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Full Length Research Paper

Studies on regression analysis between electrical conductivity and total dissolved solids as environmental variables in lower river Benue, Makurdi, Nigeria

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This study investigated the relationship between electrical conductivity and total dissolved solids as environmental variables at five different Sites downstream in lower River Benue at Makurdi. The study sites were selected based on the human activities and land-water interface on the bank of the lower river Benue at Makurdi. Water Samples for the determination of conductivity and total dissolved solids were collected on monthly basis for a period of 24 months and were examined using standard methods for the two parameters. The results of the mean conductivity of the water samples at the sampling sites varied from 64.70±37.00-139.60±215.10µS/cm while the mean concentration of total dissolved solids ranged from 28.30±11.70-69.10±106.60mg/L. The R^2 value of regression analysis varied from 0.3417- 0.7967, indicating a weak to strong relationship between conductivity and total dissolved solids across the sampling sites downstream in lower River Benue at Makurdi. There was no perfect direct linear relationship between conductivity and total dissolved solids in River Benue at the sampling sites. The study concludes that the relationship between conductivity and total dissolved solids is nonlinear but depends on the mobility of dissolved dominant ions in the water sample or solution.

Keywords: Conductivity, TDS, river Benue, regression.

INTRODUCTION

The ability of a solution to carry an electrical current is known as its electrical conductivity. The electrical conductivity of water is increased with increased dissolved ionic solids in the water. Conductivity can be considered as a crude indicator of water quality for several reasons. This is because conductivity is related to the sum of all ionized solutes or total dissolved solids content of the water. The relationship between conductivity and TDS is not directly linear, but due to the fact that the conductivity mobility of ionic species varies. Conductivity at several intervals is used as a standard water quality parameters (APHA, 1999). This is because conductivity gives a clear indication of the total ionic strength and the degree of salinity of the water and determine the TDS in a water body. The importance of conductivity in geophysical mapping of contaminated ground water and in separating hydro graphs with other water quality has been highlighted by several studies (Kumar and Sinha, 2010; Heryashi, 2004., Meshal and Morcas, 1980). Establishing conductivity as an accurate proxy indicator of total cations has become indispensable due to the ease of measuring the parameter (APHA, 1999). Nevertheless the conversional numerical relationship values do not seem to be applicable across the broad range of water bodies (Gebre *et al.,* 2002).

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Iyasele *et al.,* (2015) reported that it is not correct that water supplies for conductivity and TDS are related by a popular difference. This is because the water samples must contain materials that do not ionize in solutions. These compounds have different valences and insoluble components. It is only the compounds that can ionize in the water that affect the conductivity of the water. The main objective of this present investigation is to test empirically, the relationship between conductivity and total dissolved solids in River Benue, Makurdi during the study period at the different sampling sites.

MATERIALS AND METHODS

Study Area

The Cameroonian mountain is the main source of River Benue where it originates and flows toward the west into Nigeria. River Benue is second in size to River Niger which is the largest River in Nigeria and measures approximately 310,000 Ha. The River Benue is about 1,488Km in length with banks that are covered with alluvia fertile flood plains (Welcomme, 1986). The Benue River flows from Cameroonian mountain down streams through Makurdi and meets with River Niger at Lokoja the capital of Kogi state, Nigeria. Makurdi the capital city of Benue state is located on Latitude $7^0$41' N and Longitude 8^0 28' E. The River Benue within Makurdi and major settlement measures approximately 671 meters (Udo, 1981). The rainfall seasons at Makurdi produces a river regime of peak flows from August to early October and low flow from December to April. The rainy season which last for seven months (April to October) has a mean annual rainfall ranging from 1200-2000mm. High temperature values averaging 28-33^{0}C are recorded in Makurdi throughout the year, most notably from March to April. Harmantan winds are accompanied with cooling effects mostly during the nights of December and January (Nyagba, 1995). All the same the periodic dust plumes associated with this time of the year may encourage surface water pollution (Nyagba, 1995). Five sampling stations were selected along the river course at Makurdi, as shown in Fig. 1 as follows:

Site I (N07^0 43.663ꞌ E008^0 35.427ꞌ): it is located behind Coca cola plc plant along Gboko road and it is approximate 1.5 kilometers away from Site II.

Site II (N07^0 43.615ꞌ E008^0 35.300ꞌ): it is located directly behind Benue Brewery Plc along at Kilometer 5 along Gboko road. This site is impacted by the brewery effluents generated from the factory into the river.

Site III (N07^0 43.649ꞌ E008^0 35.302ꞌ): this site is located behind Mikap Nigeria Ltd, a rice processing factory along Gboko road. It is approximately 1 kilometer away from Site II and 2.5 kilometers away from site I. This site receive effluents from the rice mill into the river.

Site IV (N07^0 44.076ꞌ E008^0 32.840ꞌ): this site is located behind Wurukum abattoir close to the new bridge across the river. Abattoir waste is washed directly into this site. Farming and sand dredging also take place at this site on routine bases.

Site V (N07^0 44.789ꞌ E008^0 30.624ꞌ): This site is located behind Wadata market along the river water course at Makurdi. Wastes from the heap refuse dumpsite behind the market are leached directly into the river.

Water Sample Collection

Water samples for conductivity and TDS analysis were collected at five different points from each of the five sampling locations. Monthly routine sampling was conducted between 8:00am and 12:00 noon on each sampling day. Prior to the sampling day, the containers for the collection of the water samples were washed dried and corked, fully labeled and stored under laboratory condition.

Determination of Conductivity

The apparatus used for this analysis was the Conductivity/TDS meter (HANNA model). The water sample for the analysis was shaken thoroughly before the measurement was started and allowed to stabilize till all air bubbles escaped. The Conductivity/TDS meter was standardized with the standard solution of potassium chloride, 0.01M at a temperature of 25^{0}C, and then Conductivity/TDS electrode was thoroughly rinsed with distilled water as well as a small amount of the sample water. The conductivity mode of the meter was selected and the electrode was, immersed into the sample. The electrical conductivity of the sample was read from the screen of the Meter and recorded. This was replicated three times at each sampling site and the mean value was determined as the conductivity value. This measurement was carried out in situ.

Determination of total dissolved solids

The instrument used for this analysis was the Conductivity/Total dissolved solids meter (HANNA Model). The electrode was washed thoroughly first with distilled water and then with sample water. The total dissolved solid mode was selected and the electrode of the meter was then dipped into the samples to be measured and the system was allowed to stabilize before the reading was taken. This was carried out three times and the mean value of the total dissolved solids was determined and recorded. The total dissolved solids content of the water samples was determined in situ.

Data Analysis

Linear regression analysis was used to developed predictive models for conductivity and TDS (independent

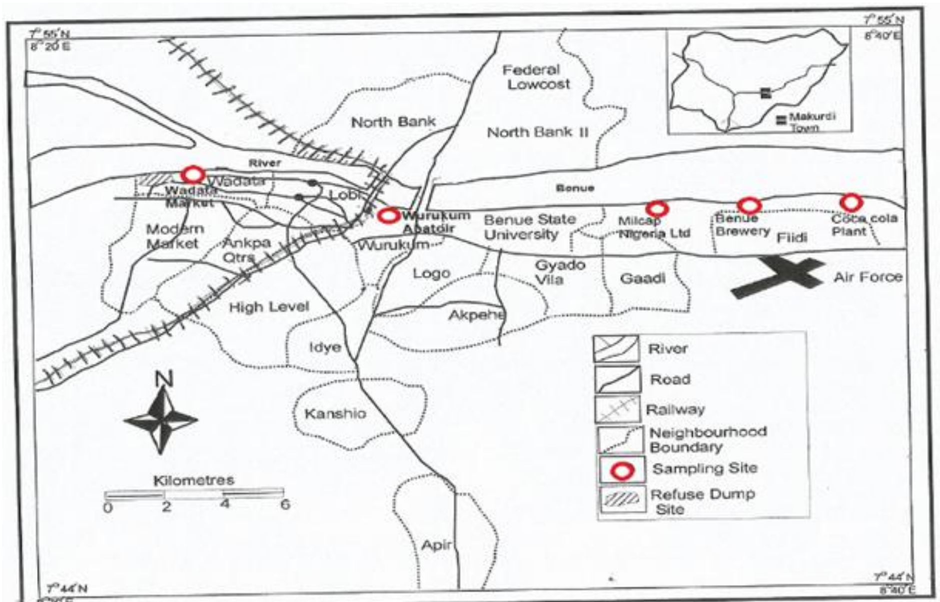

Figure 1: Map of Makurdi Town Showing Sampling Sites
Source: Ministry of Lands and Survey Makurdi

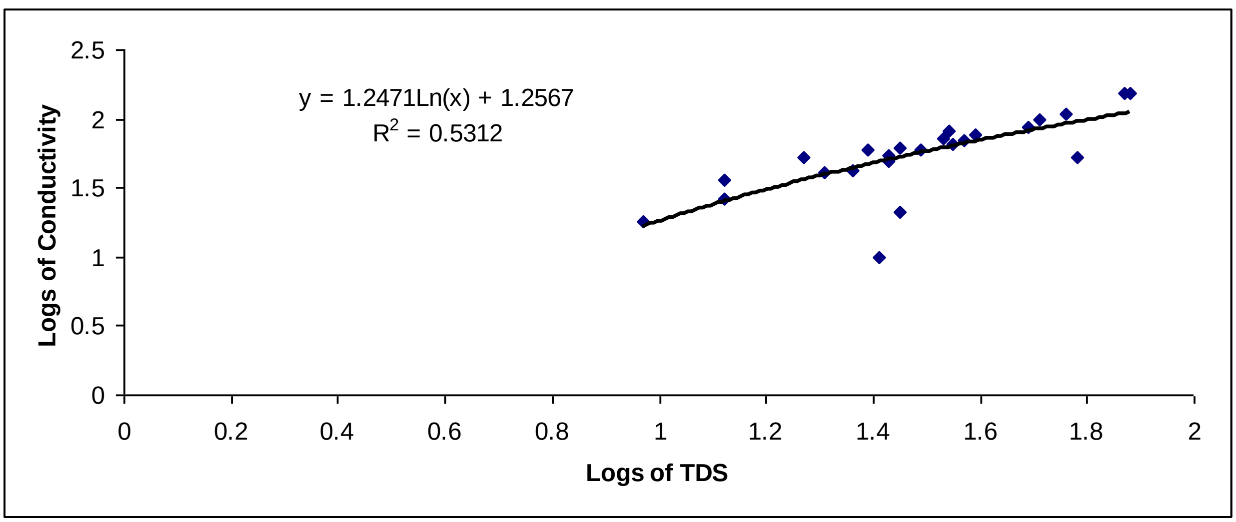

Fig 2. Regression between Logs transformed Conductivity and TDS at Site I in River Benue at Makurdi.

variables) in River Benue at Makurdi. The data were transformed to log of base 10 to normalized them and stabilize the variance. Mean, standard deviation and correlation analysis were determined using SPSS version 22. The regression graph were plot with Microsoft word version 13.

RESULTS

The data presented in Fig 2 depicts the regression between logs transformed conductivity and TDS at site I in River Benue at Makurdi. The result showed imperfect linear relationship between the two parameters with R^2 value of 0.53. All the same at Site II, a different scenario was observed in the relationship between conductivity and TDS in the River Benue at Makurdi where a nonlinear relationship occurred with R^2 value of 0.79 (Fig 3). The regression between logs transformed conductivity and TDS at Site III in River Benue during the study time is presented in Fig 4. The result revealed a weak relationship between the parameters at the study site with R^2 value of 0.34. The result in Fig 5 is the regression between logs transformed conductivity and TDS at site IV

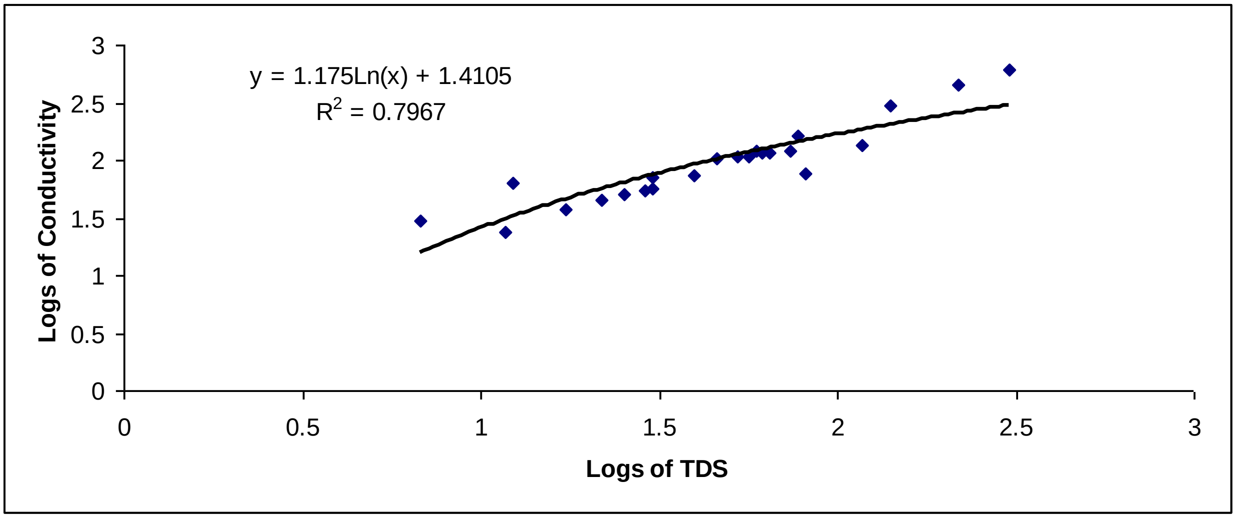

Fig 3. Regression between Logs transformed Conductivity and TDS at Site II in River Benue at Makurdi.

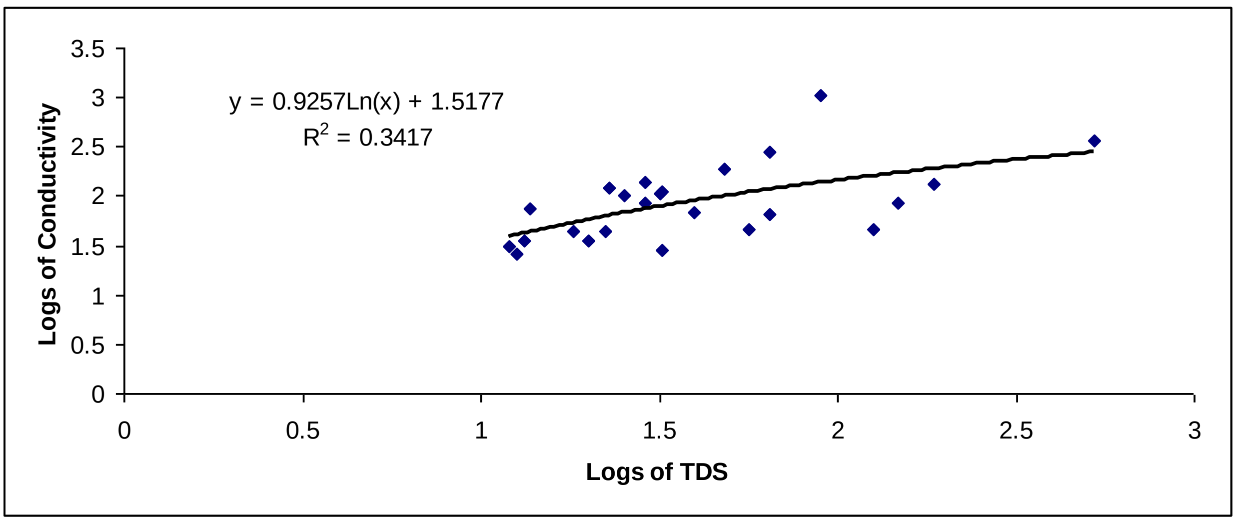

Fig 4. Regression between Logs transformed Conductivity and TDS at Site III in River Benue at Makurdi.

in River Benue at Makurdi. The result indicate a moderate non perfect linear relationship between conductivity and TDS with R^2 value of 0.55. Similarly at Site V the result presented in Fig 6 showed a nonlinear perfect relationship between conductivity and TDS with R2 value of 0.64.

DISCUSSION

The results of the relationship between conductivity and total dissolved solids in River Benue were observed to be nonlinear across the study sites during the course of the investigation. The value of R^2 varied across the studied sites in River Benue at Makurdi. At site III (Mikap Nigera Ltd) the value of R^2 was as low as 0.3417. This low value of R^2 indicate clearly a weak relationship between conductivity and total dissolved solids in River Benue during the period of the study. However at site II (Brewery) a strong relationship existed between conductivity and total dissolved solids with R^2 value of 0.7667. The variation in the relationship between conductivity and total dissolved solids at different study sites indicate that there is no clear relationship between conductivity and total dissolved solids as proposed by mathematical model. This observation is consistent with the findings of Iyasele *et. al.,* (2015). This variation may also be attributed to the fact that different ions are dissolved in the River at the different sites and account for different values of conductivity without following a

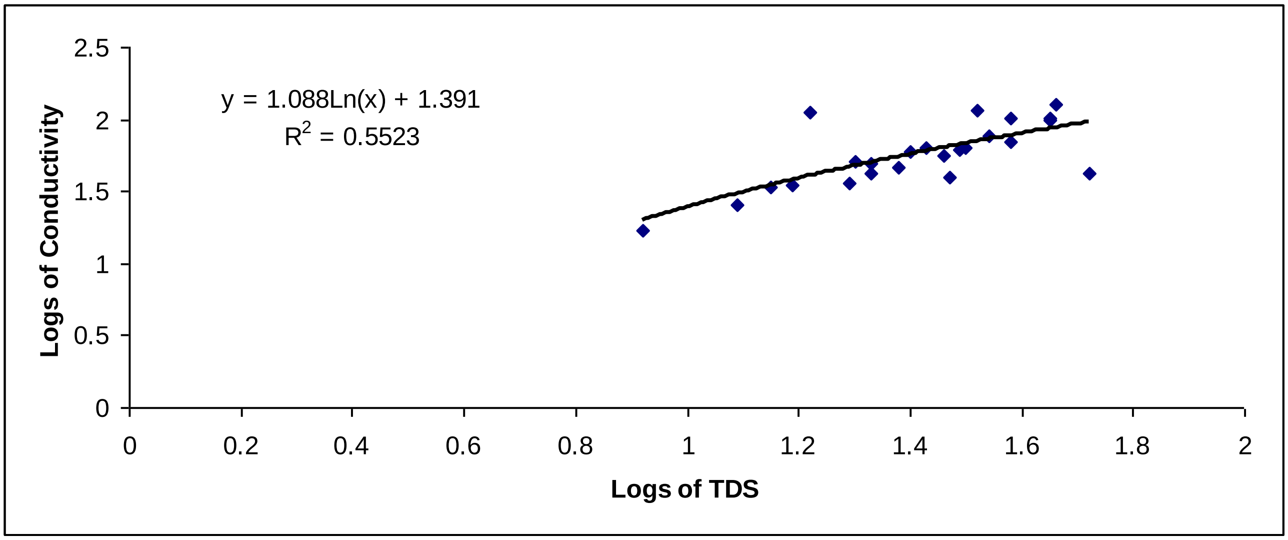

Fig5. Regression between Logs transformed Conductivity and TDS at Site IV in River Benue at Makurdi.

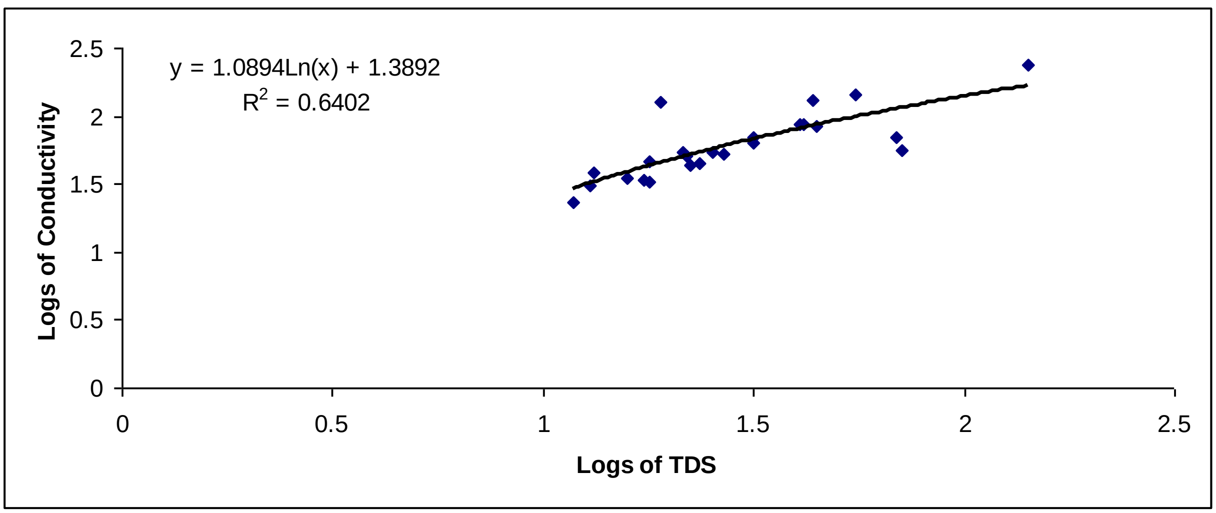

Fig6. Regression between Logs transformed Conductivity and TDS at Site V in River Benue at Makurdi.

definite trend. The findings of this study differs significantly from the report of a study in a Lake in India where the regression model developed from conductivity and total dissolved solids shows a very strong relationship with R^2 value of 0.9963 as compared to the present study but was still not a perfect straight line (Mihir *et al.*, 2015). Similarly Suresh *et al*., (2016) reported a strong relationship between conductivity and total dissolved solids with R^2 value 0.8329 in India.

The results of the plot of conductivity against total dissolved solids plotted across all the study sites in River Benue did not show a perfect linear relationship between two parameters during the period of the study. This may be attributed to the fact that the conductive mobility of ionic species that account for the conductivity value of water or any solution is variable. This is because monovalent cations are more mobile as compared to multivalent cations and consequently affects the value of conductivity of a solution of a sample. A similar trend is prevalent among the negative ions. Therefore a location of water samples with Na^+ and Cl^- as the dominant dissolved species will have a higher conductivity than one dominated by Ca^{2+} and SO_4^{2-}. This may be the situation at the different study sites in River Benue during the course of this investigation due to the fact that the different study sites are impacted by different sources of waste from the human activities on the River. The findings of this study conforms with the result of an earlier study in River Yobe-

Nigeria that did not indicate a direct linear plot of conductivity and total dissolved solids (Waziri and Ogugbuaja, 2012).

CONCLUSION

The findings of this study indicate that the relationship between conductivity and total dissolved solids is not directly linear. The assumption that total dissolved solids is a proxy indicator of conductivity is not perfect in all its ramifications.

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