Malaysian Journal of Civil Engineering 29(2):157-175 (2017)

STATISTICAL ANALYSIS OF PHYSICO-CHEMICAL PARAMETERS AT KAINJI HYDROPOWER RESERVOIR, NIGERIA

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Abstract: The study evaluated physico-chemical parameters of Kainji lake, Nigeria. Water samples were collected from three sampling stations at Kainji hydropower reservoir from July, 2013 to April, 2014. Water samples were analysed for various physico-chemical parameters using various HACH equipment. Results of the physico-chemical analysis were subjected to simple trend plot and statistical analyses descriptive using Microsoft Excel and analysis of variance (ANOVA) test in Statistical Package for Social Science (SPSS) version 16.0 to determine if there are significant difference between water quality parameters measured at upstream and downstream ends of the reservoir at 0.05 level of significance. Results of the simple trend revealed that all the parameters varied with time at upstream and downstream ends. Results also revealed that there were significant differences in the water quality parameters such as hardness, sulphate (SO_4^{2-}), copper (Cu^{2+}), nitrite (NO_2^-), nitrate (NO_3^-), manganese (Mn^{2+}) and resistivity while parameters such as water temperature, pH, salinity, suspended solids (SS), chloride (Cl^-), iron (Fe^{2+}), chromium (Cr^{3+}), electrical conductivity (EC), phosphate (PO_4^{3-}), silicon oxide (SiO_2), total dissolved solid (TDS), turbidity and dissolved oxygen (DO) were not significantly different at 0.05 level of significant at upstream and downstream locations. Comparison between the measure parameters with the Nigeria and WHO water quality standards revealed that all the parameters are within the limit permissible by the standards except NO3- concentration. High concentration of nutrients such as NO_{3-} and PO_4^{3-} may be caused by socio-economic activities of people living around the lake. In conclusion, Kainji dam hydropower reservoir operation does not have any negative significant effect on the water quality at the station.

Keywords: *ANOVA test, hydropower, Kainji, physico-chemical, water quality.*

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1.0 Introduction

Hydropower is the most important renewable energy source on the planet. Though it provides abundant benefits to society, it also has environmental and ecological consequences (Wang, 2013). Small reservoirs developed in conjunction with hydropower plants, could reduce water quality (Pimenta *et al.,* 2012). Contamination and pollution of freshwater by hydropower operation is of great concern. Hydropower development brings many negative impacts on watershed ecosystems which were not fully integrated into current decision-making. Negative impacts associated with building of large dams include displacement of people, loss of ecosystems, alteration of river flows and water quality at downstream (Mekonnen and Hoekstra, 2012). Water temperature and DO are of primary interest for most reservoirs since temperature regulates biotic growth rates. Turbidity is of considerable interest because of its effect on light transmission and water clarity. The quality of water affects its biodiversity (flora and fauna).

Water quality is one of the main characteristics of a river or reservoir even when its purpose is other than human water supply. Therefore, assessment of the quality of surface water is important in hydro-environmental management (Heydari *et al.,* 2013). Hydropower reservoir operation may affect quality of water due to: impoundment of water in the reservoir, hydropower operation and recreation activities. Kainji hydropower reservoir is choosing in this study because of its peculiarity as the pioneer hydropower station in Nigeria. It also serves other purposes apart from its primary objective, such as: fishing, drinking and irrigation source to farmers at upstream and downstream of the reservoir. There is little knowledge about the impact of the Kainji hydropower reservoir on water quality especially at the vicinity of the dam from literature. That was why this study was carried out at the selected stations. The aim of the study was to assess the physico-chemical quality of water at Kainji hydropower reservoir while the objectives included: collection of water samples for field and laboratory analyses, carrying out trend and statistical analysis on parameters and comparing the measured parameters with World Health Organization (WHO) and Nigeria drinking water standards. Figure 1 is the map of Nigeria showing Kainji Lake. The Kainji reservoir is situated on the river Niger at an altitude of 108m above sea level between Yelwa (latitude 10° 53'N: longitude 4°45'E) and Kainji (latitude 9°50'N: longitude 4°35'E). The surface area of the reservoir is 1250 km^2 and its storage capacity is $15x10^9$ m^3. The maximum length, maximum width, maximum and mean depths of the lake are: 136.8 km, 24.1 km, 60 m and 11m respectively (Dukiya, 2013).

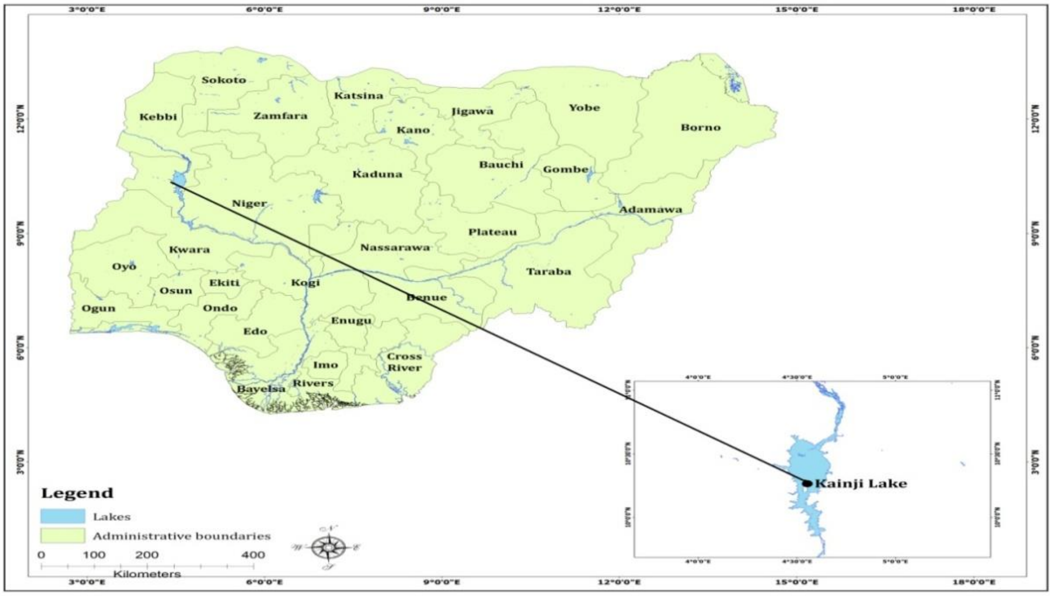

Figure 1: Map of Nigeria showing location of Kainji lake

There have been various studies carried out on the assessment of water quality parameters in rivers and reservoirs. Lee *et al.* (2012) studied physico-chemical characteristics in the filling phase of Bakun hydroelectric reservoir in Sarawak, Malaysia. Statistical analysis was performed on data collected using two ways ANOVA. Regression analysis of TDS on conductivity was performed. All analyses were carried out using the SPSS 19.0 version. Results showed that water temperature decreased by 5 °C from the surface to 20 m depth. Nhapi *et al.* (2012) studied the distribution of heavy metals in lake Muhazi, Rwanda. Water samples were analyzed using standard methods. Results indicated that the concentrations of cadmium, iron and lead were far above the recommended levels for aquatic life at all sampling points. High level of heavy metals was attributed to the riparian land use practices such as uncontrolled agriculture, urban runoff and mining activities around the lake.

Abudaya and Hararah (2013) studied the spatial and temporal variations in water quality along the coast of Gaza Strip, Palestine. The study described results of monthly sampling of physico-chemical parameters and faecal indicators at five monitoring stations over a seven-month period in 2007. The water quality parameters were subjected to statistical analysis. Results showed that spatial and temporal variations in pH, water temperature, salinity, turbidity, DO, faecal coliform and faecal enterococci had link with problems of raw sewage discharge and storm water runoff.

Mustapha (2003) studied limno-chemical conditions of pre-impoundment in Oyun lake at Ilorin, Kwara State, Nigeria using various physico-chemical parameters. Results revealed that seasonal variations between the rain and dry seasons superimposed upon the diurnal cycles in the tropics and had a great influence on the physical and chemical factors of the lake. Mustapha and Omotosho (2005) assessed physico-chemical parameters of Moro lake, Kwara State, Nigeria. Water samples were taken bi-monthly from the lake for a period of eight months spanning wet and dry seasons. Results showed that NO_3^- and PO_4^{3-} were high in the lake. This was revealed in eutrophication arising from the application of nitro-phosphate fertilizer around the lake.

Mustapha (2008) assessed water quality of Oyun reservoir, Offa, Nigeria, using some selected physico-chemical parameters. Three stations were chosen on the reservoir to reflect the effect of human activities on the reservoir habitat. Physico-chemical parameters were analysed on monthly basis between January, 2002 to December, 2003 using standard methods and procedures. Ranges of values of the parameters were found to be comparable to those reported for other African reservoirs except for NO_3^- and PO_4^{3-} which were found in higher concentration above freshwater limits.

Ajibade *et al.* (2008) assessed the water quality parameters in the major rivers of Kainji lake National Park, Nigeria for a period of twenty four month. Major rivers studied were Oli, Manyera, Nuwanzurugi and Poto. River Oli was sampled at the hippo pool and two animal drinking points. Other rivers were sampled at two animal drinking points. Results revealed that seasonal variation appeared to have influence on the physico-chemical parameters. Statistical analysis showed that there were significant differences between sampling points and locations mean values for the different parameters.

Mustapha (2009) assessed influence of watershed activities on the water quality and fish assemblages of Oyun reservoir in Offa, Kwara State. Duplicate surface water samples were collected from 10 cm depth monthly from three stations for two years (January 2002 to December 2003). Two-way ANOVA at $p<0.05$ was used to test for the effects of variations due to sampling error, stations, seasons and years. Results revealed that NO_3^-, PO_4^{3-} and SO_4^{3-} had contributed significantly to the eutrophication of the reservoir.

Maya *et al.* (2013) studied natural and anthropogenic determinants of water quality changes in a small tropical river basin, Southwest, India. A total of seventeen physico-chemical parameters were studied in different water sources. The study revealed that all the parameters were within water quality standards set by various national and international agencies except pH and dissolved oxygen (DO). Gashu (2012) assessed water quality dynamics and fish resource potential of Koga irrigation reservoir at Lake Tana, Ethiopia. The study was conducted to assess physico-chemical and biological features influencing the water quality and fish resource potential of the lake. Result showed that most of the physico-chemical parameters were optimal and the reservoir was biologically rich in plankton diversity.

Olele and Ekelemu (2008) studied physicochemical and phytoplankton of Onah lake at Asaba, Nigeria. Monthly water samples were collected at three stations from January to December, 2003. Physico-chemical parameters were analyzed to determine means, range and standard deviation. Results revealed that concentration of all nutrients were higher during dry season than rainy season. Solomon *et al*. (2013) studied some physico-chemical parameters of two fish ponds in Gwagwalada and Kuje area councils, Federal Capital Territory, Nigeria. Physico-chemical parameters of the ponds were determined from July to September, 2008 using standard methods and equipment. Result revealed that there was no significant difference ($p > 0.05$) in the levels of the parameters in the ponds.

Koli and Muley (2013) studied physico-chemical parameters of Tulashi tank of Kolhapur district, India between January to December, 2011. Results indicated that there was a significant seasonal variation in some parameters. Water quality parameters were found within the acceptable limits of Bureau of Indian Standards (BIS) for drinking water. Indabawa (2010) assessed water quality at Challawa river, Kano State, Nigeria using physico-chemical and macro invertebrate analysis. Results showed that presence of some pollution indicator species of macro invertebrates such as flies, stoneflies, caddish flies and sludge confirmed that the river was moderately polluted.

Omo-Irabor and Ogala (2014) evaluated hydro-geochemical and bacteriological characteristics of surface and groundwater within parts of Ogwashi, Asaba formation in southern, Nigeria using statistical analysis. Physico-chemical characteristics of 56 water samples were collected from ground and surface water. Statistical techniques were used to establish relationship among the measured parameters. Results revealed that the physico-chemical fell within WHO standard. Usman *et al.* (2014) assessed some physico-chemical parameters and macro-element of Lake Alau, North East, Nigeria. Monthly water samples were collected for a period of ten months (July 2012 to April 2013), covering both wet and dry seasons. Results showed a significant difference ($p<0.05$) in temperature, DO, BOD, EC, Fe, and Zn value for each months. These variations may be due to effects of application of fertilizer, herbicides and insecticides to irrigated farms around the lake. The parameters were within the range for unpolluted water bodies.

Shahata and Mohamed (2015) evaluated water quality at River Nile around New Assiut barrage and its hydropower plant. Measured water quality parameters were compared with guidelines stated by the Egyptian law 48/ 1982 concerned with protection of river Nile from pollution. Results revealed that the river is not polluted with operation of the hydroelectric power station. Teame and Zebib (2016) studied seasonal variation in physico-chemical parameters of Tekeze reservoir at northern Ethiopia. Physico-chemical parameters analyses were carried out from August 2013 to July 2014 at three sampling stations to assess the water quality. There was significant difference ($p>0.05$) in all the parameters between the stations and all measured values were within the recommended limit for fish production.

Ling *et al.* (2016) evaluated physico-chemical characteristics of water downstream of Bakun hydroelectric dam in Malaysia. Results indicated that when spillway was closed, pH and DO were lower in the river. When the spillway was opened, the water quality improved in terms of DO content (>8.0 mg/l), total sulphide (TS) and COD but deteriorated in terms of five-day biochemical oxygen demand (BOD_5).

2.0 Methodology

Water samples were collected from July, 2013 to April, 2014 covering raining and dry season from three selected locations at Kainji hydropower station. Google imagery of sampling locations of water quality on the Kainji reservoir is shown Figure 2. Equipment presented in Table 1 was used to measure water quality parameters at the selected locations. Table 2 presents WHO and Nigeria water quality standards for some selected parameters. Water samples used for laboratory analyses were stored in five-liter covered containers and kept in icebox before transported to laboratory for further analyses (Shahata and Mohamed, 2015). Water quality parameters such as temperature, pH, turbidity, electrical conductivity (EC), salinity, resistivity and total dissolved solids (TDS) were measured in situ with the appropriate equipment. Other water quality parameters were measured in the water quality laboratory of the National Centre for Hydropower Research and Development (NACHRED), University of Ilorin, Ilorin, Nigeria. Results of the physico-chemical parameters measured at situ and laboratory were subjected to simple trend plot and statistical analysis using Microsoft Excel. One-way ANOVA in SPSS was used to test if there is any significant difference between water quality parameters measured at upstream and downstream ends at 0.05 level of significance. The measured parameters were compared with the established standards: WHO and Nigeria water quality standards.

Figure 2: Google imagery of Kainji reservoir showing sampling locations

Table 1 : Water quality parameters measured and equipment used

Parameter	*Unit*	*Equipment*
Temperature	^oC	Laboratory thermometer
pH	Nil	Q40d multimeter
Turbidity	NTU	2100Q turbidimeter
EC	(µS/cm)	Q40d multimeter
Salinity	(%)	Q40d multimeter
TDS	(mg/l)	Q40d multimeter
Resistivity	(kΩ-cm)	Q40d multimeter
SS	(mg/l)	DR 2800 spectrophotometer
SO_4^{2-}	(mg/l)	DR 2800 spectrophotometer
NO_3^-	(mg/l)	DR 2800 spectrophotometer
PO_4^{3-}	(mg/l)	DR 2800 spectrophotometer
S^{2-}	(µg/)	DR 2800 spectrophotometer
Cr^{6+}	(mg/l)	DR 2800 spectrophotometer
free Cl	(mg/l)	DR 2800 spectrophotometer
Fe^{2+}	(mg/l)	DR 2800 spectrophotometer
Cu^{2+}	(mg/l)	DR 2800 spectrophotometer
Mn^{2+}	(mg/l)	DR 2800 spectrophotometer
NO_2^-	(mg/l)	DR 2800 spectrophotometer
DO	(mg/l)	DR 2800 spectrophotometer
SiO_2	(mg/l)	DR 2800 spectrophotometer
Total Cl^-	(mg/l)	DR 2800 spectrophotometer
Total hardness	(mg/l)	Digital titrator

Table 2: WHO and Nigeria water quality standards

Parameter	*Unit*	*WHO standard*	*Nigeria standard*
Temperature	^oC	Nil	Nil
pH	Nil	6.5-8.5	6.5-8.5
Turbidity	NTU	5.0	5.0
EC	(µS/cm)	Nil	1000
Salinity	(%)	Nil	Nil
TDS	(mg/l)	<500	<500
Resistivity	(kΩ-cm)	Nil	Nil
SS	(mg/l)	500-1500	0.25
SO_4^{2-}	(mg/l)	250	250
NO_3^-	(mg/l)	9.1	9.1
PO_4^{3-}	(mg/l)	>0.5	>0.5
S^{2-}	(µg/l)	Nil	Nil
Cr^{3+}	(mg/l)	0.5	0.5
Fe^{2+}	(mg/l)	0.3	0.3
Cu^{2+}	(mg/l)	1.0-2.0	2.0
Mn^{2+}	(mg/l)	0.1-0.50	0.1-0.50
NO_2^-	(mg/l)	3.0	0.02
DO	(mg/l)	4.0	> 6.0
SiO_2	(mg/l)	Nil	Nil
Total hardness	(mg/l)	150	150
Total Cl^-	(mg/l)	250-600	300

Source: Adapted from FRN (2011) and Mohan et al. (2013)

3.0 Results and Discussions

3.1 Results

Results of the seasonal variations of the measured water quality parameters at the selected locations using trend analysis are presented in Figures 3 to 21. The results of descriptive statistics of the physico-chemical parameters for the stations are presented in Tables 3 to 5 while ANOVA results are presented in Tables 6 and 7.

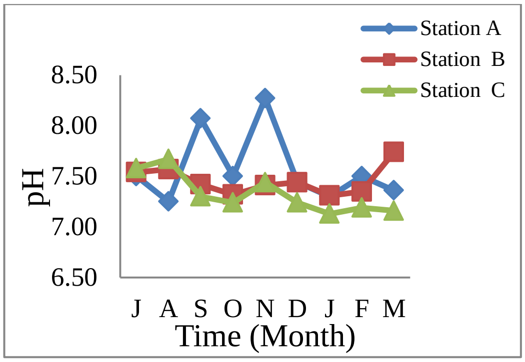

Figure 3: pH trend at the stations

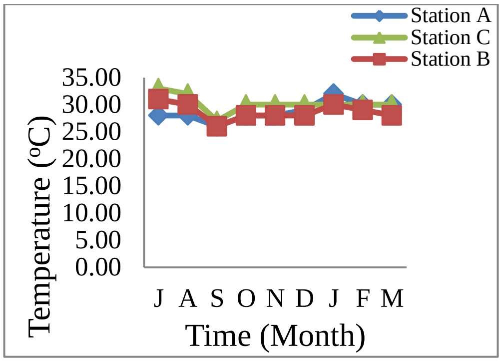

Figure 4: Temperature trend at the stations

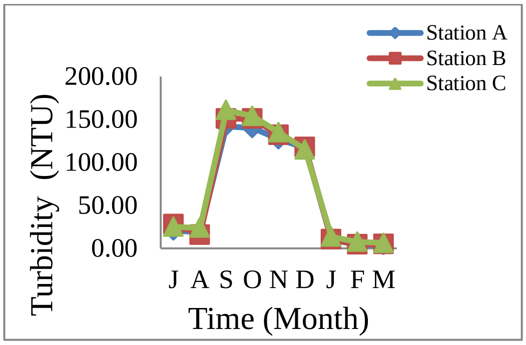

Figure 5: Turbidity trend at the stations

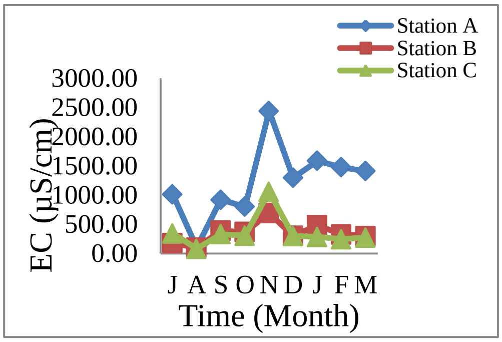

Figure 6: EC trend at the stations

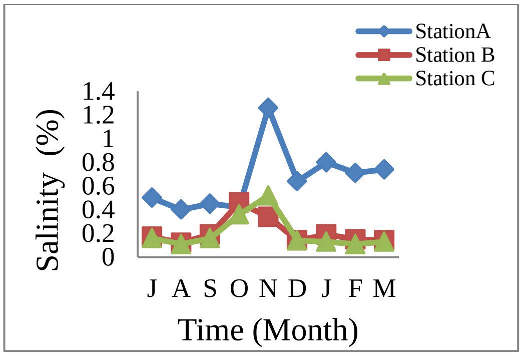

Figure 7: Salinity trend at the stations

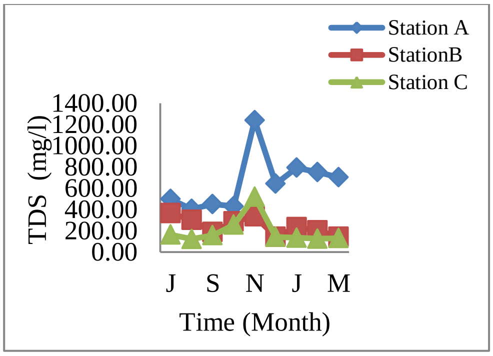

Figure 8: TDS trend at the stations

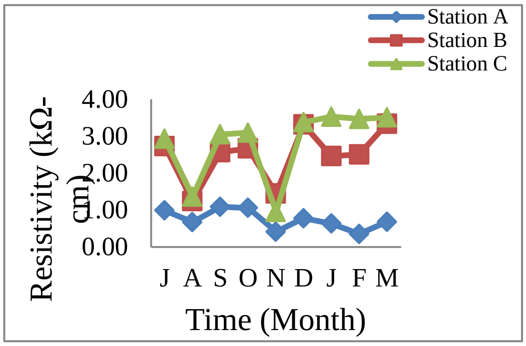

Figure 9: Resistivity trend at the stations

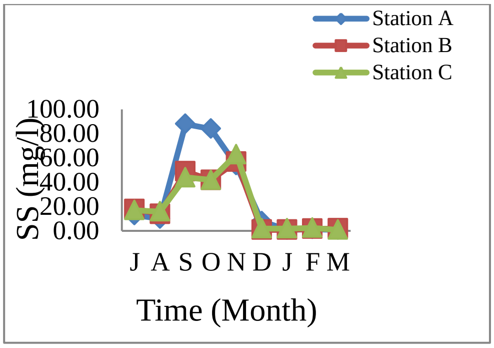

Figure 10: SS trend at the stations

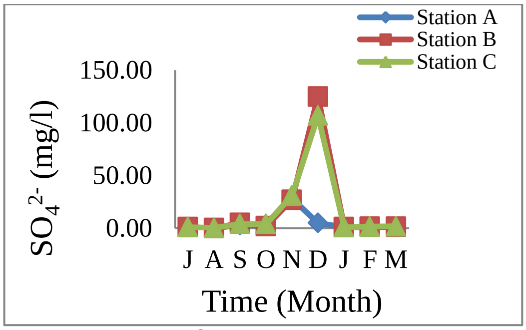

Figure 11: SO_4^{2-} trend at the stations

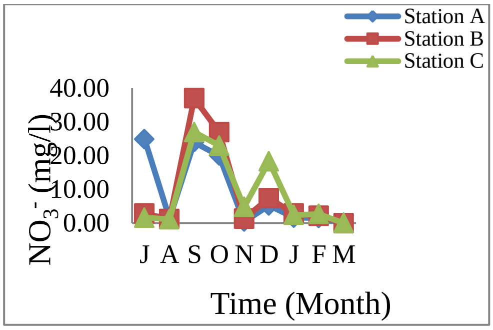

Figure 12: NO_3^- trend at the stations

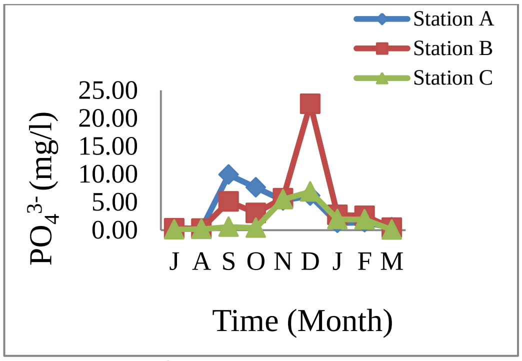

Figure 13: PO_4^{3-} trend at the stations

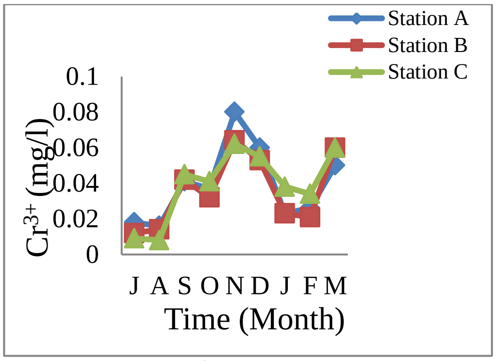

Figure 14: Cr^{3+} trend at the stations

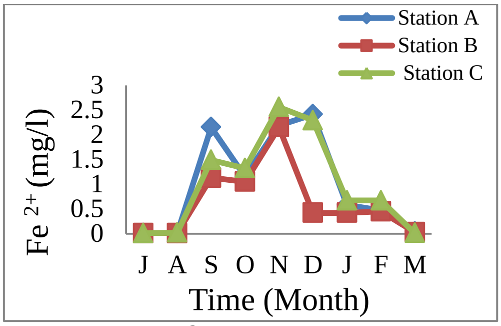

Figure 15: Fe^{2+} trend at the stations

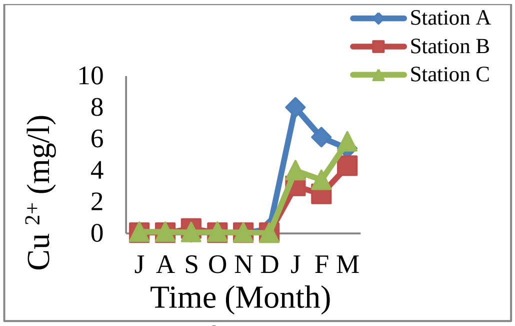

Figure 16: Cu^{2+} trend at the stations

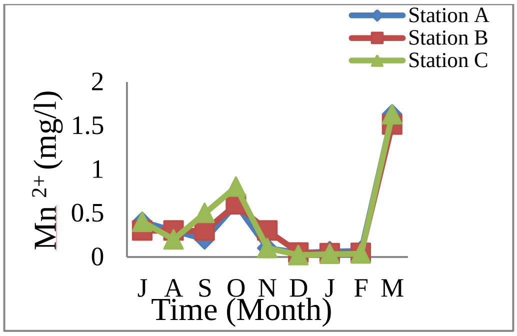

Figure 17: Mn^{2+} trend at the stations

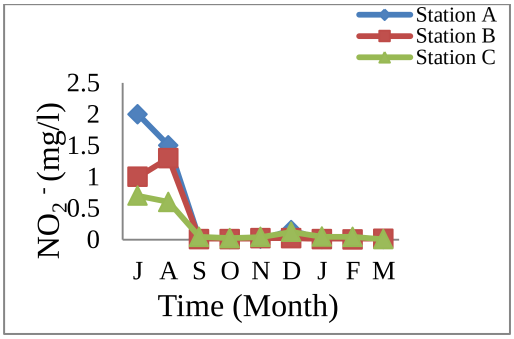

Figure 18: NO_2^- trend at the stations

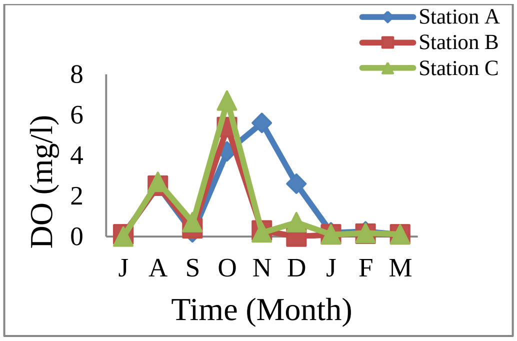

Figure 19: DO trend at the stations

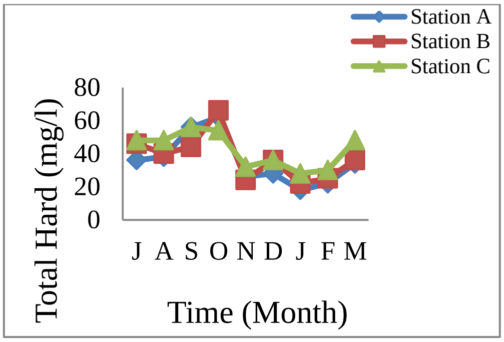

Figure 20: Total hardness trend at the stations

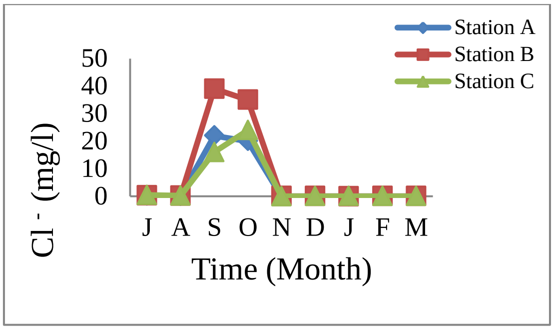

Figure 21: Cl^- trend at the stations

Table 3 : Descriptive statistics of physico-chemical parameters at station A

Parameter	*Min*	*Max*	*Mean*	*Median*	*Std dev*
Temperature ($^{\circ}$C)	26.00	32.00	28.78	28.00	1.72
pH	7.25	8.27	7.58	7.50	0.35
Turbidity (NTU)	4.00	142.00	64.88	20.50	63.85
EC (µS/cm)	101.60	2440.00	1226.96	1296.00	641.24
Salinity ($\%_o$)	0.40	1.26	0.66	0.64	0.27
TDS (mg/l)	405.00	1241.00	657.33	643.00	263.07
Resistivity (kΩ-cm)	0.35	1.09	0.74	0.68	0.27
SS (mg/l)	1.00	88.00	28.94	10.00	36.25
SO_4^{2-} (mg/l)	0.13	28.00	4.70	1.20	8.86
NO_3^- (mg/l)	0.03	24.90	8.78	1.60	10.82
PO_4^{3-} (mg/l)	0.24	9.90	3.62	1.37	3.67
S^{2-} (µg/l)	6.00	176.00	82.87	46.00	74.73
Cr^{3+} (mg/l)	0.02	0.08	0.04	0.04	0.02
Fe^{2+} (mg/l)	0.01	2.41	1.00	0.58	1.01
Cu^{2+} (mg/l)	0.02	8.00	2.21	0.05	3.28
Mn^{2+} (mg/l)	0.05	1.63	0.38	0.20	0.50
NO_2^- (mg/l)	0.00	2.00	0.41	0.01	0.77
DO (mg/l)	0.10	5.60	1.75	0.25	2.08
SiO_2 (mg/l)	0.03	28.60	8.72	8.07	9.71
Total hardness (mg/l)	18.00	62.00	35.56	34.00	14.86
Cl^- (mg/l)	0.01	22.00	4.71	0.06	9.25

Table 4: Descriptive statistics of physico-chemical parameters at station B

Parameter	*Min*	*Max*	*Mean*	*Median*	*Std dev*
Temperature (°C)	26.00	31.00	28.67	28.00	1.50
pH	7.31	7.74	7.46	7.42	0.14
Turbidity (NTU)	4.60	151.00	68.49	28.30	67.03
EC (µS/cm)	98.50	692.00	348.03	325.00	171.62
Salinity (%$_o$)	0.12	0.46	0.21	0.17	0.11
TDS (mg/l)	143.30	366.00	245.08	233.00	81.91
Resistivity (kΩ-cm)	1.24	3.34	2.48	2.57	0.72
SS (mg/l)	1.00	57.00	20.63	14.00	22.67
SO_4^{2-} (mg/l)	0.13	125.00	18.21	1.50	40.93
NO_3^- (mg/l)	0.01	37.00	9.08	2.80	13.39
PO_4^{3-} (mg/l)	0.24	22.57	4.73	2.70	6.98
S^{2-} (µg/l)	10.00	151.00	86.67	92.00	49.11
Cr^{3+} (mg/l)	0.01	0.06	0.04	0.03	0.02
Fe^{2+} (mg/l)	0.01	2.15	0.63	0.42	0.71
Cu^{2+} (mg/l)	0.02	4.28	1.13	0.03	1.66
Mn^{2+} (mg/l)	0.04	1.51	0.38	0.30	0.46
NO_2^- (mg/l)	0.00	1.30	0.26	0.01	0.51
DO (mg/l)	0.00	5.40	1.00	0.14	1.82
SiO_2 (mg/l)	0.01	25.90	7.73	6.40	8.85
Total hardness (mg/l)	22.00	66.00	37.67	36.00	13.77
Cl^- (mg/l)	0.01	39.00	8.29	0.05	16.31

Table 5: Descriptive statistics of physico-chemical parameters at station C

Parameter	*Min*	*Max*	*Mean*	*Median*	*Std dev*
Temperature (°C)	27.00	33.00	30.22	30.00	1.64
pH	7.13	7.67	7.33	7.24	0.19
Turbidity (NTU)	6.29	161.00	71.28	25.00	67.87
EC (µS/cm)	78.30	1055.00	355.92	297.00	273.39
Salinity (%)	0.11	0.52	0.20	0.14	0.14
TDS (mg/l)	124.00	520.00	195.13	142.30	128.58
Resistivity (kΩ-cm)	0.95	3.53	2.81	3.10	0.97
SS (mg/l)	1.00	63.00	21.06	16.00	23.02
SO_4^{2-} (mg/l)	0.15	107.00	16.82	1.80	35.18
NO_3^- (mg/l)	0.02	27.00	9.00	2.70	10.63
PO_4^{3-} (mg/l)	0.05	6.87	1.94	0.56	2.54
S^{2-}(µg/l)	16.00	165.00	88.89	94.00	46.57
Cr^{3+} (mg/l)	0.01	0.06	0.04	0.04	0.02
Fe^{2+} (mg/l)	0.01	2.56	1.00	0.67	0.97
Cu^{2+} (mg/l)	0.02	5.83	1.52	0.10	2.26
Mn^{2+} (mg/l)	0.02	1.63	0.41	0.20	0.53
NO_2^- (mg/l)	0.01	0.70	0.18	0.04	0.27
DO (mg/l)	0.00	6.70	1.26	0.20	2.20
SiO_2 (mg/l)	0.02	23.10	6.39	4.67	7.99
Total hardness (mg/l)	28.00	56.00	42.22	48.00	10.74
Cl^- (mg/l)	0.01	24.00	4.54	0.07	8.99

Table 6: Summary of analysis of variance (ANOVA)

Parameter		*Sum of square*	*Df*	*Mean of square*	*F-value*	*Sig.*
Temperature	Between group	12.056	3	4.01	1.7418	0.273
	Within group	11.5	5	2.3		
	Total	25.556	8			
Hardness	Between group	1758.22	6	293.037	73.259	0.0153*
	Within group	8	2	4		
	Total	1766.22	8			
pH	Between group	0.989	7	0.141	78.476	0.0867
	Within group	0.0018	1	0.0018		
	Total	0.9906	8			
Salinity	Between group	0.5327	5	0.10653	6.2543	0.0811
	Within group	0.0511	3	0.01703		
	Total	0.58376	8			
SO_4^{2-}	Between group	626.8648	6	104.4774667	417.91	0.00239*
	Within group	0.5	2	0.25		
	Total	627.3648	8			
Suspended solid	Between group	10488.722	7	1498.389	61.1587	0.09815
	Within group	24.5	1	24.5		
	Total	10513.222	8			
Cl^-	Between group	0.062	6	0.01036	6.3766	0.14175
	Within group	0.0033	2	0.00163		
	Total	0.065	8			
Cu^{2+}	Between group	74.909	6	12.485	249695	0.0015*
	Within group	0.00005	1	0.00005		
	Total	74.909	7			
Fe^{2+}	Between groups	8.088	7	1.155	190.98	0.0557
	Within groups	0.0061	1	0.0061		
	Total	8.094	8			
NO_2^-	Between group	4.762	7	0.68	54426.1	0.0033*
	Within group	0.000013	1	0.000013		
	Total	4.7623	8			

Table 7: Summary of analysis of variance (ANOVA)

Parameter		*Sum of square*	*Df*	*Mean of square*	*F-value*	*Sig.*
Cr^{3+}	Between group	0.0656	6	0.01094	6.83565	0.1331
	Within group	0.0032	2	0.0016		
	Total	0.0688	8			
EC	Between group	26.549	7	3.793	47.4097	0.1114
	Within group	0.08	1	0.08		
	Total	26.6294	8			
Mn^{2+}	Between group	3.985	7	0.5694	1265.32	0.02165*
	Within group	0.00045	1	0.00045		
	Total	3.9862	8			
NO_3^-	Between group	2.0659	7	0.2951	23611.3	0.005*
	Within group	0.0000123	1	0.000013		
	Total	2.066	8			
PO_4^{3-}	Between group	0.1482	7	0.0212	2.941	0.4219
	Within group	0.0072	1	0.0072		
	Total	0.1554	8			
Resistivity	Between groups	0.1014	5	0.0203	32.0175	0.0083*
	Within groups	0.0019	3	0.00063		
	Total	0.1033	8			
SiO_2	Between group	14.5	3	4.833	6.905	0.0315
	Within groups	3.5	5	0.7		
	Total	18	8			
TDS	Between group	1465.33	6	244.222	9.64035	0.09695
	Within groups	50.667	2	25.333		
	Total	1516	8			
Turbidity	Between group	0.1482	7	0.0212	2.9409	0.42189
	Within group	0.0072	1	0.0072		
	Total	0.1554	8			
DO	Between group	31.73	7	4.5329	1.574	0.5484
	Within group	2.88	1	2.88		
	Total	34.61	8			

** Significant at the 0.05 level*

3.2 Discussions

Water temperature varied from 26.0 to 33.0 °C at stations A, B and C, mean and standard deviation were found to vary between 28.68 to 30.22°C and 1.50 to 1.72°C respectively. The mean value of pH varied between 7.33 to 7.58 and the standard deviation varied between 0.14 to 0.35. The pH and water temperature ranges were similar to the ranges of values reported for Bakun hydroelectric reservoir Malaysia (Lee *et al*, 2012). The mean turbidity (NTU) of the water sample ranged between 4.00 to 161.00 while the standard deviation ranged between 63.85 and 67.87. High turbidity was observed at the stations during the raining season between August to November as shown in Figure 5, this due to high inflow into the lake during the periods. The mean EC (µS/cm) ranged between 78.30 and 2440.00 while standard deviation varied between 67.30 to 273.39. The mean Salinity (%) varied between 0.20 and 64.88 while standard deviation varied between 0.11 to 0.14. The mean TDS (mg/l) ranged between 195.13 to 657.33 while standard deviation varied between 81.91 to 263.07. The mean resistivity (kΩ-cm) ranged between 0.74 to 2.48 while standard deviation varied between 0.27 to 0.97. The mean SS (mg/l) ranged between 20.63 to 28.94 while standard deviation varied between 23.02 to 36.25. Trends exhibited by EC, salinity and TDS were observed to follow similar pattern at the stations (Figures 6 to 8).

The mean SO_4^{2-} (mg/l) ranged between 4.70 to 18.21 while standard deviation ranged between 8.86 to 35.18. The mean NO_3^- (mg/l) ranged between 8.78 to 9.08 while standard deviation ranged between 10.63 to 13.39. The mean NO_2^- (mg/l) ranged between 0.18 to 0.41 while standard deviation varied between 0.27 to 0.77. The mean PO_4^{3-} (mg/l) ranged between 1.94 to 4.73 while standard deviation ranged between 2.54 to 6.98. The mean Cr^{3+} (mg/) was 0.04 at the three stations while standard deviation was 0.02. The mean Fe^{2+} (mg/l) ranged between 0.63 to 1.00 while standard deviation varied between 0.71 to 1.01. The mean Cu^{2+} (mg/l) ranged between 1.13 to 2.21 while standard deviation varied between 1.66 to 3.28. The mean Mn^{2+} (mg/l) ranged between 0.38 to 0.41 while standard deviation varied between 0.46 to 0.53. Variations in the water quality parameters are similar to that observed in (Ajibade *et al.*, 2008 & Mustapha, 2008).

Simple trend plots revealed that all the parameters vary with time at the stations (Figures 3 to 20). High values observed in some parameters at some months are due to meteorological and hydrological phenomenon that fluctuates throughout the year. It may also be due to non-uniform mixing of the constituent water quality parameters at the upstream and downstream ends of the lake. Statistical analyses also revealed that the concentrations of various physico-chemical parameters were different at upstream and downstream ends. This is due to the socio-economic activities of people living around the lake and reservoir operation of the hydropower station. ANOVA results presented in Tables 6 and 7 showed that variations in water temperature, pH, salinity, SS, Cl^-, Fe^{2+}, Cr^{3+}, EC, PO_4^{3-}, SiO_2, TDS, turbidity and DO were not statistically significant at 0.05 level of significant, this implies that there is no tendency for their increase at the stations. Parameters such as hardness, SO_4^{2-}, Cu^{2+}, NO_2^-, Mn^{2+}, NO_3^- and resistivity were more statistically significant at 0.05 level of significant, this means that there is tendency for their increase in future at the stations. Water quality parameters such as: turbidity, EC, TDS, NO_3^- , PO_4^{3-}, Fe^{2+} and Cu^{2+} were found to be above the established standards at the stations, while parameters such as: pH, Cl^-, SS, DO, SO_4^{2-}, Cr^{3+}, Mn^{2+}, NO_2^- and total hardness were found to be within the established standards at the stations. Variation in the results of the physico-chemical could be influenced by the seasonal fluctuation in runoff in the study area as explained in (Ajibade *et al.*, 2008) and also due to socio-economic activities of people living around the lake such as cattle rearing, farming and fishing.

4.0 Conclusion

Water samples were analysed for physico-chemical parameters using various HACH equipment. Results of the physico-chemical analysis were subjected to simple trend plot and statistical analyses using Microsoft Excel while ANOVA in SPSS was to determine if there is significant difference between water quality parameters measured at upstream and downstream ends of the reservoir at 0.05 level of significance. The results of the simple trend revealed that all the parameters vary with time at upstream and downstream ends. Results also revealed that there were significant differences in the water quality parameters such as hardness, sulphate (SO_4^{2-}), copper (Cu^{2+}), nitrite (NO_2^-), nitrate (NO_3), manganese (Mn^{2+}) and resistivity while parameters such as water temperature, pH, salinity, suspended solids (SS), chloride (Cl^-), iron (Fe^{2+}), chromium (Cr^{3+}), electrical conductivity (EC), phosphate (PO_4^{3-}), silicon oxide (SiO_2), total dissolved solid (TDS), turbidity and dissolved oxygen (DO) were not significantly different at 0.05 level of significant at upstream and downstream locations. Excessive concentration of nutrients such as NO_3^- and PO_4^{3-} may be caused by socio-economic activities of people living around the lake such as farming, fishing and rearing of cattle around the lake and these can cause eutrophication of the reservoir. Concentration of DO was found to be within the established standards, this will favour growth of aquatic habitats. Comparison between the measure parameters with the Nigeria and WHO water quality standards revealed that all the parameters are within the permissible limits. In conclusion, Kainji dam hydropower reservoir operation does not have any negative significant effects on the water quality at station.

5.0 Acknowledgement

The authors acknowledged the cooperation and support provided by the management of Kainji Hydroelectric Power Station, New Bussa, Niger State, Nigeria for the access given to us to take water samples at the selected locations. The management of the National Centre for Hydropower Research and Development (NACHRED), University of Ilorin, Ilorin, Nigeria is appreciated for providing logistic and the needed equipment used in this study.

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