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Assessment on Pollutant Removal of Interconnected Wet Detention Pond

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Abstract: Best Management Practices (BMPs) have been used worldwide to control urban stormwater runoff. The objective of this paper is to assess the urban wet detention ponds on quality control for commercial and residential development in Denai Alam, Selangor, Malaysia. Field monitoring was conducted in this study area. Eight water samples were collected at 8 different locations from upstream to downstream of catchment area. All parameters were tested on-site except for TSS which was conducted at laboratory. The value of turbidity increased due to the occurrence of erosion and the side slope of detention pond. Total suspended solid (TSS) removal efficiency of Pond B is between 13 - 24%. However, this pond did not perform well in removing total phosphorus (TP) and ammonia nitrogen (NH_3-N) due to low concentration of dissolved oxygen. It is indicated that the water samples is classified under Class III of Department of Environment (DOE) Water Quality Classification which further treatment is required. Maintaining the detention pond could reduce pollutant loadings to meet targeted requirements of water quality improvement.

Key words: E-learning · Urban development · Stormwater Management · Wet detention pond

INTRODUCTION

Progressive development from rural to urban or industrial areas has shifted the population into urban areas. The increment of impervious surface areas is synonym with the development of urban areas. When the impervious surface areas increases, the volume of surface runoff will also increase and cause more rapid transmission of surface runoff. Detention ponds have been used to diminish the increase in runoff rates by detaining the stormwater runoff for some period, while releasing it slowly to receiving water or streams [1].

Wet detention ponds are capable in improving the quality of runoff at urban areas. They are excellent means in providing retention and treatment of contaminated stormwater runoff. The ponds are functioning to remove suspended solids, metals and dissolved nutrients through sedimentation and biological uptake; hence the water quality can be improved [2]. By maintaining a permanent pool of water among storms, microorganism and other components can acted either by chemically or biologically to provide additional removal of dissolved pollutant [3]. In addition, longer residence time provides more opportunity for solids to settle through sedimentation processes. Poor maintenance of wet ponds can also create nuisance odors, weed growth and collect trash. This can be considered unattractive by residents. Based on a case study in South Carolina, the ecological system in detention pond diminished when it received the stormwater directly from storm sewer pipe. The problem would be resolved if the flow was discharged passing through the vegetated swales or trench and promoted the infiltration process in the system [4].

For large events, removal fractions will be small as the holding time will be short. However, the integration with other BMPs such as bioretention will increase the performance of detention pond. By using bioretention, it is found that the concentration of all nitrogen-based and total nitrogen reduced significantly up to 32% [5]. A single detention is unable to cater water quality, ground water replenishment, or water supplies. Consequently, detention cannot be considered a basic solution to the environmental problems that generated by urban development [6]. The efficiency of detention pond in removing suspended solids can be increased by incorporating a forebay or pre-settling chamber for

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Table 1: Findings from three Different studies

	Percentage of removal							
	Comings et. al. 2000		*Wu et. al. 1996*			*Mallin et. al. 2002*		
Parameter	*Pond A*	*Pond C*	*LS*	*WF*	*RB*	*AM*	*SS*	*EF*
Total Suspended Solids	61	81	93	41	62	65	(37)	(22)
Total Phosphorus	19	46	45		36	23	57	(35)
TKN			32		21			
Cadmium	68	52						
Copper	37	47						
Lead	73	76						
Zinc	45	72	80		32			
Iron			87		52			
Ammonium						29	83	(75)
Phosphate						7	77	(76)

the accumulation of coarse sediment, facilitating periodic cleaning to prevent washout by subsequent runoff events. Moreover, detention pond can limit losses of aquatic habitat by reducing the peak flow rate and energy of stormwater discharges to the receiving stream [6]. In addition, agricultural activities also lead to the increment of suspended solids, nutrients from organic and inorganic fertilizers and chemical substances such as phosphorus and ammonia [7]. Thus, wet pond is facing new challenges in treating the high pollutant runoff instead of storage purposes. However, if water quality improvement is a purpose of the pond, then detention time is significant as design parameter and a chain of detention basins might be considered. Major maintenance items should be incorporated with detention storage such as weed control and sediment removal. Thus, proper planning must be included in the maintenance plan to control and dispose those two items [8].

Among the previous study included investigation on two chosen ponds where a comparison between the performances of combined water quality or flow - attenuation pond (Pond A) and water quality pond (Pond C) were made [1]. Another study was conducted on three urban wet detention ponds in the North California [9]. The ponds were Lakeside (LS), Waterford (WF) and Runaway Bay (RB). The removal efficiency of pollutants for these two studies was determined by dividing the amount of each constituent that was removed by the pond by the loading that entered the pond. Then, Event Mean Concentration (EMC) is multiplied with the real runoff to find the value of the pollutant mass exported from local drainage areas. In North Carolina, another three wet detention ponds were analyzed for pollutants removal performance. All ponds were located within the boundary of the City of Wilmington, namely Ann McCrary (AM), Silver Stream (SS) and Echo Farms (EF) [10]. The results for the three studies are summarized in Table 1.

Genetic Algorithm (GA)-based procedure has been presented to determine efficient pond configurations and land use allocations to achieve a desired level of system-wide removal of a pollutant on a watershed [11]. This study showed that managing water quality in a pond is more cost-effective by using an integrated approach rather than setting one performance standard for all ponds without taking into account the site conditions and performance of that pond. The cost savings were relatively small for this study, around 6 to 11% when using the estimated pollutant rates achieved by the individual pond design procedure as removal target. However, by considering the required TSS removal target of 85%, the cost savings of 35% were achieved [11]. Besides, new model called Cooperative Water Quality Management Approach (CWQMA) was developed to assess the performance of water in river system [12]. It found that 95% cooperation states had minimum treatment cost compared to the single discharging state of the system.

Based on study of lake and reservoir in China, water quality in China became seriously polluted where about 34.6% of lakes and reservoir were classified in below Grade V category and 23.1% achieved Class I-III [13]. This is caused by the lakes and reservoir received high amount of Total Nitrogen (TN) and Total Phosphorus (TP) which resulted to euthrophication phenomena.

This paper presents a case study on the performance assessment of wet detention ponds in controlling surface runoff quality in order to meet Interim National Water Quality Standards for Malaysia (INWQS) requirement.

Fig. 1: Aerial view of the site location showing water sampling stations

Methodology

Site Description: The research site (Fig. 1) is located at Denai Alam, Shah Alam, Selangor, Malaysia which is about 5 km north of Ladang Bukit Jelutong. It is situated adjacent to Taman Bukit Subang and it is accessible via the existing Batu Tiga - Sungai Buloh Road. Denai Alam is a mixed development which comprises of residential, commercial and recreational components. Stormwater runoff originating from the adjacent authorities (Selangor Properties) development area at the upstream drains directly into the ponds either by a several storm drains or as overland flow. Two wet detention ponds were selected for quality monitoring; namely pond B and pond D. The water runoff from detention pond B outlet is discharging into detention pond D and subsequently into the Pelampas River at the downstream.

The total catchment area is approximately 35.34 hectare comprises the majority of housing areas. Impervious surfaces cover 43% of the drainage area.

Data Collection: Water sampling and in-situ assessments were conducted to obtain the data for water quality assessment. A total of eight stations were selected for analysis; at major inlet and outlet of detention pond B and D, at the upstream and downstream of the catchment area and one point at the drainage system. Local runoff entering a detention pond is usually conveyed by storm pipes or drainage. Although many of storm pipes draining into the detention ponds existed, but due to the hot climate, not all storm pipes filled with water. Since it was impractical to monitor the local inflows from each of these storm pipes, a representative drain was selected for sampling.

In-Situ Testing: Water quality parameters examined in-situ included temperature, pH value, chemical oxygen demand (COD), total phosphorus (TP), turbidity, electrical conductivity (EC), dissolved oxygen (DO), ammonia nitrogen (NH_3-N) and coliform/bacteriological examination. In-situ experiments are preferred compared to laboratory experiments to avoid significant changes to the chemical and physical properties of water samples that may occur during transportation and storage. While total suspended solid (TSS) test was conducted at laboratory due to equipment constraint.

Water samples were collected from each selected point using a water sampler. The sampling frequencies varied for each day depending whether the samples were taken before or after a storm event. The eight water sampling points are shown in Fig. 1.

In-situ tests were conducted in two sessions in July and October. Session 1 was conducted from 30th July 2010 until 1st August 2010 while Session 2 on 5th to 7th October 2010 at the site office. Overall, three slots of in-situ experiments had been conducted each month. As for the last day of the site investigation of each month, the water samples were taken back to the laboratory for further assessment.

General water quality parameters examined included temperature, dissolved oxygen, pH, total suspended solid (TSS), electrical conductivity (EC) and turbidity. As for nutrients water variables, the parameters that had been considered were ammonia nitrogen (NH_3-N), total phosphorus (TP), chemical oxygen demand (COD) and coliform/bacteriological examination. Analyses of all the parameters were conducted according to procedures outlined in relevant *Standard methods* used in the laboratory. All parameters were tested at site except for TSS tests because this test can be conducted only at laboratory with appropriate equipment.

The pH of samples (acid, neutral or alkaline) was determined using pH measurement. The turbidity of water samples were measured using the *Turbidimeter*. Higher percentage of total suspended solids in the water sample showed in higher turbidity. As for COD, ammonia nitrogen, nitrate and total phosphorus tests, the values were read using DR 2800.

For TSS test, 47 mm filter discs were used. Tweezers were used to hold the filter discs and the filter discs were placed in the filter holder. An amount of 100 ml of each well-mixed water sample was filtered by applying vacuum to the flask. Then the vacuum from the filtering system was released slowly and the filter disc was removed gently from the folder. The disc was placed on a watch glass and oven dried at 103°C for one hour. After that the watch glass and filter were removed from the oven and placed in a desiccator. The weight of each filter disc was measured using an analytical balance.

The purpose of coliform/bacteriological examination was to detect the number of bacteria in 100 ml sample. First, the Colilert powder is added to the samples in a sterile, transparent vessel and shook until dissolved. The samples with reagent was added in Quantity Tray/2000 and sealed in a Quantity-Tray Sealer and incubated to develop the population for 24 hours at 35°C.

Water quality assessment can be defined as the evaluation process of biological, physical and chemical nature of the water. Generally, the water quality assessment was carried based on basic survey for the following purposes:

- To provide water quality assessment and information to evaluate alternative treatment for improvement
- To define the cause of current condition of the water quality

It is noted that water quality data collection process including planning, sample collection and transport, laboratory analysis and data storage affects the condition of the sample stored. The quality of wet detention pond and the receiving water bodies can be determined by analyzing the results of in-situ tests. The results eventually compared with the requirements of Interim National Water Quality Standards for Malaysia (INWQS) to assess the effectiveness of the detention pond in managing the quality of the stormwater at that particular area.

RESULTS AND DISCUSSION

Turbidity was found to differ seasonally based on surface runoff carrying soil particles especially in the event of heavy rainfall. Significant increase in turbidity, as illustrated in Fig. 2, could have been potentially contributed by the erosion from the surrounding area since the development area was still in construction stage. During heavy rain, fine particles, soil and even trash that carried by surface runoff reached to the pond in a short time. Thus, this increased the value of turbidity in the pond.

One essential part of a water quality assessment is to determine the dissolved oxygen (DO) concentrations. Oxygen is influencing most of the chemical and biological processes within water bodies. In this study, significant declination in dissolved oxygen generally occurred in passage through the wet detention ponds (Fig. 3).

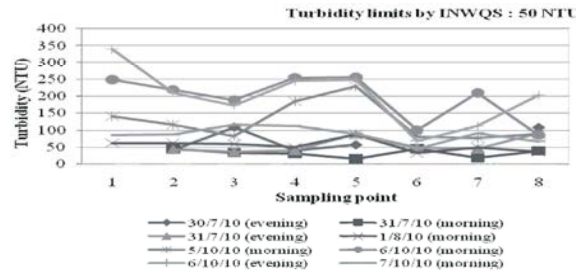

Fig. 2: Turbidity value of each water samples

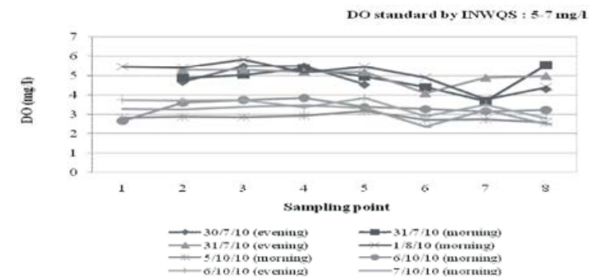

Fig. 3: Concentration of dissolved oxygen for each water samples

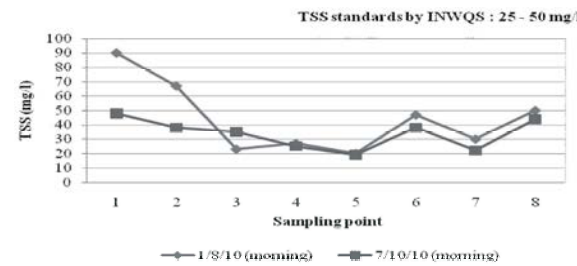

Fig. 4: Concentration of TSS for each water samples

Table 2: Percentage of removal of TSS at pond B

In-situ	TSS concentration (mg/l) Pond B inlet	Pond B outlet	% of removal
Session 1	23	20	13
Session 2	25	19	24

Based on observation at the site, this was probably a result of two factors: a reduction in dissolved oxygen, water source that came from the effluent of sewage treatment plant at the upstream area and as the result from human activities at urban area. Low concentrations of DO of less than 5 mg/l may adversely affect the survival and functioning of aquatic life, while concentration below 2 mg/l may lead to the death of fish.

Result in Fig. 4 showed that the wet detention ponds were capable in removing the suspended solids. The percentage of TSS removal is listed in Table 2. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes and sewage.

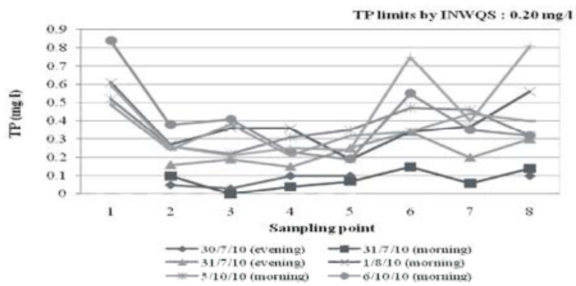

Fig. 5: Concentration of total phosphorus for each water samples

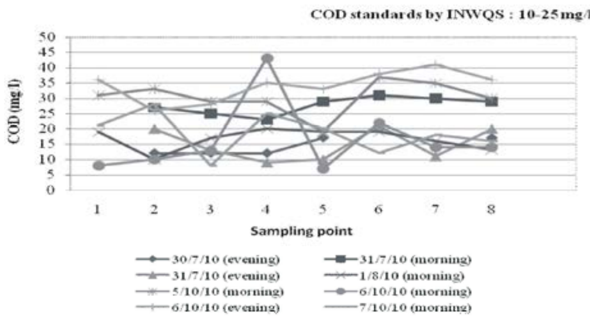

Fig. 7: Concentration of COD for each water samples

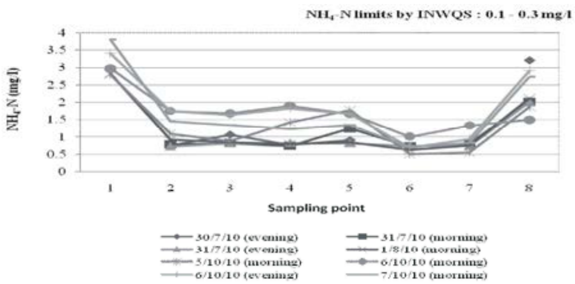

Fig. 6: Concentration of ammonia nitrogen for each water samples

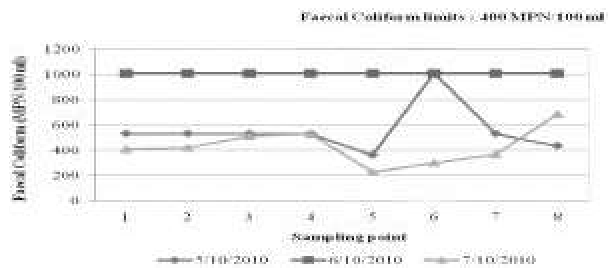

Fig. 8: Concentration of faecal coliform for each water samples

The flow rate of the water body is a primary factor in TSS concentrations. Fast running water especially from the concrete channel or drainage can carry more particles and larger-sized sediment.

The enrichment of streams, ponds and drainage with nutrients occurred as a result from human activities at urban areas are shown in Fig. 5 and 6. Both of the parameters did not meet the requirements by INWQS. High concentrations of phosphate can indicate the presence of pollution and are largely responsible for euthrophication.

The chemical oxygen demand (COD) is a useful measure of water quality since this test determines the amount of organic compounds found in surface water. Approximately more than 50% of the water samples contained high concentration of COD (Fig. 7). The higher the COD concentration in the surface water, the more oxygen the discharges demand from water bodies. A significant measure need to be taken to increase the amount of dissolved oxygen in the detention pond. Results of the feacal coliform counts also compared well with the low level of dissolved oxygen for the related samples. Fig. 8 shows that about 88% of the water samples contained high level of faecal coliform bacteria. Aerobic decomposition of organic matter that contains faecal coliform can reduce dissolved oxygen levels in water system. This will reduce the amount of oxygen required by fish and other aquatic life.

Based on the overall results obtained, the water samples fell into Class III of Department of Environment (DOE) Water Quality Classification where extensive treatment is required for the water bodies.

CONCLUSION

The quality of storm runoff from the study area was characterized by comparing values obtained from in-situ tests with the requirements of Interim National Water Quality Standards for Malaysia (INWQS). The results of this study indicated that wet ponds provide improvement in the removal of suspended solid but not for nutrients (total phosphorus and ammonia nitrogen). There are some aspects of water quality that need to be concerned, especially the total phosphorus (TP) and ammonia nitrogen (NH_3-N). The analysis showed high concentration of these two nutrients. The water samples have been classified in Class III based on DOE Water Quality Classification. Thus, it is recommended that the concentration of dissolved oxygen in the wet detention pond to be improved with the several alternatives. The integration with other BMPs such as wetland can be adopted since this approach has higher efficiency in terms of pollutant removal. Besides, a series of ponds can be provided to improve the efficiency of pollutant removal. However, the locations of the ponds need to be considered.

Sufficient concentration of dissolved oxygen in the water will increase the ability of the pond to remove nutrients since dissolved oxygen is needed for biological uptake process. The other parameter such as temperature and pH value still meets the requirement of INWQS standard.

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