STORMWATER PURIFICATION CAPABILITY OF BIOECODS

L.M. Sidek[1], A. Ainan[2], N.A. Zakaria[3], A. Ab. Ghani[4], R. Abdullah[5] and K.R. Ayub[6]

ABSTRACT

A storm water quality monitoring programme at BIOECODS is being carried out by two methods namely grab sampling and automatic sampling method. Firstly, by using grab sampling method, samples of storm water are taken from ten stations along ecological swales. In-line sensing using automatic samplers (i.e. Sonde) is also being carried out to measure four parameters i.e. pH, conductivity, temperature and Dissolved Oxygen at ecological pond. The ecological pond which is placed downstream of the BIOECODS catchments pond is a community facilities which include a wet pond and a detention pond acting as a facility to control the storm water quantity, a constructed wetland as a storm water treatment device, a wading river which connects the wetland and a recreational pond where the treated storm water flows into Kerian River. The ecological pond system is strategically placed at the downstream end of the BIOECODS to optimize and effectively attenuate and treat storm water runoff generated from the USM Engineering Campus development area. In this paper, recent results of the storm water quality data collection programme for the period of June – October 2003 are discussed.

1. INTRODUCTION

Rapid development in developing countries has resulted in increase in stormwater runoff due to the increase in impermeable areas. Therefore, there is a need for developing countries to manage urban stormwater runoff using new techniques in order to control not only flash flood but also the quality of stormwater runoff flowing into the receiving waters. In the 1990s, a number of Best Management Practices (BMPs) manual have been developed that address the control of urban runoff to protect receiving water quality and to mitigate flash flood in urban areas.

[1] Senior Lecturer, Department of Civil Engineering (Water Engineering), College of Engineering, Universiti Tenaga Nasional, KM 7, Jalan Kajang-Puchong, 43009 Kajang, MALAYSIA (lariyah@unitn.edu.my)
[2] Engineer, River Engineering Section, Department of Irrigation and Drainage Malaysia, Jalan Sultan Salahuddin, 50626 Kuala Lumpur, MALAYSIA (anita@did.moa.my)
[3] Associate Professor and Director, River Engineering and Urban Drainage Research Centre (REDAC), Universiti Sains Malaysia, Engineering Campus, Seri Ampangan, 14300 Nibong Tebal, Penang, MALAYSIA (redac01@eng.usm.my)
[4] Associate Professor and Deputy Director, River Engineering and Urban Drainage Research Centre (REDAC), Universiti Sains Malaysia, Engineering Campus, Seri Ampangan, 14300 Nibong Tebal, Penang, MALAYSIA (redac02@eng.usm.my)
[5] Lecturer, River Engineering and Urban Drainage Research Centre (REDAC), Universiti Sains Malaysia, Engineering Campus, Seri Ampangan, 14300 Nibong Tebal, Penang, MALAYSIA (cerozi@eng.usm.my)
[6] Science Officer, River Engineering and Urban Drainage Research Centre (REDAC), Universiti Sains Malaysia, Engineering Campus, Seri Ampangan, 14300 Nibong Tebal, Penang, MALAYSIA (redac03@eng.usm.my)

The use of sustainable stormwater management in the new developed areas is a continuous process. Urban stormwater runoff was identified as a major source of heavy metals and toxic organic elements (Niemczynowicz, 1999). When the source of pollution is recognized, several alternatives must be chosen to improve the quality of urban runoff. Many researchers have agreed that grassed swale as well as artificially created ponds and wetlands are important as stormwater treatment facilities. The primary mechanisms for pollutant removal in swales are filtration by the vegetation, settling of particulates, and infiltration into the subsurface zone (Yu et al. 2001). They also concluded that the effectiveness of swale in removal pollutant is highly dependent on design characteristics such as length, longitudinal slope and the presence of check dams. Burkhard et. al (2000) shows that there is no stagnant water in a carefully designed swale and it will improve the effectiveness of grass swale especially in reducing the pollutants such as suspended solids (SS), heavy metals and others organic matters.

The implementation of grassed swale as a new technique to control quantity and quality of urban runoff is still at an early stage in Malaysia. Thus, the research collaboration between Department of Irrigation and Drainage, Malaysia, and University Sains Malaysia, has resulted in the implementation of Bio-Ecological Drainage System (BIOECODS) in Engineering Campus, University of Science Malaysia as a pilot project for Malaysia. The construction of BIOECODS that covers an area of 300 acres was completed at the end of December 2002. In this paper, the capabilities of BIOECODS in purifying the urban runoff are discussed.

2. BIO-ECOLOGICAL DRAINAGE SYSTEMS (BIOECODS)

The launching of BIOECODS at national level on 4th February 2003 by Gavernor of Penang has promoted the system throughout the Malaysia as a pilot project. Major components of BIOECODS systems are ecological grassed swale, dry pond and ecological ponds namely wetpond, detention pond and wetland. There are three types of ecological swales constructed namely Type A, Type B and Type C depending on the number of modules available underneath the swale (Figure 1).

Ecological ponds namely wet pond, detention pond and wetland are located at the downstream of the BIOECODS system in the catchment area. Wet pond, detention pond and wetland have surface area of 4500m^2, 10000 m^2, and 9100 m^2 respectively. Stormwater runoff is conveyed by ecological swale to wet pond, detention pond and finally wetlands for further treatment. Several wetland species such as *Typha Augustifolia*, *Lepironia articulata*, *Hanguana Malayana* and *Eleocaris dulcis* (Figure 2) were planted in order to improve storm runoff using their capability in providing oxygen and tolerance to organic matters in storm runoff.

3. DATA COLLECTION PROGRAMME

3.1 Ecological Swale

A stormwater quality-monitoring programme is being carried out since June 2003. The results for the period of June-October 2003 are presented herein. Ten sampling points known as GS1 to GS10 (Figure 3) were established for sampling by grab. Samples were collected immediately after storm events at GS1 to GS10.

3.2 Ecological Pond

Every inlet and outlet of ecological ponds is chosen as sampling points. High marsh and micro pool which are located in the wetland are also chosen as extra water quality sampling points in order to determine the capability of wetland in removing pollutants in storm water runoff accurately. Grab sampling technique are used at all sampling points. Figure 4 shows the locations of the sampling points from the upstream to the downstream of the ecological ponds system and Table 1 shows the description of sampling locations.

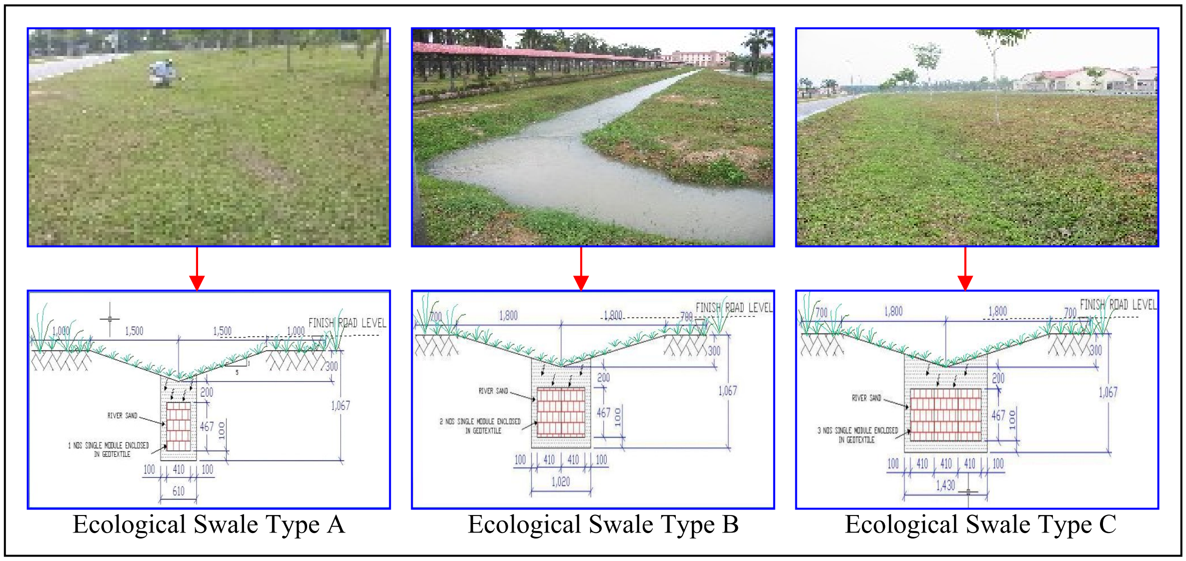

Figure 1 Bio-Ecological Swale Type A, Type B and Type C

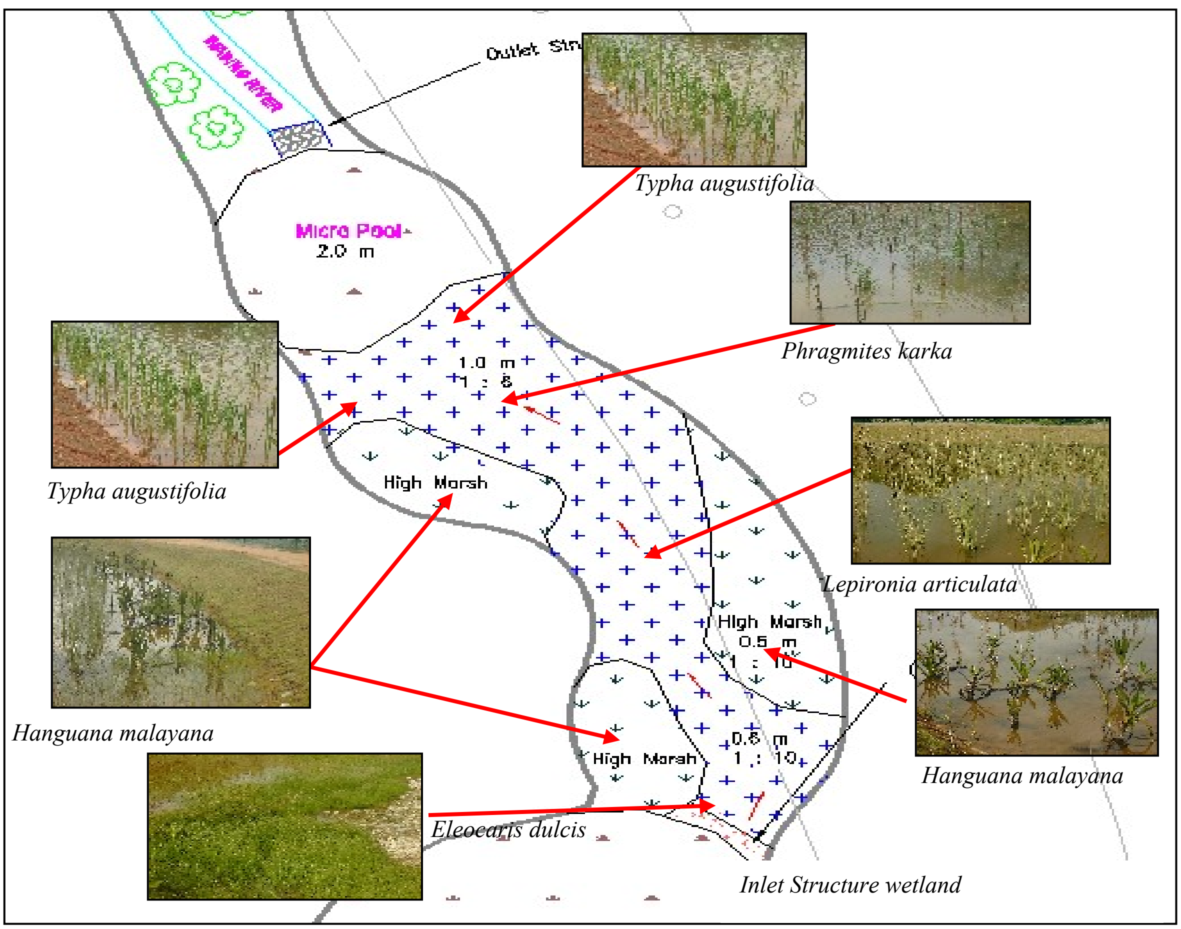

Figure 2 Type of macrophytes planted in mini wetland of BIOECODS

Figure 3 Ten sampling locations at ecological swales

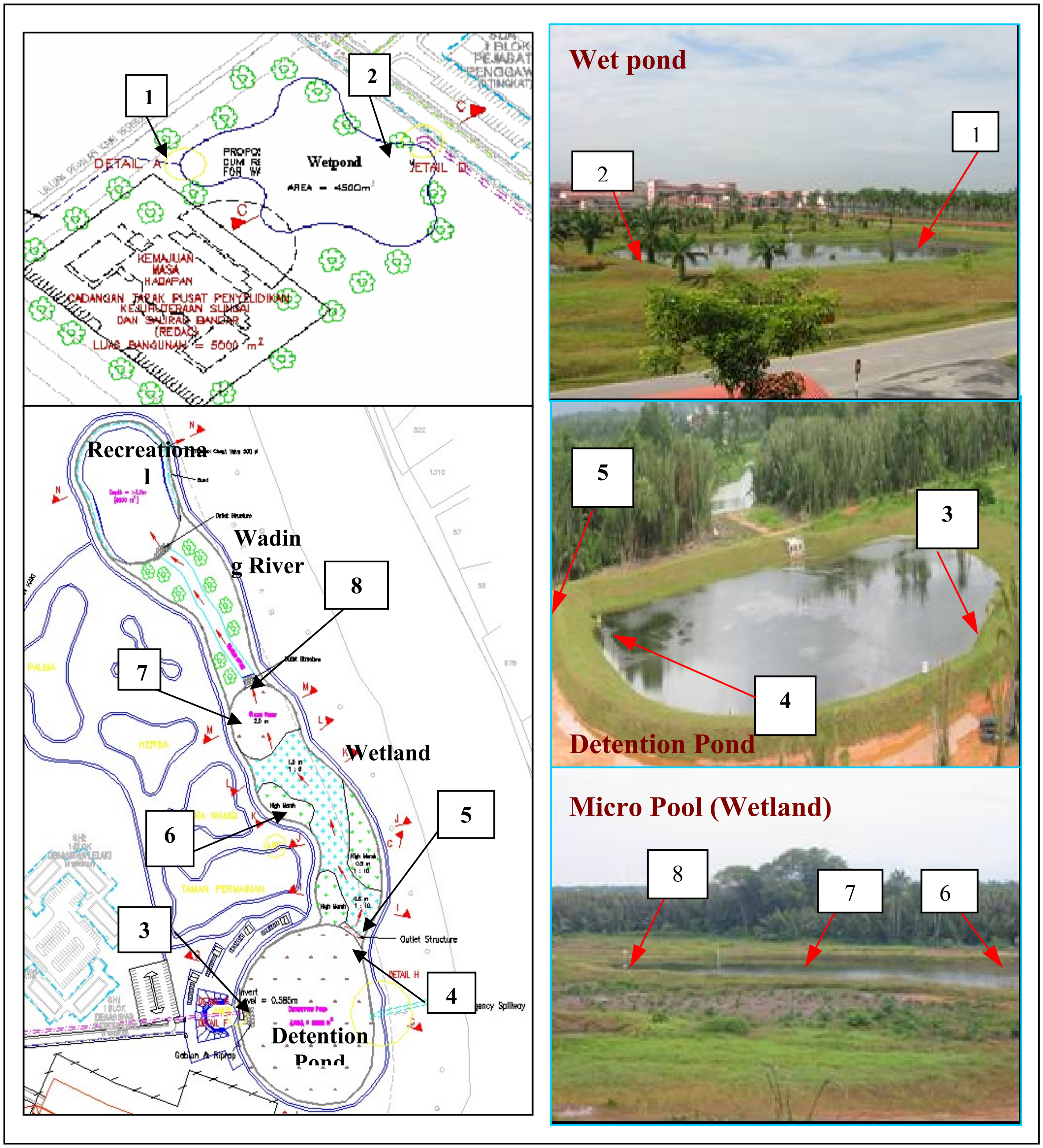

Figure 4 Sampling locations at Wet pond, Detention Pond and wetland

Table 1 Description of the sampling locations (List in the order of upstream to downstream)

Location	Description
1	Inlet at Wetpond
2	Outlet at Wetpond
3	Inlet at Detention Pond
4	Outlet at Detention Pond
5	Inlet at Wetland
6	High Marsh
7	Micro Pool
8	Outlet at Wetland

4. RESULTS AND DISCUSSION

4.1 Ecological Swale

Table 2 shows the result on 28th Jun 2003. Ten (10) parameters tested were Dissolved Oxygen (DO), pH, Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Ammoniacal Nitrogen (NH_3-N), Zinc (Zn), Lead (Pb), Nitrate (NO_3-N) and Phosphate (PO_4^{3-}). From the results, it can be observed that storm water quality from the outlet type C which is the most downstream end of the ecological swale has a range of pH between 5.88 and 6.39, TSS between 3 - 26 mg/l, DO between 5.4 and 7.9 mg/l, COD between 23.0 to 108.2 mg/l, and BOD between 2-9 mg/l. This range falls under Class 11A Standard Classification by the Department Of Environment (DOE) Malaysia. The good water quality observed at the outlet type C gives an indication that some purification occurs along the system.

Table 2 Stormwater Quality Result on 28 June 2003 at ecological swale

Station	Parameter									
	pH	DO (mg/L)	TSS (mg/L)	COD (mg/L)	BOD (mg/L)	NH_3-N (mg/L)	NO_3-N (mg/L)	PO_4^{3-} (mg/L)	Zn (mg/L)	Pb (mg/L)
GS1	5.88	6.9	3	76.8	4	0.23	0.87	0.06	0.122	0.856
GS2	6.35	5.6	2	92.3	6	0.19	0.67	0.03	0.147	0.977
GS4	6.08	5.4	10	57.6	3	0.46	1.09	0.22	0.077	0.962
GS7	6.25	5.9	10	61.4	4	0.3	0.97	0.15	0.139	0.831
GS8	6.39	6.4	6	23.0	2	0.34	0.87	0.15	0.120	0.851
GS9	6.34	7.9	7	57.6	5	0.27	1.37	0.13	0.510	0.750
GS10	6.32	6.9	26	108.2	9	0.58	1.17	0.92	0.15	0.804

Table 3 Range of water quality for each parameter (July – October 2003)

Parameter	Sampling Points at Ecological Swales									
	GS1	GS2	GS3	GS4	GS5	GS6	GS7	GS10	GS9	GS8
pH	5.66-7.88	5.44-7.82	5.53-8.22	5.36-7.87	5.38-8.13	5.42-8.69	5.53-7.43	5.42-8.24	5.62-7.80	5.40-7.43
Temperature (^{0}C)	26.1-30.1	25.6-30.5	24-31.9	24.6-30.1	25-32.1	25.0-32.1	25.6-31.5	24-28.7	24.9-26.7	26-29.6
DO (mg/L)	2.69-3.80	1.74-6.03	2.14-4.36	1.84-6.08	1.95-5.97	1.71-5.83	1.76-5.71	1.58-5.09	2.48-5.38	1.50-5.45
BOD (mg/L)	3-9.50	0-12.00	2-8.5	1-7.5	0-11	0-6	0-5	1.5-7.0	0-11.5	1.00-4.00
COD (mg/L)	0-99.05	5.59-129.52	16.78-72.38	11.19-144.76	0-80	0-110.48	2.8-190.48	16.78-87.62	13.99-110.48	2.80-83.81
TSS (mg/L)	0-19	0-3	0-27	0-10	0-13	0-28	0-19	5-48	0-60	0-9
Turbidity (NTU)	8.3-13.2	6.4-21.8	7.5-33.6	15.8-28.5	9.6-19.9	10.9-128.0	10.7-22.9	22.7-66.3	13.7-23.7	9.6-18.9
Pb (mg/L)	0-1.459	1-1.480	1-1.426	0-1.422	0-1.181	0-1.177	0-1.133	0-1.407	0-1.287	0-1.471
Zn (mg/L)	0	0	0	0	0	0	0	0	0-0.034	0
Cu (mg/L)	0-1.899	0-1.989	0-1.694	0-1.835	0-1.724	0-1.684	0-1.989	0-1.765	0-1.649	0-1.687

Table 3 shows the range of the water quality for each parameter at every sampling point. It shows most of the parameter such as pH, TSS, Turbidity, BOD and DO complies Class II, National Interim Water Quality Standard for Malaysia. For heavy metals (Pb, Zn and Cu), it was observed that they do not conform the standard due to on-going construction activities.

4.2 Ecological Ponds

The results of water quality monitoring at the ecological pond are shown Figure 5. Inconsistent result for all parameters from the upstream to the downstream of the ecological ponds were obtained systems where the ranges of BOD_5 and turbidity are between 0.5 – 7.00 mg/L and 0.69 – 7.36 NTU respectively. However, wetland has the lowest range of Oil and grease (0.0028mg/L).

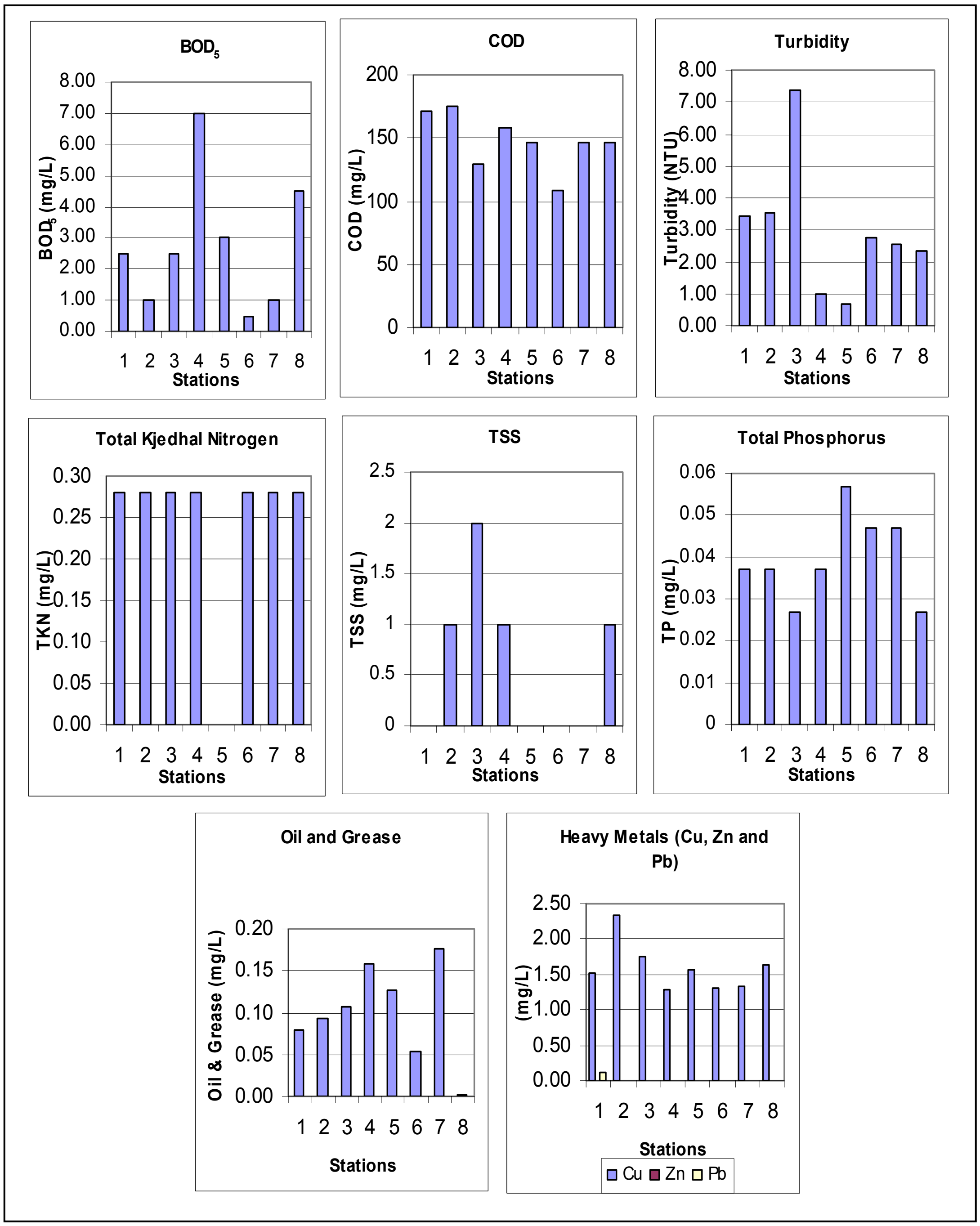

Figure 5 Stormwater quality results on 19 July 2003

Several parameters were also measured using in-line monitoring measurement at wetpond, detention pond and micro pool. For example, Figure 6 represents the result for the period of 4th – 31st August 2003. The fluctuations of DO concentration show that there are a lot of aquatic lives using the oxygen in the water. High temperature of the water may affect the concentration of DO in the ponds. It was also observed that concentration of DO increases after rainfall event especially at detention pond and wetland. The range of DO concentrations, temperature and pH are between 0.18 - 12.62 mg/L, 25.54 - 33.69 °C and 5.43 – 8.4 respectively.

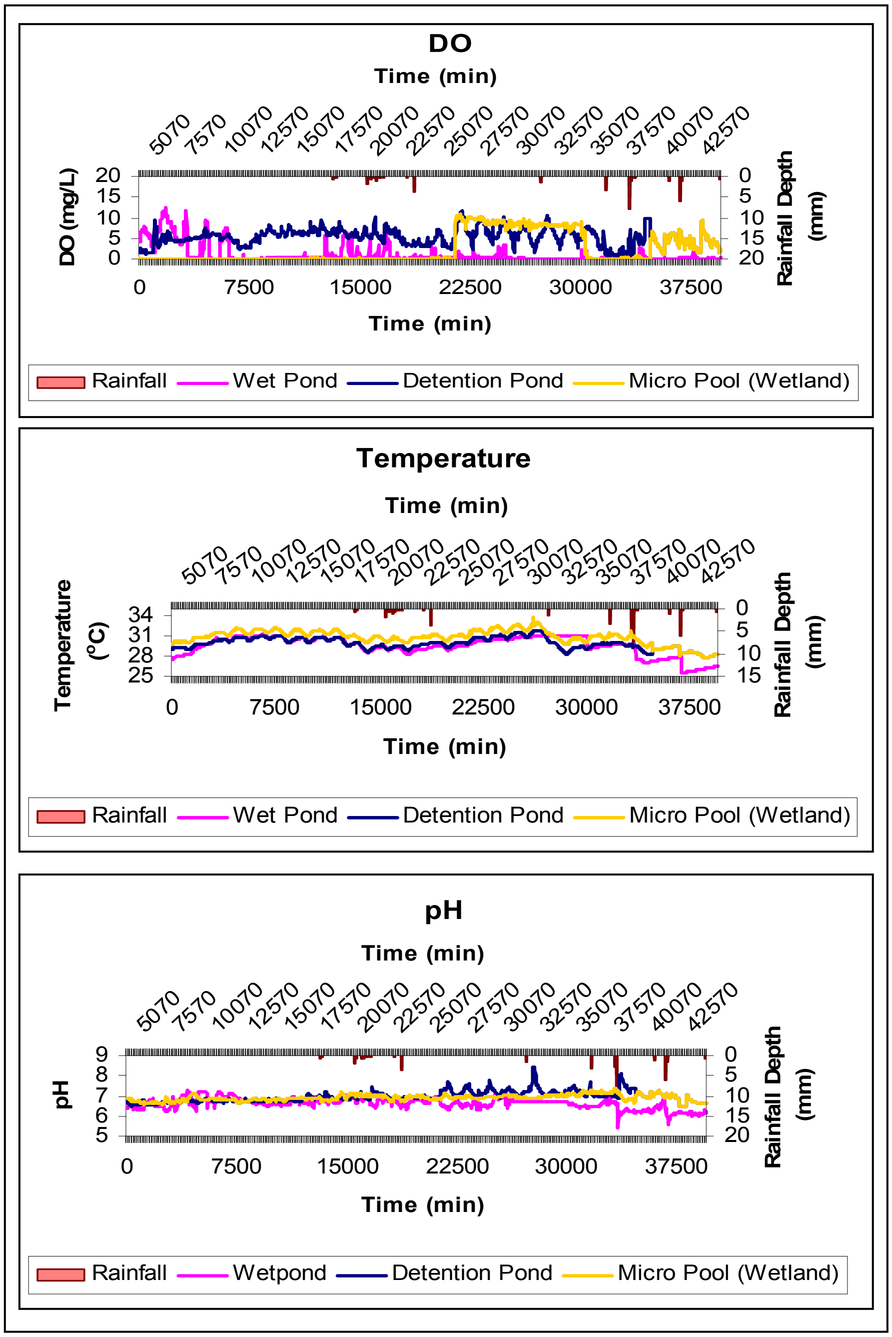

Figure 6 Result of Dissolved Oxygen, Temperature and pH on 4 – 31 August 2003 (Ecological Ponds)

The concentration of DO (Figure 7) improves on September 2003 where the range of DO concentration is between 0 and 10 mg/L. Even though DO concentrations in wetpond (upstream) is much more lower, the DO concentration increases at detention pond and it becomes higher at wetland at the downstream end.

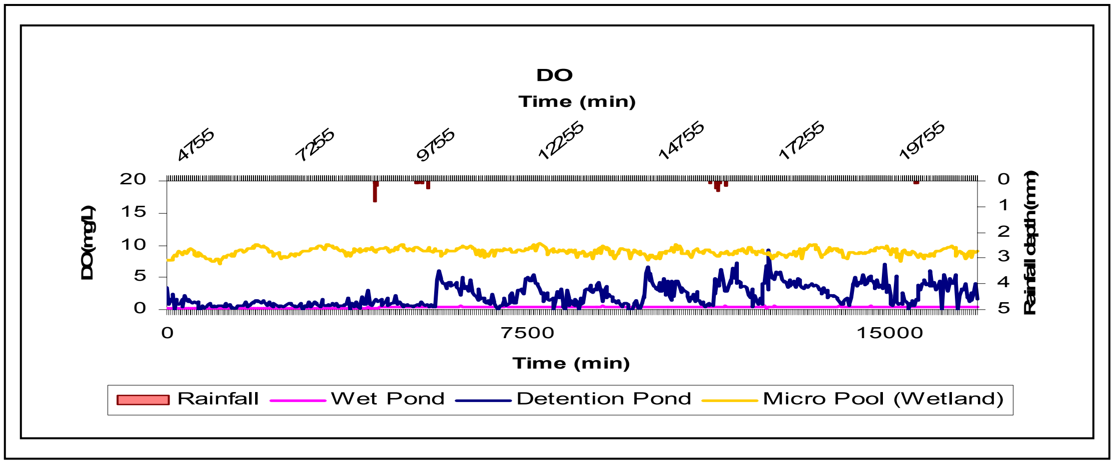

Figure 7 Value of Dissolved Oxygen at ecological pond on 11 – 23 September 2003

5. CONCLUSIONS

Performances of ecological swale in treating most pollutants show that there is reduction in their concentrations from upstream to downstream during the study period (June – October 2003). The quality of the storm runoff, which falls in Class II, National Interim Water Quality Standard for Malaysia before flowing into Sungai Kerian, shows that ecological pond performs well in treating the storm runoff to reduce the pollutants in the water. Further data however is needed in confirming the performance of BIOECODS systems in removing storm runoff pollutant.

ACKNOWLEDGEMENT

The authors would like to thank the Department of Irrigation and Drainage, Malaysia for the support in providing the research grant for this pilot project. The authors also would like to gratefully acknowledge the full support given by the Vice Chancellor of the University Science Malaysia for giving them the opportunity to construct the BIOECODS at the new USM Engineering campus. They are also grateful to His Excellency the Governor of Penang for officially launching the BIOECODS at the national level on 4th February 2003.

REFERENCES

Burkhard R, Craig A & Deletic A. (2000). "Techniques For Water and Wastewater Management: A Review of Techniques and Their Integration in Planning." Urban Water Vol. 2. pp197-221. Elsevier Science Ltd.

Niemczynowicz, J. (1999). "Urban Hydrology and Water Management – Present and Future Challenges." Urban Water Vol.1. pp 1-14. Elsevier Science Ltd.

Yu, S. L., Kou, J. T., Fassman, E. A. & Pan, H. (2001). "Field Test of Grass Swale Performance in Removing Runoff Pollutant." *Journal of Water Resources Planning and Management*, Vol. 127, No. 3, pp. 168 -171.