Pak. j. sci. ind. res. Ser. A: phys. sci. 2022 **65A**(2) 104-111

Relationship Between Electrical Conductivity and Some Mineral Composition of Benin Rivers

Uwidia Ita Erebho
Department of Chemistry, University of Benin, P.M.B. 1154, Benin City, Edo State, Nigeria

(received July 25, 2019; revised April 29, 2021; accepted June 16, 2021)

Abstract. The relationship between conductivity and some mineral compositions: calcium (Ca^{2+}), magnesium (Mg^{2+}), iron (Fe^{2+}), copper (Cu^{2+}) and zinc (Zn^{2+}) of two rivers (Ikpoba and Ogba rivers) in Benin city was investigated. Results revealed the values: electrical conductivity (8.0-20.0; 10.0-50.0) μS/cm, pH (5.2-6.0; 4.2 – 6.3), turbidity (6.0 - 15.0; 12.0 – 23.0) NTU, temperature (28 – 30; 28 – 29) °C, TDS (5.3 – 12.0; 26.5 – 28.0) mg/L; calcium (1.10-1.90 ; 2.40 – 7.70) mg/L, magnesium (0.28 – 0.41; 0.35 – 0.80) mg/L, iron (0.00 - 0.20; 0.10 – 0.20) mg/L, copper (0.00 – 0.00) mg/L ; zinc (0.01 – 0.02; 0.02 – 0.04) mg/L respectively. There were significant relationships between electrical conductivity and Fe^{2+}, Zn^{2+}, Ca^{2+} and Mg^{2+}. Medium strength was obtained for EC /Ca^{2+}, EC /Mg^{2+} (in river 1), weak relationship was obtained for EC/Zn^{2+} (in river 2), no significant relationship was obtained for EC/Fe^{2+} (in river 2) and copper was absent.

Keywords: electrical conductivity, mineral composition, relationship, rivers.

Introduction

Water is a universal solvent due to its ability to dissolve, absorb and suspend different substances. Surface water, such as rivers, streams or freshwater lakes are natural water resources that are useful to man for various activities ranging from domestic, agricultural to industrial activities. Natural waters (for example, rivers) can be classified based on their chemical composition (the major ions in the water, dissolved gases, organic and inorganic substances, micro-elements and various pollutants). Therefore, the physical and/or chemical properties of a natural water body like electrical conductivity, salinity or pH, depend on its chemical or biological components (Rim-Rukeh *et al*., 2006).

The major ions in natural water are Ca^{2+}, Na^{2+}, Mg^{2+}, K^+, Cl^-, SO_4^{2-}, HCO_3^- and CO_3^{2-}. Sources of these ions and other organic and inorganic substances in rivers are due to natural or artificial pollution. Nitrates and phosphorus are minor contributors to conductivity. Dissolved gases such as oxygen, carbon (IV) oxide, nitrogen, methane, traces of ammonia and hydrogen sulfide, are present and needed for biochemical and other processes in rivers. Oxygen is formed during photosynthesis, while gases like CO, CO_2, CH_4, NH_3, H_2S, HCl, SO_x and hydrogen can occur due to volcanic processes. All organic and inorganic substances are present in rivers either in dissolved, suspended or colloidal form (Rosberg *et al*., 2015).

River water pollution has become a concern. Most of this pollution is due to increased industrialization that leads to environmental degradation. In Nigeria, pollution of rivers may occur due to oil spillage of petroleum products. It could also occur due to surface runoffs from farm lands which may contain various organic pollutants from fertilizers or indiscriminate industrial, domestic, or commercial wastewater discharges. The chemical composition of river water varies naturally from one region to another. Therefore, a better way to assess the quality of river water is mineralization and it involves the arithmetic sum of all ions determined in the water during analysis.

Mineral elements are essential structural components of various body organs and tissues. They function as electrolytes and catalysts in enzymes and hormone systems. Therefore, they are required for maintaining human health and some physico-chemical processes in the body (Soetan *et al*., 2010). Mineral components dissolved in water are measurable by determining the electrical conductivity (EC) of the water. Electrical conductivity is a numerical expression of the ability of water to conduct an electric current. It is directly related to the concentration of salts dissolved in the water and total dissolved solids (Anna, 2018).

---

*Author for correspondence; E-mail: uwidiaie@yahoo.com

Total dissolved solids (TDS) provide information about the presence of inorganic salts (principally calcium, magnesium, potassium and sodium cations, bicarbonates, chlorides and sulfates anions) and small amounts of organic matter in a body of water.

Although TDS provides a qualitative measure of the number of ions dissolved in water, it does not offer an insight into some specific water quality issues. Examples include elevated hardness, salty taste or corrosiveness. Therefore, TDS is mostly used as an indicator to determine the general quality of water. Total dissolved solids can be related to electrical conductivity in water based on the type of dissolved cations and anions present in the water (Mohammad *et al.,* 2016).

Conductivity in water can be affected by natural factors such as geology and evaporation. Artificial factors like septic/landfill leachate, agricultural and surface runoff, road salt etc. Therefore, conductivity varies with the source of water. Assessing water conductivity is useful because salts and other substances can affect its quality as drinking water or its use in irrigation. Although electrical conductivity is a viable ionic indicator, it does not provide information about the ionic composition in the water. Knowledge of ionic components in the water is necessary. Therefore, knowledge of electrical conductivity and concentrations of the rudimentary water components in rivers will assist in determining pollution levels and sources. Also, it will aid the evaluation of river water quality for fitness for its intended use. Routine analysis and long-term monitoring of rivers will help protect consumers in the environment (Oyem *et al*., 2014; Uwidia and Ademoroti, 2011)

This study aims to determine the concentrations of some mineral contents such as Ca^{2+}, Mg^{2+}, Fe^{2+}, Cu^{2+} and Zn^{2+} in Benin rivers. It also attempts to relate these values with the electrical conductivity of the rivers and evaluate the influence of these ions on the electrical conductance of the water. Possible recommendations would also be made that will improve environmental monitoring or impact assessment and water treatment for recycling and reuse.

Materials and Methods

Description of the study area. Ikpoba and Ogba rivers (Fig. 1 and 2) are situated in the rainforest area of Edo state in southern Nigeria. Both rivers serve as a critical source of water supply for the surrounding communities. They also receive effluents from different activities around the environment.

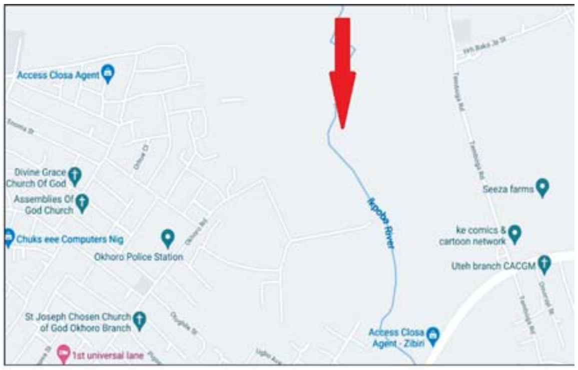

Fig. 1. Map of Ikpoba river (river 1).

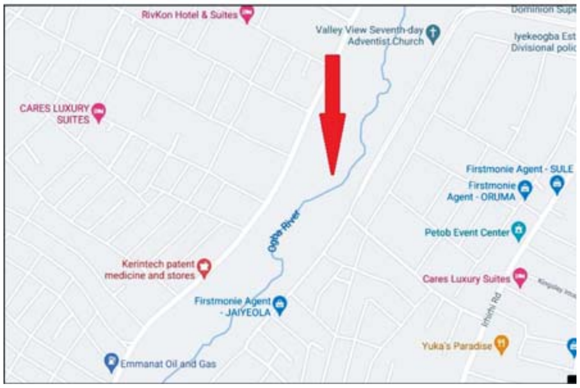

Fig. 2. Map of Ogba river (river 2).

The most common activities taking place in the area are farming and trading. A few industries are also situated in the area. Ikpoba river takes its source from the Ishan plateau in the northern part and flows along the southwest direction through valleys and sandy regions before passing through Benin to join the Osiomo river. Also, the Ogba river takes its source from Ekenwan, Benin city, and flows along the southeastern direction through Ogba village into Osiomo river. Ogba river also receives effluents from the Ogba zoo and its surrounding environment. The receiving Osiomo river empties its water finally into the Atlantic ocean.

Sample collection. Samples were collected from both rivers in a can and well-labeled plastic containers of 2L capacity. Samples were collected weekly at 1 h intervals starting from 8.00 am and ending at noon using well-labeled 2L plastic containers. These samples were preserved in an icebox and taken to the laboratory for analysis. A total of 6 composite samples were obtained from each river. Altogether twelve samples were obtained and used for the analysis.

The containers and materials used were washed and rinsed with deionized water.

Methods of analysis. Samples were analyzed according to standard methods. (APHA, 2005; Ademoroti, 1996). The pH was determined by the electrometric method using a pH meter. The meter was standardized with pH buffer 1.0, 4.0 and 9.0 solutions.

The temperature was determined with the aid of a mercury thermometer. The thermometer was immersed in the water sample up to the mark specified by the manufacturer. The reading of each of the samples was also taken after equilibration.

Electrical conductivity was determined using the Hach pH / ISE / conductivity meter 50125. Before the measurement, the meter was calibrated using the 1000 μS/cm conductivity standard. The probe was rinsed first with distilled water followed by some of the samples.

The sample conductivity was measured by inserting the probe into the sample. The meter displayed a conductivity value and the probe was allowed to stay in the water sample for about 1 min for the reading to stabilize. Then the value was recorded in (μS/cm).

Total dissolved solids was determined using the electrical conductivity method. The conductivity meter was calibrated using the 1000 μS/cm conductivity standard. The mode key was pressed until the TDS was displayed. The probe of the meter was then rinsed with some portion of the sample.

The probe was immersed into the water sample inside the beaker and the trapping of air bubbles around the temperature was avoided. The reading was allowed to stabilize before the values were recorded in mg/L.

Turbidity was determined using the Hach calorimeter. The program number for turbidity was 95. 10 mL distilled water was poured into a cell bottle and placed in the cell holder of the Hach colourimeter instrument to zero the equipment. Then the blank was replaced with 10 mL of the sample and the readings were taken.

Metals such as Ca^{2+}, Mg^{2+}, Fe^{2+}, Zn^{2+}, Cu^{2+} and Pb^{2+} were determined using Atomic Absorption Spectrophotometer (AAS). Data obtained were subjected to statistical analysis and compared with World Health Organization (WHO) standard limit (WHO, 2011).

Results and Discussion

Results of the physico-chemical parameters of rivers studied are as shown in Tables 1 and 2 Fig. 3 to 10 also depict the graphical representation of the relationship between electrical conductivity and the mineral ions studied.

When compared with the world health organization standard (WHO, 2011), as shown in Tables 1 and 2, all mean values of the parameters studied complied except for turbidity that was 10.67+ 4.51 in river 1(IKR) and 14.53+ 3.76 in river 2 (OGR). Compared with the WHO maximum permissible limit of 5.0, both values were considerably higher. Turbidity values which ranged from 6.00 -15.00 and 12.00 – 23.00 NTU in rivers 1 and 2, were relatively high. High levels of turbidity may be attributed to high levels of organic matter and solids present as dissolved and suspended solids in the river water at the time of determination. High turbidity reduces visibility and interferes directly with autotrophic production (Aina and Oshunrinade, 2016).

The nature of Benin soil has a reddish-brown or yellow colouration, may have contributed to the turbidity. The pH values of 5.20 - 6.00 with a mean value of 5.53 ±0.42 for river 1 and 4.20 - 6.30 with a mean value of 4.87± 1.24 were within permissible limits of 6.5 – 8.5 by the WHO standard.

Results of the pH analysis show that the river water analyzed was slightly acidic. Acidic pH indicates that some dissolved ions such as Fe^{2+}, Pb^{2}+, Mn^{2+}, Cu^{2+}, and Zn^{2+}, may be present in the water. Such water may taste sour and cause premature damage to metal piping and introduce stain to clothes, kitchen sinks, etc. (Mohammad *et al*., 2016).

Temperature values were 28.00-30.000 C with mean of 29.00± 1.000C for river 1 and 28.00-29.000 C with mean value of 28.67± 0.580 C for river 2. These values represent the ambient temperature at the time of determination.

Values of electrical conductivity for river 1 ranged from 8.00-20.00 Scm^{-1} with mean value of 16.67±4.51 Scm^{-1} and 10.00 - 50.00 Scm^{-1} with mean value of 50.00±0.00 Scm^{-1} for river 2. Total dissolved solids (TDS) had values ranging from 5.30-12.00 mg/L with mean value of 8.83±3.06 mg/L and 26.50-30.50 mg/L with mean value of 26.50±0.00 mg/L in both rivers.

Table 1. Data computation of parameters and mineral concentrations determined in river 1.

Parameters	Unit	Range of values obtained	Mean ± SD	WHO
Electrical conductivity	μS/cm	8.0 - 20.00	16.67 ± 4.51	900.00
pH		5.20 - 6.00	5.53 ± 0.42	6.5 - 8.5
Turbidity	NTU	6.00 - 15.00	10.67 ± 4.51	5.0
Temperature	°C	28.00 - 30.00	29.00 ± 1.00	25.00 - 35.00
TDS	mg/L	5.30 - 12.00	8.83 ± 3.06	<1000.00
Ca^{2+}	mg/L	1.10 - 1.90	1.58 ± 0.26	75.00
Mg^{2+}	mg/L	0.28 - 0.41	0.38 ± 0.06	50.00
Fe^{2+}	mg/L	0.00 - 0.20	0.12 ± 0.08	0.30
Cu^{2+}	mg/L	0.00	0.00 ± 0.00	2.0
Zn^{2+}	mg/L	0.01 - 0.02	0.02 ± 8.66 * 10^{-3}	4.0

Table 2. Data computation of parameters and mineral concentrations determined in river 2.

Parameters	Unit	Range of values obtained	Mean ± SD	WHO
~~Electrical conductivity~~	~~μS/cm~~	~~10.00 - 50.00~~	~~31.66 ± 0.12~~	~~900.00~~
pH		4.20 - 6.30	4.87 ± 1.24	6.5 - 8.5
Turbidity	NTU	12.00 -23.00	14.53 ± 3.76	5.0
Temperature	°C	28.00 - 29.00	28.67 ± 0.58	25.00 - 35.00
TDS	mg/L	26.50 – 28.00	26.50 ± 0.00	<1000.00
Ca^{2+}	mg/L	2.40 - 7.70	5.57 ± 1.96	75.00
Mg^{2+}	mg/L	0.35 - 0.80	0.56 ± 0.16	50.00
Fe^{2+}	mg/L	0.10 - 0.20	0.13 ± 0.05	0.30
Cu^{2+}	mg/L	0.00	0.00 ± 0.00	2.0
Zn^{2+}	mg/L	0.02 - 0.04	0.03 ± 8.94	4.0

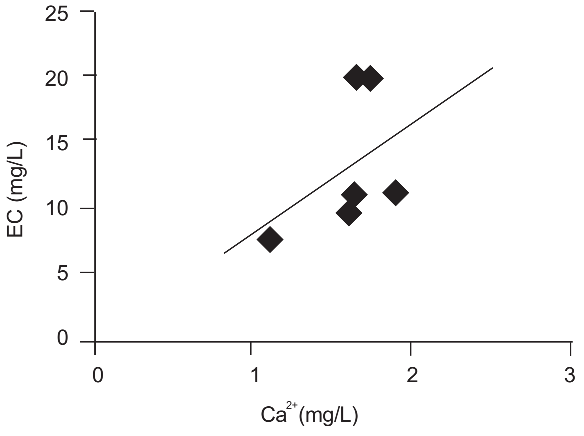

Fig. 3. Relationship between EC and Ca^{2+} in river 1.

Although TDS values in both rivers were within the WHO standard, the values obtained from river 2 were higher than those of river 1. This result shows that, compared to river 1, inorganic compounds are present in higher concentrations in river 2. However, values of EC and TDS in both rivers were a reflection of the nature of different ions present as dissolved substances in the water (Priyanka, 2017). Studies on the relationship between TDS and electrical conductivity have shown that variations of electrical conductivity at a particular temperature can occur due to alterations in TDS (Marandi *et al.,* 2013). However, correlation studies of electrical conductivity and TDS present a low cost, speedy and accurate method of evaluating either parameter which is very useful in environmental monitoring (Visconti *et al.,* 2010; Raju, 2007; Hayashi, 2004)

The composition of calcium ion in river 1 ranged between 1.10 -1.90 mg/L with mean value of 1.58 ±0.26 mg/L and 2.40-7.70 mg/L with mean value of 5.57 ± 1.96 mg/L in river 2. The major sources of calcium in water are:

(i) Carbonate rocks (for example, limestone or dolomites) dissolved by carbonic acid contained in the water and;

(ii) gypsum (found commonly in sedimentary rocks). Calcium ions are usually higher among the cation composition of low mineralized waters.

Also, calcium is more readily absorbed in acidic surroundings like acidic water, the human intestine etc (Rosberg *et al.*, 2015). Calcium salts are present as calcium carbonate ($CaCO_3$) and calcium bicarbonate ($CaHCO_3$) in water.

Magnesium levels in both rivers were found also to vary between 0.28 - 0.41 mg/L with mean value of 0.38± 0.06 mg/L and 0.35- 0.80 mg/L with mean value of 0.56 ± 0.16 mg/L respectively. Zinc levels were found to vary between 0.01- 0.2mg/L with mean value of 0.02 ± 8.66 10-3 mg/L and 0.02-0.04 mg/L with mean value of 0.03 ± 8.94 mg/L.

Magnesium ions are not predominantly present in natural waters compared with calcium.

Sources of magnesium in rivers are due to chemical weathering processes and the dissolution of rocks (dolomites, marls etc). Studies have shown that calcium, magnesium and HCO_3^- are essential dietary minerals and can play a significant role in developing a healthy body. Also Ca^{2+}, Mg^{2+} and Zn^{2+} have been reported to affect brain development. Ca^{2+} and Mg^{2+} also affect the cardiovascular system**.** Calcium, magnesium and other minerals account for countless biochemical reactions in the cells of plants and animals (Quattrini *et al.*, 2016).

The major sources of zinc in rivers are galvanized surfaces (roofs, gutters, flashing, fencing, guard rail, drainage systems/pipes etc) and wear debris from vehicle tires. Zinc is needed for the proper functioning of the immune system and may help in the healing process of body tissues.

Iron levels in both rivers were found to range between 0.00-0.20 mg/L with mean value of 0.12 ± 0.08 mg/L and 0.10 - 0.20mg/L with mean value of 0.13± 0.05 mg/L.

According to reports, the concentration of iron in drinking water is usually less than 0.3 mg/L and its taste is not noticeable at that amount. However, above 0.3 mg/L iron can cause discoloration, metallic or bitter taste in food and water. Iron in drinking water is more of a nuisance than a potential health hazard (Mohammad *et al*., 2016).

Copper was undetected in both rivers. Copper present in natural waters may be from natural or anthropogenic sources (mining activities, agriculture, metal and electrical works etc) (Mc Dowell, 1992). Copper and zinc are micronutrients with lower concentrations ranging from 0-1.2 mg/L in drinking water (Rosberg *et al*., 2015).

The relationship between electrical conductivity (EC) and mineral ions studied was examined using linear graphs, as shown in Fig. 3 – 10. The regression equations obtained and parameters correlated are as shown in Table 3.

Figure 3 shows the relationship between EC and Ca^{2+} in river 1. The correlation coefficient (r) was 0.419, implying that calcium may have contributed to the conductivity of the river in moderately low proportions. Correlations could be perfectly negative or positive (i.e. when r values are either -1 or +1). It could also be strong (when the r-value ranges from 0.6 to 0.9) or weak (when the r-value ranges from 0.4 and below). Also, 0.5 is a good correlation.

Table 3. Regression equations and "r" values obtained for parameters correlated

Parameter correlated	Correlation coefficient (r)	Regression equation	Direction of correlation
EC/Ca^{2+}	0.419	y = 8.351x + 0.0274	Positive
EC/Mg^{2+}	0.447	y = 47.734x - 4.7261	Negative
EC/Fe^{2+}	0.706	y = - 49.529x + 19.112	Positive
EC/Zn^{2+}	0.553	y = 533.33x + 5.3333	Positive
EC/Ca^{2+}	0.784	y = 7.4721x - 8.2612	Negative
EC/Mg^{2+}	0.747	y = 89.12x - 17.168	Negative
EC/Fe^{2+}	0.069	y = 25x + 30	Positive
EC/Zn^{2+}	0.360	y = -750x + 55.833	Positive

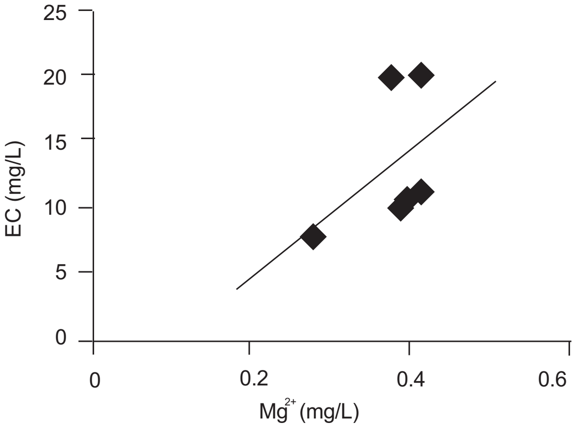

Fig. 4. Relationship between EC and Mg^{2+} in river 1.

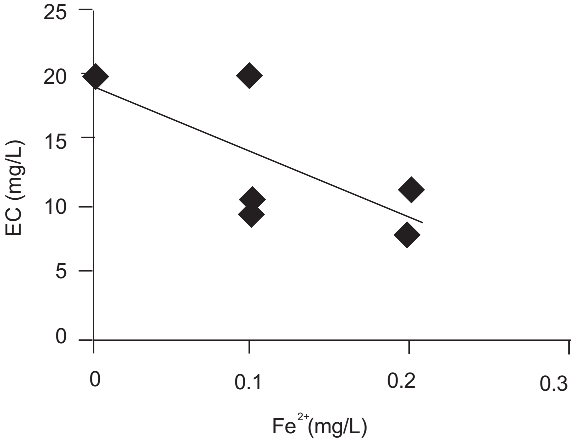

Fig. 5. Relationship between EC and Fe^{2+} in river 1.

In Fig. 4, the strength of the relationship between EC and Mg^{2+} was r = 0.447. This relationship shows that the magnitude of Mg^{2+}, which may have contributed to the conductivity of the river water, was of medium strength.

The value of "r" in Fig. 5 for the linear relationship of EC/ Fe^{2+} was 0.706 mg/L. The r-value showed a strong relationship, which reflected the composition of Fe^{2+} relative to the specific conductance in river 1. A good relationship was also found to exist between EC and Zn^{2+} in Fig. 6. The r-value was 0.553. The mineral components were examined with EC in river 2, as shown in Fig. 7 – 10. Various "r" values for relationships examined such as EC/Ca^{2+}, EC/Mg^{2+}, EC/Fe^{2+} and EC/Zn^{2+} were: 0.784, 0.747, 0.069, and 0.360 respectively. The value of r (0.784) showed that

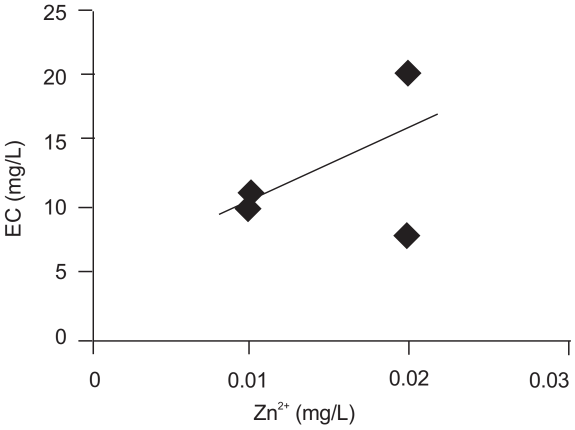

Fig. 6. Relationship between EC and Zn^{2+} in river 1.

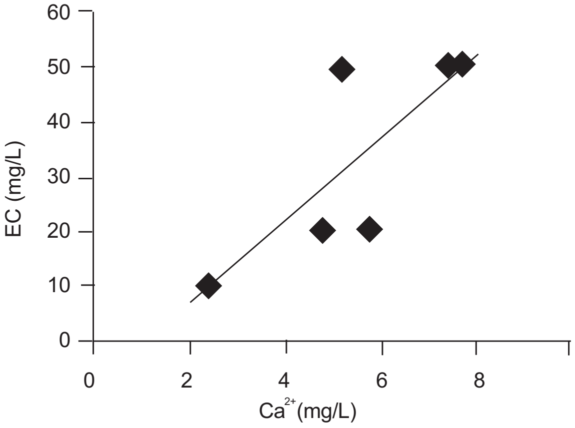

Fig. 7. Relationship between EC and Ca^{2+} in river 2.

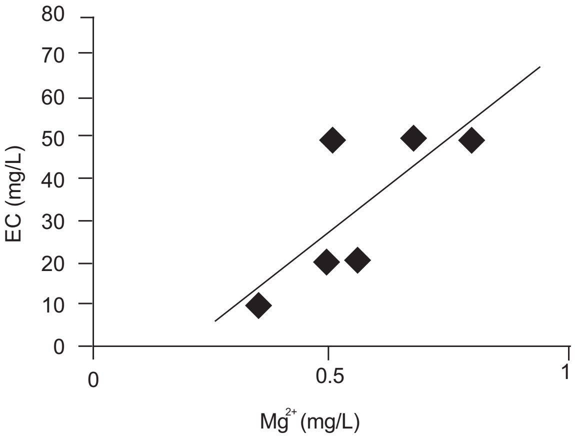

Fig. 8. Relationship between EC and Mg^{2+} in river 2.

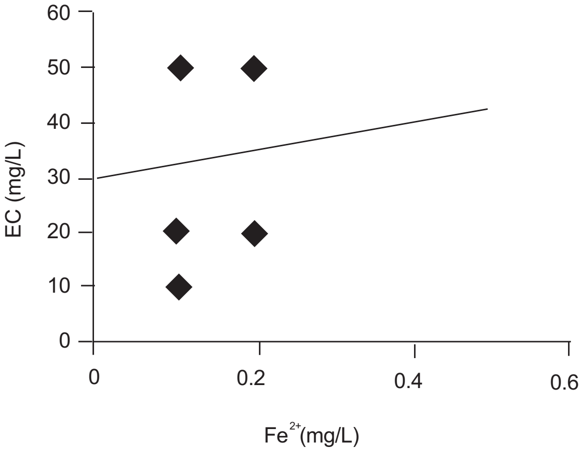

Fig. 9. Relationship between EC and Fe^{2+} in river 2.

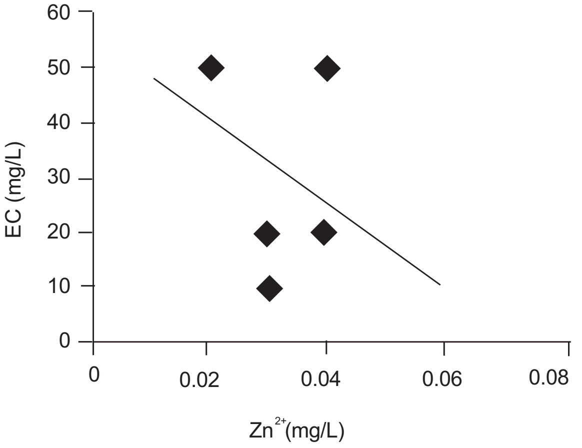

Fig. 10. Relationship between EC and Zn^{2+} in river 2.

a strong relationship was obtained for EC/Ca^{2+}. A strong relationship (r = 0.747) was also obtained between EC/Mg^{2+}. Very weak or no significant relationship (R = 0.069) was obtained between EC/Fe^{2+} and low relationship (r = 0.360) was obtained for EC/Zn^{2+}.

The relationship between EC and Cu^{2+} was not examined in both rivers because Cu^{2+} levels were below the detectable limit in the rivers from the samples analyzed. Therefore, a good relationship was observed between EC and the various ions analyzed except the relationship between EC/Fe^{2+} in Fig. 9 which was very low. Generally, calcium, magnesium, and iron are macro elements found in water. Cu and Zn are usually present in minor concentrations.

Conclusion

The study revealed that electrical conductivity (EC) was strongly related to Fe^{2+} and Zn^{2+} but moderately related to Ca^{2+} and Mg^{2+} in river 1 (rv1). Also, in river 2(rv2), a strong relationship was observed between EC / Ca^{2+} and EC/Mg^{2+}, while poor and weak relationships were observed between EC / Fe^{2+} and E C/ Zn^{2+}. No relationship existed between EC and Cu^{2+} in both rivers. The order of relationship obtained was:

EC/Ca^{2+} (rv2) > EC/mg^{2+} (rv2) > EC/Fe^{2+} (rv1) > EC/Zn^{2+} (rv1) > EC/mg^{2+} (rv1) > EC/ Ca^{2+}(rv1) > EC/Zn^{2+} (rv2)> EC/Fe^{2+} (rv2). Order of correlation coefficients was: 0.784 > 0.747 > 0.706 > 0.553 > 0.447 > 0.419 > 0.360 > 0.069 respectively for both rivers. Electrical conductivity in both rivers was a function of the concentration of mineral components in the rivers. This concentration is dependent upon the relative abundance of elements in the earth crust and also the solubility of their compounds in water.

Recommendations

Routine analysis to monitor the conductivity of rivers relative to the ionic components present is recommended. This analysis will provide information about the ionic and mineral components in such rivers. Also, such exercise will guide against concentrations at toxic levels to ensure the safety of consumers in the community who depend on the rivers for domestic and commercial activities.

Conflict of Interest. The authors declare no conflict of interest.

References

Ademoroti, C.M.A. 1996. *Standard Methods for Water and Effluents Analysis*, **28** – 118pp, Foludex Press Ltd., Ibadan, Nigeria.

Aina, A.T., Oshurinade, O.O. 2016. Comparison of water quality from boreholes and hand-dug wells around and within the University of Lagos, Lagos Nigeria. *International Journal of Research in Environmental Studies*, (*IJRES*), **3:** 93-100.

Andrew, D. E., *American Public Health Association* (APHA). 2005. American waste works Association AWWA).Works Environmental Filteration (WEF) 2005. *Standard Methods for Examination of Water and Wastewater*, 21st ed., p. iv APHA, AWWA, WPCF, Washington. DC, USA.

Anna, F.R. 2018. IOP Conference series: *Earth and Environmental Science*, **118:** 012019.

Hayashi, M. 2004. Temperature-electrical conductivity relation of water for environmental monitoring and geophysical data inversion. *Environmental Monitoring and Assessment*, **96:** 119-128.

Marandi, A., Polikarpus, M., Jõeleht, A. 2013. A new approach for describing the relationship between electrical conductivity and major anion concentration in natural waters. *Applied Geochemistry*, **38:** 103-109.

Mc Dowell, L.R.1992. *Minerals in Animal and Human Nutrition 2nd Edition*, pp. 26- 292, Academic Press Inc., New York, USA.

Mohammad, R.I., Mohammad, K.I.S., Tanzina, A., Shafkat, S.R., Rabiul, I., Barun, K.H., Abdul, K. 2016. A study on total dissolved solids and hardness level of drinking mineral water in Bangladesh. *American Journal of Applied Chemistry*, **4:** 164-169.

Oyem, H.H., Oyem, I.M., Ezeweali, D. 2014. Temperature, pH, conductivity, total dissolved solids and chemical oxygen demand of groundwater in Boji-Boji Agbor/Owa area and immediate suburbs. *Research Journal of Environmental Sciences*, **8:** 444 - 450.

Priyanka, T. 2017. Water quality assessment for drinking and irrigation purpose. *Indian Journal of Scientific Research*, **13:** 140-142.

Quattrini, S., Pampaloni, B., Luisa, B.M. 2016. Natural mineral waters: chemical characteristics and health effects: *Clinical Cases in Mineral and Bone Metabolism*, **13:** 173- 180.

Raju, N.J. 2007. A season-wise estimation of total dissolved solids from electrical conductance and silica in ground waters of upper Gunjanaeru river basin, Kadapa district, *Andhra Pradesh. Current Science*, **92:** 371-376.

Rim-Rukeh, A., Ikhifa, O., Kokoyo, P.A. Grace. 2006. Effects of agricultural activities on the water quality of orogodo river, Agbor Nigeria. *Nigerian Journal of Basic and Applied Sciences*, **2:** 256-259.

Rosberg, I., Nihlgard, B., Ferrante, M. 2015. Mineral composition of drinking water and daily uptake. In: *Drinking Water Minerals and Mineral Balance*, pp 25-30, Springer International Publishing, Switzerland.

Soetan, K.O., Olaiya, C.O., Oyewole, O.E. 2010. The importance of mineral elements for humans, domestic animals, and plants: a review. *African Journal of Food Science*, **4:** 200-222.

Uwidia, I.E., Ademoroti, C.M.A. 2011. Characterisation of domestic sewage from an estate in warri, Nigeria, *International Journal of Chemistry*, (IJC), **3:** 81- 86.

Visconti, R.F., De paz, B.J.M., Zapata, H.R.D., Sánchez, D.J. 2004. Development of an equation to relate electrical conductivity to soil and water salinity in a Mediterranean agricultural environment. *Australian Journal of Soil Research*, **42:** 381-388.

World Health Organization (WHO). 2011. *Guidelines for Drinking-Water Quality*, 4th ed. p-518 phy, 20 Avenue Appia, 1211 Geneva 27, Switzerland.