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An Assessment of the Chemical Hydrology of Jabi Lake, Abuja, Nigeria

Idowu, R. T.[1], Dankishiya, A. S.[2], Olubanjo, O. A.[3]

[1, 2, 3]Department of Biological Sciences, University of Abuja, Abuja, FCT, Nigeria

Note: *Idowu, Rachel Toyosi and Dankishiya Ahmed Salihu are Professors of Hydrobiology and Fisheries, Department of Biological Sciences, University of Abuja and Olubanjo Oluseyi Abidemi is a Ph.D Student in Environment Biology, Department of Biological Sciences, University of Abuja.*

Abstract: ***The variations in selected physico-chemical factors were investigated for two years to assess the chemical hydrology of Lake Jabi in Abuja, Nigeria. Five stations were chosen on the reservoir to reflect the effect of human activities, lacustrine and lotic habitats. dissolved oxygen, nitrate, biochemical oxygen demand, ammonia, iron, lead, copper, and zinc were analyzed monthly between January 2017 and December 2018 using standard methods and procedures. Hydrological parameters such as water current and water depth were also analyzed. The ranges of these factors were found to be comparable to those reported for other African reservoirs except for the heavy metals and nitrate. Nitrate levels were found in higher concentration above freshwater limits. Runoff of fertilizers from nearby farm lands and increasing anthropogenic activities around the watershed into the lake were found to have caused cultural eutrophication in the lake. The study concludes that Jabi Lake has moderate water quality but increasing faced with the threat of cultural eutrophication. This threat to the water quality should be arrested quickly through denitrification and nutrient control to halt the degradation of the water.***

Keywords: Chemical Hydrology, Heavy Metals, Jabi Lake, Cultural Eutrophication, Water Quality

1. Introduction

Water is vital to the existence of all living organisms, but this valued resource is increasingly being threatened as human populations grow and demand more water of high quality for domestic purposes such as drinking, cooking and agricultural production, industrial activities and other economic activities (Carr and Neary, 2006, Ojo, 2007). Water is the most basic natural resource needed for the survival of all living organisms in this biosphere. Water is one of the most important components of life and life without it is impossible. It plays an essential role in the maintenance of human health and aquatic ecosystem.

Arising from its multifarious uses, water should be accessible, affordable and available in pure form (Obi *et al.*, 2004). But in view of its occurrence and distribution pattern, water is not easily available to man in the desirable amount and quality. This is a problem experienced in most cities and towns in the developing nations not to mention their rural settings (Oluyemi *et al.*, 2010).

The quality of water in any ecosystem provides significant information about the available resources for supporting life in that ecosystem. Declining water quality due to environmental perturbations threatens the stability of the biotic integrity and therefore hinders the ecosystem services and functions of aquatic ecosystems. Owing to the multiple ecosystem services rendered by Jabi Lake to the people of Abuja and its environs, this study is aimed at assessing the chemical hydrology of the Lake to ascertain its status and make recommendations for the knowledge-based management of the lake.

2. Methods

Study Area

Abuja is the capital city of Nigeria. It lies in the central part of Nigeria, in the Federal Capital Territory (FCT; created 1976). Abuja lies at 1,180 feet (360 metres) above sea level and is located on 9° 4' 20.1504" N and 7° 29' 28.6872" E. one of the major lakes that provide ecosystem services to the people of the city of Abuja is Jabi Lake.

Jabi Lake is a water body formed from a man-made earth dam that *was* initially created to provide water to the residents of Abuja. The Lake is located between the Jabi and Kado Districts of Abuja, within the Federal Capital Territory of Nigeria. It is located within Latitude: 9°4'38"N and Longitude: 7°25'18"E. The source of the lake is a natural stream which was dredged (embanked) to serve human activities within the environs such as fishing, subsistence farming, recreation etc. Large volume of water flowed from the stream through many communities and to the present location of Jabi Lake.

The vegetation in the lake is extremely variable depending on prevailing climate condition. There is a delicate balance between available moisture and vegetation cover (Thomas *et al.*, 1991).

The lake is a multidirectional water body with shrubs and shady trees which provides cover for biodiversity along the fringes of the lake. The vegetation comprises of fringing, floating, submerged and emergent plants. Water hyacinths (evasive weeds) as well as the giant grass are also found floating in some parts of the lake. However, the lake is currently surrounded by a big shopping mall and residential houses, and is subjected to recreational activities. It is thus considered as a close basin for different types of drainages in the city of Abuja. The lake is also an important source of fishing activities in the district but subject to high levels of pollution from domestic drainage and raw domestic sewage. The drainage contaminated wastewater into the lake is a great health risk due to the possibility of large number of pathogens and antibiotic products being discharged into the water body daily (Matouke, 2019).

Since the Lake is known to have supported the farming, fishing, domestic and recreational activities of the local communities around it, any deterioration in the quality of water in the lake will have very crucial negative impact in the livelihoods of local communities and also the ecology of the macro- and micro-invertebrates in the lake (Ogoko and Sylvester, 2020).

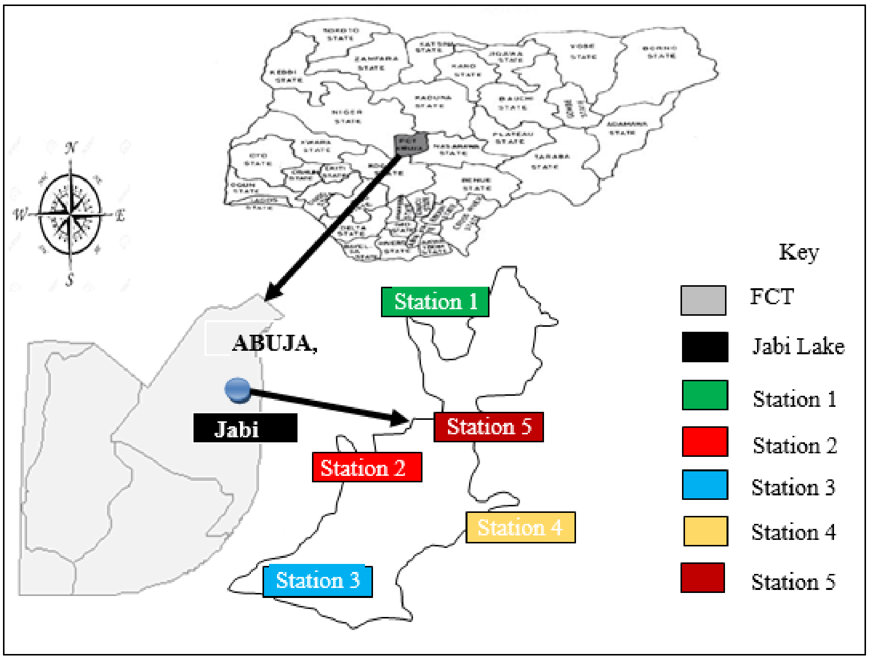

Figure 1: Map of Jabi Lake showing the five sampling stations

3. Methodology

Simple randomized block design was adopted to locate the sampling stations of the study. Five Sampling Stations were selected across the lake. The selection was based on the distinct anthropological activities occurring at each site to provide for a wide coverage of the impacts of the various activities around the lake. Duration of sampling was for 12 months on a monthly basis.

Water sampling

Water samples were collected for analysis from each sampling location in the lake. The collection of water samples was guided by standard procedure (APHA, 2001; Awoyemi *et al.*, 2014). Water samples were collected by gently lowering the container into the lake (Ozoko, 2015). The water samples were collected in clean, securely sealed white plastic containers, labeled with notes on date and site of collection. Water collected in dark 250ml reagent bottles were processed in the field for the determination of Biochemical Oxygen Demand (BOD).

The reagent bottles were dipped into the water body at each location and water is allowed to flow gently into the bottle before corking underneath the water. All samples were then taken to the laboratory for analysis.

Chemical Parameters

Based on the method used by Awoyemi *et al.* (2014), water samples for chemical analysis were preserved using 10 ml $6HNO_3$ and transported to the Biological Science Laboratory, University of Abuja, FCT. Parameters determined were Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Nitrate, Ammonia and some selected heavy metals.

Dissolved Oxygen (DO)

Dissolved Oxygen (mg/l) was measured at each site *in situ* using a handheld Oxygen meter Model YS 157.

Biochemical Oxygen Demand (BOD)

The method employed in determining the BOD was the incubation method. This is according to the method used by Ogoko and Sylvester (2020). First, the dissolved oxygen content is determined before and after incubation. The samples were collected in BOD bottles and incubated for 5 days at 20°C. A blank distilled water is then passed through the same process.

Calculation:

BOD (mg/l) = DO1- DO5

Where,

DO1 = Dissolved Oxygen Concentration diluted sample immediately after preparation (Initial)

DO5 = Dissolved Oxygen Concentration of diluted sample after 5 days.

The result is expressed as mg/l.

Nitrate (NO_3) and Ammonia (NH_3)

APHA (1995) recommended the ultraviolet spectrophotometer (screening) method for the determination of nitrate concentration and this will be used in determining the nitrate concentration in the water samples. The results are usually expressed in mg/L.

Heavy Metal (Iron, Copper, Zinc and Lead)

Water samples for heavy metal analysis were digested using nitric acid digestion method. This was to reduce interference by organic matter and to convert metal associated with particles to a form (usually the free metal) that can be analyzed and obtained. The different samples were analyzed for Iron (Fe), Copper (Cu), Zinc (Zn) and Lead (Pb), using the Atomic Absorption Spectrophotometer (AAS). The analysis was carried out using a method described by Egereonu *et al*. (2012). The results obtained were expressed in mg/l. Analysis was carried out at the Advance Chemistry Laboratory at the Science and Technology Complex, Sheda, Kwali, Abuja.

Hydrological Parameters

Depth

A long graduated metre rule was used to measure the depth of each sampling station by dipping the metre rule into the water and the level was recorded before the rule was recovered. The depth of each sampling station was measured to the nearest meter (m). This was in line with the method used by Idowu *et al.* (2018).

Water Current

Following the procedure by Rim-Rukeh (2013), the water current was measured using a buoyant object (cork). The object was placed at a starting point and the distance moved to a marked end point in relation to time (cm/sec) was noted.

Data Analysis

Bar and Pie Charts were constructed for each of the key parameters to show trends between stations and across months. Analysis of Variance (ANOVA) was used to determine if there was statistical difference in the parameters across the stations at $p < 0.05$ using Statistical Package for Social Sciences (SPSS).

Ostracods abundance diversity were based on Shannon Wiener and Simpson diversity indexes, which are commonly used to characterize species diversity in a community while the Margalef and Menhinick indexes were used to determine species richness The Pielou index accounted for both evenness of the species present. For the relationship between the physico-chemical parameters and ostracods species distribution, Pearson correlation co-efficient and one-way analysis of variance was used. The relationship between physico-chemical parameters and abundance of ostracods families was assessed using Canonical Component Analysis (CCA) to determine the parameter with the most influence on ostracods abundance. Paleontological Statistical Tool (PAST) was used to achieve this.

4. Results

Table 1: Mean ± SE Variation of physicochemical Parameters in all stations sampled in Jabi Lake from January 2017 to - December 2018

Parameter	Station1	Station2	Station3	Station4	Station5	Mean±SE, Range	WHO LIMIT
DO (mg/l)	5.71±0.17	5.72±0.16	5.23±0.16	5.87±0.15	5.68±0.15	5.65±0.16, 5.23-5.87	5.0-9.0Mg/l
BOD (mg/l)	3.01±0.15	3.53±0.12	3.23±0.15	2.92±0.13	3.52±0.14	3.24±0.14, 2.92-3.53	3.0-6.0
Nitrate (mg/l)	39.47±9.68	45.19±11.52	26.89±7.78	45.34±11.2	48.04±13.12	40.99±10.67, 26.90-48.04	5
Ammonia (mg/l)	0.98±0.16	1.19±0.23	19.79±4.78	1.03±0.19	1.57±0.30	4.92±1.13, 0.98-19.79	1000
Iron (mg/l)	1.35±0.32	2.47±0.66	1.20±0.29	1.30±0.25	1.40±0.36	1.57±0.38, 1.28-2.47	0.3
Copper (mg/l)	0.11±0.03	0.14±0.02	0.16±0.03	0.10±0.02	0.14±0.04	0.14±0.03, 0.11-0.16	1.6
Zinc (mg/l)	0.06±0.01	0.06±0.01	0.04±0.01	0.06±0.01	0.06±0.01	0.06±0.01, 0.04-0.07	15
Lead (mg/l)	0.66±0.14	0.82±0.17	0.78±0.14	0.79±0.11	1.08±0.16	0.83±0.15, 0.66-1.08	0.1

Parameter	Station1	Station2	Station3	Station4	Station5	Mean±SE, Range	WHO LIMIT
Water Current (m/sec)	6.61±0.27	5.16±0.20	6.13±0.25	6.51±0.26	5.33±0.215	5.95±0.24, 5.16-6.61	4.5
Depth (m)	2.08±0.08	1.80±0.07	2.11±0.08	2.03±0.09	1.86±0.08	1.98±0.08, 1.81-2.11	3

Dissolved Oxygen (DO) range was below (5.23 - 5.72 mg/L) with a mean of 5.65 mg/L. Station 2 showed the highest concentration (5.72 mg/L), followed by Station 1 (5.71 mg/L) while Station 3 recorded the least at 5.23 mg/L. The mean DO concentration is within the WHO standard ranfe of 5-9 mg/L. Biochemical Oxygen Demand (BOD) ranged between 3.01 – 3.53 mg/L with a mean value of 3.24 mg/L. This mean value is well within the WHO standard range of 3-6 mg/L. However, variations were experienced between the sampled stations with the most BOD value recorded in Station 2 (3.53 mg/L) followed by Station 5 (3.52 mg/L) with the least value recorded at Station 1 (3.01 mg/L). Nitrate concentration had a mean value of 40.99 mg/L which ranged from 26.89 – 48.04 mg/L. Station 5 recorded the highest nitrate concentration (48.04 mg/L) followed by Station 4 (45.34 mg/L) with the least figure of 26.89 mg/L recorded in Station 3. The mean nitrate concentration is way above the WHO threshold of 5 mg/L. Ammonia concentration was ranged between 0.98 and 19.79 mg/L with a mean of 4.92 mg/L. The most concentration was at Station 3 (19.79 mg/L) and the least at Station 1 (0.98 mg/L). The ammonia concentration was within the WHO limit of 1000 mg/L. in terms of heavy metals, Iron had a mean value of 1.57 mg/L which is way above the WHO limit of 0.3 mg/L. Station 2 recorded the most concentration at 2.47 mg/L followed by Station 5 (1.40 mg/L) with Station 3 recording the least concentration (1.20 mg/L). Cupper recorded a mean value of 0.14 mg/L with a range of 0.10 – 0.16 mg/L. The most concentration was at Station 3 (0.16 mg/L) followed by Stations 2 and 5 (0.14 mg/L). The least concentration was recorded at Station 4 (0.10 mg/L). The mean Cupper value was within the WHO standard of 1.6 mg/L. The mean Zinc value was 0.06 mg/L that ranged between 0.04 and 0.06 mg/L. Stations 1,2,4 and 5 recorded the most concentration of 0.06 mg/L with Station 3 recording the least value of 0.04 mg/L. The mean value of Zinc is within the WHO standard of 15 mg/L. Lead concentration ranged between 0.66 and 1.08 mg/L with a mean value of 0.83 mg/L. The most concentration was in Station 5 (1.08 mg/L) with Station 1 recording the least concentration at 0.66 mg/L.

The hydrology of the Lake shows a mean depth of 1.98 m that ranged between 1.80 m in Station 2 to 2.11 m in Station 3. The mean depth is well within the 3 m recommended standard. In terms of water current, a mean value of 5.95 m/sec. The range is from 5.16 m/sec in Station 2, followed by 6.15 m/sec in Station 3 while Station 1 demonstrated the highest water current at 6.61 m/sec. The mean water current value is above the recommended 4.5 m/sec.

Seasonal Mean Variation of Physico-chemical Parameters in Jabi Lake

The seasonal mean values of physico-chemical parameters of water samples collected in Jabi Lake are shown in Table 2. Dissolved Oxygen (DO) values were slightly higher during the harmmattan season (6.46±0.10mg/l) than during the dry season (5.67±0.07mg/l) and wet season (5.18±0.11mg/l) while BOD values were steady during the dry season (3.04±0.09mg/l) and wet season (3.04±0.09mg/l) but slightly increased during the harmattan season (3.92±0.12mg/l). Water Current values were higher (6.97±0.13m/sec) during the wet seasons than the values obtained during the dry season (5.22±0.17m/sec) and harmmattan season (5.19±0.17m/sec). The wet season also recorded higher values of Water Depth (2.33±0.05m) compared to the dry season (1.69±0.04m) and hammattan season (1.78±0.02m) respectively.

The values recorded for Nitrate concentration during the dry season was relatively high (26.17±9.71mg/l) but got decreased during the wet season (23.27±1.54mg/l) and harmattan season (22.37±3.67mg/l) while the values of Ammonia were higher in the harmattan season (7.39±1.39mg/l) compared to the dry season (7.18±2.95mg/l) and the wet season (6.94±0.41mg/l). The harmattan season showed higher values of Iron (6.46±0.70mg/l) and Copper concentration (3.92±0.01mg/l). The dry season recorded higher values of Zinc (0.086±0.02mg/l) while the wet season showed higher values of Lead concentration (6.97±0.11mg/l) in Jabi lake during this study.

Table 2: Seasonal Mean Values of Physico-Chemical Parameters in Jabi Lake

Parameter	Dry Season	Wet Season	Hammattan Season	WHO LIMITS
DO	5.67±0.07	5.18±0.11	6.46±0.10	5.0-9.0Mg/l
BOD	3.04±0.09	3.04±0.09	3.92±0.12	3.0-6.0
Depth	1.69±0.04	2.33±0.05	1.78±0.02	3
Nitrate	26.17±9.71	23.27±1.54	22.37±3.67	5
Ammonia	7.18±2.95	6.94±0.41	7.39±1.39	1000
Iron	5.67±0.27	5.18±0.09	6.46±0.70	0.3
Copper	3.04±0.02	3.04±0.02	3.92±0.01	1.6
Zinc	0.086±0.02	0.032±0.00	0.048±0.01	15
Lead	5.22±0.03	6.97±0.11	5.19±0.07	0.1

5. Discussion

This study suggests that Jabi Lake is well oxygenated with a mean value of 5.65 mg/L. Studies suggest that DO value higher than 10 mg/L indicate bad or sub-optimal conditions for the growth of aquatic fauna (Bhatnagar and Singh, 2010; Ekubo and Abowei, 2011). Further, high DO concentrations may indicate excessive algal proliferation (Reynolds, 2006). The mean BOD value of 3.24 mg/L also suggests the quality of the Lake water is quite good. This is similar to the findings of Bilewu *et al.*, (2022) who reported a range of 4.67 – 5.07 mg/L in some selected water bodies in Oyo and Lagos States. The BOD level in Station 5 that is characterized as being the least perturbed was comparatively low which is in the tune with Biochemical oxygen demand (BOD) is the amount of dissolved oxygen that is needed for stabilization of organic matter that are biodegradable through the action of aerobic microorganisms and the oxidation of certain inorganic materials (Tikariha and Sahu, 2014). Conversely the most perturbed Station 2 had the most BOD levels.

Nitrates were generally high with insignificant fluctuations across stations except at station 3. This fluctuation at station 3 could be as a result of relatively less agricultural inflows at this station which is at the upstream section of the lake. The mean nitrate, values recorded for the entire lake fell just within optimum recommended range which confirms the eutrophic nature of the lake (Daniel *et al.*, 2023). Ovie *et al.* (2011) reported similar nitrate trend in Omi dam, Nigeria.

Hydrological parameters like water depth, and water current recorded lower values during the rainy months than the dry months. Depth readings across the stations showed that station 3 had the highest depth. The trend in the depth shows Station 3 >Station 1 > station 4 > station 5 > station 2. The shallow nature of station 2 is likely to have contributed to its polluted status coupled with its poor water current status. Generally, hydrological parameters recorded a direct relationship with total suspended solids and dissolved oxygen, and an indirect relationship with conductivity, BOD, dissolved ions and nutrients (Akindele *et al.*, 2014).

6. Conclusions

The summary results of the mean values of physico-chemical parameters of water samples by station in Jabi Lake inferred that mean values of Nitrate were also relatively high across the five stations while the monthly mean values of other parameters such as Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), depth, water current and ammonia were very low but within the permissible limits. The monthly mean values of heavy metals were extremely low in the five stations within the 24 months of sampling and all outside the permissible limits for drinking water supply as well as fish production. The major threat to the aquatic health of the lake appears to be cultural eutrophication. There is an urgent need to arrest this threat to sustain and improve the quality of the waterbody. Periodic denitrification and nutrient control could be a solution to this threat.

References

[1] Akindele, E.O., Adu, B. W. and Ayandele, M. A (2014) Hydrology and Water Quality Characteristics of a Stressed Lotic Freshwater System in Southwest Nigeria. *Tropical Freshwater Biology, 23.* 1 - 19 http://www.ajol.info/index.php/tfb; DOI: http://dx.doi.org/10.4314/tfb.v23i1.1

[2] American Public Health Association (1995). Standard method for the examination of water and waste water, 19th Edition, American Public Health Association, Washington.

[3] American Public Health Association, American Water Works Association (APHA, AWWA and Water Environment Federation (2001). Standard Methods for the Examination of water and Wastewater, 20th edn. Washington, DC; 2001. (London, England: FFN Spon 1996). Califonia, Division of Agriculture and Natural Resources.

[4] Arimoro, F.O., Ikomi, R.B. and Iwegbue, C.M.A. (2007). ''Ecology and Abundance of Oligochaetes as indicators of Organic Pollution in an Urban Stream in Southern Nigeria'', *Pakistan Journal of Biological Science*, Vol. 3, pp. 446-453.

[5] Awoyemi, O. Achudume, A. and Okoya, A.A. (2014). The Physicochemical Quality of Groundwater in Relation to Surface Water Pollution in Majidun Area of Ikorodu, Lagos State, Nigeria. American Journal of Water Resources, Vol. 2, No. 5, 126-133

[6] Bhatnagar, O. and Singh, J. (2010). Water Quality Challenges in Fish Farms and Solution in The South Western Region Of Nigeria. Journal of Business and Management. Volume 23, Issue 7. Ser. I. PP 38-47

[7] Bilewu O. F., Ayanda I. O. and Ajayi T. O. (2022). Assessment of Physicochemical Parameters in Selected Water Bodies in Oyo and Lagos States.: Earth and Environmental Science 1054. IOP Publishing. doi:10.1088/1755-1315/1054/1/012045.

[8] Carr, G. M. and Neary, J. P. (2006). Water Quality for Ecosystem and Human Health. United Nations Environment Programme Global Environment Monitoring System (GEMS)/Water Programme.

[9] Daniel, M., Sawyerr, H.O., Opasola, O.A., Ekundayo, D.E., Atimiwoaye, A.D., Musa, O. and Sule, R. (2023). Water Quality Assessment of the Man-Made Jabi Lake, Federal Capital Territory, Abuja, Nigeria. J. Appl. Sci. Environ. Manage.Vol. 27 (6) 1141-1146

[10] Ekubo, A.A. and Abowei, J.F.N. (2011). Review of Some Water Quality Management Principles Inculture Fisheries. Research Journal of Applied Sciences, Engineering and Technology, 3, 1342-1357.

[11] Idowu, R.T., Onyemaobi, M.E. and Ali, F.A. (2018). Palaeo-Limnological Study of Ostracods in Ephemeral Ponds in North East Arid Zone, Nigeria. *Elixir Biosciences 121 (2018) 51542-51548*. Available online at *www.elixirpublishers.com (Elixir International Journal).* Department of Biological Sciences, University of Abuja, Nigeria.

[12] Matouke, B.B. (2019). Lead (Pb 2+) causes chlorophyll related changes and oxidative damage in Chlorella ellipsoids (Chlorophyceae. Brazilian Journal of Biological Sciences, 2019, Vol. 6, No. 14, p. 605-613. ISSN 2358-2731. https://doi.org/10.21472/bjbs.061412

[13] Obi, C. L., Bessong, P. O., Momba, M. N., Potgieter, N., Samie, A. and Igumbar, E.O. (2004). Profiles of antibiotics susceptibility of bacterial isolate and physicochemical quality of water supply in rural Venda communities, South Africa Water S. A., 30(4): 515-519.

[14] Ogoko, E.C. and Sylvester, A.O. (2020). Investigation on the quality of Water from Jabi Lake in Abuja, Nigeria. *J. Chem. Soc. Nigeria*, Vol. 45, *No. 5, pp 881-889 (2020).* Department of Pure and Applied Science, National Open University of Nigeria, Abuja.

[15] Ojo, O.A., Bakare, S.B. and Babatunde, A.O. (2007). Microbial and chemical analysis of potable water in public-water supply within Lagos University. *African Journal of Infectious Diseases* 1(1), 30-35.

[16] Oluyemi, E.A., Adekunle, A.S., Adenuga, A.A. and Makinde, W.O. (2010). Physico-chemical Properties and Heavy Metal Con tent of Water Sources in Ife North Local Government Area of Osun State, Nigeria. *African Journal of Environmental Science and Technology, Vol. 4(10), pp. 691-697, October 2010*. Available online at http://www.academic journals.org/AJEST.ISSN 1991-637X @2010 *Academic Journals*.

[17] Ovie S.I., Bwala R.L. and Ajayi O. (2011). A preliminary study on limnological stock assessment, productivity and potential fish yield of Omi Dam, Nigeria. Afr J Environmental Sci Technol 5: 956-963.

[18] Ozoko, D.C. and Ifediegwu, S. I. (2015). Inventory and Preliminary Investigation of Lakes in Opi-Agu, Enugu State, Nigeria. *International Journal of Science and Research (IJSR).* Vol. 4, Issue 6, June 2015. Department of Geology and Mining, Enugu State University of Science and Technology, Enugu State, Nigeria. ISSN (Online): 2319-7064.

[19] Rim-Rukeh, A. (2013). Physico-Chemical and Biological Characteristics of Stagnant Surface Water Bodies (Ponds and Lakes) Used for Drinking and Domestic Purposes in Niger Delta, Nigeria. *Journal of Environmental Protection, 2013, 4, 920-928*. http://dx.doi.org/10.4236/jep. 2013,49106. Published Online September 2013 (http://www.scirp.org/journal/jep).

[20] Thomas, D.B., Edwards, K.A., Babab, R.G. and Hoggs, I.G. (1991). Runoff erosion and conservation in a representative catchments in Morchakos district, Kenya. Pages 42-52. In Elgu, U. (ed) *Tropical Agriculture Hydrology*, John Wiley, Manchester.

[21] Tikariha, A. and Sahu, O. (2014). Study of characteristics and treatments of dairy industry waste water. *Journal of Applied & Environmental Microbiology*, 2(1), pp.16-22.

[22] WHO (2011) Guidelines for drinking water, World Health Organization for drinking water quality, WHO press; Geneva, Switzerland, 4th edition.