CHAPTER 5

DISCUSSION
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5.1 Trend of Water Quality Index (WQI)

Water quality index varied inversely with the development activity around the wetlands. The water quality index was classified into three categories, which includes polluted (WQI < 60), slightly polluted (60 ≤ WQI ≥ 80) and clean (WQI ≥ 80) stipulated under the Water Quality Index of Department of Environment. From the results of ANOVA analysis, there is significant difference of WQI among the phases (p < 0.05) (Table 35). In the pre-construction period, the WQI started off high (March – April 1997). During construction of the wetlands and surrounding area, it deteriorated to the polluted level. The lowest mean WQI was recorded in August 1997 for Upper North Wetland Cells (UN), Central Wetlands (CW) and Primary Lake (PL). This was mainly due to the heavy construction and high pollutant load deposited at the wetland cells during that period. The low mean WQI in UN may be contributed by low mean dissolved oxygen (DO) (2.9 mg L⁻¹), high mean biochemical oxygen demand (BOD) (8.2 mg L⁻¹), high mean chemical oxygen demand (COD) (21.9 mg L⁻¹), high mean ammoniacal nitrogen (AN) (2.8 mg L⁻¹) and high mean total suspended solids (TSS) (153.5 mg L⁻¹). The lowest mean WQI for CW was most probably contributed by low mean DO (3.9 mg L⁻¹), high mean BOD (4.7 mg L⁻¹), high mean COD (12.8 mg L⁻¹), high mean AN (1.2 mg L⁻¹) and high mean TSS (104.8 mg L⁻¹). As for PL, the low mean WQI was also contributed by low mean DO, high mean BOD, COD, AN and TSS respectively (4.4 mg

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L$^{-1}$, 13.0 mg L$^{-1}$, 26.8 mg L$^{-1}$, 1.1 mg L$^{-1}$ and 134.5 mg L$^{-1}$). This correlation is clearly seen by the comparison of the correlation analysis (Table 32).

However, after August 1997, the WQI increased to the clean water level (WQI ≥ 80) except for some readings obtained in September 1998, November and December 1998 for PL. This may be due to the construction of upstream wetland cells and contribution of pollutants during that period which included Upper West Wetland cells, Upper North Wetland cells, Upper East Wetland cells, Lower East Wetland cells and Central Wetland cell. Based on the WQI results, the low mean WQI at PL in September 1998 was contributed by the high TSS recorded (mean TSS = 389.8 mg L$^{-1}$). In November and December 1998, the low WQI was contributed by high mean BOD and COD concentration. The mean BOD and COD recorded were 4.3 mg L$^{-1}$ and 4.0 mg L$^{-1}$ and 10.3 mg L$^{-1}$ and 13.3 mg L$^{-1}$ respectively.

After the construction of wetland cells, mean WQI of the three wetland cells fluctuated above 80 except for one reading recorded in UN in January 2000 with WQI of 79.1. The WQI may be due to low mean DO (4.4 mg L$^{-1}$) and high mean COD (9.4 mg L$^{-1}$). COD measures the capacity for consumption of oxygen by chemical constituents of water. The high chemical demand of oxygen may be associated with the nearby water discharged from the point pollution source which included MARDI, UPM, the settlements at Upper West and Bisa catchments and Palm Golf Course. The locations of these sites are shown in Figure 2. However, the mean WQI of CW and PL was just marginally below the baseline data obtained on December 1999 from Putrajaya Holding Sdn. Bhd. (PJH, 1997) of 91.5 mg L$^{-1}$ and 89.7 mg L$^{-1}$. This indicated that the water
quality of the wetland cells recovered after the construction of the wetland cells, as compared to the water quality before construction and during the construction of wetland cells.

5.2 Trend of Water Quality Parameters

There are six parameters being discussed in this study. There are pH, DO, BOD, COD, AN and TSS. All the water quality parameters were compared with Class IIB - recreational use with body contact stipulated under the Interim National Water Quality Standards for Malaysia. Table 46 shows the Interim National Water Quality Standard for Malaysia (INWQSM).

Table 46 Interim National Water Quality Standard for Malaysia (INWQSM)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Units</th>
<th>Class A</th>
<th>Class IA</th>
<th>Class IIB</th>
<th>Class III</th>
<th>Class IV</th>
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<td>5-9</td>
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<td>-</td>
</tr>
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<td>0.3</td>
<td>0.9</td>
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</tr>
<tr>
<td>TSS</td>
<td>mg L(^{-1})</td>
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<td>50</td>
<td>50</td>
<td>150</td>
<td>300</td>
<td>300</td>
</tr>
</tbody>
</table>

Source: DOE (1995)

Notes:

CLASS I = conservation of natural environment water supply I – practically no treatment necessary. Fishery I – very sensitive aquatic species.

CLASS IIA = Water Supply II – conventional treatment required. Fishery - sensitive aquatic species.
CLASS IIB = Recreational use with body contact.
CLASS III = Water Supply II - extensive treatment required.
            Fishery III - common of economic value and tolerant species
            livestock drinking.
CLASS IV = Irrigation
CLASS V = None of the above

5.2.1 Temporal, Spatial and Seasonal Effects on pH

The pH (hydrogen-ion) concentration is an important quality parameter for water. pH measures the ability of the environment to supply (or remove) hydrogen ions to the solution. pH dependent reactions are hydroxide precipitation and carbonate formation (Houslow, 1995). Most natural fresh water has a pH close to 7.0. In many waters, the pH is controlled by the carbonate-bicarbonate buffer system. The buffer capacity of a water body is related to the alkalinity and has major influence on the pH changes that may occur in a particular water body due to the discharge of acidic or alkaline wastewater. According to Kadlec and Knight (1996), wetland water usually has a pH of around 6.0 - 8.0. Nevertheless, wetlands have a buffering capacity for inflows, bringing acid or alkaline flows back towards neutral.

pH has been monitored for the Putrajaya construction wetlands over three stages that are the pre-construction, during construction and after construction of wetland cells. Based on the ANOVA analysis, there are significant differences for pH among the three phases. Mean pH for the three sites ranged from 7.2 to 7.4 for pre-construction of wetland cells. This was close to the pH 7.0 for natural fresh water. Mean pH for the three sites was low during the construction of wetland cells, which ranged from 6.6 to 6.9. However, mean pH recorded after construction of wetland cells was lower.
compared with during construction of wetland cells. The PCA revealed the similar trend for pH values (Figure 76). The mean pH was slightly acidic which ranged from 6.0 to 6.5. This was slightly below the Class IIB limit of 6.5 – 9.0. The low pH may have strong influence on the direction of many reactions and processes, including biological transformations, partitioning of ionised and un-ionised forms of acids and bases and cation exchanged (Malcolm et al., 1998). The fluctuations of pH values may be influenced by other water quality parameters such as the DO, BOD, COD, AN and TSS. However, the result of correlation analysis of pH revealed weak correlation with other water quality parameters (Table 33). A range of pH at 6.5 to 7.5 is best for the processes of denitrifying bacteria. According to Kadlec (1998), the preferred pH for nitrogen removal as nitrifies was 7.2 and higher. Denitrifying bacteria operate best at a pH range from 6.5 to 7.5.

pH concentration varied among the study sites. Based on the ANOVA analysis, there was significant difference of pH between UN and PL and between CW and PL. UN wetland cells are located at the upper stream where the river water from Sg. Chuau starts to flow into Putrajaya constructed wetlands. The water then flows into the central wetlands and lastly the primary lake before the water joins Sg. Langat. The target water quality for the lake is Class IIB standard – suitable for body contact recreation such as swimming, boating, fishing and at the same time creates a self-sustaining and balanced lake ecosystem.

Overall, no seasonal effect on pH was obtained from the results of ANOVA analysis. Results of simple correlation reflected that there is no correlation between pH and
rainfall (Table 33). This showed that pH was not influenced by the rainfall. However, according to Kadlec (1998), during rainy season, rain can dilute wastewater concentration and when storm water runoff from non-point sources flows into the wetlands, changes in pH will be significant. During dry season, there was less runoff and the changes in pH were not significant.

5.2.2 Temporal, Spatial and Seasonal Effects on Dissolved Oxygen (DO)

Oxygen in water is measured as dissolved oxygen. DO is an indicator of the amount of oxygen available in the waterway. In the waterways, DO will be utilized in most forms of biological and chemical activities. The presence or absence of oxygen is an important factor determining whether pollutants remain contained within the wetland or are mobilized in soluble form (Malcolm et al., 1998). Based on ANZECC (1992), DO in fresh waterbody should not be permitted to fall below 6 mg L\(^{-1}\) or 80 – 90% saturation. The concentration is greatly influenced by biological activity and may vary widely in the course of 24 hours, particularly in streams or rivers where there is nutrient enrichment. Low oxygen values decrease the wetland plants cleansing capabilities (Moshiri, 1993).

DO vary significantly among the phases. There are significant differences between mean DO in pre-construction and during construction of wetland cells and between pre-construction and after construction of wetland cells. DO was found to be low at pre-construction of wetland cells for the three sites. The lowest DO was recorded in August 1997. This may be due to high oxygen requirement for sediment-litter oxygen demand.
(decomposing detritus) and dissolved carbonaceous BOD (Malcolm et al., 1998). The sediment oxygen demand is the result of decomposing detritus generated within the wetland and organic solids that enter the wetland. During construction of wetland cells, the DO concentration increased to 5 – 7 mg L⁻¹ which is well within the Class IIB Standard. Mean DO after construction of wetland was well within the Class IIB limit except for the mean DO in UN. There were two lowest points observed in the month of January and June 2000. The drops in DO concentration could be attributed to biological activity in the wetlands including DO as a source of energy for root respiration and subsequently growth of the plants (Mashauri et al., 2000). It could also be attributed to the high values of COD. The results of correlation analysis (Table 33) showed an inverse relationship between DO and COD. The PCA results revealed the low DO values before and during wetland constructions.

There was significant difference (p < 0.05) of mean DO among the study sites (Appendix 3.9). This significant difference among sites was mainly due to different demand for oxygen. Based on Figure 66, mean DO was higher in CW and PL as compared to UN. This was mainly attributed by the less demand of oxygen in the lake (CW and PL). There was no wetland planting in the lake and therefore less demand of oxygen by the plants or other biological activities such as decomposing of detritus generated within the wetlands and organic solids that enter the wetland.

Results of ANOVA analysis showed that there was significant seasonal effect in DO (Appendix 3.10). During rainy season, DO is observed to be higher in the three sites for the three phases (Figure 67). This could be observed in the PCA where most of the
samples collected during wet season had higher DO compared with dry season (Figure 76). This may be attributed to the high velocity of water flow during rain and increase the water turbulence and resulted in increase of solubility or diffusion of oxygen in water (Kadlec and Knight, 1996).

5.2.3 Temporal, Spatial and Seasonal Effects on Biochemical Oxygen Demand (BOD)

BOD is a general indicator of the organic pollution in the water. It is an important parameter to determine relative oxygen requirements of wastewaters, effluents and polluted waters. According to Moshiri (1993), the BOD is the most frequently used parameter to measure constructed wetland performance. The BOD integrates the processes of organic and chemical oxidation occurring in a water sample containing solid and dissolved pollutants. When BOD is high, oxygen values will be insufficiently low due to an imbalance between atmospheric aeration and the high amounts of BOD entering the wetland systems. The results of correlation analysis showed that there is an inverse relationship between DO and BOD ($r = -0.12$) (Table 33).

BOD varies significantly among the phases ($p < 0.05$) for the three sites. Mean BOD was high at pre-construction of wetland cells for the three sites. The highest mean BOD was recorded in August 1997 (8.2 mg L$^{-1}$ in UN and 13.0 mg L$^{-1}$ in PL), November 1997 (7.5 mg L$^{-1}$ in CW) and January 1998 (11.5 mg L$^{-1}$) (Table 16; Figure 45). This can be seen clearly in the PCA (Figure 76) where BOD values were high at (pre-construction phase) before the formation of wetland cells. That is when heavy civil
works were carried out to divert the rivers into wetland cells. According to Kadlec (1995), typical ranges of BOD in surface flow constructed wetlands are 5 – 15 mg L\(^{-1}\). Thus, the BOD values obtained is not consider too high. However, the high BOD values may be attributed to the high effluent of urban runoff from the non-point sources or construction activities at the wetlands. During construction of wetland cells, mean BOD values fluctuated within the Class IIB limits of 3 mg L\(^{-1}\) except for some extremely high reading obtained from September to December 1998 (Table 16; Figure 51). Mean BOD after construction of wetland was well within the Class IIB limit except for the slightly higher mean BOD recorded in November 1999 (3.1 mg L\(^{-1}\)), April (3.1 mg L\(^{-1}\)) and June 2000 (3.5 mg L\(^{-1}\)) for UN, CW and PL respectively.

Overall, no spatial effect was obtained on BOD based on the results of ANOVA analysis. However, results of ANOVA analysis showed that there was significant seasonal effect on BOD (Appendix 3.16). During dry season, BOD is observed to be high in the three sites for pre-construction of wetland cells (Figure 69). This was compatible to results obtained from PCA where most of the samples collected during dry season had high BOD values. According to Malcolm et al. (1998), BOD removal was observed to be the least effective in the summer. This may be attributed to internal release of decaying vegetation, high concentration of pollutant, accentuation of organic matter decomposition (Kadlec and Knight, 1996) and low oxygen concentration which give rise to adverse effect on aerobic respiration within the water column and enhance anaerobic processes (Malcolm et al., 1998). Wet seasons showed low BOD (Figure 69) as wet seasons cause pollutant dilution (Kadlec and Knight, 1996). Based on research done by Scholes et al. (1998) at two experimental wetland systems for a period of two
years, the removal of BOD is greater during storm events than during dry weather. The removal efficiency of BOD recorded was 24% and 26% at Dagendam and Brentwood, United Kingdom.

5.2.4 Temporal, Spatial and Seasonal Effects on Chemical Oxygen Demand (COD)

COD measures the chemical pollution in the water. According to Shutes and Emmerson (1998), COD has not normally been recorded for constructed wetlands but it is essential parameters for assessing highway runoff treatment. The high COD reduces the available oxygen. The results of correlation analysis showed that there is an inverse relationship between DO and COD ($r = -0.15$) (Table 33).

Based on the results of ANOVA analysis, there were significant differences of COD among the phases ($p < 0.05$) for the three sites. Mean COD was high at pre-construction of wetland cells for the three sites. Overall, the mean COD was well within the Class IIB limits of 25 mg L$^{-1}$ except for the highest mean COD (39 mg L$^{-1}$) recorded in June 1997 (Table 17; Figure 46) in PL. The high COD indicated high chemical demand for oxygen, which may be attributed to the high effluent of urban runoff from the non-point sources or construction activities at the wetlands. Mean COD values during and after construction wetlands were fluctuated within the Class IIB limits of 25 mg L$^{-1}$ (Table 23 and 29; Figures 52 & 58). According to Kadlec (1995), COD values ranges in a surface flow constructed wetlands are 30 – 100 mg L$^{-1}$. Thus, the COD values monitored during and after construction wetlands were low and within the ranges of a typical surface flow
constructed wetlands. Results of PCA revealed that the COD values were high after construction of wetland cells. However, the high COD values were mainly contributed from central wetlands and primary lake. This was likely attributed to the pollutant contributed by the heavy civil works for building construction at the Upper Bisa wetland cells (Figure 76).

Based on the results of ANOVA analysis, no spatial effect was obtained on COD. However, results of ANOVA analysis showed that there was significant seasonal effect on COD (Appendix 3.22). During dry season, COD is observed to be high in the three sites for the three phases (Figure 71). The PCA results revealed that most of the samples collected during dry season had high COD values. This may be attributed to the high concentration of pollutant, accentuation of organic matter decomposition (Kadlec and Knight, 1996) and low oxygen concentration which give rise to adverse effect on aerobic respiration within the water column and enhance anaerobic processes (Malcolm et al., 1998). Wet seasons showed low COD as wet seasons cause pollutant dilution (Kadlec and Knight, 1996).

5.2.5 Temporal, Spatial and Seasonal Effects on Ammoniacal Nitrogen (AN)

Ammoniacal nitrogen indicated sewage and animal waste pollution in the water. AN was significantly different between the pre-construction and during construction of wetland cells and between pre-construction and after construction of wetland cells ($p < 0.05$). Mean AN was high for the three sites before the formation of wetland cells. This was confirmed by the PCA (Figure 76). AN values were high in pre-construction of
wetland cells compared with AN values during and after the construction of wetland cells. The highest mean AN (3.4 mg L\(^{-1}\)) was recorded in UN in September 1997 (Table 18; Figure 47) for the three sites. The high AN may be attributed to the high influent of sewage and animal waste water from the non-point sources or construction activities at the wetlands. The AN values may be influenced by high pH (Figure 43 and 47). Results of correlation analysis showed positively significant correlations between AN and pH (r = 0.26). According to Kadlec and Knight (1996), the increases in pH would have influenced the increase of AN values. As wetland pH increases, the fraction of total ammonia that is in the unionized form increases resulting in higher toxicity. During the construction of wetland cells, mean AN ranged from 0.1 - 1.3 mg L\(^{-1}\) (Table 24). Mean AN after the construction of wetland cells ranged from 0.1 – 0.6 mg L\(^{-1}\). The slightly higher AN (vary between 0.4 – 0.6 mg L\(^{-1}\)) may be influenced by the decomposition processes which release carbon and nitrogen compounds to the water (Malcolm et al., 1998). However, mean AN values after the construction of wetlands indicated that the constructed wetlands played an important role in removing the AN from the water. The AN reduction observed was likely a result process including nitrification, denitrification, ammonia volatilization and plant uptake (Kadlec et al., 2000). The AN removal processes exist where conditions are aerobic (high DO) (Watson et al., 1989), sufficient alkalinity is available (high pH), temperature are suitable and most of the BOD has been removed (Sikora et al., 1995). The relationship was revealed in the results of correlation analysis (Table 33) where AN was positively correlated with pH (r = 0.26) and temperature (r = 0.25) and negatively correlated with DO (r = -0.05) and BOD (r = 0.30) although they are not strongly correlated. However,
in this study, it is difficult to determine the relative proportion nitrified or volatized since no measurements of volatile ammonia were made.

AN values have significant spatial changes over the study period. In general, significant difference of AN were found between UN and CW and between UN and PL. This may be attributed to the high AN concentration at the inflow (UN) before treatment of the wetland systems (Figure 72) and discharged into the CW and PL.

AN was low in the dry season during and after construction wetlands. This was likely due to the temperature dependence of the nitrification process (Malcolm et al., 1998). The correlation analysis revealed that AN has weak significant correlation with temperature \( r = 0.25 \). Vymazal (1995) summarizes that nitrification process is influenced by temperature. The optimum temperature for nitrification ranges from 25 to 35°C and in soils from 30 to 40°C.

5.2.6 Temporal, Spatial and Seasonal Effects on Total Suspended Solids (TSS)

TSS is an indicator of sediment delivery in the waterway. The higher the TSS values the higher the rate of sediment delivery and is therefore an indicator of erosion, which is generated from land-based sediments.

During the monitoring period of TSS of the wetlands construction, it was found that TSS values were generally low at the initial period of pre-construction of wetland cells (Table 19; Figure 48). However, mean TSS values began to increase in January (2133.8
mg L⁻¹ in CW) and March, 1998 (2635 mg L⁻¹ in UN) (Figure 48). Based on the PCA (Figure 76), TSS values was found high in phase 1 which is the pre-construction of wetland cells compared to phase 2 (during construction of wetland cells) and 3 (after construction of wetland cells). This was when the heavy civil works for the construction of wetlands commenced. On the other hand, the high TSS during March 1998 may be attributed by the wet seasons. According to Sholes et al. (1998), suspended solids during storm events show an increase indicating that some resuspension is taking place. During rainy season, the high velocities of water may result in increasing suspended solids levels in the water. However, based on the ANOVA analysis, the seasonality effect on TSS was not significant (p > 0.05) (Table 41). The civil works continued until May 1998 when wetland plants were introduce into the wetland cells. The high TSS may be contributed by non-point, point sources and also from macroscopic litter, the death of microflora and microfauna and growth of algae.

Pollutants including TSS from non-point sources are caused by rainfall moving over and through the ground. According to Schulz and Peall (2001), constructed wetlands are capable of retention of nonpoint source pesticide pollution such as the azinphos-methyl, chlorpyrifos and endosulfan. As the runoff from agricultural and land development moves, it picks up and carries away natural and man-made pollutants, finally depositing them into lake, rivers, wetlands, and even our underground sources of drinking water. The non-point sources are dependent on urban land use, degree of industrialization and extent of wastewater treatment (Norazmi et al., 1998). There were several contractors working at the same area at the same time on different tasks adjacent to Putrajaya during this study. These included contractor building the Electric Rail Link (ERL)
which passes by upper north wetland cells (UN8 and UN7), South Klang Valley Expressway (SKVE) which passes by upper north wetland cells (UN7 and UN6) and Taman Wetlands which is located near to upper west wetland cells. The water quality during the construction of wetland cells was high in TSS from June (1215.7 mg L\(^{-1}\) in PL) to October 1998 (212.7 mg L\(^{-1}\) in PL) and the TSS values were reduced or settled after that (Table 25; Figure 54). The high mean TSS values may be contributed by the construction activities from the upper east and lower east wetland cells which is located above the primary lake and other pollutant contributed by the non-point sources. However, after the construction of wetland cells, TSS values were low and fluctuated within the Class IIB limits of 50 mg L\(^{-1}\). During this period, the low TSS values may be attributed to the high density of vegetation, which successfully acts as a filter in trapping the suspended solids. Based on the results of ANOVA, TSS was significantly different within the phases (Table 41; Figure 74). This showed a high removal of TSS by the wetlands. The sediments are trapped in the wetlands by deposition and resuspension mechanisms (Kadlec, 1995).

5.3 Performance of Constructed Wetlands in Removing Pollutants

Water quality from the inflow (Upper North wetland cells) and outflow (Primary Lake) was compared. The aim of this comparison is to assess the performance of constructed wetlands in improving water quality and in removing pollutant after the wetlands construction. Mean water quality such as pH, DO, BOD, COD, AN and TSS values and mean WQI from October 1999 to July 2000 was used. The study showed that mean pH values from inflow 6.0 (± 0.2) was lower compared to outflow 6.5 (± 0.3) with an
increased to 8.3%. The mean pH values of outflow were within the Class IIB limit of 6.5 – 9.0. Mean DO values obtained from inflow and outflow was 5.7 (± 0.4) and 6.3 (± 0.4) respectively. This indicated an increase of 10.5% of mean DO values for water passing through the wetlands. High DO values showed the high degree of aeration in the water and less biochemical demand of pollutant (Moshiri, 1993). As for BOD and AN, mean BOD and AN values showed no changes for the inflow and outflow. However, there was a slight increase of 7% mean COD values in the outflow (7.5 ± 5.4) compared with the inflow (7.1 ± 5.1). The slight increased in mean COD values may be influenced by the discharge from the local catchment (about 25%) (Figure 6). During this period, October 1999 – July 2000, although the construction wetlands was completed, there were still other construction activities carried out for the Federal Government Administration of Putrajaya. However, the mean COD values were very low compared with the Class IIB limits of 25 mg L⁻¹.

The mean overall performance of constructed wetlands in removing pollutants such as TSS was satisfactory. From the results obtained, the surface flow constructed wetlands of Putrajaya successfully removed 61.1 % of the suspended solids from the inflow (21.1 ± 11.6 mg L⁻¹) before discharge to the outflow (8.2 ± 3.9 mg L⁻¹). Both the results of mean TSS values from inflow and outflow was well within the Class IIB limits of 50 mg L⁻¹. This indicated that the inflow water was well treated by the series of wetland cells before discharge into the main river of Sg. Langat. According to Yang et al. (1995), the subsurface flow constructed wetlands in Bainikeng, Shenzhen China successfully removed 92.6% of TSS where the average influent SS was 140.9 mg L⁻¹ compared to the SS in the final effluent of 10.9 mg L⁻¹. In addition, Gersberg et al.
reported that constructed wetlands at Santee, California demonstrated the capability of the constructed wetlands with emergent vegetation (*Scripus* spp. and *Typha* spp.) in removing 88% of suspended solids. However, the constructed wetlands are less efficient in removal of the biochemically degradable organic pollutants.

Overall, the mean WQI which represented the six water quality parameters showed that there was an increase in the mean WQI in the inflow compared with the outflow. The mean WQI obtained in the inflow was lower (84.3 ± 3.1) as compared with the mean WQI in the outflow (88.6 ± 2.8). However, the mean WQI obtained for both inflow and outflow was within the clean water rating (WQI > 80 = clean water) of the Department of Environment, Malaysia. This again showed the capabilities of wetlands in removing the pollutants before discharge into the main river of Sg. Langat.

5.4 Conclusion/Future Areas for Research

Constructed wetlands are becoming increasingly popular in New South Wales, Australia and elsewhere in the world such as Malaysia, Brazil, New Zealand and others, as a measure to address environmental issues such as water pollution control, wastewater treatment or enhancing degraded habitats. The New South Wales Department of Land and Water Conservation has designed and implemented over thirty constructed wetland systems for controlling urban stormwater pollutant (White *et al.*, 1996).
This study involved the first constructed wetlands in Malaysia. It provides some baseline data on the quality of the river water before, during and after the construction of wetlands at three difference sites. The results show the trend of overall water quality and the water quality parameters which included pH, DO, BOD, COD, AN and TSS. However, since this was a preliminary study, a detailed study is recommended to be carried out in the future.

**Areas for Future Research:**

1. Establish the role of wetlands plants in removing pollutants from the water.
2. Study the use of constructed wetlands in establishing a natural wetland system in an urban area.
3. Study the ecological aspects such as the predators of the wetland plants, which are very important aspects in pest control for wetland plants.
4. Study the influence of the soil in constructed wetlands on the capability of wetland plants in removing the pollutants.
5. Compare different wetland plant species used in constructed wetlands in purification of the water quality.
6. Research should be done on the pathogens, phosphorus, nitrogen and metal removal efficiency of the wetland plants.
7. Establish the baseline and water quality trends of other wetland arms in the Putrajaya Wetlands System.
8. Assess the effectiveness of constructed wetlands in improving water quality and removal of pollutants during storm events so as to compare the results obtained with the results from other constructed wetlands from other countries.

9. Establish the time series autoregressive-integrated moving average (ARIMA) modeling for the trend of water quality.