH below 9.3 (IWA, 2000). NH_3-N could be adsorbed on sediment or matrix in wetlands; however, such removal is not considered to be a long-term sink because the adsorbed NH_3-N is released easily when water chemistry conditions change (Kadlec and Knight, 1996). Besides, nitrogen could be also taken up by plants, but released back to the water after decomposition process, as it had been indicated by the increase in the concentration of NH_3-N during the treatment period for both planted system. Consequently, nitrification played an important and a long-term role in removing NH_3-N.

Based on plant tissues analysis, the results show that the amount of NH_3-N uptake by *Limnocharis flava* (135.2 mg/L) is higher than *Scripus atrovirens* (85.2 mg/L). It is because different plant species may exploit different niches within the same environment, gaining access to nutrients that are not available to other species (Evans and Edwards, 2001). The soil horizon that is explored by roots varies greatly between species. Other than that, it maybe cause of effect from the nature of plant. For example, the volume of root and the size of leaf for *Limnocharis flava* are larger than *Scirpus atrovirens*. This is because the volume of soil that can be explored by a given root mass varies greatly between species and is related to branching patterns and specific root length. Other than that, some roots of different plant have a specialized structure and physiology to enable them to capture a particular nutrient (Evans and Edwards, 2001).

PO_4-P removal is governed by physical (sedimentation) and chemical (adsorption) process and biological transformations (Yalcuk and Ugurlu, 2008). PO_4-P can be removed directly by macrophytes uptake or chemical storage in the sediments (Bonomo et. al, 1997). In this study, it show that a small difference uptake between planted and unplanted system. The influent concentration of PO_4-P in the leachate samples used in this study was 31.5 mg/L, which was then reduced significantly to 1.35 mg/L, 5.58 mg/L and 9.08 mg/L for reactor A, B and C, respectively as it been demonstrated in Fig. 2. The overall treatment performances for each system were achieved 95.7%, 82.3% and 71.2% for reactor A, B and C, respectively. From the Fig. 2, it shows that concentration of PO_4-P is decreasing in each reactor. This result may effect by plant because organic PO_4-P can found in plant residues, manures, and microbial tissues. It is proved when the concentration of PO_4-P in *Limnocharis flava* and *Scirpus atrovirens* also increases after 30 days. The planted and unplanted system shows a small difference in term of overall treatment performance, although the uptake of PO_4-P as high as 29.6 mg/L (52%) has been determined in the tissue of *Limnocharis flava* and 27.3 mg/L (48%) in *Scirpus atrovirens*. The results also show that the percentage of PO_4-P in *Limnocharis flava* is higher than *Scirpus atrovirens.* The ability of *Limnocharis flava* to uptake nutrients compared to the other plants is coherent with the findings by Ain Nihla et. al (2011); Ain Nihla et. al (2009); Siti Kamariah (2006). Study by Ain Nihla et. al (2011) reported that the *Limnocharis flava* planted in both horizontal and vertival SSF constructed wetland exhibit the highest uptake of PO_4-P. Where, the highest amount of PO_4-P was observed to be accumulated within the plant's root.

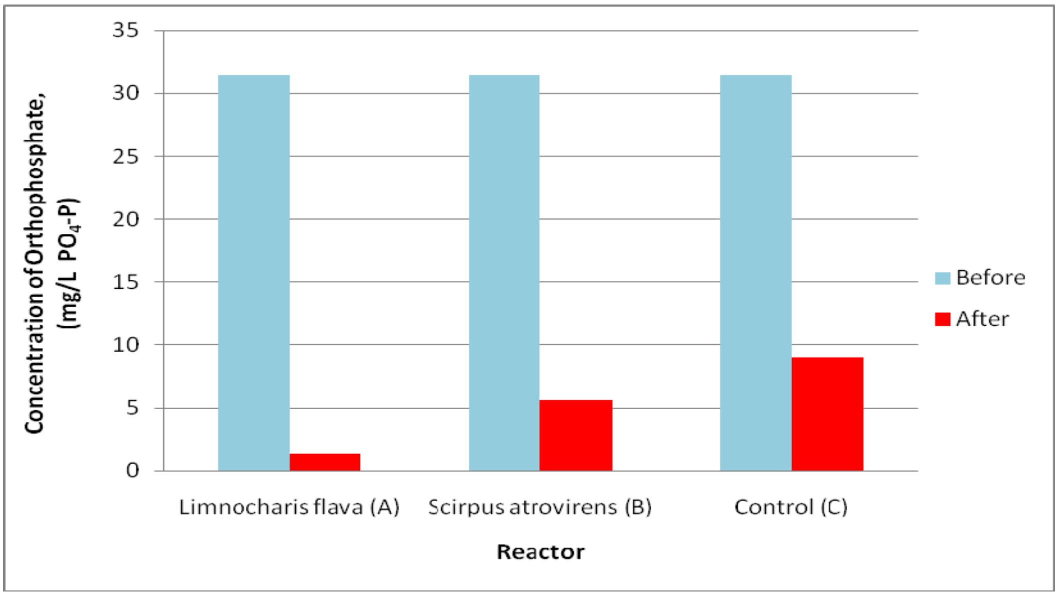

Fig. 2: Concentration of Orthophosphate (PO_4-P) before and after treatment

4. Conclusion

According to the results, both planted systems have higher removal efficiency compared to the unplanted control systems. These findings have also shows the suitability of *Limnocharis flava* and *Scirpus atrovirens* to be used in constructed wetlands to treat landfill leachate. The presences of the nutrients (NH_3-N and PO_4-P) in the *Limnocharis flava's* and *Scirpus atroviren's* tissues have proved the ability of this plant to uptake pollutant. The highest efficiency of the systems (in term of nutrients removal) was recorded by *Limnocharis flava* with 91.8% for NH_3-N and 95.7% for PO_4-P, respectively which is more than *Scirpus atrovirens.* As a conclusion, *Limnocharis flava* has a higher removal efficiency compared to *Scirpus atrovirens*.

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