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EFFECTS OF SEASONALITY ON STREAMFLOW AND WATER QUALITY OF THE PINANG RIVER IN PENANG ISLAND, MALAYSIA

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ABSTRACT: For the Pinang River, originating in the western highlands of Penang Island, the nature, sources and extent of pollution were studied. The river water samples collected at five selected sites were analyzed for various physical and chemical parameters, namely temperature, DO, BOD, COD, SS, pH, ammoniac nitrogen (AN), and conductance. Long-term data of rainfall and temperature were analyzed to determine the seasonal variations of the streamflow. The streamflow during the dry season is extremely low compared to the wet season, thus concentrations of contaminants derived from point pollution source increase due to lack of rainfall and runoff events. On the contrary, in the predominantly urban and agricultural catchments, non-point pollution source increases during rainy season through seepage and runoff. Effects of seasonal variations consequently determine the quantity and quality of the water parameters. The Jelutong River, the Dondang River and the Air Itam River carry the seepage from widely urban and residential areas to the main Pinang River systems. Water quality of the Pinang River at different points assessed by the water quality indices was compared. According to the quality indices during the study period, water quality in the upper reaches of the river is medium to good. It dwindled in the plains, due to the seepage from urban areas and discharges from the industrial and agricultural lands.

KEY WORDS: hydrology; landscape ecology; seasonal variations; water quality index; watershed

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1 INTRODUCTION

In the study of a watershed ecosystem, many variables simultaneously change with time and location, with little opportunity to control them all, systematically or otherwise. By measuring as many parameters as possible that define the system, it may be possible to understand their interactions and to assess the sustainability of the environment (HOPKE, 1985). Penang Island (Fig.1) is known as the "Pearl of the Orient", where the main economic resources derived from manufacturing and tertiary (tourism, trade, property and finance) sectors, in which such activities contributes to about 46% and 49.2% of the gross domestic product in the fiscal year 2000 (Socio-economic and Environmental Research Institute, 2000). With the rapid economic development, high population growth, and urban expansion, land area will be the major issues and targeted. Due to the limited areas of lowland and plain in this island, catchments, wetland, and coastal reclamation became major focuses and alternative to meet the demands for land. To some extent, environmental degradation became major issues, river deterioration in particular.

A flow in a river is the result of complex natural processes, which operates on a catchment scale. Conceptually, a river catchment can be perceived a series of interlinked reservoirs, each of which has components of recharge, storage and discharge. Recharge to the whole system is largely dependent on precipitation, whereas storage and discharge are complex functions of physiographic characteristics of catchment (SMAKHTIN, 2001; YUNUS *et al.*, 2003). Low streamflow resulting from climate change, El-Nino Southern Oscillation (ENSO) events, and droughts have adverse effects on water quality and aquatic biology through physical, chemical, and biological processes (BURN, 1994; HERRMANN *et al.*, 2000; CARUSO, 2001). Economic losses are apparent during such events attributable to environmental

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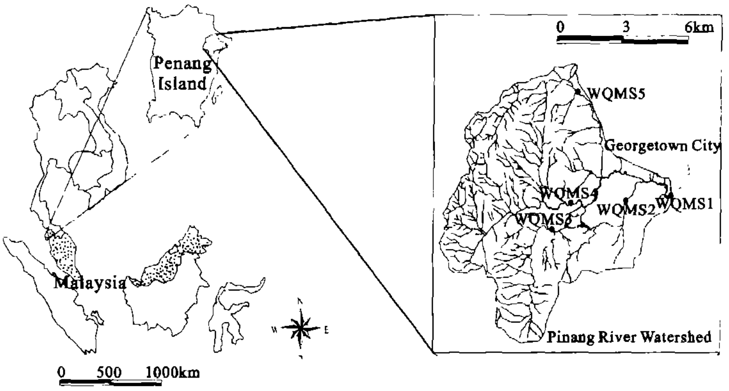

WQMS: Water quality monitoring station
Fig. 1 Location of study area and sampling sites

degradation, which subsequently affect the water quality of the rivers. Furthermore, there are strong relationship between land-use types and the quantity and quality of water in the river system (GBUREK and FOLMAR, 1999).

Although climate change can have a variety of impacts on streamflow and water quality, it appears that human activities have greater effects. Seepage and effluent from the urban and built-up area, forest clearcutting and industrial waste could pose major environmental and health problems to the aquatic systems. Paving of watersheds and the related development of artificial channels make the direct input of precipitation into stream channels increase, thereby circumventing depression storage and groundwater recharge (FOSTER *et al.*, 1999). Many rivers in the developing countries are heavily polluted due to human activities, for example, industrial and sewage discharges flowing into the river influence the quality of the river ecosystem (JONNALAGADDA *et al.*, 1991; MATHUTHU *et al.*, 1993; JONNALAGADDA and NENZOU, 1996; BORDALO *et al.*, 2001). The degree of their influence on the environment, in particular on the concentrations of contaminants, is reciprocal with the quantity of runoff. Logically, a critical situation is expected to occur in the period of low flow. There are fewer studies evaluating impacts on water quality or aquatic ecosystems from actual drought conditions (CARUSO, 2001). Previous studies show that stream dissolved solids concentrations are correlated with streamflow fluctuations and atmospheric patterns and can change considerably during lower-than-normal flows (PETERSON and CAYAN, 1988). The aim of this study was to examine the seasonal variations of streamflow during dry and wet months and their impacts on the selected water quality parameters.

2 MATERIAL AND METHODS

2.1 Sampling Area

The Pinang River is the longest river in Penang Island (Fig. 1). It has its source in the interior, and stretches over 15km, with a predominant flow direction from west to east. In the watershed Georgetown City is located. Due to the short distance from the source to the estuary, the flow is rapid in the hilly areas but slows down considerably when it reaches the flood and coastal plains in and around Georgetown. The Pinang River basin is located from 5°21′ to 5°26′N and from 100°14′ to 100°19′E geographically and covers an area of approximately $50.97km^2$ with the highest altitude of about 850m. The western part of the Pinang River basin is a hilly region composed of granite, whereas the coastal plain shows the youngest formations. These are the rather extensive tracts of the Quaternary sand and clay, usually found in river valleys and coastal plains. The Quaternary deposits are alluvial, marine and mixed terrestrial-marine sediments. The topography of the watershed is divided into two main geomorphic units, the lowland flood plains and the interior hills. Mean annual precipitation is about 2000mm to 3000mm. The western part of this basin receives the highest rainfall, due to its hilly landscape. The annual average temperature is constantly high, averaging not less than 26℃. Mean annual relative humidity is high, with an average of 80%.

Five sampling points (one in the highland, three in the plain and one near the estuary) were chosen for the study (Fig. 1). Sampling point 1 or WQMS1 (water quality measuring station 1) is located near the estuary, representing the background of the entire watershed and the Pinang River networks, i.e., with high interference from human activities. WQMS2 is situated at the downstream of the Jelutong River, where urban and commercial areas are the major landscape, to observe the effect of flux from tributary. The seepage and rainwater were transferred from the urbanized basin into the Jelutong River. WQMS3 is sited 3.5km further upstream, to monitor the changes if any in the water quality due to agricultural and livestock activities. The Air Itam Dam located at the upper stream of WQMS4 is one of the earliest dams built in Malaysia, having functioned as a major water supply since 1962. WQMS5 reflects the effect of natural stream with less human activities on the Pinang River waters, which is located in forest reserve catchment.

2.2 Data

The water quality index (*WQI*) approach (Department of Environment, Malysia and University of Malaya, 1994; Department of Environment, Malysia, 1999) is used and specially designed for tropical conditions, in order to generate a score describing general water quality for the monsoon-influenced river during wet and dry seasons. Basically, the *WQI* provides a mechanism for presenting a cumulatively derived, numerical expression, defining a certain level of water quality (MILLER *et al.*, 1986; HAMBRIGHT *et al.*, 2000; JONNALAGADDA and MHERE, 2001). No single parameter is sufficient to adequately express water quality. In this study the application of the water quality index approach to the Pinang River in Malaysia had the purpose of providing a simple, valid method for expressing the results of several parameters in order to assess the water quality.

The streamflow data and water quality parameter in wet and dry seasons of 2000 was used as a case study, while data from 1992 to 1999 were for the purpose of studying their temporal trends. Water quality data (1992–2000) were obtained from the Department of Environment, Malaysia, which take samples of surface water once every two months and analyze the samples using standard methods. The evaluation of overall water quality is not an easy task particularly when different criteria for different uses are applied (HAMBRIGHT *et al.*, 2000). Moreover, the classification of water quality follows various definitions with respect to the contents of different water parameters (GREVE, 1990; JONNALAGADDA and MHERE, 2001), and dozens of variants have been developed (SMITH, 1989; WANG, 2001). *WQI* was established based on the opinion of a panel of experts who determined the choice of parameters and weight assigned to each chosen water quality parameter. Calculations are performed not on the parameters themselves, but on their sub-indices whose values are obtained from a series of equations from rating curves. The sub-indices (SI) for these parameters are named SIDO, SIBOD, SICOD, SIAN, SISS and SIpH. The formula used to calculate *WQI* is as follows:

$$WQI = 0.22SIDO + 0.19SIBOD + 0.16SICOD + 0.15SIAN + 0.16SISS + 0.12SIpH$$

where the multipliers are the weights for the corresponding parameters with total value of 1.

The six indicator parameters used in the water quality assessment are as follows: dissolved oxygen (DO), pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (SS) and ammoniac nitrogen (AN). Data of conductivity and temperature are also used in this study because previous studies have shown that these parameters have strong relationships with water quality indicators, despite these parameters are excluded for *WQI* calculations due to some limitations and uncertainty. Temperature is a very critical aspect of water quality to animal life (JONNALAGADDA and MHERE, 2001), changes in temperature are determined by size and depth of water (CARUSO, 2001), while conductivity reflects the strength of major ions in water (MCCUTCHEON *et al.*, 1993). Since many pollutants contain soluble salts, it is conceivable that the conductivity may reflect the concentration of these materials (HOWARD and HAYNES, 1993; GURNELL *et al.*, 1994).

2.3 Streamflow Measurement

There is no streamflow data available for the Pinang River networks. Field measurements were carried out during dry season in January/February and wet season in October/November 2000. The measurement times were chosen based on the analysis of mean monthly rainfall and temperature from 1981 to 2000 (Fig. 2). Mean monthly rainfall was 69.9mm in January and 356.3mm in October. Thus results verified the seasonal rainfall variations in the study area. During the field sampling in wet season and dry season, 5 cross-sections and flow characteristics of the selected rivers were measured. Two types of current meters were employed to measure current flow, of which one is an automatic propeller driven digital current meter and the other is a calibrated hydro-pop stream flow-meter. The discharge was obtained by multiplying the rate of flow crossing a certain point by its cross-sectional area based on the established discharge measurement theory and procedures (Ministry of Agriculture, Malaysia, 1976).

2.4 Statistical Analysis

Statistics were performed with the SPSS software pack-

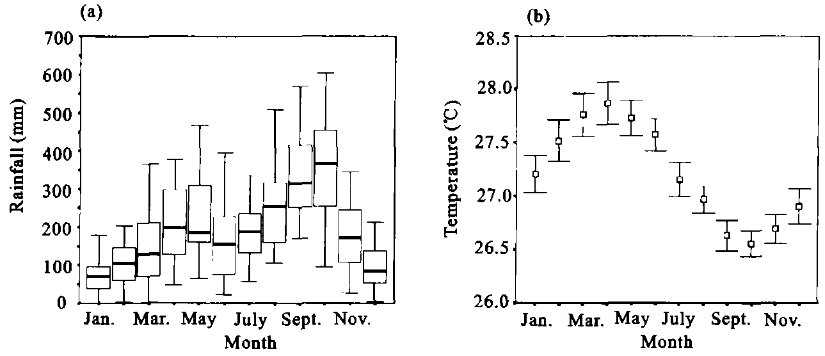

Fig. 2 Mean monthly rainfall and temperature from 1981 to 2000

age. It involved F-test two samples for variances, one-way analysis of variance (ANOVA) to test significant differences of means between seasons and stations, and Pearson's coefficient correlation analysis to test the relationship between seasonal variation of streamflow and water quality parameters.

3 RESULTS

Five physical parameters and three chemical parameters (water quality parameters) were determined for five batches of aqueous samples from five sites (1992-2000). Table 1 summarizes the mean values of the water quality parameters and results of ANOVA tests at five WQMSs along the Pinang River and its tributaries. Table 2 shows the seasonal variations (wet and dry months) of streamflow discharge and surface water parameters in 2000. A perusal of the data shows the water pollution increases as the river descends from the slopes of highlands to the plains. Such result reflects intensities of urbanization and construction, which is parallel as the river descends. Further, the analytical results are illustrated in Fig. 3 depicting the seasonal variations of each parameter at the sampling sites.

3.1 Discharge

In wet season the flux (Q) at WQMS5 and WQMS1 were 0.83m^3/s and 6.00m^3/s, respectively. In dry season they dropped to 0.03m^3/s and 0.99m^3/s (Table 2). Water deficiency and fluctuation in stream are determined by the availability, intensity, and duration of rainfall. Fig. 2 shows there are two extreme rainfall events. The wet season usually occurs from April to October due to the southwest monsoon, and dry season occurs during the northeast monsoon months, from November to March. Streamflow changes between dry season and wet season among the WQMSs in 2000 were highly significant with F value 37.743 with p-value 0.002 at $p<0.05$ (Table 2). These changes mostly related to rainfall, however at WQMS1 and WQMS2 the sharp decrease in streamflow between seasons were probably caused by construction and impervious landscape within the basin and along the river riparian. Previous studies indicated that urban land-use had strong linear relationships with water quality (LUCIE and WILLIAMS, 2001; WANG, 2001) due to point and non-point source pollution.

3.2 Temperature

The measured temperature of the water reflected the changes corresponding to the altitude of the sites, land-use types and seasonal streamflow variations. For instance, temperature profiles of water at the WQMS5 located in the upperstream, hilly and dominated forest areas remained similar and varied between 26℃ (wet season) and 24.5℃ (dry season) (Table 2). Although, WQMS1 recorded relatively higher temperatures throu-

Table 1 Average monthly value of physical and chemical parameters from the five WQMSs (1992-2000) in the Pinang River watershed and ANOVA result

Parameter	Sampling site: WQMS					ANOVA result	
	1	2	3	4	5	F	p-value
Temperature (℃)	27.90	27.32	27.32	27.10	25.25	2.14	<0.0700
DO (mg/L)	0.80	1.24	1.33	1.26	8.20	24.52	<0.0001
BOD (mg/L)	35.57	76.6	39.74	20.45	1.00	15.27	<0.0001
COD (mg/L)	125.08	207.88	129.03	63.14	10.00	9.34	<0.0001
SS (mg/L)	53.80	117.36	176.71	51.78	10.50	11.05	<0.0001
pH	6.90	6.80	6.80	6.50	7.00	7.02	<0.0001
AN (mg/L)	12.06	18.46	13.49	6.52	0.20	4.60	<0.0014
Conductivity (μS/cm)	2272.41	406.92	279.05	193.93	30.00	16.28	<0.0001

Table 2 Seasonal variations of streamflow discharge and surface water quality in WQMSs in 2000 in the Pinang River watershed (significant (p<0.05) differences based on F-test two samples for variances)

Parameter	Wet season					Dry season					F	p-value
	1	2	3	4	5	1	2	3	4	5		
Q (m^3/s)	6.00	0.11	1.50	0.32	0.83	0.99	0.04	0.45	0.25	0.03	37.743	0.002
Temperature (℃)	28.30	28.40	27.83	27.00	26.00	29.70	29.80	28.71	28.60	24.50	0.203	0.076
DO (mg/L)	0.00	0.57	2.17	0.52	8.20	0.00	0.00	1.89	0.00	8.20	0.917	0.468
BOD (mg/L)	15.00	84.00	6.00	6.00	1.00	30.00	93.00	13.00	13.00	1.00	0.899	0.460
COD (mg/L)	53.00	142.00	31.00	19.00	12.00	388.00	331.00	46.00	48.00	8.00	0.087	0.018
SS (mg/L)	37.00	46.00	64.00	15.00	20.00	18.00	282.00	57.00	15.00	1.00	0.028	0.002
pH	6.99	6.80	7.00	6.46	7.20	6.86	6.80	6.80	6.49	6.80	3.487	0.127
AN (mg/L)	5.47	5.67	2.63	0.49	0.10	8.50	6.22	6.72	5.33	0.30	0.736	0.387
Conductivity (μS/cm)	1380.00	356.00	101.00	94.20	22.00	4736.00	211.00	64.30	57.80	38.00	0.075	0.014

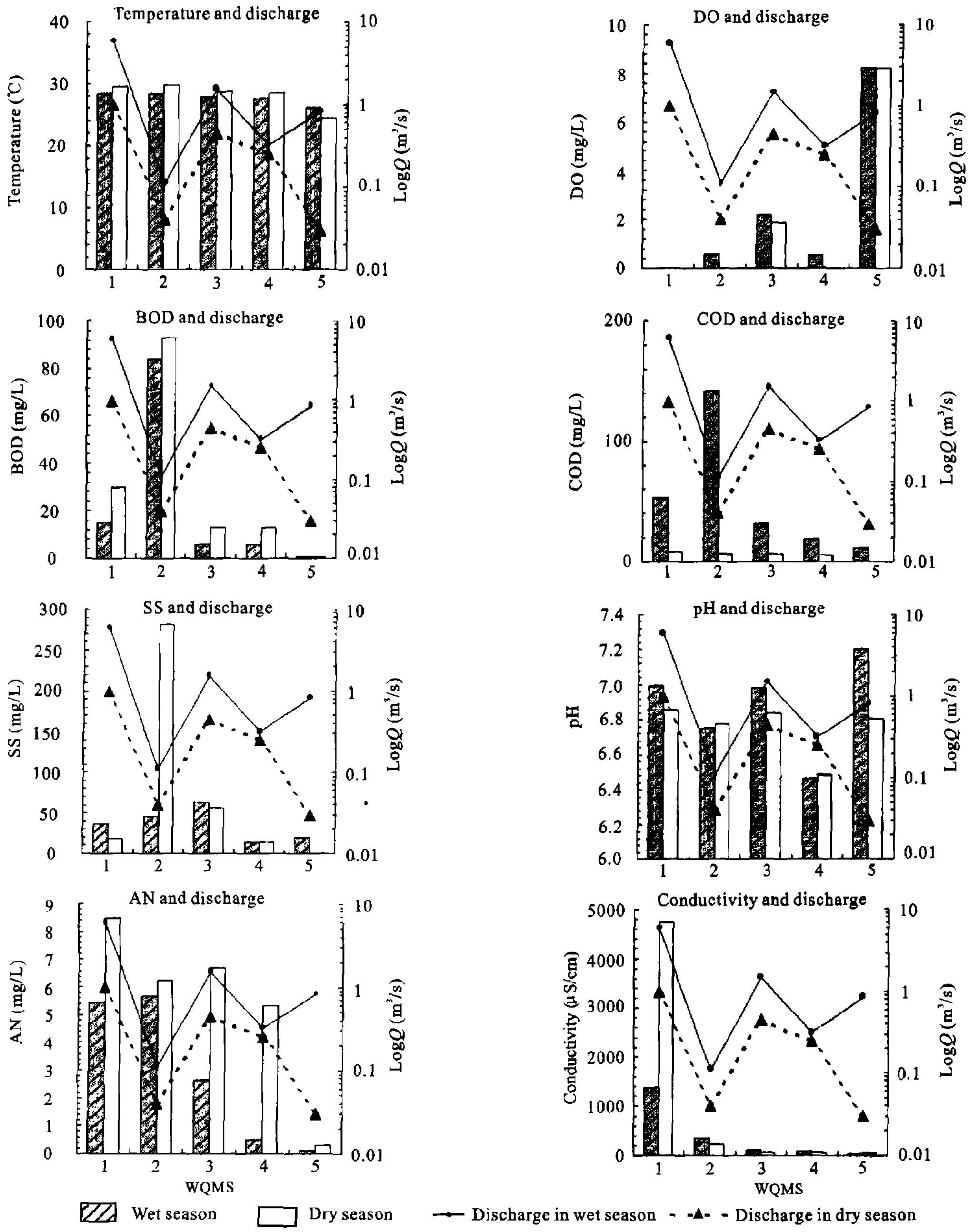

Fig. 3 Effects of seasonal streamflow on water quality parameters at each WQMS along Pinang River

ghout the study, with mean values of 29.7℃ (dry season) and 28.3℃ (wet season) (Table 2), temperatures at WQMS2, WQMS3 and WQMS4 were in the same range. Overall sites mean annual temperature from 1992–2000 varied from 25.25℃ (minimum) to 27.9℃ (maximum) (Table 1). The higher temperatures at the four sites in the plains were mostly due to the low streamflow velocity, urbanized basins and lower altitude (Fig. 3). The uncertainty is low because sampling was done in the morning.

Changes in temperature between dry season and wet season in year 2000 were significant with F value of 0.203 and p-value of 0.076 at $p<0.05$ (Table 2). Generally, these indicate that warm water is likely to occur during low discharge compared to the wet season, particularly at WQMS1 and WQMS2. While at WQMS5 water temperature relatively low both in dry season and wet season due to consistent flow velocity and catchments land-use types despite of low discharge (Q) of $0.03\text{m}^3/\text{s}$.

3.3 Dissolved Oxygen (DO)

DO is the volume of oxygen that is contained in water. The amount of oxygen that can be held by the water depends on the water temperature, salinity, and pressure (CARUSO, 2002). Statistical analysis of DO values for all WQMSs between seasons showed no significant difference with the $F = 0.917$ and p-value 0.468 at $p<0.05$. Nevertheless, WQMS5 and WQMS3, located at upper stream with moderate stream gradient, show some indication of high DO levels, due to higher velocity of streamflow compared with other WQMSs (Fig. 3). Flowing water is more likely to have high DO level than stagnant water because of the water movement at the air-water interface. For instance, in flowing water, oxygen-rich water at the surface is constantly being replaced by water containing less oxygen as a result of turbulence, creating a greater potential for exchange of oxygen across the air-water interface. Because still water undergoes less internal mixing, the upper layer of oxygen-rich water tends to stay at the surface, resulting in lower dissolved oxygen levels throughout the rest of the water levels. As expected, DO concentrations decreased and were inversely related to water temperature during dry season (Table 2 and Fig. 3).

3.4 Biological Oxygen Demand (BOD)

BOD value, which indicates the concentration of labile organic matter, showed a little spatial or temporal variation (Table 2), ranging from 1mg/L to 84mg/L in the wet season and 1mg/L to 93mg/L in the dry season. BOD values indicate the extent of organic pollution in the aquatic systems, which adversely affect the water quality. At four sampling sites of WQMS1–4, mean BOD values were high compared to WQMS5 (Tables 1 and 2). In addition, there was no significance difference between stations and seasons ($F = 0.899$, p-value=0.460, $p<0.05$). BOD level was highest at WQMS2, while at WQMS5 it was very low, only 1mg/L in both seasons. Thus it is concluded that the basin with less human activities has less sources of organic and inorganic pollutants from both point and non-point sources pollution. Relatively, very high values were observed at WQMS2 (most urbanized basin), which are likely to be due to the effluents from the domestic waste, sewage, small-scale industries, and livestock activities. Fig. 3 shows the increase in BOD values at four WQMS during dry season and reflects high burden of organic pollution discharge from point source pollution on the Pinang River and dilution capacity are low due to volume of water available in the river. For instance, at WQMS2 measured streamflow discharge was only $0.04\text{m}^3/\text{s}$ during dry season (Table 2).

3.5 Chemical Oxygen Demand (COD)

The average levels of COD obtained from five sites ranged from 10mg/L to 207.88mg/L. A high level of COD was due to high oxygen-demanding organic substances and inorganic chemicals from agricultural, urban runoff and industrial discharge (i.e. rubber and food processing industries). The stretch of river tributaries at WQMS1, WQMS2 and WQMS3 is highly polluted with high oxygen-demanding organic matters from residential, commercials and small-scale industries located near the riverbank. ANOVA test shows that there are significant different between WQMSs with $p<0.0001$ (Table 1). In addition, there is significant difference between stations and seasons($F = 0.087$, p-value 0.018, $p<0.05$), which is related to basin land-use types (Table 2).

3.6 Suspended Solids (SS)

Suspended solids in water bodies originate from soil erosion and runoff from other sources. In Malaysia, very high levels of SS were recorded in rivers during wet season. Runoff from logging, agriculture and urban areas contribute to high-suspended solids in Malaysia rivers (Department of Environment, Malaysia, 1998). Tropical rains erode the top soil from land without vegetation and soil erosion increases the level of suspended solids in river water, causes siltation in water ways, wetland, streams and rivers (Department of Environment, Malaysia, 1998). Fig. 3 illustrates the seasonal variations in the SS values and statistical analysis indicates significant difference between seasons and WQMSs (ANOVA $F = 11.05$, $p<0.0001$; $F= 0.028$, p-value = 0.002, $p<0.05$) (Tables 1 and 2). Generally, all WQMSs show increasing in SS values during wet season compared to dry season except higher levels of SS that were observed at WQMS2 during dry season , which was due to runoff water from the land clearing for construction and domestic wastes from high-density residential and commercial basins.

3.7 pH

Although not definitive, pH of the aquatic systems is an important indicator of the water quality and the extent of pollution in the watershed areas. Unpolluted streams normally show a near neutral or slightly alkaline pH. Most of the water samples at all the WQMSs had pH of about 6 to 8. Compared with WQMS5, lower pH value was observed at WQMS2 and WQMS4. This could be due to slightly acidic waters from the urban and agricultural areas, with effluent from the residential, industrial, commercial, and livestock activities (Fig. 3). Furthermore, pH value lower than 7 was most probably due to the leaching and rain-runoff effects. Table 2 shows that pH values are not significantly different between the seasons (F=3.487, p-value=0.127, $p<0.05$), thus implies that pH does not vary among the WQMSs. However, slightly increase during the wet season shows that, the effects of storm runoff and surface flow makes the water more alkaline (Fig. 3).

3.8 Ammoniac Nitrogen (AN)

Ammonia exists in an aquatic ecosystem in both un-ionic (NH_3) and ionic (NH_4^+) form. The toxicity of ammonia to aquatic organisms has primarily been linked to the un-ionized form (EMERSON *et al.*, 1975; ANKLEY and BUKHARD, 1992). The concentration of un-ionic ammonia is dependent on pH, temperature and total ammonia. At given concentration of total ammonia, pH has a greater influence than temperature on the concentration of un-ionic ammonia (EMERSON *et al.*, 1975). Waste from sewage treatment plants and rubber industries directly discharged into the Pinang River, which usually leads to high levels of ammonia nitrogen in river waters (LAW and MOHSIN, 1980). Effluent from sewage treatment plants, small-scale industries and livestock into the Pinang River especially at WQMS1, WQMS2 and WQMS3 caused high ammoniac-nitrogen levels (Table 1). Fig. 3 shows that AN concentrations considerably varied among the WQMSs and the variations were not significant between seasons ($F = 0.736$, p-value=0.387, $p<0.05$) (Table 2). The higher concentrations of AN were in WQMS 1, 2 and 3, which were most likely caused by point pollution source from urban, commercial, industrial, and livestock waste.

3.9 Conductivity

Conductivity qualitatively reflects the status of inorganic pollution and is a measure of total dissolved solids and ionic species in the waters. It varies from 0.05 for pure water to about 225mS/cm for concentrated brine (MCCUTCHON *et al.*, 1993). Since many pollutants contain soluble salts, it is conceivable that the conductivity may reflect the concentration of these materials (HOWARD and HAYNES, 1993; GURNELL *et al.*, 1994). The lowest conductance value was recorded in WQMS5 both in year 2000 and 1992–2000 (Fig. 3 and Table 1). Generally, conductance values increased as the river descended as a result of increased builtup intensity and agricultural land-use. Throughout the study period, WQMS1 recorded higher values than the other four sites and there is significant difference between seasons (F=0.075, p-value=0.014, $p<0.05$). Highest observed value was 4736μS/cm in dry season, when streamflow velocity was low. On the contrary, with increasing streamflow during wet season, the concentration of dissolved material decreased, as did the conductivity. In addition the WQMS1 represents the entire basin of the Pinang River and its proportion of urban land is the highest among all catchments, which reflects that urban areas produce a significant amount of soluble pollutants that relate to conductivity both in dry season and wet season. However, WQMS2 (356μS/cm), WQMS3 (101μS/cm), and WQMS4 (94.2μS/cm) showed increasing in conductivity during wet season, impling that seepage and surface runoff accelerate movement of the non-point source pollutant from impervious urban areas and agricultural land to the river systems (Table 2). Conductivity may not fully reflect the impact of storm water runoff, which often contributes SS to surface water. In other words, conductivity may be more appropriate to reflect the impact from point pollution sources than that from non-point pollution sources.

4 DISCUSSIONS

4.1 Streamflow Discharge and Water Quality Parameter

Pearson's product correlation analysis indicates that the correlation between conductivity and discharge (Q) is the highest (r=0.89 in dry season and r=0.92 in wet season) both in dry season and wet season and the only one with statistical significance (Table 3). However overall correlation coefficients between Q and water quality parameters show that r values are higher in dry season. Thus it is concluded that river water quality during low streamflow tends to be more polluted than high streamflow due to low dilution capacity. Such results also highlight that point pollution sources still supply large amount of pollutant in the Pinang River networks, despite regular monitoring and strict regulation from local authority and agency concerned. With only eight observations, correlation analysis can not guarantee meaningful results. The correlation coefficients, therefore, are used here as a relative measure of the strength of relationship between water quality parameters and Q, while the significance level can be only used as a reference of relative importance.

Table 3 Pearson's product movement correlation coefficients between streamflow discharges (Q) and water quality parameters in the Pinang River Watershed ($N = 8$)

Water quality parameter	Correlation coefficient	
	Dry season	Wet season
Temperature	0.48	0.33
DO	-0.44	-0.29
BOD	-0.18	-0.25
COD	0.50	-0.11
SS	-0.39	0.13
pH	0.30	0.32
AN	0.72	0.48
Conductivity	0.89*	0.92*

* Significant at $p<0.05$(two-tailed test)

4.2 Water Quality Assessment

Based on the *WQI* rating range, the water quality is categorized as follows: "Clean" (*WQI* = 81–100), "slightly polluted" (*WQI* = 60–80) and "polluted" (*WQI* = 0–59). Table 4 summarizes the results obtained at different sampling points in the both seasons. The present study shows that overall *WQI* at WQMS1 to 4 was low and badly polluted (*WQI*<59) particularly during the dry season, which indicates that the water condition is not suitable for public water supply, recreation, aquatic life and navigation. According to Department of Environment, Malaysia (1994), if *WQI*<59, only boating and transportation is feasible. Conversely, WQMS5 shows high *WQI* rating condition (*WQI*=71) and is considered slightly polluted in dry season while clean during wet season (*WQI*=94). Whereas if *WQI*>80, the river conditions are acceptable for aquatic life, water recreational activities, and public water supply with minor purification. Nevertheless, during wet season, *WQI* ratings at all sampling stations shows great improvement due to high dilution capacity from volume of water available in the river.

Table 4 Water quality index for each WQMS in 2000

	WQI rating: WQMS				
	1	2	3	4	5
Dry season	29	18	43	45	71
Wet season	40	25	54	62	94

4.3 Seasonality and Water Quality of River

Streamflow during the dry season was extremely low compared to the wet season, thus implies concentrations of contaminants derived from point pollution source will increase due to lack of rainfall and runoff events. This study has shown that these streamflow variations can have a range of effects on stream ecosystems with spatial and temporal patterns even at small region such as at watershed levels. However, the magnitude and duration of extreme values for these parameters, which are usually critical to biota, may increase somewhat during extreme low streamflow. On the contrary urban and agricultural catchments, non-point pollution source increased during wet season through seepage and runoff. Effects of seasonal variations of streamflow consequently determine the quantity and quality of the water parameters. According to the quality indices during the study period, water quality in the upper reaches of the river (WQMS5) was medium to good. It dwindled in the plains, due to the seepage from urbanized areas and discharges from the industrial and agricultural lands. While *WQI* index reflects the overall quality of the water based on all the parameters. The water quality index at WQMS1, 2, 3, and 4 deteriorated mainly due to point pollution and non-point pollution sources. The aggravating of pollution of the river seems related to the relative growth of industrial and urban activities.

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