Performance Evaluation of Constructed Wetland in Malaysia for Water Security Enhancement

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ABSTRACT: The aim of the present study is to investigate the performance of constructed wetland in BIOECODS system for water quality treatment from stormwater runoff as well as the performance from species and biodiversity composition. There were 17 sampling stations, starting from Inlet Wetland (InletWet), and Macrophyte zone, which consist of 7 sampling stations, Micropool zone, consist of 9 sampling station and end up at Outlet Wetland (Outwet). The wetland was divided into several sections due to each section possesses different composition, different area and different composition of wetland plant species. Weekly physico-chemical parameters were analysed during the one year period starting from December 2010 and finish at December 2011. The parameters studied were temperature, pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), conductivity, total suspended solids (TSS), nitrite, nitrate, ammoniacal-nitrogen (AN-NH3), and orthophosphate. The biological sample covered from phytoplankton, zooplankton and fish. The species composition and diversity for each trophic level species was analysis and relate to the water quality performance. Based on the result obtained, improvement of water quality was obtained as the concentration of nitrate, nitrite, ammoniacal-nitrogen, orthophosphate, TSS, BOD and COD decreased after the water pass through the macrophyte zone and micropool zone before it discharge to outlet wetland. The concentration of nitrite reduce from 0.035 mg/l to 0.007, remove 80%; nitrate reduce from 2.94 mg/l to 1.13mg/l remove 61.56%, ammoniacal-nitrogen reduce from 0.303 mg/l to 0.147 mg/l, remove 51.49 %, orthophosphate reduce from 0.41mg/l to 0.16 mg/l, remove 60.98%, TSS reduce from 28 mg/l to 9 mg/l, remove 67.86 %, BOD reduce from 2.78mg/l to 2.01mg/l, remove 27.7% and COD reduce from 28mg/l to 15mg/l, remove 46.43%. The decrease of concentration showed that the improvement of water quality was done in the wetland. Most of the concentrations fall in Class IIA and IIB based on National Water Quality Standards for Malaysia and Department of Environment (DOE) Water Quality Index Classification. Biological measurement showed high diversity of species. Based on the result obtained, W1 and W2 area in the macrophyte zone showed high number of species and percentage distribution of phytoplankton and zooplankton, while *Oreochromis niloticus* was the dominant species found in the constructed wetland. The improvement of water quality gave positive benefit to sustain and maintain biodiversity at each trophic level.

KEY WORDS: Constructed wetland, Water quality, Biodiversity, Stormwater runoff

1 INTRODUCTION

The issues of stormwater runoff had become one of the priority agenda of government and non-government sector, local authorities, agencies and developers all around the world in order to solve the problems of urban runoff and water pollution in the rapid urbanization area. Urban stormwater runoff is well recognized as one of the major source of pollution that could adversely affect water quality if the runoff is discharged untreated. Another impact from stormwater runoff is habitat-destroying, which can cause harm to many wildlife population such as fish and birds, and also can kill the native vegetation, which is the primary building in the pyramid chain. Malaysia is taking a proactive step by implementing a new Urban Drainage Manual in 2000 known as Urban Stormwater Management Manual for Malaysia (MSMA). A pilot project, entitled Bio-Ecological Drainage System (BIOECODS), was carried out at Universiti Sains Malaysia (USM) Engineering Campus based on 1st Edition of MSMA and the design was continuously improve in the 2nd Edition of MSMA. A constructed wetland which is one of the components in BIOECODS was built in order to provide ecological and biological stormwater treatment after purification through infiltration in swale and settling in wet pond and detention pond. The aim of the present study is to investigate the performance of constructed wetland in BIOECODS system for water quality treatment from stormwater runoff as well as the performance from species and biodiversity composition.

2 STUDY METHODS

The constructed wetland of this study area is located in the Universiti Sains Malaysia (USM) Engineering Campus. The location is located in Mukim 9 of the Seberang Perai Selatan District, Pulau Pinang (Figure 3.3). It lies between latitudes 100°29.5’ South and 100°30.3 North and between longitudes 5° 9.4’ East and 5° 8.5’ West. In this study, seventeen sampling stations had been chosen as the study area (Figure 3.4). The sampling area consist of Inlet Wetland (Inlet Wet) which located at the inlet wetland, Wetland 1 (W1), located right bank and Wetland 2 (W2) located left bank, which located after the inlet wetland. For the Wetland 3 (W3), 4 (W4), 5 (W5) and 6 (W6), the station located in the middle of wetland, with W3 and W5 located right bank and W4 and W6 at the left bank. The area from Inlet Wetland until Wetland 5 and 6 are called Macrophyte Zone. The Micropool were divided into three raw (Micropool (M); MA, MB, MC) and each rows consist of 3 equally distant (15 meter) point of station. The sampling station was choose as to consider certain numbers of aspect such as type of macrophyte or wetland plants and range of water depth. Different depth affects settlement process, treatment of water quality and distribution of biodiversity. Different wetland plant and densities of plant affect the treatment and nutrient uptake process.

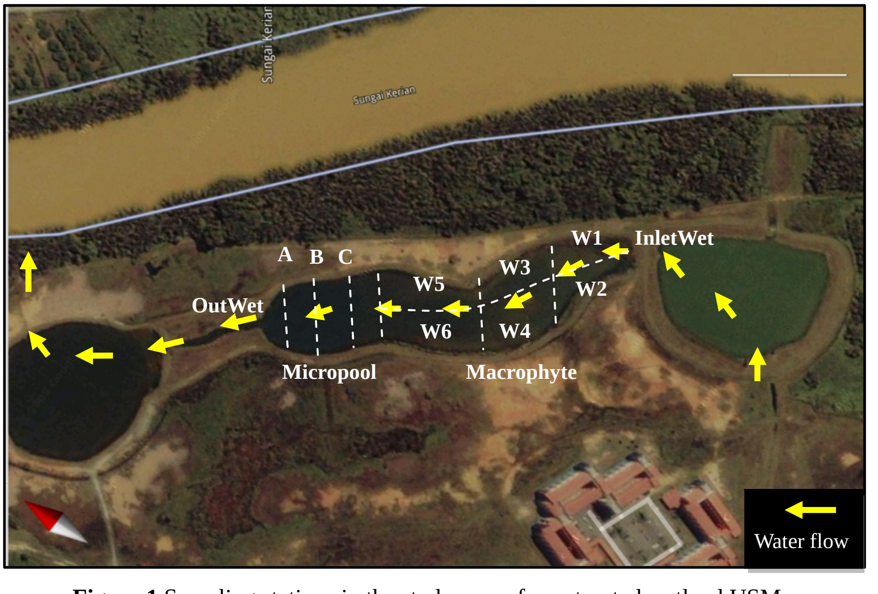
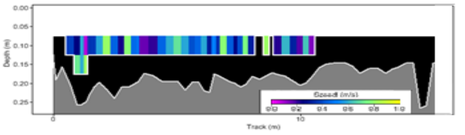
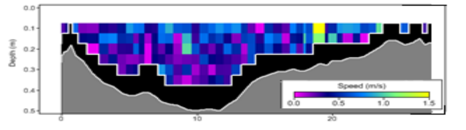


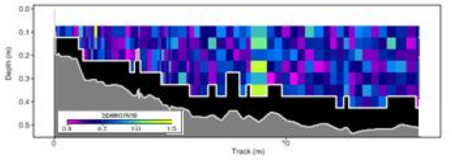
Figure 1 Sampling stations in the study area of constructed wetland USM



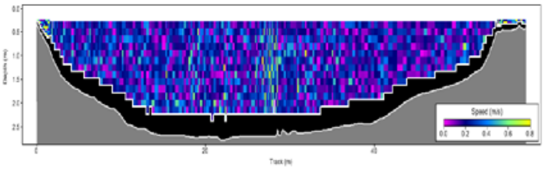
Range of water depth: 0.25-0.3m (W1-W2)



Range of water depth: 0.51-0.62m (W3-W4)



Range of water depth: 0.51-0.64m (W5-W6)



Range of water depth: 2.51-2.54m (Micropool)

Figure 2 Cross section and range of depth of station in USM Wetland

Basically, the wetland was design based on 3 month ARI (MSMA, 2011). The general design criteria of constructed wetland can be seen in the Table 1 below and Table 2 below showed type of macrophyte present at the macrophyte zone (W1-W6). The design criteria are based on Stormwater Management Manual for Malaysia (MSMA).

Table 1 Design criteria for the constructed wetland, USM (Modified from Ab. Ghani et al. 2004)

Contributing drainage area	1,011, 714. 11 m^2
Water quality volume (WQV)	14,164 m^3
Length	250 m
Width	50 m
Length to width ratio	5:1
Wetland surface area	12,500 m^2
Water depth	0.3-1.0 m
Extended detention depth	1.2 m
Wetland volume	16, 312 m^2
% Catchment area	0.7
Design inflow rate	0.25 m^3/s
Mean residence time	3 days
Mediae	Pea gravel and soil mixture
Hydraulic conductivity of gravel	10^{-3} m/s to 10^{-2} m/s

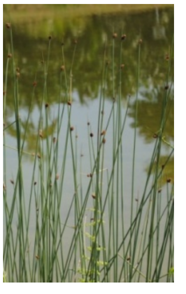
Sampling procedure was separated into two procedures, biological sampling and water quality sampling. Five types of species or indicators had been chosen to study the biodiversity in the bioassessment; phytoplankton, zooplankton, freshwater fish. The water samples were collected using grab sample. The in-situ parameter was taken at the sampling stations during the sampling. The parameters that involved are the physico-chemical parameter including temperature, pH, dissolved oxygen and conductivity. The nutrient parameter, duplicate bottles were used to run the analysis in the lab. The types of analysis were total suspended solid (TSS), nitrite, nitrate, ammoniacal nitrogen, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and Ortho-phosphate.

Table 2 Wetland plant in macrophyte zone

Eleocharis variegata (Spike rush)

Typha angustifolia (Cat-tail)

Hanguana malayana (Common Hanguana)



Lepironia articulata (Tube sedge)

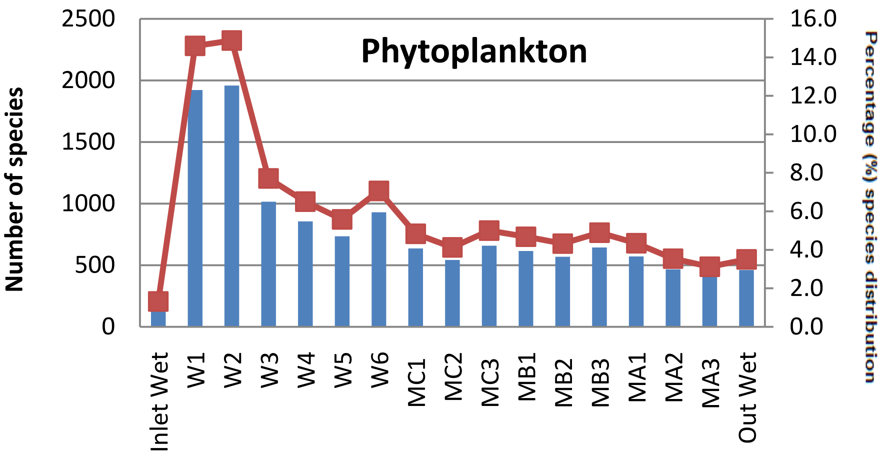
3 RESULTS AND DISCUSSION

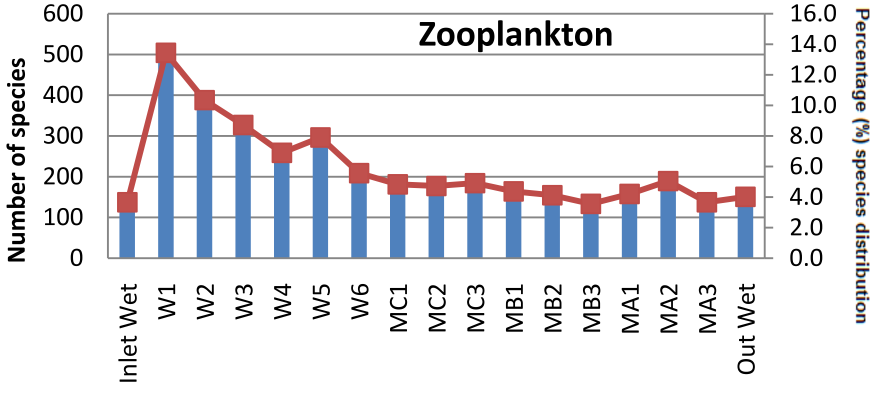
3.1 Water quality

Table 3 showed the mean and range value for each parameter measured at 17 sampling stations starting from December 2010 until December 2011. The standard deviation varied for each parameter, which some parameter showed low standard deviation (DO, pH, Nitrite, Nitrate, Ammoniacal Nitrogen, ortho-phosphate and BOD) while other showed high standard deviation (conductivity, COD, TSS and Temperature). The lowest standard deviation indicated that the value tend to be very close to mean value while highest standard deviation indicated that the values spread out over a large range of values.

Table 3:Mean for water quality parameters for 17 sampling stations for 13 month period (December 2010- December 2011)

Station	Temp. °C	Cond. (µS cm^{-1})	DO (mg l^{-1})	pH	Nitrite (mg l^{-1})	Nitrate (mg l^{-1})	PO4-P (mg l^{-1})	NH4-N (mg l^{-1})	BOD (mg l^{-1})	COD (mg l^{-1})	TSS (mg l^{-1})	Class
Inlet Wet	31.59	138	8.04	7.65	0.035	2.94	0.41	0.303	2.78	28	28	IIB
W1	32.05	141	8.26	7.71	0.032	3.43	0.40	0.324	3.30	30	29	IIB
W2	31.90	141	8.05	7.72	0.030	3.32	0.40	0.326	3.35	29	27	IIB
W3	31.94	138	8.67	7.84	0.027	2.84	0.33	0.288	2.89	24	24	IIB
W4	31.55	139	8.57	7.93	0.023	2.88	0.30	0.285	2.71	24	23	IIB
W5	31.60	140	8.31	7.78	0.016	2.48	0.29	0.267	2.78	25	22	IIA
W6	31.38	138	8.74	7.75	0.017	2.48	0.26	0.257	2.68	24	22	IIA
MC 1	30.85	136	8.13	7.88	0.013	2.00	0.22	0.218	2.44	23	17	IIA
M C 2	30.88	137	8.18	7.82	0.009	1.90	0.21	0.209	2.39	21	16	IIA
M C3	31.01	137	8.20	7.80	0.009	1.92	0.22	0.191	2.36	21	15	IIA
MB 1	30.59	135	8.09	7.78	0.008	1.80	0.20	0.180	2.24	20	13	IIA
MB 2	30.71	136	8.01	7.77	0.009	1.67	0.19	0.174	2.40	19	14	IIA
MB 3	30.79	136	8.11	7.80	0.010	1.66	0.18	0.171	2.33	17	13	IIA
MA 1	30.53	132	8.04	7.26	0.009	1.43	0.17	0.165	2.36	19	11	IIA
MA 2	30.53	134	8.03	7.70	0.009	1.38	0.16	0.160	2.19	18	11	IIA
MA 3	30.58	134	7.95	7.72	0.009	1.36	0.16	0.151	2.08	16	10	IIA
Outlet Wet	30.00	133	7.78	7.60	0.007	1.13	0.16	0.147	2.01	15	9	IIA
Percentage removal (%)	-	-	-	-	80	61.56	60.98	51.49	27.7	46.43	67.86	





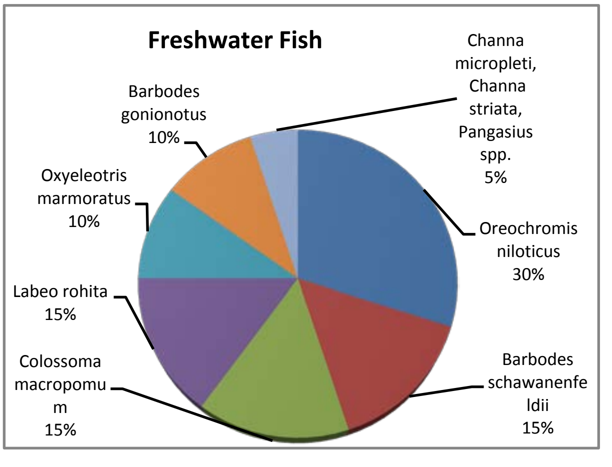


Figure 8 Graph for biological measurement: percentage distribution and number of species for phytoplankton (top) and zooplankton (centre), and pie chart show percentage distribution of freshwater fish (bottom)

Based on the result obtained, most of the nutrient analysis show some reduction, for nitrite concentration reduce from 0.035 mg/l to 0.007, remove 80%; nitrate reduce from 2.94 mg/l to 1.13mg/l remove 61.56%, ammoniacal-nitrogen reduce from 0.303 mg/l to 0.147 mg/l, remove 51.49 %, orthophosphate reduce from 0.41mg/l to 0.16 mg/l, remove 60.98%, TSS reduce from 28 mg/l to 9 mg/l, remove 67.86 %, BOD reduce from 2.78mg/l to 2.01mg/l, remove 27.7% and COD reduce from 28mg/l to 15mg/l, remove 46.43%. Most of the concentration laid on Class IIB and Class IIA. The concentration of nitrite, nitrate and ammonium had effectively decrease until in the Micropool area through the process of nitrification and denitrification in the macrophyte area as well as the nutrient uptake via plants, which is from root system and also through immersed stems and leaves from the surrounding water (Brix, 1997). The improvement shown was due to favorable physic-chemical such as high dissolve oxygen and average level of water temperature. Plant uptake is also one of the factor involve to this improvement and help to reduce to input nutrient concentration. Macrophyte, which dense with plant, helps to polish the nutrient concentration as well as provide favor able habitat for wildlife to live. As a result, high percentage of distribution can be obtained for zooplankton and fish. High percentage distribution of zooplankton, which in the range 381-495 (10.3-13.4%) found at W1 and W2 area in the macrophyte area, was due to high percentage distribution found for phytoplankton 1922-1959 (14.6-14.9 %). High distribution of phytoplankton at the W1 and W2 area was due to enough amounts of nutrient concentration (Oyanedel *et al*. 2008) as well as the favorable cross section, shallow and enough light to penetrate. *Oreochromis niloticus*, Tilapia has highly composition as compare to other species. Rana (1990) had stated that optimal development of hatching for *Oreochromis niloticus* occurred at 25-30°C. A suitable pH condition, which is in the neutral range, helps the fish to inhabit the place longer. Sufficient amount of oxygen, based on the dissolve oxygen obtained, help the fish to undergo respiration without any obstacle.

4 CONCLUSIONS

The test such as nitrite, nitrate, ammoniacal nitrogen and phosphate obviously reduce it concentration from the macrophyte area (Wetland 1 and Wetland 2) until the Micropool area. The area design for the wetland and the present of dense vegetation in the macrophyte area help to reduce the concentration of total suspended solid as well as the COD and BOD level. The USM constructed wetland possess high dissolve oxygen (DO) and favorable water temperature, with the range between 28-32 °C, and most of the time neutral in pH, help to maintain the ecological quality from diverse biodiversity. This water quality improvement had created sustainable habitat for many wildlife to live, starting from low trophic level until higher trophic level. The entire positive had enhanced the water security for not only benefit to human, as well as to biodiversity.

ACKNOWLEDGEMENT

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