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Spatial Characterization of Water Quality Using Principal Component Analysis Approach at Juru River Basin, Malaysia

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Abstract: Juru River is named as one of polluted river in Malaysia by Department of Environment (DOE) Malaysia up till recent times. The pollution loadings of this river basin come from various point and non-point sources. This study reveals that the water quality of Juru River is very much affected by the industrial activities in this locality area. The principle component analysis (PCA) display that the Juru River mainly dominates with anthropogenic pollution sources which contributing to the river water quality deterioration. New sources were apportioned using this pattern recognition technique which demonstrates anthropogenic activities (industrial activities, wood industry and rubber industry), land activities and domestic waste. The major contribution from industrial activities associated at the monitoring station of 2JR03, 2JR06, 2JR08, 2JR04 and 2JR07 while for 2JR02 was highly impacted by land development considering housing and commercial development. Meanwhile station 2JR01 and 2JR05 were suspected having pollution loading from timber and wood industries considering the high correlation of DO and arsenic parameters. Overall, Juru River having combination pollution sources coming from various activities in the studied area and urgent actions are required to conserve and protect the health of the river.

Key words: Juru River · Penang Malaysia · Principle Component Analysis (PCA) · Water quality · Spatial characterization · River pollution

INTRODUCTION

River as an important source of surface water plays an important role in daily human life. However the quality of the surface water is a matter of serious concern. Various types of pollutions domestic and industrial wastewater may potentially affect the river water quality as the common ways of discharging these types of pollutants is via river. Although several pre-treatment of wastewater were done prior to disposal, the pollution loads, river flow factor and seasonal variation may influence the surface water quality of the riverine ecosystem.

Juru River has been identified as one of the polluted river in Malaysia [1]. Extensive monitoring on the water quality was conducted by the Department of Environment (DOE) of Malaysia to evaluate the river water quality at Juru River as this river experience light and heavy industrial activities at nearby areas. Juru River still continuously become main discharge outlet for effluent produced from the substantial manufacturing industries at Prai Industrial Estate. The various types of industries that are still operating along the Juru River dominated by electronics, textiles, food processing, metal products, rubber industry, chemical plants and transport equipment [2]. The vast harbour operation with involve the petroleum based activities was also located at its estuary that also may influence the river water quality during intertidal phases changes of the river.

In this study, spatial analysis was conducted using PCA to evaluate the most significant variables that affect the health of the river [3]. It is a part of the environmetric techniques in environmental analytical study that often deal with huge amount of data set. The use of principal component analysis in order to estimate the relationship and possible structure of principal components

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influencing the data set[4]. PCA approach is a very powerful pattern recognition method that been widely applied to reduce the dimensionality of the data set consisting of the inter-correlated variables while retaining the maximum variability present in the data set [5]. The objective of this study is to investigate the main pollution contributor at Juru River during year 2007 and determine the specific sampling location that affected by the pollutants in the vicinity of the studied area using the factor scores from the principal component.

MATERIALS AND METHODS

Study Area and Sampling Sites: The study area, Juru River basin is located in Penang State North eastern of Malaysia (Figure 1). The river actually originated from Bukit Mertajam Hill with basin area of 75km^2 [6, 7]. The Juru River basin made of 2 main upstreams. The western upstream of Juru River basin is made up of 2 rivers which are Sungai Permatang Rawa and Sungai Rambai while the eastern upstream is made of Sungai Kilang Ubi and Sungai Pasir while the Sungai Juru with a length of about 7.95km forms the middle and downstream. This river receives pollution loading from both point and non-point sources such as industrial, agricultural and domestic wastes. Besides the high organic loadings this river system also contaminated with heavy metals [7, 8]. For this study, data for water quality of Juru River from monitoring locations with 26 parameters (dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids (SS), pH, ammoniacal nitrogen (NH3-NL), conductivity (COND), temperature (T), salinity (SAL), turbidity (TUR), dissolved solids (DS), total solids (TS), nitrate (NO^{3-}), chloride (Cl^-), phosphate (PO_4^{3-}), arsenic (As), chromium (Cr), zinc (Zn), calcium (Ca), ferum (Fe), potassium (K), sodium (Na), magnesium (Mg), oil and grease (OG), *Escherichia coli* (*E. coli*) and coliform) monitored for year (2007) was subjected for spatial characterization using principle component analysis (PCA) using XLSTAT2010 software.

RESULTS AND DISCUSSION

PCA was employed in this study to investigate the compositional pattern between the examined water quality parameters at the specific monitoring site. PCA with varimax show that the eigenvalues >1 represent 97.967% of variability in the data set (Table 1) and 6 varimax factors (VFs) were obtained from PCA and new source of pollution were apportion based on the values of factor loading >0.75 (strong correlation) [9]. VF1 accounts 33.321% of the total variance with strong positive loading on pH, COND, SAL, Cl^-, Fe and Na. This factor contains variables that are linked to natural sources and slight contribution of steel industry that may come from the vicinity area. The negative loading of ph may explained by land-based activities that alter the chemical and mineral changes of the water quality. VF2 consists of BOD, COD, NH3-NL, PO_4, Cr and K that can be named as anthropogenic activities. These anthropogenic activities may associated with agricultural based products industry and transport equipment-related

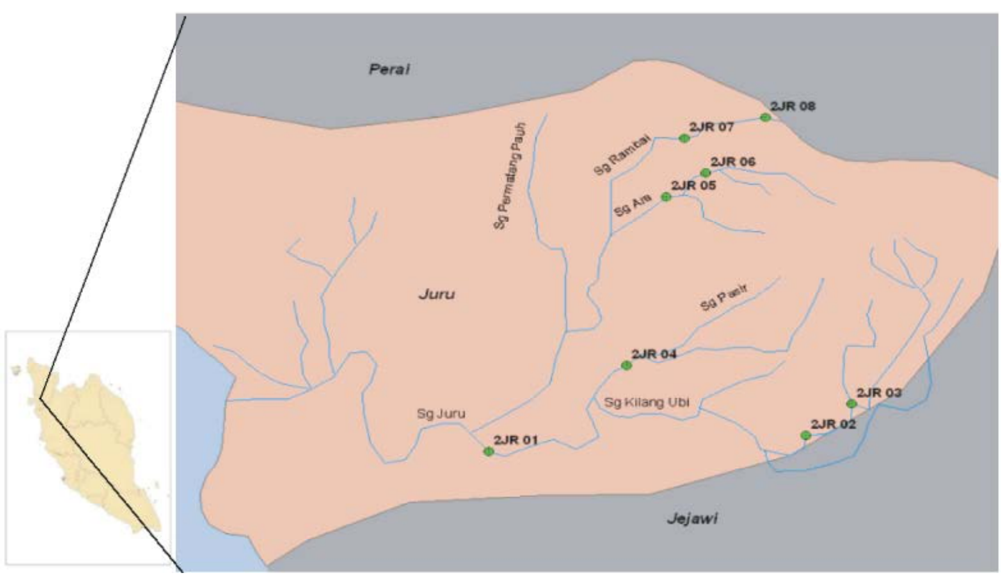

Fig. 1: Juru River Basin and sampling stations

Table 1: Factor loadings after Varimax rotation from PCA of Juru River Basin

	VF1	VF2	VF3	VF4	VF5	VF6
DO	-0.330	-0.223	-0.174	-0.764	0.392	-0.088
BOD	0.309	0.836	-0.262	0.111	-0.243	0.248
COD	0.301	0.857	-0.221	0.083	-0.239	0.243
SS	-0.006	-0.076	0.994	0.029	0.001	0.057
pH	-0.769	-0.174	-0.042	0.094	0.553	-0.125
NH3-NL	-0.041	0.980	0.047	0.073	-0.059	-0.159
T	0.170	0.035	0.871	-0.207	-0.173	-0.332
COND	0.854	0.289	0.333	0.184	0.002	0.207
SAL	0.862	0.252	0.325	0.209	0.024	0.206
TUR	-0.070	-0.080	0.903	0.276	0.195	-0.013
DS	0.725	0.632	0.211	0.094	-0.066	0.114
TS	0.265	0.169	0.941	0.060	-0.024	0.092
NO_3^-	-0.141	-0.135	0.558	-0.179	0.784	0.017
Cl	0.938	-0.209	-0.170	-0.022	-0.099	0.192
PO4	-0.223	0.922	0.115	0.175	0.221	-0.037
As	-0.022	0.324	-0.072	0.863	-0.111	-0.269
Cr	-0.132	0.785	0.553	0.038	0.212	0.109
Zn	-0.160	0.007	-0.091	-0.085	0.953	-0.223
Ca	-0.294	0.482	0.793	0.112	0.195	0.006
Fe	0.764	-0.127	-0.209	0.021	-0.453	0.145
K	0.076	0.967	0.170	0.138	-0.070	-0.059
Mg	-0.031	0.141	0.459	0.638	0.347	-0.407
Na	0.928	-0.149	-0.177	-0.064	-0.095	0.268
OG	0.435	-0.107	-0.247	-0.102	0.068	0.837
E. coli	0.274	0.298	0.191	-0.164	-0.312	0.822
Coliform	0.537	0.016	0.046	-0.108	-0.207	0.809
Eigenvalue	8.635	7.242	4.443	2.344	1.715	1.092
Variability (%)	33.212	27.853	17.090	9.014	6.598	4.200
Cumulative %	33.212	61.065	78.155	87.169	93.767	97.967

* Values in bold are considered strong loadings

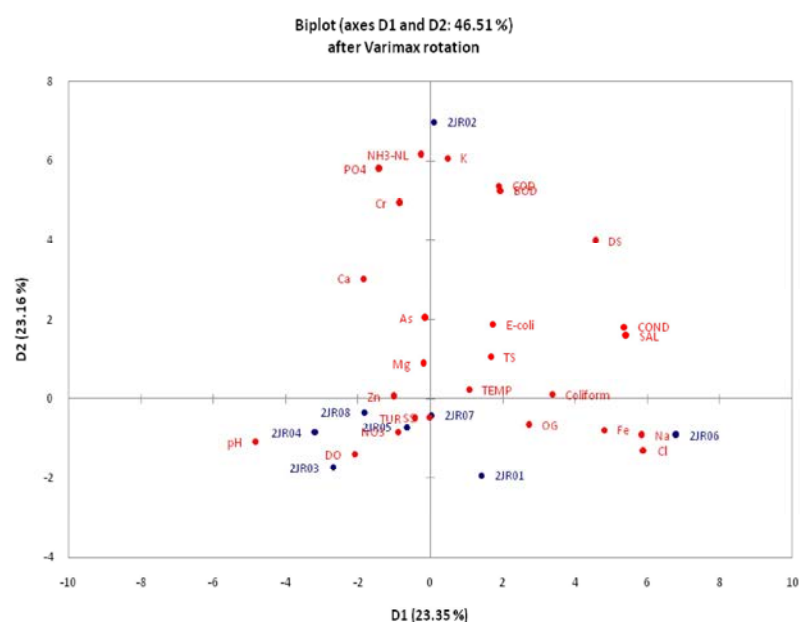

Fig. 2: The biplot of varimax factors and sampling stations at Juru River

industry as PO_4^{-3} and Cr show significant contribution to the varimax factor. Land activities with strong loadings of SS, TUR, TS, Ca and TEMP shows for VF3 (17.896% of variability) as Juru River Basin receive a lot of changes in the land development that also depends on the seasonal variation in studied area. This factor also may describe surface runoff from agricultural-related activities as NO_3^- show moderate loading values on the factor.

Moreover VF4 formed by negatively strong loading of DO and positively strong loading of arsenic. The dominant As involvement in the surrounding area of the basin may correlate with the timber based wood products as the high loading of As will directly lower the dissolved oxygen measurement of the surface water quality [10]. VF5 explain 6.598% of total variability with strong loading of Zn and NO_3^-. These factors ascribed by various industrial activities presently in Juru and Bukit Tambun district [6]. Moreover VF6 formed by strong loading of OG, *E. coli* and coliform that signify the contribution of domestic waste to the Juru River [11]. Table 1 show the factor loadings values after PCA with varimax rotation for Juru River Basin for year 2007.

Figure 2 show the biplot axes of VF1 and VF2 with total variability of 50.98% explained on the graph. Biplot graph was examined to evaluate the relationship of sources apportioned from the values of factor loading and sampling point studied. Station 2JR03, 2JR06 and 2JR08 that dominated by housing area and semi-urban village were identified as the points that received natural sources and minor as these points were correspond to the VF1 that attributed as natural sources in prior PCA analysis. Station 2JR04 and 2JR07 was highly correlated to the VF2 which consistent with anthropogenic activities as this station was located nearby industrial areas. In present time, Juru River receives several small rivers that flow through urban areas with industrial, agricultural and domestic waste that are discharged directly into these rivers [12]. Station 2JR03 that correlated to VF3 loadings was majorly impacted by land activities as these point were located at Bukit Mertajam that densely populated by humans and industrial-based increment. Station 2JR01 and 2JR05 were correlated to timber and wood industry where As is mainly used in wood preservation.

CONCLUSION

In conclusions, PCA provides comprehensive data interpretation in complex and huge amount data set. PCA reveal the major pollution contributor into the Juru River using the factor loadings values and able to give preliminary judgement of the pollutants contributor on the polluted sampling locations along the river. Overall monitoring station receives various types of land-based pollutants as the Juru River basin was surrounded by industrial activities and densely populated housing areas that undergo extensive development. Urgent actions on the river conservation must be taken in quick ways as to protect the living organisms in the vicinity areas and others environmental issues that may govern many human concerns.

REFERENCES

1. DOE, River Water Quality Report, 2008.
2. Alkarkhi, F.M.A., A. Ahmad and A.M. Easa, 2009. Assessment of surface water quality of selected estuaries of Malaysia: multivariate statistical techniques. Environmentalist, 29: 255-262.
3. Juahir, H., S.M. Zain, M.K. Yusoff, T.I.T. Hanidza, M.A.A. Samah, M.E. Toriman and M. Mokhtar, 2010. Spatial water quality assessment of Langat River Basin (Malaysia) using envirometric techniques. Environmental Monitoring Assessment.
4. Simeonov, V., C. Sarbu, D. Massart and S. Tsakovski, 2001. Danube river water data modelling by multivariate data analysis. Mikrochima Acta, 137: 243-248.
5. Singh, K.P., A. Malik, D. Mohan and S. Sinha, 2004. Multivariate statistical techniques for the evaluation of spatial and temporal variations in water quality of Gomti River (India)-a case study. Water Res., 38: 3980-3992.
6. Alkarkhi, F.M., N.A. Ismail and A.M. Easa, 2008. Assessment of arsenic and heavy metal contents in cockles (*Anadara granosa*) using multivariate statistical techniques. J. Hazardous Materials, 150: 783-789.
7. Lim, P.E. and M.Y. Kiu, 1995. Determination and speciation of heavy metals in sediment of the Juru River, Penang Malaysia. J. Environmental Monitoring and Assessment, 35: 85-95.
8. Kim, J.O. and C.W. Mueller, 1987. Introduction to Factor Analysis: What It Is and How to DO It.
9. Crowther, J., D. Kay and M.D. Wyer, 2001. Relationships between microbial water quality and environmental conditions in coastal recreational waters: The Flyde Coast, UK. Water Res., 35(17): 4029-4038.

10. Buchireddy, P.R., R.M. Bricka and D.B. Gent, 2009. Electrokinetic remediation of wood preservative contaminated soil containing copper, chromium and arsenic. J. Hazardous Materials, 162: 490-497.
11. Song, M.W., P. Huang, F. Li, H. Zhang, K.Z. Xie, X.H. Wang and G.X. He, 2010. Water quality of a tributary of the Pearl River, the Beijing, Southern China: implications from multivariate statistical analyses. Environmental Monitoring Assessment, pp: 1-15.
12. Al-Sahmi, S., C.S.M. Rawt, S.A. M. Nor, A.H. Ahmad and A. Ali, 0000. Orphological deformities in *Chironomus* spp. (Diptera: Chironomide) Larvae as a tool for impact assessment Physiological Ecol., 39(1): 210-222.