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ASSESSMENT OF THE PHYSICO-CHEMICAL PARAMETERS OF SURFACE WATER OF MAIRUA DAM, FASKARI LGA, KATSINA STATE

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Abstract

This research is focused on the assessment of the physico-chemical parameters and Water Quality Index (WQI) of water samples collected from Mairua Dam Northwestern Nigeria using standard analytical methods. The results obtained were compared to those of World Health Organization (WHO) 2011 recommended levels. The physico-chemical parameters determined were: pH ,Dissolve oxygen (DO), Biochemical oxygen demand (BOD),Total dissolve solids (TDS) ,Electrical conductivity (EC), Chloride ion (Cl^-), Nitrate ion (NO_3^-),phosphate ion (PO_4^{3-}) and Temperature.W1 is sampling point 1. pH, DO, BOD and TDS across the sampling points were found to be in the range of 8.1 ±0.03 (W11) to 8.68± 0.01 (W4), 1.20 ± 0.1 (W11) to 25.33 ± 0.58, 0.60 ± 0.00 (W2) to 12.33 ± 0.58 (W1) to 139 1 ± 0.1 (W2) to 1142.50 ± 3.8 (W1) mg/L, respectively. Similarly, those of EC, Temperature, Cl^-, NO_3^- and $PO4^{3-}$ were; 165.3 ± 0.6 (W3) to 11355.0 ± 5.00 (W1), 25 ^{0}C (W2) to 29 ^{0}C (W8) , 15.6 ± 0.01(W2) to 235.93 ± 0.01(W1) BDL (W8, W11) to 20.23 ± 0.25 (W1) and BDL (W2,W3,W5,W7,W8.W9) to 0.70 ± 0.00 (W1) mg/L, respectively. Thus, the levels of DO, BOD, TDS, EC and temperature were above the WHO (2011) permissible limits for W1,W4 and W6; W1,W1,W3,W4,W5; W1,W4 and W1,W3,W4,W5,W6,W7W8,W9,W10,W11 samples respectively. However the pH, Cl^- ,NO_3^- and PO_4^{3-}were found to be within the permissible limits set by WHO (2011). The concentrations of physico-chemical parameters analyzed across the sampling points were in the following order WI>W2 >W4>W5>W6>W3 = W7>W8>W10>W9>W11. The WQI recorded in this study was 64.969. Thus, the samples were found to be poor to be used for both domestic and agricultural purposes without subjecting it to further treatment. Subjecting the data to statistical analysis revealed that there was no significant difference in the levels of the analyzed physico-chemical parameters at $p < 0.05$ across the sampling sites. This clearly shows that the samples have a common source of pollution.

Keywords: Mairua Dam, WQI, physico-chemical parameters, Northwestern Nigeria.

Introduction

Dams are engineered structures that restrict the flow of water. They have a number of functions such as storage, flood control, water supply and use for industrial processes, recreational and irrigational purposes; they are also used for the generation of electricity [1].

Humans generally settled near dams and construct reservoirs to use in their farmlands. The run-off of fertilizers and pesticides from farm and water from residential areas get leached into dams, polluting the water and making it unsafe for drinking, recreational use and endangering aquatic animals. There are currently more than 58,000 dams built all over the world with China recording the highest number [1].

Across the world, pollution of water by toxic metals has received considerable attention due to its risk to human health and ecology [2]. Toxic metal in dams may originate from natural sources such as mineral weathering, anthropogenic processes, agrochemicals, industrial and domestic municipal wastes. Wastes from domesticated animals, food supplements, and atmospheric deposition are the consequences of human population and economic activities [3]. The increasing concentration of toxic metals cause imbalance in aquatic ecosystems and the biota growing under such habitats accumulate high amounts of toxic metals which in turn, are being assimilated and transferred within food chains by the process of magnification [4]. Although some metals like copper (Cu), iron (Fe), manganese (Mn), nickel (Ni) and zinc (Zn) are essential as micronutrients for life processes in plants and microorganisms, others like cadmium (Cd), and lead (Pb) have no known health benefits instead proven to be detrimental if ingested beyond certain limits. Diseases like edema of eyelids, tumor, congestion of nasal

mucous membranes and pharynx, stuffiness of the head and gastrointestinal, muscular, reproductive, neurological and genetic malfunctions caused by some of these heavy metals have been documented [5]. Prolonged exposure to Pb has been linked to mental retardation, coma and eventual death [6]. Ingestion of Cd on the other hand is known to cause impaired kidney functioning, hypertension, hepatic dysfunction, breast and ovarian cancer whereas Cu and Zn may cause kidney problems such as nephritis and anuria [7]. Furthermore, exposure to multiple heavy metals may induce more severe human health consequences than might be expected from low individual metal concentrations alone [8]. Exposure to heavy metals from water bodies may also occurs through bioaccumulation of metals in human food sources [9]. Thus, even if humans do not consume heavy-metal contaminated water directly, they are often exposed to high levels of heavy metals from plant and aquatic food sources grown in polluted waters [8]. This is especially important in rapidly developing areas of Nigeria where Fadama and subsistent farming represents a large fraction of the food supply to both rural and urban centers.

This study assessed the physico-chemical properties of water of Mairua Dam, Faskari LGA, Katsina State.

MATERIALS AND METHOD

Description of the study area

Mairua Dam is situated in Faskari Local Government Area of Katsina state in Nigeria at latitude $11^{o}34'.587657"$ N and longitude $7^{0}14'.238149"$ E [10].

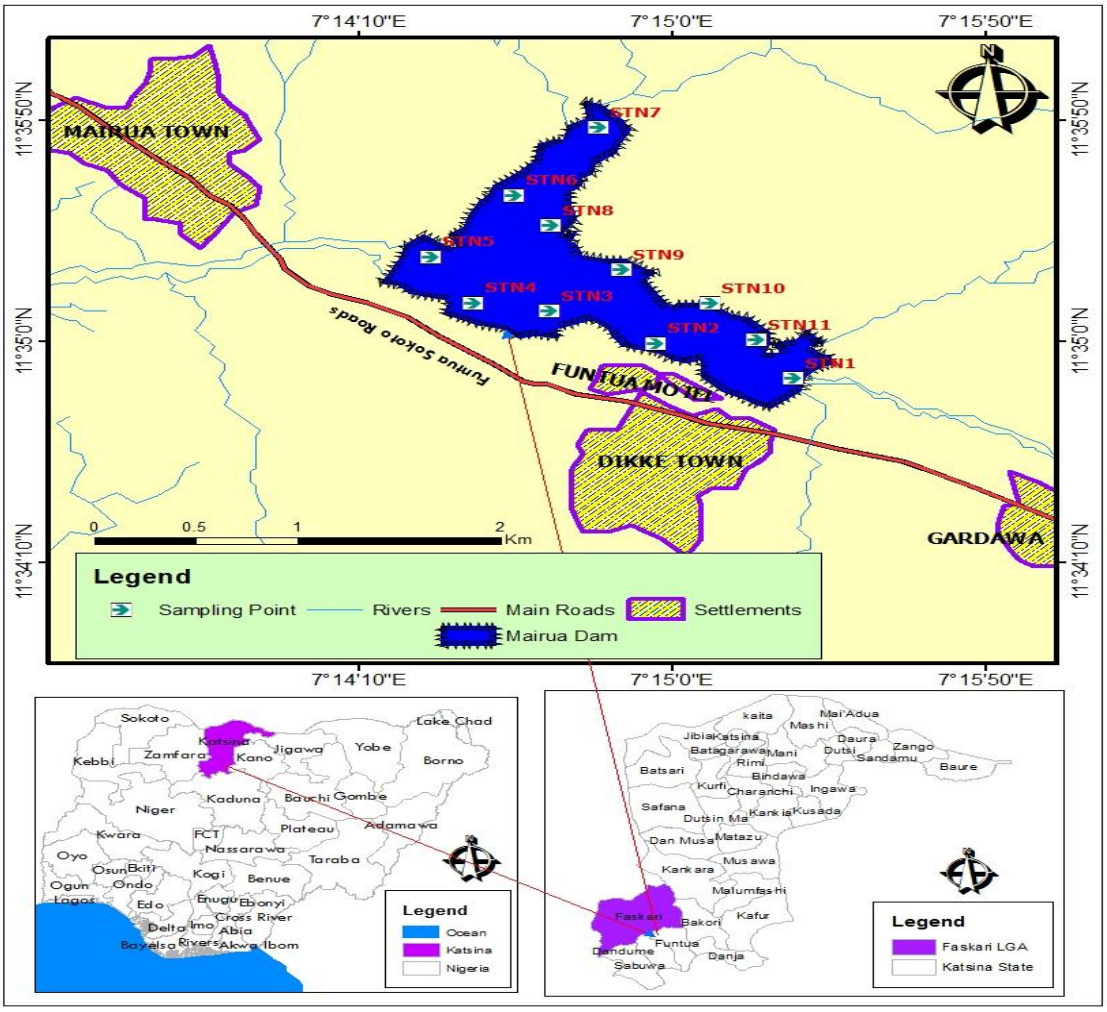

Figure 1: Map of Mairua dam showing sampling stations.

Source: GIS Lab Department of Geography ABU Zaria using ArcGIS 10.3 software.

Sample collection and pre-treatment

The water samples for analysis were collected in 120 ml plastic container which was initially washed with detergent and then rinsed with distilled water.

The plastic containers were filled up at the depth of one meter below the water. The samples were collected from eleven sampling points by dipping the plastic bottles in the water before the sediment is

reached and also at the surface to make a composite sample [11].

Quality assurance

All glassware and polythene sample bottles used in the study were washed with liquid soap, rinsed with plenty of distilled water, soaked in 10% HNO_3 for 24 hr and rinsed thoroughly with de-ionized water and thereafter dried [12].

Measurement of Physico-chemical Parameters

Water quality parameters such as pH, Electrical Conductivity (EC), Cation Exchange Capacity (CEC), Biochemical oxygen demand (BOD), Dissolve oxygen (DO), Total dissolved solid (TDS) Cl^- , NO_3^- and PO_4^{3-} ions were determined using standard analytical methods according to [13].

Statistical treatment of data

Microsoft spreadsheet was used to calculate the mean and standard deviation, while SPSS version 20.0 was used to test the significant differences in the levels of the parameters studied across the sampling points at 95% ($p \leq 0.05$) confidence level.

RESULTS AND DISCUSSION

Table 1 presents the results of the physico-chemical parameters of the analyzed surface water. pH, DO, BOD and TDS across the sampling points were in the ranges of 8.1 ± 0.03 (W11) to 8.68 ± 0.01 (W4), 1.20 ± 0.1 (W11) to 25.33 ± 0.58 mg/L, 0.60 ± 0.00 (W2) to 12.33 ± 0.58 (W1) to 139 1 ± 0.1 (W2), 1142.50 ± 3.8 (W1) mg/L respectively. Similarly, the ranges of EC, temperature, Cl^-, NO_3^- and $PO4^{3-}$ were; 165.3 ± 0.6 (W3) to 11355.0 ± 5.00 (W1) μscm^{-1}, 25 ^{0}C (W2) to 29 ^{0}C (W8) , 15.6 ± 0.01(W2) to 235.93 ± 0.01(W1), BDL (W8, W11) to 20.23 ± 0.25 mg/L (W1) and BDL (W2,W3,W5,W7,W8.W9) to 0.70 ± 0.00 (W1) mg/L, respectively.

On comparing the levels of the analyzed pH with those of [14] permissible limit of 6.5 to 8.50, the pH 8.27±0.01(W5),

8.38±0.01(W7),8.39±0.00(W8),8.14±0.01(W9),8.22±0.01(W10) and 8.10±0.03(W11) points were found to be within the range. However the pH levels at 8.65±0.01 (W1), 8.62±0.01 (W2), 8.52±0.01 (W3), 8.68±0.01(W4) and 8.52±0.00(W6) points were higher than the WHO permissible limit and this might be attributed to the farming activities at the vicinity of the dam. The pH of water fluctuates due to photosynthesis and respiration in water, also due to aquatic animal waste which is naturally acidic [15]. Similarly, the concentration ranges for dissolved oxygen (DO), biochemical oxygen demand (BOD) and total dissolved solids (TDS) were, 1.20 ± 0.1 (W11) to 25.33 ± 0.58, 0.60 ± 0.00 (W2) to 12.33 ± 0.58 (W1),139 1 ± 0.1 (W2) to 1142.50 ± 3.8 (W1) mg/L, respectively. On comparing the levels of the analyzed DO with the WHO [14] permissible limit of 5.0 mg/L, the levels recorded at points WI, W4 and W6 (25.3, 19.0 and 18.0 mg/L) were higher than the tolerable limit. However, at W2, W3, W5, W7, W8, W9, W10, W11 (1.70, 1.53, 1.60, 2.60, 2.33, 1.67, 1.43, 1.20 mg/L) were lower than the acceptable limit of WHO [14].

TABLE 1: **Physico-chemical parameters of surface water samples collected from Mairua Dam**

Parameter	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	WHO (2011)
pH	8.65±0.01	8.62±0.01	8.52±0.01	8.68±0.01	8.27±0.01	8.52±0.00	8.38±0.01	8.39±0.00	8.14±0.01	8.22±0.01	8.1±0.03	8.5
DO(mg/L)	25.33±0.58	1.70±0.00	1.53±0.06	19.00±0.00	1.60±0.10	18.00±0.00	2.60±0.00	2.33±0.06	1.67±0.06	1.43±0.06	1.20±0.1	5
BOD (mg/L)	12.33±0.58	0.60±0.00	1.00±0.10	6.33±0.58	1.70±0.00	6.00±1.00	1.70±0.00	1.20±0.10	0.83±0.06	0.70±0.00	0.80±0.1	5
TDS (mg/L)	1142.50±3.83	139.1±0.1	829.5±4.0	842.67±1.5	835.3±0.0	426.00±0.00	145.6±0.1	150.3±0.1	143.3±0.1	160.4±0.0	146.7±0.1	500
EC (µs/cm)	11355.0±5.00	277.3±1.2	165.3±0.6	1685.0±1.0	272.0±0.0	852.00±1.00	293.3±1.2	300.0±0.0	286.0±0.0	322.00±1.0	294.0±1.0	1000
C^{l-} 1(mg/L)	235.93±0.01	15.6±0.01	193.8±0.6	150.70±0.0	21.16±0.6	71.47±1.00	17.49±0.0	16.99±0.0	16.5±0.01	18.49±0.00	16.49±0.0	250
NO^{3-}	20.23±0.25	13.00±0.0	9.50±0.50	13.00±0.00	5.67±0.58	9.00±0.00	10.00±0.0	0.00±0.00	7.17±0.06	16.00±0.00	0.00±0.00	50
$PO4^{3-}$	0.70±0.00	0.00±0.00	0.00±0.00	0.30±0.00	0.00±0.00	0.51±1.00	BDL	BDL	BDL	0.30±0.00	0.20±0.00	10
Temp (^{0}C)	28.0	25.0	27.0	28.0	28.0	28.0	28.0	29.0	28.0	27.0	26.0	27.0

Table 2: Anova of physico-chemical parameter of water samples

ANOVA

Parameters		Sum of Squares	Df	Mean Square	F	Sig.
pH	Between Groups	1.110	10	.111	42.089	.000
	Within Groups	.058	22	.003		
	Total	1.168	32			
DO	Between Groups	2467.268	10	246.727	7401.805	.000
	Within Groups	.733	22	.033		
	Total	2468.002	32			
BOD	Between Groups	425.905	10	42.591	275.586	.000
	Within Groups	3.400	22	.155		
	Total	429.305	32			
TDS	Between Groups	2859232.163	10	285923.216	5.448	.000
	Within Groups	1154587.687	22	52481.258		
	Total	4013819.850	32			
EC	Between Groups	323124380.000	10	32312438.000	11107400.562	.000
	Within Groups	64.000	22	2.909		
	Total	323124444.000	32			
Cl	Between Groups	205829.787	10	20582.979	331934.857	.000
	Within Groups	1.364	22	.062		
	Total	205831.151	32			
NO3	Between Groups	1149.042	10	114.904	1944.533	.000
	Within Groups	1.300	22	.059		
	Total	1150.342	32			
PO4	Between Groups	1.808	10	.181	19893.000	.000
	Within Groups	.000	22	.000		
	Total	1.809	32			

Table 3: Water quality index of analyzed water samples

Parameter	Observed value	Sn	1/Sn	∑1/Sn	K= 1÷∑1/Sn	Wn = K /Sn	Qn	Wn x Qn
pH	**8.4**	8.5	0.118	0.685	1.460	0.172	93.33	16.053
DO(mg/L)	6.763	5	0.2	0.685	1.460	0.292	80.41	23.480
BOD (mg/L)	3.0172	5	0.2	0.685	1.460	0.292	60.344	17.620
TDS (mg/L)	451.034	500	0.002	0.685	1.460	0.003	90.207	0.270
EC (µs/cm)	1599.09	1000	0.001	0.685	1.460	0.002	159.909	0.320
C^{l-} 1(mg/L)	70.452	250	0.004	0.685	1.460	0.006	28.181	0.169
NO^{3-}	8.006	50	0.02	0.685	1.460	0.029	16.012	0.464
$PO4^{3-}$	0.183	10	0.1	0.685	1.460	0.146	1.83	0.267
Temp (^{0}C)	27.27	25	0.04	0.685	1.460	0.058	109.08	6.327
			0.685			1	638.503	64.969

$$WQI = \sum_{i=1}^{n} Wn\ Qn\ /\ \sum_{wni=1}^{n} = 64.969$$

Table 4: Terminologies for pollution classes in respect to WQI

Water quality index (WQI)	**Water quality status**
0 – 25	Excellent
26 – 50	Good
51 – 75	Poor
76 – 100	Very poor
>100	Unfit for drinking

Low level of DO might be attributed to high amount of nutrient released into the water by fishermen. DO that is too high or too low can cause harm to aquatic lives and affect water quality. If DO concentration drop below 5 mg/L fish and other aquatic organisms will leave the area in search for where there is more availability of oxygen and may not be able to reproduce and mortality rate will rise [16].

On comparing the levels of the analyzed BOD with those of WHO [14] permissible limit of 5.0mg/, the levels at point W1, W4, and W6 (12.33, 6.33 and 6.00 mg/L) were higher than the tolerable limits of 5 mg/L while those at points W2, W3, W5, W7, W8, W9, W10, W11 were lower than the permissible limit of WHO [14] as indicated in Table 1 as there is always direct relationship between BOD and DO. BOD and DO are inversely proportional to each other. A decline in DO levels reflects a high level of BOD [17].

Similarly, the levels of total dissolved solids (TDS) across the sampling points were within the tolerable limits of 500 mg/L with the exception of samples at points W1, W3, W4 and W5 (1142.50, 829.5, 842.67, 835.3 mg/L), respectively. This trend might be attributed to farming activities and leachate migration at the vicinity of the Dam. These results clearly indicate that water in the study area might contain calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$). Increased levels of TDS can give water a bitter, metallic, or salty taste, along with discoloring the water and creating an unpleasant odor [18].

Furthermore, the levels of EC across the sampling points ranged from 165.3 ± 0.6 (W3) to 11355.0 ± 5.00 (W1) as reflected in Table 1.The EC across the sampling points were within the WHO [14] tolerable limit of

1000 µs/cm with the exception of samples at points W1 and W2. Similar value was reported by [19] in drinking water of Turkey. These results clearly indicate that water in the study area were considerably ionized and has higher level of ionic concentration.

Similarly, the concentration ranges of 15.6 ± 0.01(W2) to 235.93 ± 0.01(W1), below detection limits (BDL), (W8, W11) to 20.23 ± 0.25 (W1) and BDL (W2, W3, W5, W7, W8, W9) to 0.70 ± 0.00 (W1) mg/L were obtained for Cl^-, NO_3^-, PO_4^{3-}P, respectively. It was found that these concentrations Cl^-, NO_3^-, PO_4^{3-} -P were all within the WHO [14] tolerable limits of 250, 50 and 10 mg/L, respectively without an exception. This clearly shows that the water samples were not polluted with Cl^-, NO_3^-, PO_4^{3-} -P. Similar value was reported by [20] in Portharcourt Nigeria.

The levels of temperature across the sampling points was in the range of 25 ^{0}C (W2) to 29 ^{0}C (W8), this range was in accord with the tolerable limit of 27 ^{0}C reported by WHO [14]. Water temperatures vary by season, latitude, depth, and currents. High temperatures can accelerate chemical and biological reaction rates in water, effectively lowering concentrations of minerals and the level of oxygen in the surface water, hence endangering the lives of aquatic organisms [21]. These results clearly indicate that water in the study area is safe. [22] reported similar results.

Generally, the following trend was observed across the sampling points; WI>W2 >W4>W5>W6>W3 = W7>W8>W10>W9>W11, This clearly indicates that W1 sample was the most contaminated while W11 was the least.

The pH level across the sampling points was in conformity with the tolerable limit of 8.5 reported by WHO [14]. Indicating that the water in this study were alkaline.

Similar result was recorded by [23]. The results in this study was higher than the values reported by [24] in his work on physicochemical parameters of water from selected ponds and streams in Nigeria, where acidic pH range of 5.50 – 5.86 was reported.

Results of this study were similar to those reported by [25] La Vega Dam, Mexico.

Furthermore, the results in this study were higher than the values reported by [26] for Lower Usuma Dam, FCT, Nigeria with the pH values ranging from 7.0 to 7.1. The reason for this variation might be attributed to the time of the season when the samples were collected. This indicates that the water is slightly acidic.

The Dissolved oxygen (DO) reported in this study were below the tolerable limits of 5 mg/L with exception of samples 25.33 ± 0.58 (W1), 19.0 ± 0.00 (W4) and 18.00 ± 0.00 (W6) respectively. Decreased DO levels may be indicative of too many bacteria and an excess amount of biological oxygen demand - BOD (untreated sewage, organic discharges, and anoxic discharges) which use up DO. Decreased DO might also be as a result of fertilizer runoff from farmlands. The same fertilizer which was meant to make land plants grow better now makes the aquatic plants do the same hereby reducing the level of oxygen available for aquatic organism in the water [27].

Biological Oxygen Demand (BOD) measures the amount of oxygen used by microorganisms, such as bacterium, to oxidize organic matter present in the samples. Water samples with BOD less than 5.0 mg/L are considered clean. From the result of this study, the results obtained in 12.33 ± 0.58 (W1), 6.33 ± 0.58 (W4) and 6.00 ±1.0 (W6) were higher than the tolerable limits 5 mg/L WHO [14].This might be attributed to the migration of leachate from the surrounding farmlands. The greater the BOD, the more rapidly

oxygen is depleted in the stream. This means less oxygen is available to aquatic life; aquatic organisms become stressed, suffocate, and die [28].

Furthermore, BOD in this research was higher than the values reported by [29] for Udo Awankwo River in Ikot Ekpene, Nigeria. The reason for this variation might be attributed to the presence of leachates from the nearby farms.

The total dissolve solids (TDS) were higher than that of [30] in river Sokoto, Nigeria. The TDS were found to be in the range of 83.51 – 91.93 mg/L in the three sampling points which were also lower than normal range described by WHO [15] which is 500 mg/L for drinking water. It is an indication of aesthetic characteristics of drinking water and as an aggregate indicator of the presence of chemical contaminants. High levels of TDS in some of the analyzed water samples might be as a result of agricultural runoff and residential runoff.

The EC in this study was also higher than that of [31] with values ranging from 50.65 to 53.7 µS. This was attributed to contaminants in the water, for water to properly conduct electricity; there must be ions in it.

The temperature recorded was in line with that of [29] in Udo Awankwo River in Ikot Ekpene, which ranged between 28.0 to 28.2°C which is below 32°C for safe drinking water. High temperature will affect the rate of chemical and biochemical reactions, solubility of gases in the water which could impact negatively on the taste and odor of the water at higher temperatures. The present observation is also in consonance with the result obtained for Abia Dam Nigeria by [32] who reported that the average temperature was between 28 ^{0}C-29 °C. Similarly on comparing the findings in this study with those of [33], the water temperature values recorded was in line with the range of 27 to 30^{0}C recorded in this

study. The slight increase in values of the temperature might be linked to varying weather conditions.

Comparing the findings in this study with those of [23] for Shika Dam, Zaria where the mean concentrations of Cl^- , NO_3^- ,PO_4^{3-} were recorded as 143, 58.72, and 8.47 mg/L, respectively. The mean concentrations of Cl^- , NO_3^- , PO_4^{3-} were higher than those reported in this study; and it was therefore concluded that the high concentrations of these ions in water is due to activities which include runoff from farmlands, bush burning areas, and hence it was also reported to be higher than the WHO [14] permissible limits as reflected in Table 1 above. The results of these findings were also in line with that of [26] where 0.45 to 0.5, 5.78 to 5.8 and 2.23 to 2.40 mg/L were obtained for NO_3^-, PO_4^{3-}, Cl^- respectively. This results shows that the water does not possess eutrophication features as stated by [34] and [35] who opined that high nutrients (NO^{3-}, PO_4^{3-}, Cl^-) 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.

Table 4 shows the water quality index of the analyzed water samples. Results obtained indicate that the water quality index (WQI) for the water samples across the sampling points was 64.969.This clearly shows that the water is poor for public consumption and it needs to be subjected to further treatments since WQI range of 51 to 75 is considered poor [36].

WQI in this study was within the range of 51-76.5 reported by [37] in a similar study conducted in India. The WQI obtained in this study were lower than the value reported by [38] where a WQI value of 532.53 was reported.

Conclusion

This study reveals the levels of selected physico-chemical parameters (pH, DO, BOD, TDS, EC, Cl^-, NO_3^- $PO_4^{3-}$and Temperature) of surface water of Mairua Dam Faskari LGA, Katsina Nigeria. Ten out of the eleven water samples analyzed were having higher levels of the physico-chemical parameters than the WHO (2011) recommended limits for quality water. Discharges of domestic, agricultural wastes and fertilizers as well as feeds used by the fishermen were major causes of water quality deterioration in the study area. The elevated levels of these physico-chemical parameters could ultimately contaminate the water and make it detrimental to the life of aquatic animals and thus making the water toxic for human consumption.

Recommendations

It is therefore recommended that the water quality of Mairua Dam should be continuously monitored to assess the level of pollution and the farming activities be constantly monitored to ensure that pollutant entrance into the dam are significantly minimized.

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