Journal of Fundamental and Applied Sciences

ISSN 1112-9867

Available online at http://www.jfas.info

Research Article

Special Issue

THE ASSESSMENT OF PHYSICO-CHEMICAL AND BIOLOGICAL WATER QUALITY CHARACTERISTICS OF THE IBAI RIVER BETWEEN WET AND DRY SEASONS, KUALA TERENGGANU, MALAYSIA

O. M. A. Laila[1], M. B. Gasim[1,2,*], M. E. Toriman[3] and M. A. A. Hassan[1]

[1]East Coast Environmental Research Institute (ESERI), Universiti Sultan Zainal Abidin, Gong Badak Campus, 21300 Kuala Nerus, Terengganu, Malaysia.

[2]Faculty of Bio Resources and Food Industries Universiti Sultan Zainal Abidin, Tembila Campus, 22200 Besut, Terengganu, Malaysia

[3]School of Social, Development and Environmental Studies, Faculty of Social Sciences and Humanities, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

Published online: 15 January 2018

ABSTRACT

The environmental study was carried to evaluate the condition of Ibai River, Kuala Terengganu, at East Coast of Peninsular. The objectives of this study are to determine physico-chemical, biological of water quality and classify them and to determine the spatial-temporal relationship based on one way ANOVA, regression and correlation analysis. 3 sampling stations were selected in this study to represent the water quality condition of the river. The 2005 to 2010 data of eleven water quality parameters: TSS, BOD, AN, COD, DO, TEMP, EC, SAL, TUR, NO_3 and pH were analyzed. Under the statistical approach, all the calculations were done at 5% level of significant. The results show that most of stations were classified as slightly polluted (Class II) during dry season. During wet season, almost all stations were classified as moderate polluted (Class III) even at station 2 in 2009 were classified as polluted (Class V) due to very low WQI (24%).

Keywords: Ibai River; water quality parameters; water pollution; WQI; NWQS.

Author Correspondence, e-mail: drbarzani@gmail.com

doi: http://dx.doi.org/10.4314/jfas.v10i1s.28

1. INTRODUCTION

Water is the most important element for life. Water sources in Malaysia are dependent on rainfall, an average annual rainfall being between 2000 mm and 2500 mm. Total water usage is estimated to be 14 billion cubic meters by 2020 [1]. Water quality is generally described according to biological, chemical and physical properties [2]. Water quality is determined by the physical and chemical limnology and includes all physical, chemical and biological factors of water that influence the beneficial use of the water [3]. About one third of the drinking water requirement of the world is obtained from surface sources like rivers, canals and lakes [4]. Natural water quality varies markedly and is affected by the biology, geology and hydroclimatic characteristics of the area [5]. The surface water quality is influenced by both natural (precipitation rate, weathering processes and soil erosion) and anthropogenic (urban, industrial, agricultural activities) and are increasing exploitation of water resources [6]. In Malaysia, the riverine ecosystem is become particular interest since river water provides about 98% of the country's water requirements [2]. More consideration has been paid to surface water quality as a result of its solid linkage with human prosperity [7]. Therefore, contamination of river waters poses a serious health risk to the public. The monitoring of river water quality is under the responsibility of the Department of Environment Malaysia [8]. The destruction of catchment area will lead to the deterioration in quality and quantity of the water resource. Furthermore, water quality classification is important in determining drinking water supply, irrigation, fish production, recreation and other purposes to which the water must have been impounded downstream [9]. There are two main factors that have been identified as natural pollutants contributed to deterioration of water quality including urban runoff and agricultural runoff, which are loaded by high concentrations of organic and inorganic pollutants [10]. These factors can result in flooding due to river incapable to support large quantity and immediate surface runoff during heavy rain. Furthermore, the characteristic of catchment area may influence on the rate and quantity of flow rate [11]. Generally, rivers are particularly vulnerable to land use change and ubiquitous exploitation [12-13]. Anthropogenic activities are directly reflected in land use characteristics [14].

This study adopted the DOE-WQI tool to evaluate the water quality of the Ibai Terengganu River Basin. In addition, the beneficial use of the water was also compared with the classification based on the National Water Quality Standards (NWQS). Possible sources from anthropogenic activities, which influenced the water quality were also given rivers are particularly vulnerable to land use change and ubiquitous exploitation [15]. The deterioration of river water quality due to unsustainable human activities has become a key to the environmental concern. In [16] mentioned that further complexity is introduced by seasonal flows, which alter the magnitude of land-water interactions in tropical and subtropical countries. Previous studies have suggested that alterations in water quality by land use would have greater impacts on tropical and subtropical countries than those already observed in North American and Europe watersheds [17]. High population and rapid urbanization and industrialization have effects of reducing the water quality of rivers because of indiscriminate dumping of wastes by all water user sectors into the rivers, whilst the increased rate of erosion as a result of land development causes siltation of the rivers [18].

The Ibai River plays an essential role in the daily lives of local people as it supplies water for irrigation of agricultural land and support fresh water aquaculture. It also provides water for domestic usage, for which intake points are built along the riverbanks to extract raw water for the concept of Integrated River Basin Management (IRBM) to be realized in Malaysia, inter-agency cooperation, resource sharing and coordination must first be achieved. Although DID and DOE are currently under the same provisional cluster in the federal government now, integration or cooperative ties between the two in relation to IRBM implementation has been relatively slow [19]. Finally, the objectives of this study are to determine physico-chemical and biological of water quality and classify them to determine the spatial-temporal relationship based on one way ANOVA and regression and correlation analyses under the statistical approach.

2. METHODOLOGY

2.1. Study Area

Ibai River Basin is one of basins in the district of Kuala Terengganu. It covers an area of 94 catchment areas km². The river lies between longitude 101° 48'32.9 "E to 101°52'30.5 "E and latitude 02° 54'14.9 "N to 03 ° 03'23.1 "N (Fig. 1). Average annual rainfall in the area is about 3 000 mm. The basin consists of Ibai River as the main river along the tributaries that flow there such as Pak Su Man River, Serai River, Udang River, Laca River and the Crocodile River. Formerly, the basin consist of agricultural activity that are located in the upper reaches of the river basin, other activities are municipal and settlements that are more concentrated in the area upstream to downstream. In addition, there are industrial areas located near the estuary, known as Regions Industrial Centering.

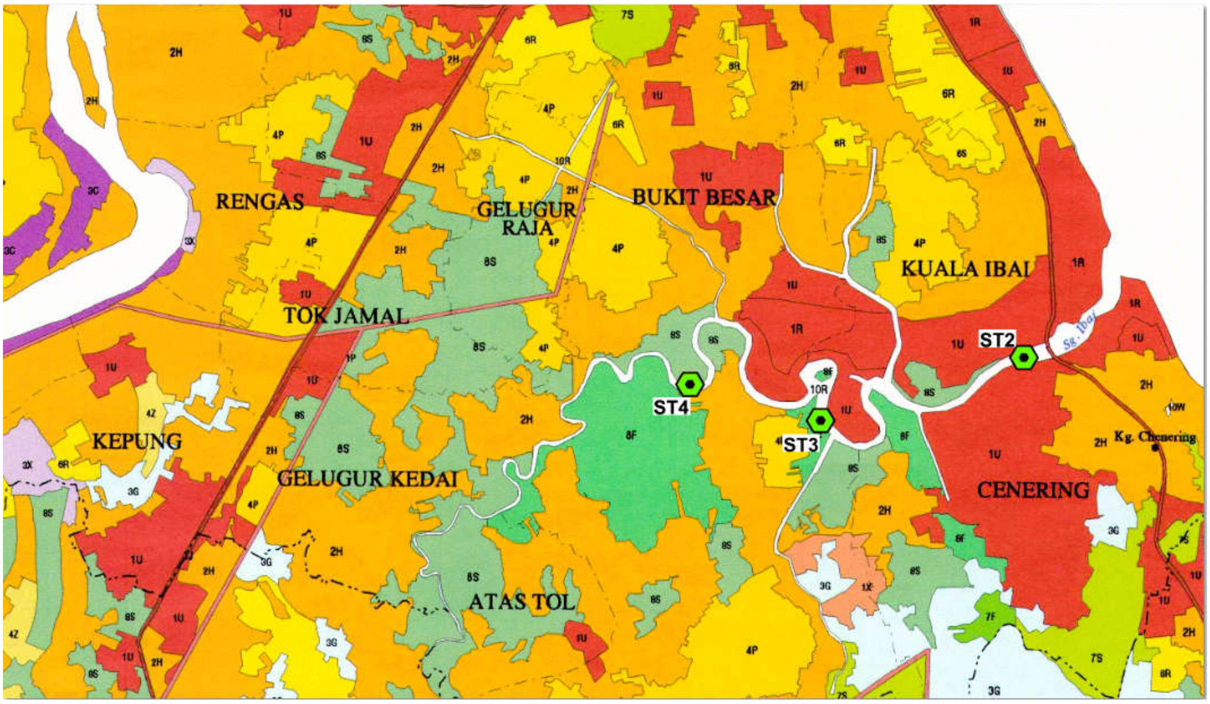

Fig.1. Map of study area which shows the distribution of three sampling locations

2.2. Water Quality Data

The 2005 to 2010 water quality data of Ibai River were obtained from the Malaysian Department of Environment (DOE). The eleven selected water quality parameters that involved in this study are Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), Ammoniacal Nitrogen (AN), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Temperature (T), Electrical Conductivity (EC), Salinity (SAL), Turbidity (TURB), Nitrate (NO3) and pH. Three stations that are relevant to the study area were chosen and selected in this study to compare the water quality of the river between two different times, they are station 2 (downstream), station 3(middle) and station 4 (upstream) based on 2005-2010 water quality data sampling that carried out by DOE (Fig. 1).

2.3. Statistical Analysis Methods

Correlation analysis was used to find the relationships among the eleven water quality parameters. Statistical analysis was fulfilled using EXCEL 2007 and SPSS version 22 and the data were interpreted using single factor analysis of variance (one way-ANOVA, $p < 0.05$) to measure the variation of water quality parameter between dry and wet seasons. The range, mean values and standard deviations of the eleven water quality parameters were analyzed in this study.

Significant differences ($p < 0.05$) for the eleven water quality parameters between dry and wet seasons were identified.

3. RESULTS AND DISCUSSION

3.1. Water Quality Parameters

The results from water quality condition based on in-situ parameters were obtained from three sampling stations for the physical characteristics for the six are shown in Fig. 2 and Table 1, while the results of water quality based on laboratory analysis for the five water quality parameters were represented in Fig. 3 and Table 2.

3.2. In-Situ Parameters

3.2.1. Temperature

In the variation of temperature during dry season was from 26 to 31.11, the minimum was at St.2 (2006) and the maximum was at St.2 (2009) (Fig. 2a). During the rainy season, temperature varied from 28.35 to 31.48°C, the lowest was observed at St.4, while the highest was at St.2 (Fig. 2a). The statistical analysis showed that there were a significant ($P < 0.05$) of mean temperature levels between sampling times (df = 5, F =2.690, P = 0.074), (df = 5, F =6.655, P = 0.003) during dry and wet seasons respectively (Table1). The temperature values were recorded at the Ibai River and classified as Class IIA of the NWQS. The temperature was one of the physical properties that influenced the rate of chemical reactions as stated by [20].

3.2.2. pH

The values of pH during dry season were ranging from 5.90 to 7.48. The highest was recorded at St.4 (2007), and the lowest was at St.2 (2008) (Fig. 2b). pH concentrations during wet season ranged from 5.74 to 7.32. The highest was recorded at St.3 (2010) and the lowest was at St.2 (2005) (Fig. 2b). Statistical analysis of one-way ANOVA revealed that there are significant differences ($P < 0.05$) in pH between time during dry season (df = 5, F =2.737, P = 0.071) and there were ($P < 0.05$) in pH between time during wet season (df = 5, F =9.735, P = 0.001) as seen in Table 1. pH values were within the class I of the NWQS. Overall, the range of pH from 6.5-9 is mainly appropriate for aquatic life. Therefore, it is very important to maintain the aquatic ecosystem within this range because high and low pH can be destructive in aquatic ecosystems [21].

3.2.3. Electrical Conductivity

During dry season, conductivity varied from 228.50 to 336555.00 μs/cm and the highest value was recorded at St.4 (2007) and the lowest was at St.3 (2010) (Fig. 2c). Conductivity during wet season was from 66.50 to 4513μs/cm, the highest was observed at St.4 and the lowest was at St.3 (Fig. 2c). There are significantly correlated between EC and salinity during dry and wet seasons, but no significantly different of EC between times (ANOVA, $P > 0.05$) as show in Table 1 and 3. The conductivity was felt into the class V of the NWQS. Generally, most of the freshwater conductivity ranges from 10-1000 μS/cm. However, the concentration can exceed 1000 μS/cm in water that receives pollution [22].

3.2.4. Dissolved Oxygen (DO)

DO concentration during dry season are ranged from 3.89 to 6.31mg/L, the lowest was at St.3 (2006) (Fig. 2e) while the highest was recorded at St.4 (2005) (Fig. 2d). DO values ranged from 2.47 to 5.79mg/L during wet season, the highest value was recorded at St.4 (2007) (Fig. 2d), while the lowest was at St.2 (2009) (Fig. 2d). There are significantly negative correlated between DO with turbidity, BOD, COD and TSS during wet season but no significant differences between times (ANOVA, $P > 0.05$) as seen in Table 1 and 3. The DO values were within the class I of the NWQS.

3.2.5. Salinity

Variation of salinity during dry season was from 0 to 22.86 ppt. The highest value was recorded at St.4 (2007) and the lowest value was at St.3 (2009) (Fig. 2e). Salinity concentrations during wet season ranged from 0.03to 29.26 ppt. The highest was recorded at St.4 (2007) and the lowest was at St.3 (2008) (Fig. 2e). There are significantly correlated between salinity and EC during dry and wet seasons, but no significant differences of salinity between times (ANOVA, $P > 0.05$) as seen in Table 1. The salinity was felt within class V of the NWQS.

3.2.6. Turbidity

Distributions of turbidity values were from 1.90 to 450.0 NTU (dry) and from 3.35 to 432.70 NTU (wet) seasons respectively. St.2 (2006) recorded the lowest value and St. 3 (2006) recorded the highest value during dry season (Fig. 2f). St.4 (2005) recorded the lowest value and St.2 (2009) recorded the highest during wet season (Fig. 2f). Statistical analysis of one-way ANOVA revealed that there is significantly correlated between turbidity and TSS during wet season, but no significant differences between times (ANOVA, $P > 0.05$) as seen in Table 1 and 3. The turbidity was felt into the class V of the NWQS.

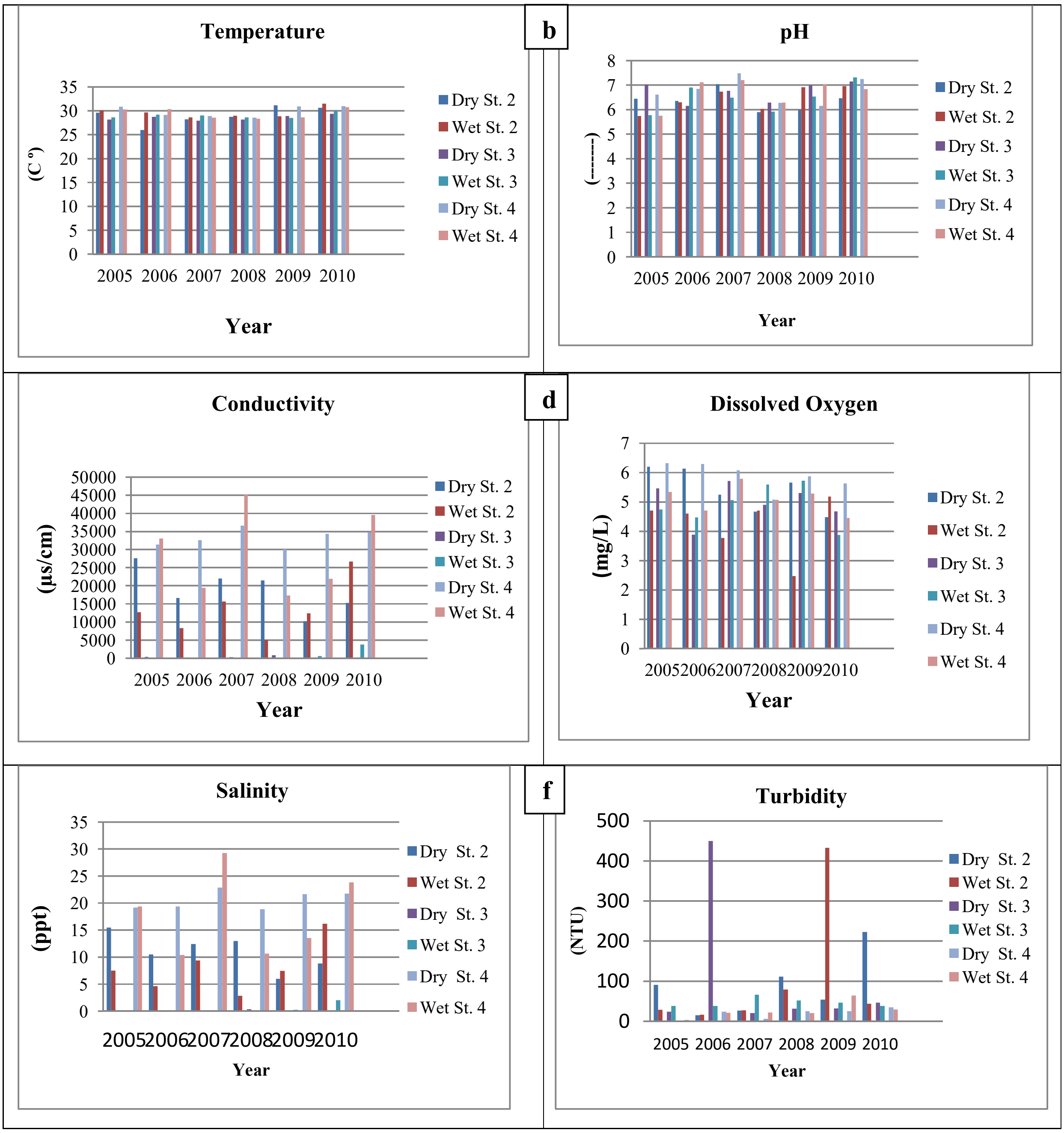

Fig.2. Distribution of physical values for (a) temperature (b) pH, (c) conductivity, (d) DO (e) salinity and (f) turbidity, between wet and dry seasons for Ibai River

Table 1. The physical characteristics of Ibai River water along different seasonal period

Parameter	Dry Season			Wet Season		
	Mean	Range	Std. Deviation	Mean	Range	Std. Deviation
Temperature	29.16	26-31.11	1.33598	29.3594	28.35-31.48	0.91922
pH	6.62	5.90-7.48	0.46	6.5483	5.74-7.32	0.53235
Dissolved Oxygen	5.42	3.89-6.31	0.69	5.1300	2.47-5.73	0.94274
Conductivity	17523.9	228.50-336555.00	14313.5	14554.2	66.50-4513	14186.7
Salinity	10.61	0.00-22.86	8.83347	8.7544	0.03-29.26	8.81872
Turbidity	70.45	1.90-450.00	107.76724	58.433	3.35-432.70	95.39105

3.3. Laboratory Analysis

3.3.1. Biochemical Oxygen Demand (BOD)

Distribution of BOD during dry season were ranged from 1.50 to 9.00mg/L, the lowest was S3 and St.4 (2007) (Fig. 3a) while the highest was at St.2 (2010 (Fig. 3a). St.3 (2007) recorded the lowest value during wet season and St.2 (2009) recorded the highest during wet season (Fig. 3a). Statistical analysis of one-way ANOVA revealed that there are ($P < 0.05$) significantly correlated of BOD with TSS during dry season (df = 5, F =2.737, P = 0.071) and correlated with BOD and turbidity during wet season (df = 5, F =9.735, P = 0.001), but there were not significantly correlated between times ($P < 0.05$) as seen in Table 2 and 3. The BOD was classified as the class V based on NWQS. In [23] mentioned that the highest concentrations of BOD5 are mostly attributed to the discharge of domestic wastes, particularly poorly executed agricultural activities and defecation activities which are located near the riverbanks.

3.3.2. Chemical Oxygen Demand (COD)

The values of COD during dry season were ranging from 12.00 to 48.50mg/L. The highest value was recorded at St.2 (2010) and the lowest was St.3 (2009) (Fig.3b). COD concentrations during wet season ranged from 11.50 to 232.00 mg/L. The highest was recorded at St.2 (2009) and the lowest was at St.3 (2010) (Fig.3b). There are significantly correlated of BOD with COD during dry season and correlated with BOD, turbidity and TSS during wet season ($P < 0.05$). There is no significant differences were found between times (ANOVA, $P > 0.05$) as seen in Table 2 and 3. COD was classified as class III of the NWQS. High values of COD indicate water pollution which linked to sewage effluents discharged from town, industry or agricultural practice [24].

3.3.3. Nitrate (NO_3)

Range of nitrate values during dry seasons was recorded from 0.01 to 0.55mg/L, the highest was at St.4 (2006) and the lowest was at St.3 and St.4 (2008, 2010) (Fig. 3c). During rainy season, NO_3 varied from 0.01 to 3.40mg/L. The lowest was observed at St.3 (2009), while the highest was at St.4 (2006) (Fig. 3c). There is no significant differences were not found between times (ANOVA, $P > 0.05$) as seen in Table 2 and 3. Based on INWQS, the nitrate was within the class I.

3.3.4. Ammonia Nitrogen

The values of $NH_3{-}N$ during dry season were ranging from 0.01 to1.00 mg/L, the highest and the lowest value obtained was recorded at St.2 and St.4 respectively (2009). $NH_3{-}N$ concentrations during wet season ranged from 0.01 to 2.6 mg/L. The highest was recorded at St.2 (2005) and the lowest concentration was at St.3 (2009) (Fig.3d). There is no significant differences were found between times (ANOVA, $P > 0.05$) as seen in Table 2 and 3. According to NQWS classification, $NH_3{-}N$ fall within class IV.

3.3.5. Total Suspended Solids (TSS)

The values of TSS concentration during dry season was from 4.00 to139.00 mg/L, St. 2 (2010) was the highest and St. 4 (2005) was the lowest (Fig. 3e). Concentration values during wet season was from 15.00 to 860 mg/L, St. 3 (2010) recorded the lowest value and St. 2 (2009) recorded the highest (Fig. 3e). There is no significant differences were found between times (ANOVA, $P > 0.05$) as seen in Table 2 and 3. TSS falls under class V according to NQWS.

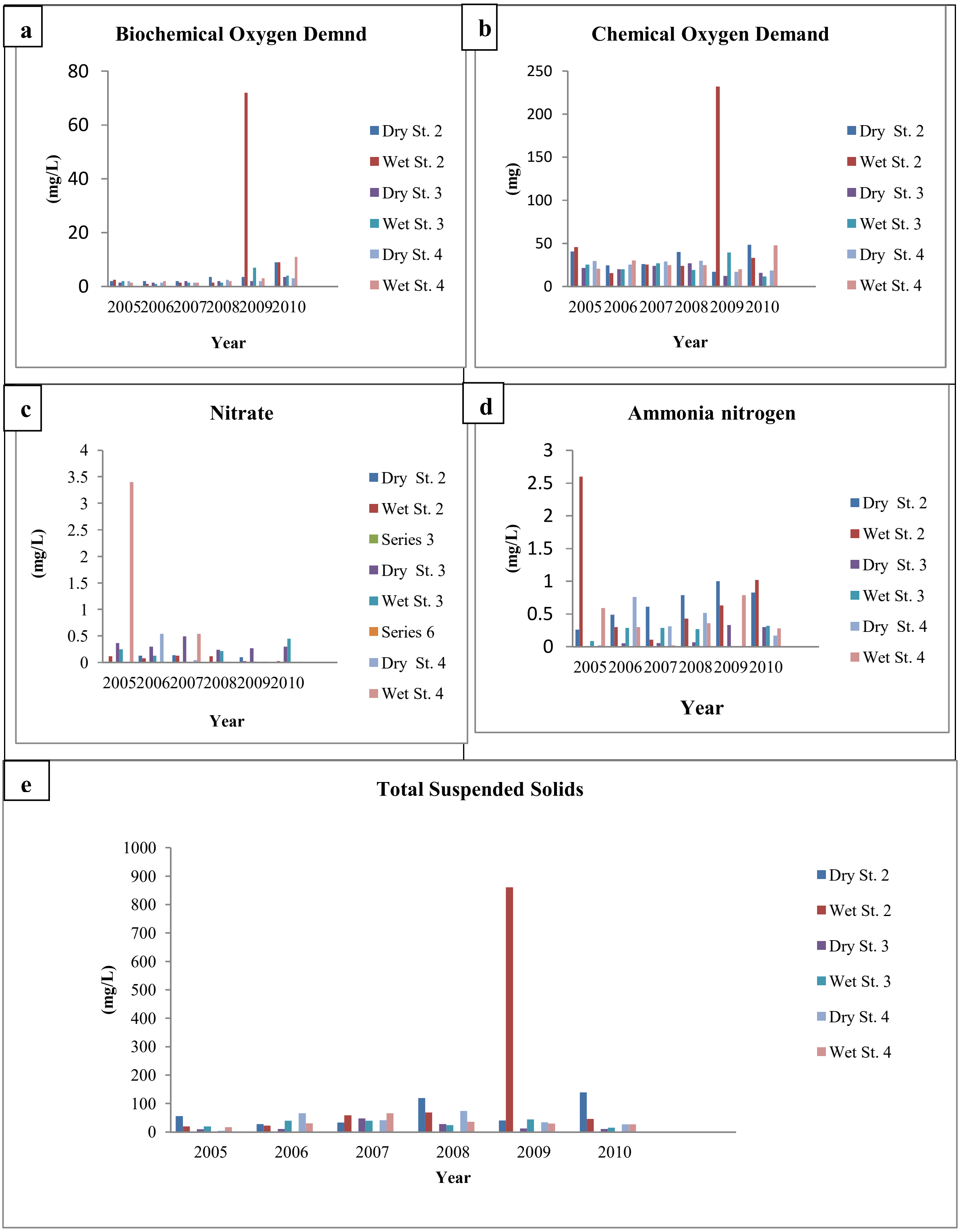

Fig.3. Distribution values for (a) BOD, (b) COD, (c) NO_3, (d) NH_3-N and (e) TSS at Ibai River between wet and dry seasons

Table 2. The chemical characteristics of five water quality parameters of Ibai River during different seasonal period

Parameter	Dry Season			Wet Season		
	Mean	Range	Std. Deviation	Mean	Range	Std. Deviation
BOD	2.6	1.5 -9.0	1.73	16.48	1.0-72.0	3.88
COD	25.9	12.0-48.5	9.4	38.1	11.5-232.0	49.3
NO_3	5.42	3.8-6.3	0.69	5.13	2.4-5.7	0.94
NH_3N	0.36	0.01-1.0	0.32	0.48	0.01-3.4	0.78
TSS	43.00	4.0-139.0	37.08	81.08	0.01-2.6	0.58

Correlation matrix of the water quality parameters between dry and wet seasons is presented in Table 3.

Table 3. The correlation matrix of water quality parameters during dry and wet seasons

	T	pH	EC	SALT	DO	COD	BOD	TURB	TSS	NO3	NH_3N
Dry Season											
T	1										
pH	-0.053	1									
EC	0.357	0.083	1								
SALT	0.354	0.085	0.998	1							
DO	0.057	0.263	0.546	0.541	1						
COD	0.017	-0.026	0.303	0.276	-0.080	1					
BOD	0.386	-0.171	-0.053	-0.062	-0.412	0.534	1				
TURB	-0.038	0.051	-0.032	-0.329	-0.188	0.233	0.282	1			
TSS	0.111	-0.355	0.262	0.246	-0.219	0.789	0.688	0.171	1		
NO_3	-0.407	0.262	-0.558	-0.561	0.032	-0.406	-0.346	0.124	-0.297	1	
NH_3-N	0.076	-0.247	0.153	0.132	-0.082	0.341	0.503	-0.028	0.651	-0.166	1
Wet Season											
T	1										
pH	0.142	1									
EC	0.378	0.299	1								
SALT	0.338	0.307	0.998	1							
DO	-0.059	-0.251	0.175	0.190	1						
COD	-0.072	0.153	0.019	0.019	-0.683	1					
BOD	-0.041	0.225	0.220	0.023	-0.698	0.987	1				
TURB	-0.840	0.189	-0.124	-0.118	-0.697	0.956	0.966	1			
TSS	-0.163	0.196	0.025	-0.020	-0.702	0.978	0.980	0.981	1		
NO_3	0.218	-0.338	0.342	0.323	0.200	-0.133	-0.121	-0.174	-0.111	1	

NH_3-N	0.387	-0.290	0.072	0.061	0.066	0.139	0.072	-0.058	0.039	0.008	1

Based on WQI results calculations on 11 water quality parameters of the three stations (2, 3 and 4) are obtained, the WQI values to be described as follows. Almost overall St. 2, 3 and 4 recorded it as slightly polluted (SP) during the dry season, but increased to moderately polluted (MP) during the wet season (Table 4). The situation here has two meanings. Firstly, during the monsoon season, the runoff has led transported all of pollutants on the surface into the river system. Secondly, as the study area is located in the coastal area, it is prone to the problem of sea water intrusion (during high tide) and the occurrence of floods. So, the complexity of this condition has led to process a substantial increase in the concentration of each water quality parameters. A significant increase occurred in 2009 at St.2 where this station recorded class II during the dry season, but then increased to class V during the wet season. There is no increase between dry to wet seasons at St.3. But, at St. 4 was increased in 2009 from class II during dry season to class III (wet season) (Table 4).

Table 4. Water Quality Index (WQI) at three stations of the Ibai River

Year	**Parameters** (WQI Sub-Index)														**Stations Classes**		**WQ Status**	
															Station 2			
	DO% Dry	**DO% Wet**	**BOD Dry**	**BOD Wet**	**COD Dry**	**COD Wet**	**SS Dry**	**SS Wet**	**pH Dry**	**pH Wet**	**AN Dry**	**AN Wet**	**WQI Dry**	**WQI Wet**	**Dry**	**Wet**	**Dry**	**Wet**
2005	81.72	65.25	2	2.5	40.5	28.3	55	19	7.21	5.74	0.26	2.6	80	70	II	III	SP	MP
2006	79.00	62.75	2	1	24.5	15.8	27.5	21.5	7.21	6.3	0.49	0.3	82	81	II	II	SP	SP
2007	62.8	43.8	2	1.5	26	27	33.5	58	6.41	6.74	0.61	0.11	76	74	II	III	SP	MP
2008	64.8	62.3	3.5	1.5	40	79.2	119	69	6.4	6.04	0.79	0.43	69	68	III	III	MP	MP
2009	78	34.20	3.5	72	17	432.	40	860	6.15	6.92	1	0.63	78	24	II	V	SL	P
2010	63.15	77.05	9	9	48.5	44.0	139	46	6.9	6.96	0.83	1.02	63	70	III	III	MP	MP
															Station 3			
															Dry	**Wet**	**Dry**	**Wet**
2005	70.8	61.45	1.5	2	21.5	25.5	9.5	19	7.01	5.77	0.01	0.09	88	81	II	II	SP	SP
2006	49.3	58.30	1.5	1	20	20	10	39.5	6.15	6.95	0.05	0.29	80	78	II	II	SP	SP
2007	67.6	65.9	2	1.5	24	27	47	39.5	6.77	6.49	0.06	0.29	83	79	II	II	SP	SP
2008	62.8	72.3	2	1.5	27	19	27	24	6.29	5.93	0.07	0.27	82	83	II	II	SP	SP
2009	69.0	70.1	2	7	12	39.5	12	44	6.99	6.53	0.33	0	85	78	II	II	SP	SP
2010	61.3	51.9	3.5	4	16	11.5	10	15	7.15	7.32	0.3	0.32	80	77	II	II	SP	SP
															Station 4			
															Dry	**Wet**	**Dry**	**Wet**
2005	93.6	79.10	2	1.5	29.5	20.5	4	16.5	6.61	5.75	0.02	0.59	91	83	II	II	SP	SP
2006	89.3	68.15	1.5	2	25.5	30.3	65.5	30.5	6.85	7.11	0.76	0.3	81	79	II	II	SP	SP
2007	82.7	88.4	1.5	1.5	29	25	41	65.5	7.48	7.21	0.31	0.02	83	87	II	II	SP	SP
2008	72.2	69.3	2.5	2	30	25	74	36	6.27	6.28	0.52	0.36	76	80	II	II	SP	SP
2009	88.6	58.25	2	3	17	20	34	29.5	6.15	7.03	0	0.79	90	75	II	III	SP	MP

2010	85.2	69.0	3	11	18.5	48	26	26.5	7.25	6.84	0.17	0.28	87	71	II	III	SL	MP
Mean													68	68	III	III	MP	MP

*DO = dissolved oxygen; BOD = biochemical oxygen demand; COD = chemical oxygen demand; AN = ammoniacal nitrogen; SS = suspended solids; C = clean; SP = Slightly polluted; MP = Moderately Polluted; P = Polluted

4. CONCLUSION

Ibai River is considering a shallow and small natural river, which has a sensitively ecosystem and very responded to the environmental changes, episodes from its surroundings. Water quality in Ibai River varies with season and the location of the sampling stations.

High precipitation during wet season can generate changes to the river water quality condition through reverse flow of flood or sea water. Significant differences in water quality were found between dry and wet seasons arising from the different pollution sources. Variation of water quality was mainly related to the seasonal changes of rainfall and inflow from upstream and salt water intrusion. During dry season, low volume and stagnant water could create eutrophic condition in the river [25]. The revival of abandoned mines had contributed to increase conductivity and sulphate concentration in the water.

Based on WQI classification, most of stations during dry season were classified as slightly polluted (Class II) and were classified during wet season almost all the stations as moderate polluted (Class III) and Class V (polluted) at station 2 (2009) due to very low WQI (24%). Under the NWQS classification, mean values of DO, pH and NO_3 were classified as class I, temperature was classified as class IIA, mean values of COD and TSS were classified as class III and finally conductivity, turbidity, salinity, NH_3-N and BOD5 were classified as class V and exceeded the permissible threshold limits of NWQS. Between the three stations, St.3 is the lowest concentration of contamination because St.2 probably receives pollution mostly from the upstream and St.4 areas receiving pollution sources from the coastal.

5. ACKNOWLEDGEMENTS

The authors would like to thank Malaysian Department of Environment for supplying the 2005 to 2010 water quality data on which this work was based.

6. REFERENCES

[1] Pillay M, Hoo T, Chu K K. Drinking water quality surveillance and safety in Malaysia for WHO workshop on drinking water quality, surveillance and safety. Country report, Kuala Lumpur: Ministry of Health, 2001

[2] Rosli N A, Zawawi M H, Bustami R A. Salak River water quality identification and classification according to physico-chemical characteristics. Procedia Engineering, 2012, 50:69-77

[3] Mustapha M K. Assessment of the water quality of Oyun Reservoir, Offa, Nigeria, using selected physico-chemical parameters. Turkish Journal of Fisheries and Aquatic Sciences, 2008, 8(2):309-319

[4] Das J, Acharya B C. Hydrology and assessment of lotic water quality in Cuttack city, India. Water, Air, and Soil Pollution, 2003, 150(1):163-175

[5] Hamzah H. Assessment on water quality and biodiversity within Sungai Batu Pahat. Master thesis, Johor: Universiti Teknologi Malaysia, 2007

[6] Singh K P, Malik A, Mohan D, Sinha S. Multivariate statistical techniques for the evaluation of spatial and temporal variations in water quality of Gomti River (India)-A case study. Water Research, 2004, 38(18):3980-3992

[7] Zhang Y, Guo F, Meng W, Wang X Q. Water quality assessment and source identification of Daliao river basin using multivariate statistical methods. Environmental Monitoring and Assessment, 2009, 152(1-4):105-121

[8] Azhar G. Managing Malaysian water resources development. Malaysian Journal of Community Health, 2000, 6:40-58

[9] Lee Y H, Shahril M H, Md Fauzan H Y, Lim C Y, Lim A G. The water quality of streams at the watershed of the Putrajaya wetlands. In Regional Symposium on Environment and Natural Resources, 2002, pp. 553-565

[10] Dalman Ö, Demirak A, Balcı A. Determination of heavy metals (Cd, Pb) and trace elements (Cu, Zn) in sediments and fish of the Southeastern Aegean Sea (Turkey) by atomic absorption spectrometry. Food Chemistry, 2006, 95(1):157-162

[11] Segura R, Arancibia V, Zúñiga M C, Pastén P. Distribution of copper, zinc, lead and cadmium concentrations in stream sediments from the Mapocho River in Santiago, Chile. Journal of Geochemical Exploration, 2006, 91(1):71-80

[12] Loukas A. Surface water quantity and quality assessment in Pinios River, Thessaly, Greece. Desalination, 2010, 250(1):266-273

[13] Iscen C F, Emiroglu Ö, Ilhan S, Arslan N, Yilmaz V, Ahiska S. Application of multivariate statistical techniques in the assessment of surface water quality in Uluabat Lake, Turkey. Environmental Monitoring and Assessment, 2008, 144(1-3):269-276

[14] Shrestha S, Kazama F. Assessment of surface water quality using multivariate statistical techniques: A case study of the Fuji river basin, Japan. Environmental Modelling and Software, 2007, 22(4):464-475

[15] Withers P J, Jarvie H P. Delivery and cycling of phosphorus in rivers: A review. Science of the Total Environment, 2008, 400(1):379-395

[16] Dudgeon D. Going with the flow: Global warming and the challenge of sustaining river ecosystems in monsoonal Asia. Water Science and Technology: Water Supply, 2007, 7(2):69-80

[17] Kao S J, Shiah F K, Owen J S. Export of dissolved inorganic nitrogen in a partially cultivated subtropical mountainous watershed in Taiwan. Water, Air, and Soil Pollution, 2004, 156(1):211-228

[18] Davis A. P., McCuen R. H. Stormwater management for smart growth. Berlin: Springer Science and Business Media, 2005

[19] Meigh J D, Bartlett J M. Integrated river basin management in Southeast Asia. Journal of Flood Risk Management, 2010, 3(3):201-209

[20] Sliva L, Williams D D. Buffer zone versus whole catchment approaches to studying land use impact on river water quality. Water Research, 2001, 35(14):3462-3472

[21] Noraini R, Seca G, Johan I, Mohd I J. Comparative study of water quality at different peat swamp forest of Batang Igan, Sibu Sarawak. American Journal of Environmental Sciences, 2010, 6(5):416-421

[22] Harun S, Abdullah M H, Mohamed M, Fikri A H, Jimmy E O. Water quality study of four streams within Maliau Basin Conservation area, Sabah, Malaysia. Journal of Tropical Biology and Conservation, 2010, 1(6):109-113

[23] Al-Sabahi E M. A study of surface water and groundwater pollution in Ibb City, Yemen. PhD thesis, Selangor: Universiti Kebangsaan Malaysia, 2007

[24] Bellos D, Sawidis T. Chemical pollution monitoring of the river pinios (Thessalia-Greece). Journal of Environmental Management, 2005, 76(4):282-292

[25] Kamarudin M K, Nalado A M, Kasmuri A, Toriman M E, Juahir H, Umar R, Jamil N R, Saudi A S, Rizman Z I, Gasim M B, Hassan A R. Assessment of river plan changes in Terengganu River using RS and GIS method. Journal of Fundamental and Applied Sciences, 2017, 9(2S):28-45

How to cite this article:
Laila OMA, Gasim MB, Toriman ME, Hassan MAA. The assessment of physico-chemical and biological water quality characteristics of the Ibai river between wet and dry seasons, Kuala Terengganu, Malaysia. J. Fundam. Appl. Sci., 2018, *10(1S), 396-411*.