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Research Article

Statistical comparison of pH, COD and NH_3-N *in-situ* physico-chemical parameter in relation to surface water pollution status at Terengganu and Kinta River Basins, Malaysia

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Abstract

Statistical comparison has been performed for Terengganu and Kinta River Basins in terms of surface water pollution status using some selected physico-chemical parameters. Surface water quality data were collected from Department of Environment (DOE) Malaysia and subjected to logarithm transformation (log-scaling), column auto scaling and z-standardization to eliminate the effects of measurement units. Results revealed that pH value is higher in Terengganu River Basin compared to Kinta River Basin. Two-way analysis of variance (2-way ANOVA) showed spatial and temporal statistical significant differences ($p<0.05$). Hierarchical Agglomerated Cluster Analysis (HACA) revealed two major statistical clusters of water quality monitoring group. Chemical oxygen demand (COD) showed higher value in Terengganu than Kinta River Basins while ammonia-nitrogen (NH_3-N) revealed higher value in Kinta compared to Terengganu River Basins. The present study, however, makes several noteworthy contributions to the existing knowledge on spatial and temporal variations of surface water quality and is believed to serve as a baseline data for further studies in surface water pollution.

Keywords: Water pollution; water quality; Bonferroni comparison test; 2-way ANOVA; cluster analysis; river basin; spatial-temporal assessment; monitoring station; *p*-value; F-test.

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Introduction

Surface water quality is affected by a wide range of natural and human influences and rivers have been contaminated as a result of discharges of wastewater containing degradable and non-degradable organic compound, nutrients, industrial effluent and agricultural waste (Mustapha *et al.,* 2012). River Basin water quality is a critical component that is assessed by its physical, chemical and biological composition and properties (Brindha and Kavitha 2014). The anthropogenic influences involves organic waters from industrial plant, municipal and industrial waste water discharge (point as well as non-point sources of pollution) constitutes the constant polluting source of river water quality (Singh *et. al*. 2004). The natural factors may include precipitation rate, weathering processes, soil erosion as well as run-off which is a seasonal phenomenon and is largely influenced by the climate and climatic type in the basin and largely affect the quantity and quality of water available (Charalampous *et al.,* 2015). Water quality has been a baseline to predict the quality level of water for daily usage such as drinking, watering plants and other more. The existence of human activities would have a serious effect on water quality both widespread and varied in the degree to which they disrupt the ecosystem and restrict water use (Dhar *et al.,* 2015; Vystavna *et al.,* 2015). Pollution of water by human faeces, for example, is attributable to only one source, but the reasons for this type of pollution, its impacts on water quality and the necessary remedial or preventive measures are varied.

In most of the developing countries, major pollution is coming from domestic waste, industrial effluents, land clearance with suspended solid (SS) as the major source contributing up to 42% to poorly planned land development, 30% from biological oxygen demand (BOD) due to industrial waste and 28% from ammoniacal nitrogen (NH_3-NL) attributed from domestic sewage disposal and animal farming activities (Padma *et al.,* 2014). The main aim of this study is to examine the statistical comparison between in-stu physicochemical parameters in relation to surface water pollution status at Terengganu and Kinta River Basins, Malaysia

Materials and Methods

Description of the study area

Terengganu River estuary (5.32°-5.35° N, 102.95°-103.15° E) is situated on the east coast of peninsular Malaysia facing the South China Sea as shown in Figure 1. Generally, the Terengganu River estuary is relatively small and shallow with the total area of the estuary is approximately 8 Km^2. Maximum depth recorded in this area was only 6 meters and the average depth was about 4 meters. Two River systems, the Nerus River and the Terengganu River channel their water into this estuary.

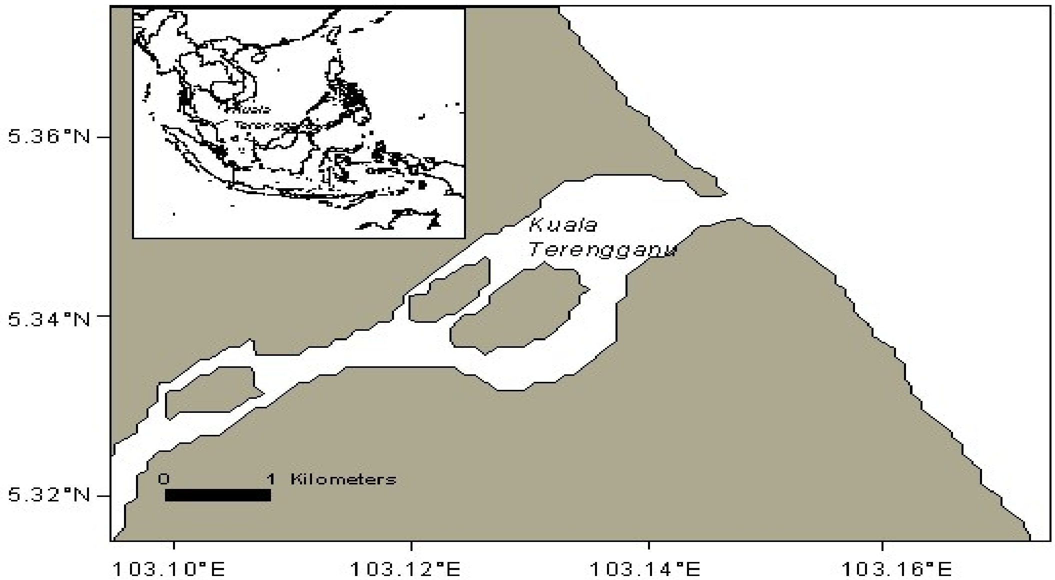

Figure 1 Map of the study area showing Location of Kuala Terengganu River estuary

The North-west monsoon rain between October and January of every year has a great impact on the ecosystem and water budget of Terengganu River estuary. The highest rainfall recorded in December 1998 was 155 mm day^{-1} with an average value of 21 mm day^{-1}. The highest evaporation rate recorded in this area was in April 1998 with 8 mm day^{-1} with an average value of 6 mm day^{-1}. The major waste waters discharged into this River and its estuary come from partially-treated domestic waste. However, substantial levels of nutrients were found in the estuary along with the high level of fecal coli form bacteria count (Panizzon *et al.,* 2012). This revealed that there is gross sewage pollution in Terengganu River estuary. Recent rapid development in this area is due to extensive crude oil production in the off-shore waters of the state, as well as the insufficient wastewater treatment systems, these may have led to water quality deterioration in this River and its estuary.

On the other hand, Kinta River is located in Perak, Malaysia. It gives its name from the Kinta Valley which surrounds Ipoh. The area is dominated by the limestone. The River Kinta flows from Gunung Korbu at Ulu Kinta, to Tanjung Rambutan. It is 100 Km long and covers an area of 2450 Km^2. Kinta River is currently classified with an average Class III water quality and a water quality index (WQI) of 51.9 – 76.5. This means that the water is polluted and requires extensive treatment before it can be used for drinking purpose (Gazzaz *et al.,* 2010).

Data used in this study were collected from The Department of Environment (DOE) Malaysia. The data were collected in March, May, July, September and December 2004 from nine water quality monitoring stations: 4TE01, 4TE02, 4TE03, 4TE04, 4TE05, 4TE06, 4TE07, 4TE08 and 4TE09 and six water quality monitoring stations obtained in February, May, August and November 2002 in Kinta River 2SPK19, 2SPK22, 2SPK24, 2SPK25, 2SPK33 and 2SPK34. Water quality data were collected based on in-situ measurements and laboratory analysis. The most common parameters measured are those related to water pollution due to land-clearing, sewage and effluents discharge. Parameters that are measured at the site include: pH, chemical oxygen demand (COD), dissolved oxygen (DO), total suspended solid (TSS), ammoniacal nitrogen (NH_3-NL), and water quality index (WQI). These raw data were used in order to determine the waters quality standard. Data obtained were subjected to normality testing of each variable by statistical tests of kurtosis and skewness. The raw data were also treated by logarithmic transformation (log scaling), column scaling, and column auto-scaling. All log transformed variables were also z-scale standardized to minimize the effects of different units and variance of variables and equally to transform the data into dimensionless format. The data were analyzed using descriptive statistics, and were interpreted into tables, histograms and box plot. All statistical analyses were conducted using Statistical Packages for Social Sciences (SPSS) version 21.

Results and discussion

The pH of a solution is the concentration of hydrogen ions, expressed as a negative logarithm. It reflects the acidicity or alkalinity of a solution. Water with a pH of 7 is neutral, lower pH levels indicate increasing acidicity, while pH level higher than 7 reveal increasingly alkaline solution. The pH values in Terengganu River Basin vary from 5.77 to 7.43 during sampling in March, May, July, September and December (Table 1). The highest pH values observed from Terengganu River Basin is 7.43 in July at 4TE02, while the lowest pH value is 5.77 in September, at 4TE05 as shown in Table 1 and Fig. 2. On the other hand, the result showed that pH values at Kinta River Basin vary from 6.26 to 7.65 with the highest value of 7.65 during November at station 2SPK24 and the lowest values in May at the 2SPK19 sampling station (Table 2 and Figure 3).

Table 1. The pH Values in Terengganu River Basin in March, May, July and December 2004

	Month				
Station	March	May	July	September	December
4TE01	7.11	6.40	6.93	6.40	6.70
4TE02	7.21	6.86	7.43	7.37	7.41
4TE03	7.35	6.69	7.34	6.48	7.12
4TE04	6.71	6.41	6.56	6.12	6.81
4TE05	6.58	6.30	6.16	5.77	6.30
4TE06	6.05	6.46	6.34	6.17	6.28
4TE07	6.22	6.33	6.47	6.21	7.11
4TE08	7.02	6.62	6.71	6.45	6.79
4TE09	6.94	6.62	6.77	6.64	6.63

Table 2 The pH values at Kinta River Basin for February, May and August and November 2002

	Month			
Station	February	May	August	November
2SPK19	6.91	6.26	6.67	6.82
2SPK22	7.27	6.64	7.33	7.51
2SPK24	7.19	7.12	7.42	7.65
2SPK25	7.04	6.68	7.23	7.09
2SPK33	7.14	6.78	6.82	6.91
2SPK34	7.30	6.85	6.99	7.04

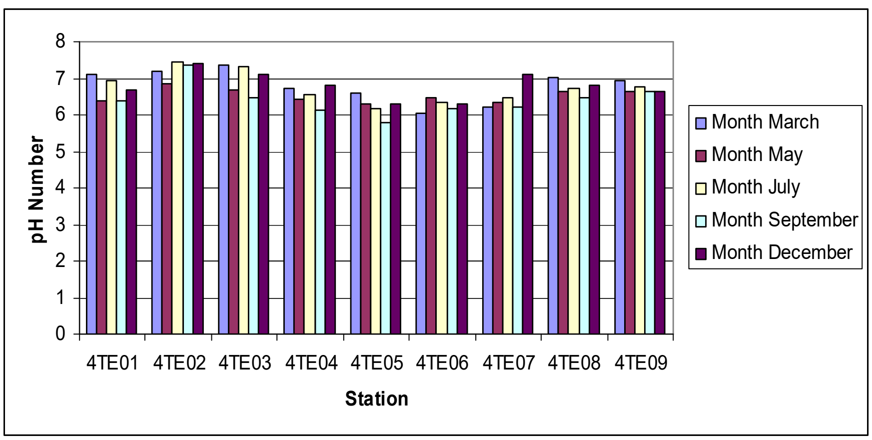

Figure 2 The comparison of pH values for March, May, July, September and December in the year 2004 from Terengganu River Basin.

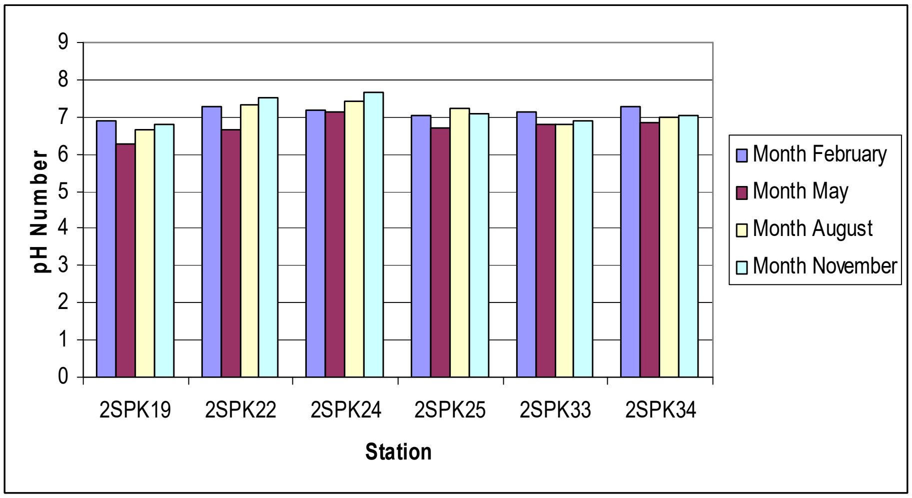

Figure 3 The histogram of pH Values in February, May, August and November 2002 from Kinta River Basin sampling station

Moreover, it can be compared that, Kinta River Basin has the highest pH values compare to pH value in Terengganu River Basin. The frequency of pH values at Terengganu River Basin is slightly similar at each sampling stations which consist of only 1 reading frequency, except pH values of 6.30, 6.40, 6.62, 6.71 and 7.11 which showed 2 reading frequency as presented in Table 3. The pH values for Kinta River Basin also revealed a slightly similar reading among the sampling stations with only one reading frequency except for pH values of 6.82, 6.91 and 7.04 which showed 2 reading frequency (Table 4).

Table 3 The frequency for pH values of Terengganu River Basin in 2004

pH	Freq	Cum. Freq.	%	Cum. %
5.77	1	1	2.22%	2.22%
6.05	1	2	2.22%	4.44%
6.12	1	3	2.22%	6.67%
6.16	1	4	2.22%	8.89%
6.17	1	5	2.22%	11.11%
6.21	1	6	2.22%	13.33%
6.22	1	7	2.22%	15.56%
6.28	1	8	2.22%	17.78%
6.30	2	10	4.44%	22.22%
6.33	1	11	2.22%	24.44%
6.34	1	12	2.22%	26.67%
6.40	2	14	4.44%	31.11%
6.41	1	15	2.22%	33.33%
6.45	1	16	2.22%	35.56%
6.46	1	17	2.22%	37.78%
6.47	1	18	2.22%	40.00%
6.48	1	19	2.22%	42.22%
6.56	1	20	2.22%	44.44%
6.58	1	21	2.22%	46.67%
6.62	2	23	4.44%	51.11%
6.63	1	24	2.22%	53.33%
6.64	1	25	2.22%	55.56%
6.69	1	26	2.22%	57.78%
6.70	1	27	2.22%	60.00%
6.71	2	29	4.44%	64.44%
6.77	1	30	2.22%	66.67%
6.79	1	31	2.22%	68.89%
6.81	1	32	2.22%	71.11%
6.86	1	33	2.22%	73.33%
6.93	1	34	2.22%	75.56%
6.94	1	35	2.22%	77.78%
7.02	1	36	2.22%	80.00%
7.11	2	38	4.44%	84.44%
7.12	1	39	2.22%	86.67%
7.21	1	40	2.22%	88.89%
7.34	1	41	2.22%	91.11%
7.35	1	42	2.22%	93.33%
7.37	1	43	2.22%	95.56%
7.41	1	44	2.22%	97.78%
7.43	1	45	2.22%	100.00%

Table 4 The frequency of pH values of Kinta River Basin in year 2002.

pH	Freq	Cum. Freq.	%	Cum. %
6.26	1	1	4.17%	4.17%
6.64	1	2	4.17%	8.33%
6.67	1	3	4.17%	12.50%
6.68	1	4	4.17%	16.67%
6.78	1	5	4.17%	20.83%
6.82	2	7	8.33%	29.17%
6.85	1	8	4.17%	33.33%
6.91	2	10	8.33%	41.67%
6.99	1	11	4.17%	45.83%
7.04	2	13	8.33%	54.17%
7.09	1	14	4.17%	58.33%
7.12	1	15	4.17%	62.50%
7.14	1	16	4.17%	66.67%
7.19	1	17	4.17%	70.83%
7.23	1	18	4.17%	75.00%
7.27	1	19	4.17%	79.17%
7.30	1	20	4.17%	83.33%
7.33	1	21	4.17%	87.50%
7.42	1	22	4.17%	91.67%
7.51	1	23	4.17%	95.83%
7.65	1	24	4.17%	100.00%

Table 5 revealed that the highest number of frequency of pH reading in Terengganu River is 6.60 while the second highest frequency reading with pH 6.32. The third highest frequency reading of pH in Terengganu River is 6.05, followed by 6.88 and 7.15. The least number of frequencies in Terengganu River obtained was 5.77 as showed in Table 5 and Figure 4.

Table 5 The reading frequency of values of pH with range of Terengganu River Basin in 2004.

Range of pH values	Freq	Cum. Freq.	%	Cum. %
5.77	1	1	2.22%	2.22%
6.05	9	10	20.00%	22.22%
6.32	11	21	24.44%	46.67%
6.60	12	33	26.67%	73.33%
6.88	6	39	13.33%	86.67%
7.15	6	45	13.33%	100.00%

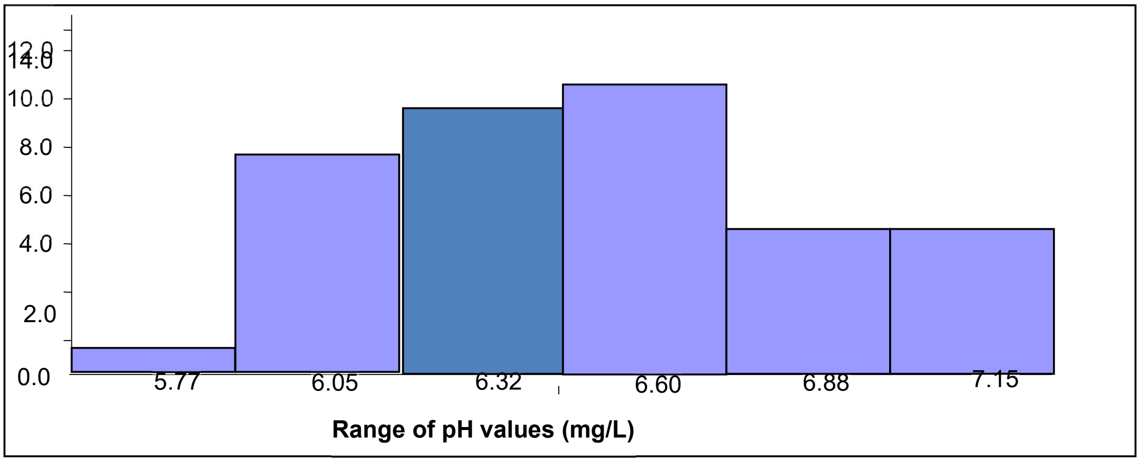

Figure 4 Histogram showing frequency of pH values in Terengganu River Basin in the yea2004

Table 6 revealed that the highest number of frequency of pH reading in Kinta River is 6.72 and 6.96 while the second highest frequency reading with pH 7.19. The third highest frequency reading of pH in Kinta River is 6.49, and 7.42. The least number of frequencies in Kinta River obtained was 6.26 as showed in Table 6 and Figure 5.

Table 6 The frequency of pH values with range at Kinta River Basin 2002.

pH	Freq	Cum. Freq.	%	Cum. %
6.26	1	1	4.17%	4.17%
6.49	3	4	12.50%	16.67%
6.72	6	10	25.00%	41.67%
6.96	6	16	25.00%	66.67%
7.19	5	21	20.83%	87.50%
7.42	3	24	12.50%	100.00%

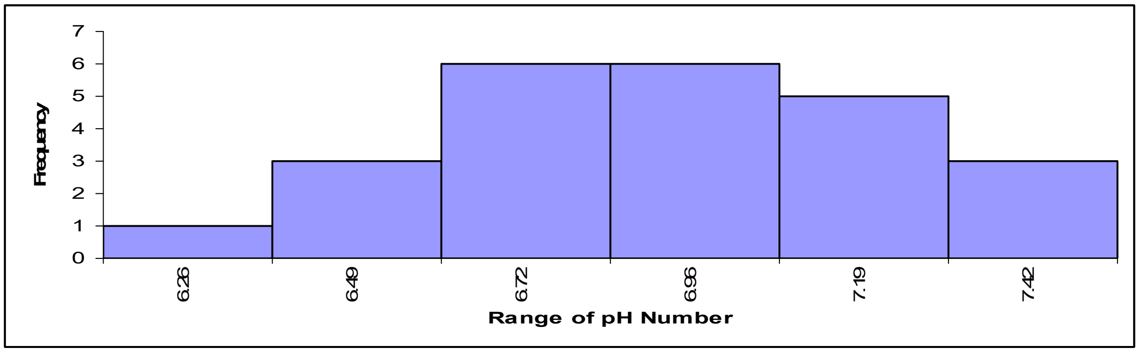

Figure 5 Histogram frequencies against pH values at Kinta River Basin 2002.

Figure 6 shows histogram of pH value obtained from 9 monitoring stations in Terengganu River. The highest pH value of 7.15 and 6.88 were obtained from 4TE02 and 4TE09 as showed in Figure 5, while the highest pH value obtained from Kinta River was 6.72 at monitoring station 2PK24 as presented in Figure 7.

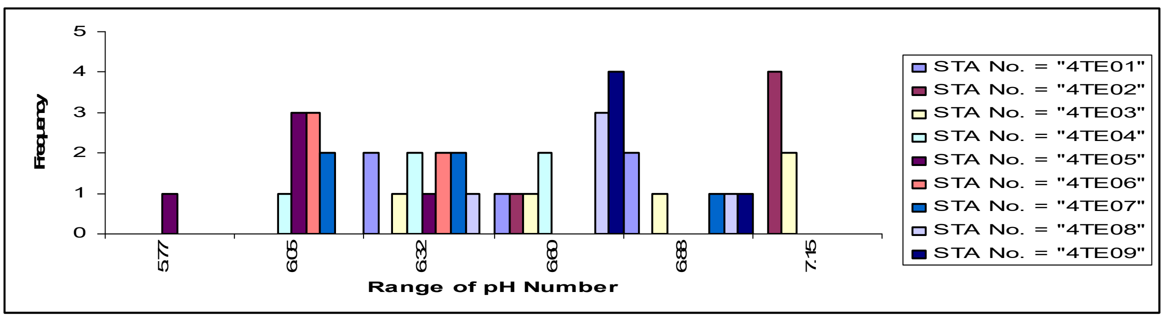

Figure 6 Histogram of pH values at Terengganu River Basin in 2004 from 9 monitoring stations

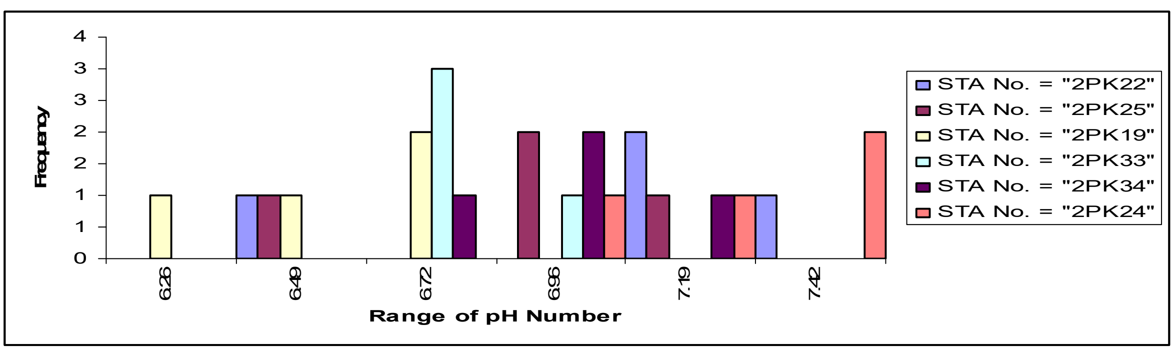

Figure 7 Histogram of pH values at Kinta River Basin in 2002 from 6 monitoring stations

Box plot in Figure 8 revealed that, the 25% of lower set data for pH values in Terengganu River Basin is greater than 6.39, while the average of pH values is greater than 6.60 and 25 % of data for pH values is greater than 6.93. There is no extreme value for upper and lower set of the pH Values in Terengganu River Basin.

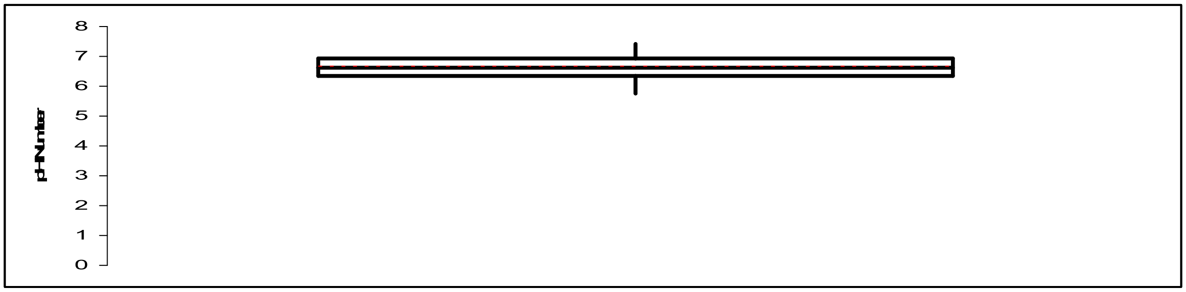

Figure 8 Box plots of pH values at Terengganu River Basin in 2004

Box plot presented in Figure 9 revealed that 25% of lower set of data for pH values in Kinta River is greater than 6.82, while the average of pH values is greater than 7.04 and 25 % of upper set data for pH values is greater than 7.24. There is no extreme value for upper and lower set for the pH Values in Kinta River Basin.

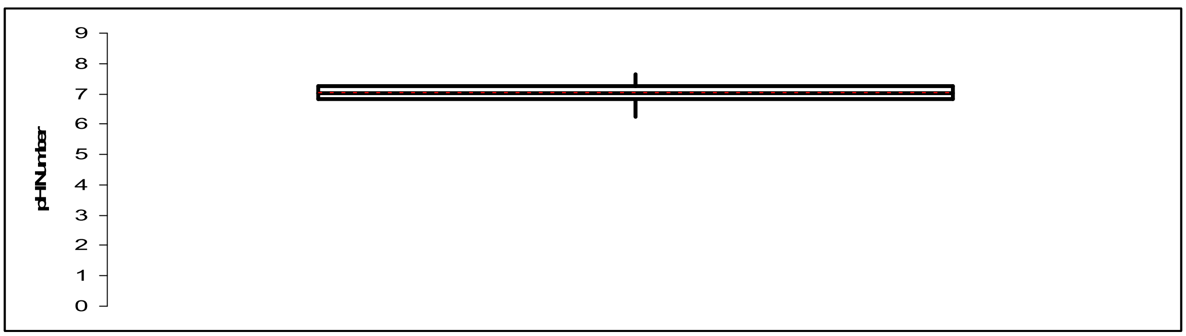

Figure 9 Box plots of pH values at Kinta River in 2002

For both Rivers, it can be concluded that, Kinta River showed higher median which is 7.24 compared to Terengganu River Basin which is 6.60. For the first quartile, Kinta River Basin showed higher pH values which is 7.04 and Terengganu River Basin is 6.39. For the third quartile, Kinta River is higher which are7.24 and Terengganu River Basin is 6.93. The trend of pH values in Kinta River ended after 25 reading among 6 stations after 4 months sampling. Initially, the reading of pH values at Kinta River was 7.27, and then it turns downward for the next three reading to 6.91.After it turns upwards for the next 2 reading to 7.3. After that, it descends to 6.26 and then increases again to 7.12. Then, it was decreased again to 6.67 and for the next reading, it was increased to 7.42. For the 20th reading, it increases from 6.82 to 7.09. Then, for 22nd reading, it was decreased to 6.91 and after that the pH values increases from 7.04 to 7.65. But moreover, the variance of reading at Kinta River Basin is minimal because the distribution of reading is not too much deviate from the mean.

The trend of pH values in Terengganu River among nine stations in 5 months sampling showed a pattern of fluctuations. Initially, the reading of pH in Terengganu River Basin was 7.11 and increases to 7.35. After that, it was decreased to 6.05 at the 7th reading. It increases to 7.02 and decreases again to 6.4. For the next reading, it increases to 6.69. For the 13th reading, the reading decrease to 6.3. After that, the pH maintains 6.62 for the next two reading. On the 20th reading, the value increases to 7.43. But then, it decrease to 6.16 on the 24th reading. However, the reading increases to 6.77 on the 28th reading. It decreases to 6.4 and increases sharply to 7.37. After that, the reading decrease to 5.77 on the 33rd reading, then increases simultaneously to 7.41. After that the reading decreases to 6.2 on 43rd reading. Then, it increases again to 7.11 before descend to 6.79 and 6.63 respectably at 45th and 46th reading (Figure 10).

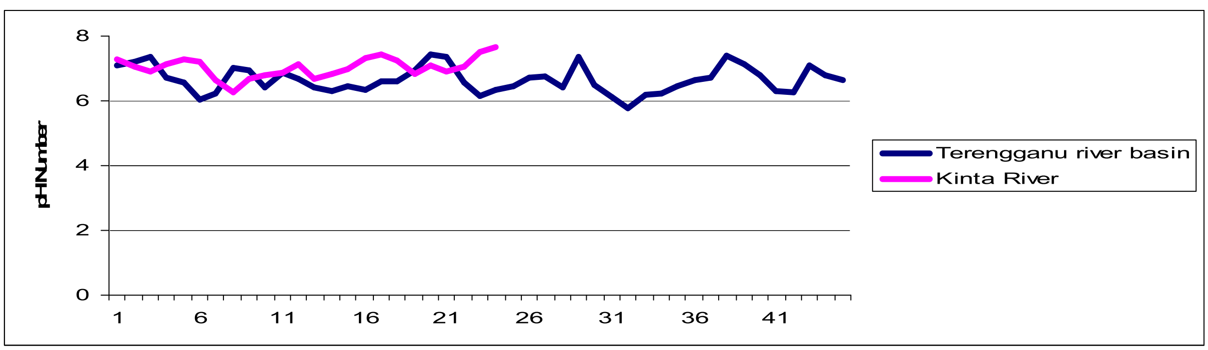

Figure 10 Comparison of pH values between Kinta River Basin and Terengganu River Basin in 2002 and 2004

Table 7 revealed that, the average pH values in Terengganu River Basin (6.64) is lower than that of Kinta River Basin (7.02). The range of pH values in Terengganu River Basin (1.66) is lower than Kinta River Basin (1.39). The standard deviation of Terengganu River Basin (0.41) is higher than Kinta River Basin (0.31) which shows higher variability of the pH reading. Kurtosis of pH values is negative in Terengganu River Basin while positive in Kinta River Basin. The skewness of pH reading in Terengganu River Basin is positively skewed while at Kinta River Basin is negatively skewed. All the three quartile and inter-quartile range in Kinta River Basin is higher than Terengganu River Basin.

Table 7 Variability statistics of pH values from Terengganu and Kinta Rivers

Type of Statistics	Terengganu River Basin	Kinta River Basin
Average	6.64	7.02
Minimum	5.77	6.26
Maximum	7.43	7.65
Range	1.66	1.39
Standard Deviation	0.41	0.31
Variance	0.17	0.09
Standard Error	0.07	0.06
Skewness	0.24	-0.22
Kurtosis	-0.47	0.31
25th Percentile	6.39	6.82
50th Percentile	6.60	7.04
75th Percentile	6.93	7.24
Inter-quartile Range	0.55	0.42

To identify the statistical spatial and temporal variations of pH in Terengganu and Kinta River Basins, Two-way between subjects factorial analysis of variance (2-way ANOVA) or factorial design ANOVA was chosen. The advantage of factorial design is that it allows a set of hypotheses to be tested at a comparable level of power by using a fraction in the subject or factor. The experimental design allows the evaluation of the interaction effects between two or more independed variables. The design in 2-way ANOVA is a full factorial if all the levels of one independent variable occur in combination with all the level of the other independent variable(s). Prior to the statistical analysis, exploratory data analysis was used on the data sets to detect outliers and extreme cases and further to test the assumptions of normality, linearity and equality of variance.

A 2 x 9 x 5 and 2 x 6 x 4 two-way analysis of variance (2-way ANOVA) between subjects effect (completely randomized) factor design in both Terrangannu and Kinta River Basins was performed on the dataset to explore the significant mean differences spatially and temporally between the pH value between the sampling site and months of study. Nine sampling points (4TE01, 4TE02, 4TE03, 4TE04, 4TE05, 4TE06, 4TE07, 4TE08, 4TE09) and five different sampling months (March, May, July, September, December) in Terangannu River Basins and Six sampling points (2SPK19, 2SPK22, 2SPK24, 2SPK25, 2SPK33, 2SPK34) and four different sampling months (February, May, August, November) in Kinta River Basin were selected and studied. The null hypothesis were stated as follow:

> H_o 1: There were no significant differences in the mean of pH value between the sampling sites in both Terranganu and Kinta River Basins.
> H_o 2: There were no significant differences in the mean of pH value between the months of the study in relation to sampling sites.

Preliminary data screening was conducted on the raw data to assess whether the assumptions of ANOVA were violated. The careful examination of a histogram of the pH values suggested that the scores had a skewed distribution, however logtransformation $x = \log10(x)$ was applied to the raw data. Log transformation removes outliers and renders the data normalized. Although log transformation is generally used to obtain normal distribution, it can also be applied to standardize the datasets and reduce the influence of extreme cases and outliers. After the transformation, the Levene Test indicated no significant violation of the homogeneity of variance assumption.

Table 8 Test between subject effects of pH in Terengganu River Basin

Source	Sum of Squares	*df*	Mean Square	*F*	*p*-value
Corrected Model	5.599a	12	0.467	9.199	0.000
Intercept	1991.343	1	1991.343	39258.26	0.000
Stations	4.423	8	0.553	10.899	0.000
Months	1.176	4	0.294	5.797	0.001
Error	1.623	32	0.051		
Total	1998.565	45			
Corrected Total	7.222	44			

R Squared = .775 (Adjusted R Squared = .691)

Table 9 Test between subject effects of pH in Kinta River Basin

Source	Sum of Squares	*df*	Mean Square	*F*	*p*-value
Corrected Model	1.862a	8	0.233	8.214	0.000
Intercept	1185.258	1	1185.258	41822.8	0.000
Stations	1.087	5	0.217	7.668	0.001
Months	0.776	3	0.259	9.124	0.001
Error	0.425	15	0.028		
Total	1187.546	24			
Corrected Total	2.287	23			

The test between subject effects (Table 8 and 9) revealed that, there was a strong statistical significant main effect on spatial pH values in Terengganu River Basin [(*F*=10.899, *df*=8, *p*-value=0.0001)], and statistical significant main effect on temporal pH values [(*F*=5.797, *df*=4, *p*-value=0.001)], while the test between subjects effects showed than pH values varies significantly spatially [(*F*=7.668, df=5, *p*-value0.001)] and temporally [(*F*=9.124, df=3, *p*-value=0.001)].

Post-hoc test using Bonferroni multiple comparison tests (Table 10 and 11) indicated that the mean differences (MD) of pH values in Terengganu River Basin in March and July were significantly different from pH values obtained in September (MD=0.3978*, SE=0.10617, *p*-value =0.007). In comparison with Kinta River Basin, Bonferroni comparison tests revealed that pH values obtained in February differ significantly with the value in May (MD=0.4200*, SE=0.0719, *p*-value= 0.004), May and November (MD=0.4483*, SE=0.0719, *p*-value =0.002), May and August (MD=0.3550*, SE=0.0719, *p*-value =0.014) Moreover, the value of pH in March and May, March and July, March and December and February and August, February and November in Terengganu and Kinta River Basins respectively did not reach statistical significance.

Table 10 Bonferroni multiple comparison test of temporal variation of pH values in Terengganu River Basin

(I) Months	(J) Months	MD (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
March	May	0.2778	0.10617	0.135	-0.0423	0.5979
	July	0.0533	0.10617	1.000	-0.2668	0.3734
	September	.3978*	0.10617	0.007	0.0777	0.7179
	December	0.0044	0.10617	1.000	-0.3157	0.3245
May	March	-0.2778	0.10617	0.135	-0.5979	0.0423
	July	-0.2244	0.10617	0.424	-0.5445	0.0957
	September	0.12	0.10617	1.000	-0.2001	0.4401
	December	-0.2733	0.10617	0.149	-0.5934	0.0468
July	March	-0.0533	0.10617	1.000	-0.3734	0.2668
	May	0.2244	0.10617	0.424	-0.0957	0.5445
	September	.3444*	0.10617	0.028	0.0243	0.6645
	December	-0.0489	0.10617	1.000	-0.369	0.2712
September	March	-.3978*	0.10617	0.007	-0.7179	-0.0777
	May	-0.12	0.10617	1.000	-0.4401	0.2001
	July	-.3444*	0.10617	0.028	-0.6645	-0.0243
	December	-.3933*	0.10617	0.008	-0.7134	-0.0732
December	March	-0.0044	0.10617	1.000	-0.3245	0.3157
	May	0.2733	0.10617	0.149	-0.0468	0.5934
	July	0.0489	0.10617	1.000	-0.2712	0.369
	September	.3933*	0.10617	0.008	0.0732	0.7134

Table 11 Bonferroni multiple comparison test of temporal variation of pH values in Kinta River Basin

(I) Months	(J) Months	MD	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
February	May	.4200*	0.09719	0.004	0.1249	0.7151
	August	0.065	0.09719	1.000	-0.2301	0.3601
	November	-0.0283	0.09719	1.000	-0.3234	0.2668
May	February	-.4200*	0.09719	0.004	-0.7151	-0.1249
	August	-.3550*	0.09719	0.014	-0.6501	-0.0599
	November	-.4483*	0.09719	0.002	-0.7434	-0.1532
August	February	-0.065	0.09719	1.000	-0.3601	0.2301
	May	.3550*	0.09719	0.014	0.0599	0.6501
	November	-0.0933	0.09719	1.000	-0.3884	0.2018
November	February	0.0283	0.09719	1.000	-0.2668	0.3234
	May	.4483*	0.09719	0.002	0.1532	0.7434
	August	0.0933	0.09719	1.000	-0.2018	0.3884

Hierarchical Agglomerated Cluster Analysis (HACA) was used to explore the spatial similarities and pattern recognition of Terengganu and Kinta River Basins. HACA is an unsupervised pattern recognition technique that uncovers intrinsic structure or underlying behaviour of a data set without making a prior assumption about the data. It provides a visual summary of the clustering processes with a dramatic reduction in the dimensionality of the original data. Two major statistically significant clusters in Terengganu River Basin sampling sites were identified based on Ward method, single and average linkage. The first cluster includes 4TE008, 4TE09, 4TE05 and 4TE06 and the second cluster comprises of 4TE04, 4TE07, 4TE03, 4TE01 and 4TE02 (Fig. 11). Similarly, Kinta River Basin sampling sites similarities were identified using HACA. Dendrogram (Fig. 12) generated two major groups of monitoring sites in a convincing way indicating relatively high independency for each cluster, cluster 1 comprises 2PK22, 2PK25, 2PK19 and 2PK33 while cluster 2 includes only 2PK34 and 2PK24. HACA provided effective representation of sampling points in the basin that could decrease the number of sampling sites with minimum loss of information.

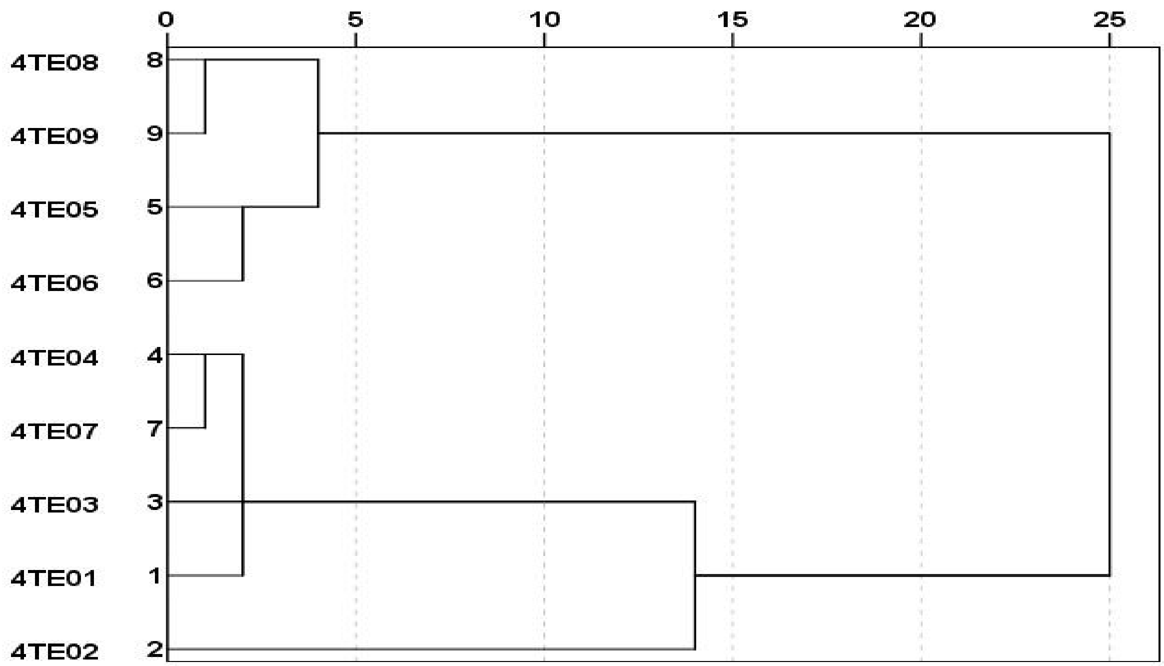

Figure 11 Dendrogram using single linkage showing spatial similarities and dissimilarities of sampling sites of Terengganu River Basin

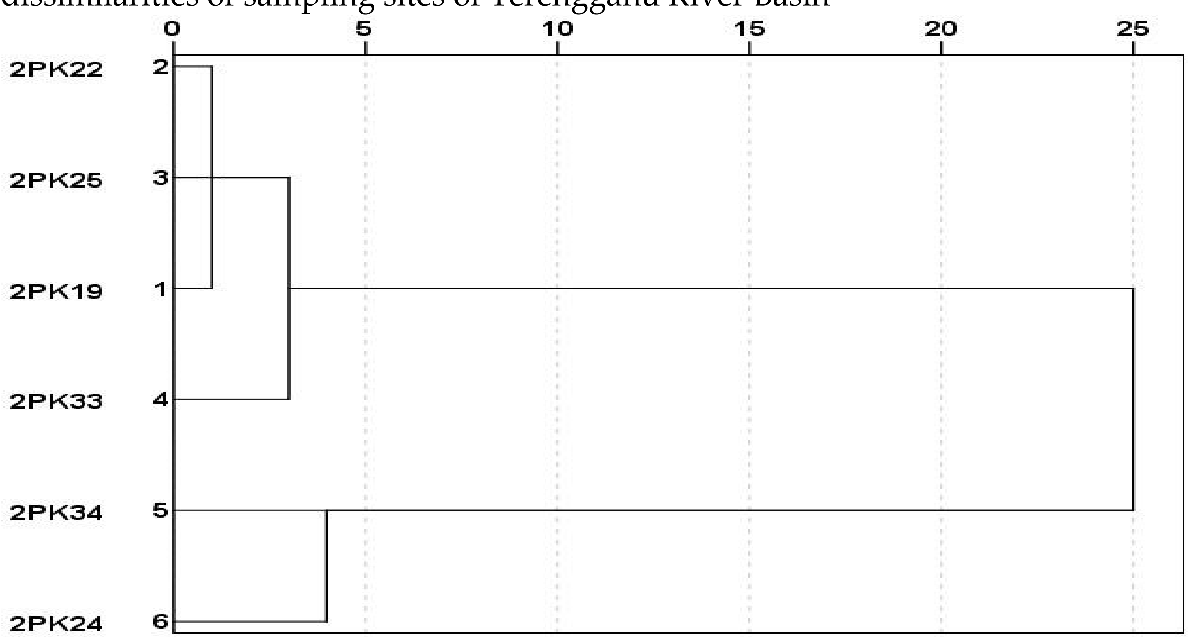

Figure 12 Dendrogram using average linkage (between group) showing spatial similarities and dissimilarities of sampling sites of Kinta River Basin

Xiangjiang River Basin, China was studied by Zhang *et al.* (2010). HACA was used to classify fifteen different sampling stations. HACA grouped the sampling stations into five clusters with similar hydrochemistry characteristics and pollution levels using a criterion value of a rescaled distance between three and twelve. The classification was determined to the practice based on valuable information regarding the locations of industrial, agricultural and residential facilities as well as administrative districts along Xiangjiang River. Bouza-Deaño (2008) used HACA for the study of spatial variability of surface water quality in Ebro River, Spain. HACA was applied to the data set with the aim of grouping similar sampling sites. HACA was performed on the normalized data by means of the ward's method and using Euclidean distance (Dlink/Dmax). Cluster analysis rendered a dendrogram where all the thirteen monitoring sites of Ebro River were grouped into three statistically significant clusters. The result of the study is convincing, because the sites in these groups have similar characteristics and natural sources type. The result of the study is convincing, because the sites in these groups have similar characteristics and natural sources type. This implies that, for rapid assessment of water quality, only one site in each cluster may be considered in the future assessment. Thus, the number of sampling site in the monitoring network will be reduced, and therefore cost without losing any value of the outcome will be saved.

Comparison of chemical oxygen demand (COD) in Kinta and Terengganu River Basins

The chemical oxygen demand (COD) content in Kinta River is 20-40 mg/L while that of Terengganu River is 25 mg/L and this showed that the COD content in Kinta River is higher than that of Terengganu River Basin. Based on Interim National River Water Quality Standard (INRWQS) COD of 25-50 mg/L revealed that river water fall within the class III and the water needs extensive treatment before consumption. The result showed that Kinta River is heavily polluted with non-degradable organic compound and requires extensive treatment before use. Terengganu River Basin has average COD content of 15-25mg/l which fall under class II of INRWQS and is less polluted and needs only conventional treatment before consumption.

Both Terengganu and Kinta River Basins value of COD content revealed almost the same values, because they fall under the class II of INRWQS (Fig. 13). In this observation the COD for the two Rivers is between 15-25mg/l. At sample observation 17-25, the COD at Kinta River is higher because it is within 30-70mg/l while that of Terengganu River is less polluted with 15-25mg/l. According to INRWQS Kinta River Basin fall under the class III and IV which means that the River water is good for irrigation activity but has to undergo extensive treatment before consumption. Terengganu River Basin has COD less than that of Kinta River Basin and is classified as class II of INRWQS that can be used for recreation but needs conventional treatment before use.

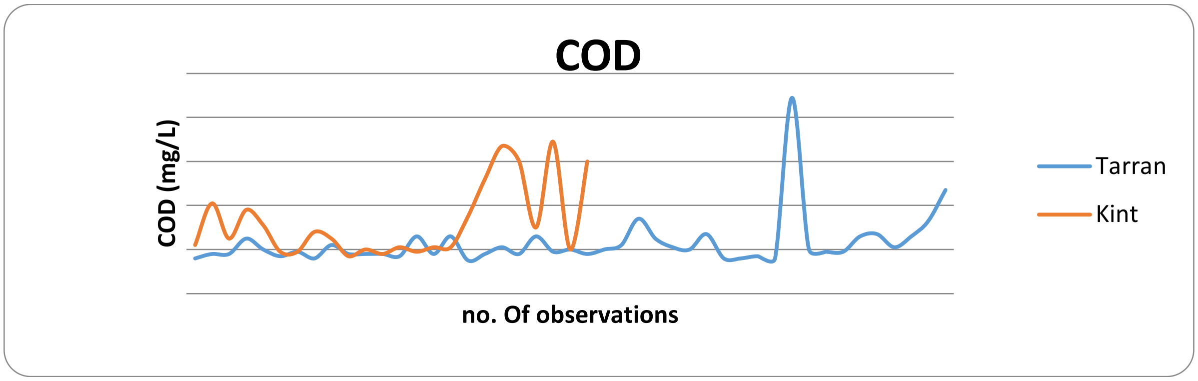

Figure 13 Comparisons of COD between Terengganu and Kinta River Basins

Comparison between Ammonia-Nitrogen (NH_3-N) Terengganu and Kinta River Basins

Ammonia (NH_3-N) levels in excess of the recommended limits may harm aquatic life. Although a NH_3-N molecule is a nutrient and required for life supporting system, excess ammonia may accumulate in the organism and cause alteration of metabolism or increases the body pH. It is an indicator of pollution from the excessive usage of ammonia rich fertilizers. Figure 14 and Figure 15 shows the frequency of concentration of NH_3-N of both Terengganu and Kinta Rivers Basin.

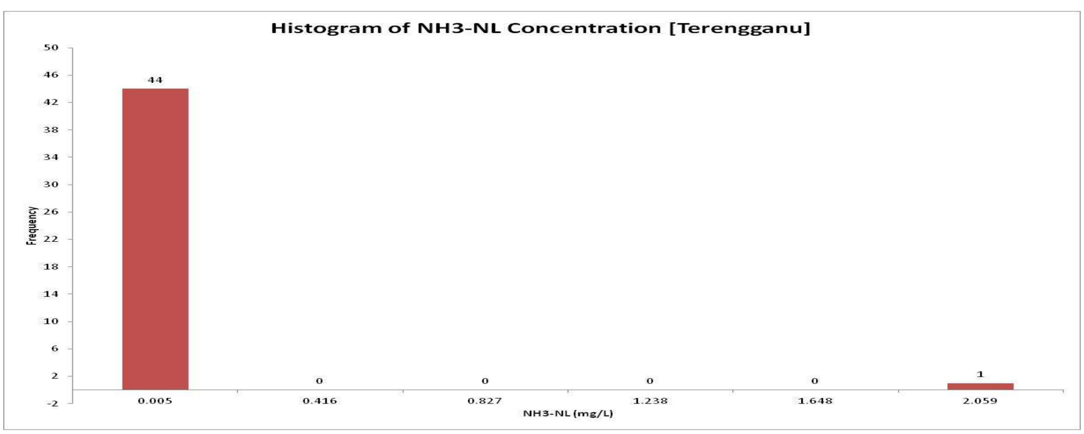

Figure 14 Histogram of frequency of NH_3-N concentration Terengganu River Basin

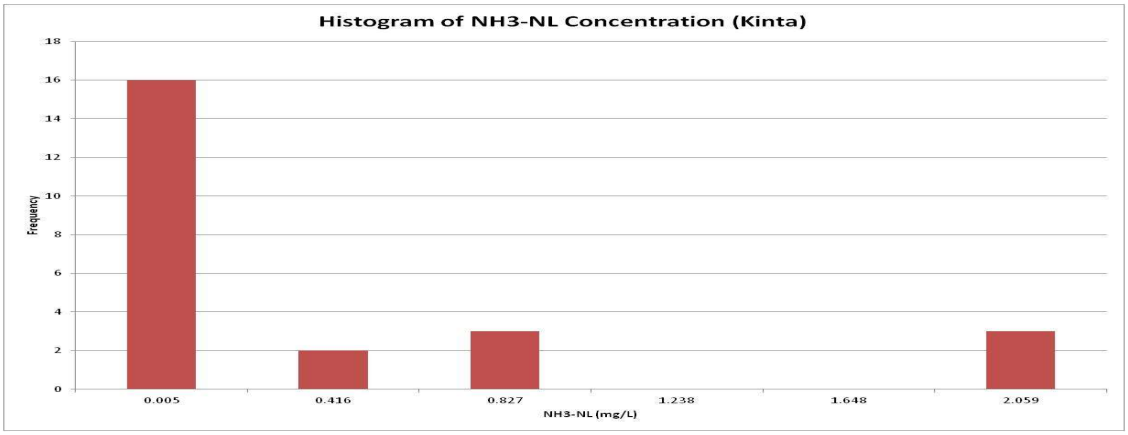

Figure 15 Histogram of frequency of NH_3-N concentration Kinta River Basin

The Figures revealed that the Kinta River Basin has a quite NH_3-N frequency this means that, Kinta River Basin is polluted with fertilizers in their agriculture activities. Terengganu River Basin has less frequency of NH_3-NL concentration which indicated less human activities around the River Basin.

Conclusions

In this present study, an attempt was made to compare the pollution status of Terengganu and Kinta River Basins based on some selected physicochemical parameters. The average pH value in Terengganu River basin was 6.64 while that of Kinta River Basin was 7.02. The pH value is positively and negatively skewed in Terengganu and Kinta River Basins. Two-way ANOVA revealed a spatial and temporal significance differences in the mean of pH value among the sampling stations and months of observations in both Terengganu and Kinta River Basins. Total suspended solids (TSS) showed that the average TSS value of Kinta River Basin is higher than that of Terengganu River Basin. Hierarchical Agglomerated Cluster Analysis (HACA) revealed two major statistical clusters of water quality monitoring groups in both river basins. Chemical oxygen demand (COD) content is lower in Kinta River Basin compared to Terengganu River Basin. Ammonia (NH_3-N) revealed higher value in Kinta when compared with Terengganu River Basin.

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