An Experiment Using the Floating Treatment Wetland For Water Quality Improvement In Stormwater Pond

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***Abstract*—The evolution of stormwater quality treatment is rapidly evolving in last two decade and Floating Treatment Wetlands (FTWs) become more popular as a stormwater treatment. FTWs provides a medium for vegetation which could absorb the nutrients from the stormwater pond. The objective of this study is to identify the feasibility of using floating wetland as a stormwater quality improvement. The study can be divided into two phases; the first phase involved with the choice of suitable plants for stormwater removal and the second phase involved with suitable design criteria for optimum removal of water quality. The floating treatment mat has been set up in three different sizes and water quality samplings were carried out to evaluate the percentage of removal according to the selected water quality parameters such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Total Nitrogen (TN), Total Phosphorus (TP), Magnesium (Mg) and Iron (Fe). The results indicated the average of removal efficiency was 86.4% for TSS, 50.51% for BOD, 36.96% for COD, 38.31% for TP, 47.20% for TN, 77.81% for Fe and 4.08% for Mg. The findings from this study indicate that FTWs contribute significantly towards managing urban runoff thus supporting government aspiration to promote green technology in Malaysia.**

Keywords— Floating Treatment Wetlands; Stormwater Treatment; Water Quality

I. INTRODUCTION

Malaysia landuse has tremendously changed due to the impact of rapid urbanization compared to the last 20 years. The urbanization process has changed the land use pattern and the urban structure where the urban development adds impervious surfaces, increases runoff, decreases infiltration, causes loss of ground water recharge and has negative effects on the local water quality and quantity balance [1]. In the long term, the urbanization has increased the occurrence of flash floods and deteriorated water quality in the urban area due to non-point source pollutants. The non-point source pollutants contain various contaminants such nutrients, pesticides, pathogens, biological oxygen demand [2]. Therefore, the concerted efforts should be carried out to reduce non-point source pollutants in order to meet the water quality compliance and implement management practices. The aim of this study is to identify the feasibility of using floating wetland as stormwater quality improvement.

II. LITERATURE REVIEW

Floating Treatment Wetlands (FTWs) are new tools that may help to overcome the water quality problem. It can be defined as the systems that employ rooted, emergent plants (similar to those used in surface and subsurface flow applications) growing as a floating mat on the surface of the water rather than rooted in the sediments. It modified from constructed wetland technology, which consists of emergent wetland plants growing hydroponically on floating structures which located on the surface of a pond-like basin [3]. Fig. 1. shows the FTWs.

Fig. 1. Floating Treatment Wetlands

In FTWs, plants may either be supported on a floating raft structure and rooted in some sort of matrix or soil media, or (as in many natural floating marshes) self-supported on intertwined mats of their own buoyant roots and rhizomes, and accumulated plant litter and organic matter [4]. Conventional treatment wetlands typically involve the flow of contaminated water amongst the shoots (surface-flow or free water surface) or root-zone (subsurface-flow or submerged bed) of emergent species of sedges, rushes and reeds. This approach also has been used for wastewater treatment, which involves the use of free-floating aquatic plants or has specially-adapted buoyant leaf-bases [3]. While Floating treatment wetlands (FTWs) are in many ways a hybridization of all of these systems, employing rooted emergent plants (similar to those used in surface and subsurface flow applications) growing on a mat floating on the surface of a pond-like water body rather than rooted in the sediments [5].

FTWs have been used for a limited range of application in overseas such as water quality improvement, habitat enhancement and aesthetic purpose, however very limited effectiveness and successful information for the design criteria parameter. Previous studies have investigated the effectiveness of FTWs [6]; [7]; [8] but on the aspect of measured nutrient uptake by macrophytes only, measured uptake by macrophytes, microbes and biotic mechanisms. The successful application of FTWs has been proven in New Zealand, India, China, United Kingdom, Belgium and Singapore. The study conducted in Belgium indicated the removal efficiency of 33%-68% for Chemical Oxygen Demand (COD), 66%-95% for Suspended Solids (SS), and 24%-61% for Total Phosphorus (TP) but variable for Total Nitrogen (TN) removal [9]. The findings based on the conducted study at Heathrow Airport in the United Kingdom indicated the removal efficiency for 20-30% for copper [3].

A. Selection of Plants

The vegetation type plays an important role to contribute the removal efficiency in FTWs. Plants roots are believed to play a major role in the treatment process. Therefore, the selected plants should have an extensive root system hanging beneath the floating mat due to the process of contamination removal. This process has occurred through the sequential process of development of biofilms and advancement of flocculation of suspended matter [4].

B. Hydraulic Characteristics- Hydraulic Retention Time

The hydraulic characteristics are an important element in order to produce the optimum removal efficiency for (FTWs). The hydraulic characteristics can be identified as hydraulic retention time (HRT), surface area and depth of water. [4] conducted a review study regarding the hydraulic characteristics for FTWs and stated that no specific design. While the assumption made by [10] indicated copper and zinc will predominantly occur through entrapment of fine particles thus the HRT seems to be a key design factor.

Suitable hydraulic characteristics especially the hydraulic retention time has been identified to contribute to the optimum removal, thus produce a better performance of the FTWs. Therefore, it is important to have knowledge of these characteristics in order to understand better the performance of FTWs.

III. METHODOLOGY

The study can be divided into two stages; the first stage involved with the selection of suitable plants and the second stage involved with suitable HRT for the optimum of removal efficiency.

A. Phase 1- Selection of suitable plants

The pilot project was performed to determine the suitable plants for the optimum removal efficiency. The selected plants in this experiment were *Eichhornia crassipes* and *Pistia stratiotes*. The experiment was conducted in 2 tanks with the volume of 0.2 m^3 at Civil Engineering Laboratory Universiti Tenaga Nasional with the total number of these two species of plants were similar in order to maintain similar characteristic. The tanks were supplied with lake water from the nearby lake at College of Engineering, Universiti Tenaga Nasional in order to experience the actual characteristic of pollutions. Water samples were collected at 0-day and 3-days, in order to evaluate which species gave the better removal efficiency. Then, the water samples were tested in accordance with *Standard Method for Examination of Water* and Wastewater 18th Edition (APHA) for selected parameters such as BOD, COD, TSS, TN, TP, Mg.

B. Phase 2- Hydraulic Characteristics- HRT

According to the finding from Phase 1, there were 3 types of numbers were selected; 30 (set 1), 20(set 2) and 10 (set 3) plants of *Eichhornia crassipes* with the similar setting as phase 1. Water samples were collected at 0-day, 1-day, 3-days, 8- days and 10- days and were tested in accordance with *Standard Method for Examination of Water* and Wastewater 18th Edition (APHA).

IV. RESULTS AND DISCUSSIONS

Results for phase 1 were shown in Table 1. The finding indicated that the *Eichhornia crassipes* gave the better removal efficiency for most of selected water quality parameters except for TSS compared to the *Pistia stratiotes*. The *Eichhornia crassipes* gave the better pollutant removal due to their plants' roots provide substantial contribution to enhance water quality [11]. Therefore, the *Eichhornia crassipes* had been selected for the further experiment in Phase 2.

TABLE I. REMOVAL EFFICIENCY FOR DIFFERENT SPECIES

Percentage of removal (%)	*Eichhornia crassipes*	*Pistilia Stratiotes*
BOD	54.5	38.46
COD	35.3	0
TSS	55.1	95.35
TN	54.3	47.67
TP	75.7	44.0
Mg	0	0
Fe	77.5	75.86

Findings for the experiments in Phase 2 based on 1 day, 3 days, 8 days and 10 days can be seen through Table II, III, IV,V respectively. As for TSS, the results indicated that the optimum removal efficiency occurred in Set 2 on HRT 8 days with the removal efficiency of 98.21%. The higher percentage of removal for TSS affected by long term trapping of suspended solids and settlement at the bottom of the box [12]. Meanwhile, for BOD the optimum removal percentage was 91.30% and obtained through Set 1 with HRT 10-days. For COD the optimum removal efficiency was found to be 68.18% and this value can be obtained in Set 2 with HRT 10-days. Set 1 with HRT 8 days indicated the optimum removal around 62.96% and 45.30% for TP and Mg respectively. As for TN Set 1 with 10 days indicated the optimum removal of 70.28% and Set 2 with HRT 10 days indicated 95.41% percentage of pollutant removal for Fe. HRT affect the duration of stormwater within the FTWs system where a longer HRT in FTWs contribute to the enhancement of the removals of pollutants. HRT is not only affected by surface area and depth of flow but also affected by the vegetation in FTWs though the nutrient supplement [13],[14].

Size of plants required to contribute towards the significant removal nutrients according to the study conducted by [15]. HRT directly affect the contact time between stormwater and plants roots and the contribution from a velocity of flow which will impact on the efficiency of settling process [4]. [16] and [17] reported that there was an improvement in wastewater quality with the presence of FTWs based on their conducted study. Furthermore, [5] suggested that plants contributed significantly to treatment performance by providing extensive attachment surfaces for microbial biofilms and assimilating nutrients.

TABLE II. REMOVAL EFFICIENCY FOR HRT 1 DAY

Percentage of removal (%)	Set 1	Set 2	Set 3
TSS	76.19	71.43	65.22
BOD	65.22	20.00	0
COD	27.27	59.09	21.43
TP	29.63	25	33.33
TN	56.60	31.41	31.95
Fe	50.28	50	33.70
Mg	5.98	0	0

TABLE III. REMOVAL EFFICIENCY FOR HRT 3 DAYS

Percentage of removal (%)	Set 1	Set 2	Set 3
TSS	73.81	94.64	91.30
BOD	52.17	0.00	55.56
COD	9.09	45.45	14.29
TP	37.04	41.67	25.00
TN	56.13	49.36	36.69
Fe	79.89	79.59	76.80
Mg	0	0	0

TABLE IV. REMOVAL EFFICIENCY FOR HRT 8 DAYS

	Set 1	Set 2	Set 3
TSS	97.62	98.21	95.65
BOD	65.22	55.0	33.33
COD	27.27	63.64	42.86
TP	62.96	54.17	41.67
TN	57.08	43.59	31.95
Fe	96.65	97.45	91.71
Mg	45.30	32.71	8.11

TABLE V. REMOVAL EFFICIENCY FOR HRT 10 DAYS

	Set 1	Set 2	Set 3
TSS	97.62	96.43	78.26
BOD	91.30	85.0	88.89
COD	36.36	68.18	28.57
TP	59.26	58.33	0
TN	70.28	64.10	37.28
Fe	93.30	95.41	88.95
Mg	30.77	41.12	3.60

V. CONCLUSION

This study indicated that the number of plants contributed to the better performance when Set 1 with 30 *Eichhornia crassipes* plants gave the better removal efficiency in most of water quality parameters compare to set 2 with 20 *Eichhornia crassipes* plants. Besides, longer HRT contributed towards better performance as well when the findings indicated HRT 10-days gave better removal efficiency in most of selected water quality parameters compared to another HRT.

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