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PHYSICOCHEMICAL ANALYSIS OF WATER BODIES IN THE MATANG MANGROVE, PENINSULAR MALAYSIA

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Abstract: This study was conducted in the Matang Mangrove Forest Reserve, Peninsular Malaysia to determine the physicochemical characteristics of its water bodies at Sg. Tiram Laut, Sg. Jarum Mas, Sg. Tinggi and Sg. Sepetang with respect to variation in tide (flood and ebb) as well as season (dry and wet). Mangrove DO, pH, EC, turbidity, TDS, salinity and temperature were determined *in situ* while TSS was determined via the Standard Methods. The findings showed that the dry and wet seasons were more significant in determining the variation of the water physicochemical characteristics in the Matang Mangrove compared to tides (flood and ebb). This study serves as a baseline for hydrological studies in mangroves, particularly in Peninsular Malaysia.

Key words: Mangrove, Hydrology, Physicochemical, Seasonal Variation

INTRODUCTION

Mangrove forests are among the most productive ecosystems in the world with well-established ecological, economic and cultural importance (Goessens et al. 2014). However, the constant pressure exerted by anthropogenic (more than natural) events is responsible for its decline at a faster rate than that of tropical rainforests (Alongi 2008). Along with mangrove cover depletion, the loss of its biodiversity and economic value are perturbing issues (Satyanarayana et al. 2012). Mangroves should be treated carefully without underestimating their role for local livelihoods, and to ensure their long-term benefits reach future generations via appropriate conservation and management practices (Lee et al. 2014).

Mangrove hydrology is dynamic and is influenced by components such as waves, tides, rivers and rainfall. These components affect water circulation by generating turbulence and longitudinal mixing and trapping of coastal water, influencing the rate of erosion and deposition of sediments in which mangroves grow. Many physical, hydrological and ecological variations are often localised within a single estuary (Duke et al. 1998).

The Matang Mangrove is known as the best mangrove forest management in Malaysia and in the world (Roslan & Nik Mohd Shah 2013). Production of wood from the Matang Mangrove Forest Reserve in Perak, Malaysia has been sustained since 1902 (Gan 1995). Roughly 1050 ha of forests are clear felled annually over a 30-year rotation cycle, with an average yield of 17.4 t ha^{-1} yr^{-1} (Gan 1995). The commercial purpose of forest harvesting affects river water.

This study is conducted given the dearth of studies on the impacts of human activities on mangrove hydrology in Malaysia. It was designed to examine the water physicochemical characteristics of the Matang Mangrove prior to disturbances from forest harvesting and aquaculture activities. Such study is necessary and well-timed considering distinct threats to mangrove existence from increasing population growth, global warming, aquaculture, and industrial and urban development.

METHODOLOGY

Study site

Matang Mangrove is located in the district of Matang, about 17 km from Taiping, in the state of Perak. This area is located in the northwest of Peninsular Malaysia, bounded by latitudes 4º 55' N and longitudes 100º 21' E and 100º 30' E. Matang Mangrove covers about 40,288 hectares and it has been recognised as one of the most well-managed mangrove forests in the world under sustainable management by the State Forestry Department of Perak for timber production since 1902. Matang Mangrove experiences a year-round warm, humid climate. Rainfall ranges 2,000-2,800 mm/year. The average air temperature ranges from a minimum of 22ºC at night to a maximum of 33ºC during the day (Roslan & Nik Mohd Shah 2013).

Sampling design

The study was conducted at Kuala Sepetang, Kuala Trong and Sungai Kerang (Figure 1). All the three areas have different disturbance levels according to remote sensing analysis on canopy cover and extent of aquaculture activities in each area (Table 1). Four main rivers were selected for the study which represents the three main areas of the Matang Mangrove Forest Reserve (Table 2). The locations of the rivers (Figure 2) and their sampling points with GPS coordinates is given in Table 3. The most important activity of concern is the aquaculture activity with areas extending gradually from year to year (Table 1). Statistical analysis used for this study were mainly Descriptive Statistic to describe the data, 3 ways Analysis of Variance (ANOVA) to determine the interaction between physicochemical parameters with respect to different rivers, seasons and tides and Pearson Correlation to show the strength and relationship among the variables.

Water sampling was conducted during the dry (June and July) and wet (November and December) seasons. Water measurements were taken during both ebb and flood tides between 7 am to 11 am for the former and between 1 pm and 4 pm for the latter. Total Suspended Solids (TSS) was determined in the lab as per the Standard Methods for the Examination of Water and Wastewater (APHA, 2005) while other water physicochemical parameters (EC, DO, pH, turbidity, TDS, salinity and temperature) were recorded *in situ*.

Figure 1. Matang Mangrove Forest showing the three main study sites

Table 1. The total area of cockle culture, net cage fish culture and aquaculture ponds within or adjacent to Matang Mangrove, in 2011 compared to 2000 (in parentheses) (Perak Fisheries Department 2012; Roslan & Nik Mohd Shah 2013).

Areas	Total Area (ha)	Cockle Culture (ha)	Net Cage fin fish (ha)	Aquaculture ponds (ha)	Percentage (%)
Kuala Sepetang	21,188	2,138 (2,234)	1.27 (2.9)	56.5 (42)	10.36
Kuala Trong	10,674	412 (708)	0.64 (0.4)	85.8 (31)	4.67
Sungai Kerang	8,426	437 133)	1.13 (0.9)	53.3 (5)	5.83
Total	**40,288**	**2,987 (3,075)**	**3.34 (4.2)**	**196 (78)**	**7.9**

The basis of sampling was in low and high tide with three replications for each measurement. Each stations were visited two times for each seasons. The time of sampling depends on the tide which is for low tide, the measurement and water samples were collected mainly between 7 a.m. to 11 a.m., while, for high tide, the samples were collected mainly between 1 p.m. to 4 p.m. The measurements for physicochemical water quality parameters were in-situ measurements except for Total Suspended Solids (TSS) that requires laboratory analysis according to the Standard Methods for the Examination of Water and Wastewater (APHA 2005). The in situ measurements were conducted using YSI300 EC Meter to measure EC, temperature, salinity and TDS, while HANNA Instruments 9829 Multiparameters were used to measure DO and pH.

Table 2. List of rivers sampled in the study which shows differences in disturbance levels.

Areas	Rivers	Disturbance level	No. of stations
Kuala Trong	Sungai Tiram Laut	Least disturbed	5
Sungai Kerang	Sungai Jarum Mas Sungai Tinggi	Moderately disturbed	6 5
Kuala Sepetang	Sungai Sepetang	Most disturbed	8

Table 3. Rivers and their precise water sampling stations

River	Station	Coordinates	
Sungai Tiram Laut	STR1	N 04° 43' 13.1"	E 100° 35' 32.1"
	STR2	N 04° 44' 00.6"	E 100° 36' 41.4"
	STR3	N 04° 44' 19.4"	E 100° 37' 28.7"
	STR4	N 04° 44' 21.4"	E 100° 38' 11.6"
	STR5	N 04° 43' 45.9"	E 100° 38' 31.6"
Sungai Jarum Mas	SJM1	N 04° 35' 41.5"	E 100° 38' 48.5"
	SJM2	N 04° 35' 57.6"	E 100° 38' 34.4"
	SJM3	N 04° 35' 43.6"	E 100° 38' 14.3"
	SJM4	N 04° 35' 33.1"	E 100° 37' 49.4"
	SJM5	N 04° 35' 10.7"	E 100° 37' 37.2"
	SJM6	N 04° 36' 10.1"	E 100° 38' 19.4"
Sungai Tinggi	STG1	N 04° 35' 59.0"	E 100° 39' 42.2"
	STG2	N 04° 36' 42.2"	E 100° 39' 26.7"
	STG3	N 04° 37' 28.8"	E 100° 38' 47.2"
	STG4	N 04° 38' 01.1"	E 100° 38' 10.7"
	STG5	N 04° 38' 22.8"	E 100° 37' 37.5"
Sungai Sepetang	SSP1	N 04° 53' 18.0"	E 100° 38' 02.5"
	SSP2	N 04° 52' 30.8"	E 100° 38' 05.4"
	SSP3	N 04° 52' 11.6"	E 100° 37' 35.1"
	SSP4	N 04° 51' 35.41"	E 100° 37' 28.18"
	SSP5	N 04° 50' 48.4"	E 100° 37' 28.0"
	SSP6	N 04° 49' 37.2"	E 100° 37' 42.1"
	SSP7	N 04° 48' 42.8"	E 100° 37' 22.8"
	SSP8	N 04° 48' 08.0"	E 100° 37' 32.6"

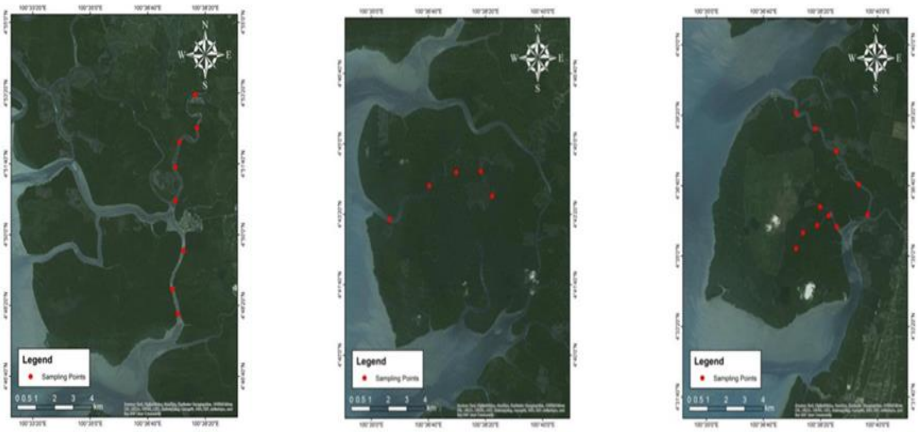

Figure 2. The Matang Mangrove Forest showing the three main study sites (Kuala Sepetang, Kuala Trong & Sungai Kerang)

RESULTS AND DISCUSSION

Descriptive statistical analysis was carried out as in Table 4. A three way ANOVA was run on 576 data for each physicochemical parameter to examine the effect of different seasons, tides and rivers on each parameter. There is a statistically significant three way interaction between seasons, rivers and tides for pH [F (3,560) = 8.186, p = 0.000], Total Dissolved Solids (TDS) [F (3,560)=3.118, p =0.026], respectively (Table 5). The significant difference between seasons and tides denotes the seasonal and tidal variation in hydrology in the Matang Mongrive as proposed by Mohammad et al. (2013).

Dissolved Oxygen (DO) refers to the oxygen content in water bodies. The higher the DO, the better the water quality (Brönmark & Hansson 2005). DO is positively correlated with TDS, TSS and temperature (r=0.542, 0.273 and 0.430 respectively, p<0.01) (Table 6). The DO reading in the dry season was higher than the wet season for all four rivers (Figure 3a). In the dry season, lowest DO was recorded in Sungai Sepetang (mean: 4.04 ± 0.23mg/L) and the highest was recorded in Sungai Jarum Mas (mean: 5.69 ± 0.45 mg/L). While, in the wet season, the lowest reading was recorded in Sungai Sepetang (mean: 2.78 ± 0.27 mg/L), and the highest was recorded in Sungai Tinggi (mean: 4.41 ± 0.31 mg/L). Higher DO from this study during the dry season contradicts with most studies (Saifullah et al. 2014; Vijaya & Vijaya 2013) possibly because, in the dry season, river water is shallow with less decomposition as compared to during the wet season, resulting in higher DO levels. Furthermore, the decrease in water temperature and respiratory activities of aquatic creatures and vegetation as well as the aerobic process by microorganisms will result in increased oxygen content (Nasir 2012). Vijaya & Vijaya (2013) stated that higher values of DO were recorded in Kundapura Mangrove Forest, Karnataka, India during the monsoon (wet) season and relatively lower values during the summer (dry) season due to the influence of rainfall.

Temperature is important biologically and plays an important role in the metabolic activities of organisms (Sirajudeen & Mubashir 2013). Temperature was positively correlated with Salinity, DO, Turbidity, TDS and TSS (r=0.315, 0.430, 0.189 and 0.291 respectively, p<0.01) (Table 6). Water temperature had a higher reading in the dry season as compared to the wet season for all the rivers except for Sungai Tiram Laut (Figure 3b). The difference was slight and did not exceed 1 ºC. In dry season, the lowest temperature was recorded in Sungai Jarum Mas (mean: 29.55 ± 0.14 ºC) and the highest was recorded in Sungai Tinggi (mean: 30.40 ± 0.11 ºC). In the wet season, the lowest temperature was recorded in Sungai Sepetang (mean: 28.76 ± 0.16 ºC) and the highest was recorded in Sungai Tinggi (mean: 30.38 ± 0.16 ºC). Water temperature is influenced by canopy cover (Seca 2015), river width and time of sampling. Sungai Tinggi is a broader river lacking canopy cover. In relation of time of sampling, most of the readings that recorded higher temperature were taken in the afternoon.

The pH did not show any significant correlation with other water parameters (Table 6). pH was high in the wet season as compared to the dry season for all rivers (Figure 3c). pH during the dry season was lowest in Sungai Tiram Laut (mean: 6.9 ± 0.06) and highest in Sungai Jarum Mas (mean: 7.4 ± 0.11). During the wet season, the lowest pH was recorded in Sungai Sepetang (mean: 7.6 ± 0.07) and the highest was recorded in Sungai Jarum Mas (mean: 8.2 ± 0.09). During the wet season, the pH values were relatively higher due to river discharge from rainfall which promotes alkaline water. Seca et al. (2014) states in mangrove ecosystem, water with a high and low pH might be unsafe to aquatic life, therefore suggested that neutral pH (6.91-7.51) is best water condition for fish and other aquatic life as found in his study.

The EC did not show any significant correlation with any of the water parameters (Table 6). EC in the dry season was higher than during the wet season in all rivers except for Sungai Sepetang (Figure 3d). Higher values in the dry season may be due to a decrease of fresh water flow and high evaporation rate, which may significantly increase the concentration of dissolved conducting minerals (Mohammad et al. 2013). In the dry season, the lowest readings were recorded in Sungai Sepetang (mean: 37.14 ± 7.74 µS/ cm) and the highest was recorded in Sungai Tinggi (mean: 44.22 ± 0.75 µS/cm). During the wet season, the lowest EC reading was in Sungai Jarum Mas (mean: 29.63 ± 0.71 µS/ cm), while the highest was in Sungai Sepetang (mean: 63.73 + 18.48 µS/ cm). The variations in EC values can be due to fresh water influx and a mixing with saline waters during flood and ebb flows. Chong (2006) is of the opinion that the variation of EC in Sungai Sepetang is due to dissolved nutrients and other dissolved ions from industry effluents into Sungai Sepetang.

The TDS was found to be positively correlated with TSS and Temperature ($r=0.444$ and 0.291 respectively, $p<0.01$) (Table 6). TDS values were higher during the dry season as compared to the wet season for all the rivers (Figure 3e). In the dry season, the lowest values was recorded in Sungai Sepetang (mean: 12.44 ± 1.07 g/L) and the highest was recorded in Sungai Tinggi (26.91 ± 0.49 g/L). While for the wet season, the lowest was also recorded in Sungai Sepetang (mean: 5.39 ± 1.24 g/L) and the highest was recorded in Sungai Tiram Laut (mean: 21.78 ± 0.24 g/L). Mohammad et al. (2013) showed that TDS ranged from 22.2 to 24.4 g/L in the summer season, while it ranged 40.0 to 53.3 g/L in the rainy season at Passur River in Sundarban Mangrove in Bangladesh, the. This, however, is contrast to the results from the current study. The results from this study revealed that there is a distinct variation of TDS for different seasons. Theoretically, TDS concentration is related directly to EC. All four rivers in Matang recorded low concentrations of dissolved solids in their water bodies as their conductivity was low.

Salinity was positively correlated with DO, TDS, TSS and Temperature ($r=0.560$, 0.990, 0.452 and 0.315 respectively, $p<0.01$) (Table 6). Salinity was higher during the dry season as compared to the wet season (Figure 3f). For the dry season, Sungai Sepetang recorded the lowest values (mean: 11.99 ± 1.05 ppt) while Sungai Tinggi recorded the highest (mean: 26.73 ± 0.59 ppt). For the wet season, Sungai Sepetang also recorded the lowest value (mean: 2.64 ± 0.39 ppt) while Sungai Tiram Laut recorded the highest (mean: 20.88 ± 0.26 ppt). The low salinity in Sungai Sepetang compared to other rivers provide evidence that it was the most disturbed area with human activities such as plantation, aquaculture and tourism. A study in Sundarban Mangrove by Mohammad et al. (2013) showed that the salinity was 1 to 20 ppt throughout the whole year, were in range of this data with the maximum salinity was observed in summer. Salinity in the mangrove is affected by the mixing of seawater freshwater flow.

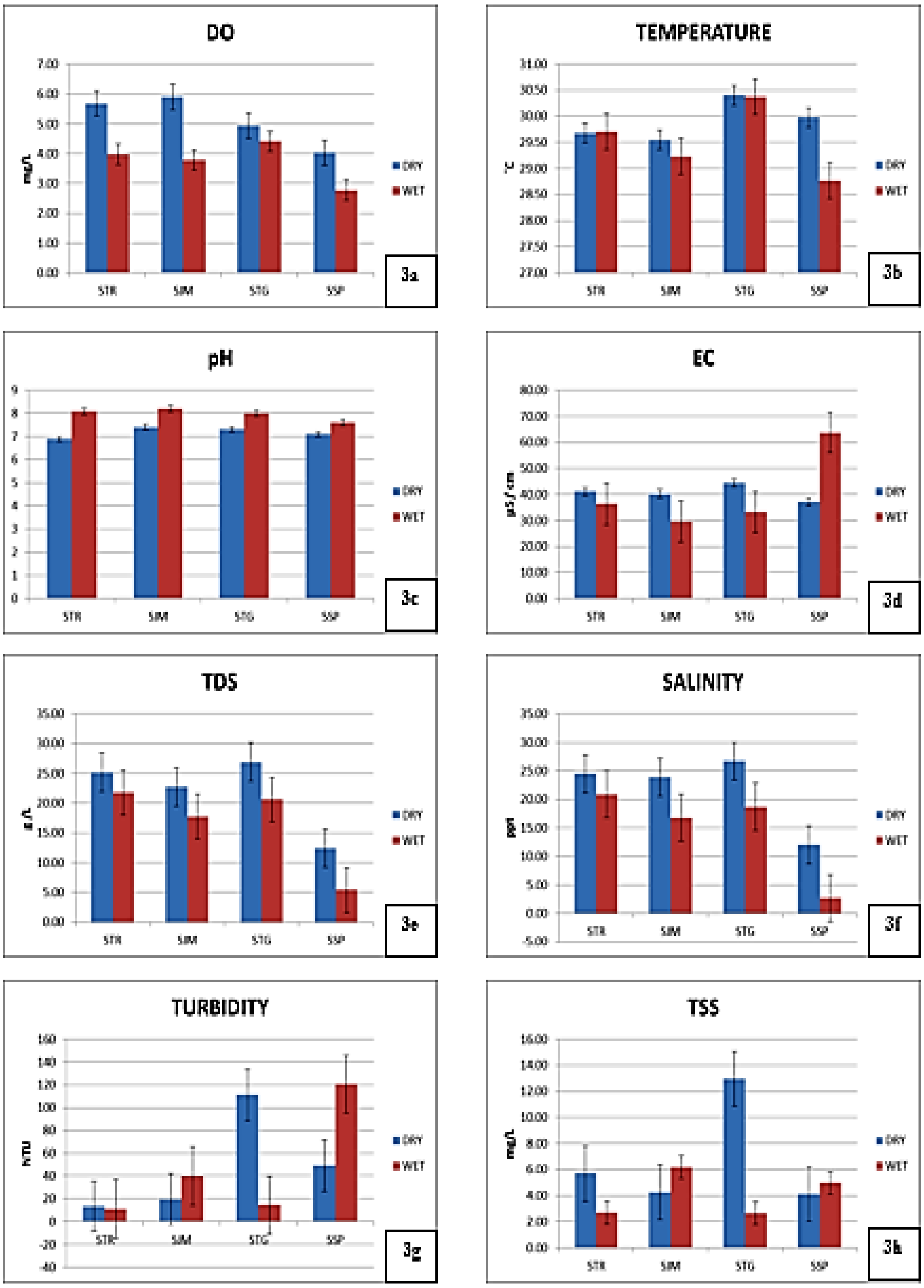

Figure 3. The variation of water physicochemical parameters with Standard Error during the dry and wet season for four rivers in Matang Mangrove (DO Dissolved Oxygen; EC - Electric Conductivity; TDS -Total Dissolved Solids; TSS - Total Suspended Solids; STR - Sg. Tiram Laut; SJM - Sg. Jarum Mas; STG - Sg. Tinggi; SSP - Sungai Sepetang).

Table 5. The summary of three way ANOVA for physicochemical analysis between seasons, rivers and tide.

Physicochemical Variables	Sources	Type III Sum of Squares	df	Mean Square	F	Sig.
EC	season * river	41120.282	3	13706.761	3.860	.009*
	season * tide	1695.105	1	1695.105	.477	.490
	river * tide	11990.795	3	3996.932	1.126	.338
	season * river * tide	8635.270	3	2878.423	.811	.488
DO	season * river	45.071	3	15.024	3.328	.019*
	season * tide	2.573	1	2.573	.570	.451
	river * tide	33.244	3	11.081	2.455	.062
	season * river * tide	28.473	3	9.491	2.103	.099
pH	season * river	8.726	3	2.909	11.505	.000*
	season * tide	.061	1	.061	.240	.624
	river * tide	6.660	3	2.220	8.782	.000*
	season * river * tide	6.209	3	2.070	8.186	.000*
Turbidity	season * river	531260.265	3	177086.755	40.013	.000*
	season * tide	11990.447	1	11990.447	2.709	.100
	river * tide	51036.102	3	17012.034	3.844	.010
	season * river * tide	31189.681	3	10396.560	2.349	.072
TDS	season * river	261.961	3	87.320	2.678	.046*
	season * tide	3.255	1	3.255	.100	.752
	river * tide	151.255	3	50.418	1.546	.202
TDS	season * river * tide	305.081	3	101.694	3.118	.026*
Salinity	season * river	632.177	3	210.726	13.214	.000*
	season * tide	10.636	1	10.636	.667	.414
	river * tide	121.673	3	40.558	2.543	.055
	season * river * tide	32.727	3	10.909	.684	.562
Temperature	season * river	49.823	3	16.608	15.175	.000*
	season * tide	64.150	1	64.150	58.614	.000*
	river * tide	12.813	3	4.271	3.902	.009*
	season * river * tide	2.658	3	.886	.810	.489
TSS	season * river	3063.443	3	1021.148	36.410	.000*
	season * tide	1.813	1	1.813	.065	.799
	river * tide	136.142	3	45.381	1.618	.184
	season * river * tide	260.559	3	86.853	3.097	.026*

*significant at p>0.05

Turbidity showed positive relationship with TSS and temperature (r=0.684 and 0.189 respectively, p<0.01(Table 6). Sungai Tiram Laut and Sungai Tinggi recorded higher turbidity in dry season than wet season, while Sungai Jarum Mas and Sungai Sepetang recorded higher turbidity during the wet season. Sungai Tiram Laut (mean: 13.40 ± 1.99 NTU) recorded the lowest value during the dry season while the highest was in Sungai Tinggi (mean: 111.26 ± 15.60 NTU) (Figure 3g). Sungai Tiram Laut (mean: 11.07 ± 1.35 NTU) recorded the lowest value during the wet season while the highest was in Sungai Sepetang (mean: 120.56 ± 17.80 NTU). The large difference of turbidity between the wet and dry seasons in Sungai Tinggi was probably due to rainwater flushing during the wet season which may have increased water turbidity. The results were in line with Toriman et al. (2013) that they found that with average from 5.44 to 7.78 in dry season and 6.65 to 10.67 NTU in wet season, which is in good agreement with Sungai Tiram Laut.

The TSS showed positive relationship with temperature (r=0.283, p<0.01). TSS was higher in the dry season in Sungai Tiram Laut and Sungai Tinggi (Figure 3h) while it was higher in the wet season for Sungai Jarum Mas and Sungai Sepetang. The relatively higher TSS in Sungai Tinggi may be due to less freshwater flow, bank erosion and forest litter. TSS was lowest in Sungai Sepetang (mean: 4.11 ± 0.61 mg/L), and highest in Sungai Tinggi (mean: 12.99 ± 1.85 mg/L) during the dry season and lowest in Sungai Tinggi (mean: 2.65 ± 0.27 mg/L) and highest in Sungai Jarum Mas (mean: 6.19 ± 0.66 mg/L) during the wet season. The range of the TSS in the rivers for both the dry and wet seasons was below the limit of the Water Quality Standard of EPA (2001) which is 50 mg/L.

Table 6. Pearson correlation coefficient (r) between water physicochemical parameters

	Salinity	pH	EC	DO	Turb.	TDS	TSS	Temp.
Salinity	1							
pH	0.077	1						
EC	-0.009	-0.003	1					
DO	0.560**	0.145*	0.021	1				
Turb.	0.111	0.047	0.005	0.043	1			
TDS	0.990**	0.062	-0.046	0.542**	0.114	1		
TSS	0.452**	0.087	0.019	0.273**	0.684**	0.444**	1	
Temp.	0.315**	0.000	-0.028	0.430**	0.189**	0.291**	0.283**	1

** Correlation is significant at the 0.01 level; * correlation is significant at the 0.05 level.

The findings illustrate the seasonal and tidal variation of physicochemical characters of water in Matang Mangrove. The conditions of the water were affected by the upstream activities particularly in Sungai Sepetang (i.e. aquaculture, agriculture, human settlements and tourism) (Azahar & Nik Mohd Shah 2003). It was apparently demonstrated by the values of critical parameters such as Dissolved Oxygen, Turbidity and Total Suspended Solids. Our finding is consistent with findings by Vijaya & Vijaya (2013) where they state that intense pollution from both agricultural inputs and shrimp culture in Kundapura Mangrove Forest in Karnataka, India is one of reasons of deterioration of water quality in mangrove. Moreover, Saifullah et al. (2014) also found that low anthropogenic disturbance in Kuala Sibuti River Estuary in Sarawak could be a plausible reason that kept the water quality in its best condition. Their studies suggested that the effect of anthropogenic affect could be the reason of water quality deterioration in mangrove.

CONCLUSIONS

The present study highlights a pronounced variation for most of the physicochemical parameters with variation in season and geographical location within the Matang mangroves. As the season changes, there is a fluctuation in the physicochemical characters of the water. This may be due to ebb and flow, flushing of rainwater, changes in temperature and salinity as seasons change. The present information on the physicochemical characteristics of water would form a useful tool for further ecological assessment and monitoring of the mangrove ecosystems.This study confirmed that the water quality in the coastal area of Matang is deteriorating. There are numerous causes including increasing number of industries in the neighbouring region, aquaculture, and global climate change, which are responsible for deteriorating the water quality in this vast and diverse forest. The present study provided invaluable information for a better conservation and management policy at Matang Mangrove.

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