Physicochemical Parameters and Water Quality Index of Water in the Lower Usuma Dam, Fct, Nigeria.

Ogbodo C., Wuana R., Itodo A. U. and Eneji I. S.
Federal University of Agriculture,
P.M.B. 2373, Makurdi, Benue State, Nigeria.
Corresponding author: uniquechiogb@gmail.com

Abstract
The study assessed some physicochemical parameters and the overall water quality index of the Lower Usuma dam water during the rainy and dry seasons in a cycle (year 2019). Parameters such as temperature, pH, sulphates, nitrates, phosphates, total hardness, turbidity and colour were determined using respective standard methods and the overall water quality index for the period under review was determined using the weight arithmetic WQI method. The results showed that optimum water quality for the dam is obtainable during the dry season and there is poor water quality during the rainy season. The water from the dam was observed to have an overall WQI value of 72.02 (grade C), indicating that it is suitable for irrigation and industrial use but requires treatment before drinking. The data obtained were analyzed using one way analysis of variance (ANOVA) and significant differences accepted at $p \leq 0.05$. There was observed statistical difference in the physicochemical properties of the water in the rainy and dry seasons.

Keywords: *Turbidity; hardness; water quality index; Usuma dam; concentration.*

1.0 Introduction

With the depletion of fresh water sources around the globe (Ramakrishna and Babu, 1999a), man has adapted new means of ensuring availability of water for domestic, agricultural and industrial use. One of such adapted means is dam construction. A dam is an artificial barrier constructed to hold water from natural sources for water supply all year round. The lower Usuma dam is one of the known dams in Nigeria, embanking water from three sources: the River Usuma, River Gidna and River Gurara (Gurara dam). Like an artificial lake that it is, the dam receives fresh water constantly without any outflow, except to the treatment plant. The river Usuma is a natural flowing water body cutting across several locations with domestic and industrial activity along its shores, while the Gurara water transfer provides for the transfer of raw water from Gurara dam in Kaduna state to Lower Usuma dam in Federal Capital Territory (FCT), Abuja through a 75 km conduit pipeline to augment water supply to FCT as a result of rapid population growth (Okunlola *et al.*, 2014). Such impounding of water from diverse sources without an outflow, can accumulate toxic substances or create poor water quality over time.

The specific objectives of this study are to:
i. Determine physicochemical parameters of the water in the Lower Usuma dam and
ii. Evaluate the water quality index (WQI) of water from the dam.

A water quality index (WQI) provides a single number that expresses overall water quality at a certain location and time based on several water quality parameters (Kumar and Dua, 2009). It helps in understanding the general water quality status of a water source hence, it has been applied for both surface and ground water quality assessment all around the world since the

last few decades (Horton, 1965; Chapman, 1996; Terrado *et al*., 2010; Sharma and Kansal, 2011; Alam and Pathak, 2010; Tyagi *et al.*, 2013; Echoke *et al.*, 2018).
WQI aims at giving a single value to the water quality of a source by translating the list of parameters and their concentrations present in a sample into a single value, which in turn provides an extensive interpretation of the quality of water and its suitability for various purposes like drinking, irrigation, fishing, industrial use, etc. (Amadi, 2011).

The WQI, which was first developed by Horton in the early 1970s, is basically a mathematical means of calculating a single value from multiple test results (Horton, 1965). The index result represents the level of water quality in a given water basin, such as a lake, river or stream. After Horton, a number of workers all over the world developed WQI based on rating of different water quality parameters.
Such indices, which have been formulated by several national and international organizations to summarize water quality data in an easily expressible and easily understood format, include the Weighted Arithmetic Water Quality Index (WAWQI), National Sanitation Foundation Water Quality Index (NSFWQI), Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), Oregon Water Quality Index (OWQI), etc. These indices are often based on the varying number and types of water quality parameters as compared with respective standards of a particular region. On the basis of reviewed literature, available indices have many variations and limitations based on number of water quality variables used and some are not accepted worldwide (Bordalo *et al*., 2001; Chaturvedi *et al*., 2010).
The WQI approach applied in this study is the Weighted Arithmetic Water Quality Index. Its merits and demerits are outlined below while the equations involved are shown in section 2.2.3.

Weighted arithmetic WQI (Tyagi *et al*., 2013; Akoteyon *et al.*, (2011); Yogendra *et al*., (2008))
Merits: i. Incorporate data from multiple water quality parameters into a mathematical equation that rates the health of water body with number. ii. Less number of parameters required in comparison to all water quality parameters for particular use. iii. Useful for communication of overall water quality information to the concerned citizens and policy makers. iv. Reflects the composite influence of different parameters i.e. important for the assessment and management of water quality. v. Describes the suitability of both surface and groundwater sources for human consumption.
Demerits: i. WQI may not carry enough information about the real quality situation of the water. ii. Many uses of water quality data cannot be met with an index. iii. The eclipsing or over-emphasizing of a single bad parameter value. iv. A single number cannot tell the whole story of water quality; there are many other water quality parameters that are not included in the index. v. WQI based on some very important parameters can provide a simple indicator of water quality.

In this research, important parameters such as temperature, pH, total dissolved solids (TDS), electrical conductivity, biochemical oxygen demand (BOD), nitrates, phosphates, sulphates, colour and turbidity were taken during the rainy and dry seasons of the year 2019, and the values used for the calculation of WQI of Lower Usuma dam water, using the weighted arithmetic WQI method.
The analyses of physicochemical parameters were done in the main laboratory of the Usuma dam water works (the water treatment plant).

2.0 Materials and Methodology

2.1 Materials

2.1.1 Reagents

Only chemicals of analytical reagent grade (99.9% purity) were utilized and they were obtained from reputable chemical distribution companies. The following reagents were used for the analyses: Na-EDTA, NH_4Cl, Erichrome Black-T, Aqueous ammonia, HCl. Doubly distilled, de-ionized water was used in the preparation of all solutions in the experiments.

2.1.2 Apparatus

Thermometer, pH meter, multi conductivity meter, oxygen meter, turbid meter, UV-Vis spectrophotometer, 50 mL burette, 25 mL pipette, 250 mL conical flasks, retort stand.

2.1.3 Description of the study area

The Lower Usuma dam, shown in figure 1, is located within Ushafa community Abuja, between latitude 7° 25' 16"E and longitude 9° 01' 12"N and it covers a land mass of 2,500,000 m^2. It is located at about the highest point of the Nigerian Federal Capital Territory, about 15 km northwest of Abuja on 570 m altitude. It is sited on a virgin location where human activity is minimal, thereby ensuring non pollution of the environment and freedom from industrial impurity. Though, pollution may be transported into the dam from the contributory rivers.

The barrier system consists of two (2) dams: the main dam and the saddle dam. The main dam has a length of 1.3 km and a height of 47 m, with a crown that is 10m wide. The saddle dam is 470 m long and has a height of 15 m. The lake has a width of 3.5 km and a length of 3 km and holds 1.2 x 10^8 m^3 of raw water (Ibrahim *et al.*, 2014).

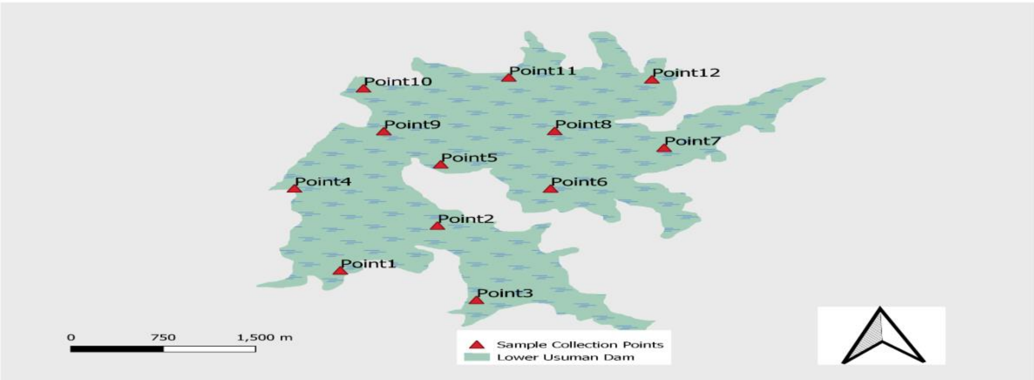

Fig. 1: Map of Lower Usuma Dam (showing sampling points)

2.2 Methods

2.2.1 Sampling

Prior to sampling, plastic bottles of 500 mL capacity were soaked overnight in a solution of HCl (0.05M), washed thoroughly the next day and rinsed several times with distilled water before being sun-dried.

Water samples were collected at a depth of 0.3m in the dam, from 12 random locations and homogenized. These were collected during the rainy and dry seasons of the year 2019. After sampling, samples were stored at 4^0C in the laboratory refrigerator, and analyzed within 24 hours for parameters not measured on-site (WHO, 2011).

2.2.2 Determination of physicochemical parameters (George *et al.*, 2013)

Temperature: Surface water temperature was determined on site using the temperature sensor of a dissolved oxygen probe. The probe was immersed in the reservoir water to a depth of 0.3 m and allowed to stabilize before temperature readings were taken in ^{0}C.

pH: The pH of the water was measured on site using a portable pH meter. The pH probe was lowered to a depth of about 0.3 m, allowed to stabilize and the pH value, read.

Electrical conductivity: A multi-range conductivity meter was used to measure electrical conductivity (EC) of surface water at the sampling site. The meter probe was lowered into the reservoir water to a depth of 0.3 m and allowed to stabilize before taking the conductivity readings in µS cm^{-1}.

Turbidity: The turbidity of water in the site was determined by use of a turbidity meter. The measurement was read in Nephelometric Turbidity Units (NTU).

Dissolved oxygen (DO): Dissolved oxygen (DO) was measured on site using a JENWAY 970231B Oxygen meter. The DO probe was immersed into the reservoir water at a depth of approximately 0.3 m. While gently stirring the water with the DO probe, the readings were allowed to stabilize and DO read in mg L^{-1}.

Biochemical oxygen demand (BOD): BOD in water was measured using dissolved oxygen values taken initially at sample collection and the dissolved oxygen value after five (5) days of incubation. The difference (in mg/L) represents the amount of oxygen consumed by microorganisms to break down the organic matter present in the sample during the incubation period (Jouanneau *et al.*, 2014).

Total dissolved solids (TDS): TDS was measured using the probe of a conductivity multi-meter. The value was recorded in mg/L.

Nitrates: Nitrate concentration was determined using a HACH 5000 UV-Vis spectrophotometer. The value was recorded in mg/L.

Phosphates: Phosphate concentration was determined using a HACH 5000 UV-Vis spectrophotometer. The value was recorded in mg/L.

Sulphates: Sulphate concentration was determined using a HACH 5000 UV-Vis spectrophotometer. The value was recorded in mg/L.

Colour: Colour of the water was measured using a HACH 5000 UV-Vis spectrophotometer. The value was recorded in PtCo.

Total hardness: Hardness in the water was measured by titrating the water samples in triplicate using EDTA solution with a K10 buffer, and Erichrome Black T indicator. The result was recorded in mg/L.

Results from the analyses above were used to determine the water quality index (WQI) of the lower Usuma dam water, using the **weighted arithmetic method**.

2.2.3 Evaluation of WQI (Weighted Arithmetic method) Tyagi *et al.*, (2013); Akoteyon *et al.*, (2011); Yogendra *et al.*, (2008)

WQI was evaluated using the following equations:

$$WQI = \sum QiWi / \sum Wi \quad (1)$$

The quality rating scale (Qi) for each parameter is calculated by using this expression:

$$Qi = 100[(Vi - Vo)/(Si - Vo)] \quad (2)$$

where,

Vi is estimated concentration of ith parameter in the analysed water.

Vo is the ideal value of this parameter in pure water and, *Vo* = 0 (except pH =7.0 and DO = 14.6 mg/L)

Si is recommended standard value of ith parameter.

The unit weight (Wi) for each water quality parameter is calculated by using the following formula:

$$Wi = K/Si \quad (3)$$

Where, K = proportionality constant and can also be calculated by using the following equation:

$$K = \frac{1}{\Sigma(\frac{1}{Si})} \quad (4)$$

The rating of water quality according to this WQI is given in Table 1.

Table 1: Water Quality Rating as per Weighted Arithmetic Water Quality Index Method

WQI	Grade	Water Quality Status (WQS)	Possible usage
0–25	A	Excellent	Drinking, irrigation and industrial
26–50	B	Good	Drinking, irrigation and industrial
51–75	C	Poor	Irrigation and industrial
76–100	D	Very poor	Irrigation
> 100	E	Unsuitable for drinking and fish culture	Proper treatment required before use

2.2.4 Statistical analysis

Descriptive statistics was conducted to determine the mean of investigated physicochemical parameters in the water samples. The test of significance and one-way ANOVA were also carried out on the data.

Statistical analysis was done using IBM SPSS 23 software.

3.0 Results

3.1 Physicochemical Parameters

Table 2 and figure 2 show the values of physicochemical parameters obtained for water at the Lower Usuma dam, during the period of study while table 3 and figure 3 compare the values of the physicochemical parameters determined, with national and international standards.

Table 2: Physico-chemical Parameters (Rainy and Dry Season 2019) for LUD Water

Parameter	Vi Rainy Season	Vi Dry Season	ViMean
Temperature (^{0}C)	23.7	22.5	23.1
pH	7.1	7.1	7.1
Turbidity (NTU)	6.86	4.43	5.645
Nitrates (mg/L)	8.6	2.9	5.75
Phosphates (mg/L)	0.49	0.41	0.45
Sulphates (mg/L)	10	6	8
DO (mg/L)	7.88	9.1	8.49
BOD (mg/L)	4.1	2.75	3.425
Electrical Conductivity (µS)	67.1	79.1	73.1
Total Dissolved Solids (mg/L)	53.7	47.6	50.65
Colour (PtCo)	81	33	57
Hardness (mg/L $CaCO_3$)	54	34	44

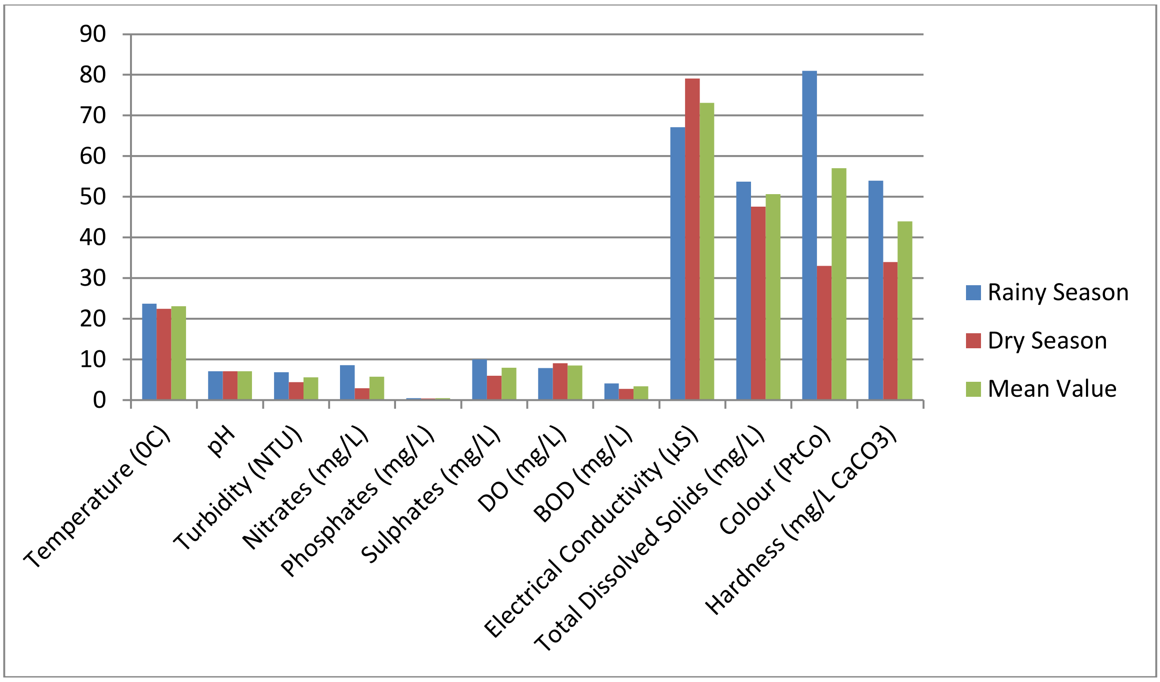

Figure 2: Physicochemical Parameters for LUD Water Rainy and Dry Season 2019

Table 3: Comparison of Mean Physico-chemical Parameters with Standards (WHO, 2011; SON, 2015)

Parameter	Mean Value	WHO/NSDWQ Value
Temperature (^{0}C)	23.1	30
pH	7.1	6.5-8.5
Turbidity (NTU)	5.645	5
Nitrates (mg/L)	5.75	50
Phosphates (mg/L)	0.45	6.5
Sulphates (mg/L)	8	100
DO (mg/L)	8.49	5
BOD (mg/L)	3.425	5
Electrical Conductivity (µS)	73.1	1000
Total Dissolved Solids (mg/L)	50.65	500
Colour (PtCo)	57	15
Hardness (mg/L $CaCO_3$)	44	150

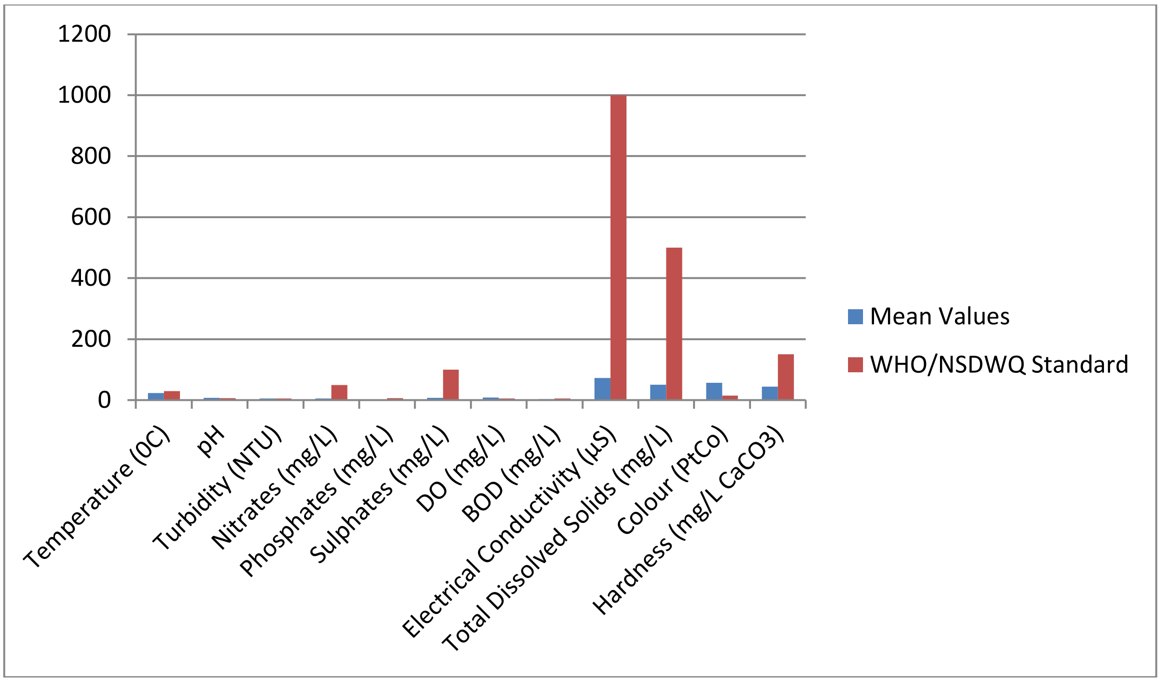

Figure 3: Comparison of Mean Values of Physicochemical Parameters with Standards

3.2 Water Quality Index

Table 4 shows the computation of the overall water quality index (WQI) for LUD water during the period of study.

Table 4: Water Quality Index of Lower Usuma Dam Water

Parameter	ViMean	Vo	Si	Source of Si	1/Si	K	Wi	Vi - Vo	Si - Vo	Qi	QiWi
Temperature (^{0}C)	23.1	0	30	WHO	0.03	0.98	0.03	23.1	30	77.00	2.50
pH	7.1	7	6.5	WHO	0.13	0.98	0.15	0.1	-0.5	-20.00	-3.00
Turbidity (NTU)	5.6	0	5	NSDWQ	0.20	0.98	0.19	5.645	5	112.90	21.99
Nitrates (mg/L)	5.8	0	50	NSDWQ	0.02	0.98	0.02	5.75	50	11.50	0.22
Phosphates (mg/L)	0.5	0	6.5	WHO	0.15	0.98	0.15	0.45	6.5	6.92	1.04
Sulphates (mg/L)	8.0	0	100	NSDWQ	0.01	0.98	0.01	8	100	8.00	0.08
DO (mg/L)	8.5	14.6	5	WHO	0.20	0.98	0.19	-6.11	-9.6	63.65	12.40
BOD (mg/L)	3.4	0	5	NSDWQ	0.20	0.98	0.19	3.425	5	68.50	13.34
Electrical Conductivity (µS)	73.1	0	1000	NSDWQ	0.00	0.98	0.00	73.1	1000	7.31	0.01
Total Dissolved Solids (mg/L)	50.7	0	500	NSDWQ	0.00	0.98	0.00	50.65	500	10.13	0.02
Colour (PtCo)	57.0	0	15	NSDWQ	0.07	0.98	0.06	57	15	380.00	24.67
Hardness (mg/L $CaCO_3$)	44.0	0	150	NSDWQ	0.01	0.98	0.01	44	150	29.33	0.19

WATER QUALITY INDEX = ΣQiWi/ ΣWi = 73.46/1.02 = 72.02

3.3 Statistical Analysis

Tables 5 and 6 show ANOVA results of the physicochemical parameters determined for the raw water in the lower Usuma dam during the rainy and dry seasons of 2019.

Table 5: ANOVA Result of Physicochemical Parameters for the Rainy Season.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8991.072	9	999.008	261.2	.004
Within Groups	7.649	2	3.824		
Total	8998.721	11			

Table 6: ANOVA Result of Physicochemical Parameters for the Dry season.

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	6589.883	9	732.209	67.6	.02
Within Groups	21.651	2	10.826		
Total	6611.534	11			

4.0 Discussion

4.1 Physicochemical Parameters

During the rainy season, temperature of the dam was ambient at 23.7^{0}C; pH of the water was within NSDWQ and WHO range at 7.1; Turbidity at 6.86 NTU, was much higher than the WHO/NSDWQ standard of 5.0 NTU and the water was highly coloured, having a colour value of 81 PtCo. These parameters gave the water very low quality during the rainy season. This could be attributed to the presence of organic matter pollution, other effluents, run-off with high level of suspended particles and heavy rainfall (Chapman, 1996).

For the dry season, temperature of the dam remained ambient at 22.7^{0}C; pH of the water also remained within NSDWQ and WHO range at 7.1; Turbidity dropped significantly to an acceptable 4.43 NTU while colour of the water became slightly clear at 33 PtCo. Other

parameters determined like nitrates, phosphates, sulphates, DO, BOD, conductivity and TDS remained below national and international standards both during the rainy and dry seasons.
The mean levels of water nutrients (NO_3^-, PO_4^{3-}, SO_4^{2-}) in this study showed that the water does not possess eutrophication features as stated by Harbel (2009). Flynn (2001) opined that high nutrients (NO_3^-, PO_4^{3-}, SO_4^{2-}) level often recorded in water bodies may be a reflection of direct discharge of pollutants among which domestic, fertilizer and wood wastes rank high, directly into the water but this was not observed in the study area, during the period of study.

4.2 Water Quality Index

From the overall WQI result (72.02), the Lower Usuma Dam water is classified under grade C, as being suitable for irrigation and industrial use but requiring proper treatment before drinking. The Federal Capital Territory Administration already ensures this is done through the Usuma Dam Water Works, a 20,000 m^3-capacity water treatment plant, charged with the responsibility of treating water from the Lower Usuma dam continuously and distributing the potable water to homes and industries in the Federal Capital Territory (Ibrahim *et al.*, 2014).
Regular monitoring needs to be maintained, to ensure that the treatment process is effective, especially during the rainy season.

4.3 Statistical Analysis

Calculated F-ratio is equal to 261.2 at P-value of 0.004. Since P-value is below 0.05 level of significance, there is significant relationship between the physicochemical parameters for the raw water in Lower Usuma Dam Abuja during the rainy season. For the dry season, the calculated F-ratio is equal to 67.6 at P-value of 0.02, which is less than 0.05 level of significance. There is significant relationship between physicochemical parameters of the raw water in Lower Usuma Dam Abuja, during the rainy and dry seasons.

5.0 Conclusion

Physicochemical parameters (temperature, pH, colour, turbidity, electrical conductivity, total dissolved solids, nitrates, phosphates, sulphates, total hardness, dissolved oxygen and biochemical oxygen demand) of water from Lower Usuma Dam, Abuja, Nigeria was determined for the rainy and dry seasons of 2019. The water quality index (WQI) of the water was also evaluated and interpreted.
Physicochemical parameters measured were mostly within acceptable range, especially during the dry season. The overall water quality index (WQI) value of 72.02 showed that the Lower Usuma dam is suitable for irrigation and industrial applications but will require proper treatment to be suitable for drinking.
Being a highly protected environment, it is unlikely that any person/organization goes to discharge waste directly into the dam. Contamination must have come from one or more of the rivers whose waters are embanked in the dam. Runoffs during the rainy season, domestic, agricultural and industrial discharge into the river Usuma and the Gurara waterfall at different points, is considered to be a key source of contamination in the dam, though minimal.

There should be very cheap testing kits for every home, which consumers can use to check by themselves, the quality of their drinking water, before drinking the water. Proper routine checks by regulatory agencies should continually be carried out to monitor the quality of both raw and treated water from the lower Usuma dam. This will ensure proper treatment processes are followed, particularly, clarification and disinfection.
Ibrahim *et al*. (2014) recommended that the surrounding forest of the Lower Usuma dam water may be declared a “Protected Zone” to minimize human activities (farming, fishing, leisure,

etc.) around the water catchment zone which contributes to source water contamination. This is very correct and should be implemented immediately.

Fernández-Luqueño *et al*. (2013) proposed that a global effort for offering affordable and healthy drinking water should be launched throughout the world, while various laws and regulations to protect and improve the utilization of drinking water resources should be updated or created, including the low income countries. He also proposed the development of robust, cheaper and sustainable technologies to improve the drinking water quality.

Further research may be carried out to assess the health status of humans living around the Lower Usuma dam, to find out if there are health challenges arising from use of water from the dam.

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