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Storm water treatment using Bio-Ecological Drainage System

KHAIRUL RAHMAH AYUB, *Tutor, River Engineering and Urban Drainage Research Centre (REDAC), Universiti Sains Malaysia, Kampus Kejuruteraan, Seri Ampangan, 14300 Nibong Tebal, Penang, Malaysia*

LARIYAH MOHD SIDEK, *Senior Lecturer, Department of Civil Engineering (Water Engineering), College of Engineering, Universiti Tenaga Nasional, KM 7, Jalan Kajang-Puchong, 43009 Kajang, Malaysia*

ANITA AINAN, *Engineer, River Engineering Section, Department of Irrigation and Drainage Malaysia, Jalan Sultan Salahuddin, 50626 Kuala Lumpur, Malaysia*

NOR AZAZI ZAKARIA, *Director, REDAC, Universiti Sains Malaysia, Kampus Kejuruteraan, Seri Ampangan, 14300 Nibong Tebal, Penang, Malaysia*

AMINUDDIN AB. GHANI, *Deputy Director, REDAC, Universiti Sains Malaysia, Kampus Kejuruteraan, Seri Ampangan, 14300 Nibong Tebal, Penang, Malaysia*

ROZI ABDULLAH, *Lecturer, School of Civil Engineering, Universiti Sains Malaysia, Kampus Kejuruteraan, Seri Ampangan, 14300 Nibong Tebal, Penang, Malaysia*

ABSTRACT
The treatment of stormwater as it flows through a Bio-Ecological Drainage System (BIOECODS) is the result of a complex interaction between the physical, chemical and biological processes that occur within the system. A stormwater quality monitoring programme at BIOECODS is being carried out by grab sampling method for the period of April–November 2003. Samples of stormwater are taken from ten stations along ecological swales and eight stations along ecological pond. The ecological pond (wet pond, detention pond, constructed wetland, wading river and recreational pond) which is placed downstream acting as a facility to control the storm water quantity and storm water treatment device before 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.

Keywords: BIOECODS; stormwater; water quality; swale; wetpond; detention pond; constructed wetland.

1 Introduction

Urban development in Malaysia may change the natural hydrology and infiltration characteristic of the catchments area due to the increases of impermeable area. In order to control quantity and quality of stormwater in new development area, new techniques of drainage system are needed. Beside, urban stormwater runoff was identified as a major source of heavy metals and toxic organic elements (Niemczynowicz, 1999). 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. (Ab. Ghani *et al.*, 2004; Zakaria *et al.*, 2003.)

2 Bio-Ecological Drainage Systems (BIOECODS)

The launching of BIOECODS at national level on 4th February 2003 by His Excellency, The Head of State of Penang has promoted the system throughout the Malaysia as a pilot project. Major components of BIOECODS 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 areas of 4500 m^2, 10,000 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*

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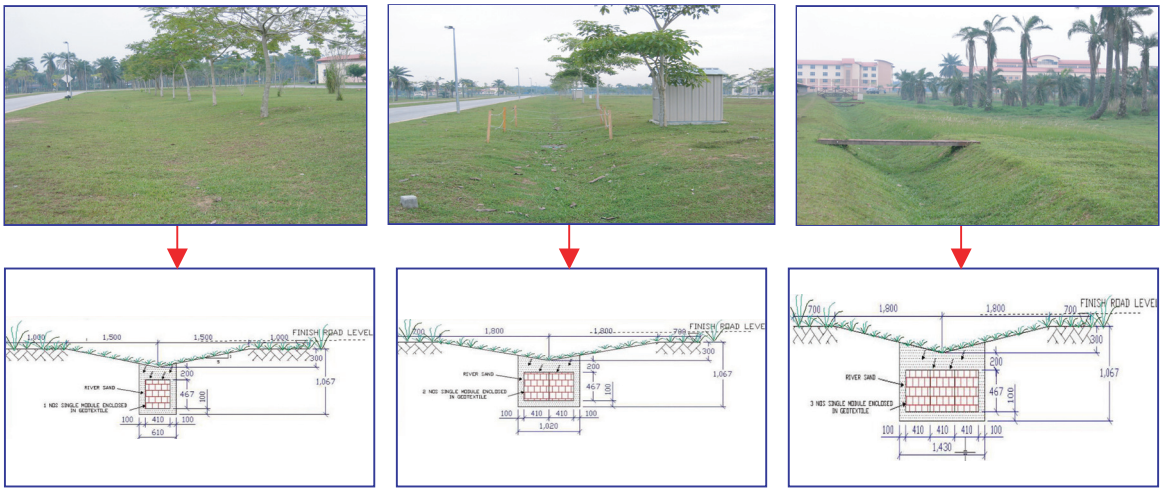


Figure 1 Bio-Ecological swale Type A, Type B and Type C.

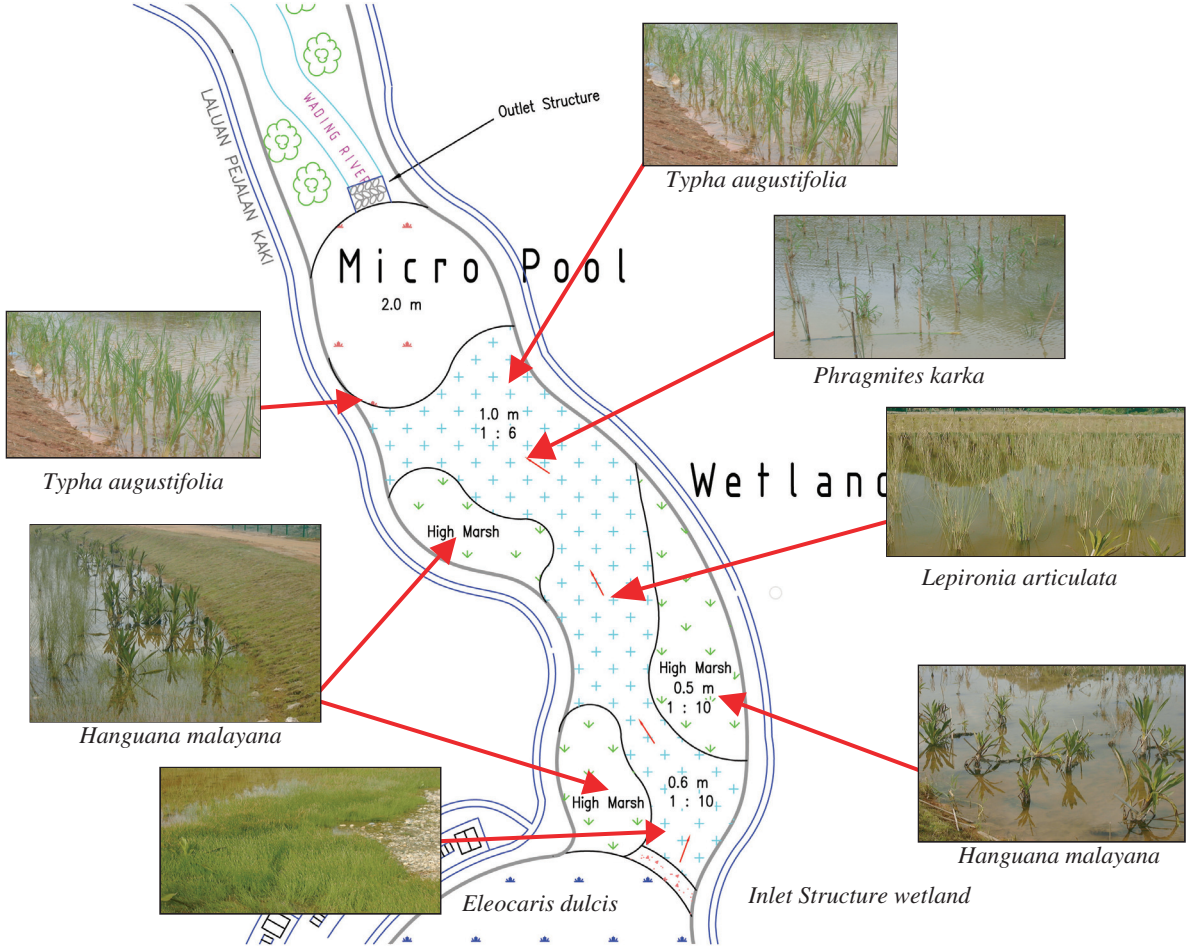
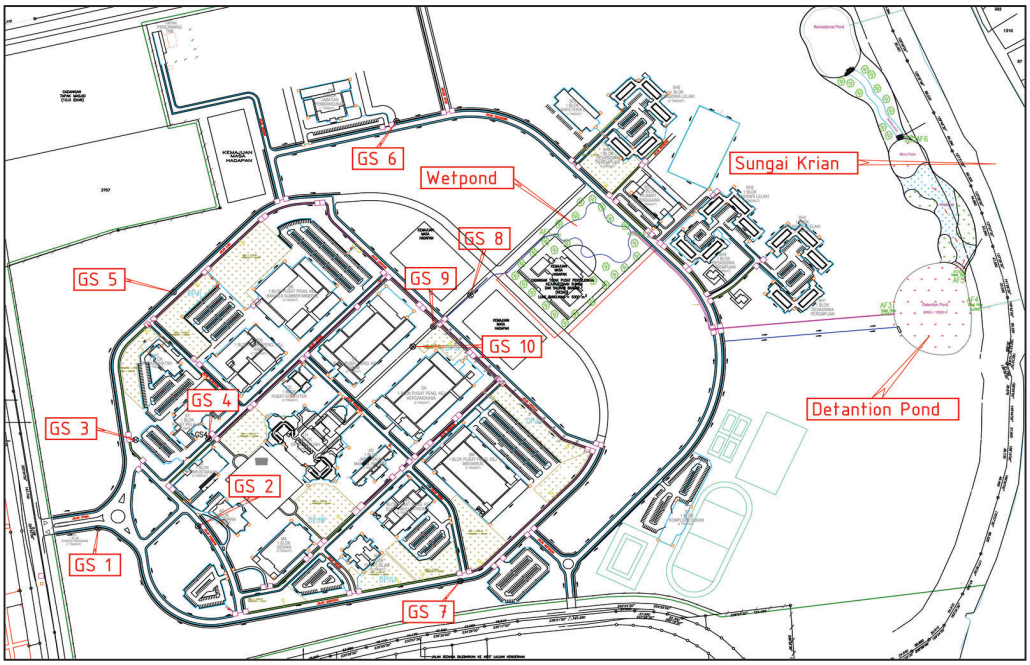


Figure 2 Type of macrophytes planted in mini wetland of BIOECODS.

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 (Mohd Sidek *et al.*, 2004).

3 Data collection programme

Since April 2003 until October 2003, data collection of stormwater quality has been carried out.



GS1 (Perimeter swale)

GS2 (Perimeter swale)

GS3 (Type A)

GS4 (Perimeter swale)

GS5 (Type B)

GS6 (Perimeter swale)

GS7 (Type B)

GS8 (Type C)

GS9 (Type B)

GS10 (Dry Pond)

Figure 3 Ten sampling locations at ecological swales.

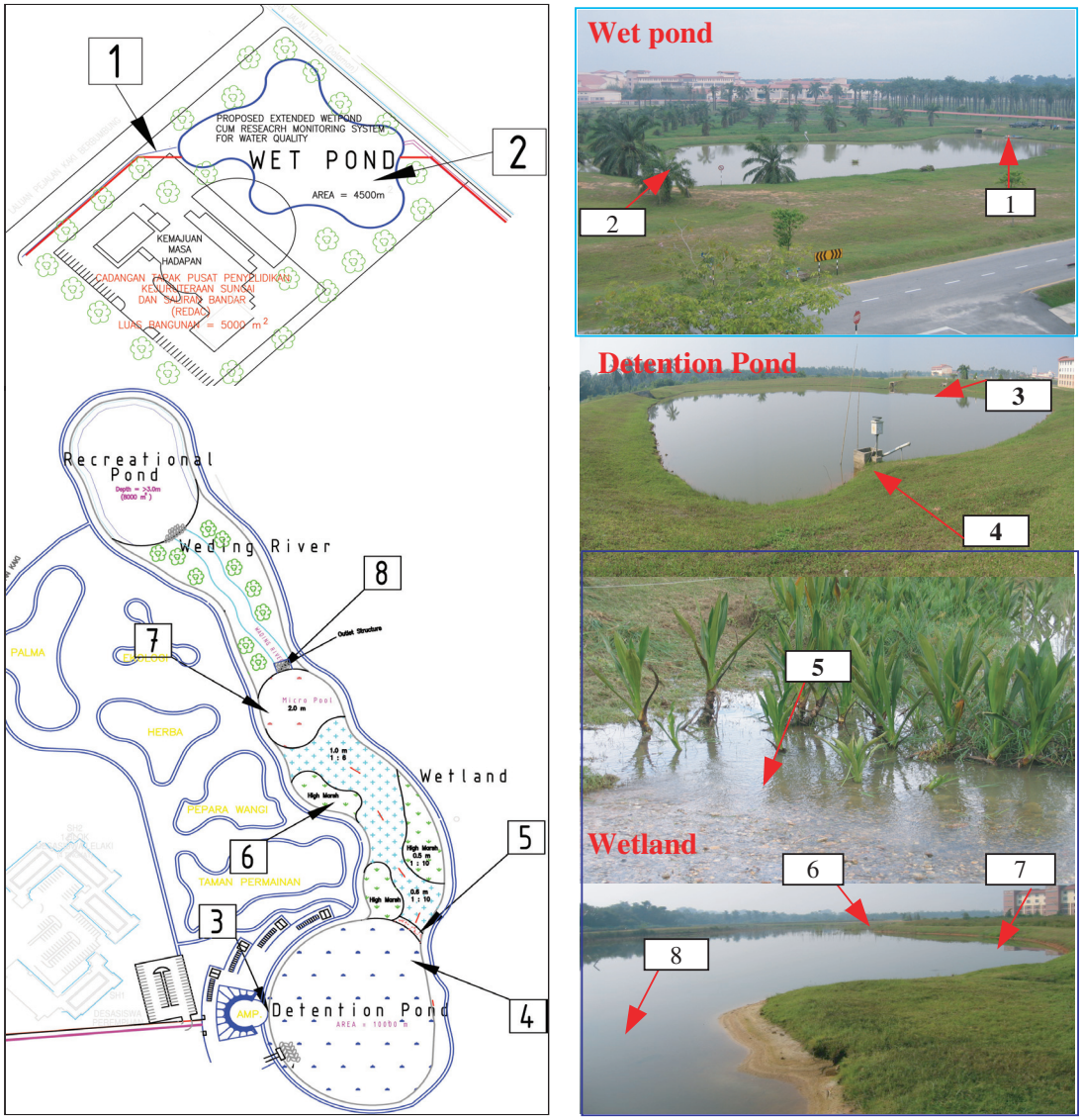


Figure 4 Sampling locations at Wet pond, Detention Pond and wetland.

3.1 Ecological swale

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

Eight sampling points were established in ecological pond and located at every inlet and outlet of ecological ponds. 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. Figure 4 shows the locations of the sampling points from the upstream to the downstream of the ecological ponds system.

4 Results and discussion

4.1 Ecological swale

Six parameters were tested for storm water samples for event on 21st April 2003. The quality of stormwater has a consistent value along the ecological swale for all parameters (Table 1). The result shows the quality of stormwater for this event in the range of Class I to Class III based on Interim National River Water Quality Standards for Malaysia or known as Water Quality Index (WQI). The performance of the ecological swale also varies in treating stormwater for the event on 8th September 2003 (5 years ARI). The values of temperature, BOD_5 and TSS are low, but the values of COD and Pb are slightly higher (Table 2).

Throughout the period of study, the range of stormwater runoff from the upstream to the downstream falls onto Class I to Class III (Table 3).

Table 1 Stormwater quality in ecological swale (21st April 2003 (≃ 3 – Month ARI)).

Station	pH	TSS (mg/L)	DO (mg/L)	COD (mg/L)	BOD_5 (mg/L)	NH3-N (mg/L)	Range (WQI)
GS1	8.0	6	9	21	3	0.2	I–II
GS2	7.8	6	7	22	6	0.1	I–III
GS3	8.2	8	6	23	6	0.1	I–III
GS4	7.8	2	6	23	9	0.2	I–III
GS7	7.8	8	8	23	5	0.2	I–II
GS10	7.3	7	6	23	15	0.3	I–V
GS9	7.9	8	8	22	7	0.3	I–III
GS8	7.7	7	6	23	6	0.2	I–III
Class II B, WQI	6–9	50	5–7	25	3	0.3	
Standard B, EQA 1974	5.5–9.5	100	–	100	50	–	

Table 2 Stormwater quality in ecological swale (8th September 2003 (5 – years ARI)).

Station	pH	DO (mg/L)	BOD_5 (mg/L)	COD (mg/L)	TSS (mg/L)	Turbidity (NTU)	Pb (mg/L)	Cu (mg/L)	Zn (mg/L)	Range (WQI)
GS1	6.2	3	3	99	19	9	1.4	0.0	0.0	I–III
GS2	6.1	3	0	61	3	11	1.4	0.0	0.0	I–III
GS3	6.1	4	9	65	10	20	0.8	0.1	0.0	I–III
GS4	6.1	3	1	34	1	21	0.9	0.0	0.0	I–II
GS5	6.1	4	4	53	1	14	0.3	0.1	0.0	I–III
GS6	6.0	3	1	65	7	32	0.9	0.0	0.0	I–III
GS7	6.0	4	2	84	6	15	1.1	0.0	0.0	I–III
GS10	6.0	4	3	61	6	24	1.2	0.1	0.0	I–III
GS9	6.0	5	2	107	1	24	1.3	0.1	0.0	I–V
GS8	6.0	4	3	84	0	15	1.2	0.0	0.0	I–III
Class II B, WQI	6–9	5–7	3	25	50	–	–	–	–	
Standard B, EQA 1974	5.5–9.5	–	50	100	100	–	0.5	1.0	2.0	

Table 3 Range of stormwater quality in ecological swale (April–October 2003).

Station	pH	DO (mg/L)	BOD_5 (mg/L)	COD (mg/L)	TSS (mg/L)	Turbidity (NTU)	NH3-N (mg/L)	NO3-N (mg/L)	Phosphate (mg/L)	Pb (mg/L)	Zn (mg/L)	Range (WQI)
GS1	5.7–8.0	2–7	3–9	0–99	0–19	8–13	0.0–0.2	0.0–0.9	0.0–0.1	0–1.4	0.0–0.1	I–III
GS2	5.4–7.8	1–6	0–12	5–129	0–3	6–21	0.1–0.2	0.0–0.7	–	1–1.4	0.0–0.1	I–IV
GS3	5.5–8.2	2–8	2–8	16–72	0–27	7–33	0.0–0.1	–	–	1–1.4	–	I–III
GS4	5.3–7.9	1–6	1–9	11–144	0–10	15–28	0.2–0.5	0.0–1.1	0.0–0.2	0–1.4	–	I–III
GS5	5.4–8.1	1–5	0–11	0–80	0–13	9–19	–	–	–	0–1.1	–	I–III
GS6	5.4–8.7	1–5	1–5	0–110	0–28	10–128	–	–	–	0–1.1	–	I–III
GS7	5.5–7.8	1–8	1–5	2–190	0–19	10–22	0.2–0.3	0.0–1.0	0.0–0.2	0.1.1	0.0–0.8	I–II
GS8	5.4–7.7	1–7	1–7	2–83	0–9	9–18	0.2–0.3	0.0–1.0	0.0–0.2	0.1.4	0.0–0.8	I–III
GS9	5.6–7.9	1–8	2–8	13–110	0–60	13–23	0.3–0.3	0.0–1.4	0.0–0.1	0–1.2	0.0–0.7	I–III
GS10	5.4–7.8	1–7	1–9	16–108	5–48	22–66	0.3–0.6	0.0–1.2	0.0–0.9	0–1.4	0.0–0.8	I–III
Class II B, WQI	6–9	5–7	3	25	50	–	0.3	–	–	–	–	
Standard B, EQA 1974	5.5–9.5	–	50	100	100	–	–	–	–	0.5	2.0	

4.2 Ecological pond

The concentrations of several pollutants were reduced from the upstream to the downstream for the event on 9th September 2003. Table 4 shows the values of turbidity and TSS decrease and fall onto Class I. Basically, stormwater quality for most monitoring stations in ecopond are in the range of Class I to Class III Water Quality Index. On 25th November 2003, the results show stormwater quality has inconsistent value for parameters such as BOD_5, (15–25 mg/L), COD (1–27 mg/L) and Turbidity (2–12 mg/L). All stations fall onto Class I to Class V (Table 5). Table 6 shows the range of the stormwater quality throughout July 2003 until November 2003. All station falls onto Class I to Class V of Water Quality Index.

Table 4 Stormwater Quality in Ecopond (9 September 2003 (5 – year ARI)).

Station	Temperature (°C)	pH	DO (mg/L)	BOD_5 (mg/L)	COD (mg/L)	Turbidity (mg/L)	TSS (mg/L)	Cu (mg/L)	Zn (mg/L)	Pb (mg/L)	Range (WQI)
Inlet WP	33.4	8.5	8	3	66	10	0	0.0	0.0	1.6	I–III
Outlet WP	33.5	9.0	9	2	67	8	4	0.0	0.0	1.4	I–III
Inlet DP	33.0	7.2	5	3	72	14	0	0.0	0.0	1.1	I–III
Outlet DP	33.8	7.9	6	1	71	7	1	0.0	0.0	1.4	I–III
In. Wetland	33.0	7.5	6	1	52	7	4	0.0	0.0	1.2	I–III
High Marsh	33.5	7.2	7	2	41	7	7	0.0	0.0	1.1	I–II
Micro Pool	33.4	7.1	7	5	29	5	0	0.0	0.0	1.1	I–II
Out. Wetland	33.4	7.2	8	3	22	5	0	0.0	0.0	1.3	I–II
Class II B, WQI	–	6–9	5–7	3	25	–	50	–	–	–	
Standard B, EQA 1974	40	5.5–9.5	–	50	100	–	100	1.0	2.0	0.5	

Table 5 Stormwater Quality in Ecopond (25 November 2003 (1 – year ARI)).

Station	pH	DO (mg/L)	BOD_5 (mg/L)	COD (mg/L)	Turbidity (mg/L)	TSS (mg/L)	Cu (mg/L)	Zn (mg/L)	Range (WQI)
Inlet WP	6.9	3	20	3	12	0	0.1	0.0	I–V
Outlet WP	7.0	3	15	27	5	0	0.0	0.0	I–V
Inlet DP	7.3	4	20	9	11	1	0.1	0.0	I–V
Outlet DP	7.3	4	25	8	4	0	0.0	0.0	I–V
In. Wetland	6.7	3	25	1	11	0	0.0	0.0	I–V
High Marsh	6.6	3	20	15	3	0	0.0	0.0	I–V
Micro Pool	6.6	3	20	2	4	0	0.0	0.0	I–V
Out. Wetland	6.4	3	15	9	2	1	0.0	0.0	I–V
Class II B, WQI	6–9	5–7	3	25	–	50	–	–	
Standard B, EQA 1974	5.5–9.5	–	50	100	–	100	1.0	2.0	

Table 6 Range of stormwater quality in ecopond from July 2003 to November 2003.

Station	Temperature (°C)	pH	DO (mg/L)	BOD_5 (mg/L)	COD (mg/L)	Turbidity (mg/L)	TSS (mg/L)	Cu (mg/L)	Zn (mg/L)	Pb (mg/L)	Range (WQI)
Inlet WP	26.0–32.4	6.3–8.6	2–9	3–76	3–171	3–12	0–8	0.0–1.5	0.0–0.3	0.0–0.9	I–V
Outlet WP	27.0–32.5	6.6–8.7	2–10	2–20	8–175	1–8	0–17	0.0–2.3	0.0–0.0	0.0–1.5	I–V
Inlet DP	26.5–33.1	6.2–7.4	2–8	0–20	9–158	2–14	0–5	0.0–1.7	0.0–0.0	0.0–1.7	I–V
Outlet DP	26.8–33.0	6.1–7.5	2–7	1–28	8–183	1–7	0–7	0.0–1.3	0.0–0.2	0.0–1.6	I–V
In. Wetland	26.9–33.4	6.3–7.3	3–7	1–25	1–175	1–11	0–6	0.0–1.6	0.0–0.0	0.0–1.5	I–V
High Marsh	27.1–31.8	6.2–8.0	3–7	1–25	15–138	3–7	0–11	0.0–1.3	0.0–0.5	0.0–1.3	I–V
Micro Pool	27.5–33.4	6.1–7.7	3–7	0–35	2–163	3–5	0–16	0.0–1.3	0.0–0.0	0.0–1.2	I–V
Out. Wetland	27.2–33.1	3.9–7.9	2–6	1–20	9–163	2–7	0–12	0.0–1.6	0.0–3.7	0.0–1.3	I–V
Class II B, WQI	–	6–9	5–7	3	25	–	50	–	–	–	
Standard B, EQA 1974	40	5.5–9.5	–	50	100	–	100	1.0	2.0	0.5	

5 Conclusions

The results obtained shows that Bio-ecological Drainage System is efficient in reducing pollutants. However, further data is needed in confirming of BIOECODS in removing stormwater runoff pollutants for various ARI.

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