Bangladesh J. Bot. **47**(2): 187-196, 2018 (June)

EVALUATION OF PHYSICOCHEMICAL PARAMETERS OF SURFACE WATER QUALITY IN GEBENG INDUSTRIAL AREA, PAHANG, MALAYSIA

Masoud Gabar Salah, Mir Sujaul Islam[1]*, Md Abdul Karim[2], Mohamad Idris Ali and Noram Irwan Ramli

Faculty of Civil Engineering and Earth Resources, University Malaysia Pahang, 26300 Kuantan, Pahang, Malaysia

Keywords: Gebeng industrial area, Water quality index, Tunggak river, Pollution

Abstract

The contamination level in Gebeng watershed has increased due to industrialization and release of most of the wastewater from the industries, which are pollutants and dumped into the surface water. The present study was carried to evaluate the surface water quality of Gebeng industrial estate, Pahang, Malaysia. Principal component analysis classified the analyzed parameters to 5 components according to the sources of pollutants and the correlation demonstrated on the relation between all these groups. Cluster analysis was grouped 10 monitoring sites into two groups (high and moderate pollution). Water quality of Gebeng was classified based on Water quality index (WQI), Malaysia as class III and IV, which are slightly polluted due to lower dissolved oxygen (DO) concentration, low pH value, and higher levels of Ammoniacal nitrogen (AN), Biochemical oxygen demand (BOD), Chemical oxygen demand (COD) and Total suspended solids (TSS). It is evident that sites IZ2, IZ3, HA1, HA2 and DS received the highest pollutants discharge from the industrial sectors.

Introduction

Substantial deterioration of water quality is being caused by intensive land use in river watersheds and rapid response of organic pollutants from different sources, which pose a direct or indirect threat to the health of aquatic ecosystem (Cohen *et al*. 2014, Zhao *et al*. 2016 and Xiaoping *et al*. 2017). The quality of water is necessary for mankind since it is connected with human health. The anthropogenic input from mining and industrial activities such as wastewater from electroplating smelting, corrosion of copper tubing and metal engraving industries are considered as important source of surface water pollution. Nowadays, large quantities of untreated industrial wastewater have been discharged into surface water bodies (Shazia *et al*. 2013).

Malaysia is rich in many water resources which contribute to the economic and industrial development of the country. However, according to the Environmental Quality Report 2010, approximately 50% river water is polluted in Malaysia. Conventional and non-conventional pollutants in the industrial area are directly discharged in the river systems and cause the deterioration of water quality (Nasly *et al*. 2013). The contamination level in surrounding Gebeng watershed has increased due to industrialization, and most of the wastewater released from the industries contains pollutants and dumped into the surface water (Islam *et al*. 2013), especially in the space of the Balok and Tunggak river (Tanjung 2013). Nowadays, continuous and regular monitoring programs have been under taken to observe the spatial and temporal variations in

---

*Author for correspondence: <sujaul@ump.edu.my>. [1]Centre for Earth Resources Research and Management (CERRM), University Malaysia Pahang, Malaysia. [2]Department of Botany, University of Dhaka, Dhaka-1000, Bangladesh.

physio-chemical properties of water and to have the reliable information about surface water quality properties (Singh *et al*. 2005). Pearson regression and correlation, principal component analysis (PCA) and cluster analysis (CA) have widely been used for interpretation and assessment of large and complex water quality data sites (Mustapha and Aris 2012, Singh *et al*. 2012, Juahir *et al*. 2011 and Mohammad and Assefa 2017). Under this circumstance an attempt was taken to investigate the present status of water quality based on water quality standard.

Materials and Methods

Gebeng industrial estate is one of the potential industrial areas of Malaysia. The industrial park is situated between 03°54´00" to 04°00´00" North and 103°21´00" to 103°25´30" East. This city is about 20 km far from Kuantan and near to Kuantan port. The two rivers, namely Balok and Tunggak are flowing through the industrial area and ended into the South China Sea (Islam *et al*. 2013). Different types of industries such as steel, polymer, chemicals, petrochemicals, metal works factories, pipe coating, palm oil mills, oil and gas industries, energy, chicken food, cool mining, detergent, air product and concrete ducting discharge their pollutants in these rivers causing pollution to these areas (Sobahan *et al*. 2013).

Water samples were collected from 10 sampling sites (Table 1) during October, 2016 to February, 2017 and 10-15 cm below the surface by using 1000 ml HDPE bottles. Sampling for BOD analysis was collected by using dark BOD bottles (300 ml), according to Bartram and Balance (1996) and APHA (2012). Collected samples were kept immediately in the cool box and transported to the laboratory for further study.

Table 1. The sampling sites with their geographical coordinates at Gebeng area.

Sites No.	Name	Geographical coordinates	Source of pollution
US	Upstream site	N 03°59`13.8" E 103°23`17.9"	Adjacent to nice rika bio technology industry Sdn. Bhd.
IZ1	Industrial zone 1	N 03°58`32.9" E 103°23`18.2"	Adjacent to starting point of Gebeng industrial area (GIE)
IZ2	Industrial zone 2	N 03°58`12.0" E 103°23`22.2"	Adjacent to Asturi Metal builder's industry (M) Sdn. Bhd.
IZ3	Industrial zone 3	N 03°57`54.1" E 103°23`21.4"	Located at wood industry and southern steel mesh industry Sdn. Bhd.
HA1	Housing area 1	N 03°57`41.3" E 103°23`13.7"	Adjacent to Sewage water of Jalan Pintasan Kuantan
HA2	Housing area 2	N 03°57`28.6" E 103°23`06.7"	Located at Sewage water of Lorong Seberang Balok 104
DS	Downstream site	N 03°56`34.7" E 103°22`30.5"	Adjacent to sea water of South China Sea
BS1	Balok site 1	N 03°59`34.8" E 103°21`27.5"	Adjacent to Polyplactic Asi PARC industry Sdn. Bhd.
BS2	Balok site 2	N 03°57`33.3" E 103°21`47.9"	Near peat swamp forest of Jalan Pintasan Kuantan
BS3	Balok site 3	N 03°56`30.9" E 103°22`19.3"	Adjacent to sea water of South China Sea

Six parameters (Temperature, pH, turbidity, DO, EC and salinity) were measured *in situ* using a portable YSI multisensory (model 6600-M). Analysis of AN, phosphate, sulphate, nitrate and COD were measured using Spectrophotometer (HACH DR5000 model) (HACH 2010). BOD was analyzed by DO meter whereas TSS and TDS were measured in the laboratory by using the Gravimetric method (APHA 2012).

The assessment of water quality of the Tunggak and Balok Rivers was done by using Water Quality Index (WQI). Six parameters were obtained to calculate WQI (DO, BOD, COD, AN, TSS, and pH) (DOE 2008). The following equation (1) was used to calculate DOE-WQI.

$$WQI = 0.22 \times SIDO + 0.19 \times SIBOD + 0.16 \times SICOD + 0.15 \times SIAN + 0.16 \times SISS + 0.12 \times SIPH$$

where, the SI indicates the sub-index function.

IBM SPSS software version 21 was used to calculate Pearson regression and correlation to identify the significant differences among the physicochemical water quality parameters. PCA was applied to identify the possible sources of pollution whereas cluster analysis (CA) was done to group the monitoring sites according to pollutants level (Arafat *et al*. 2017).

Results and Discussion

Results of physicochemical parameters from 10 sampling sites are presented in Figs 1 and 2.

Water temperature recorded was between 27.73 and 29.73°C while the mean temperature was 28.55 ± 0.68°C, which was within the normal standard of the department of environment Malaysia (DOE 2014). The temperature had a strong positive relation with EC at (r = 0.526). Except site BS1, the pH was in acidity range in the rest 9 sites (5.09 - 6.66) and mean pH was 6.32 ± 0.68 and it had significant positive correlation with EC and DO at (r = 0.307, r = 0.434), respectively. Conductivity was within the permissible ranges of NWQS at all sites (Fig. 1). The EC value ranged from 220.99 to 646.67 µS/cm and mean value was 429.51 ± 127.44 µS/cm. Oxygen is necessary for aquatic life and DO in a water body is considered an important water quality parameter owing to low DO had been identified as a major water quality problem (Zhen and Jun 2015). In the study area, DO was 4.30 ± 0.56 mg/l which was under class III (DOE 2014) and it had a strong positive significance with pH (r = 0.434). The TDS, TSS, turbidity and salinity values were 8.14 ± 3.21 mg/l, 39.58 ± 8.82 mg/l, 79.06 ± 44.08 NTU and 0.11 ± 0.18%, respectively. The highest TSS (106 mg/l) was recorded at site DS which is the last site on the Tunggak River and closed to the South China sea that receive all the pollutants from the other sites. Correlation results showed that there was a significant positive correlation between TDS and salinity at (r = 0.772). One the other hand, salinity had a strong positive correlation with sulfate (SO_4) (r = 0.740).

The higher BOD (28.36 mg/l) was recorded at site IZ2 and the lowest (7.70 mg/l) at site BS3. The COD ranged between 17.11 and 46.89 mg/l and the mean value was 30.02 ± 10.01 mg/l that was higher than the standard recommended by the DOE Malaysia in 2014. Hossain *et al.* (2014) had reported the similar results and indicated the causes of industrial wastewater. There was a significant positive correlation (r = 0.722) between COD and BOD.

NO_3-N ranged from 0.02 to 0.22 mg/l with an average 0.10 ± 0.02 mg/l. The highest NH_3-N was recorded at site BS1, whereas the lowest was at site IZ1 (5.27 mg/l and 1.33 mg/l, respectively). The surface water of the study area was significantly polluted by NH_3-N and more similar results are in agreement with the results of Islam *et al*. (2015). NH_3-N had a strong positive correlation with Turbidity, BOD, COD and phosphate at r = 0.515, r = 0.633, r = 0.528 and r = 0.397, respectively. However, the excessive presence of phosphate and sulfate in water bodies is the result of the untreated sewage effluent and agricultural run-off, which cause eutrophication problem in rivers, and oceans. Eutrophication induces overgrowth of phytoplankton, thus deteriorating water quality, depopulating aquatic species and accelerating water scarcity (Weiya *et al*. 2017). COD, BOD and the distribution of nutrients at different sampling sites are presented in Fig. 2. Pearson correlation coefficient (r) among water quality parameters (two-tailed) analysis is presented in Table 2.

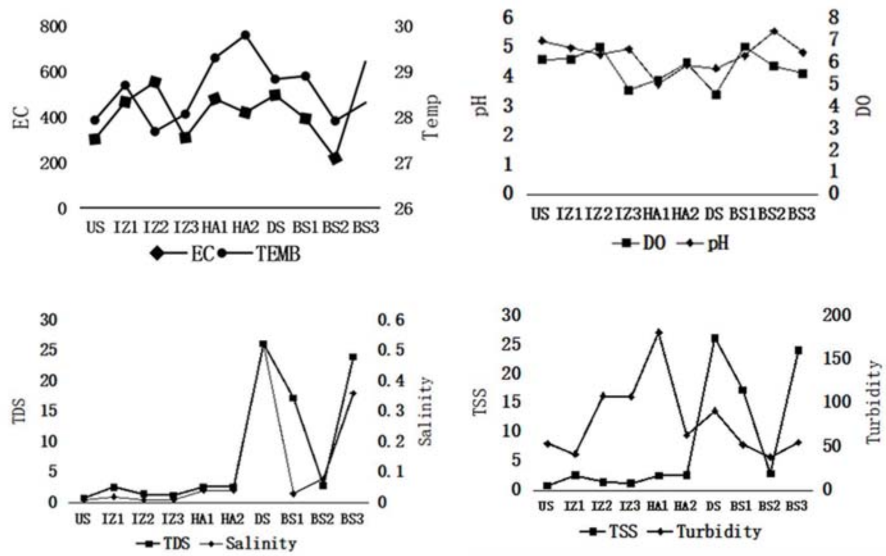

Fig.1 Physicochemical parameters at different sampling sites.

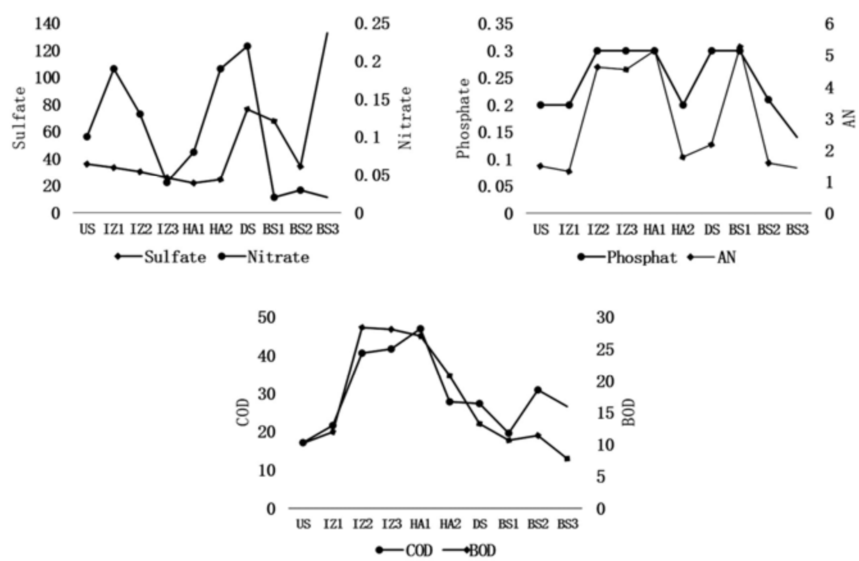

Fig. 2. COD, BOD and the distribution of nutrients at different sampling sites.

Table 2. Pearson correlation coefficient (r) among water quality parameters.

	Temp	pH	EC	DO	Turbidity	Salinity	BOD	COD	NO_3-N	PO_4	NH_3-N	SO_4	TDS	TSS
Temp	1													
pH	0.163	1												
EC	0.526**	0.307**	1											
DO	0.094	0.434**	0.181	1										
Turbidity	–0.315**	–0.399**	–0.230*	–0.132	1									
Salinity	–0.022	–0.264*	0.069	–0.419**	0.035	1								
BOD	–0.256*	–0.433**	–0.208*	–0.192	0.604**	–0.243*	1							
COD	–0.338**	–0.185	–0.092	–0.166	0.755**	–0.071	0.722**	1						
NO_3-N	0.423**	–0.012	0.236*	–0.028	–0.125	0.248*	0.004	–0.160	1					
PO_4	–0.562**	–0.294**	–0.511**	–0.048	0.574**	0.133	0.549**	0.584**	–0.083	1				
NH_3-N	–0.149	–0.320**	–0.084	0.060	0.515**	–0.304**	0.633**	0.528**	–0.354**	0.397**	1			
SO_4	–0.227*	–0.128	0.081	–0.128	0.029	0.740**	–0.323**	–0.053	–0.195	0.212*	–0.179	1		
TDS	0.062	–0.098	0.121	–0.124	0.019	0.772**	–0.323**	–0.063	0.059	0.047	–0.103	0.749**	1	
TSS	–0.317**	–0.203	–0.229*	–0.121	0.398**	0.402**	0.369**	0.354**	0.167	0.609**	0.233*	0.241*	0.295**	1

**Correlation is significant at the $p < 0.01$ level (2-tailed) and *Correlation is significant at the $p < 0.05$ level (2-tailed).

Principal component analysis is considered as a multivariate analysis technique that has been used to find new variables characterized by a linear combination of variables having correlations via the variance-covariance matrix of several multivariate variables; it clarifies most of the total variations with some important principal components (Kang *et al*. 2016). The pollutants can be classified into various groups by PCA according to their loading, where the component with higher loading described the characteristic of the total data set (Milad *et al*. 2017). Five principal components (PC) were acquired with Eigen values >1 summing almost 81% of the total variance in the water data set (Table 3). The first PC accounted for 30.97% of total variance which was correlated with the highest loading (> 0.75) of phosphate (PO_4), turbidity, BOD and COD and there was a strong positive correlation among these parameters (Table 2). Therefore, this factor interpreted as the representative impact from point sources such as manufacturing processes and this result matched with Simeonov *et al*. (2003). The second PC, accounting for 21.53% and described that salinity, TDS and sulfate had a significant loading, whereas TSS had moderate loading. These parameters include the similar group because of the sea water influence and these observations are in agreement with the previous results (Boyacioglu and Gunduz 2005). The third PC, strong loading on nitrate and temperature fall under PC3 which accounted for 11.31% of the total variability and the correlation showed a strong positive relation between two parameters. The fourth PC has strongly loaded on DO, pH and EC and represents the physicochemical source of variability. This is similar to the research findings of Farhad (2017). The fifth PC has only loaded on nitrate and this nutrient comes from non-point sources such as atmospheric deposition and agricultural runoff (Simeonov *et al*. 2003 and Sobahan *et al*. 2015). Those classifications and groupings are supported by the component plot (Fig. 3).

Table 3. Rotated component matrix for physicochemical parameters.

Parameters	Components				
	PC1	PC2	PC3	PC4	PC5
Temp	–0.590	–0.098	0.609	0.156	–0.163
pH	–0.526	–0.227	–0.279	0.434	0.351
EC	–0.492	0.011	0.425	0.562	–0.269
DO	–0.244	–0.351	–0.258	0.625	0.357
Turbidity	0.807	–0.008	0.166	0.195	–0.100
Salinity	0.024	0.952	0.175	–0.035	–0.007
BOD	0.797	–0.343	0.346	–0.019	–0.017
COD	0.791	–0.136	0.159	0.288	–0.087
NO_3-N	–0.245	0.140	0.741	–0.115	0.531
PO_4	0.825	0.152	–0.141	0.068	0.352
NH_3-N	0.646	–0.332	0.061	0.327	–0.345
SO_4	0.040	0.857	–0.298	0.229	–0.163
TDS	–0.045	0.858	0.008	0.292	–0.128
TSS	0.581	0.406	0.153	0.153	0.462
% of variance	30.970	21.530	11.310	9.480	8.210

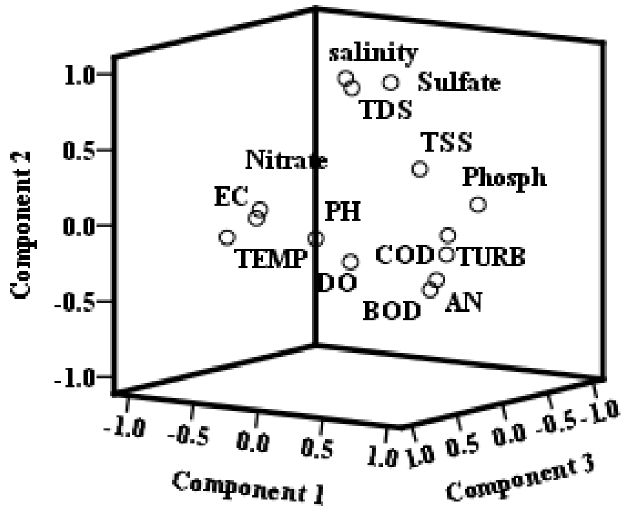

Fig. 3. Component plot in rotated shape for the parameters.

Cluster analysis is widely used for assessment of both temporal and spatial variations and the interpretation of large and complex water quality data sets (Mohammad and Assefa 2017). CA has classified the water quality sites based on their similarity level. It is applied to give spatial variation among sampling sites (Mohd *et al*. 2011). In this study, two clusters that created according to their similarity are Cluster 1 (BS1 and DS) and Cluster 2 (US, IZ3, IZ2, BS2, BS3, HA1, HA2, and IZ1). Cluster 1 assigned as high pollution source (HPS), while Cluster 2 assigned as a moderate pollution source (MPS) (Fig. 4). This method offered reliable clustering of water quality of any area and can drown the future spatial sampling strategies (Juahir *et al*. 2010).

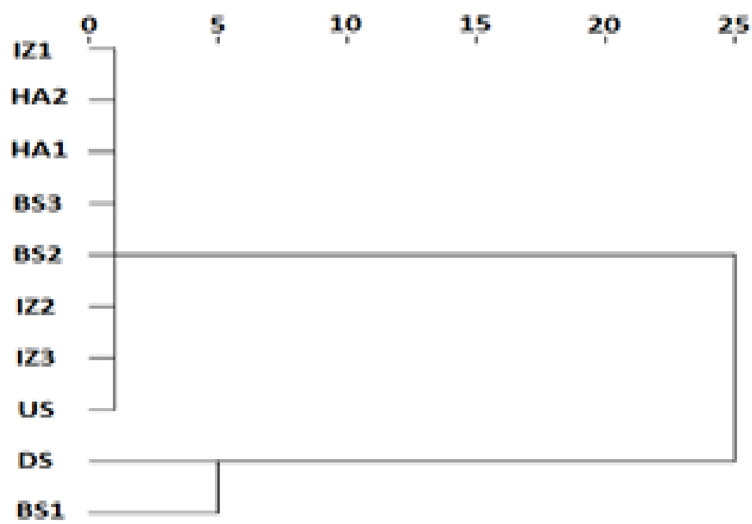

Fig. 4. Dendrogram showing different clusters of sampling sites located in the study area.

Water quality has been categorized by WQI into 6 classes according to the Department of Environment, Malaysia. In this study, the water quality of the study site was classified into slightly polluted to highly polluted (Class III and IV). The lowest WQI score was at site5 (HA1) (43) followed by site 4 (IZ3) (44) and site 3 (IZ2) (50), which classified under class IV (highly polluted) and all these three sites were located in the middle of the Tunggak river, while the highest WQI was at site 1 (US) followed by site 2 (IZ1) and 10 (BS3) at (69, 66, and 66), respectively (Table 4). The deterioration sequence of water quality was found to be HA1 > IZ3 > IZ2 > DS > HA2 > BS1 > BS2 > IZ1 > BS3 > US. It is clear that the downstream of the Tunggak River at IZ2 site until DS site was more polluted than others (e.g. US and IZ1), due to higher anthropogenic activities at those sites. In addition, most of the industries such as metal, wooden,

Table 4. Water quality classification of the study sites.

Sites	DOE-WQI	WQ class	WQI status
US	69	III	SP
IZ1	66	III	SP
IZ2	50	IV	P
IZ3	44	IV	P
HA1	43	IV	P
HA2	60	III	P
DS	53	III	P
BS1	63	III	SP
BS2	64	III	SP
BS3	66	III	SP

*SP = Slightly polluted and P = Polluted. *Class I = >92.7, Class II = 76.5 - 92.7, Class III = 51.9 - 76.5 and Class IV = < 51.9.

gas and energy, chemical, petrochemical, mining and food industries were established there and discharged their wastes in the mid-stream of the river, which takes its way then to the South China Sea (Nasly *et al*. 2013). The last three sites BS1, BS2 and BS3 situated in the Balok River were less polluted because this river is located outside the industrial area and the industrial activities were less there. Generally, the water quality of both rivers was polluted and cannot be used for water supply without extensive treatment (DOE 2008).

Acknowledgement

This study was supported by scholarship under Libyan government. The authors are very much thankful to Faculty of Civil Engineering and Earth Resources for financial support through the project RDU 170342.

References

APHA 2012. Standard methods for the examination of water and wastewater. 22nd Ed. American Public Health Association, American Water Works Association, Water Environment Federation, Washington, DC.

Arafat MY, Islam SM, Karim MA, Zularisam AW and Edriyana AA 2017. Characterization of Chini Lake water quality with Malaysian WQI using multivariate statistical analysis. Bangladesh J. Bot. **46**(2): 691-699.

Bartram J and Balance R (Ed.) 1996. Water quality monitoring: a practical guide to the design and implementation of freshwater quality studies and monitoring programs. CRC Press, Boca Raton, FL, USA.

Boyacioglu HB and Gunduz O 2005. Application of factor analysis in the assessment of surface water quality in Buyuk Menderes river Basin. European water **9**(10): 43-49.

Cohen QL, Zhen BH and Wang SJ 2014. Optical signatures of chromophoric dissolved organic matter in water body of Tien Lake. Spectrosc. Spectra. Anal. **34**(3): 698-70.

DOE 2008. Interim National Water Quality Standards for Malaysia, Department of Environment, Kuala Lumpur, Malaysia.

DOE 2014. Department of Environment, Malaysia; Ministry of Natural Resources and Environment.

Farhad HM 2017. An assessment of surface water chemistry with its possible sources of pollution around the Barapukuria Thermal Power Plant impacted area, Dinajpur, Bangladesh. Groundwater for Sustainable Development **5**: 38-48.

HACH 2010. Data sheet DR 500 UV-Vis Laboratory Spectrophotometer. Colorado, USA.

Hossain MA, Islam MS and Nasly MA 2014. Application of QUAL2Kw for water quality modeling in the Tunggakriver, Kuantan, Pahang, Malaysia. Res. J. Recent Sci. **3**(6): 6-14.

Islam MS, Hossain M, Nasly MA and Sobahan MA 2013. Effect of industrial pollution on the spatial variation of surface water quality. Amer. J. Environ. Sci. **9**: 120-129.

Islam MS, Sobahan MA, Edriyana FM and Yahaya RM 2015. Adverse Impacts of Poor Wastewater Management Practices on Water Quality in Gebeng Industrial Area, Pahang, Malaysia. International Journal of Environment, Ecological, Geological and Geophysical Engineering **9**(5): 286-289.

JuahirH, Zain SM, Aris AZ, Yusof MK,Samah MAA and Mokhtar M 2010. Hydrological Trend Analysis Duo to Land Use Changes at Langat river Basin. Environment Asia **3**: 20-31.

Juahir H, Zain SM, Yusoff MK, Hanidza TIT, Armi ASM, Toriman MF, Mokhtar M 2011. Spatial water quality assessment of Langat river Basin (Malaysia) using environmetric techniques. Environ. Monit. Assess. **173**: 625-641.

Kang YJ, Kyung-Lak L, Toe HI, In JL, Shin K, Kun-Yeun H and Jung MA 2016. Evaluation of water quality for the Nakdong river watershed using multivariate analysis. Environ. Technol. Innov. **5**: 67-82.

Milad E, Erin L and Thomas D 2017. Temporal performance assessment of wastewater treatment plants by using multivariate statistical analysis. Journal of Environmental Management **193**: 234-246.

Mohammad H and Assefa MM 2017. Assortment and spatiotemporal analysis of surface water quality using cluster and discriminant analyses. Catena. **151**: 247-258.

Mohd SS,Hafizan J, Sharifuddin MZ and NurHazirah A 2011. Surface River Water Quality Interpretation Using Environmetric Techniques: Case Study at Parlis River Basin, Malaysia. International Journal of Environmental Protection **5**: 1-8.

Mustapha A and Aris AZ 2012. Spatial aspects of surface water quality in the Jakara Basin, Nigeria using chemometric analysis. J. Environ. Sci. Health, Part A: Tox. Hazard. Subst. Environ. Eng. **47**: 1455-1465.

Nasly MA, Hossain MA and Islam MS 2013. Water quality index of Sungai Tunggak: An analytical study. 3rd International conference on chemical, biology and environment science (ICCEB'2013) January 8-9, Kuala Lumpur (Malaysia).

Shazia I, Sadia K, Iftikar A, Tauseef T, Vishandas S and Mahmood MH 2013. Assessment of physicochemical parameters of wastewater samples. Environ.Monit. Assess. **185**: 2503-2515.

Simeonov V, Stratis JA, Samara C, Zachariadis G, Voutsa D, Anthemidis A, Sofoniou M and Kouimtzis TH 2003. Assessment of the surface water quality in Northern Greece. J. Water Res. **37**: 4119- 4124.

Singh KP, Malik A and Sinha S 2005. Water quality assessment and apportionment of pollution sources of Gomti river (India) using multivariate statistical techniques-a case study. Anal. Chim. Acta **538**: 355-374.

Singh KP, Sharma NK and Sharma BK 2012. Use of clustering to improve the standard of the education system. Int. J. Appl. Inf. Syst. **1**: 16-20.

Sobahan MA, Sujaul IM, Ideris B and Hossain MA 2013. Surface water contamination due to Industrial activities in Gebeng area, Kuantan, Malaysia. International conference on civil and architecture engineering (ICCAE'2013) May 6-7, Kuala Lumpur, Malaysia.

Sobahan MA, Sujaul IM and Karim MA 2015. Status and contamination level of the wastewater of Gebeng industrial estate, Pahang, Malaysia. Bangladesh J. Bot. **44**(1): 103-110.

Tanjung LE 2013. Assessment of heavy metal deposition in surface water and sediment in Balok and Tunggakriver, Kuantan, Pahang. Thesis, Master of Engineering, Faculty of Civil Engineering and Earth Resource, University Malaysia Pahang, Malaysia.

Weiya H,Yuanming Z and Dan L 2017. Adsorptive removal of phosphate from water using mesoporous materials: A review. J. Environ. Managem. **193**: 470-482.

XiaopingW, Fei Z, Hsiang-te K, Abdulwasit G, Adam L, Jianying Y, Yan Rand Yunqing J 2017. Evaluation and estimation of surface water quality in an arid region based on EEM- PARAFAC and 3D fluorescence spectral index: A case study of the Ebinur Lake Watershed, China. Catena. **155**: 62-74.

Zhao Y, Song K, LiS, Ma J and Wen Z 2016. Characterization of CDOM from urban waters in Northern-Northeastern China using excitation-emission matrix fluorescence and parallel factor analysis. Environ, Sci. Poll. Res. **23**(15): 15381-15394.

Zhen X and Jun YX 2015. Rapid field estimation of biochemical oxygen demand in a subtropical eutrophic urban lake with chlorophyll a fluorescence. Environ. Monit. Assess. **187**: 4171.

(Manuscript received 28 October, 2017; revised on 12 February, 2018)