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EVALUATION OF NATURAL AND ANTHROPOGENIC INDUCED PROCESSES ON WATER QUALITY IN RIVER KADUNA

[1]Isiyaka H. I., [1]Mustapha A., [2]Getso B. U., [1]Yusuf Y.A.

[1]Department of Geography, Faculty of Earth and Environmental Sciences, Kano University of Science and Technology Wudil, Nigeria
[2]Department of Biology, Faculty of Sciences, Kano University of Science and Technology Wudil, Nigeria

ABSTRACT

The dynamic nature of large water bodies is the main reason for the variability of physical, chemical and biological processes as well as their parameters. This scenario defines water quality particularly in some areas with special critical uses that need preventive actions. Changes in land use has for long been found to be threatening the quality of River Kaduna. This study aims to identify the major possible sources of water pollution along Kaduna River and simplify the complex and dynamic relationship that exist in the water quality samples. However, the characteristics of the examined parameters and the major possible sources of pollution were identified using principal component analysis (PCA). Three varifactors rotated to an eigenvalue greater than one (>1) and a cumulative variance of 76% were obtained using PCA. PCA revealed that the pollutants are rich in mineral components from weathered parent rocks, untreated wastewater discharge and application of synthetic fertilizer for agricultural activities. PCA also indicates high level of turbidity from silt, clay and sand materials from sand mining, construction, erosion and other human induced activities. Furthermore, sensitivity analysis using the leave-one-out cross-validation method with coefficient of determination R^2 = 0.741 and root mean square error RMSE show that total hardness, total iron, calcium, turbidity and pH are the most dominant parameters polluting the water to about 72%. These findings indicate that river Kaduna is polluted from anthropogenic activities (land use change) and natural process (weathering and erosion). The study proposes a prompt action by government and other stakeholders to reduce the level of pollution in Kaduna River.

Key words: Principal component analysis, sensitivity analysis, multiple linear regression, water pollution, natural and anthropogenic sources.

1.0 Introduction

Water is next to air in importance for all living thing particularly human, plants and animals (Suleyman et al. 2008) and makes up 75% of the earth crust. A River is made up of a system of interconnected tributaries (Mustapha et al. 2012) that can be utilized for domestic, industrial, agricultural and efficient inland transport systems (Ogweleka et al. 2015). River water significantly provides for the domestic needs of population, source of hydropower and control of flood discharges (Juahir et al. 2011). Moreover, the floodplains of rivers possess favourable conditions for people's habitation. It provides highly fertile land for agriculture and land for housing, recreation, and industrial developments (Juahir et al. 2011). In recent years, there has been a constant increase concerning river water quality and different problem related to the presence, utilization and management of water resource (Botkin and Keller, 2011). The assessment of water quality has become a vital issue because fresh water will be a scarce resource in the future (Pinto and Maneshwari, 2011).Changes in land use has for long been found to be threatening to river pollution problems (Juahir et al. 2011). The settling of people along the river areas results to developmental activities which subject the river environment to disturbances. This subjectively increases the degree of pollution into water bodies (Juahir et al. 2011). Water is polluted when the physical, chemical and biological make up exceed the normal threshold needed for different consumption (Mustapha et al. 2014). Deterioration of water quality has been a major environmental challenge due to industrialization, mechanized system of farming and urbanization (Mustapha et al. 2014; Isiyaka et al 2015). The dynamic nature of large water bodies is the main reason for the variability of physical, chemical and biological processes as well as their parameters, which define water quality particularly in some areas with special critical uses that need preventive actions.

However, anthropogenic and natural induced pollution source depends on multifaceted natural factors such as duration, intensity and composition of rainfall, chemical interactions between soil sediments and human practices (Samsudin et al 2011). A combination of these factors can modify the hydrological cycle as well as the water hydrochemistry. This can easily degrade the quality of surface water and impair its usability (Wang et al 2014). Most Water quality studies along river Kaduna apply simple descriptive statistics that cannot explore and extract the hidden latent variables and complex relationships among water quality parameters. However, application of environmentric techniques like PCA and sensitivity analysis can provide an in-depth understanding and a simplification of doubtful observations (Isiyaka et al 2015; 2015). Environmentric techniques have been described as the most efficient second generation approach that can be used for water quality exploration, management and decision making (Juahir et al 2011, Mustapha et al 2014).

2.0 Materials and Methods

2.1 Study Area

Kaduna River is situated between latitude 8° 45′ and 8° 47′N and the longitudes 5° 48′ and 6° 46′E. The river channel passes through Plateau State on the Jos Plateau Southwest of Jos town, it then flows from plateau through Kaduna State and meets the Niger River in Niger State. Rainfall within the study area receive an average annual rainfall of about 1350mm with temperature ranging between 19.7°C in the rainy season and 37.3 °C in dry season. The geological characterised of this area is made of the Precambrian migmatite-gneiss complex, Metasediments, volcanic of Jurassic and basement complex rocks. The map of the study area is described in figure 1.The sample size comprises of key monitored parameters that accurately represent the water quality of Kaduna River. Measurement of the selected parameters was carried out by the Kaduna State Water Board. Monthly sampling was done to monitor changes caused by the seasonal hydro-chemistry composition during the rainy season (May to August 2016). There are many water quality parameters available but only 14 consistently sampled parameters were selected, analysed and interpreted using Multivariate statistics techniques. These sampled parameters comprise of turbidity, conductivity (µS/cm), total iron, nitrate (mg/l), silica (mg/l), free carbon-dioxide (mg/l), pH, sulphate, total dissolved solid (mg/l), bicarbonate alkalinity (mg/l), total alkalinity (mg/l), chlorides (mg/l), total hardness (mg/l), and calcium (mg/l).

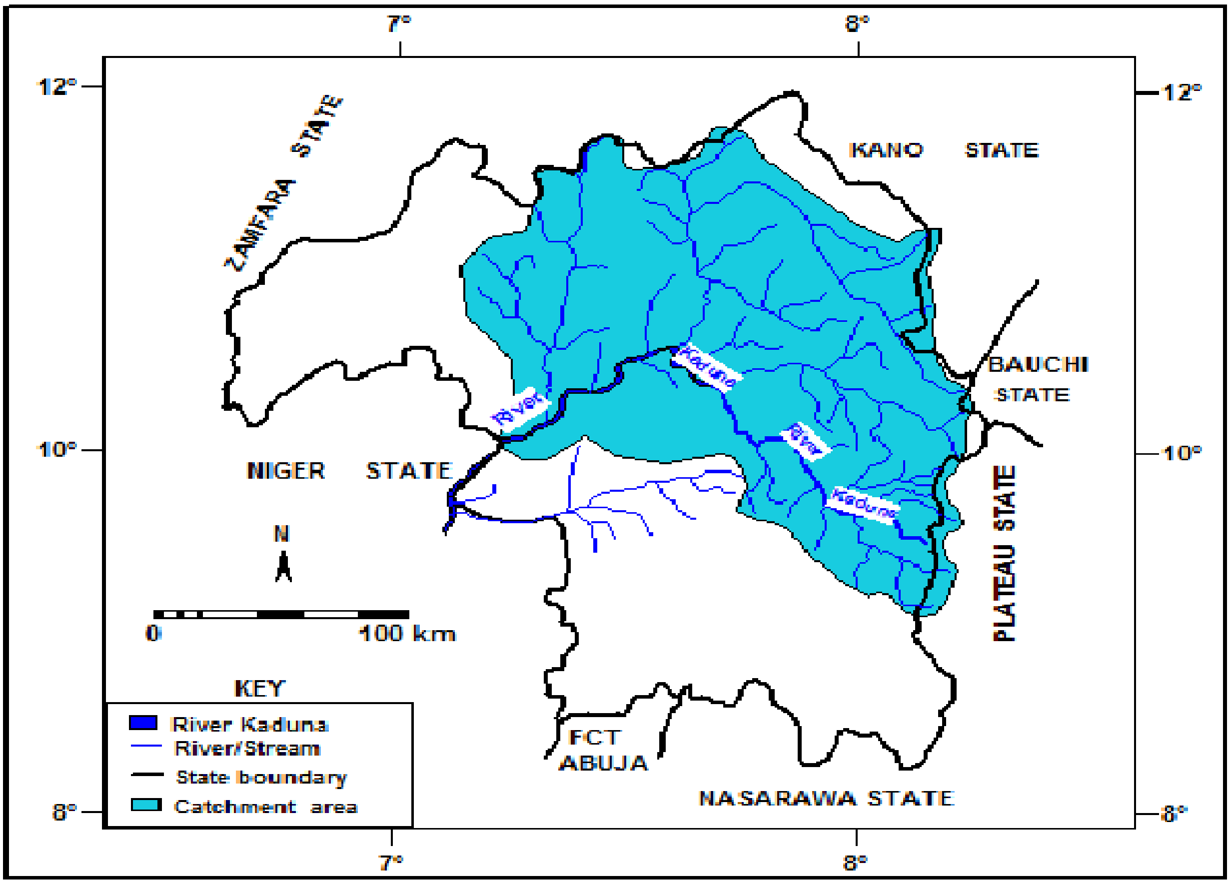

Figure 1: Map of the Study Area.

2.2 Principle Component Analysis

Principal component analysis (PCA) technique is used to extracts the eigenvalues and eigenvectors from the covariance matrix of original variables (Mustapha et al 2012; Isiyakas et al 2015; 2015). They are weighted linear combinations of the original variables that provide information on the most meaningful parameters, which describes the whole data set, affording data reduction with minimum loss of the original information (Isiyakas et al 2015).

2.3 Sensitivity Analysis

The Physicochemical characteristics of water pollution exhibit a complex and dynamic relationship and sensitivity analysis is applied to understand the level at which these pollutants influences the level of water quality. The percentage contribution of each parameter is modelled using a standardized coefficient (bar chart), coefficient of determination (R^2) and leave-one-out method (pie chart). The degree of the reliability of fit in the linear model is determined by the value of the coefficient of determination (R^2) for the best fitting regression linear equation (Norusis, 1990; Wahid et al., 2013; Razak et al., 2014). Furthermore, the model with the highest R^2 (1) and lowest RMSE (0) is considered as the best linear model (Norusis, 1990).

3.0 Results and Discussion

3.1 Source Attributes of Pollution

PCA was applied in this study to identify the major possible sources of pollution and provide a major data reduction in the complex observation. The Kaiser's criterion (Kaiser 1960) was followed to determine the number of PCs to be extracted. According to these criteria, the number of PCs having eigenvalue equal to or greater than 1 was accepted as the possible sources of variance with strong factors that explain the water chemistry and can be used to spot the major source of pollution. Using this method, three PCs were developed with a cumulative variance of 76%. A reasonable interpretation of the PCs is done using the values of the respective loadings augmented with the knowledge of major contributors of pollution at various sources. Furthermore, the loadings were classified as strong (0.75), moderate (0.74-0.50) and weak (0.4-0.30) (Liu et al. 2003). The loadings with absolute values greater than 0.75 of the maximum value are selected for the PC interpretation (Liu et al 2003). PC1 explains more than 50% of the total variance in the data set. The parameters have a strong positive loading for bicarbonate alkaline (0.995), total alkaline (0.915), total hardness (0.895), silica (0.795) and free carbon dioxide (0.995). The composition of these parameters represent factors that are rich in mineral components from weathered parent rocks and untreated wastewater discharge from industries such as food processing industries, Aluminium industries, textile industries, plastics industries pharmaceutical industries (Juahir et al 2011, Wang et al. 2014). However, these parameters are likely to increase the level of water hardness which accelerating the cases of kidney stones and heart diseases (Napacho & Manyele, 2011). Hard water is formed when water percolates through deposits of limestone and chalk which are largely made up of calcium and magnesium carbonates (Reza & Singh, 2010). Hard water may have moderate health benefits, but can pose serious problems in industrial settings unless where water hardness is monitored to avoid costly breakdowns in boilers, cooling towers, and other equipment that's handles water (reference). High concentration of alkalinity is result from the dissolution of calcium carbonate (C_aCO_3) especially in limestone bedrock (Sharma et al 2015) which is eroded during the natural process of weathering (Nwinyi et al. 2011). Excess alkalinity results to a distinct flat and unpleasant taste and scale formation. Trace metals (Fe) gain access into rivers possibly through anthropogenic and natural sources (Das & Nag, 2015). Some trace metals are potentially toxic because they act on the cell membrane or interfere with cytoplasmic or nuclear functions after entry into the cell (Das & Nag, 2015). Hence, their accumulation in the human body could result to malfunctioning of organs (Jarup, 2003). At high concentrations, they cause acute systemic poisons. Use of raw water with high salts (silica) result to nauseous, saline taste with purgative tendency and dehydration (reference). Bicarbonate alkalinity is the alkalinity of water due to the presence of bicarbonate ions (HCO_3). The bicarbonate ion is the main alkaline factor in almost all water. Bicarbonate alkalinity is introduced into water by CO_2 dissolving carbonate-containing minerals.

Table 1: Factor loadings after Varimax rotation:

	PC1	**PC2**	**PC3**
Turbidity (mg/l)	-0.150	**0.679**	-0.310
pH (mg/l)	-0.397	**0.731**	0.048
Conductivity (µS/cm)	-0.055	-0.173	**0.567**
Chlorine (mg/l)	0.389	0.064	**0.557**
Nitrates (mg/l)	-0.995	0.030	0.007
Bicarbonate Alkalinity (mg/l)	**0.995**	-0.030	-0.007
Total Alkalinity (mg/l)	**0.915**	-0.030	-0.007
Total Hardness (mg/l)	**0.895**	-0.030	-0.007
Total Iron (mg/l)	-0.192	0.031	**0.837**
Silica (mg/l)	**0.795**	-0.030	-0.007
Sulphate (mg/l)	0.000	0.000	0.000
Free Carbon dioxide (mg/l)	**0.995**	-0.030	-0.007
Calcium (mg/l)	0.470	**0.540**	0.265
Total Dissolve Solid (mg/l)	0.101	**0.708**	0.077
Eigenvalue	6.560	1.818	1.503
Variability (%)	50.464	13.983	11.565
Cumulative %	50.464	64.447	76.012

PC2 has moderate to strong positive loading for TUR (0.679), pH (0.731), Calcium (0.540) and Total dissolve solid (0.708). High TUR reflect the presence of silt, clay, organic matter and other microorganism (Jaafar et al. 2014) capable of altering the level of water clarity that limits light penetration as well as affect aquatic life (Ruˇzdjak & Ruˇzdjak, 2015). TUR can also encourage the existence of virus and bacteria parasites that can cause diarrhoea and headache (Jaafar et al. 2014). The source of this pollutant originates from transport of loose materials from mining, construction and agricultural field as well as erosion of river bank and bed (Folorunsho et al. 2012; Ogwueleka, 2015). pH is the measure of hydrogen ion concentration or hydroxide ions concentrations in a solution. High concentration of pH denotes the presence of alkaline that originates from erosion of river banks and weathering of existing parent materials rich in carbonates and bicarbonates limestone rocks. Ca occurs naturally in water since its primary origin is from parent rock. The high concentration (Ca) can lead to colorectal cancer, obesity, kidney stone, stroke and hypertension (WHO, 2011).

Factor 3 has strong positive loading for COND (0.567), Cl (0.557) and total iron (0.837). Cl encourages corrosion when in contact with metal ions thereby produce high concentration of metal in drinking water with a salty taste (Kanmani and Gandhimathi 2013).

3.2 Sensitivity Analysis

In this case, each parameter for sensitivity analysis was independently introduced to the linear model to observe their contribution in polluting Kaduna River. However, the following observations have been made in figure 2 and 3. Figure 2 describes a visual representation in the linear relationship between the actual and predicted water quality characteristics at R^2 = 0.741 and RMSE = 4.121 in a scatter plot. This result indicates that MLR can predict the level of water quality to a tune of 74% with a linear effect.

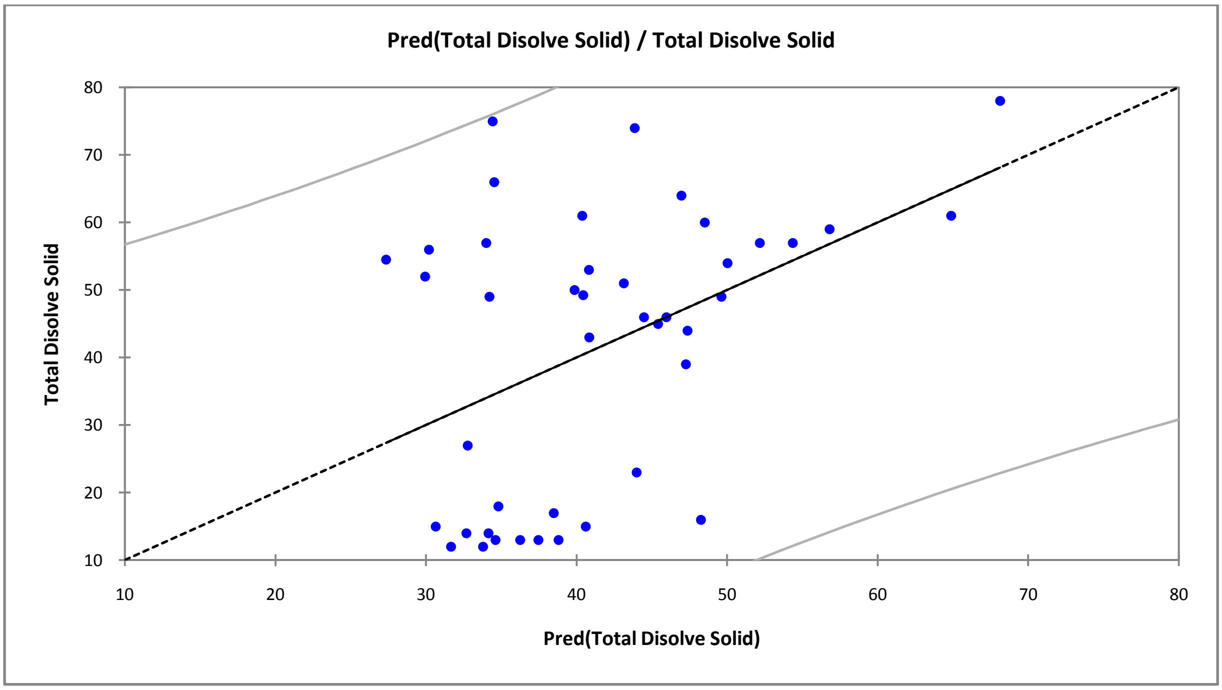

Figure 2: Actual and predicted water quality characteristics

Furthermore, Figure 3 denotes the individual contribution of each observed parameter based on the leave one out cross validation method. In this case, the deterioration in the network performance if one parameter is eliminated determines the efficacy and significance of the variable in the overall network performance (Pastor-Bárcenasetal.2005) based on sensitivity analysis. The findings indicate that pollution of Kaduna River is influenced by total hardness and total iron to a tune of 24% and 13% respectively. Furthermore, calcium pollute the water to about 15%, TUR 12% pH 8%, bicarbonate alkaline 6%, total alkaline 6%, sulphate 6%, chlorine 5% and other parameters range between 1 and 2%.The result indicate that the water is characterised as hard water with a total hardness of 24%

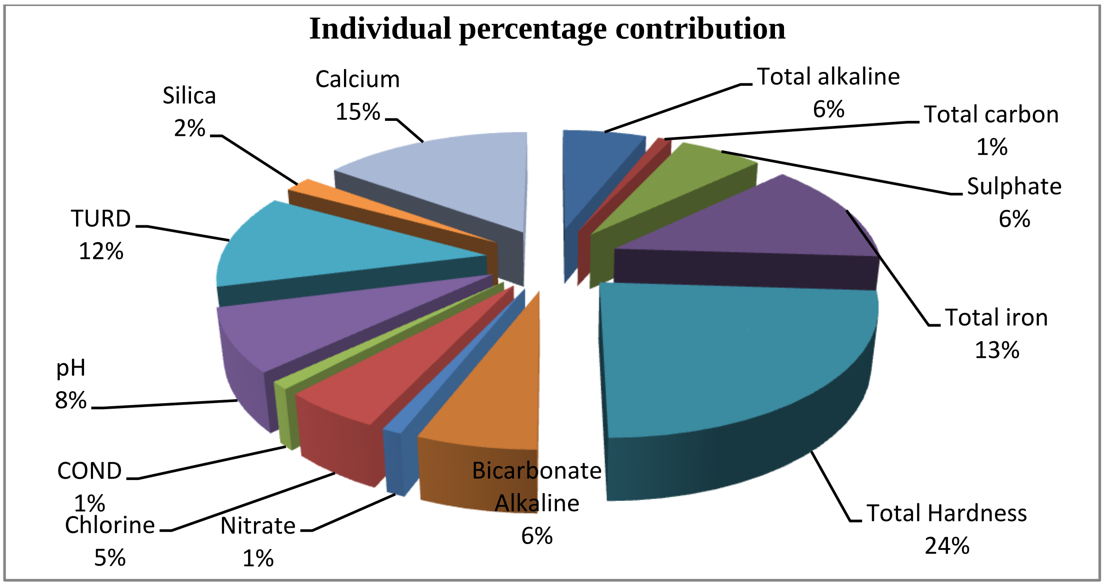

Figure 3: Result for Sensitivity Analysis

3.3 Conclusion

This study concludes that three varimax factors rotated to an eigenvalue greater than one (>1) and a cumulative variance of 76% were obtained using Principal Component Analysis (PCA). PCA revealed that the pollutants are rich in mineral components from weathered parent rocks, untreated wastewater discharge and application of synthetic fertilizer for agricultural activities. PCA also indicates high level of turbidity from silt, clay and sand materials from sand mining, construction, erosion and other human induced activities. Furthermore, sensitivity analysis using the leave-one-out cross-validation method with coefficient of determination R^2 = 0.741 and root mean square error RMSE show that total hardness, total iron, calcium, turbidity and pH are the most dominant parameters polluting the water to about 72%. These findings indicate that river Kaduna is polluted from anthropogenic activities (land use change) and natural process (weathering and erosion). The study proposes a prompt action by government and other stakeholders to reduce the level of pollution in Kaduna River.

REFERENCES

Botkin, D. B., Keller, E. A., & Rosenthal, D. B. (2011). *Environmental science*. Wiley.

Das & Nag (2015) Application of multivariate statistical analysis concepts for assessment of hydrogeochemistry of groundwater—a study in Suri I and II blocks of Birbhum District, West Bengal, India Appl Water Sci DOI 10.1007/s13201-015-0299-6.

Isiyaka,H.A&Juahir, H. (2015). Analysis of Surface Water Pollution in the Kinta River Using Multivariate Technique *Malaysian Journal of Analytical Sciences, Vol 19 No 5: 1019 – 1031.*

Isiyaka, H.A &Azid, A (2015). Air Quality Pattern Assessment in Malaysia Using Multivariate Techniques. *Malaysian Journal of Analytical Sciences, Vol 19 No 5, 966 – 978.*

Jaafar, S. A., Latif, M. T., Chian, C. W., Han, W. S., Wahid, N. B. A., Razak, I. S., &Tahir, N. M. (2014). Surfactants in the sea-surface microlayer and atmospheric aerosol around the southern region of Peninsular Malaysia. *Marine pollution bulletin*, *84*(1), 35-43.

Juahir, H., Zain, S. M., Yusoff, M. K., Hanidza, T. T., Armi, A. M., Toriman, M. E., &Mokhtar, M. (2011).Spatial water quality assessment of Langat River Basin (Malaysia) using environmetric techniques. *Environmental Monitoring and Assessment*, *173*(1-4), 625-641.

Kiaser, H. F. (1960). The application of Electronic computers to factor analysis.*Educational and Physocological Measurement*, doi.org/10.1177/001316446002000116.

Liu, C. W., Lin, K. H., & Kuo, Y. M. (2003). Application of factor analysis in the assessment of groundwater quality in a black foot disease area in Taiwan. *Science of the Total Environment*, *313*(1), 77-89.

Mustapha, A., Aris, A. Z., Juahir, H., Ramli, M. F., Kura, N.U. (2012). River water quality assessment using environmentric techniques: case study of Jakara River Basin Environ SciPollut Res DOI 10.1007/s11356-013-1542-z.

Mustapha, A., Aris, A. Z., Yusoff, F. M., Zakaria, M. P., Ramli, M. F., Abdullah, A. M. and Narany, T. S. (2014). Statistical Approach in Determining the Spatial Changes of Surface Water Quality at the Upper Course of Kano River, Nigeria. *Water Quality, Exposure and Health* 6(3): 127-142. 14.

Norusis, M.J., 1990. SPSS Base System User's Guide. SPSS, Chicago, IL, USA

Ogwueleka, T., C. (2015).Use of multivariate statistical techniques for the evaluation of temporal and spatial variations in water quality of the Kaduna River, Nigeria. *Environmental monitoring and assessment*, *187*(3), 1-17.

Pastor-Bárcenas, O., Soria-Olivas, E., Martín-Guerrero, J. D., Camps-Valls, G., Carrasco-Rodríguez, J. L., &del Valle-Tascón, S. (2005). Unbiased sensitivity analysis and pruning techniques in neural networks for surface ozone modelling. *Ecological Modelling*, *182*(2), 149-158.

Pinto, U., & Maheshwari, B. L. (2011). River health assessment in peri-urban landscape: An application of multivariate analysis to identify the key variable. Water Research, 45, 3915–3924.

Reza R, Singh, G. (2010) Heavy metal contamination and its indexing approach for river water. Int J Environ SciTechnol 7(4):785–792

Ruˇzdjak, A.M., & Ruˇzdjak, D. (2015) Evaluation of river water quality variations using multivariate statistical techniques Sava River (Croatia): a case study Environ Monit Assess 187: 215, DOI 10.1007/s10661-015-4393-x

Samsudin, M. S., Juahir, H., Zain, S. M., & Adnan, N. H. (2011). Surface river water quality interpretation using environmetric techniques: Case study at Perlis River Basin, Malaysia. *International Journal of Environmental Protection*.

Samsudin, M.S., Juahir, H., Zain, S.M., Adnan, N.H. (2011) Surface River Water Quality Interpretation Using Environmetric Techniques: Case Study at Perlis River Basin, Malaysia *International Journal of Environmental Protection,* DOI 10.5963/IJEP0105001 IJEP Vol.1 No.5 2011 PP.1-8 www.ij-ep.org ○C World Academic Publishing.

Sharma, M., Kansal, A., Jain, S., Sharma, P. (2015) Application of Multivariate Statistical Techniques in Determining the Spatial Temporal Water Quality Variation of Ganga and Yamuna Rivers Present in Uttarakhand State, India Water Qual Expo Health DOI 10.1007/s12403-015-0173-7

Suleyman, A. Muyibi, Abdul RaufuAmbal.,i Garoot Suleiman Eissa Received (2008) The Impact of Economic Development on Water Pollution: Trends and Policy Actions in Malaysia Water Resour Manage 22:485–508 DOI 10.1007/s11269-007-9174-z

Wang, Y. B., Liu, C. W., Liao, P. Y., & Lee, J. J. (2014). Spatial pattern assessment of river water quality: implications of reducing the number of monitoring stations and chemical parameters. *Environmental monitoring and assessment*, *186*(3), 1781-1792.