PAPER • **OPEN ACCESS**

Assessment of Kelantan River water quality using water quality index (WQI)

To cite this article: F S Radin Nizar *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **842** 012005

Assessment of Kelantan River water quality using water quality index (WQI)

F S Radin Nizar[1], R Mohd Ghazi[1,*], N R Awang[1] and M Muhammad[1]

[1]Faculty of Earth Science, Universiti Malaysia Kelantan, 17600 Jeli, Malaysia
*Corresponding author: rozidaini@umk.edu.my

Abstract. Kelantan River is the main river in Kelantan, and it has been used for water sources for irrigation, small-scale fishing industries, transportation, and sand mining. WQI is a comprehensive method for displaying water quality status and achieving good water quality. This study is aims to identify the significant difference in water quality index (WQI) parameters and the correlation between WQI parameters in urban, suburban, and residential area along the Kelantan River from 2015 until 2019. Water quality stations in urban, suburban, and residential areas were selected with facilitation of ArcMap 10.0 software. In this study, Kota Bharu represented urban area, Kuala Krai represented suburban area and Tanah Merah represented residential area. The significant difference between WQI value with different stations were determined using analysis of variance (ANOVA). Meanwhile the correlation between WQI parameters were determined using Pearson correlation. From this research, there is no significant difference in water quality between urban, suburban, and residential areas along Kelantan River. The correlation of water quality parameters varies between locations which indicates different water pollution contributors except correlation between biochemical oxygen demand (BOD) and chemical oxygen demand (COD), pH and ammoniacal nitrogen (AN), and total suspended solid (TSS) and WQI. WQI in urban, suburban, and residential areas were classified in Class II from 2015 until 2019 except WQI in residential area in 2019 which was classified in Class III. This study will provide scientific reference for future use to protect local aquatic environment in Kelantan River and can be used to manage the river basin development in future.

1. Introduction

Deteriorating water resource quality would induce dying ecosystem, depletion of fish stocks in the river and water-borne diseases. Usually, in developing country includes Malaysia, the wastewater from industries and domestic has been discharged into the surface water because lack of improper wastewater treatment facilities [1].

In Malaysia, the resident depends on river as main water resources either being consume directly or indirectly. In Malaysia, 60% of major rivers are used for domestic usage, agricultural activities, and industrial manufactures which led to major pollution in Malaysia [2]. The main river basin in Kelantan is Kelantan River which has the most tributaries among other river basins. As the longest river in Kelantan, Kelantan River is flowing from Mountain Ulu Sepat which is in Perak state of Malaysia to South China Sea [3]. It flows through seven main towns. The river has often been utilized for irrigation for plantation, agricultural, sand mining activities and small-scale fishing industries [4]. In consequence, Kelantan River had been classified in Class II with WQI value of 79 and was categorized as slightly polluted river [5].

In Malaysia, National Water Quality Standard (NWQS) has been published by Department of Environment (DOE) Malaysia. In NWQS, DOE Water Quality Index (WQI) has six parameters to be counts in which are Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Potential of Hydrogen (pH), Total Suspended Solids (TSS) and Ammoniacal Nitrogen (AN). WQI is a comprehensive method for displaying water quality status [6] and achieving good water quality. Because of various activities, WQI levels vary in different places. The entire Kelantan River has flow through urban, suburban and residential areas with each different environment.

As stated in the Environmental Quality Report, the most significant parameters in the WQI of Malaysia's rivers are BOD, AN and TSS due to livestock farming, untreated or partially treated sewage from manufacturing and agro-based industries. In Kelantan, there was limited study conducted on the correlation of WQI in urban, suburban and residential areas along Kelantan River. The information about the comparison on WQI in selected areas were also limited. Therefore, this research study aims to compare Water Quality Index (WQI) and its parameter in urban, suburban and residential area in Kelantan River using statistical analysis and to correlate between the parameters in urban, suburban and residential area along Kelantan River using Pearson correlation.

2. Materials and method

2.1. Study area

The study area encompasses along Kelantan River basin in Kelantan. Kelantan River flows from the north-east Malaysia through capital city of Kota Bharu, Kelantan to South China Sea (longitude 101˚ 20’ to 102˚ 20’ N and latitude 4˚ 40’ to 6˚ 12’ E). The locations were selected based on suitability of locations meeting the criteria’s of urban, suburban, and residential areas.

Selected DOE water quality stations are located at Sultan Yahya Petra Bridge in Kota Bharu (urban area), Guillemard Bridge in Tanah Merah (residential area) and Tangga Krai in Kuala Krai (suburban area). The surrounding area at Sultan Yahya Petra Bridge, Kota Bharu is dense with buildings and infrastructures along Kelantan River with population about 596,900 [7]. The surrounding area at Tangga Krai, Kuala Krai is less dense with buildings and infrastructures than Kota Bharu with population about 135,200. Lastly, the surrounding area at Guillemard Bridge, Tanah Merah is the least dense with buildings and infrastructures but dense with houses and has approximately 149,200 residents.

Moreover, the selection of DOE water quality stations also based on the sufficiency of water quality data for five years from 2015 to 2019. DOE water quality stations namely 4KE01, 4KE06, 4KE19 were selected representing river water quality in urban, suburban, and residential areas in Kelantan River as shown in Table 1.

Table 1. Selected water quality stations characteristics.

Station No.	Area	Location	Latitude	Longitude
4KE01	Residential	Tanah Merah	102.151374	5.775413
4KE06	Urban	Kota Bharu	102.227101	6.116425
4KE19	Suburban	Kuala Krai	102.195505	5.534445

Using ArcMap 10.0 software, urban, suburban, and residential areas along with DOE water quality stations were selected. Figure 1 shows the map of study area in Kelantan River. Kota Bharu, Kuala Krai and Tanah Merah and DOE water quality stations were marked in Figure 1.

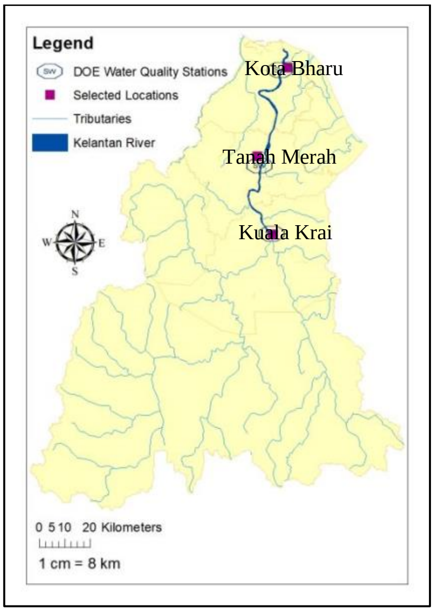

Figure 1. Map of study area in Kelantan River basin and locations of DOE water quality stations.

2.2. Data collection

Water Quality Index (WQI) and its parameters data from 2015 until 2019 were obtained from Department of Environment (DOE). The required data are DO, BOD, COD, pH, TSS and AN.

2.3. Statistical analysis

International Business Machines Corporation Statistical Package for the Social Sciences (IBM SPSS Statistics) software was utilized to run Analysis of Variance (ANOVA) and Pearson correlation. ANOVA was utilized for determining significant value to compare parameters in Water Quality Index (WQI) and determined the effect size values of every parameter in Kota Bharu, Kuala Krai and Tanah Merah. The mean of WQI, its parameters and subindex parameters were obtained from descriptive analysis using IBM SPSS Statistics software. WQI and its parameters in urban, suburban, and residential areas were compared using Analysis of Variance (ANOVA). The effect size values were determined from sum of squares of every parameter.

The correlation analysis was analysed using Pearson correlation. The correlation analysis was able to identify the association of WQI parameters. Direct correlation in Pearson correlation is exists when increase or decrease in the value of parameter is associated with a corresponding increase or decrease value of another parameter. Correlation between water parameters in WQI were analyzed to indicate the association between two parameters (variables) of six parameters in WQI. Besides, the most influence parameter in WQI calculation was identified in correlation analysis between six parameters and WQI value in the area either in urban, suburban, and residential areas.

3. Results and discussion

3.1. Trends analysis

In the findings, the yearly WQI and its parameters differs between urban, suburban and residential areas. The trends of WQI and its parameters in Kota Bharu, Kuala Krai and Tanah Merah from 2015 to 2019 are shown in Figure 2.

The range of DO concentration in Kelantan River was from 5.5 mg/L to 7.5 mg/L. The DO in Kuala Krai and Tanah Merah rose gradually by years but DO in Kota Bharu decreased in 2016 and then continued to increase steeply until 2018. The degradation of the DO might be due to a rise in the growth rate of the micro-organism that utilize the organic matter found in the improper disposal that was drained into the river [8]. According to DOE WQI Classification, DO had improved in all three locations. From 2015 to 2017, DO was classed in Class II, but in 2018 to 2019, DO has improved to Class I.

The BOD in Kota Bharu and Kuala Krai fluctuated from 2015 to 2019 between 3.8 mg/L - 7 mg/L. However, in 2019, the BOD in Kota Bharu was increased. Meanwhile BOD in Kuala Krai and Tanah Merah were dropped. BOD in Kota Bharu had worsened in 2019 and dropped from Class III to Class IV. BOD in Kuala Krai had classed in Class IV in 2015, 2016 and 2018 while in 2017 and 2019, BOD in Kuala Krai were in Class III. Lastly, BOD in Tanah Merah was in Class III throughout years except year 2018. The low value of BOD suggests that there is less organic matter in the water sample to be metabolised by bacteria [9].

COD in Kuala Krai was the highest in 2015 while COD in Tanah Merah increased gradually from 2015 to 2018. Therefore, it indicated more oxygen was required to chemically oxidize organic matters in water. The trend of COD and BOD plots was quite similar which is fluctuated because COD and BOD has a strong relationship. COD and BOD are linearly correlated in most studies [10]. High COD value would specify that there were many organic contaminants such as leachate in sample [11]. However, COD in all three locations were classed in Class II throughout years.

TSS in Kota Bharu, Kuala Krai and Tanah Merah ranged from 71 mg/L - 1036 mg/L. TSS in Kota Bharu and Tanah Merah increased from 2015 to 2017 and slightly decreased from 2018 to 2019. However, TSS in Kuala Krai increased steadily from 2016 to 2019. The increased of TSS in Kuala Krai may come from nearby soil erosion caused by human activities [12]. TSS of Kota Bharu, Kuala Krai and Tanah Merah had reached Class V in 2019. The deterioration of TSS in all three locations might cause from the development nearby river and sand mining activities because excessive particles polluted Kelantan River [13].

All three locations recorded lowest pH in 2016. pH in Kota Bharu, Kuala Krai and Tanah Merah dropped in 2016 and then increased steadily until 2019. pH in Tanah Merah increased lower than pH in Kota Bharu and Kuala Krai. It might be due to amount of organic matter that had been decomposed in Tanah Merah was higher than other locations. The composition of organic matter in water increases the amount of carbon dioxide which is acidic in river which could lower pH. pH has improved in all locations from 2016 and classed in Class I in 2019.

AN in all three locations ranged from 0.049 mg/L - 1.314 mg/L. AN had steep increased in 2016 in Kota Bharu, Kuala Krai and Tanah Merah and then continued to fluctuate within 0.09 mg/L - 0.27 mg/L from 2017 to 2019. The highest AN recorded was in 2016 with the highest AN location is Tanah Merah, based on DOE WQI Classification, it was in Class IV. Thus, Tanah Merah has exceeded the maximum level of proposed AN which can support aquatic environment in 2016. Untreated sewage might have contributed into the increase of AN. But, in 2019, AN has improved and was classed in Class I for Kuala Krai, and Class II for Kota Bharu and Kuala Krai.

WQI in Kota Bharu, Kuala Krai and Tanah Merah steadily ranged between 84.8 and 77 from 2015 to 2019 except for Tanah Merah in 2019. WQI in Tanah Merah was deteriorating from 2015 to 2016 and from 2018 to 2019, however WQI was slightly levelled from 2016 to 2018. According to DOE WQI classification, the WQI of three locations were in Class II throughout the years except for Kota Bharu in 2016 and Tanah Merah in 2019 were of Class III. According to classification of river water quality using DOE water quality index, all WQI in the selected locations were slightly polluted except for Kota Bharu in 2015, Kuala Krai in 2015 and 2016, and Tanah Merah in 2015 which were classified as clean.

IOP Conf. Series: Earth and Environmental Science **842** (2021) 012005 doi:10.1088/1755-1315/842/1/012005

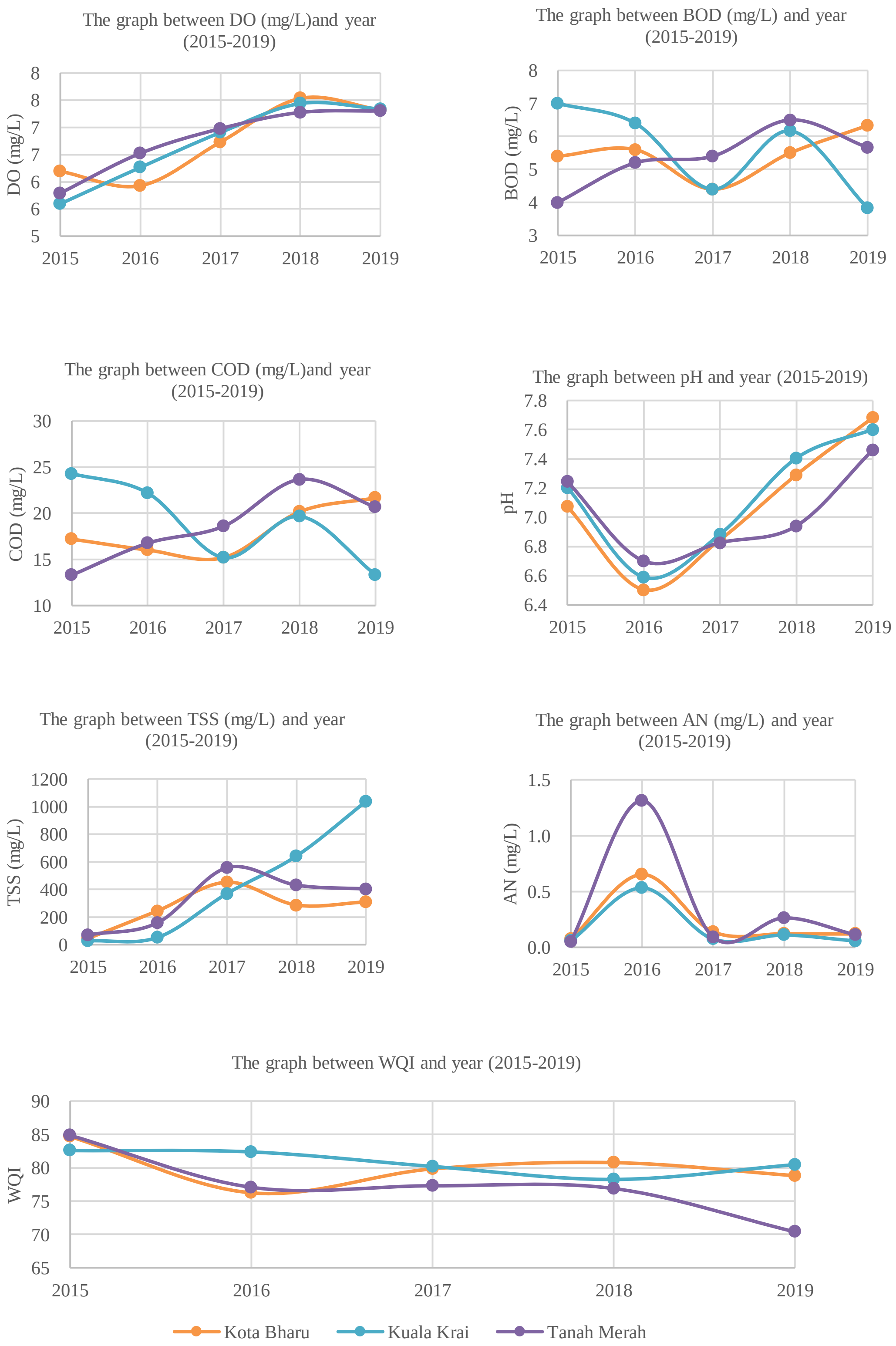

Figure 2. Trends of DO, BOD, COD, pH, TSS, AN and WQI in Kota Bharu, Kuala Krai and Tanah Merah (2015-2019).

3.2. *Comparisons of water quality index (WQI) and its parameters between urban, suburban and residential areas*

The contributions of urban (Kota Bharu), suburban (Kuala Krai) and residential (Tanah Merah) area to the values of WQI and its parameters were evaluated using one-way between groups analysis of variance (ANOVA). The ANOVA assumptions of normality and homogeneity of variance were not violated, and F-test were not significant, $F(2,12) = 0.025, 0.051, 0.068, 0.396, 0.086, 0.412, 0.070, 0.018, 0.014, 1.430, 0.003, 0.232$ and 1.298 for parameters DO, BOD, COD, TSS, pH, AN, SIDO, SIBOD, SICOD, SIAN, SISS, SIpH and WQI respectively as the values did not exceed from F-statistic = 3.89.

Based on the result, mean of each parameter and WQI has been analyzed. The significance values (p-values) of ANOVA were 0.976, 0.951, 0.934, 0.681, 0.918, 0.671, 0.933, 0.982, 0.986, 0.277, 0.997, 0.796 and 0.309 for parameters DO, BOD, COD, TSS, pH, AN, SIDO, SIBOD, SICOD, SIAN, SISS, SIpH and WQI respectively. The p-values of the parameters were higher than p-value = 0.05, thus there was no significant differences between the groups. Therefore, the null hypothesis (H_0) is accepted. There were no significant contributions of different locations to the value of parameters and WQI thus these parameters and WQI values distributed equally between locations.

Furthermore, the values of effect size indicate the percentage of variability in dependent variables (parameters) can be attributed to the independent variables (locations). All effect size values ($\eta2$) of parameters were below than 0.2 and Cohen suggested that $\eta2$ less than 0.2 is weak [14].

3.3. *The correlation between parameters in water quality index (WQI)*

To analyze the relationship between every water quality parameter, Pearson correlation had been conducted. The correlation classified into three groups location, Kota Bharu (KB), Kuala Krai (KK) and Tanah Merah (TM). Table 2 shows the strength of Pearson correlation of WQI and its parameters.

Table 2. Strength of Pearson correlation of WQI and its parameters.

Parameters	Locations	DO	BOD	COD	SS	pH	AN	WQI
	KB	-	W	VS	W	VS	-M	VW
DO	KK	-	-S	-S	VS	M	-W	-VS
	TM	-	VS	VS	S	W	-VW	-VS
	KB	W	-	S	-W	M	VW	-VW
BOD	KK	-S	-	VS	-S	-W	W	W
	TM	VS	-	VS	S	-VW	VW	-S
	KB	VS	S	-	-VW	VS	-M	VW
COD	KK	-S	VS	-	-VS	W	M	M
	TM	VS	VS	-	S	-VW	-VW	-S
	KB	W	-W	-VW	-	VW	VW	-M
TSS	KK	VS	-S	-VS	-	S	-M	-S
	TM	S	S	S	-	-VW	-W	-M
	KB	VS	M	VS	VW	-	-S	W
pH	KK	M	-W	W	S	-	-S	-M
	TM	W	-VW	-VW	-VW	-	-S	-VW
	KB	-M	VW	-M	VW	-S	-	-S
AN	KK	-W	W	M	-M	-S	-	M
	TM	-VW	VW	-VW	-W	-S	-	-VW
	KB	VW	-VW	VW	-M	W	-S	-
WQI	KK	-VS	W	M	-S	-M	M	-
	TM	-VS	-S	-S	-M	-VW	-VW	-

Where, positive correlation: VW = very weak, W = weak, M = moderate, S = strong, VS = very strong; negative correlation: -VW = very weak, -W = weak, -M = moderate, -S = strong, -VS = very strong; KB = Kota Bharu, KK = Kuala Krai, TM = Tanah Merah.

In Kota Bharu and Tanah Merah, DO had very strong positive correlation with COD, r-value=0.848 and r-value=0.931 respectively. In Kota Bharu, DO and pH has very strong positive correlation (r-value=0.847). Very strong correlation between DO and pH can be explained by photosynthesis reaction in water. The rapid consumption of carbon dioxide during photosynthesis resulted in and the correlation is a linear positive. pH of carbon dioxide ranges between 5.2 and 5.8 which is acidic [15]. Photosynthesis has resulted in an increase of oxygen in water, thus, DO increase. However, the correlation between DO and pH in Kuala Krai is moderate and in Tanah Merah is weak.

The correlations between WQI parameters varied in locations. However, BOD and COD had strong positive correlation in all three locations which were Kota Bharu; r-value = 0.79, Kuala Krai; r-value = 0.987, significant at $p < 0.01$, and Tanah Merah; r-value = 0.982, significant at $p < 0.01$. In natural wastewater, BOD and COD are significantly correlated, and the correlation is a linear positive. Correlation of BOD and COD indicated biodegradability in water. Therefore, r-value of correlation between BOD and COD more than 0.6 indicates the waste in water can be treated effectively using biological treatment. Generally, most of pollutants in Kelantan River can be treated biologically.

Furthermore, pH and AN had negative strong correlation in all three locations due to chemical reaction between hydrogen ion (H^+) and AN. pH in Kelantan River was ranged between 6.5 to 7.7. When the pH of the solution is less than 9.3, H^+ reacts with AN to produce ammonium ions ($NH4^+$) [16]. AN has a more toxic form at high pH which is NH_3, and a less toxic form at low pH which is $NH4^+$ [17]. In addition, correlation between TSS and WQI had found to be negative in all three locations which are -0.563, -0.669, -0.595. It indicated that increase of TSS resulted in decrease of WQI. Thus, the most influential WQI parameter to WQI values is TSS.

4. Conclusion

In conclusion, there is no significant difference between Water Quality Index (WQI) and its parameters in Kota Bharu (urban), Kuala Krai (suburban) and Tanah Merah (residential) in Kelantan River. WQI in urban, suburban, and residential areas were classified in Class II throughout 2015 until 2018. Most contributor of pollution in Kelantan River is TSS in three selected locations. The correlation of water quality parameters varies between selected locations which indicate different water pollution contributors.

Acknowledgement

Special thanks to Department of Environment (DOE) Malaysia for providing river water quality data. The authors also acknowledge the Ministry of Higher Education Malaysia (MOHE) and Universiti Malaysia Kelantan (UMK) for technical support and facilities.

References

[1] Edokpayi J N, Odiyo J O and Durowoju O S 2017 Impact of Wastewater on Surface Water Quality in Developing Countries: A Case Study of South Africa *Water Quality* ed Tutu H Intech Open United Kingdom 401-414.

[2] Juahir H, Zain S M, Yusoff M K, Hanidza T T I, Armi A S M, Toriman M E and Azmi A S M 2011 Spatial water quality assessment of Langat River Basin (Malaysia) using environmetric techniques *Environ. Monit. Assess.* **173** 625–641.

[3] Ibbitt R, Takara K, Desa M N B M and Pawitan H 2002 Catalogue of Rivers for Southeast Asia and the Pacific- Vol IV. The UNESCO-IHP Regional Steering Committee for Southeast Asia and the Pacific. UNESCO - IHP Publication.

[4] Hee Y Y, Suhaimi S and Azyyati A A 2019 Water Quality and Heavy Metals Distribution in Surface Water of the Kelantan River basin of Malaysia *Oriental Journal of Chemistry* **35(4)** 1254-1264.

[5] Department of Environment (DOE) 2017 River Water Quality. Environmental Quality Report 2017. River Monitoring. Department of Environment, Ministry of Environment and Water.

[6] Baghapour M A and Shooshtarian M R 2017 Assessment of Groundwater Quality for Drinking Purposes Using Water Quality Index (WQI) in Shiraz, Iran (2011 to 2015) *Iranian Journal of Health, Safety & Environment* **5(1)** 881-893.

[7] Department of Statistic Malaysia (DOSM) 2018 Population by state administrative district and sex 2016-2018. Open Data. Population & Demography.

[8] Zaideen I M M, Suratman S and Tahir N N 2017 The Evaluation of Spatial Variation of Water Quality in Sungai Setiu Basin, Terengganu *Sains Malaysiana* **46(9)** 1513–1520.

[9] Singh R K B, Singh T C and Singh T R 2016 Assessment of Water quality index of Nambul River, Imphal, Manipur, India *International Research Journal of Engineering and Technology* **3(12)**1462–1467.

[10] Abdallaa K Z and Hammam G 2014 Correlation between Biochemical Oxygen Demand and Chemical Oxygen Demand for Various Wastewater Treatment Plants in Egypt to Obtain the Biodegradability Indices *International Journal of Sciences: Basic and Applied Research* **13(1)** 42-48.

[11] Samudro G and Mangkoedihardjo S 2010 Review on BOD, COD and BOD/COD Ratio: A Triangle Zone for Toxic, Biodegradable and Stable Levels *International Journal of Academic Research* **2(4)** 235-239.

[12] Al-Badaii F, Shuhaimi-Othman M and Gasim M B 2013 Water Quality Assessment of the Semenyih River, Selangor, Malaysia *Journal of Chemistry* **871056** 1-10

[13] Rahim M A C A, Aproi A, Shi X, Liu S, Ali M M, Yaacob W Z W and Mohamed C A R 2019 Distribution of Chromium and Gallium in the Total Suspended Solid and Surface Sediments of Sungai Kelantan, Kelantan, Malaysia *Sains Malaysiana* **48(11)** 2343 – 2353.

[14] Gail M S and Richard F 2012 Using Effect Size—or Why the P Value Is Not Enough *J. Grad. Med. Educ.* **4(3)** 279–282.

[15] Boyd C E 2000 *Water Quality*. Springer. Boston, MA.105

[16] Gupta V K, Sadegh H, Yari M, Ghoshekandi R S, Maazinejad B and Chahardori M 2015 Removal of ammonium ions from wastewater: A short review in development of efficient methods **1(2)** *Spring* 149-158.

[17] Wurts A W 2003 Daily pH Cycle and Ammonia Toxicity *World Aquaculture* **34** 20-21.