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Rivers and Lakes as Natural Heritage: Water Quality Status in the Northern States of Peninsular Malaysia

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Abstract. Rivers and lakes are natural heritage that should be preserved at all cost. The history of human civilisation has proven the importance of rivers and lakes to humans but development activities had changed the water quality status of rivers and lakes. Due to pollution, they are no longer of any use to human beings. This study was conducted to evaluate the changes of water quality in major rivers, lakes and dams in the northern region of Peninsular Malaysia. Sampling was carried out in February 2010 and completed in April of the same year. The sampling consisted of 62 sampling stations located in rivers, lakes and dams in Perlis, Kedah and Penang. Readings were taken based on 11 hydrological and physicochemical parameters and the water quality status was classified under the Interim National Water Quality Standards (INWQS) which tabulated six levels of pollution ranging from moderate to extremely polluted in the order of I, IIA, IIB, III, IV and V. Results from the study show that most readings from the rivers which were located in forested areas and areas that have experienced less development in Kedah and Penang show moderate pollution between Class I and IIA. In urban areas, the rivers are categorised under Class IIB and III while in Perlis, upstream rivers are slightly polluted and categorised under Class IIB and III. However, the pollution level decreases in the middle area but increases gradually as it approaches the urban areas. This study would be useful to planners to ensure development will not interfere with rivers and lakes. As natural heritage, it is of the utmost importance to preserve these rivers.

Keywords and phrases: natural heritage, water quality, northern Peninsular Malaysia, INWQS

Introduction

Natural heritage can be classified under: (1) "nature's treasure" that refers to physical formation, the flora and fauna; (2) "geology and rock formation" covering animals and plants; and (3) "natural sites" which refer to natural areas (non-human built) which have universal value from the perspectives of science, conservation and natural beauty (Yazid Saleh 2010). As such, lakes, rivers and its catchment area are the main component of natural heritage that has to be preserved. Forest in the catchment area should not be disturbed by any means and need to be preserved as they are the repository of our natural heritage besides their association with rivers which are important water resources (Uzzell 1989). Very often, life or civilisations evolved in an environment that had water resources such as marsh, river mouth, streams, lakes or ponds (Suhaimi Suratman and Norhayati Mohd Tahir 2013; Nor Azman Kasan 2006). Beginning with springs in the upper reaches, they form river channel as it flows downstream (Sukadi 1999). Quite often, parts of the upstream are free from pollution due to the surrounding ecosystem (forest lands) which has not been disturbed by human activities. As for the midstream, there is incidence of pollution due to increasing land use (development activities), while the downstream is polluted or extremely polluted (*mSTAR Online* 2005). The water quality status as monitored by the Department of the Environment (Department of Environment, Ministry of Natural Resources and Environment Malaysia 2010) shows a decreasing trend for the clean category for river basins as well as moderately polluted and polluted river basins (Table 1).

Table 1. The number and percentage of river basins according to category in 2005–2009

Category	**2005**		**2006**		**2007**		**2008**		**2009**	
	No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Number of monitoring stations	1085		1086		1064		1063		1063	
Number of river basins	146	100	146	100	143	100	143	100	143	100
Clean	80	54.8	80	54.8	91	63.6	76	53.1	70	48.9
Moderately polluted	51	34.9	59	40.4	45	31.5	60	42	64	44.8
Polluted	15	10.3	7	4.8	7	4.9	7	4.9	9	6.3

At present, the water from rivers in Malaysia for human consumption is questionable due to its quality (Nor Azman 2006). Water quality refers to the level of suitability for human use and that could sustain other living organisms. In broad terms these include irrigation, recreation and to sustain marine life (Talha et al. 1978). Significant changes to the water quality are indicated by the incidence of land development (Lazaro 1979). Commonly used measurement of physical parameters are associated with scent, temperature, solid materials and water taste (Nor Azman 2006) while nutrients, heavy metals and *faecal coliform* are indicators for the chemical and biological parameters. High concentration of phosphorus and nitrogen in the water could limit the productivity of the river system that would lead to increases of nutrients exportation into the water causing eutrophication (Dresneck 1998; Fatimah Mohd Yusof 1996; Nemerow 1991).

The causes of pollution are either *point source pollution* or *non-point source pollution* (Novotny and Chester 1981) or whether it was caused by human activity or caused by nature. Water pollution in rivers caused by natural factors is closely related to climatic characteristics (Fatimah 1996), geographic and geological conditions (Madera 1982; Mohd Ekhwan and Large 2004) as well as rainfall distribution in a particular area (Sosrodarsono and Takeda 1980). The status or level of pollution on ground water needs to be measured before any actions could be taken to create sustainable rivers. In this study, the level of ground water pollution such as rivers, lakes, pond and dams are measured and classified according to the INWQS.

In Malaysia, the use of the INWQS is enforced by the Department of Environment (Ainon Hamzah and Yanti Hattasrul 2008). It is an important standardisation measurement that is most helpful in assessing and monitoring surface water (Yisa and Jimoh 2010). The main purpose of INWQS is to classify rivers into classes within the water quality parameters. The classes ranged from Class I to V (I, IIA, IIB, III, IV and V).

It is hoped that the result from this study could provide a guide to the government and other relevant bodies that are responsible for managing the rivers and lakes, especially the Drainage and Irrigation Department in planning and implementing development without endangering our natural heritage. The authors also hope that this study will increase awareness among locals to preserve the natural heritage for future generations.

Study Area

The study was carried out in Perlis, Kedah and Penang (Figure 1). Their total area was estimated to be 810 km^2, 9,426 km^2 and 1,033 km^2 respectively (Official websites of the Perlis, Kedah and Penang State Governments 2010). A total of 62 sampling stations were chosen for the field study which was conducted in early February 2010 and completed in April of the same year. During the research period, Perlis had experienced severe drought in early March with the weather hot and dry. The state receives the least annual rainfall compared to the other states in Malaysia (Salleh Bakar et al. 2007).

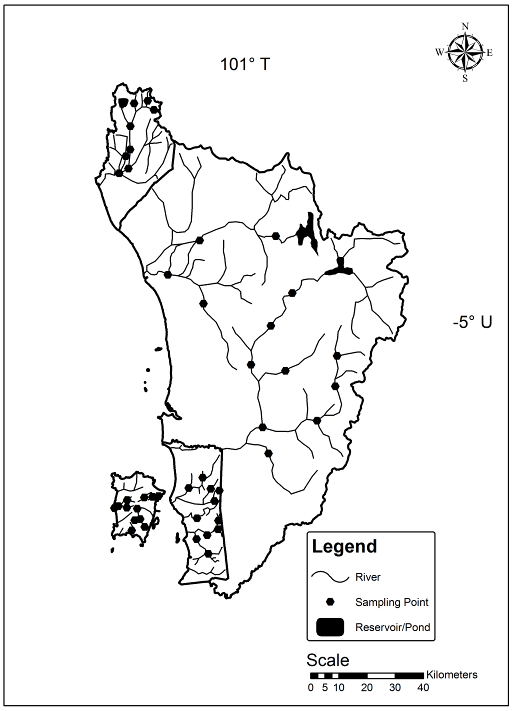

Figure 1. Sampling stations for rivers and ponds/dams in Perlis, Kedah and Penang

The chosen sampling area was based on major rivers or catchment areas that irrigate these states starting from the upstream, midstream and downstream. The main river in Perlis is the Sungai Perlis which is 9.5 km long while its river basin covers an area of 505 km^2. The major rivers in Kedah and Penang are the Sungai Muda and the Sungai Pinang, while in Seberang Perai, the major rivers are the Sungai Juru and the Sungai Perai. The Sungai Muda is 180 km long while its river basin covers an area of 4,210 km^2. The Sungai Pinang is only 3.1 km long with an equally smaller river basin of 50.97 km^2 while the 7.95 km Sungai Juru has a 54.95 km^2 river basin. The 23-km-long Sungai Perai is endowed with 505 km^2 river basin.

The rainfall distribution in the sampling areas is an important factor that influences the quality of river water. Figure 2 shows the rainfall distribution for the period 2005–2009 over various sampling stations in Perlis, Kedah and Penang. These indicate low rainfall distribution pattern between January and April. The highest monthly rainfall was recorded in August 2005 which measured 1,150 mm at the Sg. Korok station while the lowest annual cumulative rainfall was recorded in Sungai Juru in 2005 measuring 333 mm.

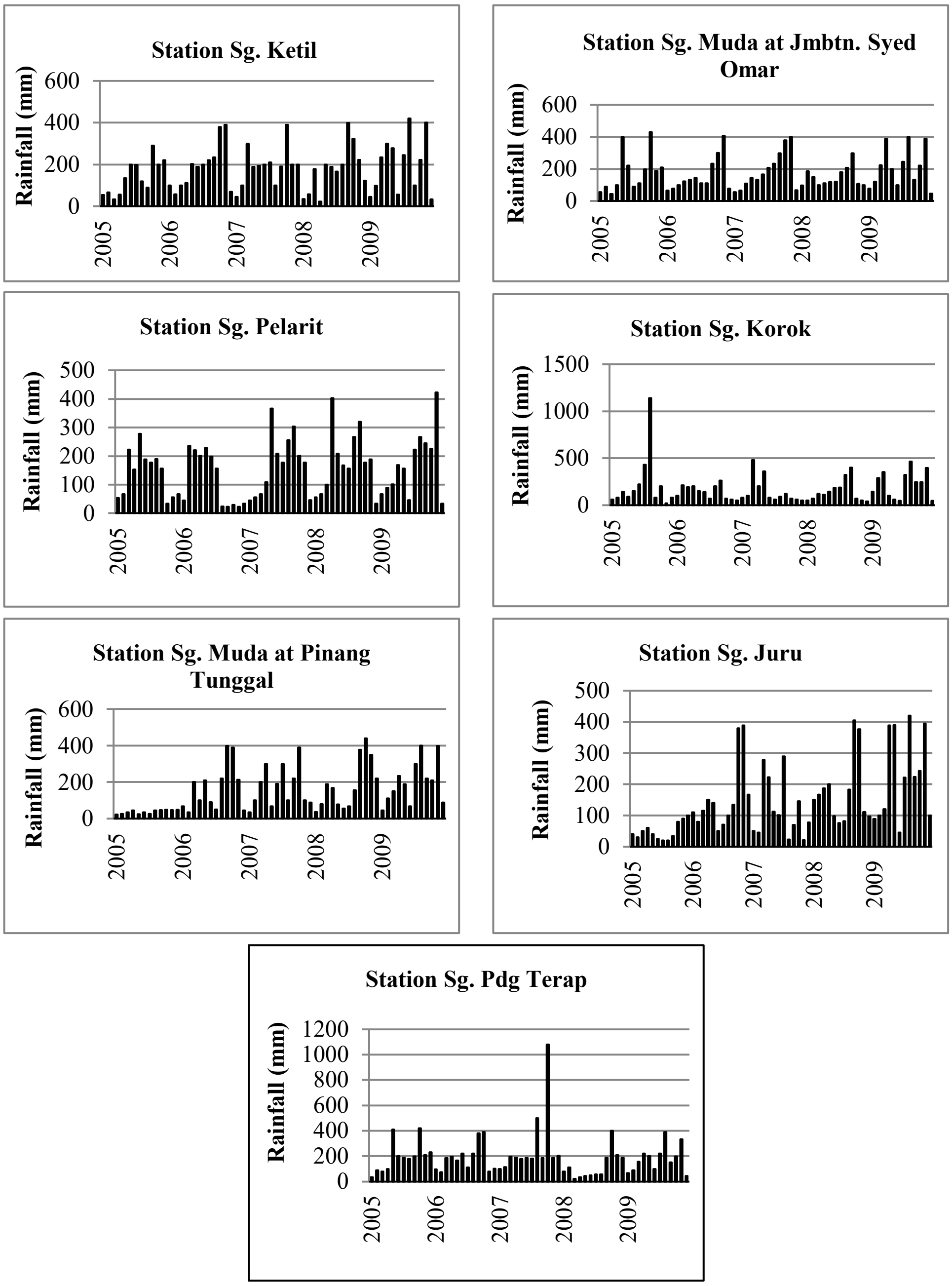

Figure 2. Rainfall distribution for sampling stations for the period 2005–2009 (source: Drainage and Irrigation Department)

Methodology

The study involves 11 water quality parameters. A multi instrument parameter YSI-556 is used at every sampling station to measure temperature, pH level, conductivity, total dissolved solid, turbidity and dissolved oxygen. Water samples are brought back to the laboratory for analysis which involves parameters like total suspended solids, nitrite-nitrogen (NO_2-N), nitrite-nitrogen (NO_3-N), ammonia-nitrogen (NH_3-N) and phosphate (PO_4). These parameters are determined by American Public Health Association (APHA) standard (APHA 1999) and the brief standard procedure by Adam (1990). The parameter for total suspended solids is based on the filtration method (Gordon et al. 1992) while the INWQS (Tong and Goh 1997) was used to classify water quality in the study area.

Table 2a. INWQS Malaysia classification

Parameter	Unit	Classification					
		I	IIA	IIB	III	IV	V
DO	mg/L	7	5–7	5–7	3–5	<3	<1
pH		6.8–8.5	6–9	6–9	5–9	5–9	–
TSS	mg/L	25	50	50	150	300	>300
Temperature	°C	–	Normal ± 2	–	Normal ± 2	–	–
Turbidity	NTU	5	50	50	150	300	>300
Nitrite	mg/L		0.4		0.4 (0.03)	1	
Nitrate	mg/L		7	7		5	
Ammonia Nitrogen	mg/L	0.1	0.3	0.3	0.9	2.7	>2.7

Table 2b. INWQS Malaysia classification

Class	Description
I	Preservation for natural environment Water supply – treatment not needed Fishery – sensitive aquatic species
IIA	Water supply – needs conventional treatment Fishery – sensitive aquatic species
IIB	Suitable for recreational activities that involve body contact
III	Water supply – needs intensive treatment Fishery – for livestock drinking
IV	Only suitable for irrigation
V	Extremely polluted

Results and Discussion

The result of the study is highlighted in Tables 3–6. Findings from the study show that the parameters at the upstream and midstream were moderately polluted ranging between Class I and Class IIA. However, there were parameters that indicate the presence of pollution which fall under Class III and IV. For example, the upstream area of the Sungai Perlis recorded the lowest average reading for dissolved oxygen (3.66 mg/L: Class III) although average reading for dissolved solids was quite high (2378.39 mg/L: Class IV). These readings put the upstream area of Sungai Perlis between Class IIB and III which is only suitable for recreation, irrigation and to support aquatic animals that could withstand such level of pollution.

Table 3a. Average water quality parameters from upstream, midstream and downstream of rivers in Penang (Island)

Parameter/ River Segment	**Penang (Island)**					
	Upstream Average (Range)		**Midstream** Average (Range)		**Downstream** Average (Range)	
Temperature (°C)	26.68 (25.8–28.1)	N	28.40 (26.5–31.1)	N	27.88 (26.8–28.9)	N
Dissolved Oxygen, DO (mg/L)	5.90 (3.83–7.57)	IIA	5.36 (0.51–7.80)	IIA	4.38 (1.13–7.12)	III
pH	6.62 (6.0–7.09)	I	6.64 (6.33–6.98)	I	6.76 (6.39–7.16)	I
Turbidity (NTU)	3.85 (1.51–8.64)	I	10.28 (2.86–26.55)	IIA	13.00 (1.42–23.50)	I
Conductivity (μS/cm)	32.433 (17.0–48.5)	I	75.222 (33.5–220.3)	I	133.90 (25.0–269.0)	I
Total Dissolved Solid, TDS (mg/L)	13.550 (7.33–19.67)	I	32.847 (13.67–101.25)	I	69.850 (7.5–179.3)	I
Total Suspended Solids, TSS (mg/L)	3.400 (0.53–11.80)	I	8.544 (0.40–28.67)	I	10.853 (0.40–22.6)	I

Table 3b. Average water quality parameters from upstream, midstream and downstream of rivers in Penang (Seberang Perai)

Parameter/ River Segment	Penang (Seberang Perai)					
	Upstream Average (Range)		**Midstream** Average (Range)		**Downstream** Average (Range)	
Temperature (°C)	28.99 (28.6–29.7)	N	30.84 (28.06–34.8)	N	28.20 (28.07–28.46)	N
Dissolved Oxygen, DO (mg/L)	5.15 (4.12–7.12)	IIA	3.58 (1.54–4.47)	III	1.85 (0.65–2.62)	IV
pH	6.91 (6.71–7.13)	I	7.01 (6.81–7.37)	I	7.23 (6.76–7.69)	I
Turbidity (NTU)	54.56 (22.0–143.0)	I	78.51 (18.62–138.2)	I	146.2 (133.2–170.7)	I
Conductivity (µS/cm)	60.667 (30.5–83.5)	I	201.083 (57.67–540.0)	I	207.778 (149.33–296.0)	I
Total Dissolved Solid, TDS (mg/L)	25.396 (12.67–33.0)	I	61.625 (26.5–148.0)	I	86.583 (55.0–136.0)	I
Total Suspended Solids, TSS (mg/L)	43.400 (16.6–98.4)	IIA	91.817 (9.33–168.2)	IIA	109.289 (95.2–122.0)	IIB

Table 4. Average water quality parameters from the upstream, midstream and downstream of rivers in Kedah

Parameter	River segment					
	Upstream Average (Range)		**Midstream** Average (Range)		**Downstream** Average (Range)	
Temperature (°C)	28.64 (27.17–30.04)	N	27.99 (25.51–29.10)	N	29.23 (27.92–30.20)	N
Dissolved Oxygen, DO (mg/L)	4.88 (3.63–6.31)	III	5.24 (4.23–5.89)	III	4.11 (1.03–5.20)	III
pH	7.48 (6.98–8.21)	I	7.24 (6.68–7.70)	I	7.02 (6.60–7.53)	I
Turbidity (NTU)	12.41 (5.99–19.63)	IIA	17.47 (1.57–49.30)	IIA	40.18 (24.80–60.83)	IIA

(*continued on next page*)

Table 4. (*continued*)

Parameter	River segment					
	Upstream Average (Range)		**Midstream** Average (Range)		**Downstream** Average (Range)	
Conductivity (µS/cm)	60.6 (49–79)	I	51.8 (28–101)	I	59.5 (22.0–93.3)	I
Total Dissolved Solid, TDS (mg/L)	36.40 (29.00–47.00)	I	31.67 (17.00–61.00)	I	35.73 (13.67–56.00)	I
Total Suspended Solids, TSS (mg/L)	5.973 (1.2–12.0)	I	10.552 (0.93–40.40)	I	17.013 (11.867–23.733)	I

Table 5. Average water quality parameters from the upstream, midstream and downstream of rivers in Perlis

Parameter	River segment					
	Upstream Average (Range)		**Midstream** Average (Range)		**Downstream** Average (Range)	
Temperature (°C)	30.05 (28.59–31.35)	N	32.78 (30.2–36.57)	N	32.99 (32.67–33.49)	N
Dissolved Oxygen, DO (mg/L)	3.66 (2.74–4.41)	III	4.49 (3.12–6.93)	III	3.85 (3.34–4.33)	III
pH	7.95 (7.83–8.14)	I	7.98 (7.92–8.07)	I	7.50 (7.35–7.66)	I
Turbidity (NTU)	14.94 (10.32–20.55)	IIA	29.21 (9.69–47.8)	IIA	24.42 (16.19–33.37)	IIA
Conductivity (µS /cm)	228.67 (15.50–455)	I	338.56 (315–363)	I	1037.28 (328–2448)	I
Total Dissolved Solid, TDS (mg/L)	2378.39 (131.50–6740)	I–IV	193.33 (178.67–215.00)	I	1158.78 (185.00–1902.33)	IIA
Total Suspended Solids, TSS (mg/L)	5.71 (1.60–9.00)	I	15.02 (4.00–26.67)	I	24.67 (12.40–40.40)	I

Table 6a. Results of 11 parameters for lakes, dams, and ponds in Perlis, Kedah and Penang

Parameter	Pond/Dam/Lake							
	Kolam Gua Kelam (Pond)		Timah Tasoh Dam		Tasik Melati (Lake)		Tasik Muda (Lake)	
Temperature (°C)	26.08	N	35.32	N	32.82	N	31.51	N
DO (mg/L)	4.31	III	5.14	IIA	8.60	I	5.46	III
pH	7.74	I	8.43	I	8.94	IIA	7.01	I
Turbidity (NTU)	3.36	I	10.36	IIA	25.00	IIA	8.88	IIA
CND (μS/cm)	33.50	I	187.70	I	264.00	I	42.70	I
TDS (mg/L)	214.00	I	102.00	I	150.00	I	24.67	I
TSS (mg/L)	4.667	I	8.133	I	15.467	I	4.667	I
NO_2 (mg/L)	0.0303	IIA	0.0494	IIA	0.0587	IIA	0.0235	IIA
NO_3 (mg/L)	0.0326	IIA	0.0198	IIA	0.0568	IIA	0.5848	IIA
NH_3 (mg/L)	0.0263	I	0.0330	I	0.0739	I	0.0662	I
PO_4 (mg/L)	0.0292	N	0.0040	N	0.0062	N	0.0004	N

Table 6b. Results of 11 parameters for lakes, dams, and ponds in Perlis, Kedah and Penang

Parameter	Pond/Dam/Lake							
	Tasik Pedu (Lake)		Beris Dam		Lata Bayu		Mengkuang Dam	
Temperature (°C)	32.31	N	31.45	N	25.34	N	32.26	N
DO (mg/L)	4.70	III	4.47	III	7.55	I	6.24	IIA
pH	7.26	I	6.96	I	6.27	I	8.50	I
Turbidity (NTU)	9.06	I	4.17	I	4.08	I	2.05	I
CND (μS/cm)	40.30	I	22.00	I	15.00	I	32.00	I
TDS (mg/L)	23.00	I	13.00	I	8.33	I	12.00	I
TSS (mg/L)	0.933	I	1.867	I	2.000	I	2.533	I
NO_2 (mg/L)	0.0113	IIA	0.0129	IIA	0.0230	IIA	0.0179	IIA
NO_3 (mg/L)	0.0958	IIA	0.0232	IIA	0.0365	IIA	0.0558	IIA
NH_3 (mg/L)	0.0640	I	0.0619	I	0.0920	I	0.0915	I
PO_4 (mg/L)	0.0030	N	0.0035	N	0.0036	N	0.0078	N

In Situ Parameters

This study found out the average water temperature in forested areas or at the upstream area was between 26.68°C and 30.0°C compared to those of the midstream and urban areas which were recorded between 27.88°C and 32.99°C (Tables 3–5). This condition is considered normal for waterbody despite the differences in temperature range. In reference to temperature range for dams and lakes, on average the values are quite high ranging between 31.45°C and 35.32°C (Table 6). The thick forest canopy provides cover for waterbody hence the low temperature while the exposed waterbody in dams and lakes had resulted in the high water temperature.

As a parameter, dissolved oxygen (DO) is used to measure water quality. The DO reading shows the amount of dissolved oxygen (O_2) in a waterbody. According to Holgate (1979), the DO parameter is important for aquatic biology. In the study, the DO readings decreased gradually from upstream to the downstream. In Penang, the average DO reading for rivers is 5.9 mg/L in the upstream (forest) and 5.36 mg/L for the midstream. The reading decreased further to 4.38 mg/L for the downstream (Table 3). In comparison, the average DO readings were lower than Seberang Perai which were 5.15 mg/L, 3.58 mg/L and 1.85 mg/L respectively. This low reading is due to Seberang Perai's rapid development including urbanisation and industrialisation (Sulong Mohamad et al. 2005). Based on the INWQS classification, rivers in Seberang Perai were placed under Class III and IV. In Kedah, the average DO readings for rivers were 4.88 mg/L (upstream), 5.24 mg/L (midstream) and 4.11 mg/L (downstream) (Table 4). Perlis rivers however recorded a marked difference in the DO readings (Table 5) with lower average readings at the upstream compared to the midstream or downstream.

The reason is that Perlis rivers at the upstream are heavily polluted due to agricultural activities notably sugarcane and rubber cultivation (Salleh et al. 2007) besides business and hawking activities in the Padang Besar area. Padang Besar is a well-known town in the northern region. The Khlong Wang Rua remains one of the most polluted rivers in the country. This was contributed by human activities around or near Padang Besar.

The pH level is a measurement used to measure water acidity. In the present study, the pH level for rivers ranged between 6.0 and 8.21 (Tables 3–5). Based on the INWQS, all three states showed an average pH level within Class I and IIA. Those with below than neutral pH level were probably caused by land use dominated by agriculture and industrial activities. Other contributors include waste disposals (chemicals and agricultural fertilisers) from factories could lead to more acidic pH level.

Ponds, dams and lakes act as a water supply area, generator for power, flood insulator and recreation (Department of Town and Country Planning 2005). However, differences in geology, weather and types of reservoir and land use near these water bodies affected the readings of the parameters. For example, the concentration of total suspended solids (TSS) in Perlis's Gua Kelam was very low (4.67 mg/L) compared to Tasik Melati which was three times greater (15.47 mg/L) (Table 6). Turbidity is caused by fine inert materials inside a water body. The high concentration of TSS and turbidity in Tasik Melati was probably due to bank erosion and chemicals from the use of agricultural fertilisers. According to Maisarah Ali et al. (2007), excessive use of fertilisers that were subsequently channelled into lakes by rainwater promotes the growth of algae which could develop into "algae bloom". One of the main factors for the high concentration of nitrate (NO_3), nitrite (NO_2) and ammonia nitrogen (NH_3) within this lake was due to the increase of algae. Based on the INWQS classification for the NH_3 parameter, the pond inside Gua Kelam was placed in Class I while the Timah Tasoh Dam, based on the NO_2 and NO_3 parameters, was placed in Class IIA (less polluted) (Table 6). Overall, the water quality in Tasik Melati of Perlis, Tasik Muda, Tasik Pedu, Beris Dam and Lata Bayu in Kedah and the Mengkuang Dam in Seberang Perai was between Class I–IIA (less polluted).

Physico-chemical

There was a significant difference on the average parameter of physic-chemical in Penang and Seberang Perai (Table 4). The average reading for turbidity in the upstream was 10.28 mg/L while for the downstream the reading was 13.00 mg/L. The upstream had a turbidity index within Class I as the surrounding areas are still covered with forests whereas, in the midstream and downstream characterised by human activities. As a result, the turbidity index was categorised in Class IIA. This differed from the rivers in Seberang Perai where the average turbidity readings were 54.56 mg/L for the upstream, 78.51 mg/L for the midstream and 146.20 mg/L for the downstream (Class IIA-IIB). The difference in turbidity readings between the upstream area on the island and Seberang Perai was due to the high level of land use notably agriculture and urbanisation as suggested by Lazaro (1979). Land use on hilly and forested terrains on the island is minimal as its development is still in its early stage, while at the midstream and downstream the main focuses are settlements, urbanisation and industrial areas. The situation in Seberang Perai was different as the land use focuses on agricultural development and industrial activities besides settlements (Department of Environment, Ministry of Natural Resources and Environment Malaysia 2006). These further contribute to the increase of high turbidity readings in the upstream and downstream. According to Mohd Rashid Mohd Yusoff (1988), turbidity is caused by the existence of suspended materials such as silt, soil, insoluble materials and microscopic organisms. Turbidity takes place when surface water is washed into the river which adds more concentration to suspended particles in rivers and the increase turbidity readings. This situation was also found in rivers in Kedah and Perlis. Class IIA turbidity index means the turbidity is affected mostly by human activities including agriculture and settlements. Whether for the upstream, midstream or downstream there were very little differences in the turbidity index for these states.

The average reading of the total dissolved solid (TDS) in the upstream area of Kedah was higher (36.4 mg/L) compared to the downstream area (35.73 mg/L) which include the Alor Setar urban enclave. The reading was recorded in Class I (good) despite the difference in the concentration of the total dissolved solid. A similar phenomenon was also observed for Penang rivers (Tables 3–4). The TDS parameter is an important water quality indicator for drinking water and also as a general indicator for pollution. TDS refers to the amount of cations (positive charge) and anions (negative charge) in water. TDS contains inorganic salt (especially calcium, magnesium, potassium, sodium, bicarbonate, chloride and sulphate) and a small portion of organic materials. This study had shown that the average TDS was high in the upstream area of Perlis rivers which was 2,378.39 mg/L (Class IV) but the TDS reading decreased in the downstream area to 1,158.78 mg/L (Table 5). If the upstream area of Perlis rivers were to be measured in terms of its TDS concentration according to the INWQS, they would be closer to Class IV. At this level the water quality was unsafe for humans or even aquatic animals. It would require costly treatment.

The range for the total suspended solid (TSS) in the upstream area of Kedah rivers are 1.2 mg/L–12.0 mg/L, 0.93 mg/L–40.4 mg/L for the midstream and 11.87 mg/L–23.73 mg/L at the downstream (Table 4). Based on this index, the rivers are placed in Class I. A similar situation is found in Penang. Based on the INWQS, the rivers are categorised under Class I. These readings are consistent with the assumption that the TSS concentration is lower at the upstream compared to the downstream area due to the high level of human activities. As TSS readings are associated with intensive land development (Mohd Noor 2003), suspended solid consists of usually of mud, refined waste minerals, fine sand particles, silt and clay. The high TSS reading could actually disturb the ecosystem for aquatic life by preventing sunlight from penetrating the water surface. Based on Table 5, the ranges of TSS index for the upstream area of Perlis rivers are 1.6 mg/L–9 mg/L and 4.0 mg/L–26.67 mg/L for the midstream while for the downstream, the range was between 12.4 mg/L and 40.4 mg/L. Previous studies had shown that the higher the TSS concentration in rivers, the higher the level of pollution in the river (Zullyadini and Wan Ruslan 2013; Wan Ruslan and Zullyadini 1994; Arms 1990; Peavy et al. 1986). The present study had shown that TSS concentration for rivers in Perlis had increased from the upstream to the downstream area. This showed that the rivers were becoming more polluted as they flow downstream.

Nutrient

The nutrient parameters used in this study were nitrate-nitrogen (NO_3), nitrite-nitrogen (NO_2), ammonia-nitrogen (NH_3-N) and phosphate (PO_4). A form of inorganic nitrogen, the ammonia nitrogen (NH_3-N) can be toxic while phosphate (PO_4) is a non-toxic component that could affect the productivity of the aquatic system when appear in large concentration. Phosphate is produced through untreated or partially treated sewage, agricultural runoffs and through the use of crop fertilisers. In general, issues pertaining to the quality of river water are related to nutrients caused by the release of ammonia (and ammonium) from the sewage system.

Figure 3 shows high concentration of nitrate, nitrite, ammonia and phosphate at the upstream area, while in the midstream the concentration was found to be low. The index increased as it approached the downstream area of Sungai Perlis. The Khlong Wang Rua River in Padang Besar which is located on the upstream area of the Sungai Perlis contributed to the high concentration of nutrients. The polluted water of the Khlong Wang Rua was probably caused by business activities around Padang Besar and the residential areas and sugarcane plantation in the surrounding area. Through surface runoff, chemicals (fertilisers and other organic materials) made their way into the river (Salleh Bakar et al. 2007). The concentration of nutrients inside the waterbody was also attributed to domestic sewage, faecal wastes (Mohd Noor 2003) or wastes from the Padang Besar wet market. The average amount of ammonia concentration in the upstream area was recorded at 0.24 mg/L which put the river under Class IIA while for the downstream area the reading was 1.2995 mg/L which condemned it to Class IV. However, the concentration of nutrients was low in the midstream but increased rapidly when the river enter the urban areas.

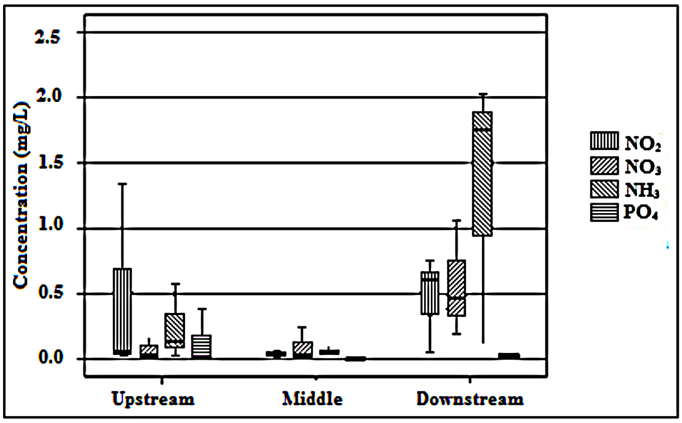

Figure 3. Boxplot concentration for nitrate, nitrite, ammonia and phosphate in the upstream, midstream and downstream area of rivers in Perlis

With reference to Figure 4, the boxplot shows an increase of concentration for the four nutrient parameters from the upstream to the downstream area of rivers in Kedah. The average concentration of nitrate (NO_3) in the upstream area was 0.1193 mg/L which is within Class IIA. Despite the high concentration of nitrate on the downstream area (0.77 mg/L), the rivers still remained in Class IIA. Nitrate was formed when microorganisms broke down through decomposed fertilisers, decaying plants/vegetation or other excesses of fertilisers. The increase of nitrate concentration in water could lead to problem of survival for aquatic insects/water insects or even fish.

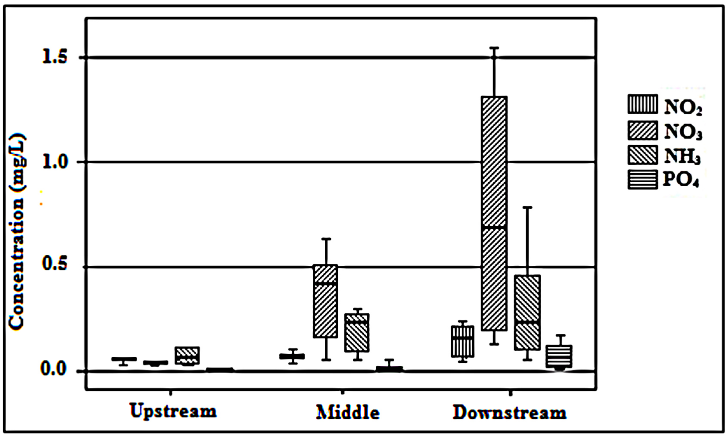

Figure 4. Boxplot concentration for nitrate, nitrite, ammonia and phosphate in the upstream, midstream and downstream area of rivers in Kedah

Figure 5 shows the boxplot graph on the changes in nutrient concentration in rivers in Seberang Perai and Penang island. Rivers in Seberang Perai show a high concentration of nitrate in the upstream and midstream with an average reading of 1.38 mg/L and 1.0 mg/L (Class IIA). The high concentration of nitrate was likely due to agricultural activities nearby where fertilisers or animal faeces were washed away by rainwater into streams and rivers in the upstream area. These turned into sediments in the midstream. Based on the INWQS, the upstream area was placed under Class IIA (1.3875 mg/L) while the downstream area under Class I (0.815 mg/L) for nitrate; as for ammonia (NH_3-N) it was placed under Class IV (1.5494 mg/L).

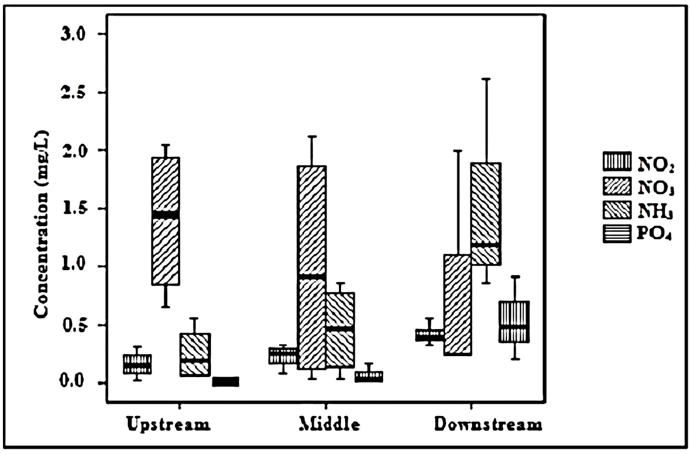

Figure 5. Boxplot concentration for nitrate, nitrite, ammonia and phosphate in the upstream, midstream and downstream area of rivers in Penang (Seberang Perai)

The increasing level of concentration for nutrients from the upstream to the downstream area especially during the rainy season proved that surface runoffs play an important role in carrying excess of phosphate elements to the downstream as shown by the high reading in Figure 6. This concentration of nutrients is essential for plantations to increase the eutrophication process in lakes or rivers (Klapper 1992; Gao and Song 2005; Telesh 2004). The reading for nitrate in rivers in Seberang Perai was categorised under Class IIA and Class I–IIA for the upstream areas because of the presence of ammonia. Based on both nutrients (NO_3 and PO_4) the downstream areas were categorised under Class I–IIA. If these readings were to be compared with Sungai Labu (Lim et al. 2001) and Sungai Langat (Mazlin et al. 2001) it was still considered low. As for the Sungai Langat industrial activities had contributed to the pollution of the river.

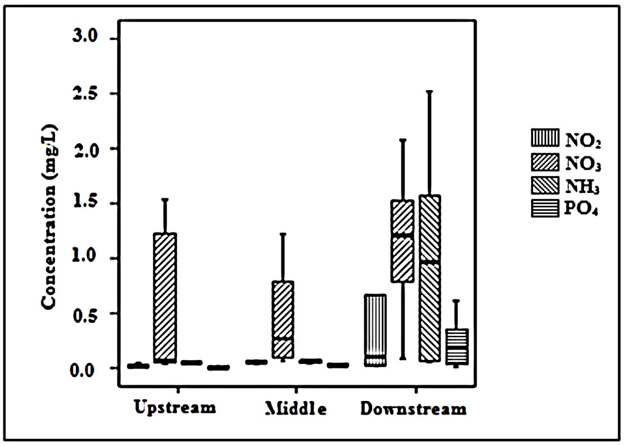

Figure 6. Boxplot concentration for nitrate, nitrite, ammonia and phosphate in the upstream, midstream and downstream area of rivers in Penang (Island)

Conclusion

This study has shown decreasing water quality from the upstream (forest) to the downstream (residential and urban areas). The different patterns of land development starting from the upstream to the downstream have affected the quality of river within the sampling stations. Based on the INWQS classification, the water quality of rivers in the upstream and midstream for Kedah and Penang is still at a positive level (Class I and IIA). The downstream is still clean and in good condition but require monitoring so as to keep the rivers free from pollution be it chemicals or waste disposals. The water quality at the downstream or within urban areas particularly in Seberang Perai, Penang and the upstream of Sungai Perlis are categorised into Class IIB and III. This means that the water is usable for recreational purposes but unsuitable for sensitive aquatic species without some form of high technology treatment. Various measures must be put in place to maintain the existing water quality and to control pollution in our rivers. Forests area must be protected, as it provides the function of watershed area that supplies a clean and undisturbed water to be used by human without costly treatment. This also requires consistent enforcement of the various regulations and acts besides instilling more awareness among Malaysians to value nature and to preserve our natural heritage. It is only through preservation that we have a sustainable natural heritage that can be passed on to the following generations.

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