Field evaluation of BMP performance in BIOECODS

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ABSTRACT
This paper describes the use of Removal Rate (RR) method and Effluent Probability Method (EPM) to evaluate the performance for BMPs in BIOECODS on 3 water quality parameters namely COD, TSS and TP. 6 set data, 3 from each dry and wet weather were collected and are presented and use for evaluation. The results show, Detention Pond and Wetland shown some significant results in treating water quality while the Wet Pond and Recreational Pond shows deterioration of water quality parameters. While RR method provide the magnitude of treatment, EPM shows the treatment pattern not available in numerical method. It is recommended that both numerical method and graphical method are combined for BMPs evaluations. The data set shows tendency of being normally distributed but further study are required pertaining this claim.

Keywords: RR method; EPM; BMPs; BIOECODS.

1 Introduction

The problems of urban runoffs always come along with civilization and development. It is an unavoidable issue that we often need to altered pristine nature of environment when it comes to meeting the urbanization requirements. Urbanization often change the ratio of previous and impervious surface and this disturb the hydrological cycle and the routing of storm water. Zakaria, 2003 indentified that urbanization contribute pollutant in two stage. In the initial stage, due to upland construction site, a significant amount of eroded sediment wills travel downstream. In second stage, the dominant source of pollutant comes from wash off from impervious surface due to storm event. Urban storm water runoff was identified as a major source of heavy metals and toxic organic elements (Niemczynowicz, 1999). Study by drainage and Irrigation showed that 9% of the country's land mass is prone to floods which affect about 12% of the population. As a results, frequent occurrences of flash flood occur at downstream of new development areas resulted in an average loss of RM100 million(Zakaria, 2003, Mohd Sidek, 2002(b)) Tackling urban runoff problems are often hampered by lack of funding, lack of integration with other resource management strategies, and lack of understanding in nature mechanism and engineering knowledge. We often observed problems such as flash flood, polluted river and water scarcities in urbanized cities despite various engineering approach have been attempted. However, the efforts continue. From the history of water resource management in Malaysia, the direction of storm water management now shifted to protection of the natural water cycle and ecological system by the introduction of local source control, flow attenuation and treatment in natural or through storm water best management practices (BMP), such as ponds, wetlands and treatment facilities. It is generally accepted that storm water should be attenuated locally(Zakaria, 2003). BMPs have been applied in many overseas urban drainage. The implementation of integrated measures of storm water BMP's in Malaysia is still at early stages, there is a lack of research and field data that would provide a basis for sound design practices under Malaysia hydrological condition as Malaysia has tropical climate with very high intensity rainfall. University Science Malaysia (USM) has taken proactive step to implement the BMPs. Bio-ecological Drainage System (BIOECODS) in engineering campus and become the first university with this concept as demonstration project for source control concept in Malaysia. (Mohd Sidek, 2002(b))

Since completion in 2001, BIOECODS has been continuous for its performance. An overall comment from previous researchers is that BIOECDS shows promising performance in solving water quantity and quality issues for engineering campus. XP-SWMM simulation confirms BIOECODS consist of storage, flow retarding and infiltration engineering, capable of attenuating flood discharge and managing storm water at source(Zakaria, 2003). Final discharge from grass swale shows significant purification in BIOECODS(Ayub, 2004, Ayub et al., 2005, Mohd Sidek, 2004, Zakaria, 2003). Study on wetland and found significant reduction in TSS, Turbidity, Pho[horus, DO, nitrogen component (Ismail, 2008). Mohd Sidek 2002(a) found that drainage module could effectively increase the dissolved oxygen with respect with time, distance and velocity, this may due to the patter of the modular that has created turbulence flow. However, the module did not show high metal removal, as low as Zinc (10.9%), Cuprum (38.7%), Nickel (33.3%), and Plumbum (15.9%) probably due to slow chemical decomposition process, no infiltration and very much depends on inflow characteristics. Previous studies have showed that the effluent from BIOECODS falls in class IIA of standard classification by the Department of Environment (DOE) Malaysia (Ayub, 2004, Ayub et al., 2005). In this research, an attempt will be made to re-evaluate the performance of BIOECODS using removal rate (RR), efficiency ratio(ER), summation of total load (SOL), and effluent probability (EPM) methods.

2 Project Site

USM engineering campus, where BIOECODS is constructed within, is located in Mukim 9 of Seberang Perai Selatan district, Penang. 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. Comparison with neighbor town, it is 2Km south east from Nibong Tebal Town, and1.5km north-east of Parit Buntar. The construction of BIOECODS covers an area of 300 acres locating BMPs such as grass swale, wet pond, detention pond, wetland, and recreational pond. The design details of these BMPs are shown in (Ab. Ghani et al., 2004). Figures 1-4 shows the study site in BIOECODS.


Figure 1 Wet Pond


Figure 2 Detention Pond


Figure 3 Wetland


Figure 4 Recreational Pond

3 Methodologies

The sampling of water quality data on BIOECODS started on 3^{rd} March 2011 and is still ongoing. Sample were collected from the inlet and outlet of four ponds namely Wet Pond, Detention Pond, Wetland and Recreational Pond, Six sampling were conducted with 3 are collected on dry weather and 3 are from wet weather.

The water sample were collected using grab sample. Sample collected on site will be preserved in icebox and will be deliver to cold room within 2 hours. In-site data, (Tempereture, DO, pH) were measure by YSI Pro 20, YSI 60 and YSI 6920V2. Meanwhile, for parameters BOD, COD, TN, TP and TSS, laboratory work will be conducted within 1 weeks after sampling. All the laboratory works meets the APHA specification. (APHA et al., 1912)

Runoff flow is measured by multiple the inlet or outlet area with water velocity measured by Marsh Mcbirney Flo-mate^{TM} Model 2000. Velocity is taken on several depth of the flows and the average is taken as representative for the overall flow.

For dry weather, one sample is collected for the event bi-weekly while for wet weather (storm event), the water sample is collected on starting form Wet Pond to Recreational Pond. This process will be repeated until the flow recede for one storm event. Rough estimation for the interval for every sampling would be 1 hours.


Figure 5 YSI 6920V2 (Top) and YSI 650MDS(Bottom)


Figure 6 YSI Pro 20 (left) and YSI 60 (right)


Figure 7 Marsh Mcbirney Flo-mateTM Model 2000

3.1. Removal Rate (RR)

Removal method is the percentages of difference between inlet and outlet concentration of BMPs divided by the inlet concentration as shown in Equation 1 where C_{in} is the average of inlet concentration (from several sampling results) of BMPs while C_{out} is the average outlet concentration.

$$RR = \frac{C_{in} - C_{out}}{C_{in}} \times 100\% \qquad (1)$$

Efficiency Ratio(ER)
The efficiency ratio is defined in terms of the event mean concentration (EMC) of pollutants over some time period. (EPA, 2002).

$$ER = \frac{EMC_{in} - EMC_{out}}{EMC_{in}} \times 100\% \qquad (2)$$

This formula is similar to RR except with the replacing the concentration with EMC. EMC_{in} is for influent and EMC_{out} is for effluent. EMC is the ratio of the total pollution mass to total runoff volume in a single storm event.

$$EMC = \frac{\sum_{i=1}^{n} C_i V_i}{\sum_i^n V_i} \qquad (3)$$

where C_i and V_i is the average pollution concentration and runoff volume in sampling period *i*.

3.2. Summation of Load (SOL)

The summation of loads method defines the efficiency based on the ratio of the summation of all incoming loads to the summation of all outlet loads(EPA, 2002). Unlike ER and RR, SOL use pollutant mass instead of concentration.

$$SOL = 1 - \frac{\sum_{i=1}^{n} C_{out} V_{out}}{\sum_{i=1}^{n} C_{in} V_{in}} \times 100\%$$

3.3. Effluent Probability Method(EPM)

To plot out EPM, the data were first being tested for normality, as the storm water runoff quality mostly normally or log-normally distributed (Burton and Pitt, 2002). However, other transformation are also possible EPM. Due to small sample size, Shapiro-Wilk Test was used for normality test. Furthermore, Q-Q plot, skewness and kurtosis were also used to graphically and numerically check for normality. The criteria for acceptance for normality are as follow:

1) Kolmogorove-Smirve Test- Data set is considered if normally distributed if the significance value fall below 0.05, otherwise, data is not normally distributed
2) Q-Q Plot- Data set is considered normally distribute if the data points are close to diagonal line.
3) Skewness- Data set is considered normally distribute if the skewness is around 0±1 (Filliben, 2010)
4) Kurtosis- Data set is considered normally distribute if the kurtosis is around 0±1 (Filliben, 2010)

After the data set are verified normally distribute or log-normally, the data are sort in increasing order and plotted against cumulative probability. The data set will formed a straight line if the data are normally distributed. Inlet concentration and outlet concentration of BMPs will be plotted for to assess treatment performances.

4 Results and Discussion

Table **1** shows the average inlet and outlet concentration on wet weather and dry weather for four ECOPOND components and their RR. It is observed that Wetland are able to treat all the quality parameters on wet weather but not COD, -10%(RR), on dry weather. Detention Pond in the other hand show improvement in quality for the three parameters in dry weather while failing to treat TP,-40%, in wet weather. Overall, detention pond and wetland show improvement in water quality whereas Wet Pond and Recreational Pond shows deterioration of water quality parameters.

Highest RR for all three parameters are observed in dry weather. Detention Pond have highest RR for COD, 66%, and TP,68% while Wetland have highest RR in TSS, 85%. The differences in TP concentration for Wet Pond and Detention Pond are -7.11mg/l and 6.63mg/l, which is almost similar but their RR differs in great magnitude, with an alarming -2163% for Wet Pond and 68% for Detention Pond. The reason for this phenomena is the smaller inlet concentration of TP in Wet Pond, 0.38mg/l, compared to 6.20mg/l in Detention Pond. The sensitivity of RR towards inlet concentration might provide confusing indication to BMPs treatment performances.(Strecker et al., 2001, Barrett, 2008).

Figures 8 and 9 shows the mean concentration of COD, TSS and TP along the BMPs one dry and wet weather. It is observed that pollutant concentration tend to have increasing pattern traveling from Wet Pond outlet to Detention Pond inlet. The route between these points in earth channel. There might be re-suspension, and erosion of pollutant from this channel that contribute to increment in pollutant. Pollutant level decrease traveling from Detention Pond inlet to Wetland outlet, confirming the statement above that these two pond contribute to pollutant treatment. In Recreational Pond, the pollutant show slight increasing pattern for the parameters except for TP on wet weather.

Overall, final effluent concentration at Recreational Pond indicate that water quality discharged for BIOECODS system fall in class I for TSS, and Class II for COD. Further evaluation of other parameters (BOD, DO, SS, AN) are required to calculate the WQI for the effluent. TP, however, fail to meet EPA water quality criteria that stated phosphate level should not exceed 0.025mg/l within lake or reservoir, 0.1mg/l in stream or flowing water.

Because we could not sample all the storm event, statistical analysis need to be performed to gain confidence in the occurrences of data collected. Kolmogorove-Smirve one sample test is used to check the normality, and significance of mean and standard deviation of each data set.

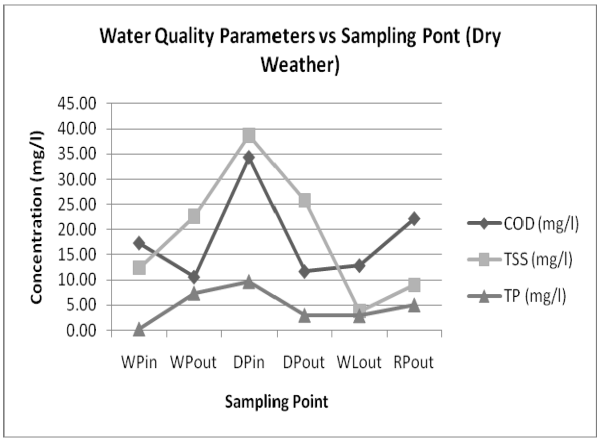

Figure 8 WQP vs Sampling Point (Dry Weather)

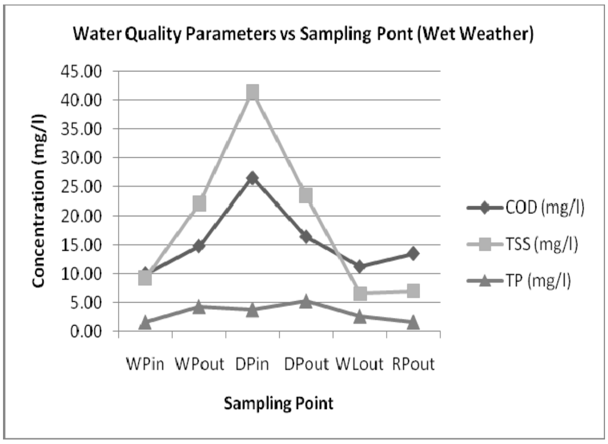

Figure 9 WQP vs Sampling Point (Wet Weather)

4.1. Statistical Analysis

If the maximum absolute difference (KS) were found with the critical value KSα of 0.521, it indicating that the distribution is normal, and the mean and standard deviation are can be used as our model. All the data set have KS< KSα. However, due to small sample size, n=6, the sign value of the results are >0.05, which mean that there is insufficient data neither reject nor accept our hypothesis. Therefore, Q-Q plot, skewness and kurtosis were used as alternative check for the distributions. It is found that some of the data shows promising pattern for normal distribution or log-normal distribution as shown in Figures 10-13 (Burton and Pitt, 2002).

For the time being, TSS performance on Wet Pond Detention Pond were selected to be plotted out in probability plot as shown in Figure 14 and 15. The results shows that Wet Pond do not do not reduce TSS concentration on Wet Pond while in Detention Pond, higher treatment performance were observed on higher inlet TSS concentration. It is observed that in Wet Pond, the TSS concentration of inlet and outlet formed a parallel line. The higher inlet concentration, the higher outlet concentration. This indicate that the outlet concentration are slightly or not influenced by the inlet concentration (McNett et al., 2011). However, in Detention Pond, treatment performance are low on low inlet TSS concentration but gradually increase as the concentration increase. The treatment of detention Pond started at 20mg/l to 60mg/l. This on the other hand shows that outlet concentration are effected by inlet concentration (Barrett, 2008). Therefore, it could be conclude that performance of BMPs varies for different BMPs. Further studies are required to justify this theory.

The treatment pattern and info obtained from probability plot are not easily observed on removal rate method as show in Table 1. It provide information on the treatment pattern and also the range of concentration where treatment occurs. However, probability plot method could not provide a definite answer to the magnitude of our treatment performance such as how many percent water quality is treat. It is suggested that the selection of method to analyze BMPs performance should be based on what requirement needed and if two or more method could be used to complement each other if one could not provide sufficient information.

Table 1 Mean Parameters Concentration and Removal Rate for Wet and Dry Weather

No	ECOPOND components	Mean COD (mg/l)			Mean TSS(mg/l)			Mean TP(mg/l)		
		Inlet	Outlet	RR(%)	Inlet	Outlet	RR(%)	Inlet	Outlet	RR(%)
Wet Weather										
1	Wet Pond	10.00	14.80	-48%	9.23	22.07	-139%	1.65	4.30	-161%
2	Detention Pond	26.53	16.43	38%	41.40	23.47	43%	3.75	5.26	-40%
3	Wetland	16.43	11.20	32%	23.47	6.53	72%	5.26	2.65	50%
4	Recreational Pond	11.20	13.50	-21%	6.53	6.98	-7%	2.65	1.62	39%
Dry Weather										
1	Wet Pond	17.37	10.63	39%	12.40	22.64	-83%	0.33	7.44	-2163%
2	Detention Pond	34.36	11.73	66%	38.69	25.76	33%	9.69	3.06	68%
3	Wetland	11.73	12.89	-10%	25.76	3.82	85%	3.06	2.95	3%
4	Recreational Pond	12.89	22.22	-72%	3.82	9.00	-135%	2.95	5.08	-72%

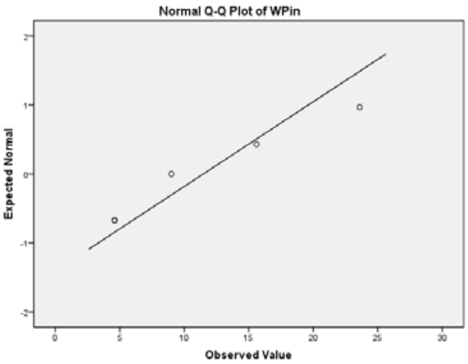

Figure 10 Q-Q plot for Wet Pond Inlet TSS Concentration (Skewness= 0.916, Kurtosis= -0.468)

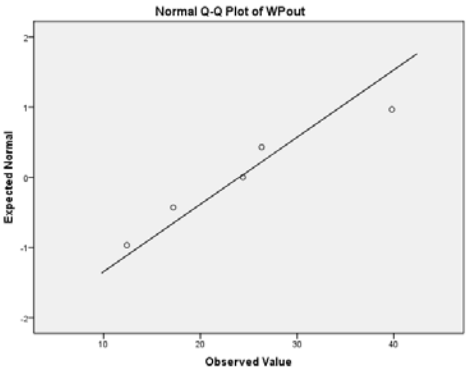

Figure 11 Q-Q plot for Wet Pond Outlet TSS Concentration (Skewness=0.750, Kurtosis= 0.666)

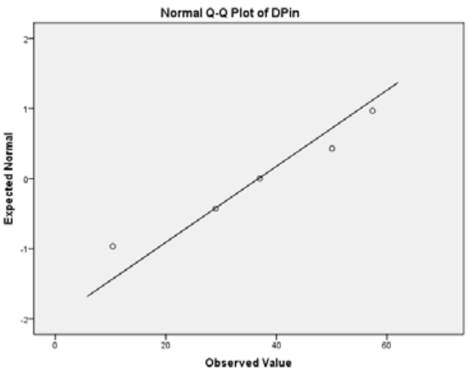

Figure 12 Q-Q plot for Detention Pond Inlet TSS Concentration (Skewness= -0.512, Kurtosis=-0.415)

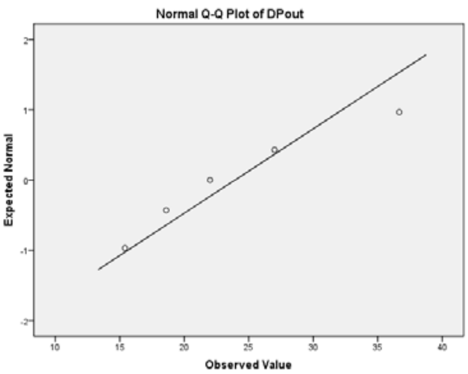

Figure 13 Q-Q plot for Wet Pond Inlet TSS Concentration (Skewness= 0.952, Kurtosis= 0.501)

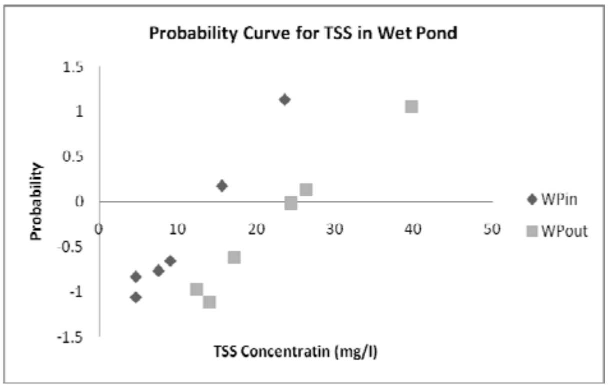

Figure 14 Probability Curve for TSS in Wet Pond

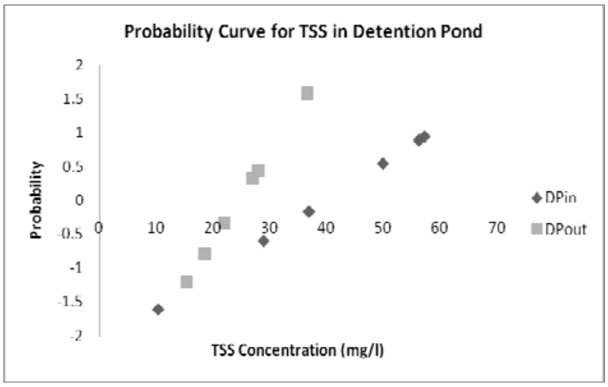

Figure 15 Probability Curve for TSS in Detention Pond

5 Conclusion

The author is regretted that the other two method namely ER and SOL method are not available for the time being. This evaluation will be further conducted on BIOECODS.

The results of RR method and EPM shows that both method provides insights to the performances of BMPs. Since there is still no one method that can claim "best" to represent BMPs performance, several methods could be used to compliment each others.

It is shows that Detention Pond and Wet land in BIOECODS shows improvement of water quality while Wet Pond and Recreational Pond shows deterioration of water quality parameters. Overall, final effluent concentration at Recreational Pond indicate that water quality discharged for BIOECODS system fall in class I for TSS, and Class II for COD. TP, however, fail to meet EPA water quality criteria that stated phosphate level should not exceed 0.025mg/l within lake or reservoir, 0.1mg/l in stream or flowing water. Further study are required to gain more confident on the data collected.

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