Variation of Some Physicochemical Parameters in Surface Water of Elelenwo River, Rivers State, Niger Delta, Nigeria

EDORI, Onisogen Simeon[1], IYAMA, William Azuka[2], AMADI Mary Queenet Chidimma[1]

[1]*Chemistry Department, Ignatius Ajuru University of Education, Port Harcourt, Nigeria*

[2]*School of Basic Studies, Rivers State College of Health Science and Technology, Port Harcourt, Nigeria*

***Abstract*:- Water samples collected from three points along the Elelenwo River in the months of June July and August were analyzed for some physicochemical parameters. The results showed variations of the parameters in the sampled locations and months. conductivity, turbidity, chlorides, and sulphates were higher than the recommended limit for domestic water by WHO, while other parameters such as TSS, TDS, temperature, pH, redox potential, salinity, nitrates and phosphates were within the acceptable limits. The mean values of the parameters within the period of analysis were conductivity, 11933.333±3233.247 µS/cm, total suspended solids (TSS), 17.333±2.055 mg/L, total dissolved solids (TDS), 6.407±1.893 mg/L, turbidity, 6.967 NTU, temperature, 23.917 ^{o}C, pH, 6.78±0.041, redox potential, 174±5.354, salinity 8.397±1.406 mg/L, chloride, 7108.667±310.201mg/L, nitrates 1.497±0.089 mg/L, sulphates, 751.111±4.219 mg/L and phosphates, 0.500±0.016 mg/L. the underlying condition of the water from the river showed human influence on the concentrations of some parameters and salt water influence on chlorides. Therefore, efforts should be geared at protecting the river from human interferences to enable it attains to suitability for human uses.**

I. INTRODUCTION

One of the most vital and ubiquitous compound in the universe is water. The survival and growth of living things (Plants and animals) on the surface of the earth majorly depends on water (Sharma *et al*., 2015). The value and quality attached to water generally is defined on the basis of its physicochemical and biotic or biological properties and other natural environmental conditions like the prevailing climatic conditions, vegetation and lithology (Ashu and Parveen, 2010; Sharma and Walia, 2014). All over the world, the state and purity of fresh water sources are constantly compromised and as such polluted, thus rendering it unfit for human consumption (Ndamitso et al., 2013).

Water being an unavoidable constituent of survival on the earth contains essential that can serve useful purposes in human nutritional needs, as well as other aquatic plants and animals for metabolic processes. Fresh water reservoirs give special benefits to man, in the irrigation or watering of crops, used in the fisheries cultivation and for farm animals (). Beside these, it serves for recreational purposes and for the transportation of goods and services, tourist centres and provide natural beauty when properly preserved (Arain *et al*., 2008). Diversities of aquatic plants and animals dwell in fresh water. If the quality of the water is adversely compromised as a result of human and natural interferences, the natural aquatic ecosystem will be altered and so will lead to either death or migration of aquatic species().

The physical and chemical factors of water are actual indispensable and significant to examine the fitness of water, before being put to drinking, domestic, agricultural or industrial uses. The purity of water therefore, needed to be examined through the testing for different physical and chemical qualities (Dirican, 2015), so that it can truly serve the purpose for which it was intended**.**

On a daily basis, enormous amounts of wastes are discharge into the river without following adequate and stipulated standard procedures for such discharge, especially in countries without strict environmental laws and punishment for offenders(Muthukumar et al., 2013).Most of these releases are largely from multinational companies operating within the area. Although, there is the belief these releases contain very low concentrations of toxicants, yet continuous or unabated discharges might lead to accumulations above the thresh hold levels, which can be negatively consequential on the ecosystem on the long run(Quevenco, 2011; Raji *et al*., 2015).

This study thus investigated the physicochemical parameters of water from Elelenwo River in River State, Nigeria

II. MATERIALS AND METHODS

Water samples were collected from the Elelenwo River with plastic vials at a depth of 25 cm under water at the different points and the vials immediately capped. Sampling was done in triplicates at each sampling point and was done between the months of June – August, 2019.

The samples were placed in ice-cold chest packs and transported to the laboratory, where they were stored at 4 ^{o}C temperature. Subsequently on site, such parameters as pH, conductivity, turbidity, temperature, TDS and salinity were examined on site (in-situ) using the water checker electrometric instrument Hanna (model H19828) USA.TSS, redox potential and chloride were determined using the APHA (1995) method of analysis for water and wastewater.

The obtained results of the physicochemical parameters were subjected to statistical analysis and the mean ± SD was calculated with an excel package.

III. RESULTS AND DISCUSSION

Physical Parameters

The results of the physical parameters are presented in Figures 1 – 5 and Table 1. The conductivity values obtained between the months of June – August in the Woji axis varied from 9450-16,400 µS/cm. In the Akpajo station, the observed range of conductivity values was 9400 – 16600 µS/cm, while in Rumuwuji, the value range was 9500 -16500 µS/cm. The mean values for the months showed 16500±81.65 µS/cm for June, 9850±40.82 µS/cm for July and 9450±40.82 µS/cm for August. The observed values were higher than the permissible limit by WHO, USEPA, SON and FAO standards for drinking and irrigation purposes.

This is a measure of water capacity to conduct electric current. It estimates total amount of solid dissolved in water and ionic content in a solution (Lee *et al*., 2012;Manohar, 2018).The high conductivity values of the water samples may suggest that there was a high concentration of soluble salts in the river (Manohar, 2018). The higher the electrical conductivity, the lesser the available water to plants and reduces yield potential also usable plant water in the soil solution decreases as electrical conductivity increases. The high conductance of the water samples from the river is a function of not the input of salt water into the river, but also from numerous human activities within the area that introduced ion carrying species into the river. This observation is in agreement with the observation of Manohor (2018), in Winam (Nyanza) Gulf of Lake, Kenya.

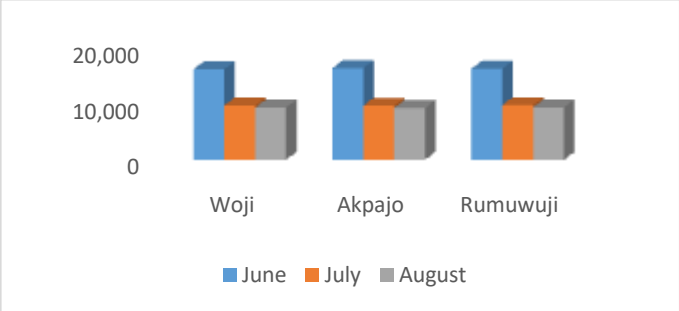

Figure 1: Conductivity (µS/cm) of water samples from Elelenwo River in the Sampled Months

The values of total suspended solids (TSS) observed in the examined stations indicated that the variation within the months of determination ranged from 14 -20 mg/L in Woji, 15 – 22 mg/L in Akpajo and 16-18 mg/L in Rumuwuji. The monthly mean variations of TSS was 17±0.82, 15±0.82 and 20±1.63 mg/L for June, July and August respectively.

When the value of suspended solid particles is increased in water medium, there is a resultant increase in the level of turbidity of the water (Edori*et al*., 2019). The major anthropogenic factors that leads to increased TSS of water are those that have to do with loosening the compactness of soil and as such are vulnerable to erosion and transported through runoffs to river, streams and creeks. These factors include; land tilling, road construction, building of structures, excavation, mining and the season (wet or dry) (Edori *et al*., 2019). Naturally induced Suspended particles comprises mainly algae, silt and sediment particles. However, TSS values above threshold values is either through resuspension of sediments due to turbulence flow of and anthropogenic inputs. The level of contamination of water can also be revealed by the status of TSS, which when at extreme concentrations introduces taste, odour and colour to water.

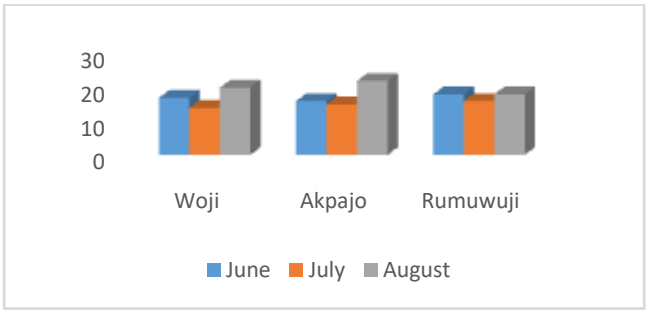

Figure 2: Total Suspended Solids (mg/L) of Water Samples from Elelenwo River in the Sampled Months

The results of total dissolved solids (TDS) with the monthly period of June – August in the stations showed that in Woji, the variation was in the range of 4.70 - 9.10 mg/L, in Akpajo, the values ranged between 4.47 – 9.05 mg/L and in Rumuwuji, the range fell within 4.72 – 9.01 mg/L. The mean monthly values were 9.05±0.04, 5.45±0.58 and 4.72±0.02 mg/L in June, July and August respectively .The range of TDS falls between 500–1500 mg/L recommended by the USEPA (1997) and WHO (2011).

TDS take into consideration the measurement of the concentrations of ions present in a given solution whose sizes are lesser than two microns. It is a quantity of inorganic salts, organic matter and other materials in the water solution, whether surface or ground water (USEPA, 1986). Elevated levels of TDS in waters has the capacity to promote eutrophication after a long period of time. Living organisms within an aquatic environment of high concentration of TDS finds it difficult to move about the water column. Excessive intake of water overburdened with dissolved solids has the potential to cause harm to public health, which includes; effect on central nervous system, paralysis of the tongue, lips and face, prickliness and vertigo. When manmade organic compounds are present in water even in very small concentrations, they give obnoxious and unpleasant tastes, odors and colors to fish and aquatic plants (Chang, 2005).

Water to be used in homes are required to have TDS that are less than 500 mg/L, while those for agricultural purposes must be less than 1200 mg/L to avoid damage to delicate crops(Masood and Anwar, 2002).

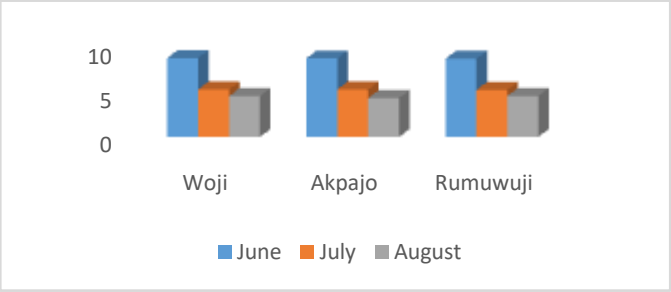

Figure 3: Total Dissolved Solids (mg/L) of water Samples from Elelenwo River within the Sampled Months

The observed turbidity values within the stations in the examined months varied as follows; Woji, 6.00 – 8.40 NTU, Akpajo, 6.10 -8.60 NTU and Rumuwuji, 6.20 -8.20 NTU. The mean monthly values were; 8.4±0.05 in June, 6.1±0.03 in July and 6.4±0.08 in August. The observed values of turbidity in the stations along the river were slightly above the permissible limit by WHO, SON and FAO.

Turbidity measures the opacity or obscurity of a solution. Turbidity of water is a result of the presence of colloidal and fine particles exceptionally dispersed in water or any other solution. The major negative effect of turbidity lies with its capacity to prevent the penetration of light, which therefore causes deleterious effects on aquatic flora and fauna and the depreciation of water quality. A highly turbid water deposits fine particles on the surfaces of the leaves of aquatic plant, thereby reducing the ability of the plants to carry out photosynthetic activity, hinders the effectiveness of treatment processes such as chlorination and removal of pathogens from water (Verma et *al*., 1984).According to Sawyer *etal*. (2003), the range of 2.5 to 5 NTU has been proposed by the above mentioned body for turbidity depending on the treatment source and the purpose for which the water will be applied.

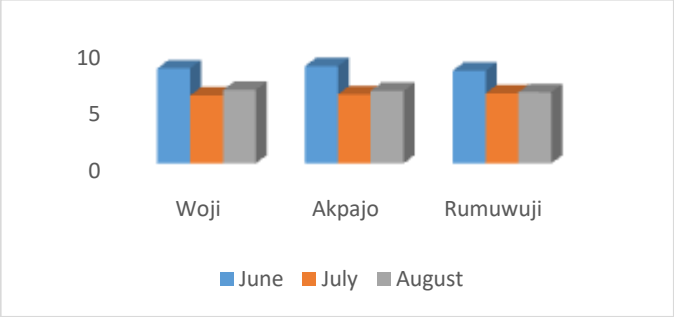

Figure 4: Turbidity (NTU) of Water Samples from Elelenwo River within the Sampled Months

The values of temperature observed within the months of investigation in the Elelenwo River varied as follows in the stations; Woji, 23.56 - 24.20^{o}C, Akpajo, 23.58 – 24.22 ^{o}C and Rumuwuji, 24.00 – 24.54 ^{o}C. The mean monthly values observed within the period were 23.97±0.01^{o}C in June, 24.22±0.12^{o}C in July and 23.56±0.02^{o}C in August. The observed temperature values were within the threshold value of WHO, FEPA and SON. The result is similar to the observations of Kidu*et*al.(2005), who observed values ranging from of 21.8 to 23.6 NTU in TsaedaAgam River in Mekelle city, Tigray, Ethiopia.

Temperature is an imperative physical property of water ecologies (Dea*set al*., 2000). This is based on the fact that life of aquatic organisms, physical and chemical characteristics of water are dependent on the temperature (Edori and Nna, 2018). All components on the natural water ecology is either directly or indirectly affected with temperature situations. A rise in temperature of water increases photosynthetic processes, with the concomitant rise in nutrient production (Boulton *etal*., 2012).Results obtained showed that the temperature values recorded from the river is favourable for aquatic ecosystem.

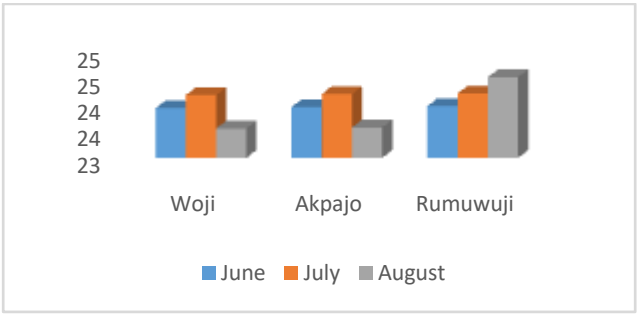

Figure 5: Temperature (^{o}C) of Water Samples from Elelenwo River in the Sampled Months

Table 1: Mean Values of Physical Parameters in Elelenwo River within the Sampled Months

Parameters	Months		
	June	July	August
Conductivity (µS/cm)	16500±81.65	9850±40.82	9450±40.82
TSS (mg/L)	17±0.82	15±0.82	20±1.63
TDS (mg/L)	9.05±0.04	5.45±0.58	4.72±0.02
Turbidity (NTU)	8.4±0.05	6.1±0.03	6.4±0.08
Temperature (^{o}C)	23.97±0.01	24.22±0.12	23.56±0.02

Chemical Parameters

The results of the chemical parameters are presented in Figures 6 – 9and Table 2. The pH values in the examines stations varied from 6.73 – 6.84 in Woji station, 6.67 – 6.88 in Akpajo station and 6.69 – 6.83 in Rumuwuji station. The mean monthly values observed were 6.83±0.58 in June, 6.78±0.08 in July and 6.73±0.05 in August. The values are within permissible limit of WHO, ICMR, CPCB, BIS and FAO which are within the range of 6.5 to 8.5.

The intensity of basicity and acidity of a solution is characterized by its pH value. The acido-basic properties of any solution is a function of the amount of chemical species dissolved and the associated biochemical processes taken place in the solution (Saksena *et al*., 2014). It is the concentration of hydrogen ion in a solution. At low pH,

metals solubility, mobility and toxicity in surface water increases (Kelly *et al*., 2004). According to Ayers *etal*. 1994),any water which falls within the stipulated 6.5 to 8.5 value is suitable for drinking and irrigation purposes. However, if the pH becomes lower than 6.5, the biochemical processes of production of vitamins and minerals in the human body is affected and above 8.5, it causes eye touchiness and skin ailment. At pH values in the range 3.5–4.5, there is great danger of the survival of aquatic organisms (Adarsh *et al*.,2006).

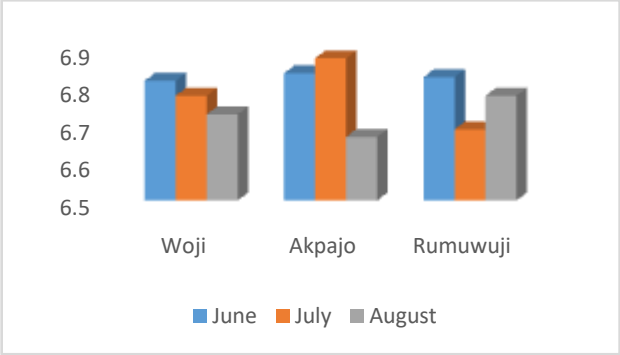

Figure 6: pH of Water Samples from Elelenwo River in the Sampled Months

The values of redox potential of the surface water samples from the Elelenwo River in the different stations were167 – 180 in Woji, 169 – 181 in Akpajo and 165 – 179 in Rumuwuji. The mean in values in the months were 167±1.62, 175±1.29 and 180±0.82 in June, July and August respectively.

Redox (reduction-oxidation reaction), involve the movement of electrons from a reducing agent to an oxidizing agent. Redox reactions in any medium is controlled by the activity of free electrons in that medium. This is normally expressed in terms of the redox potential (Sposito, 1984).

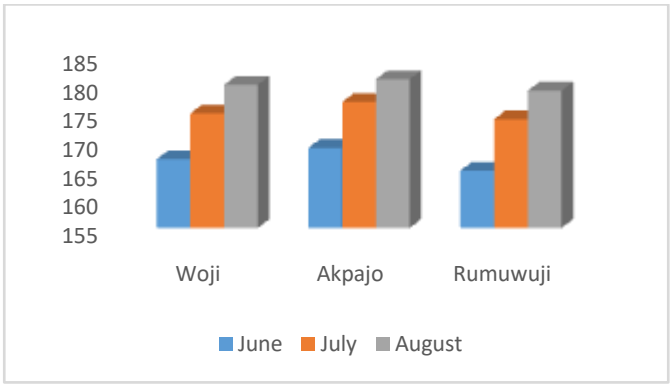

Figure 7: Redox Potential of Water Samples from Elelenwo River in the Sampled Months

The concentration values of salinity in the water samples from Elelenwo River showed that in Woji, the variation ranged from 6.77 – 10.20 mg/L, in Akpajo, the values were within the range of 6.73 – 10.10 and those of Rumuwuji ranged from 6.80 – 10.30. The mean monthly values were 10.2±0.08 in June, 6.77±0.14 in July and 8.22±0.03 in August. The salinity values observed were low when compared to the nature of the environment sampled in the present work, which was a brackish water. All the observed values were lower than 5% which were lower than the allowable limit by WHO, USEPA, SON and FAO for drinking and irrigation of farmlands and feeding of livestocks.

Salinity of a solution, river or any medium is defined by the quantity of salt dissolved in it. Salinity impacts on the density of water and also lead to water stratification().Elevated levels of salinity in water has the capacity to cause corrosion of machinery and infrastructures like bridges, because there is high presence of charge carriers which transfer electrons from one ion to the other. It also affects the health and general wellness of natural aquatic vegetation and then death of plants and animals in severe cases with the water ecologies. This has very serious detrimental effect on the occurrence and biodiversity of plants and animals with the dominance of salt resistant species present, thereby naturally changing the ecological unit and structure().

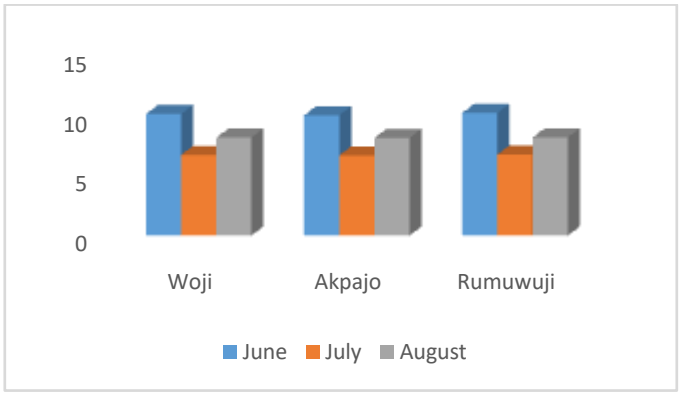

Figure 8: Salinity (mg/L) of Water Samples from Elelenwo River in the Sampled Months

The values observed for chlorides in the stations showed concentration range of 6694 – 7440 mg/L in Woji, 6690 – 7445 mg/L in Akpajo and 6698 – 7435 mg/L in Rumuwuji. The observed monthly mean values were 7440±4.08mg/L in June, 7192±4.73mg/L in July and 6694±3.27mg/L in August.

Chloride concentration in water indicates pollution resulting from sewage. High values of chloride in water causes purgative effects and injurious to sensitive food crops. The results of chlorides were higher than the 250 mg/L required by WHO. The very high level of chloride in the present work may be from storm water runoff to the river and industrial activities around the area. Sources of chloride in water arise mostly from re-suspension of chloride contaminated sediments, sewage and industrial discharges. One major effect of chloride in water is the improvement of the electrical conductivity of water and corrosion of metals on contact with the water. Metals in the presence of chlorides react to give soluble salts, thereby increasing the concentration of metals in water. Both galvanic and pitting corrosion are enhanced by the presence of chlorides. (Gregory, 2013).

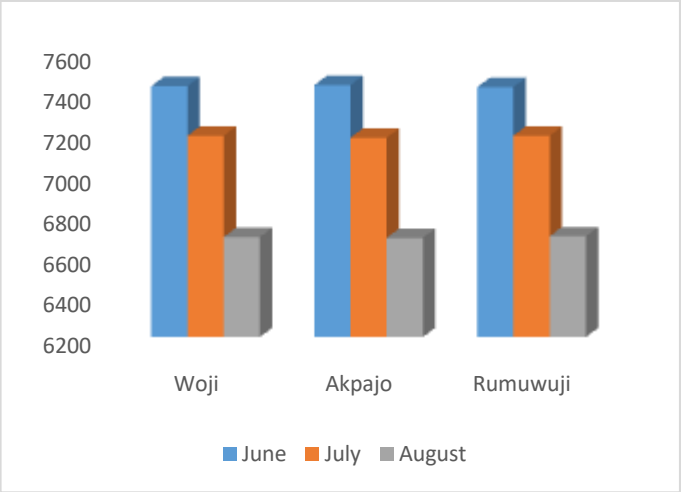

Figure 9: Chloride (mg/L) content of Water Samples from Elelenwo River in the Sampled Months

Table 2: Mean Values of Chemical Parameters in Elelenwo River within the Sampled Months

Parameters	Months		
	June	July	August
pH	6.83±0.58	6.78±0.08	6.73±0.05
Redox Potential	167±1.62	175±1.29	180±0.82
Salinity ((mg/L)	10.2±0.08	6.77±0.14	8.22±0.03
Chloride (mg/L)	7440±4.08	7192±4.73	6694±3.27

Nutrient Parameters

The values observed for nitrates in the stations showed concentration range of 1.13 - 1.25 mg/L in Woji, 1.69 - 2.01 mg/L in Akpajo and 1.33 - 160 mg/L in Rumuwuji. The observed monthly mean values were 1.406±0.229 mg/L in June, 1.617±0.315 mg/L in July and 1.467±0.252 mg/L in August. The observed values of nitrates in the surface water of the Elelenwo River were lower than the WHO values for drinking water.

The presence of nitrates in water is a consequence of redox reactions which involves ammoniacal nitrogen and nitrites and also from the mineralization of the river living organisms. Nitrogen based fertilizers washed in the river through runoffs and other forms of natural processes such as decay of plant parts (Nas and Berktay, 2006; USEPA, 2012). Effects of increased nitrates in water are, reduction in the amount of oxygen in water, eutrophication andblue baby syndrome disease in children (a result of the reaction of nitrite and iron with red blood cell that leads to met hemoglobin which deplete oxygen level). Generally, the level of nitrates observed in the present study in Elelenwo River waters do not pose risk of nitrate pollution.

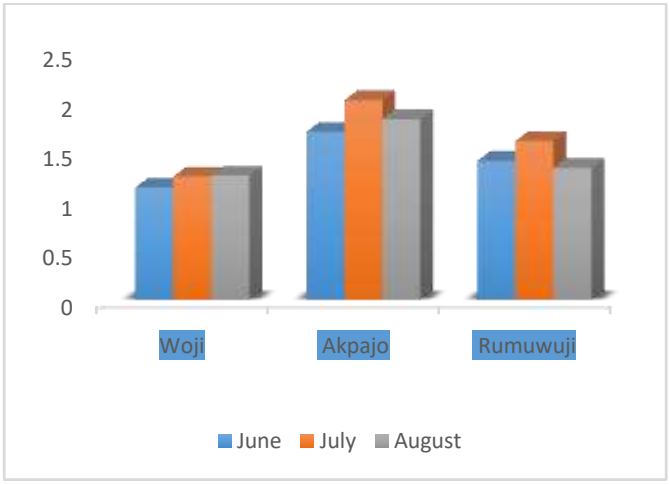

Figure 10: Nitrates (mg/L) content of Water Samples from Elelenwo River in the Sampled Months

The values observed for sulphates in the stations showed concentration range of 732 -757 mg/L in Woji, 714 - 730 mg/L in Akpajo and 771 - 801 mg/L in Rumuwuji. The observed monthly mean values were 747.333±24.253 mg/L in June, 757.000±33.146 mg/L in July and 749.00±25.469 mg/L in August. The concentrations of sulphates in the surface water of the Elelkenwo River is higher than the WHO and FAO value of 200 – 500 mg/L limit in domestic water.

Sulphate arises naturally in water due to leaching from gypsum containing rocks and other minerals of sulphur origin. Wastes from industrial discharges as well as domestic sewage escalates the concentration of sulphate in water. High level of sulphates in irrigation water has the propensity to reduce the intake or availability of phosphorus to plants().

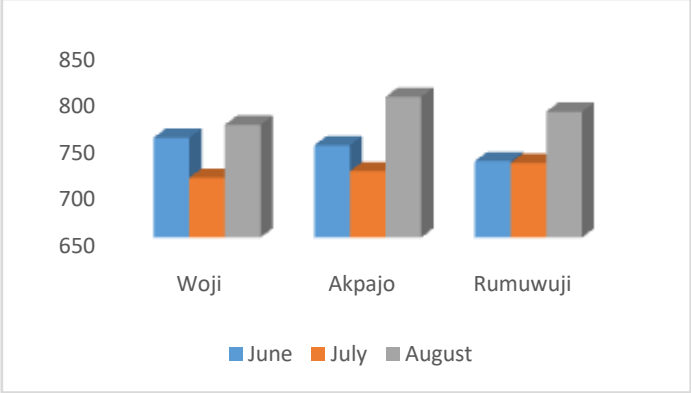

Figure 11: Sulphates (mg/L) content of Water Samples from Elelenwo River in the Sampled Months

The values observed for phosphates in the stations showed concentration range of 0.683 - 0.788mg/L in Woji, 0.098 – 0.114 mg/L in Akpajo and 0.598 - 0.714 mg/L in Rumuwuji. The observed monthly mean values were0.520±0.302mg/L in June, 0.499±0.282 mg/L in July and 0.481±0.265 mg/L in August. The results of phosphates in the present work were below the permissible limit by WHO and FAO for drinking and irrigation and purpose.

Phosphate can either be in organic or inorganic form. It is present as free ion in water systems and as salt in land or soilenvirons (Turner, 2012). Phosphates bound fertilizers applied in agricultural farms is one of the major sources of phosphates in the environment. When they are applied on farms, rain water carries them to water bodies through runoffs. High concentration of phosphate in domestic water can cause muscle harm, effect breathing and kidney failure (Nyamangara *et al.*, 2013). Increased phosphate content in water bodies leads to eutrophication and reduction in the amount of dissolved oxygen in water (Davies, 2003).

Figure 12: Phosphates (mg/L) content of Water Samples from Elelenwo River in the Sampled Months

Table 3: Mean Values of Nutrient Parameters in Elelenwo River within the Sampled Months

Parameters	Months		
	June	July	August
Nitrates	1.406±0.229	1.617±0.315	1.467±0.252
Sulphates	747.333±24.253	757.000±33.146	749.00±25.469
Phosphates	0.520±0.302	0.499±0.282	0.481±0.265

IV. CONCLUSION

The values of the physicochemical parameters of surface water from the Elelenwo River showed that conductivity, turbidity, chlorides, and sulphates were higher than the recommended limit for domestic water by WHO, while other parameters such as TSS, TDS, temperature, pH, redox potential, salinity, nitrates and phosphates were within the acceptable limits. Due to the fact that some of the parameters fall short of the requirement for human use, the river therefore, need effective supervisory steps to be taken in order to meet up the required fitness for both human, industrial and aquatic processes. Furthermore, public awareness campaign should be put in place to enlighten the people within the environment on the health implication of direct discharge of waste into the river.

REFERENCES

[1] American Public Health Association (APHA). (1995). Standard methods for the examination of water and waste water, Edn 19th, Washington, DC.

[2] Arain, M.B., Kazi,T.G., Jamali,M.K.,Afridi, H.I.,Baig, J.A., Jalbani, N. and Shah, A.Q. (2008). Evaluation of physicochemical parameters of manchar lake water and their comparison with other global published values. *PakistanJournal* of *Analytical and Environmental Chemistry*, 9: 101-109.

[3] Ashu, A. and Parveen, T. (2010). Water Quality Assesment of Three Tributaries of Beas Drainage System in Himachal Pradesh in Upper Reaches of Himalayan Region. *Biological Forum-An International Journal*, 2(1): 63-66 (2010)

[4] Dirican, S. (2015). Assessment of Water Quality Using Physico-chemical Parameters of Çamlıgöze Dam Lake in Sivas, Turkey. *Ecologia*, 5 (1): 1-7.

[5] Edori, O. S. and Nna, P. J. (2018). Determination of physicochemical parameters of effluents at discharge points into the New Calabar River along Rumuolumeni axis, Niger Delta, Nigeria. Journal of Environmental and Analytical Toxicology, 8(3), DOI: 10.4172/2161-0525.1000585.

[6] Edori, O. S., Kieri, B. S. I. and Festus, C. (2019). Physicochemical Characteristics of Surface Water and Sediment of Silver River, Southern Ijaw, Bayelsa State, Niger Delta, Nigeria. *American Journal of Environmental Science and Engineering*, 3(2): 39-46.

[7] Lee, N., Yee, T. L. and Grinang, J. (2012). Physico-chemical Characteristics in the Filling Phase of Bakun Hydroelectric Reservoir, Sarawak, Malaysia. International Journal of Applied Science and Technology 2: 92-101.

[8] Manohar, S. (2018). Physicochemical Parameters and Planktonic Species as Indicators to Assess Water Quality of River Basin and Winam (Nyanza) Gulf of Lake Victoria Catchment, Kisumu County, Kenya (East Africa). *Journal of Environmental and Analytical Toxicology*, 8:2, DOI: 10.4172/2161-0525.1000560

[9] Masood A. and Anwar, A. (2002). Water quality in and around industrialized city of Delhi East and Sahibabad, *IndianJournalofEnvironmentalProtection*, 22(8): 900-904.

[10] Muthukumar, A.,Idayachandiran, G.,Kumaresan, S., Kumar, T.A. andBalasubramanian, T. (2013). Petroleum hydrocarbons (PHC) in sediments of three different ecosystems from Southeast Coast of India. *International Journal of Pharmacy and Biology Archives*, 4: 543–549

[11] Ndamitso. M. M., Idris, S., Likita, M. B., Jimoh, O., Tijani, A. I., Ajai, A. A. and Bala, M. (2013). Physicochemical and Escherichia coli assessment of selected sachet water produced in some areas of Minna, Niger State, Nigeria. *International Journal of Water Resources and Environmental Engineering*, 5(3): 134-140

[12] Quevenco, R. (2011). Sustainable Growth of Coastal Waters: A profile of the history and levels of coastal pollution in the Caribbean emerges. *IAEA Bulletin*, 53(1): 32–37

[13] Raji, M. I. O., Ibrahim, Y. K. E., Tytler, B. A. and Ehinmidu, J. O. (2015). Physicochemical Characteristics of Water Samples Collected from River Sokoto, Northwestern Nigeria. *AtmosphericandClimateSciences*, 5 (3), 194.

[14] Sawyer, C. N., McCarthy, P. L. andParkin, G. F. (1994) Chemistry for Environmental Engineering and Science. 4th edn. McGraw Hill International Edition, New York, pp: 365-577.

[15] Sharma, V. andWalia, Y. K. (2014). Analysis of water quality using physicochemical parameters of GovindSagar Lake H.P. (India). *AsianJournalofAdvancedBasicSciences*, 2(3): 83-91.

[16] Sharma, V.,Walia, Y. K. and Kumar, A. (2015). Assessment of Physicochemical Parameters for Analysing Water: A Review. *JournalofBiologyandChemistryChronicles*, 2(1): 25-33.

[17] Sposito, G. (1984). The surface chemistry of soils, Oxford University Press. 234 p

[18] Verma, S. R., Sharma, P., Tyagi, A., Rani, S. and Gupta, A. K. (1984). Pollution and saprobic status of eastern Kalinadi. *Limnologia* 15: 69-133.

[19] WHO (2011). Guidelines for Drinking Water Quality. 4th Edition, WHO Press, Switzerland