Journal of Fundamental and Applied Sciences

ISSN 1112-9867

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

Research Article

Special Issue

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

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Published online: 08 August 2017

ABSTRACT

The objective of this study is to determine the physicochemical, biological condition and their water classification of the Nerus River, to identify the spatial-temporal relationship between water quality and the pollution by using statistical techniques. The methodology of the study starting with analyze of 13 of water quality parameters such as temperature, pH, DO, conductivity, TDS, salinity, turbidity, TSS, COD, BOD, NH_3-N and *E.coli*. Total of three sampling stations (station 6, 7 and 11) were selected and sampling was carried out during dry and wet seasons from 2005 to 2010. Results of the study based on WQI, the river at station 6 and 7 was classified as Class II and Class III, while Class III and Class IV for station 11.Under NWQS, the level most of the parameters remained at Class II and Class III.

Keywords: Nerus River; anthropogenic activities; water quality index; national water quality standard.

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doi: http://dx.doi.org/10.4314/jfas.v9i2s.36

1. INTRODUCTION

Water is one of among the wealthy natural resources employed by all mortals, animals, plants and alternative living beings. The surface water quality is influenced by each natural (precipitation rate, weathering processes and soil erosion) and evolution (urban, industrial, agricultural activities and increasing exploitation of water resources) factors [1]. Water quality is set by the physical, chemical and biological factors of water that influence the helpful use of the water [2]. Organic wastes are created by animals and humans and embrace such things as fecal matter and crop detritus [3]. Consistent with water quality standards, water should satisfy the quality parameter worth that is given by the World Health Organization (WHO). Malaysia is situated in the tropics between 2° and 5° north of the equator and at eastern longitude 103°E. The climate of peninsular Malaysia is very much influenced by monsoon season. The southwest monsoon occurs from May to August while the northeast monsoon occurs from November to March yearly [4-5]. The riverine ecosystem in Malaysia is of particular interest since river water provides about 98% of the country's water requirements [6]. The period of the southwest monsoon is a drier period for the whole country. While during the northwest monsoon, the eastern areas of Peninsular Malaysia receive heavier rains than the other parts in the country. The excessive concentrations of these variables may result in diverse problems in the aquatic ecosystem such as loss of oxygen, fish deaths, an increase in the extent of algal blooms and general loss of biodiversity. Generally, rivers are particularly vulnerable to land use change and ubiquitous exploitation [7-8]. The deterioration of river water quality due to unsustainable human activities has become a key to environmental concern [9]. More consideration has been paid to surface water quality as a result of its solid linkage with human prosperity [10]. Contamination of river waters poses a serious health risk to the public and monitoring of river water quality is under the responsibility of the Department of Environment Malaysia [11]. Causes of main water problems had been addressed in previous studies which are included land use change either legal or illegal developments, uncontrolled river water abstraction in upstream, poor solid waste management, low awareness of local community and unplanned development [12]. Any activities related to urbanization and agriculture basically are main contributors to alterations in the chemical composition of aquatic habitats [13]. There are two main factors that have been identified as natural pollutants contributed to the deterioration of water quality including urban and agricultural runoffs, which are loaded by high concentrations of organic and inorganic pollutants [14-16]. Discharge of toxic chemicals, alternations of physico-chemical water characteristic as well as increase of nutrient inputs [17]. Furthermore, the characteristic of catchment area may influence the rate and quantity of flow rate [18]. In general, human activities related to land use around Nerus River pose a threat to the aquatic ecosystem and the provinces where the river water usually uses as domestic supply [19-20]. Consequently, to protect the water resources, the land use activities must be planned and controlled. Therefore, it is crucial to keep the health of the river at an acceptable level. The DOE-WQI scale classifies the water quality as ‘clean’, ‘slightly polluted’, ‘moderately polluted’ and ‘polluted’ if the WQI-DOE falls within the range of 91 to 100%, 81 to 90%, 71 to 80% and 0 to 69% respectively [21-22]. In addition, the beneficial use of the water was also compared with the classification based on the National Water Quality Standards (NWQS). Recently, there has been an increasing awareness of river system contamination with different contaminants physicochemical water. Essentially, rivers play more important roles in the community particularly as a source of water supply and the fishing industry in order that rivers pollution either directly or indirectly can mostly influence [23]. The Nerus River is located between latitudes 103º00’ E to 103º06’E and longitude of 05º13’N to 05º23’N that situated in Kuala Terengganu (Fig. 1). Nerus River is one of the important rivers in Malaysia with perspective as sources for domestic water supply. Therefore, to find ‘driving forces’ (economic sectors, human activities) through ‘pressures’ (emissions, waste) to states of physicochemical and biological impacts on ecosystems, human health and functions and eventually leading to political responses [24]. The main objective of this study is to determine water quality condition of the Nerus River at Kuala Terengganu, Peninsular Malaysia during wet and dry seasons based on six years period of the secondary data.

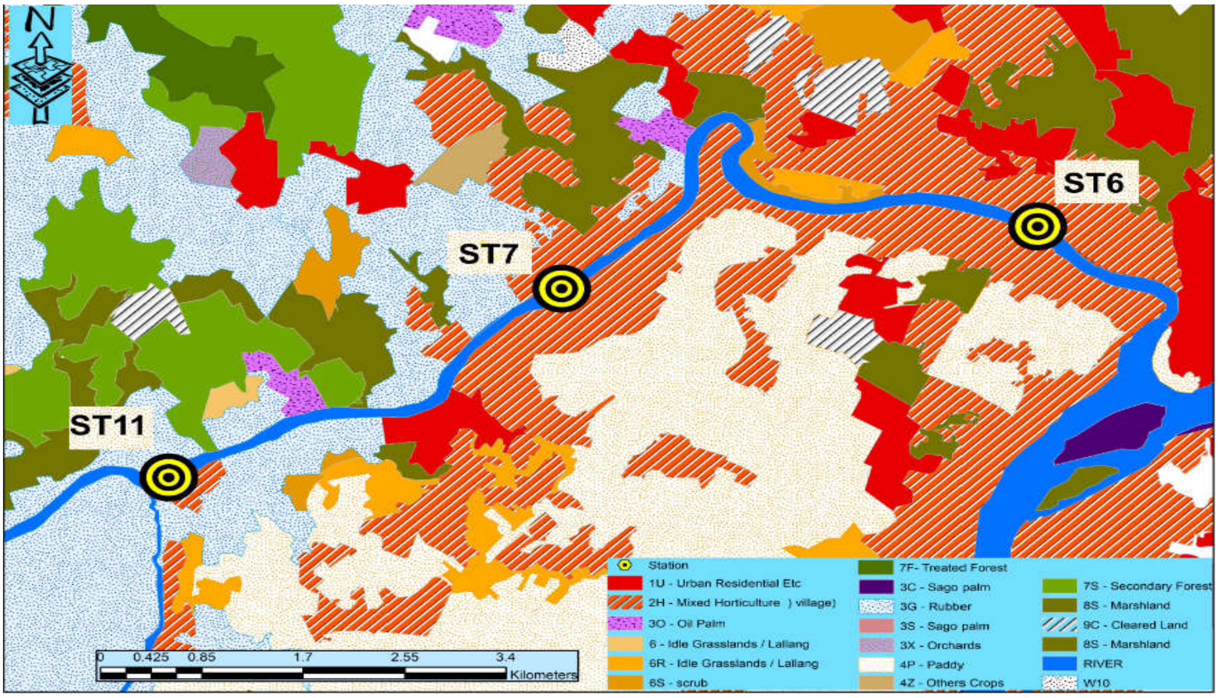

Fig.1. Locations of the Nerus River catchment and position of sampling sites

2. MATERIALS AND METHODS

2.1. The Study Area

Nerus River is located in Kuala Terengganu, East Coast Malaysia, the river flows stretches along 77km between latitude 103º00' E to 103º06'E and longitude of 05º13'N to 05º23'N. It is belongs to the subtropical zone with a mean annual temperature ranging from 26 to 28^{0}C and a mean annual precipitation from 1200 to 3500mm or at average 3000mm annually. The totals area of catchments is 851 km^2. Its flows from their source from Gunung Sarut and flows south eastern towards Terengganu River estuary before finally discharging into the South China Sea. At least 9 tributaries of Nerus River namely Sg.Tepuh, Sg.Pelung, Sg. Telemong, Sg. Las, Sg. Tong, Sg. Linggi, Sg. Tayur, Sg. Temiang and Sg. Semelang.

2.2. Water Quality Data

In this study, Sungai Nerus was chosen as an example to analyze the spatial and temporal variations in this region. The 2005 to 2010 water quality parameters data were used in this study provided from the DOE. Instead of twelve monitoring sampling stations that carried out by DOE, only three sampling stations were located this river namely St.6, St.7 and St.11. Thirteen parameters were selected in the different seasons are temperature, pH, dissolved oxygen (DO), conductivity, total dissolved solids (TDS), salinity, turbidity, total suspended solids (TSS), chemical oxygen demand (COD), biochemical oxygen demand (BOD), nitrate (NO_3), ammonia-nitrogen (NH_3-N) and *E.coli*. The sampling was carried out during wet and dry seasons for period of six years, which can provide continuous measurements at three selected water quality monitoring stations alongthe Nerus River.

2.3. Statistical Analysis Methods

A study was conducted to determine the concentration of selected water quality parameters and physicochemical in Nerus River, and to evaluate the contamination level using Water Quality Index (WQI) and National Water Quality Standard (NWQS) for Malaysian rivers and the multivariate statistical methods based on Analysis of Variance (ANOVA). Water quality was measured at the Nerus River and classified according to NWQS and WQI classifications, issued by the Department of Environment. The Physico-chemical and biological parameters including of pH, temperature, conductivity, DO, BOD, COD, TSS, TDS, NH_3-N, NO_3, turbidity, salinity and *E.coli*. correlation analysis was used to find the relationships among the water quality parameters [25]. One-way analysis of variance (ANOVA) (one way-ANOVA, $p < 0.05$) to measure the variation of water quality parameter among stations and between dry and wet seasons. The range, mean values and standard deviations of the 13 water quality parameters were analyzed in this study. Significant differences ($p < 0.05$) for 13 water quality parameters between dry and wet seasons were identified. All the mathematical and statistical computations were conducted using EXCEL 2007 (Microsoft Office10) and SPSS softwares.

3. RESULTS AND DISCUSSION

3.1. In-Situ Parameter Analysis

3.1.1. Temperature

The average value of temperature measured in Nerus River during dry season was (27.34°C) which was ranged from 23, 83°C in 2009 at St.7 to 30.77°C in 2006 at St.11. The average value of temperature during wet season was (26.89°C), which was ranged from 25.11°C in 2006 at St.6 to 30.35°C in 2005 at St.11 (Fig. 2a). This is within the normal range value of water temperature for Malaysian temperature [11]. The statistical analysis showed that there were no significant differences ($P > 0.05$) of mean temperature levels between parameters and different years, in a dry and wet season respectively. The temperature during wet season was lower than during dry season (df = 5 , F = 1.049 , P = 0.434), (df = 5 , F = 0.411 , P = 0.832) (Table 1). Increase or decrease of temperature will affects the process of dissolved oxygen and biological activity. The correlation analysis showed very strong positive correlation ($r > 0.7$, $P < 0.05$) between temperature and most of the water quality parameters during dry season, but showed a negative correlation with DO and conductivity (Table 2). During wet season, temperature showed negative correlation ($r < 0.7$, $P > 0.05$) with DO, turbidity, BOD, NO_3 and *E.coli*. Moreover, the temperature was within the normal range and did not influence the solubility of the organic components and the rate of chemical reactions and was classified as normal based on the NWQS and classified as Class I.

3.1.2. pH

The average value of pHduring dry season was 5.2 which was ranged from 4.3 in 2009 at St.11 to 7.5 in 2006 (St.6). The average value of pH during wet season was 4.8, which was ranged from 3.3 in 2005 at St.11 to 7.3 in 2006 (St.6) (Fig. 2). Two-factor ANOVA test showed that the pH values were no significantly ($p > 0.05$) between time during dry season (df = 5, F = 0.549, P = 0.737). Also, there were no significant ($P > 0.05$) between time during wet season (df = 5, F = 1.038, P = 0.439 as seen in (Table 1) among the sampling stations and dates of sampling. In general, there was a decreasing trend of pH values in going from the upstream stations to the downstream stations. Based on NWQS classifications, the pH values for most of the stations were in Class II with the exception of St.11 which were in Class III.

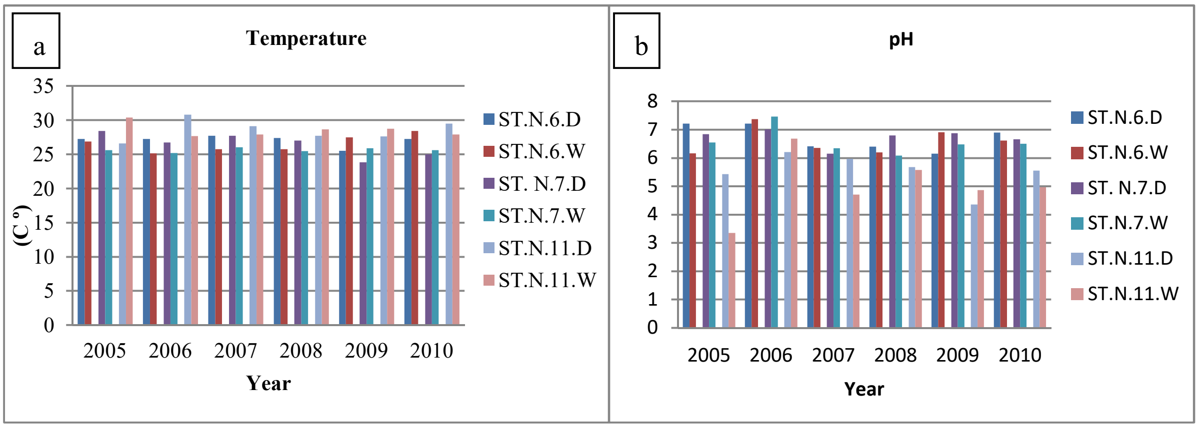

Fig.2. Comparison of temperature (a) and pH (b) during dry and wet seasons in different years

3.1.3. DO

During dry season, DO concentration was ranged from 3.19 mg/L in 2008 (St.11) to 7.59 mg/L in 2009 at St.7 with the average levels of was 6.23 mg/L. The average DO value during wet season was 6.17mg/L, which was ranged from 2.78mg/L in 2005 (St.6) to 7.72mg/L in 2005 (St.7) (Fig. 3). The ANOVA test showed that the values were no significantly differences of mean DO levels between parameters and different seasons (ANOVA, $P = 0.946$. $P = 0.995$) (Table 1). The DO value was lower during wet season thanDO during dry season, but DO value for both two seasons was within Class II. In addition, the correlation analysis showed a very strong negative correlation ($r < 0.7$, $P > 0.05$) between DO and all the water quality parameters during dry season (Table 2) but showed a positive correlation ($r > 0.7$, $P < 0.05$) with turbidity, BOD, NO_3 and *E.coli* during wet season (Table 3).

3.1.4. Conductivity

Conductivity values during dry season was ranged from 18.00µs/cm at St.7 (2010) to 400.40 µs/cm at St.11 (2005) with average value of 97.85 µs/cm. The lowest conductivity during wet season (22.00 µs/cm) at St. 7 (2010) and the highest (891.00 µs/cm) was recorded at St.11 (2005) with average value of 134.05 µs/cm. A two-factor (ANOVA $p < 0.05$) test showed that the conductivity values were no significantly different ($P > 0.05$) among the sampling stations and years of samplings ($P = 0.918$, $P = 0.769$). Based on NWQS classifications, conductivity values for most of the stations were in Class I. In addition, the correlation analysis showed a very strong positive correlation($r > 0.7$, $P < 0.05$) between conductivity with allof the water quality parameters during dry season (Table 2). The correlation of analysis showed negative correlation ($r < 0.7$, $P > 0.05$) between conductivity and turbidity, BOD, NO_3 and *E.coli* during wet season (Table 3).

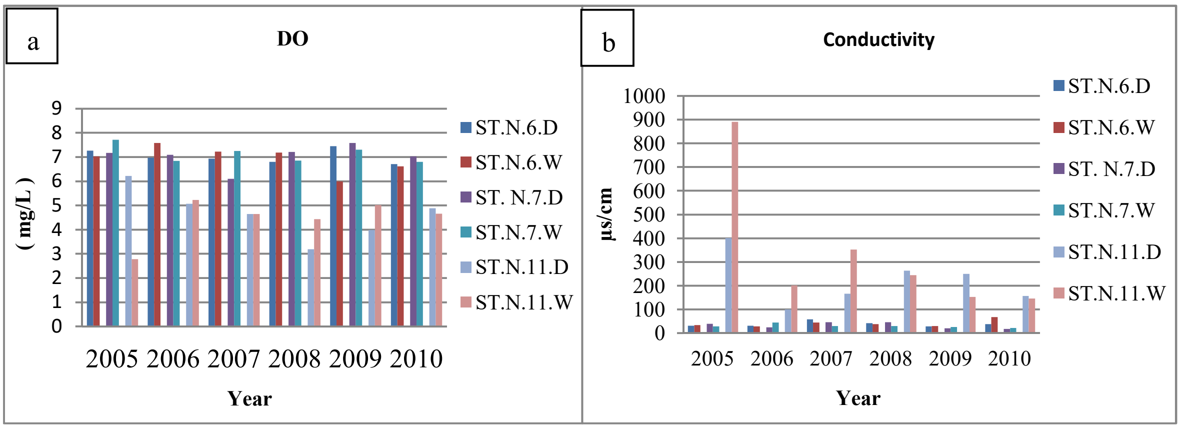

Fig.3. Distribution of DO (a) and conductivity (b) values between dry and wet seasons in different years

3.1.5. Salinity

Concentration of salinity during dry season ranged from 0.01 to 0.19 ppt and the concentration during wet season ranged from 0.01 to 0.44 ppt. Both dry and wet seasons were recorded the highest value of the salinity at St.11(2005) and the lowest values was recorded at St.7 during 2009 and 2010 (Fig. 4a). The statistical analysis in this study showed that there were no significantly differences ($p > 0.05$) of mean salinity levels within the sampling stations, and between sampling times (ANOVA, $P = 0.927$, $P = 0.778$) (Table 1). In addition, the correlation analysis showed a negative correlation ($r < 0.7$, $P > 0.05$) between salinity and *E. coli* during two seasons (Table 2 and 3). The salinity was found to be within the recommended level under NWQS classification (Class I).

3.1.6. Turbidity

Turbid in water was caused by suspended and colloidal matters such as clay and silt, sedimentswas divided into organic and inorganic matter. The subindex value for all stations. Indicated that the river was slightly polluted with sediments. This is probably due to the existence of logging, agriculture and land reclamation activities, which was carried out in the upstream area. Turbidity values were ranged from 12.75 NTU in 2006 (St.7) to 128.05 NTU in 2009 (St.6) with the average of 47.86 NTU during dry season. The lowest during wet season was 3.00 NTU in 2010 (St.11) to 279.45 NTU in 2005 (St.6) with the average of 82.88NTU (Fig. 4b). The correlation analysis showed a very strong negative correlation ($r < 0.7$, $P > 0.05$) between turbidity and all of the water quality parameters, but showed a positive correlation with COD, TSS and *E.coli* for dry season (Table 2). During wet season, the correlation analysis showed a positive correlation (r > 0.7, P < 0.05) between turbidity with COD, BOD, NO_3 and *E.coli* (Table 3). In terms of seasonal variations, suspended sediment concentrations were unevenly,high during wet season which could be a result of the movement of particulate matter into water bodies from sediment transport and erosion only from the selected station. Correlation analysis showed that turbidity was a positive relationship with total suspended solid (ANOVA, P = 0.092, P = 0.255). Overall, turbidity was higher during wet season rather than during dry season. The turbidity was fell into Class III.

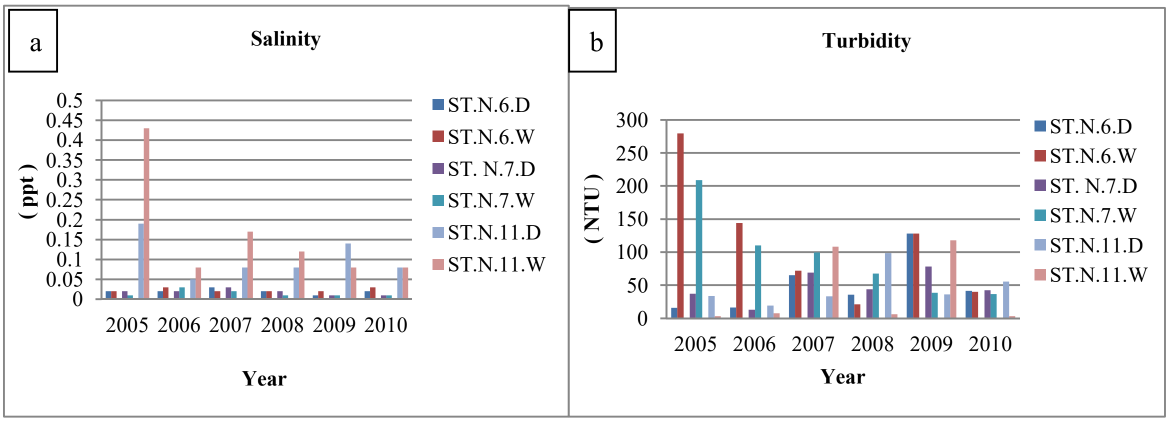

Fig.4. Distribution of salinity (a) and turbidity (b) during dry and wet seasons in the different years

3.1.7. TDS

The range of TDS values for the dry season in this study were 11.5 mg/L in 2007 (St.7) to 237.00mg/L in 2006 (St.11), with a mean value of 70.36mg/L. During wet season, the lowest value 8.00mg/L in 2005 (St.7) and the highest TDS was 506.00mg/L in 2005 (St.11) with a mean value of 74.75mg/L (Fig. 5). On the other hand, the statistical analysis showed that there were no significant differences in TDS concentration levels in the sampling stations and no significant between sampling times (ANOVA, P > 0.05, P = 0.998, P = 0.816) respectively. According to NQWS, TDS falls under Class II. The correlation analysis showed very strong positive correlation (r > 0.7, P < 0.05) between TDS and most of the water quality parameters in different seasons, but showed a negative correlation with NO3 and *E.coli* (Table 2 and 3).

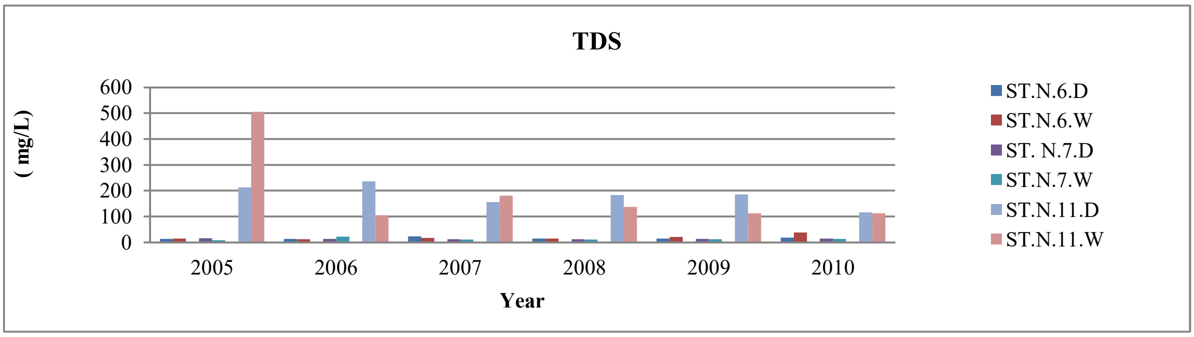

Fig.5. Distribution of TDS during dry and wet seasons in different years

3.2. Laboratory Analysis

3.2.1. TSS

Increases in the amount of sediment entering a watershed are likely to occur as an area grows and soil is moved from an undeveloped to a developed state [26]. Erosion from construction is a harmful pollutant, clogging stream channels and water intakes. The presence of sediment increases turbidity reducing the amount of light penetration, retards photosynthesis and hence may lead to decreases in the food supply available to aquatic life. Therefore. TSS is thought to be a good indicator of the potential adverse effects of land conversion on water quality monitoring. The TSS values during dry season ranged from 23.00mg/L in 2006 at St.6 to 437.5 mg/L in 2008 at St.8 with the average of 117.25 mg/L. During the wet season, the lowest 21.00 mg/L in 2010 at St.7 to 515.5mg/L in 2005 at St.11 with the average of 154.6mg/L (Fig. 6a). There are no significant of TSS between seasons (ANOVA $P > 0.05$, $P = 0.940$, $P = 0.665$) (Table 1). The correlation analysis showed very strong positive correlation ($r > 0.7$, $P < 0.05$) between TSS and most of the water quality parameters during dry and wet seasons, but showed a negative correlation ($r < 0.7$, $P > 0.05$) with NO_3 and *E.coli* during wet season (Table 2 and 3). The NWQS level of TSS for supporting healthy aquatic life in a freshwater ecosystem is 150 mg/L. The TSS values for most of the stations were in Class II with the exception atSt.11 which was under Class III.

3.2.2. COD (Chemical Oxygen Demand)

The range of COD during dry season was from 8.0 mg/L in 2010 (St.6) to 58.0 mg/L in 2007 (St.6) with an average of 24.38 mg/L. The range of COD during wet season was from 9.0 mg/L in 2008 (St.7) to 41.0 mg/L in 2007 (St.11) with an average of 21.75 mg/L (Fig. 6b). On the other hand, the statistical analysis showed that there were no significantly differences in

COD concentration levels of the sampling stations but significantly different between sampling times (ANOVA, P > 0.05, P = 0.930, P = 0.360). The COD values for most of the stations were in Class II within NWQS. In addition, the correlation analysis showed COD have very strong positive correlation (r > 0.7, P < 0.05) with all of the water quality parameters (Table 2 and 3).

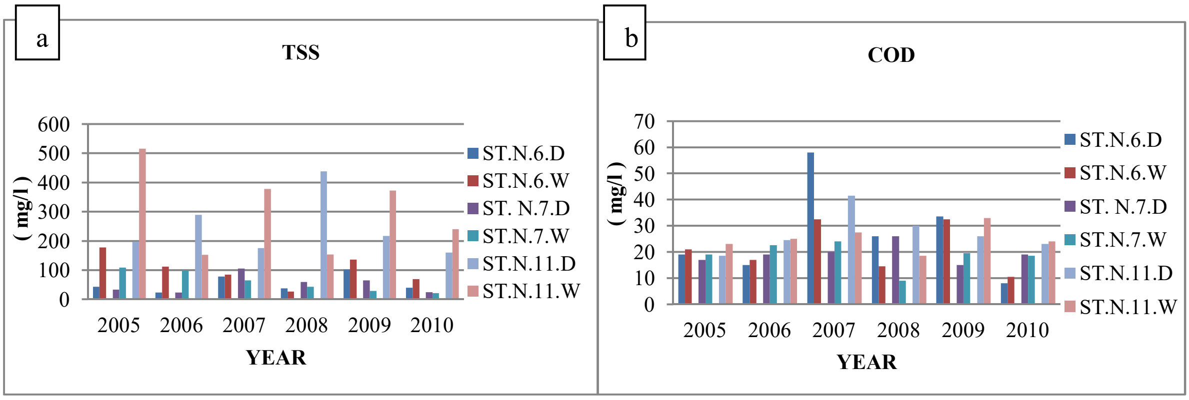

Fig.6. Distribution of TSS (a) and COD (b) during dry and wet seasons in different years

3.2.3. BOD (Biochemical Oxygen Demand)

The range of BOD values was from 1.20mg/L to15.80 mg/L with the average of 4.41mg/L during the dry season, and from 1.20 to 7.50 mg/L during wet season with average of 3.23mg/L. The lowest value was at St.7 (2007) during dry season, while the highest value of BOD was observed at St.11 (2006). In addition, during wet season St.6 (2009) recorded the highest value and St.11 (2006, 2007) recorded the lowest value (Fig. 7a). Results on statistical analysis using one-way ANOVA showed no significant differences in BOD (ANOVA, p > 0.05, P =0.935, P = 0.238). The correlation analysis showed very strong positive correlation (r > 0.7, P < 0.05) between BOD and all of the water quality parameters during dry season (Table 2). But, it showed a negative correlation (r < 0.7, P > 0.05) between BOD and TDS, TSS, NH_3-N, salinity and temperature during wet season (Table 3). Under the NQWS classification BOD was classified as Class III.

3.2.4. Nitrate (NO_3)

The range of nitrate values during the dry seasons was from 0.02 to 0.48 mg/L or at an average of 0.20 mg/L. Nitrate concentrations varied from 0.04 to 0.64 mg/L or at an average of 0.28 mg /L during wet season. The highest values during dry and wet seasons were at St.11and at St.6 (2009) respectively, while the lowest was at St.11 (2008) (Fig. 7b). The statistical analysis in this study showed that there were no significantly differences of mean NO_3 levels within the sampling stations and times (ANOVA P > 0.05, P = 0.645, P = 0.335) (Table 1). According to NQWS classification, all of the Nerus River's feeder rivers were in Class I for nitrate content. Additionally, NO_3 indicated a strong negative correlation (r < 0.7, P > 0.05) with NH_3-N and *E.coli* during dry season and negative correlation with NH_3-Nand salinity (Table 2 and 3).

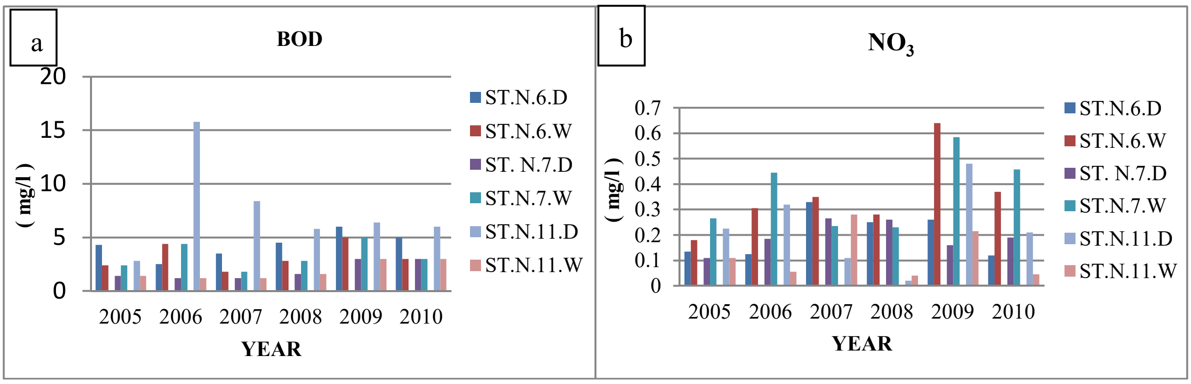

Fig.7. Comparison of BOD (a) and NO_3(b) during dry and wet seasons in different years

3.2.5. Ammoniacal Nitrogen (NH_3-N)

The value of ammoniacal nitrogen during dry season ranged from 0.02 to 2.95 mg/L with the average of 0.73 mg/L, while during wet season was from 0.03 mg/L to 1.45 mg/L with the average of 0.40 mg/L. The highest concentration was observed at St.11 (2006 and 2007), while the lowest concentration was recorded at St.7 (2008 and 2010) in both dry and wet seasons respectively (Fig. 8a). Based on the NWQS, the NH_3.N of Nerus River is classified as Class V. The statistical analysis of NH_3-N show that there were no significant differences in the sampling times (ANOVA p > 0.05, P = 0.751, P = 0.944). The correlation analysis showed very strong positive correlation (r > 0.7, P < 0.05) between NH_3-N and most of the water quality parameters during dry season, but showed a negative correlation (r < 0.7, P > 0.05) with *E.coli* during wet season (Table 2 and 3).

3.2.6. *E. Coli*

The ranged of *E.coli* concentration in Nerus River during dry season was from 100.0 CFU/100mL to 21000.0 CFU/100mL with average value 5422.55 CFU/100mL. The highest value was at St.11 (2008) and the lowest value at St.11 (2005 and 2010). The *E.coli* concentration during wet season was from 250.0 to 12400.0 CFU/100mL with the average value was 2325.00 CFU/100mL. The highest value was at St.6 (2009) and the lowest St.11 (2008) (Fig. 8b). The statistical analysis of *E.coli* show that there were significant differences of mean levels of *E.coli* during dry season, but no significant differences during wet season (ANOVA, P = 0.010, P = 0.452). Based on the NWQS, the *E.coli* content of the Nerus River was classified as Class III. In this study, the *E.coli* and total coliform showed very strong positive correlation (r > 0.7, P < 0.05) with temperature, NH_3-N, NO_3, BOD, COD, TSS and turbidity and very strong positive correlation (r > 0.7, P < 0.05) with pH, DO, turbidity, COD and NO_3 (Table 2 and 3).

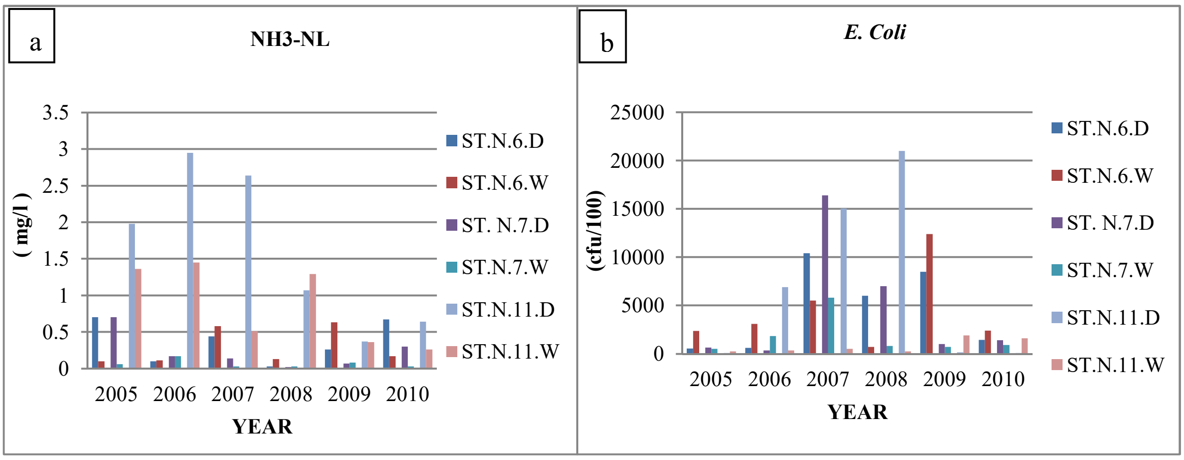

Fig.8. Comparison of NH_3-N (a) and *E. coli* (b) during dry and wet seasons in different years

In summary, the results of the 13 parameters of water quality in the study area can be seen in Table 1.

Table 1. The physicochemical and biological characteristics during two seasons of the Nerus River

Parameter	Dry Season				Wet Season			
	Mean	Range	Std.deviation (df)	Sig	Mean	Range	Std.deviation (df)	Sig
Temperature	27.34°C	23.83-30.77 °C	1.592	0.434	26.89°C	25.11-30.35°C	1.525	0.832
pH	6.32	4.36-7.21	0.733	0.737	6.06	3.35-7.46	1.026	0.439
DO	6.23mg/L	3.19-7.59	1.30	0.946	6.17	2.78-7.72	1.38	0.995
Conductivity	97.85	18.00-400.40	108.04	0.918	134.05	22.00-891.00	210.95	0.769

Salinity	0.047ppt	0.01-0.19	0.498	0.927	0.066	0.01-0.43	0.1011	0.778
Turbidity	47.86NTU	12.75-128.05	30.388	0.092	82.88	3.00-279.45	75.75	0.255
TDS	70.36mg/L	11.50-237.00	84.34	0.998	74.75	0.00-506.00	120.58	0.816
TSS	117.25mg/L	23.00-437.5	111.94	0.940	154.61	21.00-515.50	138.26	0.665
COD	24.38mg/L	8.00-58.00	11,34	0.93	21.75	9.00-33.00	6.91	0.360
BOD	4.41mg/L	1.20-15.80	4.41	0.935	3.23	1.20-7.50	3.23	0.238
NO_3	0.20mg/L	0.02-0.48	0.10	0.654	0.28	0.04-0.64	0.17	0.335
NH_3-N	0.736mg/L	0.02-2.95	0.88	0.751	0.408	0.03-1.45	0.47	0.944
E.coli	5422.55CFU/100mL	100.00-21000.00	6537.32	0.01	2325.00	250.00-12400.00	3009.89	0.452

Correlation matrix of water quality parameters between dry and wet seasons is presented in Table 2 and 3.

Table 2. Correlation matrix of water quality during dry season

Correlation Matrix	**TEMP (°C)**	**pH**	**DO(mg/L)**	**COND.(µS)**	**TURB.**	**COD**	**BOD**	**TDS**	**TSS (mg/L)**	**NO_3**	**NH_3-N**	**SAL.**	***E.coli* (cfu/100ml)**
Dry season													
Temperature (° C)	1.000												
pH	-.273	1.000											
DO (mg/L)	-.563	.759	1.000										
Conductivity (µS)	-.352	-.785	-.689	1.000									
Turbidity(NTU)	.352	-.233	-.071	.021	1.000								
COD (mg/L)	.236	-.287	-.226	.123	.317	1.000							
BOD (mg/L)	.539	-.291	-.511	.207	-.161	.228	1.000						
TDS (mg/L)	.521	-.738	-.813	.841	-.088	.161	.670	1.000					
TSS (mg/L)	.424	-.674	-.876	.725	.285	.255	.566	.859	1.000				
NO_3(mg/L)	.108	-.513	-.071	.107	-.033	.300	.212	.194	.020	1.000			
NH_3-N(mg/L)	.595	-.294	-.496	.513	-.238	.188	.747	.783	.581	-.078	1.000		
Salinity (ppt)	.254	-.813	-.628	.969	-.107	.086	.196	.817	.603	.262	.492	1.000	

E. coli (cfu/100ml)	.241	-.200	-.454	.136	.504	.552	.199	.195	.540	-.150	.232	-.016	1.000

Table 3. Correlation matrix of water quality during wet season

Correlation Matrix	TEMP. (°C)	pH	DO(mg/L)	COND	TURB.	COD	BOD	TDS	TSS (mg/L)	NO_3	NH_3-N	SAL	*E. coli* (cfu/100ml)
Wet season													
Temperature (°C)	1.000												
pH	-.759	1.000											
DO(mg/L)	-.892	.820	1.000										
Conductivity (µS)	.759	-.818	-.853	1.000									
Turbidity(NTU)	-.320	.292	.454	-.351	1.000								
COD (mg/L)	.274	-.224	-.318	.169	.144	1.000							
BOD (mg/L)	-.346	.472	.387	-.466	.363	.041	1.000						
TDS (mg/L)	.790	-.842	-.879	.995	-.367	.191	-.443	1.000					
TSS (mg/L)	.784	-.841	-.838	.836	-.023	.462	-.346	.857	1.000				
NO_3(mg/L)	-.445	.526	.517	-.441	.179	.078	.698	-.454	-.440	1.000			
NH_3-N(mg/L)	.681	-.425	-.755	.691	-.439	.332	-.430	.681	.517	-.456	1.000		
Salinity (ppt)	.756	-.821	-.852	.998	-.334	.178	-.442	.996	.849	-.434	.668	1.000	
E. coli (cfu/100ml)	-.087	.335	.209	-.300	.262	.483	.483	-.291	-.167	.508	-.076	-.281	1.000

The average of temperature, pH, DO, BOD, COD, NH_3-N and *E. coli* concentration were higher during dry season ($p < 0.05$). In contrast, the average values of conductivity, salinity, turbidity, TDS, TSS, NO_3 were significantly higher during wet season ($p < 0.05$). The deterioration of river water quality due to unsustainable human activities has become a key to environmental concern. The concentration values of NO_3, conductivity, salinity and temperature was classified as Class I while DO, TSS, COD and TDS were categorized as

Class II. Other parameters such *E.coli*, pH, BOD and turbidity were categorized as Class III and the highest (Class V) was NH_3-N based on the NWQS for Malaysian rivers. Overall, the anthropogenic pollution sources were the main reason of the water quality deterioration in the Nerus River [27]. The WQI calculation of the water classification for the three stations (6, 7 and 11) show that during dry and wet seasons falls within the Class II and Class III except for St.11 (Class IV). During dry and wet seasons, St.6 falls within Class II and Class III; the whole of St. 7 consist of Class II and Class III for the St.11 (Table 4). The lowest water quality (Class IV) was during wet season at St. 11 (2005) (WQI = 48).

Table 4. The classification of WQI for water quality value

Year	DO% Dry	DO% Wet	BOD Dry	BOD Wet	COD Dry	COD Wet	TSS Dry	TSS Wet	pH Dry	pH Wet	NH3-N Dry	NH3-N Wet	Station 6 Dry	Station 6 Wet
2005	91.14	88	5.41	5.41	19	21	43.5	177.5	7.21	6.17	0.7	0.1	II	II
2006	90.18	94.85	2.5	4.4	15	17	23	112	7.21	7.37	0.1	0.11	II	II
2007	87.1	90.45	3.5	1.8	58	32.5	78.5	84.5	6.41	6.36	0.44	0.58	III	II
2008	88.28	87.95	4.5	2.8	26	14.5	37.5	27	6.4	6.2	0.03	0.13	II	II
2009	85.02	75.3	4	7.5	33.5	32.5	102	136	6.15	6.91	0.26	0.63	II	III
2010	80.84	84.95	3	2.5	8	10.5	39.5	69	6.9	6.62	0.67	0.17	II	II
Year	DO%	DO%	BOD	BOD	COD	COD	TSS	TSS	pH	pH	NH3-N	NH3-N	Station 7	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
2005	92.5	94.65	1.4	2.4	17	19	33	108.5	6.84	6.55	0.7	0.06	II	II
2006	88.85	84.1	1.2	4.4	19	22.5	23.5	98.5	7.01	7.46	0.17	0.17	II	II
2007	77.3	89.6	1.2	1.8	20	24	105	65	6.15	6.35	0.14	0.03	II	II
2008	88.85	83.35	1.6	2.8	26	9	59	43.5	6.8	6.09	0.02	0.03	II	II
2009	91.5	89.6	3	5	15	19.5	65	29	6.88	6.48	0.07	0.08	II	II
2010	86.6	82.6	5	6	19	18.5	24	21	6.66	6.5	0.3	0.03	II	II
Year	DO%	DO%	BOD	BOD	COD	COD	TSS	TSS	pH	pH	NH3	NH3-N	Station 11	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
2005	65.2	37.4	2.8	1.4	18.5	23	197.5	515.5	5.43	3.35	1.98	1.36	III	IV
2006	72.7	66.1	15.8	1.2	24.5	25	289	152.5	6.21	6.68	2.95	1.45	III	III

2007	52.8	56.7	8.4	1.2	41.5	27.5	175.5	377.5	5.97	4.71	2.64	0.51	III	III
2008	53.9	41.45	5.8	1.6	30	18.5	437.5	154	5.68	5.58	1.07	1.29	III	III
2009	49.7	62.8	6.4	3	26	33	217	372	4.36	4.87	0.37	0.36	III	III
2010	64.6	56.8	4	3	23	24	160.5	240	5.56	4.97	0.64	0.26	III	III

5. CONCLUSION

The water quality of the Nerus River varies based on the seasons and locations of the sampling stations. The seasonal variation of water quality and the important factors driving this variation of the river. Six of the physico-chemical parameters were higher during dry season and seven parameters were higher during wet season. Variation of water quality was mainly related to the seasonal changes of rainfall and inflow from upstream and salt water intrusion. High tides increase the movement of seawater further to the upstream and affected pH, salinity, concentration of the river. This is due to the concentration of high dissolved salts, which later also increase water's ability to conduct electricity. The status of the 13 water quality parameters (temperature, pH, conductivity, DO, BOD, COD, TSS, TDS, NH_3-N, NO_3, turbidity, salinity and *E. coli*) during dry season was considered as slightly polluted (Class II), while during wet season was considered as moderately polluted (Class III). The main reason is that the pollutants had been washed away into the river by surface runoff. The land use activities such as land clearing, forest fire and soil erosion usually take place before wet season time which increasing the pollutants load into river by flash out during rainfall.

The mean WQI during dry seasons was Class II and Class III during dry and wet seasons falls within the class II except for St.11 during wet season which falls within Class III and Class IV respectively. Changes of water quality parameters between dry and wet seasons for 5 year water quality parameters ($p < 0.05$) for different seasons were significant differences.The WQI calculation of the water classification for the three stations (6, 7 and 11) show that during dry and wet seasons falls within the Class II and Class III except for St.11 during wet season (Class IV).

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How to cite this article:
Alssgeer HMA, Gasim MB, Azid A, Alabyad LOM. The evaluation of physic-chemical and biological characteristics of water quality between wet and dry seasons of the Nerus River, Kuala Terengganu, Malaysia. J. Fundam. Appl. Sci., 2017, *9(2S), 563-582.*