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Quality Status of Kafin-chiri Reservoir, Kano State, Nigeria for Drinking Water Supply

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

The quality of drinking water depends largely on the treatment process and the distribution network. Water samples were collected from different locations in the reservoir, treatment plant and potable water from the tap and analyzed for physical and chemical parameters; pH, temperature, TDS, conductivity, turbidity, total hardness, suspended solids, total solids, color, DO, BOD, Cl^- NO_2^-, NO_3^-, COD and PO_4^{3-} in three seasons of the year November - February (cold season); March - June (dry season) and July - September (rainy season). The results obtained showed no significant variations $p<0.05$ between the three sampling locations but with significant seasonal variations. The values obtained for most of the parameters were above the threshold limit set by WHO. There is no effectiveness in the treatment process in the removal of contaminants from the treated water. Water quality index (WQI) was calculated for the three sampling sites; reservoir, treated and potable water with a result of 147, 97 and 102 respectively which indicates very poor water quality. This gives serious concern over the possible adverse effect on human health. Excessive use of phosphate and nitrate based fertilizers and other anthropogenic activities around the reservoirs should be discouraged.

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Keywords: Water treatment; drinking water; Kafin-chiri reservoir; water quality index.

1. INTRODUCTION

Kano is the commercial nerve center of Northern Nigeria. There are many industries in the city comprising textiles, tanneries, chemical industries and steel production [1]. Wastes from these industries are discharged into the two main river basins in the city River Jakara to the North and River Kano to the South for the main industrial areas of Bompai, Sharada and Challawa [2]. These rivers discharge their content into reservoirs (Dams) that are used for the supply of drinking water [3]. Kafin-chiri is an agricultural town with little industrial activities observed around the reservoir and the tributary rivers. Domestic waste and agricultural activities are abound in the area with a lot of grazing animals. These anthropogenic activities coupled with geological origin of the reservoir may serve as a source of pollution to the reservoir.

Water treatment process was developed to produce safe and clean drinking water to avert contamination that emanates from contaminated water. The quality of water is as important as the quantity available, hence the need to study the physical and chemical parameters to determine whether the water is suitable for domestic, industrial and agricultural purposes. Recent reports point to the increasing dangers of environmental pollution [4] which calls for the need for public awareness on ways of minimizing or averting the perpetual problems of pollution in the Kano environment. Physical parameters such as color, turbidity, light permeability, water temperature and electrical conductivity (EC) and chemical parameters pH, dissolved oxygen (DO), biological oxygen value (BOD), chemical oxygen demand (COD) and total hardness (T/H) are indicators of pollution in aquatic environment [5]. Human activities may have direct consequences on the level of these parameters and can have adverse effect on quality of the water. Water for human consumption must be free from contaminants such as chemical substances, organic waste and other anthropogenic inputs. Similarly, potable drinking water should have aesthetically acceptable quality parameters and should not possess unpleasant or objectionable taste, odor or color [6]. This work is aimed at assessing the quality status of raw water, treated and pipe bone water in Kafin chiri reservoir, Kano state and to assess its fitness for drinking water supply.

2. MATERIALS AND METHODS

2.1 Study Area

Kafin-Chiri has an elevation of 478 meters above sea level. Its center lies at a latitude of 11.6 and longitude of 8.8 [7]. It receives water from rivers Dudduru (at Garin Ali town), Zabaro (at Mai manda town) and Marmara (at Dakatsalle town) [8].

2.2 Collection of Samples

Surface water (Approximately 1000 cm^3) was collected from the reservoir within a depth of 20 cm into a pre cleaned plastic containers [9]. Analar grade reagents were used throughout. Five locations were chosen in the reservoir. These include the water inlet (three points), outlet (spillway) and center. The inlet serves as the entry points of adjourning rivers. The spillway serves as discharge point to the reservoir in periods of flood and heavy rain. Within each location, five sampling points were randomly selected and samples of water were collected at each point. Treated water was collected from water treatment plants that receive water from the reservoirs under study and potable water was collected from the consumer end in five towns that receive water from the treatment plant.

2.3 Methodology

Physical parameters temperature, total dissolved solids (TDS), EC, turbidity and suspended solids (SS); chemical parameters. pH, T/H, DO, BOD, Cl^-, NO_2^-, NO^-_3, COD, and PO_4^{3-} were analyzed using standard methods and procedures [10], Some of the parameters were determined *in situ* using pre-calibrated hand held equipment. pH was measured using Jenway pH meter model 3505. DO was determined using water proof Jenway DO_2 meter model: 9200; conductivity, TDS and temperature were measured using HI ECi model No. 961. Turbidity was determined using Wagtech turbidity meter Wag WT 3020 model. The other parameters were analyzed in the laboratory using standard procedures and methods [11]. Chloride was measured in the laboratory by silver nitrate titration method. Suspended solid was measured gravimetrically after filtration. BOD was measured using HACH BODTrak meter model No. 205 by measuring initial and final DO after incubation in the dark for

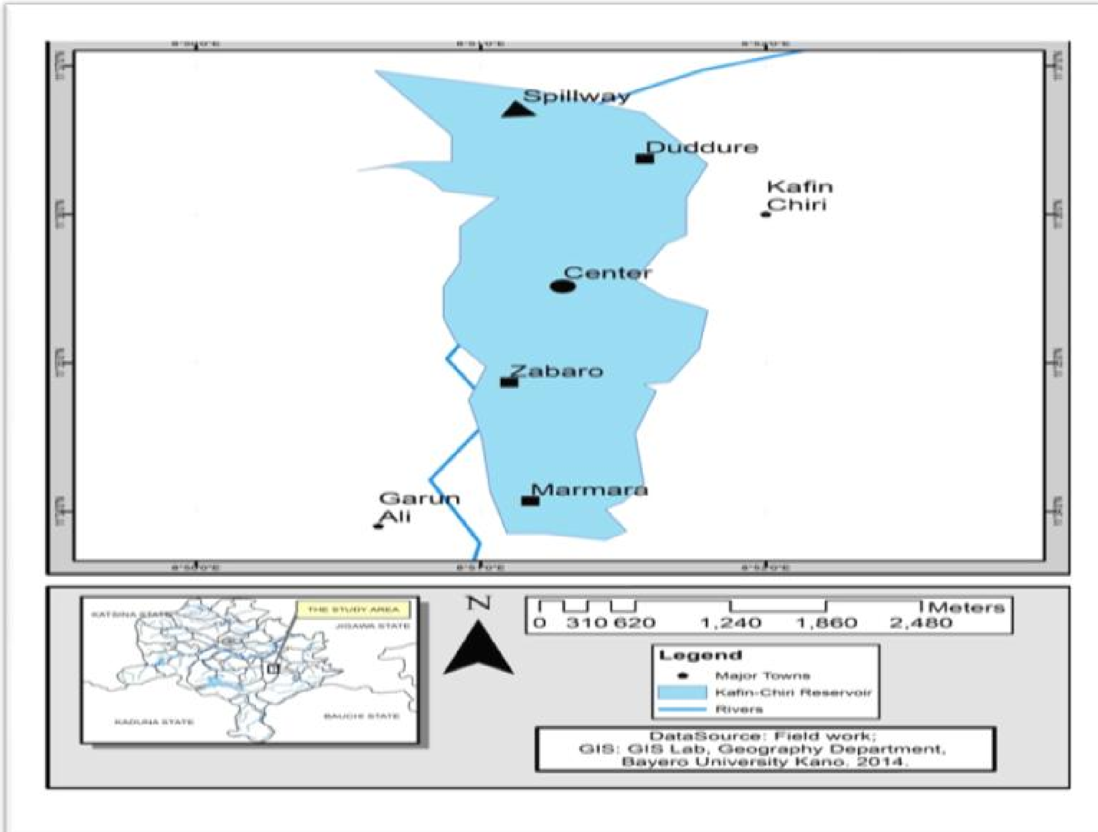

Fig. 1. Map of Kafin-chiri reservoir showing the sampling site

five days. Nitrite was determined using sulphanilamide spectrophotometric method and Nitrate was determined by cadmium reduction method using HACH colorimeter model No. 890. COD was determined by dichromate oxidation method. PO_4^{3-} was measured using ascorbic acid molybdate spectrophotometric method.

2.4 Water Quality Index

In this study, water quality index (WQI) was calculated using WHO and NIS standards for drinking water quality. The weighted arithmetic index was adapted [12]. The overall water quality index was calculated by aggregating the quality rating with the unit weight linearly using the equation below;

$$WQI = \frac{\Sigma\,(qn\,Wn)}{Wn}$$

Where; the sub index or quality rating (qn) was calculated using the following expression;

$$qn = \frac{100\,(Vn - Vi)}{(Sn - Vi)}$$

for n parameter, the quality rating or sub index qn corresponds to nth parameter value or limit. Vn = experimental or observed value of the nth parameter at a given sampling station. Vi = ideal value of nth parameter. Sn = standard permissible value of the nth parameter. Wn = unit weight for nth parameters calculated by a value inversely proportional to the recommended standard value of the corresponding parameter.

$$Wn = \frac{K}{Sn}$$

$K =$ proportionality constant.

3. RESULTS AND DISCUSSION

Kafin chiri reservoir recorded mean DO values in the range of 1.52 to 4.20 mg/L (Tables 1-6). The minimum DO values were obtained in the reservoir in dry season and the maximum DO levels were obtained in potable water in rainy season. The effect of season is noticed in Kafin-chiri reservoir. The low DO values may be as a result of high temperature, decomposition of algae and organic matter [13]. Similar values were reported by [14] 1.04 to 6.68 mg/L when assessing qualities of surface water from selected major rivers in south western Nigeria. The mean DO results showed significant difference $p<0.05$ between the three sampling seasons. The result obtained for DO is fairly consistent in the three sampling sites; reservoir, treated and potable water. The DO is a measure of the degree of pollution by organic matter, the destruction of organic substances as well as the self-purification capacity of the water body [7].

Kafin-chiri recorded mean BOD values in the range of 1.92 to 3.39 mg/L. The low BOD values in the treated and potable water may be as a result of the reduction of organic matter in the treatment process. BOD level in the range of 3 to 5 mg/L indicates moderately clean water. Chloride is one of the major anions to be found in water and sewage. The mean values of chloride obtained in all the sampling locations ranged from 17.40 to 50.46 mg/L. The result showed significant seasonal variations $p<0.05$ (Tables 1-6). The chloride values were fairly consistent in most of the locations. The mean values of nitrite and nitrate ranged from BDL to 0.074 mg/L and 8.81 to 32.68 mg/L respectively. Excessively high level of nitrate was recorded. This is may be due to the use of nitrate based fertilizer in the agricultural fields around the reservoir especially its major tributary, River Dudduru. There is no remarkable seasonal variation observed (Tables 1-6).

Table 1. Seasonal variations of chemical parameters (mg/L) of Kafin-chiri reservoir water

Season	DO	BOD	Chloride	Nitrite	Nitrate	COD	Phosphate
Dry	1.52	3.39	20.00	0.01	24.52	28.21	3.07
Cold	2.88	3.24	49.14	0.07	32.68	124.80	3.42
Rainy	4.01	2.14	27.91	0.01	8.82	46.04	1.13

Table 2. Seasonal variations of physical parameters (mg/L) of Kafin-chiri reservoir water

Season	pH	Temp °C	TDS	SS	TS	*EC	*Turb.	*Color	T/H
Dry	7.96	34.27	47.56	0.77	48.31	95.40	50.67	6.16	34.45
Cold	7.00	29.88	45.80	64.20	110.00	92.20	89.40	540.00	240.00
Rainy	8.88	34.24	47.60	164.60	211.80	95.68	136.48	345.60	45.92

**Units: EC= μS/cm; Turbidity = FAU; Color = hazen*

Table 3. Seasonal variations of chemical parameters (mg/L) of Kafin-chiri treated water

Season	DO	BOD	Chloride	Nitrite	Nitrate	COD	Phosphate
Dry	2.27	2.02	17.40	0.01	9.52	30.42	2.34
Cold	2.36	2.32	50.46	0.00	21.26	164.60	3.22
Rainy	4.08	2.08	18.40	0.01	6.26	52.00	3.24

Table 4. Seasonal variations of physical parameters (mg/L) of Kafin-chiri treated water

Season	pH	Temp °C	TDS	SS	TS	*EC	*Turb	*Color	T/H
Dry	7.96	32.46	60.40	1.13	61.52	111.20	56.40	31.20	42.24
Cold	7.06	28.38	44.40	44.60	89.00	83.80	66.60	504.00	41.60
Rainy	8.56	29.72	46.00	37.00	83.00	90.00	63.60	136.00	29.60

**Units: EC= μS/cm; Turbidity = FAU; Color = hazen*

Table 5. Seasonal variations of chemical parameters (mg/L) of Kafin-chiri potable water

Season	DO	BOD	Chloride	Nitrite	Nitrate	COD	Phosphate
Dry	2.21	1.92	18.30	0.00	17.38	28.20	1.90
Cold	2.76	2.18	49.10	0.02	22.62	138.60	4.04
Rainy	4.20	2.64	18.20	0.02	6.44	44.60	3.16

Table 6. Seasonal variations of physical parameters (mg/L) of Kafin-chiri potable water

Season	pH	Temp °C	TDS	SS	TS	*EC	*Turb	*Color	T/H
Dry	7.90	34.16	55.40	4.62	60.02	107.80	53.80	49.00	29.18
Cold	7.47	27.76	41.80	44.40	86.20	84.80	65.60	518.00	35.20
Rainy	8.68	34.04	40.20	27.60	67.80	80.00	71.40	115.60	31.20

**Units: EC= μS/cm; Turbidity = FAU; Color = hazen*

The high nitrite and nitrate values observed may be as a result of human induced changes in the watershed. This means that pollution by nitrate containing substances are very likely from non-point sources like agricultural fields or deposition of raw sewage into the water source and because nitrate is very soluble, it flows very easily into the water body. Nitrite occurs in water as an intermediate byproduct in the biological breakdown of organic nitrogen. The presence of large quantities of nitrites is indicative of waste water pollution. Similar values of nitrite were obtained 0.001 to 0.007 mg/L by reference [15] in the determination of physical and chemical parameters of River Shkumbi (Pena). COD is a measure of the total quantity of oxygen required to oxidize all organic materials into carbon dioxide and water [16]. Both BOD and COD measure the amount of oxygen consumed during the microbial or chemical breakdown of oxygen-depleting substances in water, such as sewage and farm slurry. The values obtained for COD in this study ranged from 28.20 to 164.60 mg/L. The COD levels exceeded the limit of 10 to 20 mg/L in most of the locations which is an indication of organic pollution. COD values obtained during cold season indicate presence of inorganic chemicals that are oxygen demanding in nature [7] and the presence of biologically resistant organic substances [17]. Higher values of COD were obtained by reference [14], with a range of 72.80 to 292.00 mg/L when assessing the qualities of surface water, sediments and aquatic fish from selected major rivers in south-western Nigeria.

The concentration of phosphate in Kafin-chiri ranged from 1.12 to 4.04 mg/L. The result obtained for phosphate is markedly high in all the sampling sites; reservoir, treated and potable water with no significant seasonal differences. Excessive agricultural activities were observed along the major tributaries. The agricultural practice may involve the use of phosphate based fertilizer which was washed by run-off from the watershed. Similar phosphate values 0.85 to 4.02 mg/L were obtained by reference [13] in the study of limnological features of Ikere Gorge reservoir, Iseyin south western Nigeria. The maximum permissible limit for phosphate was 10 mg/L. phosphates and nitrates are usually harmless, but can fertilize the algae which overgrow in reservoirs and lead to eutrophication which can kill life in reservoirs and rivers. In some cases, a particular alga can also poison the drinking water used by humans and livestock [18].

pH values were obtained in the range of 7.00 to 8.88 mg/L. Higher pH values were obtained in rainy season with significant variations for ANOVA $p<0.05$. This might be due to the deposition of some organic matters into the water from run-off in rainy season. There is however no marginal difference in pH values between the sampling sites; reservoir, treated and potable water. Low pH values recorded in dry and cold seasons may be as a result of influx of municipal waste from the tributaries into the reservoirs [19] which stretch the buffering capacity of the reservoirs.

This is because; decomposing organic waste reduces the pH of aquatic systems. Reference [20], obtained lower pH values in the range of 5.40 to 6.70 in ground water quality assessment of Jada area, north eastern Nigeria. Reference [13] also recorded highest pH values in rainy season (July) and least pH values in cold season (December) 7.50 and 7.16 respectively in the study of limnological features of Ikere gorge reservoir in south western Nigeria. The mean temperature recorded in this study ranged from 27.76 to 34.26ºC. Dry season temperature was significantly higher $p<0.05$ than cold and rainy seasons. No significant variations were seen among the sampling sites reservoir, treated and potable water. The natural climate of the study area features savanna vegetation and a hot, semi-arid climate, which explain the excessive temperature recorded in this study. Temperature has a negative effect on dissolved oxygen. Increase in water temperature more than necessary lead to decrease in dissolved oxygen level in water [11]. High temperature enhances the growth of microorganisms and may increase taste, odor, color and corrosion problems. It can also trigger algal bloom in the presence of elevated concentrations of nutrients such as phosphates and nitrates [6] and this is potentially hazardous to human health due to the production of cyanotoxins.

Concentrations obtained for TDS in this study ranged from 41.80 to 60.40 mg/L. Higher concentrations were obtained in dry season with significant variations $p<0.05$. TDS values were found to be within the maximum permissible limit of 500 mg/L. Concentrations of TDS from natural sources have been found to vary from less than 30 mg/L to as much as 6,000 mg/L depending on the solubility of minerals in different geological regions. TDS in water originates from natural sources, sewage, urban run-off and industrial waste water. Conductivity is the measure of the ability of water to pass an electric current. Conductivity is not specific. It is a measure of the total concentration of ions in solution. In this study, mean conductivity values in the range of 80.00 to 111.20 µS/cm were obtained. Higher conductivity values were obtained in dry season which may be as a result of decrease in total volume of the water and high temperature. Higher conductivity was obtained by reference [20] with a range of 25 to 425 µS/cm and a mean of 141.30 µS/cm.

Total solids refer to matter suspended or dissolved in water or waste-water and is related to both specific conductance and turbidity [10]. The mean SS and TS values obtained in this study ranged from 0.76 to 164.60 mg/L and 48.31 to 211.80 mg/L. Higher mean values of SS and TS were obtained in Kafin-chiri in rainy season. Reservoir recorded the highest mean SS and TS values with significant variations $p<0.05$. Reference [13] recorded mean SS values of 34.66±23.03 mg/L. All the samples in this study recorded mean turbidity values in the range of 50.66 to 136.48. Higher levels were obtained in rainy season with significant variations $p<0.05$. Turbidity concentrations showed no marginal difference ($p<0.05$) between reservoir, treated and potable water indicating poor treatment efficiency. Reference [21] working on impacts of industrial effluents on quality of Asa River Ilorin, Nigeria obtained turbidity level ranging from 4.6 to 189.0 FAU and attributed the high turbidity to the presence of suspended matter in the water sample due to human activities around the watershed.

The results obtained for color in this work have a mean range value of 6.16 to 540.00 hazen. Kafin-chiri recorded high color values in all the sampling sites reservoir, treated and potable water. This is an indication of poor treatment efficiency. The absence of effective treatment tools observed in this site may have contributed. Generally, color in drinking water may be due to the presence of colored organic substances, the presence of metals such as iron, manganese and copper; or the presence of highly colored industrial waste; common of which are pulp and paper and textiles wastes.

The mean values obtained for total hardness ranged from 29.18 to 45.92 mg/L which is lower than the threshold limit set for water hardness (130 mg/L) with significant difference $p<0.05$. Kafin-chiri reservoir water is therefore categorized as soft. Reference [14] recorded higher values (>200 mg/L) in the assessment of qualities of surface water from selected major rivers in south western Nigeria. The use of WQI, which combines a large quantity of chemical information of a water sample into a single value, facilitates spatial and temporal water quality evaluation of the area threatened by the industrial and domestic wastewaters. The results obtained for the various physico- chemical parameters in this study were used for the WQI calculations. Water quality index calculation is presented in Tables 7-10. The water quality index obtained for Kafin-chiri is presented as; 144, 97 and 101 for reservoir treated and potable water respectively. The values obtained showed that the reservoir and the potable water are not safe for human consumption while the treated water have very poor water quality (Table 10). The higher values obtained in potable water is due to exposed pipelines and old age of the storage tanks at the treatment plant. The pipelines were laid over 50 years ago and have serious leakages [4] that can cause problems in the distribution network of the packaged treatment plant with chlorination facility (PTP/C) [3]. The result indicates excessive pollution of the sampling area and poor treatment process at the treatment plant.

Table 7. Calculation of the water quality index of Kafin-chiri reservoir

Parameters	Observed values Vn	Standard values Sn	Unit weight Wn	Quality rating Qn	Wnxqn
pH	7.00	6.5 - 8.5	0.12	0.13	0.02
Temp.	30	25	0.04	119.52	4.78
TDS	46	500	0.02	9.16	0.02
Cond.	92	1000	0.01	9.22	0.01
Turb.	89	5	0.2	1788	375.6
BOD	3	5	0.2	64.8	12.96
Color	540	15	0.07	3600	240.12
TH	40	130	0.01	30.77	0.24
DO	3	5	0.2	57.6	11.52
Cl	49	250	0.04	19.66	0.08
NO_2^-	.07	0.2	5	37	185
NO_3^-	33	50	0.02	65.36	1.31
COD	125	20	0.05	624	31.2
PO_4^{3-}	3	10	0.1	34.2	3.42
			∑Wn = 6.01	∑qn 6459.42	∑(Wnqn)=866.27

WQI = ∑ (Wnqn)/ ∑Wn = 144

Table 8. Calculation of the water quality index of Kafin-chiri treated water

Parameters	Observed values Vn	Standard values Sn	Unit weight Wn	Quality rating Qn	Wnxqn
Ph	7.06	6.5 - 8.5	0.12	3.86	0.45
Temp.	28	25	0.04	93.52	3.74
TDS	44	500	0.02	8.88	0.02
Cond.	84	1000	0.01	8.38	0.08
Turb.	67	5	0.2	1332	266.4
BOD	2	5	0.2	46.4	9.28
Color	504	15	0.07	3360	224.11
TH	42	130	0.01	32	0.25
DO	2	5	0.2	141.67	28.33
Cl	50	250	0.04	20.18	0.08
NO_2^-	.002	0.2	5	1.2	6
NO_3^-	21	50	0.02	42.52	0.85
COD	165	20	0.05	823	41.15
PO_4^{3-}	3	10	0.1	32.2	3.22
			∑Wn = 6.01	∑qn = 5945.82	∑ (Wnqn)=583.89

WQI = ∑ (Wnqn)/ ∑Wn = 97

Table 9. Calculation of the water quality index of Kafin-chiri potable water

Parameters	Observed values	Standard values Sn	Unit weight Wn	Quality rating Qn	Wnxqn
pH	7.47	6.5 - 8.5	0.12	31.07	3.65
Temp.	28	25	0.04	111.04	4.44
TDS	42	500	0.02	8.36	0.02
Cond.	85	1000	0.01	8.48	0.01
Turb.	66	5	0.2	1312	262.4
BOD	2	5	0.2	43.6	8.72
Color	518	15	0.07	3453.33	230.34
TH	35	130	0.01	27.08	0.21
DO	3	5	0.2	123.33	24.67
Cl	49	250	0.04	19.64	0.08
NO_2^-	.01360	0.2	5	6.8	34

Parameters	Observed values	Standard values Sn	Unit weight Wn	Quality rating Qn	Wnxqn
NO_3^-	23	50	0.02	45.24	0.90
COD	139	20	0.05	693	34.65
PO_4^{3-}	4	10	0.1	40.4	4.04
			∑Wn = 6.00899	∑qn = 5923.37	∑(Wnqn)=608.13

WQI = ∑ (Wnqn)/ ∑Wn = 101

Table 10. Quality index and status of water quality (Yogendra and Puttaiah, 2008)

Quality index level ality index level	Water quality status er quality status
0-25	Excellent water quality
26-50	Good water quality
51-75	Poor water quality
76-100	Very poor water quality
>100	Unsuitable for drinking

4. CONCLUSION

The quality parameters analyzed in this work indicates that Kafin-chiri reservoir is heavily polluted. The pollutants largely come from agricultural activities, urban run-off and geological origin around the reservoir. The treatment process is poor and fails to remove the contaminants. There is therefore the need to upgrade the treatment plant to modern standard for supply of safe drinking water. The result of the WQI indicate excessive pollution of the study area and this can serve as a guide for policy makers in implementing water quality control measures.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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