Stormwater Treatment Using Constructed Wetland

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ABSTRACT
The urban stormwater management in Malaysia has shifted from rapid disposal approach to control at source concept. The Bio-Ecological Drainage System (BIOECODS) is planned, designed and constructed at Engineering Campus USM employs control at source approach uses for water quantity and quality controls. This is an environmentally friendly drainage system which is based on the infiltration engineering, storage and flow retardation principles to attenuate the post-development hydrograph and treat the stormwater. Constructed wetland is one of the components of Bio-Ecological Drainage system which is used for stormwater treatment. The stormwater is conveyed into the constructed wetland via bio-ecological swale for treatment in term of biological, chemical and physical aspects before the water flow into recreational pond. Essential design features and suitable plant species are required for the construction of wetland that can be used to improve the water quality. The constructed wetland is primarily design for stormwater treatment, provision of habitat, aesthetics amenity, campus recreation area and a wetland research center.

Keywords: Constructed wetland, stormwater treatment, water quality.

1 Introduction

Constructed wetland system incorporates the natural function of wetland to aid pollutant removal from stormwater. Constructed wetlands can also to certain extent, particularly for frequent events, provide for stormwater quantity control by the provision of storage above the permanent pool water level. Constructed wetland is particularly appropriate in area where there is higher groundwater level as the availability continuous supply of water necessary to sustain the wetland system. A wetland is designed to develop dense wetland vegetation and with sufficient retention time to effectively treat the stormwaters (Urbonas & Strecher, 1996). Constructed wetland can be defined as engineered system designed to simulate

natural wetland to exploit the water purification functional value for human use and benefit (Sidek, 2001; Hammer, 1986). Constructed wetland consists of former upland environment that have been modified to create poorly drained soil and wetland's flora and fauna for primary purpose of contaminant or pollutant removal from wastewater or runoff.

Constructed wetland normally can be divided into two categories which consist of Subsurface Flow System and Free Water Surface System. The Subsurface Flow System (SF) consists of permeable medium with a porous substrate of rock and gravel. This system is also known as root-zone system, rock reed filter and vegetated submerged bed system. The Subsurface Flow System used the gravel to ensure better bed porosity with the depth typically ranging between 0.3 - 0.6m. This system is similar to Free Water Surface System but they may have difference water depths. A layer of lining is also used to ensure that there is no seepage. The advantages of Subsurface Flow System are greater assimilation potential per unit level and minimization of pest. The disadvantages of Subsurface Flow system are more expensive to construct, higher cost for maintenance and repair, facing the problem of clogging and unintended surface flow.

The Free Water Surface (FWS) mimics the natural wetland with the water surface is exposed to the atmosphere. It also consists of shallow basin to support the vegetation and a shallow depth of water is maintained through its hydraulic control structure. The water depth can range from a few centimeters to 0.8 m or more. A typical operating water depth is 0.3 m. The basin normally contained a combination of gravel, clay or peat based soils and crushed rock that planted with macrophytes. The advantage of FWS is a lower capital and operating cost and their construction, maintenance and also operation are straightforward. The main disadvantage of this system is that it required a larger land area compare to the other system.

Among the two types of constructed wetland, the frequent type that is normally constructed in Malaysia is Free Water Surface System (FWS) based on their advantages and in term of their construction cost. The constructed wetland (FWS) treatment system has been successfully used across the country. For example, the Putrajaya and Pandan Indah Wetlands are designed based on Free Water Surface System. The constructed wetland is designed to include the water quality treatment aspect and also other functions such as flood storage, habitat for fish and wild life, active recreation, education, research and aesthetics enhancement (Selamat, 2001).

Based on research that have been done in mid–80s on the used of constructed wetland for urban stormwater treatment, suggested that constructed wetland is able to improve the water quality of surface runoff. From the research on twenty stormwater wetland sites in the mid Atlantics region United State of America, the results shown that the long term pollutant removal rates were found to be 75% for total suspended solids, 45% total phosphorus, 25% total nitrogen, 15 % organics carbon, 75% lead and 50% zinc. (Sidek, 2001; Schueler, 1992). The results obtained from monitoring Putrajaya Wetlands in Malaysia, indicate that average water quality indexs between 82 - 92 which is in second category where the status is good have been achieved (Selamat, 2001).

2 Objectives

The study examines the potential for constructed wetland as stormwater treatment. The main objectives of this study are:

(a) This project will examine the use of constructed wetland as stormwater treatment by monitoring pollutants in

stormwater and suspended sediment of wetland. The monitoring will focus on pollutant removal efficiency such as physical aspect, chemical aspect and biological aspect.

(b) To collect the data that can be used to develop a computer model to assess the treatment performance of constructed wetland

(c) To evaluate the currently recommended procedures for estimating constructed wetland water balance under tropical climate.

3 Water Quality

The water quality control is the main goal in constructed wetland. The constructed wetland can be designed to be part of sustainable drainage system which manages both the water quantity and quality measure. Stormwater may contain many pollutants including sediment and heavy metals, that exist in particulate form and soluble. The constructed wetland which consists of complex combination of water, substrate, plant and array of microorganisms, posses the mechanism that needed to improve the water quality successfully. These mechanisms include the settling of suspended particulate matter, chemical transformation, and transformation of pollutant by microorganisms and plants. The pollutants and sediment are removed from the water when they are allowed to settle to the bottom of the pond. Therefore, the pond is design with sufficient retention time to allow for settling of suspended sediments and non pollutants for water quality improvement. In addition, aquatic plants in the constructed wetland are able to improve water quality by using some of the soluble pollutants and incorporating them into plant tissue. Water quality refers to the quantity of suspended and dissolved solids, dissolved gasses and microorganisms in a given quantity of water. In nature, impurities will enter and leave the water through the hydrologic cycles.

4 Consideration of Parameter

The main function of constructed wetlands is for urban stormwater treatment to achieve the water quality control. The parameters are selected to ensure that performance and efficiency of the constructed wetlands can be evaluated. The water quality can be measured based on the parameters such as: BOD, TSS and heavy metal.

4.1 Water Quality Analysis

i) Total Suspended Solids (TSS)

Suspended solids are determined according to an international standard method. The content of total suspended solids (TSS) was analyzed by filtering the stormwater through a glass fibre filter.

ii) Biological Oxygen Demand (BOD_5)

This parameter is used to determine the approximate quantity of oxygen that is required to stabilize biologically the organic matter.The BOD removal mechanism in the attached biofilm is similar to that of trickling filter.

iii) Lead (Pb)

Heavy metal such as lead is determined by using Atomic Spectrometer (AAS). Wetland plants however can influence metals removal and storage indirectly through their effects on hydrology, sediment chemistry and microbial activity. Beside, the performance of constructed wetland is determined by calculation of percentage for pollutant reduction between inlet and outlet of the system.

5 Result and Discussion

The TSS values in Figure 1 show that the value is decreased at the outlet of the wetland which can be attributed to removal process are taken place. The value of TSS (Table 1) are generally low which fulfill the Class IIB, WQI Standard B, EQA 1974 where the range should be less than 50 mg/l.

Table 1 Comparison of Total Suspended Solid in the Constructed Wetland.

	Total Suspended Solid					
Station	17-Jul-03	19-Jul-03	14-Aug-03	23-Aug-03	26-Aug-03	9-Sep-03
Inlet wetland	2	0	0	0	0	4
High Marsh	0	0	1	4	9	7
Outlet wetland	1	1	1	4	3	0
Percent of Reduction (%)	50	-	-	-	-	100

The BOD values shown in Table 2, indicate that the value of BOD for inlet, high marshes and outlet are generally acceptable and fulfill the requirement of Standard B, EQA 1974 for water quality where the value should be less than 50mg/l. However, the values of BOD lie outside of Class IIB, WQI where the value should be less than 3 mg/l is not satistified. The Plumbum data in Table 3 shows that the measured values are not complied with the Standard B, EQA 1974 where the value should be less than 0.5 mg/l. This can be attributed to the system which is still undergoing development. Although the measured value of Plumbum do not satified with the requirement but the values are generally small.

Table 2 Comparison of BOD_5 in the Constructed Wetland.

	Biological Oxygen Demand (BOD_5)					
Station	17-Jul-03	19-Jul-03	14-Aug-03	23-Aug-03	26-Aug-03	9-Sep-03
Inlet wetland	5	3	5	4	6	1
High Marsh	1	1	4	7	3	2
Outlet wetland	1	5	1	1	4	3
Percent of Reduction	80	-	80	75	33.3	-

Table 3 Comparison of Plumbum in the Constructed Wetland.

	Lead, Pb					
Station	17-Jul-03	19-Jul-03	14-Aug-03	23-Aug-03	26-Aug-03	9-Sep-03
Inlet wetland	0.0	0.0	1.3	1.5	1.1	1.2
High Marsh	0.0	0.0	1.3	1.1	1.3	1.1
Outlet wetland	0.0	0.0	1.0	1.1	1.2	1.3
Percent of Reduction	-	-	23	26.6	-	-

6 Conclusion

Constructed wetland can effectively function as stormwater treatment based on the data collected in this study. The water quality control for urban stormwater can be achieved with the used of appropriate design features and suitable macrophyte plants. In addition, the sufficient maintenance and monitoring may also contribute to achieve the objective. The better designed and constructed systems will posses high efficiency to remove the contaminants from the inflowing water. However, further research should be undertaken in order to identify other factors that contribute to the efficiency of constructed wetland as stormwater treatment device.

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