APPLICATION OF ANOVA STATISTICAL TOOL FOR WATER QUALITY MANAGEMENT OF KAINJI RESERVOIR

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ABSTRACT

Data on water quality at Kainji hydropower reservoir in four sampling locations from January, 2010 to December, 2015 was subjected to monthly variation and descriptive statistical analyses. Analysis of variance (ANOVA) test was carried out to reveal significant difference between water quality parameters measured at upstream and downstream ends of the reservoir at 0.05 level of significance. Results revealed that there were more statistically significant differences in phosphate (PO_4^{3-}) and oil/grease concentrations at the upstream locations, while total hardness, pH, turbidity and oil/grease concentration were more statistically significant at the downstream locations of the reservoir. The concentration of oil/grease is higher at the turbine discharge, implying a need to check and correct for likely mechanical defects at the turbine and generator compartments. The results obtained were compared with the Nigeria and World Health Organisation (WHO) water quality standards for drinking water and aquatic habitats, the comparison revealed that many of the water quality parameters fell within the limits permissible by the standard; however, Fe^{2+} and turbidity were found to be higher than the permissible standards at all the selected locations. Total suspended solid (TSS) was found to be high at boatyard, turbine discharge and tailrace; this is as a result of turbulence of due to hydropower reservoir operation. The concentration of nitrate (NO_3^-) was found to be above the permissible standards at the turbine discharge and tailrace sections; this is due to the activities like farming and rearing of cattle around the lake which result to in the lake eutrophication. Dissolved oxygen (DO) concentration was found to be within the established water quality standards and will favour the growth and well being of aquatic habitat.

Keywords: ANOVA test, Hydropower, Kainji, Physico-Chemical, Water Quality

1. INTRODUCTION

Hydropower is the most important renewable energy source on the planet. Though it provides abundant benefits to the society, it also has some environmental and ecological consequences (Wang, 2013). Hydropower development brings many negative impacts on watershed ecosystems. Such negative impacts include displacement of people, loss of ecosystems, alteration of river flows and water quality at downstream (Mekonnen and Hoekstra, 2012). Hydroelectric projects may alter the timing and magnitude of the natural flow hydrograph which can affect pH. Project impoundments may increase water temperature and influence the availability of nutrients in a way which may promote increased algal and aquatic plant growth. Enhanced respiration and photosynthesis can cause excessive DO and pH fluctuations (ODEQ, 2012); while small reservoirs developed in conjunction with hydropower plants, could reduce water quality (Pimenta *et al*. 2012). It has been established that temperature varied inversely proportional with DO in water, as the temperature of freshwater increases DO reduces (Rangwala *et al*., 2012 ; Langman *et al*., 2012). Also temperature is negatively related to DO in surface water system. 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; and in general the quality of water affects biodiversity (flora and fauna). One of the negative impacts of hydropower is the rise of summer water temperatures in the reservoir upstream of dams. Hydroelectric projects impound water into reservoirs, disrupting natural temperature dynamics and distribution, leading to high summer temperatures, warm surface layers in the reservoir and thermal stratification (Wang, 2013). 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).

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

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characteristics in the filling phase of Bakun hydroelectric reservoir in Sarawak, Malaysia. Statistical analysis was performed on data collected using ANOVA. Results showed that temperature in the reservoir 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. The results indicated that the concentrations of cadmium, iron and lead were far above the recommended levels for aquatic life at all sampling points. Abudaya and Hararah (2013) studied the spatial and temporal variations in water quality along the coast of Gaza Strip, Palestine. The study described the results of monthly sampling of physico-chemical parameters and faecal indicators at five monitoring stations over a seven-month period in 2007. The results showed that spatial and temporal variations in pH, water temperature, salinity, turbidity, DO, faecal coliform and faecal enterococci had link with the problems of raw sewage discharge and storm water runoff.

Mustapha (2003) studied the limno-chemical conditions of pre-impoundment in the Oyun lake at Ilorin, Kwara State, Nigeria using various physico-chemical parameters. The results revealed that the seasonal variations between the rain and dry seasons superimposed upon the diurnal cycles in the tropics had a great influence on the physical and chemical factors of Oyun lake. Mustapha and Omotosho (2005) assessed the 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. The results showed that nitrate and phosphate were high in the lake. Mustapha (2008) assessed the 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. The ranges of values of the parameters were found to be comparable to those reported for other African reservoirs except for nitrate and phosphate 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. Results revealed that seasonal variation appeared to have influence on the physico-chemical parameters. Mustapha (2009) assessed the influence of watershed activities on the water quality and fish assemblages of Oyun reservoir in Offa, Kwara State. The results revealed that nitrate, phosphate and sulphate had contributed significantly to the eutrophication of the reservoir.

Maya *et al*. (2013) studied the natural and anthropogenic determinants of water quality 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 except pH and DO all the other parameters were within the water quality standards set by various national and international agencies. Gashu (2012) assessed the water quality dynamics and fish resource potential of Koga irrigation reservoir, Lake Tana, Ethiopia. The result showed that most of the physico-chemical parameters were optimal and biologically the reservoir was rich in plankton diversity.

Olele and Ekelemu (2008) studied the physico-chemical and phytoplankton of Onah lake, Asaba, Nigeria. It was observed that the concentration of all the nutrients were higher during the dry season than the rainy season. Koli and Muley (2013) studied the physico-chemical parameters of Tulashi tank of Kolhapur district, India between January to December, 2011. It was found that there was a significant seasonal variation in some physico-chemical parameters. Indabawa (2010) assessed the water quality at Challawa river, Kano State, Nigeria using physico-chemical and macro invertebrate analysis. It was noticed that the presence of some pollution indicator species of macro invertebrates such as flies, stoneflies, caddish flies and sludge confirmed that the river is moderately polluted.

Oyewale and Musa (2006) showed that there is appreciable increase in the concentration of metals especially manganese (Me) and iron (Fe) in the sediment and water quality of the Kainji lake. The potential risk of exposure to this effect can emanate from fish caught in the lake and subsequently consumed by human. High concentrations of heavy metals in the Kainji lake were reported to have been found in the downstream followed by upstream and midstream (Amoo *et al.,* 2005). This study is therefore timely because it has been established by the above studies that the lake is being polluted by the hydropower operation and anthropogenic activities around the lake. Furthermore, Kainji hydropower reservoir was chosen for 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 as irrigation water source to farmers at upstream and downstream of the reservoir. The main objective of the study was to carry out trend and statistical analysis on the water quality parameters and compare them with WHO and Nigeria drinking and aquatic water standards.

The Kainji dam is located in New Bussa at Borgu Local Government Area of Niger State, Nigeria. Kainji hydropower reservoir is fed by many tributaries such as Malando, Danzaki and Sokoto-Rima rivers. It lies at an altitude of 108 m above sea level, between Yelwa (latitude 10° 53'N: longitude 4°45'E) and Kainji (latitude 9° 50'N: longitude 4°35'E). It is underlained by basement complex rocks such as porphyritic granite, mica and quartzite (Ifabiyi, 2011). Kainji lake is the largest man-made lake in Nigeria with a surface area of 1270 km^2. It has 104 different species of fish, with a diversity index of 0.91 when compared with other inland reservoirs in the country (Amoo e*t al.,* 2005). The storage capacity is 15 x 10^9 m^3 with a total live storage of 12 x10^9 m^3. Kainji hydropower reservoir has an installed capacity of 760 MW. Kainji reservoir is characterized by prolonged high temperature, low rainfall and low relative humidity; it exhibits evaporation values that are in excess of rainfall (Abam, 2001). Figure 1 is the map of Nigeria showing Kainji Lake. Figure 2 is the Google Imagery of Kainji reservoir showing the location of water quality sampling.

2. METHODOLOGY

Data on water quality was collected from the environmental section of the Kainji hydropower station for the period 2010 to 2015 covering both rain and dry seasons. The data was available for four selected locations at the upstream and downstream ends of the reservoir. The sampling locations and their corresponding coordinates are presented in Table 1. The water quality parameters measured and the equipment used are presented in Table 2. The data collected was subjected to monthly, seasonal variation and statistical analysis. One-way ANOVA was used to test statistically significant difference between water quality parameters measured at upstream and downstream ends of the reservoir at 0.05 level of significance. Microsoft Excel and SPSS 16.0 software were used for the analysis. The water quality parameters were compared with the established standards: WHO and Nigeria water quality standards. Table 3 presents WHO and Nigeria water quality standards for some selected parameters.

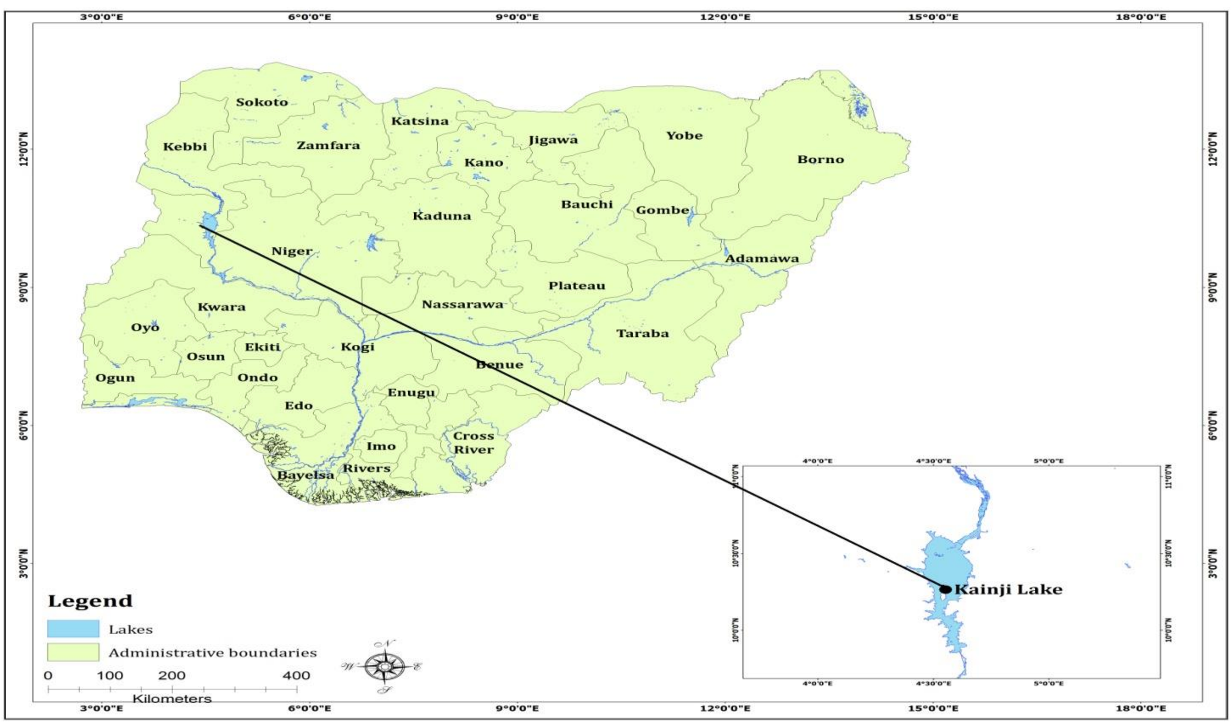

Figure 1: Map of Nigeria Showing Location of Kainji Lake

Figure 2: Google Imagery of Kainji Reservoir Showing Sampling Locations

Table 1: Sampling Locations and Coordinates

Sampling Location	Description	Latitude	Longitude
A	Power Intake	9° 51' 54.2"	4° 36 50"
B	Tailrace	9° 51' 49.7"	4° 36' 47.3"
C	Boatyard	9° 52' 09.8"	4°37' 12.5"
D	Downstream Tailrace	9° 51' 43.6"	4° 36' 58.5"

Table 2: Water Quality Parameters Measured and Equipment Used

Parameter	Unit	Equipment
Temperature	°C	Hanna Piccolo Plus (ATC pH/°C)
pH	Nil	Hanna Piccolo Plus (ATC pH/°C)
Turbidity	NTU	Turbidimeter
EC	(µS/cm)	Hanna HI 98303
TSS	(mg/l)	Hanna HI 98301
SO_4^{2-}	(mg/l)	3B Perkin Elmer Spectrophotometer
NO_3^-	(mg/l)	3B Perkin Elmer Spectrophotometer
PO_4^{3-}	(mg/l)	3B Perkin Elmer Spectrophotometer
Fe^{2+}	(mg/l)	Atomic Absorption Spectrophotometer (Perkin Elmer Model 403)
DO	(mg/l)	Hanna HI 9146
Cl^-	(mg/l)	3B Perkin Elmer Spectrophotometer
Total hardness	(mg/l)	Atomic Absorption Spectrophotometer (Perkin Elmer Model 403)
BOD	(mg/l)	Hanna HI 9146
COD	(mg/l)	Hanna HI 9146
Oil/Grease	(mg/l)	3B Perkin Elmer Spectrophotometer

Source: Environmental Unit, Kainji Hydropower Station *(2015)*

Table 3: 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	5
EC	(µS/cm)	Nil	1000
TSS	(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
Fe^{2+}	(mg/l)	0.3	0.3
Cu^{2+}	(mg/l)	1.0-2.0	2
Mn^{2+}	(mg/l)	0.1-0.50	0.1-0.50
DO	(mg/l)	4	> 6.0
Total Hardness	(mg/l)	150	150
Cl^-	(mg/l)	250-600	300

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

3. RESULTS AND DISCUSSIONS

Results

The results of the monthly variations of the water quality parameters at the selected locations using trend analysis are presented in Figures 3 to 17. The results of descriptive statistics of the parameters for the stations are presented in Tables 4 to 7 while the results of the ANOVA are presented in Tables 8 and 9.

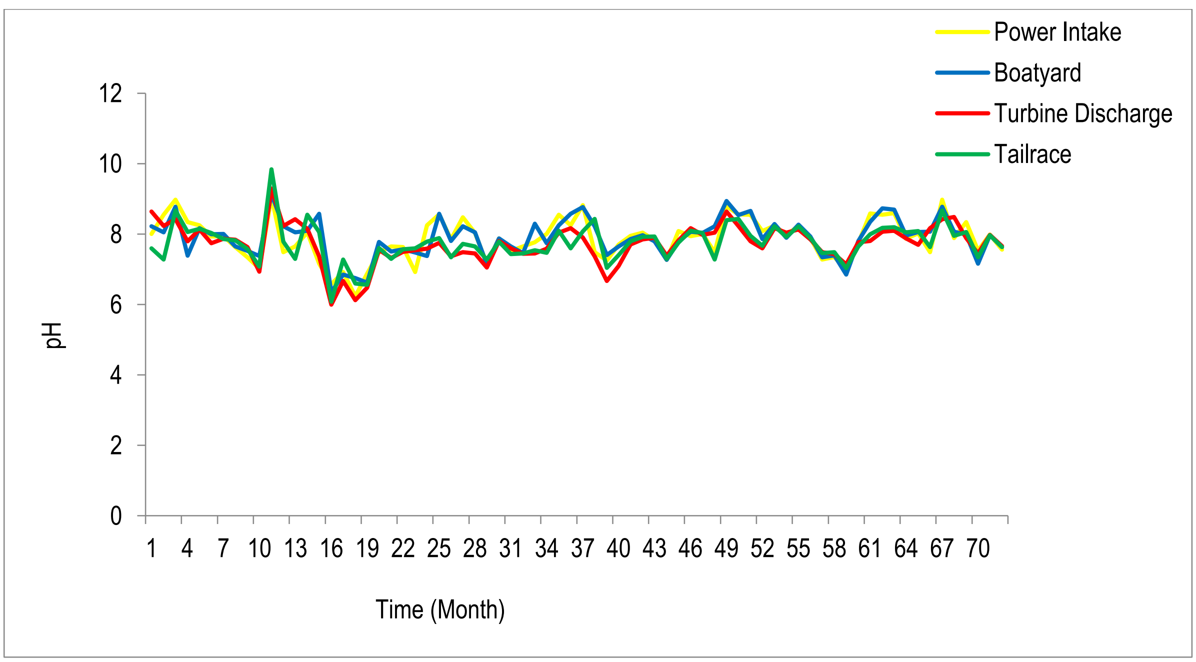

Figure 3: Monthly pH concentration *at selected stations*

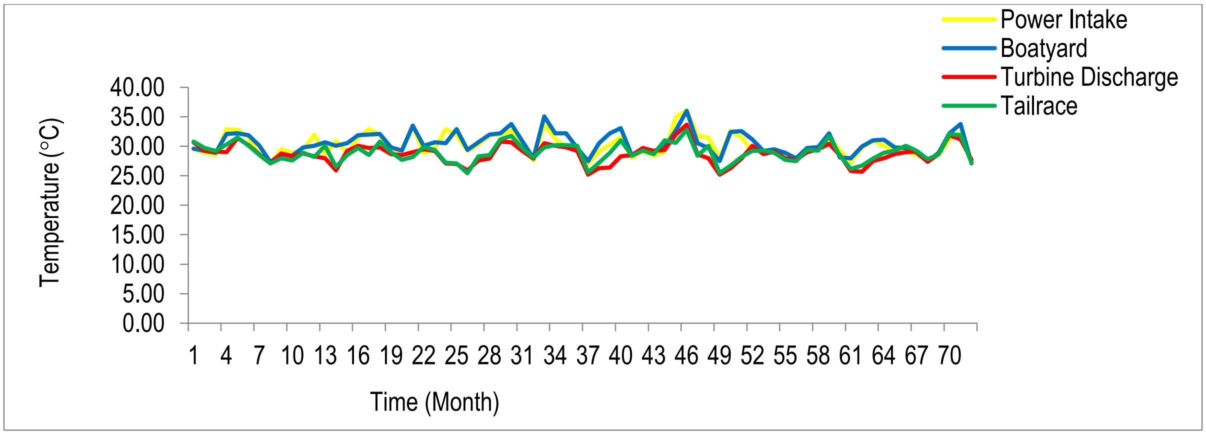

Figure 4: Monthly temperature *concentration (°C) at selected stations*

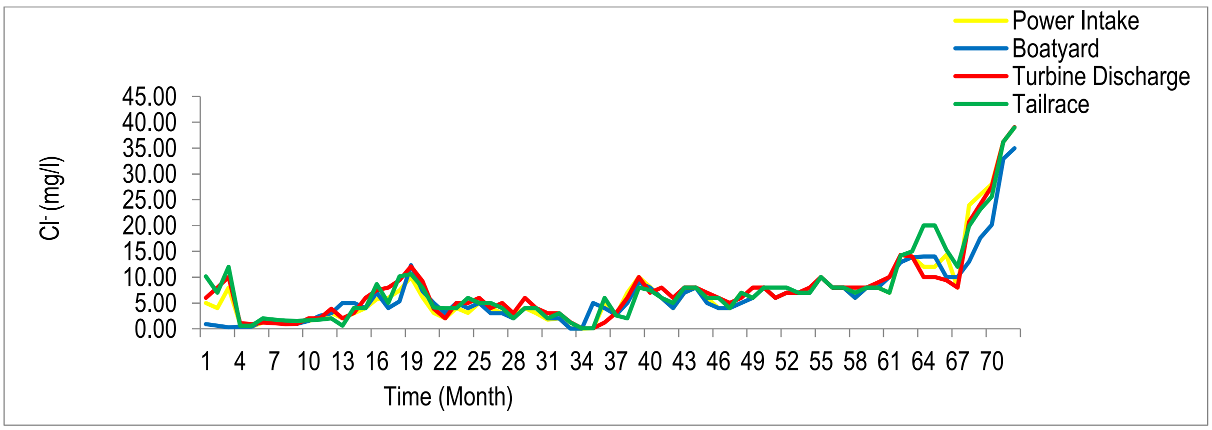

Figure 5: Monthly Cl^- *concentration (mg/l) at selected stations*

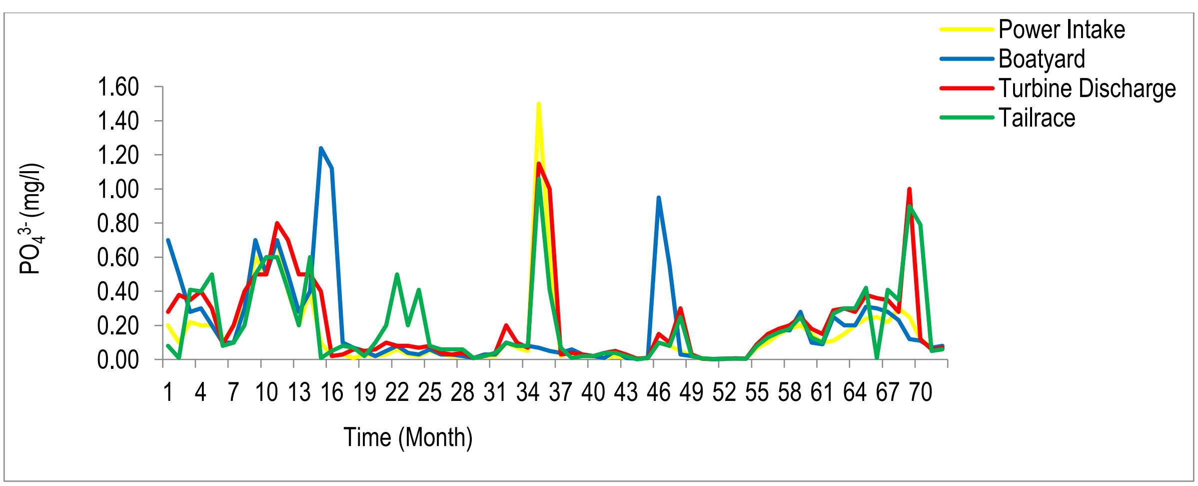

Figure 6: Monthly PO_4^{3-} *concentration (mg/l) at selected stations*

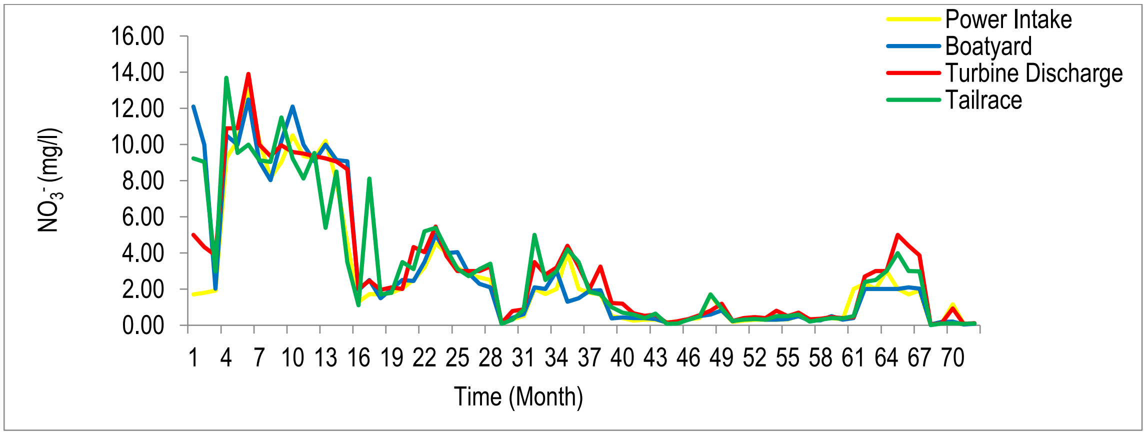

Figure 7: Monthly *NO_3^- concentration (mg/l) at selected stations*

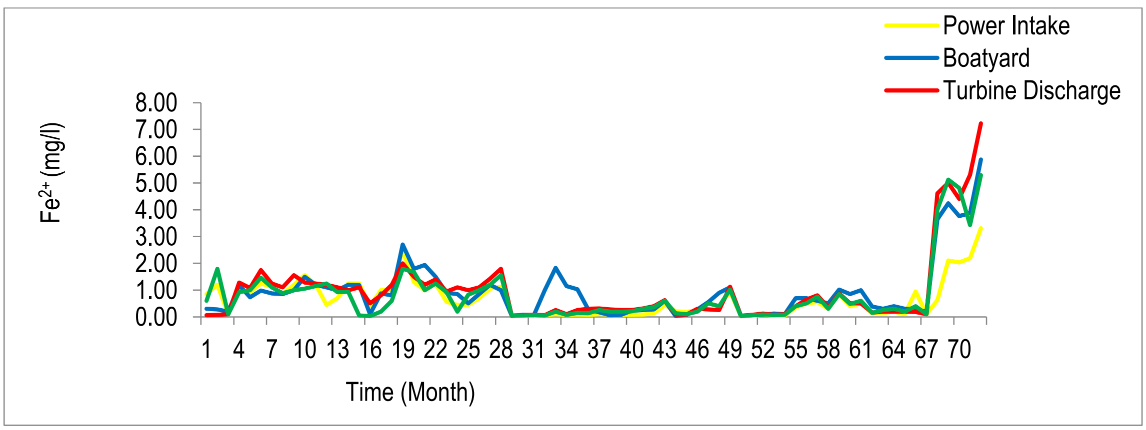

Figure 8: Monthly *Fe^{2+} concentration (mg/l) at selected stations*

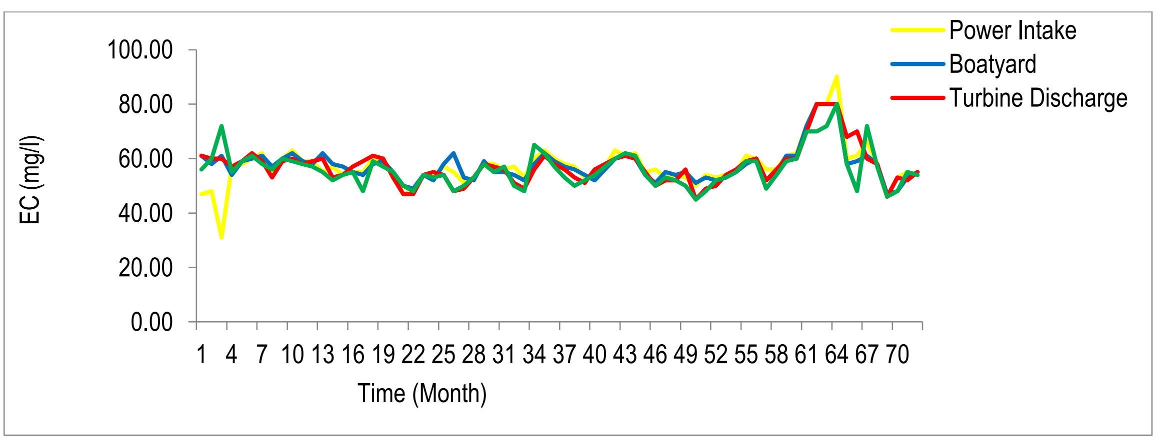

Figure 9: Monthly EC *concentration (mg/l) at selected stations*

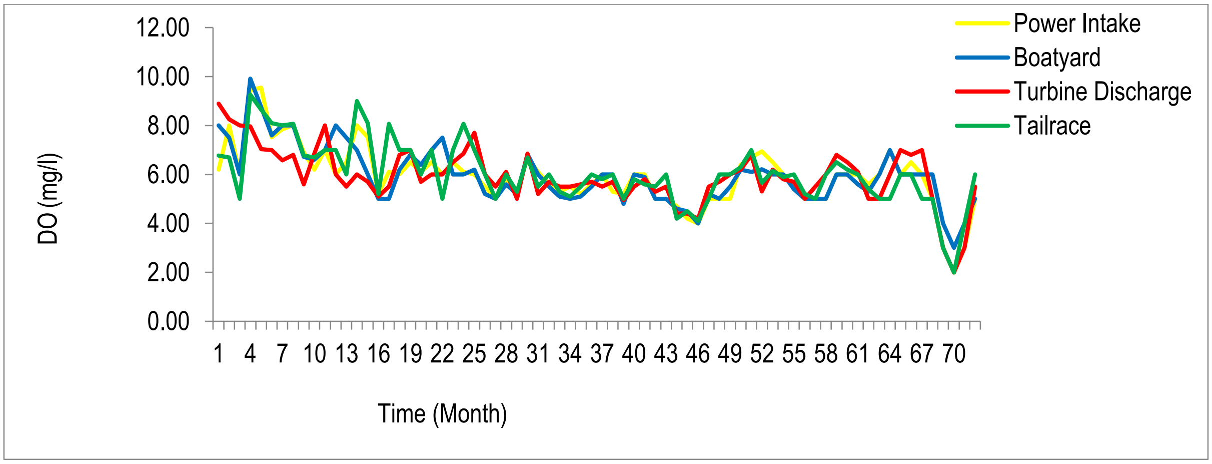

Figure 10: Monthly DO *concentration (mg/l) at selected stations*

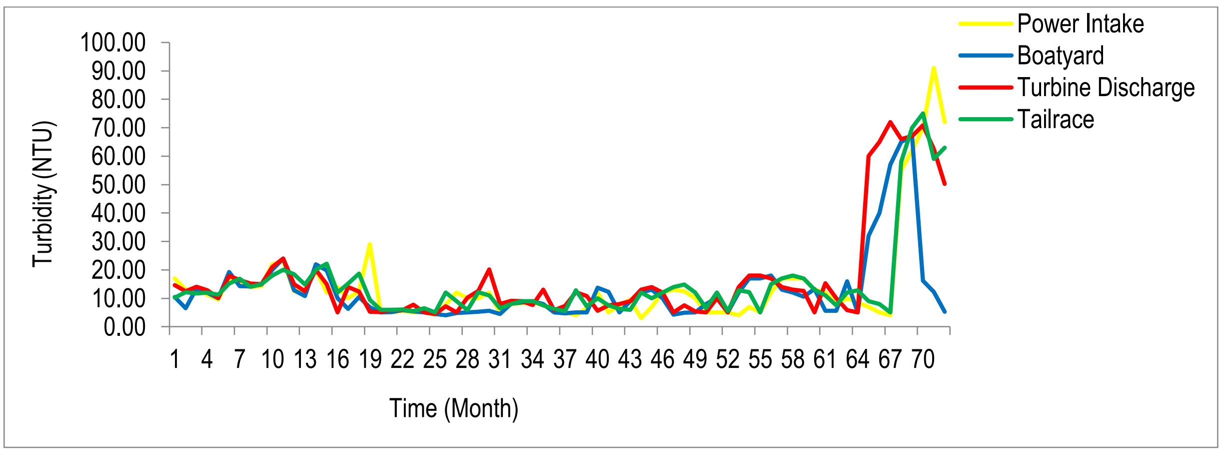

Figure 11: Turbidity *concentration (NTU) at selected stations*

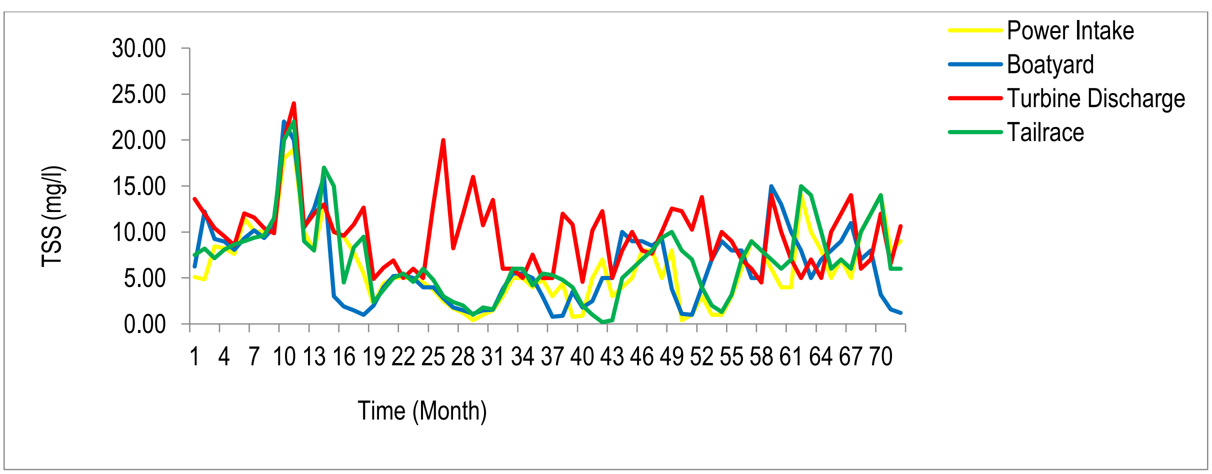

Figure 12: TSS *concentration (mg/l) at selected stations*

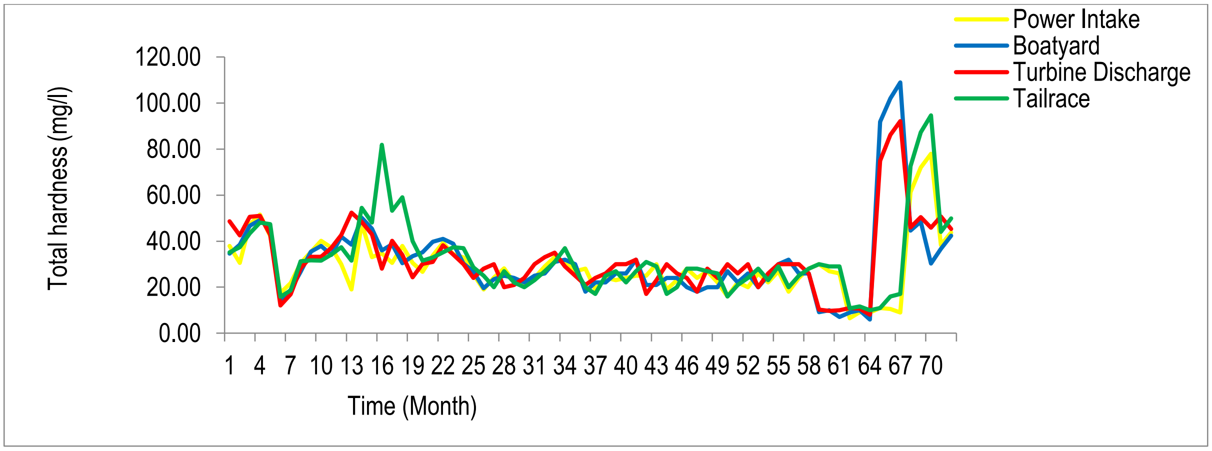

Figure 13: Total hardness *concentration (mg/l) at selected stations*

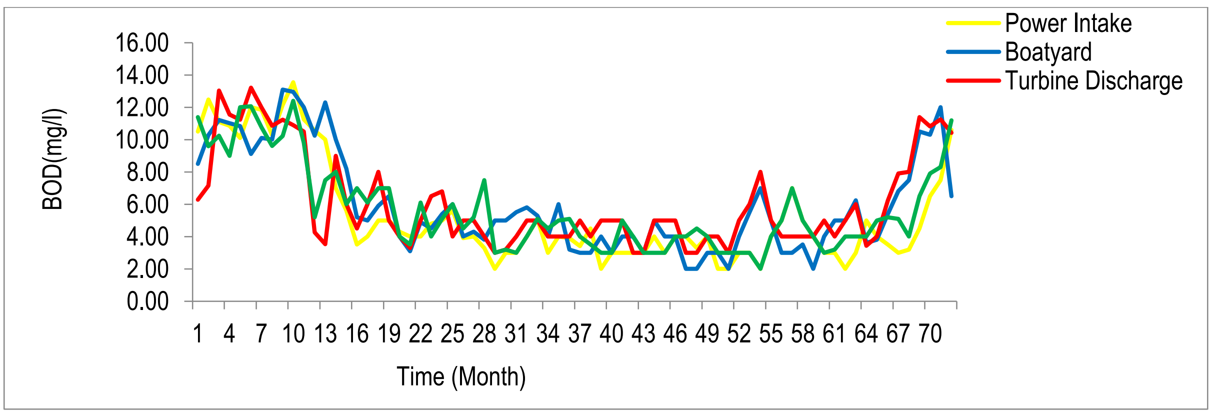

Figure 14: BOD *concentration (mg/l) at selected stations*

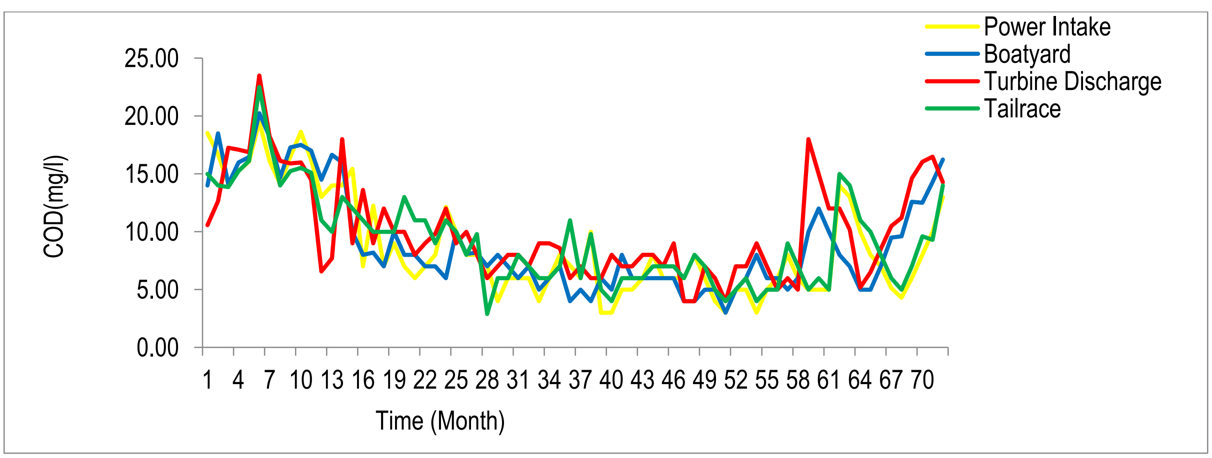

Figure 15: COD *concentration (mg/l) at selected stations*

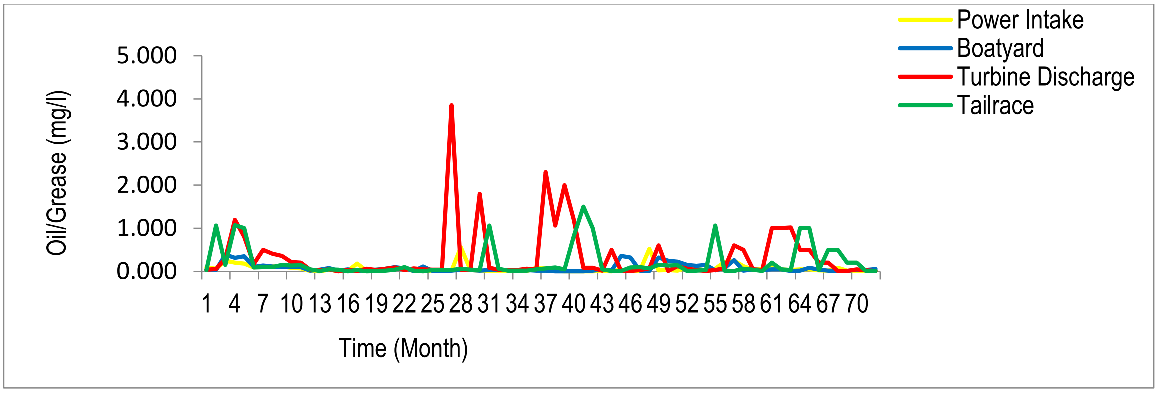

Figure 16: Oil/Grease concentration (mg/l) at selected stations

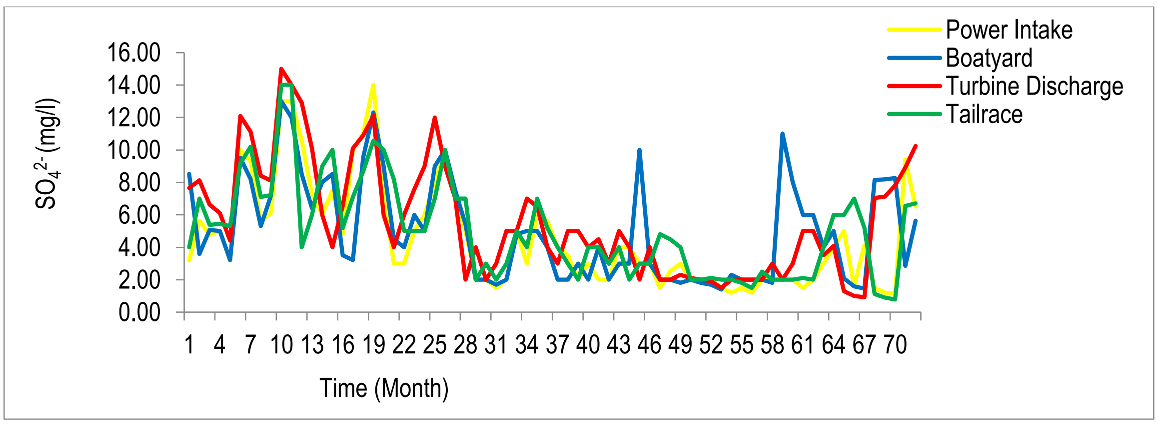

Figure 17: SO_4^{2-} concentration (mg/l) at selected stations

Table 4: Descriptive Statistics of Water Quality Parameters at Power Intake

Parameter	Min	Max	Mean	Median	Std Dev
pH	6.23	9.06	7.915	7.870	0.582
Temperature (°C)	27.00	36.1	29.6	30.176	1.933
Cl^- (mg/l)	0.06	39.00	6.00	7.1414	7.456
PO_4^{3-}	0.002	1.50	0.07	0.1462	0.221
NO_2^- (mg/l)	0.02	13.00	1.73	2.673	3.260
Fe^{2+} (mg/l)	0.03	3.31	0.45	0.657	0.663
EC (mg/l)	31.00	90.00	56.5	57.292	7.736
DO (mg/l)	2.00	9.55	6.00	5.914	1.240
Turbidity (NTU)	3.00	91.00	10.00	14.394	16.416
TSS (mg/l)	0.40	19.00	5.00	6.209	4.0007
Total hardness (mg/l)	6.50	78.00	27.00	28.909	12.726

BOD (mg/l)	2.00	13.55	4.00	5.329	3.162
COD (mg/l)	3.00	19.50	7.05	8.753	4.416
Oil/Grease (mg/l)	0.002	0.56	0.03	0.068	0.099
SO_4^{2-} (mg/l)	1.16	14.00	3.35	4.576	3.218

Table 5 : Descriptive Statistics of Water Quality Parameters at Boatyard

Parameter	Min	Max	Mean	Median	Std Dev
pH	6.35	9.14	7.97	7.910	0.558
Temperature (°C)	27.1	36.00	30.1	30.485	1.895
Cl^- (mg/l)	0.07	35.00	5.00	6.613	6.266
PO_4^{3-} (mg/l)	0.002	1.24	0.085	0.194	0.261
NO_2^- (mg/l)	0.04	12.5	1.93	3.010	3.722
Fe^{2+} (mg/l)	0.03	5.88	0.765	0.940	1.083
EC (mg/l)	47.00	80.00	57.00	57.486	6.242
DO (mg/l)	3.00	9.92	6.00	5.959	1.175
Turbidity (NTU)	4.00	67.00	10.005	12.831	12.433
TSS (mg/l)	0.80	22.00	5.24	6.380	4.475
Total hardness (mg/l)	6.00	108.92	26.9	31.524	17.973
BOD (mg/l)	2.00	13.10	5.00	5.985	3.061
COD (mg/l)	3.00	20.25	7.50	9.074	4.430
Oil/Grease (mg/l)	0.002	0.39	0.04	0.079	0.097
SO_4^{2-} (mg/l)	1.40	13.00	4.25	5.0349	3.131

Table 6 : Descriptive Statistics of Water Quality Parameters from Turbine Discharge

Parameter	Min	Max	Mean	Median	Std Dev
pH	6.00	9.30	7.80	7.729	0.552
Temperature (°C)	25.2	33.7	28.75	28.711	1.628
Cl^- (mg/l)	0.09	39.04	6.50	7.590	7.114
PO_4^{3-}(mg/l)	0.004	1.15	0.10	0.211	0.2450
NO_2^- (mg/l)	0.02	13.90	2.285	3.255	3.430

Fe^{2+} (mg/l)	0.04	7.23	0.50	0.958	1.334
EC (mg/l)	45.00	80.00	56.5	57.083	6.942
DO (mg/l)	2.00	8.89	5.75	5.912	1.148
Turbidity (NTU)	4.5	72.00	12.425	16.854	17.600
TSS (mg/l)	4.5	24.00	10.00	9.718	3.839
Total hardness (mg/l)	8.00	92.11	30.00	32.269	15.574
BOD (mg/l)	3.00	13.22	5.00	6.048	2.872
COD (mg/l)	4.00	23.50	9.00	10.049	4.237
Oil/Grease (mg/l)	0.004	3.85	0.06	0.346	0.640
SO_4^{2-} (mg/l)	0.92	15.00	5.00	5.620	3.479

Table 7 : Descriptive Statistics of Water Quality Parameters at Tailrace

Parameter	Min	Max	Mean	Median	Std Dev
pH	6.08	9.84	7.79	7.757	0.531
Temperature (°C)	25.40	32.80	28.9	28.965	1.615
Cl^- (mg/l)	0.08	39.00	6.00	7.760	7.405
PO_4^{3-} (mg/l)	0.002	1.06	0.08	0.194	0.229
NO_2^- (mg/l)	0.01	13.70	2.125	3.161	3.430
Fe^{2+} (mg/l)	0.03	5.29	0.44	0.833	1.139
EC (mg/l)	45.00	80.00	55.00	56.097	6.667
DO (mg/l)	2.00	9.26	6.00	6.037	1.277
Turbidity (NTU)	5.00	75.00	12.00	14.900	14.520
TSS (mg/l)	0.20	22.00	6.00	6.945	4.334
Total hardness (mg/l)	10.00	94.63	28.3	32.129	16.566
BOD (mg/l)	2.00	12.40	5.00	5.669	2.698
COD (mg/l)	2.90	22.50	8.50	9.221	3.977
Oil/Grease (mg/l)	0.002	1.50	0.05	0.210	0.359
SO_4^{2-} (mg/l)	0.79	14.00	4.65	5.003	2.990

Table 8 : Summary of Analysis of Variance (ANOVA) for Upstream Locations

Parameter		Sum of Square	Df	Mean of Square	F-value	Sig.
Temperature	Between Group	230.31	37	6.225	6.047	0.000*
	Within Group	35	34	1.029		
	Total	265.31	71			
Total Hardness	Between Group	11115.034	50	222.301	12.168	0.000*
	Within Group	383.656	21	18.269		
	Total	11498.69	71			
pH	Between Group	20.822	53	0.393	2.211	0.033
	Within Group	3.198	18	0.178		
	Total	24.02	71			
BOD	Between Group	656.583	40	16.415	9.509	0.000*
	Within Group	53.511	31	1.726		
	Total	710.094	71			
SO_4^{2-}	Between Group	637.89	40	15.947	5.084	0.000*
	Within Group	97.249	31	3.137		
	Total	735.139	71			
Total Suspended solid	Between Group	863.009	44	19.614	1.937	0.035
	Within Group	273.414	27	10.126		
	Total	1136.422	71			
Cl^-	Between Group	3862.244	31	124.589	58.767	0.000*
	Within Group	84.802	40	2.12		
	Total	3947.046	71			
COD	Between Group	1083.414	29	37.359	5.211	0.000*
	Within Group	301.118	42	7.17		
	Total	1384.532	71			
Fe^{2+}	Between Groups	28.424	40	0.711	7.956	0.000*
	Within Groups	2.769	31	0.089		
	Total	31.194	71			
NO_2^-	Between Group	643.855	46	13.997	3.16	0.001*
	Within Group	110.722	25	4.429		
	Total	754.577	71			
Oil/Grease	Between Group	0.214	29	0.007	0.635	0.99
	Within Group	0.489	42	0.012		
	Total	0.703	71			
EC	Between Group	2975.391	17	175.023	7.422	0.000*
	Within Group	1273.484	54	23.583		
	Total	4248.875	71			
PO_4^{3-}	Between Group	1.556	32	0.049	0.987	0.511
	Within Group	1.921	39	0.049		
	Total	3.477	71			
Turbidity	Between Group	18904.123	54	350.076	26.007	0.000*
	Within Group	228.831	17	13.461		
	Total	19132.954	71			
DO	Between Group	95.576	27	3.54	11.486	0.000*
	Within Group	13.561	44	0.308		
	Total	109.137	71			

* Significant at the 0.05 level

Table 9 : Summary of Analysis of Variance (ANOVA) for Downstream Locations

Parameter		Sum of Square	Df	Mean of Squar	F-value	Sig.
	Between Group	173.491	41	4.232	8.671	0.000*
Temperature	Within Group	14.641	30	0.488		
	Total	188.131	71			
	Between Group	11678.237	42	278.053	1.455	0.146
Total Hardness	Within Group	5542.12	29	191.108		
	Total	17220.357	71			
	Between Group	17.363	49	0.354	1.812	0.065
pH	Within Group	4.303	22	0.196		
	Total	21.666	71			
	Between Group	522.589	28	18.664	12.763	0.000*
BOD	Within Group	62.879	43	1.462		
	Total	585.469	71			
	Between Group	592.868	31	19.125	2.873	0.000*
SO_4^{2-}	Within Group	266.241	40	6.656		
	Total	859.108	71			
	Between Group	750.806	40	18.77	1.968	0.027
Total Suspended solid	Within Group	295.668	31	9.538		
	Total	1046.474	71			
	Between Group	3226.018	30	107.533	11.794	0.000*
Cl^-	Within Group	364.703	40	9.118		
	Total	3590.722	70			
	Between Group	841.05	23	36.567	4.048	0.000*
COD	Within Group	433.626	48	9.034		
	Total	1274.67	71			
	Between Groups	121.816	39	3.124	22.043	0.000*
Fe^{2+}	Within Groups	4.534	32	0.142		
	Total	126.35	71			
	Between Group	748.901	46	16.281	4.713	0.001*
NO_2^-	Within Group	86.358	25	3.454		
	Total	835.259	71			
	Between Group	7.178	20	0.359	0.836	0.662
Oil/Grease	Within Group	21.907	51	0.43		
	Total	29.085	71			
	Between Group	2458.095	19	129.373	6.983	0.000*
EC	Within Group	963.405	52	18.527		
	Total	3421.5	71			
	Between Group	3.369	28	0.12	4.904	0.000*
PO_4^{3-}	Within Group	1.055	43	0.025		
	Total	4.424	71			
	Between Group	15511.715	41	378.335	1.751	0.056
Turbidity	Within Group	6481.499	30	216.05		
	Total	21993.213	71			
	Between Group	69.578	29	2.399	4.19	0.000*
DO	Within Group	24.049	42	0.573		
	Total	93.627	71			

* Significant at the 0.05 level

Discussion of Results

The approaches adopted in this study have been used to assess the water quality of some African reservoirs (Mustapha, 2008). The mean pH varied between 6.00 to 9.14 while water temperature varied from 26.0 to 33.0 °C at the locations. Also, the values of pH were noticed to vary with temperature at the four stations as shown in Figures 3 and 4. 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 TSS concentration ranged between 20.63 to 28.94 mg/l. The mean turbidity of the water sample varied between 3.00 to 91.00 NTU. The water was turbid at the power intake and turbine discharge especially during the raining seasons as seen in Figure 11 this is as result of flooded inflow from the upstream tributaries. Turbidity trend was observed to vary uniformly with time until the middle of 2015 when it increased sharply at the stations. The trend of the TSS at the turbine discharge was observed to be higher compared to other sampling station (Figure 12) this is due to turbulence of water at the turbine discharge as a result of hydropower reservoir operation. The mean EC ranged between 45.00 and 90.00 µS/cm at the stations and found to be within the standard permissible by Nigeria and WHO. The mean SO_4^{2-} concentration ranged between 0.79 to 15.00 mg/l and mean NO_3^- concentration ranged between 0.02 to 13.9.0 mg/l. The SO_4^{2-} concentration was high between 2010 to 2011 at the selected locations while it was low in the year 2012. This is due to the excess runoff into the reservoir during the period. The mean PO_4^{3-} ranged between 0.002 to 1.50 mg/l with higher values obtained at the reservoir upstream (power intake and boatyard). The high concentration of SO_4^{2-}, PO_4^{3-} and NO_3^- in the reservoir can lead to eutrophication thereby reducing the reservoir capacity. The mean value of Fe^{2+} varied between 0.03 to 7.23 mg/l with the highest values obtained at the turbine discharge and tailrace while the least was obtained at the power intake and boatyard respectively as shown in Figure 8. The likely causes of increasing trend of Fe^{2+} at the turbine discharge and tailrace is as a result of wear and tear due to the running of the turbines for power generation.

The mean DO, BOD and COD concentrations were observed to vary between 2.00 to 9.92, 2.00 to 13.55 and 3.00 to 23.50 respectively. The concentration of BOD and COD were observed to follow similar patterns but COD was a little higher than BOD at the stations as presented in Figures 14 and 15; this confirmed the presence of non-biodegradable substances in the reservoir. The DO concentration was found to be highest at the boatyard followed by power intake, tailrace and at turbine discharge respectively. The slight reduction in the DO at turbine discharge is due to turbulence of water as a result of hydropower reservoir operation. The DO value at all the sampling locations were found to be higher than the 4.0 mg/l required for fish and aquatic survival (Mohan et al., 2013) and Nigeria freshwater and ecological standard as provided in (FRN, 2011). Low DO was observed between September to November, 2015 at the power intake and at turbine discharge, and also in October, 2015 at boatyard and September and October, 2015 at the tailrace. The implication of the low DO at some locations is that it will affect survival of fish and other aquatic lives at these locations. Though the period (3 months) in which the low DO was observed was not significant compared to the entire period (72 months) of sampling at the locations. The concentration of the COD is higher than that of the BOD at all the sampling locations, this is as a result of the presence of higher chemical compounds than the biodegradable compounds in the water. The concentration of oil/grease was obtained ranged between 0.002 to 3.85 mg/l at all the sampling locations. The highest value was obtained at the turbine discharge; this is due to oil/grease that spill into the water due to the operation turbine/generator.

The results of the monthly variation revealed that all the parameters varied with time at the upstream and downstream ends of the reservoir. Results also revealed that there are more statistically significant differences in the water quality parameters such as: PO_4^{3-} and oil/grease concentration at the upstream locations. Whereas water quality such as: total hardness, pH, turbidity and oil/grease concentration were more statistically significant at the downstream locations of the reservoir. Variation in the results of the physico-chemical characteristics was influenced by the seasonal fluctuation in runoff in the study area (Ajibade et al. 2008) and also due to cattle rearing, farming and fishing activities by the people living around the lake.

The results obtained were compared with the Nigeria and WHO water quality standards for drinking and aquatic *habitats, the comparison revealed that many of the water quality parameters are within the limits permissible by the standards. Parameters such as Fe^{2+} and turbidity were found to be higher than the permissible standards at all the selected locations. TSS was found to be high at boatyard, turbine discharge and tailrace. DO concentration was found to be within the established water quality standards and will favour growth and well being of aquatic habitat.*

4. CONCLUSION

Data on water quality for four sampling locations were obtained from the environmental section of the Kainji hydropower station for a period of six years (January, 2010 to December, 2015). The data was plotted to establishing any trend and statistical analyses (descriptive and ANOVA) were carried out to reveal significant difference between water quality parameters measured at upstream and downstream ends of the reservoir. The results showed that all the parameters varied with time at the upstream and downstream ends of the reservoir. Results also revealed that there are more statistically significant differences in the water quality parameters such as PO_4^{3-} and oil/grease at the upstream locations of the reservoir. Whereas water quality such as total hardness, pH, turbidity and oil/grease concentration were more statistically significant at the downstream locations of the reservoir. Comparison the results with the Nigeria and WHO water quality standards for drinking and aquatic habitats revealed that most water quality parameters were found within the permissible limits.

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