Assessment of Physico-Chemical Characteristics of River Niger at Ajaokuta, Kogi State, Nigeria

Peter Oyelade Ogungbile[1]
Adefemi Olatayo Ajibare[2*]
Timothy Oyebamiji Ogunbode[3]
John Adebayo Akande[3]
Chioma Bella Aliku[4]
Mynepalli Kameswara Chandra Sridhar[5]

Abstract

Water from the River Niger in Ajaokuta, Kogi State, Nigeria, was tested for physico-chemical characteristics. Temperature, dissolved oxygen (DO), electrical conductivity (EC), total hardness, total alkalinity, magnesium (Mg), calcium (Ca) and chloride were the variables studied (Cl). During the rainy and dry seasons, water samples were taken in triplicate from six separate locations along the river and were subjected to physico-chemical analyses using APHA standardized procedures. The results were compared to World Health Organization (WHO) and Nigerian Standards for Drinking Quality Water (NSDQW). Consequently, the majority of the parameters examined were below the WHO's recommended safe drinking water threshold. However, the pH and surface water temperature were above WHO guidelines. Comparison of data obtained between rainy and dry seasons was made using t-statistics at $P \leq 0.05$ and this revealed significant seasonal variation in water temperature (28.80^{o}C and 29.40^{o}C), DO (6.43mg/l and 7.18mg/l), Ca (5.21mg/l and 4.16mg/l) and Cl (5.20mg/l and 3.50mg/l). Therefore, in order to protect the communities living along the water body, it is recommended that regular water quality testing be made mandatory.

Keywords: Pollution, Seasonal Variation, Steel Mill, Water Chemistry, Water quality.

[1]Department of Environmental Management and Toxicology, Lead City University of, Ibadan, [2]Department of Fisheries and Aquaculture Technology Olusegun Agagu, University of Science and Technology Okitipupa, Nigeria, [3]Environmental Management and Crop Production, College of Agriculture, Engineering and Science Bowen University Iwo, Nigeria, [4]Centre for Environmental Management and Control, University of Nigeria, Enugu, [5]Department of Environmental Health Sciences, Faculty of Public Health, University of Ibadan, Nigeria.

*Corresponding Author's e-mail: mrajifem@yahoo.com

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Introduction

All living organisms require water to survive. It is an essential component in aquaculture and other forms of agriculture, in addition to its utility in homes and industries. However, due to natural and anthropogenic activity, water quality has deteriorated globally over time (Vadde et al., 2018). Rivers that flow through cities provide recreational resources for fishing, boating, and sport fishing, as long as the water quality is maintained at an ideal level (Kakoyannis and Stankey, 2002). Waters and associated resources are abundant; renewable; and their continued utility is dependent on sustainable management of delicate ecosystems, as human activities have the potential to degrade water quality (Vadde et al., 2018).

There are around 24 significant rivers in Nigeria that have the ability to irrigate the country's large land area. They have also been used for a variety of other things. The Niger and Benue rivers are the two main rivers. The River Niger is Africa's third biggest river, measuring 1174 kilometers in length. River Benue has a length of 769.5 kilometers, while River Yewa has a length of 120.7 kilometers (Ben-Coker, 2012). There are other streams and tributaries in addition to these rivers. The majority of these rivers are utilized for drinking, bathing, washing, fishing, agriculture, and navigation by rural residents. The same rivers are used for industrial purposes as well as providing drinking water. Some companies, unfortunately, release effluents and untreated liquid pollutants into the rivers. Many streams that pass through cities are heavily polluted and then link to major rivers.

Rivers are utilized to dispose of garbage, human excrement, and abattoir waste in many parts of Nigeria. This means that streams and rivers running through regions with a lot of human activity, such as farms, cities, and industrial sites, are prone to contamination. Wastes at large concentrations in water bodies may have negative effects on the substratum's physico-chemical properties. When inappropriate substances are dumped into a river, the composition or condition of the water changes, rendering it unsuitable for home, agricultural, and industrial usage (Kumar et al., 2005). Water is a universal solvent that may contain dissolved materials in its natural state and is home to aquatic creatures. The composition of wastes in water varies greatly and might include both inorganic and organic materials. Pollution of the aquatic environment is defined as the introduction of substances, heavy metals, or energy into the environment by man, either directly or indirectly, which have negative consequences such as harm to living resources, hazards to human health, impediments to aquatic activities, and degradation of water quality, according to UNEP/WHO (1996). River pollution occurs when natural water is contaminated and polluted by a range of pollutants introduced into the stream, resulting in a decrease in water quality.

The chemical, physical, biological, and radiological characteristics of water are all measured (Diersong, 2009). Water quality parameters are characteristics that aid in determining the quality of water. They were categorized into three categories: biological parameters, chemical parameters, and physical parameters (Ben-Coker, 2012). Temperature, pH, turbidity, total suspended solids (TSS), electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), phosphates, sulphates, chemical oxygen demand (COD), biochemical oxygen demand (BOD) and other contaminants are among the physico-chemical parameters. Water is considered safe if these criteria fall within a specified range that is both safe for people to consume and tolerable to aquatic species (Ajibare, 2014 and Ajibare et al., 2019).

The Ajaokuta Steel Mill was established in 1975 as part of a policy initiative by the Federal Government of Nigeria to industrialize local communities. Among other things, the program aimed to employ hundreds of individuals both within and beyond the community, including international expats, so boosting the local and national economies. The effort has had an influence in one way or another, and this study aimed to assess the physico-chemical characteristics of nearby River Niger waters in the Geregu area, which would continue to service the Ajaokuta township.

Materials and Methods

Study Area

The study area is along River Niger adjacent to the Ajaokuta Steel Mill. The Ajaokuta Steel Rolling Mills Company is located at the Latitude 7° 30′ 26.52″ and longitude 6° 41′ 19.52″. The company has an area of about 800 hectares, located on the West bank of River Niger in Okene area of Kogi State. It is about 538-550km away from the mouth of the River. The catchment area of the river upstream of the plant site is 1077 x $10^3 km^2$. On the right bank exists the Geregu village with about 200 houses and a population of about 1000. Occasionally, one finds some floating population from nearby areas. The people use the river for bathing, washing clothes and for navigation purposes. Once in every five days is a market day when the river is extensively used. It is also a day that people bring produce for sale. There are at least eleven (11) points before the water intake where people use the water from dawn to dusk. On the left bank lies the village of Eroku with much lower population.

Water Sample Collection

Samples were collected periodically at 9a.m and 3p.m from the six (6) locations shown in Table 1. Samples collections from locations 1 and 3 are from the intake area, sample 2 is downstream and sample locations 4 and 5 are upstream. Sampling location 6 is from River Ero and sample location 6 indicates the upstream of River Niger at the confluence of River Ero. Samples were collected for rainy season (May to October) for 15 days and dry season (November to April) for 15 days. Samples were also collected vertically from surface to the bottom of the intake point to find out possible benthic decomposition at the intake. Water samples were taken from different depths of 7m, 5m and 3m deep respectively at the intake point with improvised water sampler (Potasznik and Szymezyk, 2015). On one day of the 15 days during the rainy season, samples of water were collected at locations 1 and 4 at hourly intervals for an on-the-spot determination of pH value, temperature and dissolved oxygen.

Table 1: Geographical positioning Survey of Water Sampling Locations

Sampling location	Longitude	Latitude
1	6.69977	7.47457
2	6.6965	7.44743
3	6.70039	7.48455
4	6.69711	7.54451
5	6.69955	7.56196
6	6.6942	7.57022

Physico-chemical analyses of water

The temperature, pH and dissolved oxygen was determined in-situ with mercury in glass thermometer, portable pH meter and Horiba water Checker (model U-10) respectively while samples were collected with 1L sampling bottles and transported in ice chest to the laboratory for the determination of electrical conductivity (EC), Total alkalinity, Total hardness (TH), Calcium (Ca), Magnesium (Mg), and Chloride (Cl) according to American Public Health Association (2000). All of the water samples collected from the six (6) locations were subjected to physico-chemical analyses. AnalaR (BDH, England) reagents were utilized for the various analyses, as well as distilled water for solution preparation.

Results and Discussion

The results of physico-chemical characteristics of river Niger at Ajaokuta, Kogi State, Nigeria collected during dry and rainy seasons are presented in Table 2. The results were within the World Health Organization's (2007) permissible limits for drinking water (except for temperature). However, the results of pH, Total Alkalinity, Total Hardness, Calcium Magnesium, and Chloride in both the dry and rainy seasons were below the standards stipulated for drinking water by the Nigeria Standard for Drinking Water Quality (NSDWQ 2007). The average temperature in the dry season was 29.4°C and was significantly different from 28.8°C recorded in the rainy season at $P<0.05$.

The mean pH value recorded for the dry and rainy seasons was 7.2. The results revealed no statistical difference ($P>0.05$) between the mean values of EC in the dry (0.058s/cm) and rainy (0.054s/cm) seasons. The dry season had a significantly higher dissolved oxygen value of 7.18mg/L than the rainy season, which had 6.43mg/L. The mean alkalinity was 24.8mg/L in the dry season and 24.7mg/L in the rainy season, indicating no significant seasonal variation at $P>0.05$. Statistical analysis revealed no significant differences between the Total hardness recorded in the dry season (16.9mg/L) and in the rainy season (17.40mg/L). This can be attributed to the consistently lower carbonate and bicarbonate concentrations in the water irrespective of season. The mean values of Ca during the dry and rainy seasons were 4.16mg/L and 5.21mg/L respectively. The T-test result revealed significant seasonal variation, which could be attributed to greater deposit and accumulation of limestone and gypsum concentrations during the rainy season (Faizal and Ahmed, 2011). In addition, the mean concentration of Magnesium in the dry season (2.33mg/L) was not significantly different from the concentration recorded in the rainy season (2.52 mg/L). The results also revealed that the average concentration of Cl in the dry season was 3.5mg/L and 5.2mg/L in the rainy season. The increase was found significant at $P <0.05$ and may result from agricultural, or irrigation discharges, urban run-off, or from sewage and industrial effluents (Ajibare, 2014).

Table 2: Physico-Chemical Characteristics of Water Samples In The Dry and Rainy Seasons

Characteristics	Dry Season			Rainy Season			Standards	
	Minimum	Maximum	**Mean**	Minimum	Maximum	**Mean**	WHO 2007	NSDW, 2007
Water Temperature, °C	25	34.5	**29.40[b]**	28	32	**28.80[a]**	25	Ambient
pH Value	7.8	8.3	**7.20[a]**	7	8.3	**7.20[a]**	6.5-8.5	6.5-9.2
Electrical conductivity, µs/cm	0.052	0.085	**0.058[a]**	0.04	0.08	**0.054[a]**	1000	-
Dissolved oxygen, mg/1	5.8	8.4	**7.18[b]**	5	7.9	**6.43[a]**	7	-
Total alkalinity (as $CaCO_3$) mg/1	23	30	**24.80[a]**	18.5	45	**24.70[a]**	400	-
Total hardness (as $CaCO_3$) mg/l	14	20	**16.90[a]**	12	30	**17.40[a]**	150	150
Calcium (Ca), mg/l	3.2	8	**4.16[a]**	2.4	8	**5.21[b]**	75	75
Magnesium (Mg), mg/l	1.9	3.9	**2.33[a]**	1.5	7.3	**2.52[a]**	50	20
Chloride (Cl), mg/l	3	5	**3.50[a]**	5	7	**5.20[b]**	250	250

The results of analysis of water samples collected from different depths at the intake point is shown in Table 3. The water temperatures were both 29°C at the depth of 7m and 5m respectively, while the temperature was 29.3°C at 3m depth. The water gets colder with depth and warmer on the surface. The higher temperature at 3m depth may be due to higher air temperature particularly in the tropics by sunlight. The greatest source of heat transfer to water temperature is from sunlight (Faizal and Ahmed, 2011). The pH values at the three depths of 7m, 5m, and 3m were 7.6, 7.5 and 7.3 respectively. The pH changes at different depth may be due to changes in photosynthesis and other reactions. According to Ajibare et al. (2019), respiration and decomposition processes lower pH. The pH value of 7.3 at 3m depth might be as a result of photosynthesis of algae and plants which makes the water acidic and therefore lowering the pH. This corroborates the reports of Ajibare (2014) and

Faizal and Ahmed (2011) that elevated temperature and pH can affect water toxicity, which can consequently negatively affect the resident fishes and ultimate human consumers along the food chain.

The results of electrical conductivity at the three different depth were 0.069 µs/cm, 0.058 µs/cm and 0.055 µs/cm respectively. The highest electrical conductivity was 0.069µs/cm at depth of 7m and lowest 0.055µs/cm at the depth of 3m. Conductivity in water is subject to changes by the dissolved solids (Faizal and Ahmed, 2011). The result shows that there were more dissolved substances with depth of the river. The values of dissolved oxygen at the depths of 7m and 5m were both 6.4mg/l while at 3m depth it was 6.7mg/l. Dissolved oxygen concentrations are often affected by the diffusion and aeration, photosynthesis respiration and decomposition (Ajibare, 2014). The high concentration of dissolved oxygen at 3m of depth might be due to higher temperature of 29.3^{o}C at that depth, similarly the aquatic plants at the surface when they undergo photosynthesis release oxygen, which diffuses into the water with the resultant effect of increasing dissolved oxygen.

Total Alkalinity of the water samples at depths of 7m and 5m was 24mg/l while the mean concentration of total alkalinity at the depth of 3m was 23.5mg/L. The high concentrations of total alkalinity at depth of 7m and 5m might be due to the presence of limestone at the bottom of the river (Ajibare, 2014; Potasznik and Szymezyk, 2015). Furthermore, the higher the pH value the higher the total alkalinity (Faizal and Ahmed, 2011). The pH values at 7m and 5m were both 7.6 and 7.5 respectively and were higher than the pH value of 7.3 at 3m depth. The concentrations of total hardness of water samples at the three different depths of the river were the same value 16mg/l (Table 4). The concentrations of Calcium at depth of 5m and 3m were the same value (4.0mg/l). The highest concentration of calcium 4.8mg/l was recorded at the depth of 7m. The cause of the high concentration of calcium at the depth of 7m might be to the abundance of calcium in water due to its natural occurrence in the earth's crust (Potasznik and Szymezyk, 2015).

The mean concentration of magnesium in the water samples from the 7m depth was 2.9mg/l while the concentrations at 5m and 3m depth were both 2.4mg/l. This result is in agreement with the findings of Potasznik and Szymezyk (2015) who reported that concentrations Mg increase with depth in rivers. Chloride concentrations at the three depths of water sampling locations from the river were 5.0gm/l. The presence of Cl in municipal wastes and sewage effluent eventually increases Cl content in surface water. The same concentrations of Cl at all the three depths of water might be caused by the absence of disposal of municipal wastes and sewage effluent into the body of the river.

Table 3: Results of Analysis of Water Samples from Different Depths at the intake point

Parameter	DEPTHS		
	7m deep	5m deep	3m deep
Water Temperature, ^oC	29.0	29.0	29.3
Air temperature	25.5	25.5	25.5
pH Value	7.6	7.5	7.3
Electrical Conductivity, μmhos x 10^3	0.069	0.058	0.055
Dissolved Oxygen, mg/1	6.4	6.4	6.7
Total alkalinity (as $CaCo_3$) mg/l	24	24	23.5
Total hardness (as $CaCo_3$) mg/l	16	16	16
Calcium (Ca), mg/1	4.8	4	4
Magnesium (Mg), mg/l	2.9	2.4	2.4
Chloride (Cl), mg/l	5	5	5

The result of analysis of water samples at locations 1 and 4 at hourly interval during the rainy period is presented in Table 4. Water temperature ranges between 28^{o}C and 29.1^{o}C for both locations 1 and 4. The highest temperature values were recorded 29.1^{o}C at 5pm at location 1 and 29^{o}C at 10a.m location 4. The WHO (1999) for water temperature for drinking water is 25^{o}C. The values of water temperature were high probably due to tropical climatic conditions (Ajibare, 2014). The pH values ranges between 7.1 and 7.3 for both locations 1 and 4 (Table 4). The maximum pH values were recorded 10a.m at location 1 and 11pm locations 4. The WHO (1999) the results of Dissolved Oxygen of water samples at locations 1 and 4 revealed highest concentrations of 7.5mg/l at location 1 and 7.3mg/l at sampling location 4. The maximum values of DO concentration were observed at 12pm at both locations 1 and 4 (Table 4).

Table 4: Results of Analysis of Water Samples at Points 1 and 4 at Hourly Intervals During Rainy Period

TIME	SAMPLES AT LOCATION 1			SAMPLES AT LOCATION 4		
	Temperature °C	pH Value	Dissolved Oxygen, mg/1	Temperature °C	pH Value	Dissolved Oxygen, mg/1
10:00 AM	29	7.3	6.2	29	7.1	6.3
11:00 AM	29	7.3	6.3	29	7.2	6.3
12 noon	29	7.2	6.3	29	7.2	6.3
1:00 PM	29	7.2	6.3	29	7.2	6.3
2:00 PM	29	7.2	6.5	29	7.2	6.4
3:00 PM	29	7.1	6.3	29	7.1	6.3
4:00 PM	29	7.1	6.3	29	7.1	6.4
5:00 PM	29.1	7.2	6.4	29	7.2	6.4
6:00 PM	29	7.2	6.4	29	7.2	6.4
7:00 PM	28.9	7.2	6.7	28.9	7.2	6.4
8:00 PM	28.5	7.2	6.2	28.5	7.2	6.4
9:00 PM	28.5	7.2	7	28.5	7.2	6.5
10:00 PM	28.5	7.2	6.9	28.5	7.1	7
11:00 PM	28.3	7.2	7	28.3	7.3	6.7
12:00 PM	28.1	7.2	7.5	28.1	7.1	7.3
1:00 AM	28	7.2	7	28	7.1	6.6
2:00 AM	28	7.2	6.7	28	7.2	6.8
3:00 AM	28	7.2	6.9	28	7.2	6.7
4:00 AM	28	7.2	6.6	28	7.2	6.6
5:00 AM	28	7.2	6.6	28	7.2	6.6
6:00 AM	28	7.2	6.7	28	7.2	6.7
7:00 AM	28	7.1	6.4	28	7.1	6.4
8:00 AM	28.2	7.2	6.4	28.2	7.2	6.4
9:00 AM	28.5	7.1	6.3	28.5	7.1	6.4

Interrelationship of Physico-Chemical Parameters of the Water

Interrelationship (two-tailed correlation coefficient (r) values) of the physico-chemical parameters of river Niger at Ajaokuta, Kogi State, Nigeria in rainy season was presented in Table 5. Water temperature was positively correlated with Magnesium at $P<0.05$. Water temperature was also strongly correlated with pH, alkalinity, Total hardness and Calcium at $P<0.01$. pH was positively correlated with magnesium at $P<0.05$ and positively correlated with alkalinity, total hardness, calcium and chloride at $P<0.01$. Electrical conductivity however, was negatively correlated with magnesium at $P<0.05$ and negatively correlated calcium at $P<0.01$. Alkalinity was positively correlated with total hardness, calcium and magnesium at $P<0.01$ and calcium was positively correlated with calcium and magnesium at $P<0.01$.

Meanwhile, interrelationship (two-tailed correlation coefficient (r) values) of the physico-chemical parameters of the water in the dry season was presented in Table 6. The table revealed that when water temperature rises, pH, Calcium, Magnesium concentrations decline at $P<0.05$. pH was positively correlated with total hardness at $P<0.01$. Also, electrical conductivity was positively correlated with alkalinity and total hardness at $P<0.01$ while dissolved oxygen was negatively correlated with Chloride at $P<0.01$. The alkalinity was positively correlated with total hardness, calcium and magnesium at $P<0.01$. The total hardness was also positively correlated with calcium and magnesium (at $P<0.05$). The table further revealed that calcium was positively correlated with magnesium and chloride at $P<0.01$. The positive correlation implied that as one variable increased the other variable also increased while negative correlation shows that one variable increased and the other variable decreased (Ajibare et al., 2019).

Table 5: Two-tailed correlation coefficient between the physico-chemical parameters of water in rainy season

Parameter	Temperature °C	pH value	Electrical Conductivity µmhos x 103	Dissolved oxygen, mg/l	Alkalinity (as CaCo3), mg/l	Total hardness (as CaCo3), mg/l	Calcium (ca), mg/l	Magnesium (Mg), mg/l	Chloride (CL), mg/l
Temperature °C	1								
pH value	.589**	1							
Electrical Conductivity µmhos x 103	0.137	0.113	1						
Dissolved oxygen, mg/l	0.009	0.095	-0.103	1					
Alkalinity (as CaCo3), mg/l	.541**	.711**	-0.075	0.016	1				
Total hardness (as CaCo3), mg/l	.441**	.622**	-0.121	0.061	.845**	1			
Calcium (ca), mg/l	.316**	.386**	-.282**	0.002	.661**	.701**	1		
Magnesium (Mg), mg/l	.155*	.190*	-.275*	0.094	.276**	.274**	.349**	1	
Chloride (CL), mg/l	0.083	.316**	-0.055	-0.138	0.137	0.132	-0.031	-0.024	1

**Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at 0.05 level (2-tailed)

Table 6: Two-tailed Correlation coefficient between physic-chemical parameters of water in dry season

Parameter	Temperature °C	pH value	Electrical Conductivity µmhos x 103	Dissolved oxygen, mg/l	Alkalinity (as CaCo3), mg/l	Total hardness (as CaCo3), mg/l	Calcium (ca), mg/l	Magnesium (Mg), mg/l	Chloride (CL), mg/l
Temperature °C	1								
pH value	-.160*	1							
Electrical Conductivity (µmhos x 103)	-0.211	0.103	1						
Dissolved oxygen, mg/l	-0.125	-0.07	0.164	1					
Alkalinity (as CaCo3), mg/l	0.084	-0.028	.459**	0.045	1				
Total hardness (as CaCo3), mg/l	0.08	-.270**	.289**	0.131	.400**	1			
Calcium (ca), mg/l	-.169*	0.07	0.154	-0.041	.279**	.196*	1		
Magnesium (Mg), mg/l	-.181*	0.074	0.18	-0.035	.301**	.189*	.963**	1	
Chloride (CL), mg/l	0.114	-0.005	0.015	-.232**	0.141	-0.073	.202**	.202*	1

**Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at 0.05 level (2-tailed)

Conclusion

The waters of the River Niger, being tropical, have fairly high temperatures (above 28ºC) in the rainy and dry seasons. The pH was also above 7.0. Elevated temperature and pH can affect water toxicity and negatively affect the resident fishes and ultimate human consumers along the food chain. Other physico-chemical parameters analyzed (apart from temperature and pH) were below the WHO recommended values. Nonetheless, periodic monitoring of the water body is recommended to avert further contamination due to increasing population pressure and industrial activities in the area.

References

Ajibare, A.O. (2014). Assessments of Physico-Chemical Parameters of Waters in Ilaje Local Government Area of Ondo State, Nigeria. *International Journal of Fisheries and Aquatic Studies*. 1(5B): 84-92.

Ajibare, A.O., Ayeku, P.O. Akinola, J.O. and Adewale, A.H. (2019). Plankton Composition in Relation to Water Quality in the Coastal Waters of Nigeria. *Asian Journal of Fisheries and Aquatic Research* 5 (2): 1-9

Angela P. and Slavomir S. (2015). Magnesium and Calcium concentrations in the surface water and Bottom deposits of a River-lake System. *Journal of Elementology* 20(3): 677-692.

American Public Health Association (APHA) (2000). Standard Methods of Examination of water and Wastewater 20th Edition American Public Health Association D.C.

Arokoya, S.B. and Ukpere, D.R. (2014). Access to safe water supply and sanitation in lower Orashi Otamiri-Oche River basin. Rivers State, Nigeria. ARPN *Journal of Science and Technology*, 4: 1-3.

Ben-Coker, M.O. (2012). Effects of Slaughter house discharge on Water Quality of Ikpoba River, *Nigeria Bioscience Technology*, 52(1): 1-4.

Diersong, N. (2009). Water Quality; Frequently Asked Questions. Florida Brooks National marine Sanctuary, Key West. Pp. 1-2.

Kakoyannis, C. and Stankey, G.H. (2002). Assessing and Evaluating Recreational uses of Water Resources: Implications for an integrated Management Framework United States Department of Agriculture USDA. Pacific Northwest Research Station General Technical Report PNW – GTR 536 pp. 1-72.

Kumar, R., Singh, R.D. and K.D. Sharma (2005). Water Resources of India. *Current Science*. 794-811.

Mohammed F.M. and Rafiuddin A. (2011). On the ocean heat budget and ocean thermal energy conversion. *International Journal of Energy Research* 35(13): 1119-1144 https://doi.org/10/1002/er.1885.

NSDWQ (2007). Nigeria Standard for Drinking Water Quality.

UNEP/WHO (1996). Water Quality Monitoring – A practical Guide to Design and Implementation of Freshwater Quality Studies and Monitoring Programme. Edited by Jamie Bartram and Richard Balance Published on behalf of United Nations Environment Programme and World Health Organization. pp. 1-22.

Vadde, K.K., Jianjun, W., Long, C. Tiama, Y., Alan J. and Raju, S. (2018). Assessment of water quality and identification of pollution risk locations in Tiaoxi river (Taihu watershed) China. Water 10. 183.

World Health Organization (WHO) (1999). International Standard for drinking water. 5 pp. 3-6.