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# Assessment of Hydrogeochemical Characteristics of Water Pollution along River Kaduna during Rainy Season

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ABSTRACT

This study applies multivariate statistical technique to understand the hydro-geochemistry characteristics of pollutants along River Kaduna. Fourteen key monitored parameters that accurately represent the water quality during the rainy season (May-August) were provided by the Kaduna State Water Board. Cluster analysis (CA) grouped the sampled parameters into three independent classes (turbidity (TUR), conductivity (COND) and twelve parameters). As such, correlation of COND and TUR is worked out with the rest of the analyzed parameters based on the result generated in the CA. The findings indicate an excess concentration of TUR and COND with no significant relationship with other observed parameters. This finding is an indication that water quality parameters poses hidden complex characteristics that can only be simplified and understood when subjected to multivariate statistics and effort should be put by stakeholders to checkmate the concentration of the dominant pollutants.



## Introduction

Water is an essential resource that is needed for all aspects of human and ecosystem survival [1]. It is a universal solvent on the earth which main sources include streams, rivers, ponds lakes springs and reservoirs [2]. In addition to drinking and personal hygiene, water is needed for agricultural production, industrial and manufacturing processes, hydroelectric power generation, waste assimilation, recreation, navigation, enhancement of fish and wildlife, and a variety of other purposes [3,4].

Surface water is a finite resource that is very essential for human existence without any doubt; inadequate quantity and quality of water resources have a serious impact on sustainable development [5]. Despite its uniqueness, most surface water receive inputs of pollutants from point sources and nonpoint sources, as they are often situated in the vicinity of highly populated and industrial settlement [6].

River water quality is normally governed by manmade (anthropogenic) pollution, natural processes (weathering and climate) and change in river hydrology. Anthropogenic influence are via urban, industrial and agricultural activities, while natural processes cuts across precipitation input, erosion of river bank, weathering of rock minerals [7]. However, in recent years, due to industrial growth, large-scale application of synthetic fertilizers, pesticides and insecticides for agricultural production have caused serious concern regarding susceptibility of surface water contamination especially along the Kaduna River [2]. Within the Kaduna industrial estate, about 24,200m$^3$/day of industrial effluent is discharged into Kaduna River [8]. Surface runoff during the rainy season carries along large quantity of synthetic fertilizer and deposits them in River Kaduna.

Several un-quantified point source and nonpoint source pollutants are being discharged in the Kaduna River [2]. River monitoring process is required to understand the characteristics of pollutants and the level at which water is being polluted for sustainable water use and management strategies [4, 9].

Unfortunately, the data collected during sampling are large and complex which makes interpretation of latent meaningful information difficult [10] Understanding the pattern and level of pollution is very difficult especially when dealing with ordinary descriptive or conventional statistic because of the complex relationship associated with the pollutants [10,11]. Revealing this relationship will require robust and modern statistical techniques that have multivariate capabilities. This study aims to employ multivariate technique to understand the hydro geochemistry characteristics of pollutants along River Kaduna and to reveal the complex relationship that exist in the hidden latent variables. Multivariate statistic techniques are esteemed to be the best approach to avoid misinterpretation of large amounts of complex environmental monitoring data [4, 10]. The methods have been widely used by [3, 4, 9, 10, and 11] in conveying meaningful information for decision making and policy implementation.

## Materials and Methods

### Study Area

River Kaduna is one of the significant water body put under high level of utilization in Nigeria. The river is located between latitudes 8° 45′ and 8° 47′N and the longitudes 5° 48′ and 6° 46′ E. The river is regarded as a major tributary of the Niger River which flows several kilometres through Nigeria.

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The river channel stretches Plateau State on the Jos Plateau southwest of Jos Town. It then flows from the Plateau through Kaduna State and meets the Niger River in Niger State [12]. The study area experiences an average annual rainfall of about 1350 mm. with temperature ranging between 19.7°C in the rainy season and 37.3 °C in dry season. The rock formation is the Precambrian migmatite-gneiss complex, metasediments, volcanic of Jurassic and basement complex rocks. The map of the study area is described in figure 1.

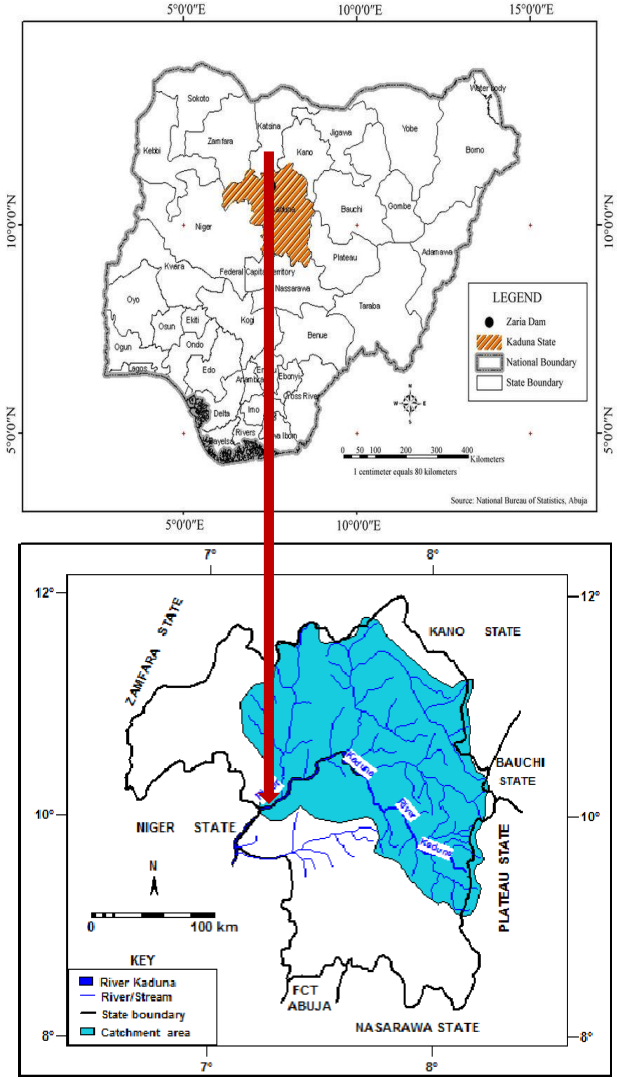



**Figure 1. Map of the study Area.**

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, analyzed 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).

**Cluster Analysis (CA)**

CA provides an aggregate of entities based on a large number of interdependent variables that exhibit high internal similarities within cluster and high external dissimilarities between clusters [11].

It is an unsupervised statistical technique that does not require a prior knowledge of group classes an object belongs [15]. This classification can be illustrated with the aid of a dendrogram that measures the degree of risk homogeneity through Ward's method and Euclidian distance measurement [16].

**Correlation Analysis**

The correlation analysis was devised by [17] based on the value of correlation coefficient 'r'. The correlation between two parameters plotted on a XY scatter diagram can be termed as positive or negative. Correlation analysis is a common and useful statistical tool for water quality studies indicating which ions control the water chemistry [18, 19]. It is simply a measure to exhibit how well one variable predicts the other [20].

**Results and Discussion**

Cluster analysis (CA) was performed to identify the spatial similarities and differences in the characteristics of the water pollution along the Kaduna River. The parameters that pose a strong level of spatial homogeneity were unsupervisely grouped into one cluster. This process resulted in the formation of three clusters as shown in the dendrogram of Figure 2. The three clusters in the dendrogram are independent of their characteristics. The dendrogram generated demonstrate high homogeneity within the clusters and high heterogeneity between the clusters [21]. Cluster 1 has a strong independent characteristics dominated by Turbidity (TUR). Turbidity (TUR) is a measure of the cloudiness of the water, which is related to the shape, size and concentration of particles suspended in the water. Turbidity represents a high concentration of rock and mineral fragments ranging from microscopic particles (finer sand, silt, clay, and even finer colloidal particles) that can produce a sediment pollution problem [13]. During the rainy season, Kaduna River is highly turbid due to increase in the velocity of water, abrasion of river bank and bed as well as transport of loose materials from construction, mining and agricultural activities [2,12]. High turbidity levels can reduce the amount of light reaching lower depths, which can inhibit growth of submerged aquatic plants and consequently affect species which are dependent on them, such as fish and shellfish. High turbidity levels can also affect the ability of fish gills to absorb dissolved oxygen [13]. TUR also increases the risk that people may develop gastrointestinal diseases. This is especially problematic for immune-compromised people, because contaminants like viruses or bacteria can become attached to the turbid water. This scenario distinguishes its characteristics from other parameters.

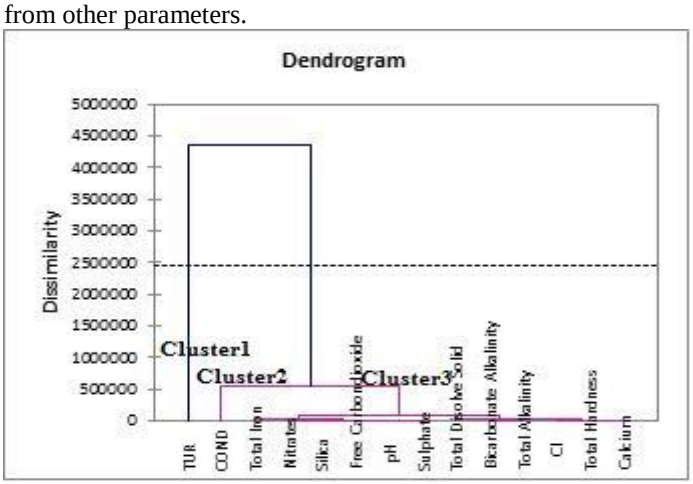


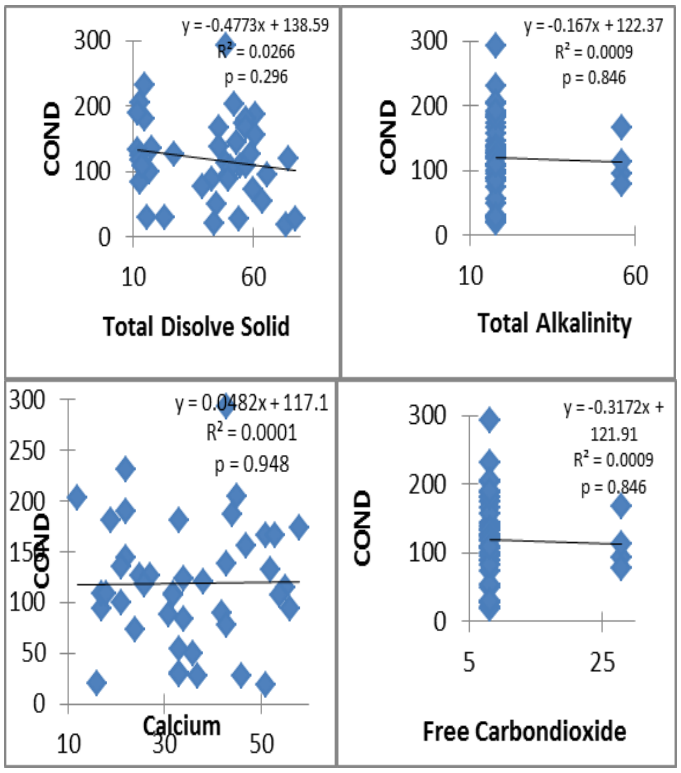

**Figure 2: Spatial characteristics of water pollution**

Cluster 2 is independent with one parameter (Conductivity). Water conductivity measures the water's ability to conduct an electric current. It is related to the total dissolved salts (ions) in the water [4]. Large fluctuations in conductivity can occur after a heavy rainfall during the rainy season. The ions are sourced from dissolved salts and inorganic materials, among which are alkalis, chlorides, sulphides and carbonate compounds. The more ions that are present, the higher the conductivity of water.

In cluster 3, twelve parameters were identified with similar characteristics comprising of total iron, nitrate, silica, free carbon, pH, sulphate, total dissolve solid, bicarbonate alkalinity, chlorine, total hardness and calcium. These parameters pose strong level of spatial homogeneity in their characteristics. This describes the level of the water hardness that can affect the quality level for drinking and irrigation activities [4].

**Pearson correlation**

The correlation coefficient *r* measures the strength and direction of linear relationship between two variables on a scatterplot [22]. In the present study, correlation of COND and TUR has been worked out with the rest of the analyzed water quality parameters based on the result generated in the cluster analysis. However, the dendrogram in the cluster analysis based on Wards method and Euclidian distance distinguish three main clusters, with COND and TUR as independent from other observed parameters. As such, correlation was applied to further clarify and see if there is any statistical relationship between other parameters and the two independent parameters (COND & TUR). The following observations have been made from the trend analysis graphs during the rainy season in figure 3 (COND & other parameters) and figure 4 (TUR and other parameters). All the results in figure 3 have a p-value greater than the level of alpha = 0.05. This indicating that there is no significant correlation between COND and all the twelve observed parameters. This result gives a clearer understand of why COND stands independent from other parameters in the dendrogram in figure 2.



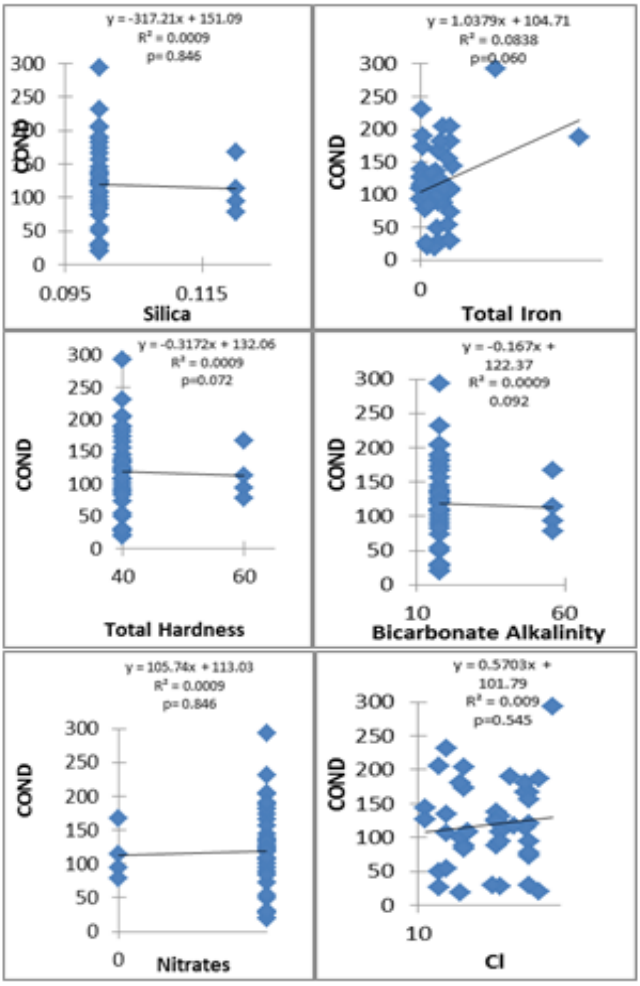
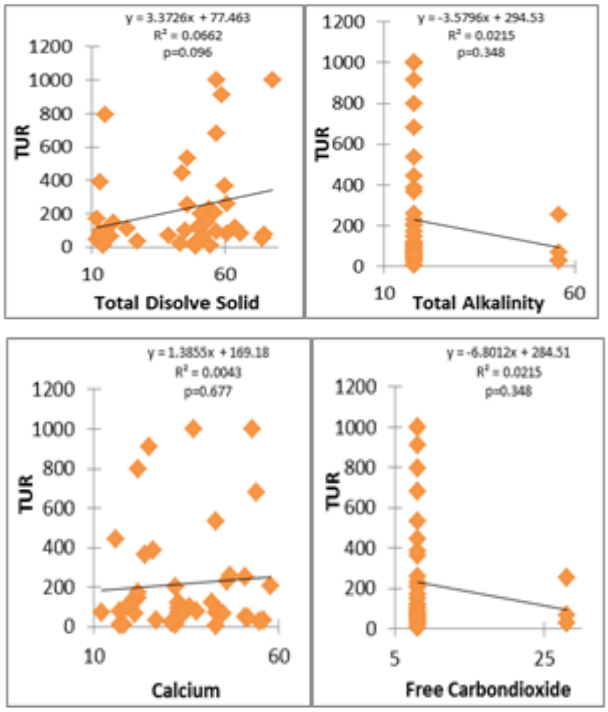




**Figure 3. Correlation analysis trend of Conductivity with other parameters**

Furthermore, the relationship between TUR and twelve observed parameters was correlated to observe if there is any statistical significance. The result indicate that all the observed parameters have a p-value greater than the level of alpha. This indicates a statistical significance of no relationship. The result is described in the scatter plots below.



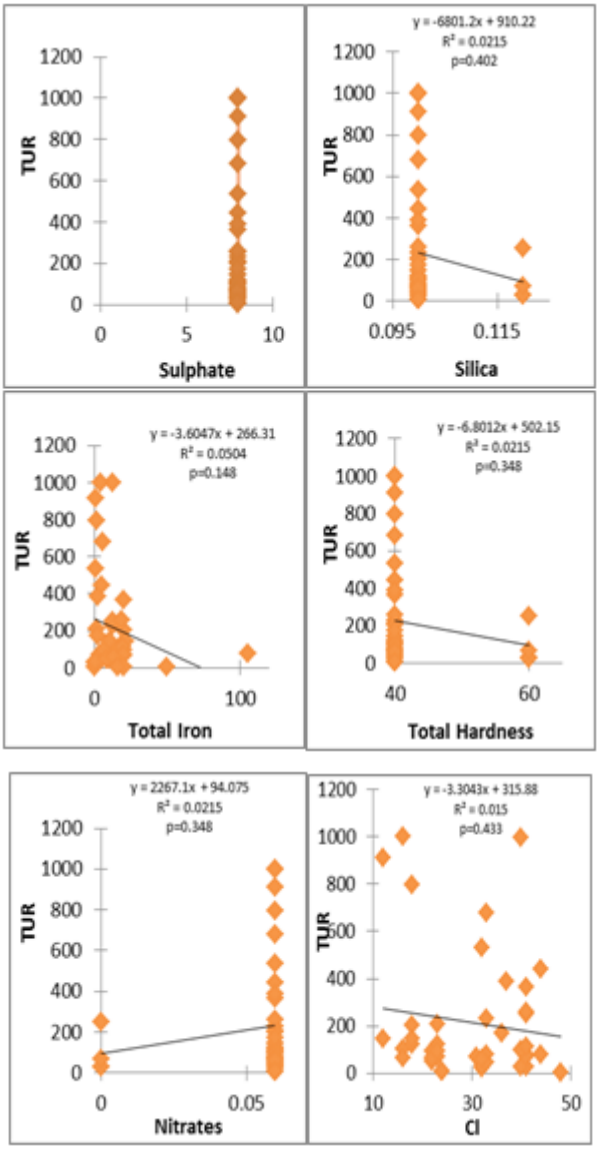



**Figure 4. Correlation analysis trend of TUR with other parameters.**

## Conclusion

However, from the scatter plots and cluster analysis result, it is very obvious that there is no any linear relationship between COND/TUR in relation to the twelve observed parameters. This finding is an indication that water quality parameters poses hidden complex characteristics that can only be simplified and understood when subjected to multivariate statistics and TUR/COND form the dominant parameters influencing the hydro-geochemical characteristics of the Kaduna River. As such effort should be put by stakeholders to checkmate the concentration of TUR and COND as well as understand the major possible sources of these pollutants for water quality assurance.

## Acknowledgement

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