International Scholars Journals

African Journal of Water Conservation and Sustainability ISSN: 2375-0936 Vol. 8 (2), pp. 001-013, February, 2020. Available online at www.internationalscholarsjournals.org © International Scholars Journals

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Full Length Research Paper

Water quality parameters in the major rivers of Kainji Lake National Park, Nigeria

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Accepted 21 November, 2019

This study examined the physical and chemical properties of waters of the major rivers in Kainji Lake National Park for a period of twenty four months. The implications on the public health and aquatic organisms were also determined. The major rivers include; Oli, Manyera, Nuwanzurugi, and Poto. River Oli was sampled at the hippo pools at Kilometers 8 and 12 and two animal drinking points. Other rivers were sampled at two animal drinking points. Standard methods were used to monitor the physical and chemical parameters. Physical parameters that were considered include; temperature, colour, total suspended solid and turbidity. The chemical parameters include hardness, chemical oxygen demand (COD), biological oxygen demand (BOD), dissolved oxygen (DO), iron, manganese, calcium, chloride, nitrate, pH, phosphate, ammonium and electrical conductivity. Seasonal variation appeared to have influence on the physical and chemical parameters. Statistical analysis shows that there were significant differences between sampling points and locations mean values for the different physical and chemical parameters examined. The presence of hippopotamus affected some parameters such as BOD, DO, COD, pH and turbidity significantly. The BOD and COD were strongly, significantly correlated and positively correlated ($r = 0.757$, $P \leq 0.05$). The ammonium and nitrite contents are not significantly correlated but positively and weakly correlated ($P<0.05$, $r = 0.141$) between the dry seasons and wet seasons mean values.

Key words: Water quality, Oli River, River Nuwanzurugi, River Manyera, River Poto.

INTRODUCTION

Kainji National Park was the first National Park established in Nigeria by Decree No 46 in 1979. The Park covers an area of 5,830 sq Km. The park is located between 90 50’N and 100 12’N, 40 00’E and 40 34’E. There is a distinct rainy season from April to October with maximum rain in august and September. Generally the main daily temperatures are high. The lowest daily temperatures are recorded in December and January during the Hammattan, while the highest was recorded in April and May before the onset of the rainy season. The services provided by the Park include; Wilderness experience, Park viewing, Bird Watching, Lake crushing, Historical/cultural site viewing, Sport fishing and Recreation.

The major rivers in the Park support the lives of aquatic and terrestrial wildlife species and domestic animals. The farmers and their families in the villages that share boundaries with the Park also depend on the water both in the dry and wet seasons. There is little or no information on the qualities of the water in the Park Rivers. As a result, this research work examined the physicochemical parameters of these waters. Information provided in this study will assist in the better management of water resources in the park.

Communities that use untreated supplies such as most villages in the developing countries face more serious problems, if there is a chemical problem associated with their water sources. If they lack a necessary chemical, it will be extremely difficult to add some chemical, and since

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Figure 1. Map of Nigeria showing the approximate location of Kainji lake National park and game reserves in relation to the vegetation zones in Nigeria.

the water is untreated, it is impossible to remove harm-ful chemical pollutants. In addition chemical water pollu- tion may leads to an unpleasant taste or appearance and this may cause people to abandon certain sources in favour of others which are more acceptable to them. Water chemistry may be considered under 3 headings: i). The essence of necessary chemical, ii) . The excess of harmful organics. iii). The excess of harmful inorganic (Sandy and Richard, 1995).

The modern society or communities are concerned about the quality of their water resources and are confronted by a number of problems threatening these resources. One obstacle in accessing the magnitude of this problem is difficulty of defining acceptable water quality for specific uses. Boyd (1981), defined water quality as any characteristics of water, whether physical, chemical and biological, that affect the survival, repro-duction, growth and management of fish. However more stringent control of water contaminants and higher quality standards apply to water intended for human consum-ption than for other uses.

METHOD

Figures 1 and 2 show the maps of the study area.

Sampling and Analysis

Four sampling points were sited for River Oli, these include; Hippo pool kilometer 8 and Hippo pool kilometer 12, Animal drinking point 1 and Animal drinking point 2. Two sampling points were sited for River Manyera, these include; Animal drinking point 1 and Animal drinking point 2. Two sampling points were also sited for River Nuwanzurugi. They are Animal drinking point 1 and Animal drinking point 2. Poto River was also sampled at Animal drinking point 1 and Animal drinking point 2. Sampling depth was 20cm. Rivers were sampled during the wet and dry seasons for two years consecutively (4^{th} August for wet seasons and 14^{th} January for dry season samplings). Sampling bottles of 1 litre capacity were used. Samples were taken in triplicates and average figures were recorded.

Study area: Kainji lake national park

Samples were analyzed for physical and chemical parameters. These include chlorine, hardness, electrical conductivity, nitrite,

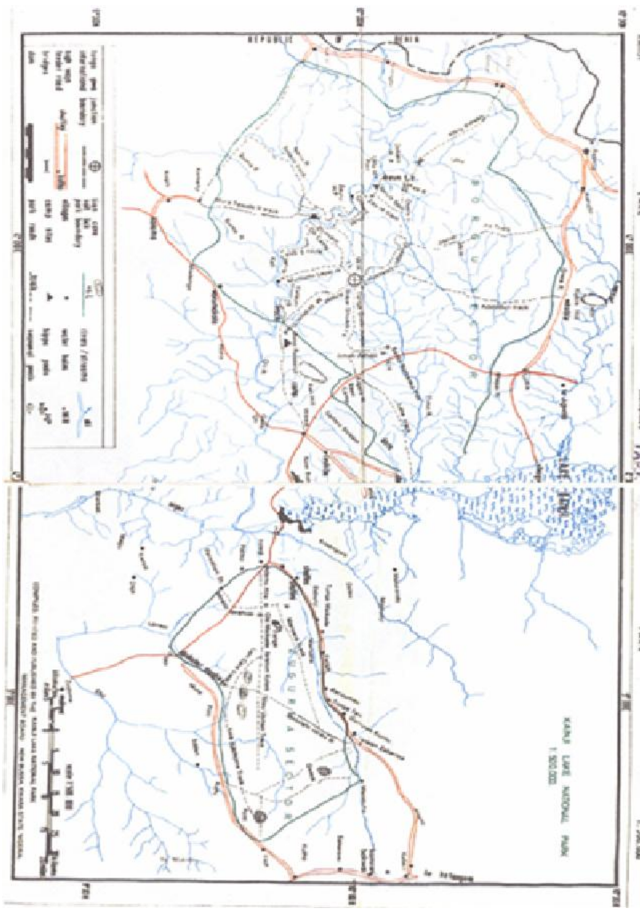

Figure 2. Map of Kainji lake national park.

BOD, COD, DO, Ph, Ca, Mn, ammonium nitrate, Fe and turbidity, according to methods described by Boyd (1981) and APHA (1975) Pearson correlation coefficient and one tailed t-test were used for statistical analysis

RESULTS

Tables 1 - 4 show the physicochemical characterization of aquatic media of Kainji Lake National Park for two years 2005 and 2006. While Table 5 and 6 show the mean values. In 2005, during the wet season the chlorine content, hardiness, the COD, the BOD, The pH, calcium ion content, the manganese ion content, the ammonium content, iron content, nitrate, DO, phosphate, turbidity and temperature across the sampling points were statistically and significantly varying (P<0.05). During the 2005 dry season, the chlorine content, Hardness, Electrical conductivity, the nitrite, the BOD, COD, the pH, calcium ion content, manganese ion, ammonium content, iron ion content, the nitrate, the DO, the phosphate content, the turbidity and temperature across the sampling points were statistically and significantly varying (P≤ 0.05). In 2006 wet season the chlorine content, hardness, Elec-trical conductivity, nitrite, COD, BOD, pH, calcium ion content, manganese ion content, ammonium content, iron ion content, The nitrate content, the DO, phosphate content, turbidity and temperature across various sampling points were statistically and significantly varying (P<0.05). During the 2006 dry season, the chlorine content, hardness, Electrical conductivity, nitrite content, COD, BOD, pH, calcium ion content, manganese ion content, ammonium content, nitrate content, DO, phosphate content, turbidity and temperature across various sampling points were statistically and significantly varying (P<0.05).

In 2005, the wet season variations of the examined parameters according to the sampling locations are as follows: the chlorine content, hardness, Electrical conductivity, nitrite content, COD, BOD, pH, calcium ion content, manganese ion content, ammonium content, iron ion content, nitrate content, DO, phosphate content, nitrite content, COD, BOD, pH, The calcium ion content, manganese ion content, ammonium content, iron ion content, nitrate content, DO across, phosphate content, turbidity, temperature across various sampling locations were statistically and significantly varying (P<0.05).

In 2006 wet season the chlorine content, hardness, Electrical conductivity, COD, BOD, pH, calcium ion content, manganese ion content, ammonium content, iron ion content, nitrate content, DO, phosphate content, turbidity across, temperature. During the 2006 dry season, the chlorine content, hardness, Electrical conductivity, nitrite content, COD, BOD, pH, calcium ion content, manganese ion content, ammonium content, iron ion content, nitrate content, DO, phosphate content, turbidity, temperature across various sampling locations were statistically and significantly varying (P≤0.05).

In 2005, the chlorine content (mean = 14.78) was statistically and significantly varying [P<0.05] greater than raining season (mean = 12.53). The dry season hardness (mean = 36.59) was not statistically and significantly varying (P>0.05) lesser than raining season of the same year (mean = 39.71). Electrical conductivity in dry season (mean = 0.012) was statistically and significantly varying (P>0.05) lesser than raining season (mean = 0.045). The nitrite content across dry season (mean = 0.0310) was not statistically and significantly varying (P< 0.05) lesser than the raining season (mean = 0.0427). The COD in the dry season (mean = 8.562) was not statistically and significantly varying (P>0.05) lesser than the raining season (mean = 7.571) . The BOD in the dry season (mean = 11.242) was not statistically and significantly varying (P < 0.05) lesser than the raining season (mean = 10.515). The pH in the dry season (mean = 6.03) was statistically and significantly varying (P < 0.05) lesser than the raining season (mean = 7.38). The calcium ion content in the dry season (mean = 15.805) was statistically and significantly varying (P>0.05) lesser than the raining season (mean = 20.945). The manganese ion content in the dry season (mean = 0.142) was statistically and significantly varying (P>0.05) lesser than the raining season (mean = 0.329). The ammonium content in the dry season (mean = 0.13)

Table 1. Physiochemical characterization of aquatic media of Kainji Lake National Park in dry seasons 2005.

Code	Name/Location	Cl^- ppm	Hardness ppm	ms/cm	Nitrite ppm	COD mg/l	BOD mg/l	pH	Ca^{2+} ppm	Mn^{2+} ppm	NH_4 ppm	Fe ppm	NO_3 ppm	DO mg/l	PO_4 ppm	Colour(TCU)	Turbidity(cm)	(°C)	(mg/l)
1	River Oli Animal Drinking Point 1	20.0	68.0	0.02	0.04	3.12	10.20	6.2	30.02	0.03	0.20	2.25	0.00	5.2	0.2	Colourless 9	120	30.0	0.06
2	River Oli Animal Drinking Point 2	8.0	64.0	0.02	0.02	6.05	8.00	6.3	23.96	0.15	0.00	1.94	0.30	5.4	0.2	Colourless 5	118	30.0	0.05
3	River Manyera Animal Drinking Point 1	16.0	20.0	0.01	0.03	8.19	6.61	6.4	4.41	0.22	0.00	2.18	0.00	8.4	0.2	Colourless 4	105	28.2	0.04
4	River Manyera Animal Drinking Point 2	14.6	23.2	0.01	0.02	7.65	4.65	6.2	5.65	0.21	0.00	2.34	0.06	7.6	0.2	Colourless 6	112	29.6	0.05
5	River Nuwanzurugi Animal Drinking Point 1	12.0	24.0	0.01	0.10	14.06	15.08	6.1	10.26	0.07	0.00	2.48	0.00	2.4	0.3	Brownish 35	80	23.0	1.30
6	River Nuwanzurugi Animal Drinking Point 2	13.3	23.8	0.01	0.06	12.04	13.64	6.0	12.52	0.06	0.00	2.62	0.02	3.8	0.2	Light brown 31	82	22.6	1.26
7	River Poto 1	14.4	53.22	0.01	0.06	17.22	23.70	5.9	16.34	0.07	0.80	5.54	3.20	7.2	0.6	Brown 42	70	24.4	1.40
8	River Poto 2	17.6	49.00	0.01	0.02	10.03	18.02	5.7	18.40	0.17	0.20	3.26	4.50	7.0	1.0	Light brown 29	68	25.0	0.23
9	River Oli Hippo Pool Km 8	10.0	18.68	0.01	0.00	4.26	5.41	5.7	13.64	0.25	0.00	1.89	0.20	5.6	0.1	Colourless 5	60	28.6	0.90
10	River Oli Hippo Pool Km 12	19.9	22.00	0.01	0.00	3.00	7.11	5.8	22.85	0.19	0.10	1.77	0.30	5.8	0.1	Colourless 4	68	28.4	0.08

Table 2. Physiochemical characterization of aquatic media of Kainji Lake National Park in wet seasons 2005.

Code	Name/Location	Cl^- ppm	Hardnessppm	ElectricalConductivityms/cm	Nitriteppm	CODmg/l	BODmg/l	pH	Ca^{2+} ppm	Mn^{2+} ppm	NH_4^+ ppm	Fe^{3+} ppm	NO_3^- ppm	DOmg/l	PO_4^- ppm	Colour(TCU)	Turbidity(cm)	Temperature (°C)	
1	River Oli Animal Drinking Point 1	15.6	71.8	0.07	0.06	2.34	11.16	7.3	43.00	0.74	0.63	7.14	0.15	6.6	0.6	Colourless 4	80	23	0.01
2	River Oli Animal Drinking Point 2	6.4	68.5	0.05	0.04	5.43	9.32	7.2	38.00	0.28	0.07	4.86	0.72	7.5	0.4	Colourless 4	80	25	0.03
3	River Manyera Animal Drinking Point 1	14.8	23.8	0.01	0.03	9.03	5.02	8.4	11.51	0.38	0.08	6.88	0.12	7.4	0.6	Colourless 5	90	21	0.02
4	River Manyera Animal Drinking Point 2	11.2	34.2	0.04	0.03	4.23	4.32	8.2	10.20	0.25	0.07	6.57	0.14	6.4	0.5	Colourless 6	86	21	0.02
5	River Nuwanzurugi Animal Drinking Point 1	10.6	23.5	0.03	0.04	4.67	7.4	7.8	13.60	0.38	0.06	5.33	0.12	7.2	0.4	Light brown 8	70	23	0.01
6	River Nuwanzurugi Animal Drinking Point 2	10.6	25.8	0.03	0.05	13.85	15.01	7.3	14.32	0.44	0.05	4.26	0.16	3.6	0.5	Brownish 9	75	25	0.04
7	River Poto 1	14.8	46.8	0.05	0.06	15.67	20.02	7.4	13.65	0.12	1.42	6.35	5.11	8.8	0.9	Brownish 7	65	24	0.04
8	River Poto 2	16.3	47.5	0.08	0.03	9.06	19.07	6.8	23.05	0.31	3.65	6.53	4.23	9.3	1.7	Light brown 8	80	23	0.03
9	River Oli Hippo Pool Km 8	9.20	29.6	0.04	0.03	3.48	5.36	6.6	18.06	0.16	0.10	4.52	1.35	6.0	0.9	Colourless 5	60	26	0.03
10	River Oli Hippo Pool Km 12	15.8	25.6	0.05	0.05	7.95	8.47	6.8	24.06	0.23	1.04	7.63	1.36	7.3	1.0	Colourless 4	60	26	0.01

Table 3. Physicochemical characterization of aquatic media of Kainji Lake National Park in dry seasons 2006.

Code	Name/Location	Cl^- ppm	Hardness ppm	ms/cm	Nitriteppm	CODmg/l	BODmg/l	pH	Ca^{2+} ppm	Mn^{2+} ppm	NH_4^+ ppm	Fe^{3+} ppm	NO_3^- ppm	DOmg/l	PO_4^- ppm	Colour(TCU)	Turbidity(cm)	C)	(mg/l)
1	River Oli Animal Drinking Point 1	18.6	72.40	0.03	0.06	3.41	11.16	6.4	30.32	0.04	0.25	2.54	0.01	5.6	0.3	Colourless 8	105	31	0.07
2	River Oli Animal Drinking Point 2	8.4	68.00	0.04	0.03	6.50	9.20	6.2	26.39	0.12	0.01	2.40	0.28	5.8	0.2	Colourless 6	120	31.5	0.06
3	River Manyera Animal Drinking Point 1	15.6	23.30	0.02	0.02	9.18	6.58	6.3	5.14	0.31	0.02	3.21	0.00	6.8	0.3	Colourless 3	90	30	0.03
4	River Manyera Animal Drinking Point 2	13.8	25.00	0.02	0.02	7.32	6.45	6.2	6.34	0.32	0.45	3.40	0.04	6.5	0.2	Colouless 4	87	30.3	0.06
5	River Nuwanzurugi Animal Drinking Point 1	11.3	23.45	0.03	0.04	8.43	7.43	6.0	10.34	0.14	0.33	2.45	0.43	6.3	0.3	Brown 38	97	25.4	0.04
6	River Nuwanzurugi Animal Drinking Point 2	12.8	21.80	0.01	0.09	15.02	15.31	6.0	10.62	0.30	0.00	2.84	0.08	2.8	0.2	Light Brown 32	107	23	1.38
7	River Poto 1	15.2	50.32	0.03	0.08	16.35	24.32	6.0	15.46	0.06	0.78	5.35	3.18	7.0	0.5	Reddish 46	83	25	1.32
8	River Poto 2	18.7	48.76	0.01	0.02	11.02	17.92	5.8	18.6	0.18	0.16	2.87	4.32	7.2	1.0	Yellowish 28	87	23	0.32
9	River Oli Hippo Pool Km 8	10.2	19.21	0.02	0.01	4.20	4.85	5.6	14.36	0.22	0.02	2.01	0.18	5.8	0.2	Colourless 7	88	27	0.85
10	River Oli Hippo Pool Km 12	18.7	21.30	0.03	0.01	2.86	7.38	5.7	25.28	0.17	0.09	1.67	0.28	5.6	0.1	Colourless 7	85	27.5	0.06

Table 4. Physicochemical characterization of aquatic media of Kainji Lake National Park in wet seasons 2006.

Code	Name/Location	Cl ppm	Hardness ppm	Electrical Conductivity ms/cm	Nitrite ppm	COD mg/l	BOD mg/l	pH	Ca ppm	Mn ppm	NH_4 ppm	Fe ppm	NO_3 ppm	DO mg/l	PO_4 ppm	Colour (TCU)	Turbidity(cm)	Temperature (C)	Total suspended solid (mg/l)
1	River Oli Animal Drinking Point 1	15.4	72.6	0.05	0.08	2.14	10.61	7.5	32.10	0.13	0.53	3.34	0.42	6.3	0.4	Colourless 4	21.26	23	0.01
2	River Oli Animal Drinking Point 2	6.5	69.0	0.13	0.04	5.32	9.41	7.0	26.20	0.13	0.04	2.04	0.31	7.4	0.3	Colourless 3	8.43	24	0.05
3	River Manyera Animal Drinking Point 1	14.2	24.8	0.06	0.03	8.92	4.82	8.5	10.12	0.12	0.03	3.12	0.00	7.6	0.5	Colourless 5	7.82	23	0.02
4	River Manyera Animal Drinking Point 2	13.2	22.5	0.05	0.04	7.64	5.43	7.4	11.65	0.11	0.13	1.24	0.00	7.2	0.6	Colourless 5	8.65	24	0.04
5	River Nuwanzurugi Animal Drinking Point 1	11.4	32.6	0.06	0.05	14.22	10.20	8.2	13.56	0.14	0.07	3.65	0.27	3.7	0.4	Brown 7	30.00	24	0.05
6	River Nuwanzurugi Animal Drinking Point 2	10.8	26.5	0.03	0.06	13.13	14.64	7.4	12.23	0.11	0.02	4.52	0.17	3.5	0.4	Brownish Yellow 8	28.9	26	0.07
7	River Poto 1	14.3	47.2	0.04	0.05	10.04	15.30	6.9	14.36	0.18	0.39	3.17	0.28	9.5	0.8	Greenish brown 6	33.43	25	0.01
8	River Poto 2	16.0	46.6	0.02	0.01	9.14	16.80	7.2	22.41	0.15	0.62	3.72	0.23	9.3	1.8	Light brown 8	16.72	26	0.05
9	River Oli Hippo Pool Km 8	9.8	28.8	0.03	0.00	3.56	3.14	6.9	18.22	0.16	0.00	1.04	0.31	6.2	0.8	Colourless 4	4.63	22	0.02
10	River Oli Hippo Pool Km 12	15.8	25.3	0.06	0.02	1.21	8.25	7.2	23.06	0.18	0.02	7.16	0.42	7.2	0.6	Colourless 5	4.93	26	0.02

Table 5. Mean values of the physicochemical parameters in 2005.

Parameters	Mean Values ± Std. Deviation	
	Dry seasons (2005)	Wet Seasons(2005)
Cl^- ppm	14.58 ± 3.76	12.53 ± 3.20
Hardness ppm	36.59 ± 18.65	39.71 ± 17.35
Electrical Conductivity ms/cm	0.012 ± 0.004	0.045 ± 0.02
Nitrite ppm	0.035 ± 0.029	0.042±0.012
COD mg/l	8.562 ± 4.54	7.571 ± 4.22
BOD mg/l	11.242 ± 5.90	10.515 ± 5.43
PH	6.03 ± 0.24	7.38 ± 0.57
Ca^{2+} ppm	15.805 ± 7.77	20.945 ± 10.75
Mn^{2+} ppm	0.142 ± 0.074	0.329 ± 0.17
NH_4^+ ppm	0.13 ± 0.24	0.717 ± 1.08
Fe^{3+} ppm	2.627 ± 1.05	6.007 ± 1.11
NO_3^- ppm	0.858 ± 1.53	1.346 ± 1.74
DO mg/l	5.84 ± 1.72	7.01 ± 1.49
PO_4^- ppm	0.31 ± 0.27	0.75 ± 0.38
Turbidity (cm)	88.3 ± 21.9	74.6 ± 9.97
Temperature (^oC)	26.98 ± 2.77	23.7 ± 1.73
Total suspended solid (mg/l)	0.537 ± 0.57	0.024 ± 0.01

Table 6. Mean values of the physicochemical parameters in 2006.

Parameters	Mean Values ± Std. Deviation	
	Dry seasons (2006)	Wet Seasons(2006)
Cl^- ppm	14.33 ± 3.50	12.74 ± 2.92
Hardness ppm	37.35 ± 19.59	39.59 ± 17.64
Electrical Conductivity ms/cm	0.024 ± 0.009	0.053 ± 0.03
Nitrite ppm	0.038 ± 0.027	0.038 ± 0.022
COD mg/l	8.429 ± 4.39	7.532 ± 4.20
BOD mg/l	11.06 ± 5.94	9.86 ± 4.41
PH	6.02 ± 0.25	7.42 ± 0.51
Ca^{2+} ppm	16.285 ± 8.24	18.391 ± 6.91
Mn^{2+} ppm	0.186 ± 0.096	0.141 ± 0.02
NH_4^+ ppm	0.211 ± 0.24	0.185 ± 0.22
Fe^{3+} ppm	2.874 ± 0.96	3.30 ± 1.66
NO_3^- ppm	0.88 ± 1.46	0.241 ± 0.14
DO mg/l	5.94 ± 1.18	6.79 ± 1.90
PO_4^- ppm	0.33 ± 0.25	0.66 ± 0.41
Turbidity (cm)	94.9 ± 11.48	16.447 ± 10.59
Temperature (^oC)	27.37 ± 3.06	24.3 ± 1.34
Total suspended solid (mg/l)	0.419 ± 0.52	0.034 ± 0.02

was statistically and significantly varying (P<0.05) lesser than the raining season (mean = 0.717). The iron ion content in the dry season (mean = 2.627) was statistically and significantly varying [P<0.05] lesser than the raining season (mean = 6.0403). The nitrate content in the dry season (mean = 0.858) was not statistically and significantly varying (P<0.05) lesser than the raining season (mean = 1.346). The DO in the dry season (mean = 5.84) was statistically and significantly varying (P<0.05) lesser than the raining season (mean = 7.01). The phosphate content in the dry season (mean = 0.13) was statistically and significantly varying (P<0.05_ lesser than the raining season (mean = 0.729). The turbidity in the dry season (mean = 53.4) was statistically and significantly varying (P<0.05) greater than the raining season (mean = 38.6). The temperature in the dry season (mean = 26.98) was statistically and significantly varying ($P<0.05$) greater than the raining season (mean = 23.7).

In 2006, the chlorine content in the dry season (mean = 14.33) was not statistically and significantly varying ($P<0.05$) greater than raining season (mean = 12.74). The dry season hardness (mean = 37.354) was not statistically and significantly varying ($P>0.05$) lesser than raining season of the same year (mean = 39.59). Electrical conductivity in dry season (mean = 0.025) was statistically and significantly varying ($P>0.05$) lesser than raining season (mean = 0.053). The nitrite content across dry season (mean = 0.0380) was not statistically and significant ($P< 0.05$) lesser than the raining season (mean = 0.0383). The COD in the dry season (mean = 8.3357) was not statistically and significantly varying (P>0.050 higher than the raining season (mean = 7.5327). The BOD in the dry season (mean = 11.06) was not statistically and significantly ($P < 0.05$) higher than the raining season (mean = 9.86). The pH in the dry season (mean = 6.02) was statis-tically and significantly varying [$P < 0.05$] lesser than the raining season (mean = 7.2867). The calcium ion con-tent in the dry season (mean = 16.285) was statistically and significantly varying ($P>0.05$) lesser than the raining season (mean = 18.391). The manganese ion content in the dry season (mean = 0.186) was statis-tically and significantly varying ($P>0.05$) lesser than the raining season (mean = 0.141). The ammonium content in the dry season (mean = 0.2113) was statistically and significantly varying ($P<0.05$) lesser than the raining season (mean = 0.1853). The iron ion content in the dry season (mean = 2.874) was statistically and signify-cantly varying ($P<0.05$) lesser than the raining season (mean = 3.30). The nitrate content in the dry season (mean = 0.8803) was not statistically and significantly varying ($P<0.05$) greater than the raining season (mean = 0.2447). The DO in the dry season (mean = 5.94) was statistically and significantly varying ($P<0.05$) lesser than the raining season (mean = 6.79). The phosphate content in the dry season (mean = 0.3) was statistically and significantly varying ($P<0.05$) lesser than the raining season (mean = 0.66). The turbidity in the dry season (mean = 94.9) was statistically and significantly varying [$P<0.05$] greater than the raining season (mean = 53.6). The temperature in the dry season (mean = 36.0) was statistically and significantly varying ($P<0.05$) greater than the raining season (mean = 24.3).

Effects of hippopotamus

In the year 2005 dry and wet seasons, the presence of hippopotamus brought about no significant difference in chlorine content, electrical conductivity, nitrite content, ammonia, iron, nitrate, phosphate and temperature ($P<0.05$) between the different locations but brought about significant difference in the hardness, BOD, COD, pH, calcium content, manganese, DO and turbidity. In the year 2006 dry and wet seasons, the presence of hippopotamus brought about the same effects as in 2005 except that there were no significant differences in ammonia content.

Relationship between COD and BOD

The COD and BOD are strongly and significantly correlated and positively correlated IP<0.05; r = 0.757).

Relationship between ammonia and nitrite

The ammonium content and nitrite are not significantly correlated but positively and weakly correlated ($P<0.05$; $r = 0.141$).

DISCUSSION

The geology of the park area consists of granites, migmatite of the basement complex, schists and some *quarzites.* The vegetation of the area is mainly of Northern Guinea type with some area, showing characteristic of transition from Southern to Northern Guinea type. The main vegetation types are *Burkea africana, Terminalia avicenoides* savannah*, Isoberlinia to mentosa* Woodland, *Terminalia mactoptera* savannah, G*ardenia/maytenus* Scrubland, Oli Complex, *Riparian* Forest and *Acacia* Woodland (Afolayan, 1979).

Water quality parameters obtained from this study are comparable with those of water of most tropical rivers and lakes (Khana and Ejike, 1984; Olaniran, 2000; Kolo, 1996).

The importance of water as resources is not only tied to its availability and quantity, but also to its quality as it supports the aquatic and terrestrial lives. The qualities of water therefore are explained by its physicochemical and biological properties. Kolo (1996) reported that variation in water qualities could be attributed to or explained in terms of dominance of precipitation chemistry, bedrock chemistry or evaporation – crystallization process within the entire water body. The sediment load of a river depends not only upon its drainage area discharge but also upon the geo-logy, topography and climate of the drainage basin. Ave-rage loads in many rivers can change as a result of man’s continuing meddling in riverine process. Dam and flood control devices tends to reduce transfer of sediments to the oceans while urbanization and poor farming techniques accelerate erosion and sediment transportation.

The surface temperature for all the rivers ranges between 22.6 – 31^{O}C in the dry seasons and between 21 – 26^{O}C in the wet seasons. These ranges compared well with the ranges reported for other tropical waters (Khana and Ejike, 1984; Ovie and Adeniji, 1993). The highest values in the dry seasons could be attributed to the warming effect of the solar radiation. Temperature recommended for aquatic life in the tropical environment like Nigeria is between 21 and 32^{O}C (Ayodele and Ajani, 1999; Olukunle 2000; Boyd 1981). FEPA 1991 recommended a temperature below 40^{O}C for drinking water. The pH (potential hydrogen ion) ranges between 5.6 and 7.4 in the dry seasons, while the wet seasons pH ranges between 6.6 and 8.5. The lower pH values could be attributed to the decay process of allocthonous organic matter acelerated by the high temperature during the dry seasons. The higher values in the wet seasons could be due to greater values of water level and greater retention period. The observed values are in agreement with Boyd (1979) . The pH range for existence of most biological life is quite narrow and critical, the acceptable pH range for drinking water is between 7.0 and 8.3 (WHO, 1983), 6.5 and 8.5 (WHO 1984), 6.0 and 9.0 (FEPA 1991), (WHO 2006). This implies that waters in the Parks are not potable during the dry seasons. Ayodele and Ajani (1999) recommended a pH range of 6.5 and 9 for best fish production while Olukunle, (2000) and Pescord (1977) recommended a range of 6.5 and 8.5.

The values of dissolved oxygen (DO) range between 2.4 and 8.4 ppm in the dry seasons and between 3.5 and 9.5 ppm in the wet seasons. The values obtained for dry seasons are probably due to low water depth and less agitation by wind current. Higher values obtained in the wet seasons are due to agitation and frequent wind current in the water (Kolo, 1996), Oxygen is required for respiration of aquatic organism; the D. O. recommended for the survival of aquatic life in tropical water is between 3 and 5 ppm (Ayodele and Ajani, 1999; Olukunle, 2000 and Boyd, 1981).

The biological oxygen demand (BOD) is the amount of oxygen require by bacteria to decompose the organic matter in the water, while chemical oxygen demand (COD) is the amount of oxygen in water required to oxidize organic matter in the water to carbon dioxide. As a result, the level of BOD and COD are always closely related. The higher values in the dry seasons may be due to submerge woody nature of the rivers sites. Therefore decay of organic matter favoured by high temperature of the dry seasons, led to high values of BOD in the dry seasons than in the wet seasons. The highest desirable level (HDL) of BOD is 5 ppm while the Maximum permissible level (MPL) is 6 ppm. (WHO, 1972). This implies that the water in the river Oli Km 8 fall within the recommended level for portable water. High BOD values can lead to ammonia and hydrogen-sulphide production which will result in the following in the water.

Effects of sublethal concentration of ammonia according to Boyd (1979), include:

i. Pathological changes in fish organs and tissues. Histological effects were attributed to continuous exposure to ammonia concentration of 0.006 to 0.34 mg/l.
ii. Poor growth of fish culture tanks has also been attributed to accumulation of ammonia.
iii. Reduced growth and gill damage at concentration of 0.012mg/l. He did not notice any harmful effect at 0.06 mg/. High concentrations of total ammonia present as NH_3. Among workers that he quoted include Smith and Piper, (1975), Andrew et al (1971).

Boyd also listed the effects of un-ionized hydrogen sulphide in aquatic life. He stated that un-ionized hydrogen sulphide is extremely toxic to fish at concentration, which may occur in natural waters. He listed some of the effects as follows:

i. Egg survival and fry development were limited by concentration of 0.06 mg/l hydrogen sulphide.
ii. Bluegills are also very sensitive to hydrogen sulphide. Growth of adult Bluegill was retarded by 0.11 mg/l.
iii. At pH 7, the lethal concentration, for hydrogen sulphide was 1.0 mg/l for fingerlings of channel catfish.
iv. High concentrations of hydrogen sulphide were responsible for poor growth of channel catfish.

The HDL of COD is 10 ppm, the level in the sampled water ranges between 3.12 and 17.22 ppm in the dry seasons and between 2.14 and 15.67 ppm in the wet seasons, and this implies that some of the sampled river waters were not within the desirable values. (Appendices I-IV)

Phosphate level ranges between 0.1 and 1.00 ppm in the dry seasons and between 0.4 and 1.7 ppm in the wet seasons. Phosphate gets to rivers through plants. It is higher in some samples than others. High values of phosphate support algae growth and hence good plankton bloom (Boyd, 1979). FEPA (1991) recommended a maximum of 20mg/litre while WHO (2006) did not put any range.

Total hardness in the dry seasons ranges between 18.68 and 72.4 ppm while it ranges between 23.8 and 72.6 ppm in the wet seasons. Calcium hardness also ranges between 23.06 and 43.00 ppm in the wet seasons while it ranges 4.41 and 30.32 ppm in the dry seasons. The values in the dry according to Beadle (1984) are as a result of reduced volume of water which has impact of altering physiccal and nutrient situation of water bodies. It was observed that some samples have considerable amount of calcium, nevertheless, all the samples have calcium and hardness values which were within the acceptable range (WHO, 1972; 1984, 2006) (Appendices I-IV).

Iron (III) levels in the samples ranges between 1.04 and 7.63 ppm in the wet seasons and ranges between 1.64 and 5.34 ppm in the dry seasons, the observed difference is due to the water level difference in the dry and wet seasons. The values exceeded WHO recommendation as it may have contributed to the colouring and the taste, making the samples not to be potable. Manganese levels are within the permissible level but are well above the desirable level which may be of the same effects as iron (WHO, 1972, 1984, 2006) (Appendices I-IV).

The chloride levels in the raining and dry seasons are below the recommended values, excess of chloride according to WHO (1972, 1984, 2006) is attributed to bone damage. The water conductivity in the dry seasons range between 0.01 and 0.03 and between 0.03 and 0.08 in the wet seasons. The higher values in the rainy seasons were due to the leaching of the mineral salt from the bedrock and re-suspension of solids. Higher values of nitrate and other nutrient in the wet seasons could be attributed to the run off from nearby vegetation.

Turbidity ranges between 30 and 48 cm in the wet seasons. The values are high in the dry seasons ranging between 36 and 60 cm. The higher values during the dry seasons is due to the absence of floodwater, surface runoff and settling effect of the suspended solids due to secession of rainfall, (Kolo, 1996) . The values obtained are within the acceptable values of 30 and 60 cm according to Ayodele and Ajani (1999) for fish production. Values obtained are compared with those of waters of most tropical rivers and Lakes (Olaniran, 2000; Kolo, 1996; Khana and Ejike, 1984).

Total suspended solids in the dry seasons were higher than those observed in the wet seasons values ranges between 0.01 and 0.07 ppm in the wet seasons to between 0.03 and 1.38 ppm in the dry seasons. The values in all the sampled water were in line with 30 ppm recommended by FEPA (1991). This is in line with the report of Licktkippler (1979) and Pickford (1977). This will affect the transparency and turbidity of the water and hence the light penetration. This will affect the life of the water plankton and hence the fish food.

Effects of hippopotamus

The beneficial relationship between the Hippopotamus and fish have been established. Hippopotamus usually defeacates in water and excrements enrich the nutrient in the water resulting in favourable conditions for for large fish populations. Some fish, including Laboo spp were observed to feed on micro-organisms and algae that grow on the skin of the Hippopotamus (Onyeanusi, 1996).

Conclusion and Recommendations

The seasonal variations in the physicochemical parameters of the Park Rivers were as a result of the effects of hydrological regime of the rivers and the prevailing weather conditions of the site environment. Allocthonous materials contributed a lot to the water chemistry. The wet seasons and dry seasons physicochemical parameters of the Park rivers' waters were within the range that can support aquatic life. However, the lower pH values during the dry seasons and faecal pollution during the rainy season made the waters not to be potable. Also the Biological Oxygen Demand (BOD) values obtained for River Oli fall within the highest desirable level and minimum permissible level.

Statistical analysis confirmed that there were significant differences between the dry seasons and wet seasons sampling points and locations mean values for the different parameters examined. The presence of hippopotamus affected some parameters such as COD, BOD, DO, pH and turbidity significantly. The BOD and COD are strongly significantly correlated and positively correlated $P>0.05$; $r = 0.757$. The ammonium content and nitrite are not signifycantly correlated but positively and weakly correlated ($P<0.05$, $r = 0.141$)

The problem of water quality during the dry seasons should be addressed with all seriousness. Water sheds should be provided for the animals especially at the Zugurma section of the park. Bore holes should be provided for the villagers that share boundaries with the Park and the Park workers.

Appendix

Appendix I. Mean values of the physicochemical parameters in 2005

Parameters	Mean Values ± Std. Deviation	
	Dry seasons (2005)	**Wet Seasons(2005)**
Cl^- ppm	14.58 ± 3.76	12.53 ± 3.20
Hardness ppm	36.59 ± 18.65	39.71 ± 17.35
Electrical Conductivity ms/cm	0.012 ± 0.004	0.045 ± 0.02
Nitrite ppm	0.035 ± 0.029	0.042±0.012
COD mg/l	8.562 ± 4.54	7.571 ± 4.22
BOD mg/l	11.242 ± 5.90	10.515 ± 5.43
PH	6.03 ± 0.24	7.38 ± 0.57
Ca^{2+} ppm	15.805 ± 7.77	20.945 ± 10.75
Mn^{2+} ppm	0.142 ± 0.074	0.329 ± 0.17
NH_4^+ ppm	0.13 ± 0.24	0.717 ± 1.08
Fe^{3+} ppm	2.627 ± 1.05	6.007 ± 1.11
NO_3^- ppm	0.858 ± 1.53	1.346 ± 1.74
DO mg/l	5.84 ± 1.72	7.01 ± 1.49

Append. 1 cont.

PO^-_4 ppm	0.31 ± 0.27	0.75 ± 0.38
Turbidity (cm)	52.4 ± 8.42	38.8 ± 5.09
Temperature (^0C)	26.98 ± 2.77	23.7 ± 1.73
Total suspended solid (mg/l)	0.537 ± 0.57	0.024 ± 0.01

Mean Values of the Physicochemical Parameters in 2006.

Parameters	**Mean Values ± Std. Deviation**	
	Dry seasons (2006)	**Wet Seasons(2006)**
Cl^- ppm	14.33 ± 3.50	12.74 ± 2.92
Hardness ppm	37.35 ± 19.59	39.59 ± 17.64
Electrical Conductivity ms/cm	0.024 ± 0.009	0.053 ± 0.03
Nitrite ppm	0.038 ± 0.027	0.038 ± 0.022
COD mg/l	8.429 ± 4.39	7.532 ± 4.20
BOD mg/l	11.06 ± 5.94	9.86 ± 4.41
PH	6.02 ± 0.25	7.42 ± 0.51
Ca^{2+} ppm	16.285 ± 8.24	18.391 ± 6.91
Mn^{2+} ppm	0.186 ± 0.096	0.141 ± 0.02
NH_4^+ ppm	0.211 ± 0.24	0.185 ± 0.22
Fe^{3+} ppm	2.874 ± 0.96	3.30 ± 1.66
NO^-_3 ppm	0.88 ± 1.46	0.241 ± 0.14
DO mg/l	5.94 ± 1.18	6.79 ± 1.90
PO^-_4 ppm	0.33 ± 0.25	0.66 ± 0.41
Turbidity (cm)	53.6 ± 8.26	36.8 ± 2.98
Temperature (^0C)	27.37 ± 3.06	24.3 ± 1.34
Total suspended solid (mg/l)	0.419 ± 0.52	0.034 ± 0.02

Appendix II. Interim effluent limitation guidelines in Nigeria for all categories of industries.

Parameters	**Units in milligram per litre (mg/l) unless otherwise stated**	
	Limit for discharge into surface H_2O	**Limit for local Application**
Temperature	Less than 40^0C within 15 m of outfall	
	7	Less than 40^0C
Colour (Levibond unit)	6-9	-
pH	50	6-9
BOD_5 at 20^0C	30	500
Total suspended solids	2000	-
Total dissolved solids	600	2000
Chloride (as Cl)	500	600
Sulphate (as SO^{2-}_2)	0.2	1000
Sulphide (as CN -)	0.1	-
Detergent (linear alkylate)		-
Sulphanate as methylene blue acrider substance	15	
Oil and grease	10	15
Nitrate (as NO^{-3})	20	30
Phosphate (as PO^{-4})	5	-
Arsenic (as Ar)	0.1	10
Barium (as Ba)	5	-
Tin (as Sn)	10	5

Append. II cont.

Iron (as Fe)	20	10
Manganese (as Mn)	5	-
Phenolic compound (as phenol)	0.2	-
Chloride (free)	1.0	-
Cadinum (col)	<1	-
Chromium (trivalent and hexavelent)	<1	-
Copper	<1	-
Lead	<1	-
Zinc		-

Source: FEPA (1991)

Appendix III. Water quality and standards substances and characteristics affecting the acceptability of water for domestic supply.

Substance of characteristic	Undersirable effect that may be produced	Guidelines value
Aluminium chloride colour	Discolouration taste; corrosion to pipes discolouration	0.2 mg/l 250 mg/l (as Cl-) 15 true colour units
Copper	Bitter taste; discolouration; corrosion of steel and galvanized pipes	1.0 mg/l
Hardness	Scale deposition; taste	500 mg/l (as CaCO3)
Hydrogen sulphide	Odour, taste	Not detectable by consumer
Iron	Taste; discolouration; deposits and growth of iron bacteria; turbidity	0.3 mg/l
Manganese	Taste; discolouration; deposits in pipes; turbidity	0.1mg/l
Monodichlorobenzene	Odour	3.0 µg/l
1,2 dichlorobenzene	Odour	0.3 µg/l
1,4 dchlorobenzene	Odour	0.1 µg/l
pH	Corrosion	6.5-8.5
Phenols	Taste	1.0 µg/l
Sodium	Taste	200 mg/l
Sulphate	Taste; gastro-intestinal irritation	400 mg/l (as SO_4^{2}-)
Taste and odour	Taste and odour	Inoffensive[1]
Total dissolved solids	Taste	1000 mg/l
Turbidity	Turbidity	5 nephelometric units[2]
Zinc	Taste	5.0 mg/l

1. To most consumers.
2. Preferably less than 1 unit for disinfection efficiency. *Source*: From WHO (1984).

Appendix IV. NAFDAC packaged water quality standard physiochemical examination

S/N	Parameter/Unit	WHO Standard
1.	Colour Hazen Units	15
2.	pH at 20c	7.0 – 8.5
3.	Conductivity	-
4.	Turbidity, NTU	5
5.	Total Solids, mg/l	500
6.	Total Suspended Solids, mg/l	-
7.	Total Dissolved Solids, mg/l	500
8.	Total hardness, mg/l	100

Append. IV cont.

9.	Sulphate, mg/l	200
10.	Total Alkalinity, mg/l	100
11.	Chloride, mg/l	200
12.	Residual Chlorine	0.3
13.	Nitrate, mg/l	50
14.	Nitriate, mg/l	3
15.	Phosphate, mg/l	-
16.	Calcium, mg/l	75
17.	Magnesium, mg/l	30
18.	Iron, mg/l	0.3
19.	Lead, mg/l	0.01
20.	Manganese, mg/l	0.5
21.	Copper, mg/l	2.0

Source: WHO, 2006

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