Water Quality Assessment of Gurara Water Transfer Project and Lower Usuma Dam, Abuja - Nigeria

Shuaibu Ahmed Mahi and Shuaibu Isah

Geology Department, Federal University Gusau, Zamfara - Nigeria

Abstract- The aim of this research is to assess the water quality of Gurara water transfer scheme. The geology and hydrology of the area were studied. The water quality of Gurara Dam and Lower Usuma Dam at different depth of the reservoir at the peak of the dry and rainy season was assessed in order to determine the effects of geology on the water quality, extent of anthropological effect(s) and its Suitability for domestic and industrial purposes. This was done by subjecting 20 water samples from both Dams collected at predetermined depth for comprehensive physicochemical and bacteriological analysis using APHA standard methods of analysis for both rainy and dry seasons. The overall Water quality results were poor for drinking and aquatic, but fair for recreation and livestock, and good for irrigation. These were due to high concentration of COD, BOD, total hardness, turbidity, potassium, magnesium, cadmium, lead and iron. The results of the analysis when compared with the Nigerian standard for drinking water quality and world health organization permissible limits showed that the Gurara Dam and lower Usuma Dam were polluted and that the water was not safe for drinking. The major sources of pollution of the Gurara Dam, Lower Usuma Dam are the dissolution of the host rocks and weathered sediments in the area and the run-off and surface water flows of other water bodies within the catchment area. Anthropogenic activities on these water bodies are numerous such as industries municipal waste, agricultural and urban. All those factor contributed to the run-off that get discharged into the water bodies thereby flows into the Gurara Dam and Lower Usuma Dam through surface water flows processes and deteriorates the water quality. It is therefore recommended that the water from the both dams should undergo treatment when pumping it for domestic usage.

Index Terms- Geology, Hydrochemistry, Water quality, Gurara and Lower Usuma Dams, Abuja.

I. INTRODUCTION

Water is life. It is the very substance of life, comprising more than 60 percent of human body. Every part of our lives relies on water, water thus equals survival. These properties have enabled large diverse species of organisms to inhabit the water body. Man has also exploited these properties and the biotic components to its utmost advantages for economic and social benefits. At the same time, he has misused and abused the water to the detriment of himself and the biotic communities it contains (Mustapha, 2005).

Dam reservoirs are normally constructed for one function which has a fundamental influence upon their morphology and limnology. Reservoirs for single function are constructed for societal demand for, drinking water, irrigation, hydroelectric power generation, flood protection industrial water supply, recreation and production of fish. With time, though, generally reservoirs have had derivative functions superimposed upon them such as sediment control, navigation, pest and water borne disease control, industrial processing and cooling, urban run-off control and tourism Tundisi and Matsumura-Tundisi (2003).

The population growth rate of Federal Capital Territory (FCT), Abuja is geometric due to relocation of the FCT from Lagos to Abuja. Consequently, people migrated from other parts of Nigeria together with relocation of businesses into the new FCT. The water demand of the region expectedly has increased tremendously, thus, putting the existing water production and supply systems under great pressure. Clearly, this calls for expansion of the systems and a concomitant need to get more water from elsewhere into the territory.

To meet the present and future water demands of the new Capital, the Federal Government of Nigeria, through the Federal Ministry of Water Resources, commissioned a study in 1998 to assess the Gurara Water Transfer Project.

Under a comprehensive framework, the investigation adopted a holistic approach by broadening the effort to identify and assess all feasible sources of water both within and outside the FCT. Whether the already existing Lower Usuma Dam or groundwater, available in sufficient quantities to meet and sustain the Territory’s demands over a 30-yr planning horizon (Onah, 2002)

The effort which ranged from feasibility studies to field investigations identified the gravity based Gurara Water Transfer Project (GWTP) as the most suitable for the Capital. Gurara River source was found sufficient to meet, not only the 30-yr demand, but also the ultimate water requirement of the FCT, over the next 50 years (Onah, 2002).

Hence, it becomes very important to study the quality of the raw water in the Dams which is the focus of this study and provide background values for future usage

II. THE STUDY AREA

Location and Accessibility

The study area covers the Upper Gurara Dam area falling within Latitudes $9^0 13'$N and $9^0 39'$ and Longitudes $7^0 26'$E and $7^0 42'$E, an area approximately $150km^{2.}$ (Figure1).

Also considered is the pipeline route, a corridor some 60m wide and 75km in length, for pipeline conveyance of water from Upper Gurara Reservoir in Kaduna State to the existing Lower Usuma Lake in the Federal Capital Territory.

The study area region comprises parts of the Akwana West and East reserves and some scatter settlements such as Atara, Anguwan Kagarko, Akwana. It is a rugged terrain with light to heavy bush and farms. The pipeline runs through Giwa Forest reserve, the vast rugged terrain of Chinka, Douphe, Gami in Kagako LGA and Bwari settlement areas to Usuma Forest Reserve around Ushafa in the FCT.

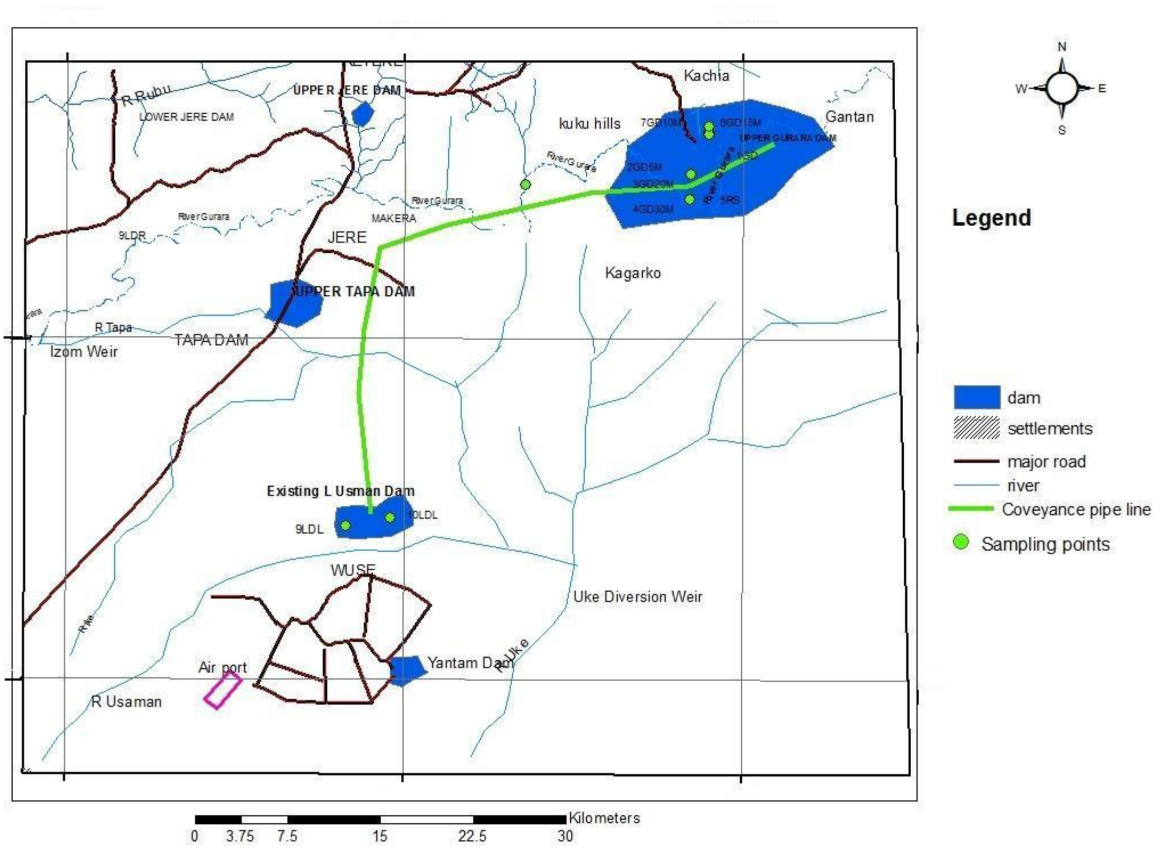


Figure 1 Location Map of the Study Area

Local Geology of the Area

The area is part of the Precambrian basement complex of Nigeria which bears imprints of thermo-tectonic events dating from Archaean to Early Palaeozoic times the rocks are essentially gneiss-schist suites cut by granitic intrusive which are pan African in age (600Ma) are well exposed as dome shaped hills and elongate ridge whereas the host metasediments underlie the plain and subdued hills. This good correlation between topography and bedrock geology was very useful in delineating the exposures of the intrusive from those of the host gneiss-schist suites which were often covered by regolith and vegetation (Figure 2).

The major rock types are

I. Porphyritic Granite
II. Fine – medium Granite
III. Granite Gneiss
IV. Schist
V. Migmatites

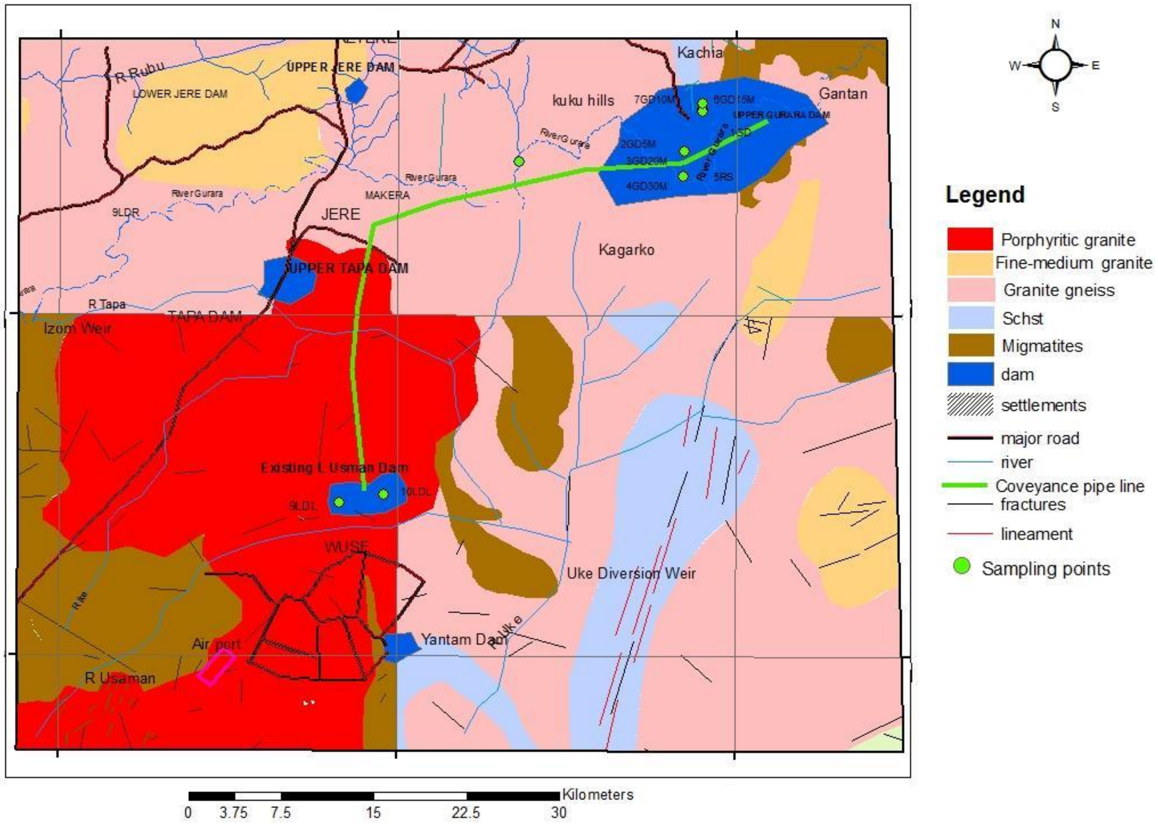


Figure 2: Geological Map of Part of Upper Gurara Dam Lower Usuma Dam (by author)

Data on Dams and Auxiliaries

The project is to transfer raw water impounded by Upper Gurara Dam in Kachia L.G.A. of Kaduna State via a 75 km Long pipeline traversing Kagarko, L.G.A of Kaduna State and Bwari Area Council in FCT, to feed Lower Usuma Dam Reservoir and Treatment plant

Features of the project as established by final design have been grouped under lots; namely:

Lot A- dam and associated works

Lot A comprises a dam across River Gurara, a spillway, bottom outlet, a hydroelectric power plant, the conveyance pipeline intake tunnel, foundation treatment and river diversion works.

Lot B- Water conveyance pipeline

The Water Conveyance pipeline, denoted Lot B, comprises 75 km log, 3000mm diameter internally plastic and externally Bituseal coated steel pipeline, all necessary fittings, valves and washouts, reinforced concrete saddle supports, a pipeline service road with bridges and culverts, control stations, high and low voltage power transmission system, line support transformers and generators.

Detailed Layout

Dam

This is a 3 km long, 55m high composite rock fill and random fill dam, with a central clay core; and a crest width of 6m. The total volume of fill is 7,335,000 m^3 while the inundated reservoir area is 62.8km^2 at probable maximum flood of 4,200 m^3\s

Plate I: Over View of the Gurara Dam Intake with Tower at Extreme Left

Spillway/Stilling basin

The spillway is a 340m long ungated ogee crest weir type crossed by a 340m long RC bridge. The stilling basin is a USBR Type III. The spillway crest level at 624m designed to discharge a peak flood of 2,800m^3/s.

Plate II: Spillway/Stilling Basin of Gurara Dam

Bottom outlet

A bottom outlet is located on the right bank with a capacity of 260m^3/s and an additional flow return function of 10m^3/s. This structure, which also provides flow diversion during dam construction, comprises two 4m + 3m adjacent conduits running under the dam body. The outlet structure is designed to evacuate the reservoir in 45 days.

Plate III: Bottom Outlet Structure of Gurara Dam

Pipeline intake and tunnel

The Water Conveyance Intake located at the right bank is separated from the dam installations with an unlined 1.3m long and 4.3m diameter tunnel bored in the rock with intake tower constructed to meet the beadworks of the conveyance pipeline.

Plate VI: Pipeline Intake and Tunnel of Gurara Dam

Access Road

Access to the Dam right bank is through the combination of an existing 31.5 km track and the construction of additional of 6.5 km road from Kateri Village off the Abuja-Kaduna Road to the Dam site.

Hydroelectric Power Plant

The project incorporates a hydro power plant located at the right bank toe of Dam. The plant is designed under the following controls:

Full Supply Level (FSL)	624 masl
Minimum Operating Level (MOL)	610 masl
Firm Energy Shortfall Rate	5% in number of months
Load Factor of Power plant	0.6
Installed Capacity of Power Plant	30 MW

Plate V: The Power House and Switch Yard of Gurara Dam

Pipeline

The pipe is 3000mm internal diameter x 15mm wall thickness spiral welded APL 5L Grade x42 quality steel. It is protected externally with fibre glass/bitumen (BITUSEL) and internally with plastic epoxy.

These pipes were manufactured at a pipe manufacturing plant site at Ushafa. The plant comprises of the spiral weld pipe mill, hydrostatic testing machine, pipe socketing machine (Belling press) and can produce in excess of 50,000 tonnes per annum.

Total length of pipeline is 75 km was buried over most of its length except at river and major stream crossing where it is supported on piers. In the buried mode, trenches which may be in rock or soil are typically 5m deep with the pipe laid on a support base and protected by 1m soil cover.

Plate VI: The 75 Km Long, 3m Inner Diameter Transfer Pipes

Azara - Jere irrigation scheme

To optimally harness the full potential of the Gurara dam and improve national and food security for sustainable development the Azara- Jere irrigation scheme was adopted by the Federal Government. The facilities is to transfer raw water through a 29km DN 1400 steel pipeline to irrigate some 4000ha irrigable land of the Gurara valley within Azara – Jere downstream of the Gurara Dam.

Plate VII: Azara – Jere Pivot Irrigation Scheme

The Lower Usuma Dam

The lower Usuma Dam project was planned to provide adequate supply of water during the initial phase of the growth of the new Federal Capital city, and it is capable of serving about 800,000 populations but the population expansion of the city, the water in the lower Usuma Dam became insufficient (Onah, 2007).

The earth fill laterite with impermeable core dam has a reservoir surface area of 10km^3 and storage volume of 121million m^3 at maximum storage, height of 49m and width of 250m. The crest width of 10m and 1.35km long, a saddle Dam also earth fill with a crest of 450m and maximum height of 25m.

The bottom outlet (deep sluice) is 350m long and 6.5m x4.0m cross-sectional area. The intake structure is a dry tower intake of 40m height and 7m diameter. The treatment plant is capable of treating 3,000m3 of water per hour, and the storage tank has a capacity of storing 24,000m^3 with a pipeline of 1300mm that transport water 33km to FCT.

The major use of the lower Usuma Dam is for Water supply to the FCT however some fishing activities are going on within the Ushafa Area of the Dam.

Plate VIII: The Outlet Structure where the Water from Gurara Dam Enters the Lower Usuma Dam during Full Discharge

III. METHODOLOGY

A total of 20 water samples (10 water samples dry season and 10 water samples rainy season) were taken in this order: **Point A:** reservoir edge of Gurara Dam 2 water samples, a water sample each for both dry and rainy season respectively. **Point B:** Intake tower of Gurara Dam (Plate VII) 6 water samples were taken, 3 water samples each for both dry and rainy season at pre-determined depths of 5m, 15m and 25m respectively. **Point C:** Pipeline Intake of Gurara Dam (Plate VIII), 6 water samples were taken, 3 water samples each for both dry and rainy season at pre-determined depths of 5m, 15m and 25m respectively. **Point D:** Gurara River 2 water samples were taken each for both dry and rainy season respectively. **Point E:** Lower Usuma Dam, 4 water samples were taken, 2 water samples each for both dry and rainy season respectively. The sampling were done during the peak of wets season (July) and dry season (March) in order to capture the effect of seasonal variations, Using a special water sampling grabber. All the samples were collected in 1.5 litre plastic bottles which were thoroughly rinsed with the waters to be sampled, well labelled (Table 1) then wrapped in black polythene bags, before taken to laboratory in ice packed cooler on the same day the sampling was done for analysis.

Sample were analysed for physical and chemical parameters such as Electrical Conductivity, Total dissolve solid, pH, Temperature, Turbidity, Taste, Odour, and Chemical oxygen demand (COD), Dissolve oxygen (DO), Biological oxygen demand (BOD), Tss, Total hardness, chloride, Nitrate, Sulphate, Carbonate, Bicarbonate, Sodium, Potassium, Calcium, Magnesium, Cadmium, Lead, Iron, E-coli using standard water quality laboratory equipments and procedures APHA, (1995, 1998).

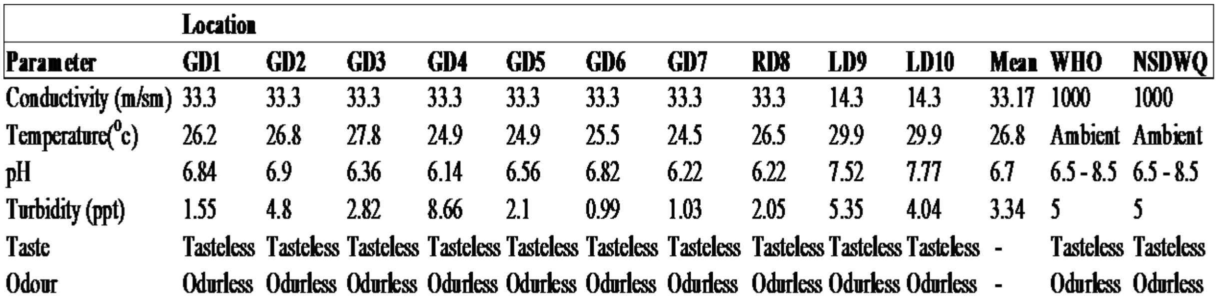
Table 1: Sampling Location Code and the Description of Sampling Location

N/S	Location Code	Description Of Location
1	GD1	Reservoir edge of Gurara Dam (Plate I), dry season sampling
2	GD2	Bottom outlet of Gurara Dam (PlateII) at pre-determined depths of 5m for Dry season sampling
3	GD3	Bottom outlet of Gurara Dam (PlateII) at pre-determined depths of 15m for dry season sampling
4	GD4	Bottom outlet of Gurara Dam (PlateII) at pre-determined depths of 25m for Dry season sampling

5	GD5	Pipeline Intake of Gurara Dam (Plate VII), at pre-determined depths of 5m for dry season sampling
6	GD6	Pipeline Intake of Gurara Dam (Plate VII), at pre-determined depths of 15m for dry season sampling
7	GD7	Pipeline Intake of Gurara Dam (Plate VII), at pre-determined depths of 15m dry season sampling
8	RD8	Gurara River dry season sampling
9	LD9	Right edge of Lower Usuma Dam (Plate IX), dry season sampling
10	LD10	Left edge of lower Usuma Dam (Plate IX), dry season sampling
11	GR1	Reservoir edge of Gurara Dam (Plate I), rainy season sampling
12	GR2	Bottom outlet of Gurara Dam (Plate VII) at pre-determined depths of 5m for rainy season sampling
13	GR3	Bottom outlet of Gurara Dam (PlateII) at pre-determined depths of 15m for rainy season sampling
14	GR4	Bottom outlet of Gurara Dam (PlateII) at pre-determined depths of 25m for rainy season sampling
15	GR5	Pipeline Intake of Gurara Dam (Plate VI), at pre-determined depths of 5m for rainy season sampling
16	GR6	Pipeline Intake of Gurara Dam (Plate VI), at pre-determined depths of 15m for rainy season sampling
17	GR7	Pipeline Intake of Gurara Dam (Plate VI), at pre-determined depths of 15m rainy season sampling
18	RR8	Gurara River rainy season sampling
19	LR9	Right edge of Lower Usuma Dam, (Plate IX) rainy season sampling
20	LR10	Left edge of lower Usuma Dam, (Plate IX) rainy season sampling

IV. RESULTS AND DISCUSSION

Table 2: Result of physical test (in-situ) of Water Samples during Dry Season



	Location												
Parameter	GD1	GD2	GD3	GD4	GD5	GD6	GD7	RD8	LD9	LD10	Mean	WHO	NSDWQ
Conductivity (m/sm)	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	14.3	14.3	33.17	1000	1000
Temperature(^{0}c)	26.2	26.8	27.8	24.9	24.9	25.5	24.5	26.5	29.9	29.9	26.8	Ambient	Ambient
pH	6.84	6.9	6.36	6.14	6.56	6.82	6.22	6.22	7.52	7.77	6.7	6.5 - 8.5	6.5 - 8.5
Turbidity (ppt)	1.55	4.8	2.82	8.66	2.1	0.99	1.03	2.05	5.35	4.04	3.34	5	5
Taste	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	-	Tasteless	Tasteless
Odour	Odurless	Odurless	Odurless	Odurless	Odurless	Odurless	Odurless	Odurless	Odurless	Odurless	-	Odurless	Odurless

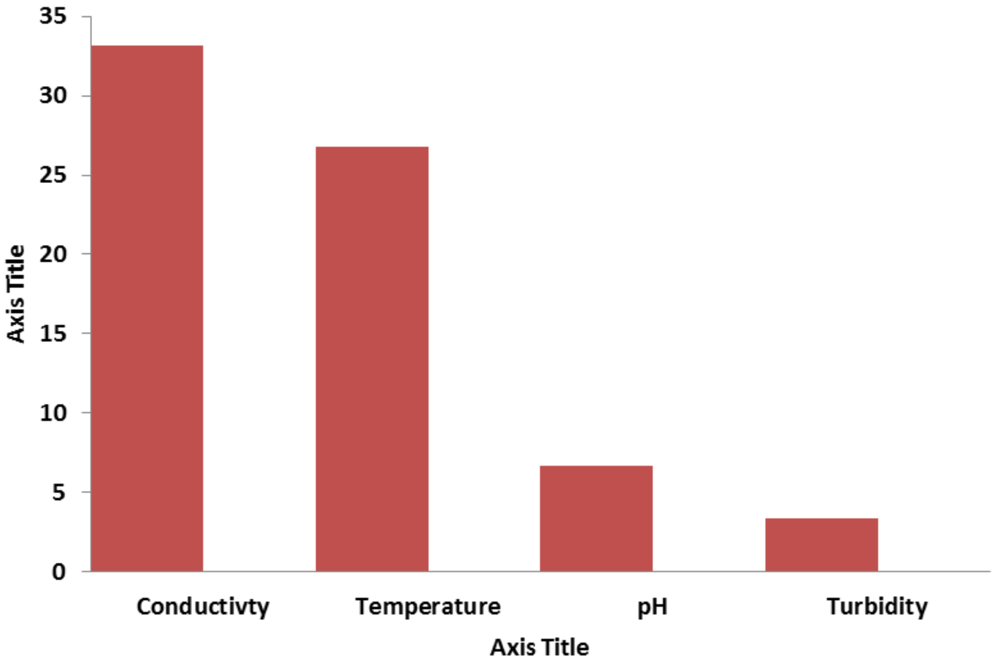


Figure 3: Physical Parameters for Dry Season Water Sampling

Table 3: Result of physical test (in-situ) of Water Samples during Rainy Season

	Location												
Parameter	**GR1**	**GR2**	**GR3**	**GR4**	**GR5**	**GR6**	**GR7**	**RR8**	**LR9**	**LR10**	**Mean**	**WHO**	**NSDWQ**
Conductivity (m/sm)	33.3	50	50	33.3	50	50	50	100	20	25	46	1000	1000
Temperature(^{0}c)	26.3	26.1	25.2	23.9	26.3	25.5	24.4	26.3	28.3	28.9	26.1	Ambient	Ambient
pH	6.51	5.9	5.33	5.1	6.93	6.93	6.93	6.92	6.94	6.94	6.44	6.5 - 8.5	6.5 - 8.5
Turbidity (ppt)	2.75	4.53	10.54	3.3	57.9	5.56	5.56	12.3	1.03	1.1	5.01	5	5
Taste	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	-	Tasteless	Tasteless
Odour	Odurless	Odurless	Odurless	Odurless	Odurless	Odurless	Odurless	Odurless	Odurless	Odurless	-	Odurless	Odurless

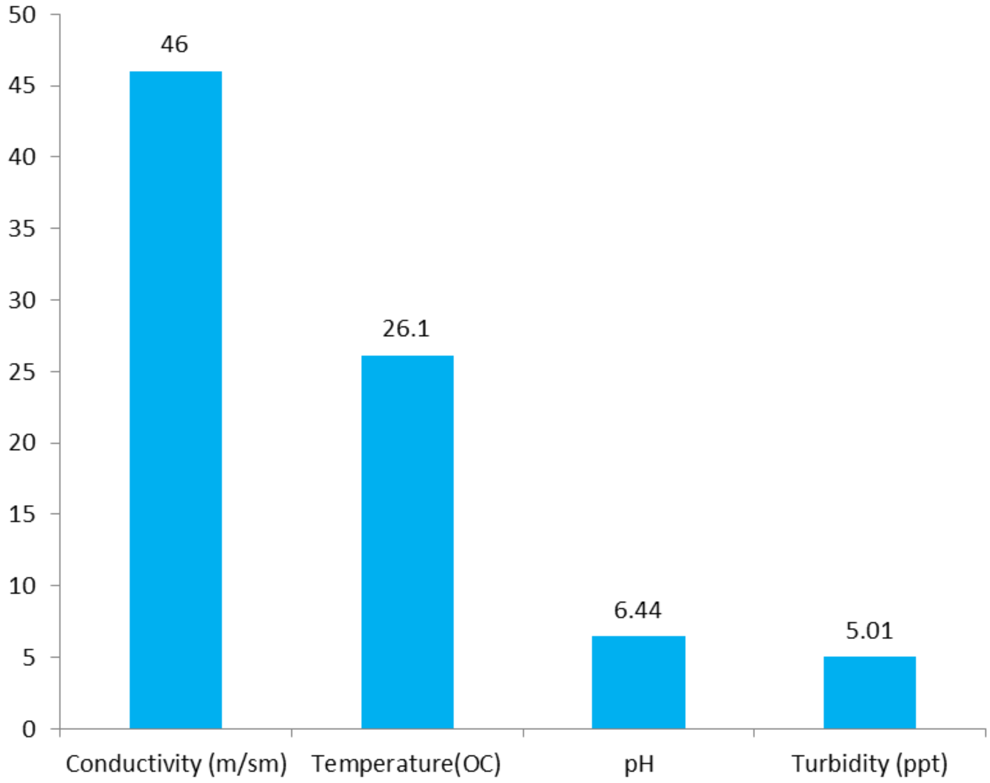


Figure 4: Physical Parameters for Rainy Season Water Sampling

Taste: Drinking water according to NSDWQ (2007) and WHO (2011), guidelines is supposed to be tasteless and free from any odour. Physical (*in-situ)* tests for both rainy and dry seasons recorded in Tables 2 and 3 show that all the water samples are tasteless and odourless.

Electrical Conductivity: Electrical conductivity of water measures the capacity of water to conduct electric current. It is an indicator of how salt-free, ion-free or impurity free a water sample is. The standards for drinking water both NSDWQ (2007) and WHO (2011), is 1000µS/cm. All the samples analyzed in the study are below the recommended limit.

Temperature: Temperature ranges between 23.3^{0}C to 28.9^{0}C during the rainy season. The dry season recorded lower values which ranged between 24.5^{0}C to 29.9^{0}C and this might not be unconnected with the cold harmatan experienced during the period of sampling.

pH: The pH of a water body is very important in determination of water quality since it affects other chemical reactions such as solubility and metal toxicity. Tables 2 and 3, The pH values for dry season samples ranges from 6.14 – 7.77 with a mean value of 6.67 and water with pH values higher than 7.00 indicates that the water is slightly alkaline. The lowest value of 6.14 was recorded at GD4 which is at a sampling depth of 25m and equally the deepest point of the Gurara Dam. Samples obtained at the surface of the reservoir (GD1) recorded the higher pH values 6.84. The lowest value of 5.1 and highest values of 6.51 was recorded at same locations (GR4 and GD1) during the wet seasons. It could be concluded that lowest pH values are associated with depth of the dam. The above values usually indicate the presence of carbonates of calcium and magnesium in water.

The dry season samples value ranges from 5.1 – 6.94 with a mean value of 6.44 indicates that the water is slightly acidic during the rainy season. The test result in tables 4.4 and 4.5 also indicates that the Gurara dam is more acidic than the Lower Usuma dam, although the pH values for (GD3, GD4 and RD8) which are (6.36, 6.14 and 6.22) respectively for rainy season and GR2, GR3 andGR4 which are (5.9, 5.3 and 5.1) respectively did not fall within the within the recommend guidelines of NSDWQ (2007) and WHO (2011) of 6.5 - 8.5.

Turbidity: Turbidity in water is caused by suspended particles or colloidal matter that obstructs light transmission through the water. It may be caused by inorganic or organic matter or a combination of the two. The turbidity value obtained from the research ranges from 1.1 NTU - 12 NTU in the rainy season and 0.99 NTU - 8.66 NTU in dry season. GD4 and LD9 turbidity values are 8.66 and 5.35 respectively for dry season while DR3, GR5, GR& and RR8 turbidity values are 10.5 NTU, 5 NTU, 9 NTU, 5.56 NTU and 12.3 NTU respectively as beside the maximum permissible limit of 5 NTU by the NSDWQ (2007) and WHO (2011). It also indicates that the water is more turbid in the rainy season than dry season. This could be as a result the presence of organic matter pollution, other effluents, run-off with high suspended particles and heavy rainfall.

Hydrochemical Parameters

Results of Physico-chemical and Bacterological tests on the water samples for both dry and rainy seasons are presented in Tables 4 and 5 respectively.

TABLE 4: Physico-Chemical and Bacterological Result during Dry Season

			Location													
S/N	**Parameter**	**Unit**	**GD1**	**GD2**	**GD3**	**GD4**	**GD5**	**GD6**	**GD7**	**RD8**	**LD9**	**LD10**	**Min**	**Max**	**Mean**	**WHO**	**NSDWQ**
1	TDS	mg/l	25.8	48.5	45.6	46.1	45.5	30.5	28.9	26.4	46.4	43.9	25.8	48.5	38.8	600	500
2	COD	mgO_2	52	62	18	34	12	2	22	90	74	78	2	90	44.4	10	-
3	DO	%	2	10	2	11	18	18	19	17	18	17	2	19	13.2	-	-
4	BOD	mg/l	0.42	0.91	0.25	1.06	1.76	1.72	1.29	1.31	1.62	1.41	0.25	1.76	1.18	6	-
5	TSS	mg/l	21	27	30	52	13	18	13	7	12	17	7	52	21	500	-
6	Total Hardness	mg/l	160	100	160	180	100	160	140	160	260	260	100	260	168	150	150
7	Chloride	mg/l	3.75	3.75	1.25	4.99	2.49	3.75	9.99	4.99	4.99	2.69	1.25	9.99	4.26	200	250
8	Nitrate	mg/l	0	0	0	0	0	0	0	0	0	0	0	0	0	25	50
9	Sulhate	mg/l	0	0	0	0	0.48	0.47	0.49	0.5	0.63	0.63	0	0.63	0.32	100	200
10	Bicaronate	mg/l	3.97	4.42	3.81	3.66	3.51	3.51	3.51	3.66	2.59	2.89	2.59	4.42	3.55	100	-
11	Carbonate	mg/l	0	0	0	0	0	0	0	0	0.75	0.9	0	0.9	0.165	100	-
12	Sodium	mg/l	7.4	6.8	8.5	8.2	6.8	8	7	7.6	8.4	7.2	6.8	8.5	7.59	200	200
13	Potassium	mg/l	16.9	19.9	26.4	26.7	29.6	29.3	28.9	30.2	32	36.4	16.9	36.4	27.63	12	-
14	Calcium	mg/l	1.14	0.76	0.79	0.31	1.03	0.75	1	0.45	1.65	1.23	0.31	1.65	0.843	75	-
15	Magnesium	mg/l	5.99	4.72	5.19	2.5	4.86	4.96	4.94	4.72	7.19	6.3	2.5	7.19	4.644	0.2	30
16	Cadmium	mg/l	0.56	0	0.39	0	0	0	0	0	0.2	0	0	0.56	0.171	0.003	0.003
17	Lead	mg/l	0.58	0	0.88	0.56	0	0.37	0	0	0	0	0	0.88	0.24	0.01	0.01
18	Iron	mg/l	0.33	0.62	0.24	0.35	0.28	0.33	0.33	0.54	0.85	1.82	0.24	1.82	0.54	0.1	0.3
19	E.coli	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 5: Physico-Chemical and Bacterological Result during Rainy Season

	Rainy Season Sample		Location													
S/N	**Parameter**	**Unit**	**GR1**	**GR2**	**GR3**	**GR4**	**GR5**	**GR6**	**GR7**	**RR8**	**LR9**	**LR10**	**Mini**	**Max**	**Mean**	**WHO**	**NSDWQ**
1	TDS	mg/l	26.5	26.5	26.2	27.8	29.8	26	26.2	45.3	38.6	39.7	26	45.3	31.26	600	500
2	COD	mgO_2	6.66	0.333	0.333	0.333	0.333	0.333	1	6	6.667	6.667	0.333	6.667	2.87	10	-
3	DO	%	103	104	89	75	106	109	104	77	155	100	75	155	102.2	-	-
4	BOD	mg/l	9.55	9.24	8.24	6.5	6.51	9.84	8.84	6.8	10.19	8.47	6.5	10.19	8.42	6	-
5	TSS	mg/l	2.7	3.7	2.3	3.4	2.7	2	1.9	9.1	2.1	2.5	2	9.1	3.34	500	-
6	Total Hardness	mg/l	30	42	30	28	22	30	20	12	40	34	12	42	28.8	150	150
7	Chloride	mg/l	0.033	0.015	0.013	0.01	0.02	0.012	0.011	0.014	0.012	0.01	0.01	0.003	0.015	200	250
8	Nitrate	mg/l	0	0	0	0	0	0	0	0	0	0	0	0	0	25	50
9	Sulhate	mg/l	0	0	0	0	0	0	0	0	0	0	0	0	0	100	200
10	Carbonate	mg/l	0	0	0	0	0	0	0	0	0	0	0	0	0	100	-
11	Bicaronate	mg/l	2.1	0.84	0	0	0	0	0	0	0	0	0	2.1	0.294	100	-
12	Sodium	mg/l	10.55	1.66	4.56	7.77	6.77	4.44	8.88	8.33	8.33	4.44	1.66	10.55	6.573	200	200
13	Potassium	mg/l	5.833	3.33	2.5	1.67	2.5	3.33	4.167	5	7.5	11.75	1.67	11.75	4.758	12	-
14	Calcium	mg/l	2.959	2.47	2.47	2.889	3.247	3.247	2.827	2.984	4.682	4.26	2.47	4.682	3.204	75	-
15	Magnesium	mg/l	11.63	10.86	10.86	10.42	10.8	10.8	10.53	11.12	11.12	10.82	10.42	11.63	10.9	0.2	30
16	Cadmium	mg/l	0.047	0.006	0.042	0.042	0.07	0.07	0	0.033	0.033	0.008	0	0.07	0.004	0.003	0.003
17	Lead	mg/l	0	0.109	0.003	0.003	0	0	0	0.102	0.102	0	0	0.109	0.032	0.01	0.01
18	Iron	mg/l	0.62	0.35	0.35	0.35	0.46	0.56	0.62	0.45	1.24	0.76	0.35	I.26	0.58	0.1	0.3
19	E.coli	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

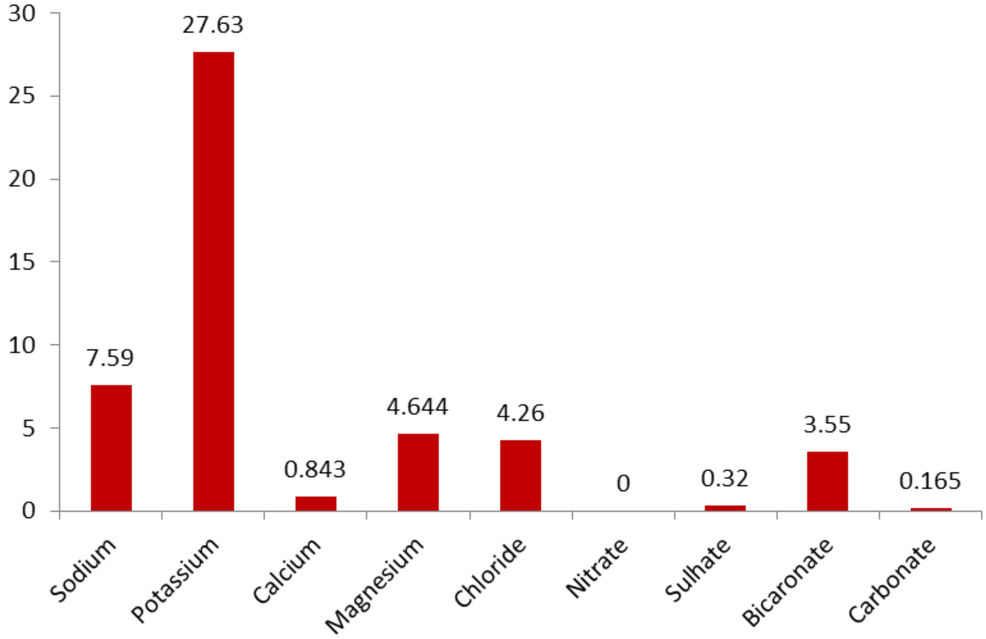
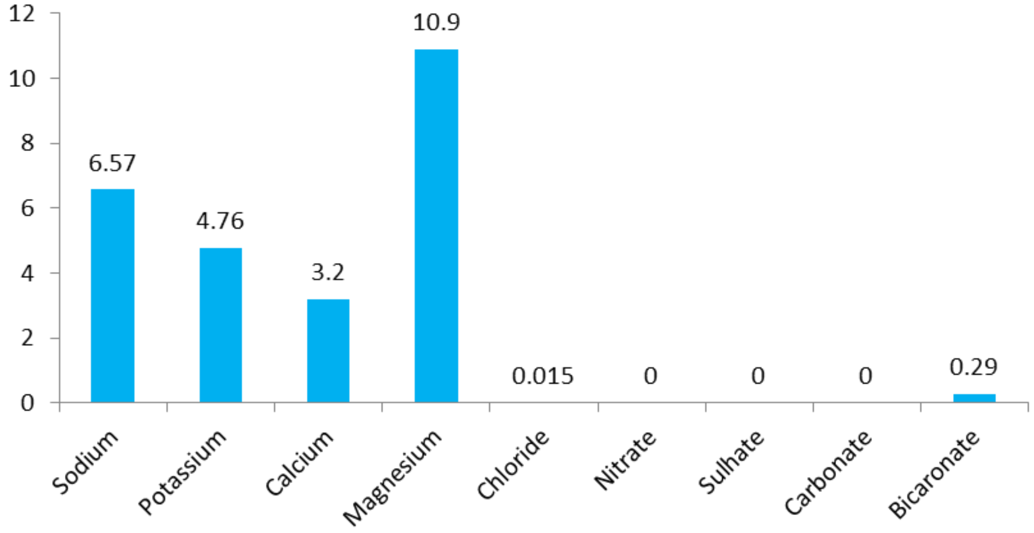


Figure 5: Chemical Parameters for Dry Season Water Sampling

Figure 6: Chemical Parameters for Rainy Season Water Sampling



Hydrochemistry of the Area

Total Dissolved Solid (TDS): This comprises inorganic salts (mainly calcium, potassium, magnesium, bicarbonates, sodium, chlorides and sulphates) and little amounts of organic matter dissolved in water. TDS in drinking-water comes from natural sources, urban runoff, sewage and industrial wastewater. The palatability of water which has TDS level of less than about 600 mg/l is normally considered to behealty for drinking WHO (2011) as the water becomes considerably and gradually more unpalatable at greater levels. The TDS values range from 26mg/l – 45.3mg/l in the rainy season and 25.8mg/l – 48.5mg/l in dry season, indicating that all samples have TDS levels less than the maximum permissible limit of 600mg/l.

COD and BOD: Organic matter pollution in the water samples during the dry season was determined using Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD): While BOD is a measure of the quantity of dissolved oxygen used by microorganisms in the oxidation of organic matter, COD measures the amount of biologically active and inactive organic matter in water. Sources of organic matter may include plant decay, nutrients from lawn fertilizers, animal and human wastes. A low number of COD and BOD is an indicator of good quality water while a high COD and BOD indicates polluted water. COD and BOD are usually associated with sewage water and not with drinking water therefore most standards for drinking water made no mention of their limits;

meaning that there should be no trace of them. Although, the WHO, recommended a BOD limit of 6mg/l and COD limit 10mg/l for drinking water until 1971, no limit is now recommended.

In a study on organic pollution of drinking water and liver cancer by showed that mortality due to liver cancer for men and women was positively correlated with the COD in drinking water.

From the result in table 4 and 5, below the COD for rainy season ranges from 0.33 mg/l – 6.66 mg/l and a mean of 2.87 mg/l, falls within the WHO recommended limit of 10mg/l. The dry season ranges from 2mg/l -90mg/l and a mean of 44.4mg/l are all above the WHO recommended limit, with exception of GD1 and GD3 which are both 2mg/l each.

From the result in table 2 and 3, above: the BOD for dry season samples ranges from 0.25 mg/l – 1.76 mg/l with a mean of 1.18 mg/l falls within the WHO recommended limit of 6mg/l, while that of rainy season ranges 6.5mg/l – 10.19mg/l and a mean of 8.42mg/l are all above the WHO recommended limit of 6mg/l. The linear relation between (BOD) and (COD) might be attributed to increase in salinity, temperature and biological activity.

Dissolved Oxygen (DO): The dissolved oxygen content of water is influenced by the source, raw water temperature, treatment and chemical or biological processes taking place in the distribution system. Depletion of dissolved oxygen in water supplies can encourage the microbial reduction of nitrate to nitrite and sulfate to sulfide. It can also cause an increase in the concentration of ferrous iron in solution, with subsequent discoloration at the tap when the water is aerated. No health-based guideline value is recommended.

From the result in table 4 and 5, below: the DO for dry season samples ranges from 2mg/l to 19mg/l with a mean of 13.2. The rainy season samples ranges from 75mg/l – 155mg/l with a mean of 102.2mg/l, which is of high level and might exacerbate corrosion of metal pipes WHO (2011).

Total hardness (TH): Hardness caused by calcium and magnesium is usually indicated by precipitation of soap scum and the need for excess use of soap to achieve cleaning. Consumers are likely to notice changes in hardness WHO (2001). The total hardness value obtained in the research for rainy season indicates that all the samples are within the permissible limit of NSDWQ (2007) and WHO (2011), while the values obtained in the dry season indicates that they are above the permissible limit of 150m/L by the NSDWQ (2007) and WHO(2011).This might be due to the presence of dissolved magnesium and calcium ions. Only locations GD2, GD5 and GD7, falls within the permissible limit.

Chloride (Cl^-): Chlorides are salts resulting from the combination of the gas chlorine with a metal. Chlorine is regularly be found in the ground as rock salts or halite and is generally bond with sodium. In combination with a metal such as sodium, it becomes essential for life. High chloride loads may be related to a variety of factors, including increases in wastewater and septic-system discharges, sewage and animal waste, recycling of chloride from drinking water, and leachate from landfills and salt storage areas. Continuing drinking of chlorinated water is also associated with increase in developing bladder and rectal cancers. Chloride is a widely distributed element in all types of rocks in one form or the other and is an indication that the water is of a marine source. Its affinity towards sodium is high. High concentration of chloride makes water unpalatable and unfit for drinking and livestock watering. The NSDWQ (2007) stated no limit for chloride concentration in drinking water but the World Health Organisation has its maximum permissible limit at 250mg/l. From the result from tables 4 and 5, chloride composition in the water samples range between 0.009 to 0.033mg/l and a mean value of 0.015 for rainy season and 1.25 mg/l – 9.99 mg/l and a mean value of 4.26m/L in the dry season which is within the WHO (2011) permissible limit.

Nitrate (NO_3^-): Nitrate is a colourless, odourless and tasteless compound that is essential to all life. Most plants require large quantities to sustain high yields. Nitrate is an integral part of the nitrogen cycle in the environment and can also form when microorganisms breakdown fertilizers, decaying plants, manures or other organic residues. Although nitrate occurs naturally, in most cases higher levels are thought to result from human activities such as fertilizers and manures, animal feedlots and wastes, municipal wastewater and sludge, septic systems and N-fixation from atmosphere by legumes, bacteria and lightening.

High nitrate levels in water can cause methemoglobinemia or blue baby syndrome, a condition found especially in infants less than six months which reduce oxygen supply to vital tissues such as the brain. Nitrate concentrations in the water samples are generally zero for all samples both for rainy and dry season.

Sulphate (SO_4^{2-}): Sulphate can be found in almost all natural water. The origin of most sulphate compounds is the oxidation of sulphite ores, the presence of shale or industrial wastes. It can also be formed from decomposing underground deposits of organic matter such as decaying and animal material. People not used to drinking water with high levels of sulphate can experience dehydration and diarrhoea. However, people tend to get used to high sulphate levels after few days. Sulphate gives a bitter or medicinal taste to water when concentrations are high making it unpleasant to drink.

The maximum permissible limit of sulphate in drinking water by NSDWQ (2007) and WHO (2011) standards is 100mg/l and 200mg/l respectively. Sulphate concentration in all the samples falls below these limits. The sulphate values are generally low ranging from 0mg/l to 0.63mg/l in the dry season and 0m/l in rainy season respectively

Carbonate CO_3^{2-} : In geology and mineralogy, the term "carbonate" can refer both to carbonate minerals and carbonate rock (which is made of chiefly carbonate minerals), and both are dominated by the carbonate ion, CO_3^{2-}. Carbonate minerals are extremely varied and ubiquitous in chemically precipitated sedimentary rock. The most common are calcite or calcium carbonate, $CaCO_3$, the chief constituent of limestone (as well as the main component of mollusc shells and coral skeletons); dolomite, a calcium-magnesium carbonate $CaMg(CO_3)_2$; and siderite, or iron(II) carbonate, $FeCO_3$, an important iron ore.

The Nigerian Standard has no stated limit for carbonate concentration in water but the WHO (2011) standard put it at 100mg/l. The concentrations of carbonate in the water samples are generally low, no concentration for rainy season and concentration 0.75mg/l and 0.9mg/l only in location LD9 and LD10 respectively i.e. in lower Usuma Dam.

Bicarbonate (HCO_3^-): Bicarbonates in water occur when water comes from limestone aquifers or lakes, rivers and canals that cut into limestone.

Bicarbonate is fundamental for our bodies and is found in all biological fluids. Bicarbonates play a central role in maintaining the body's internal acid-base balance and in stomach secretions and it are essential to the process of digestion. One of the few adverse effects of bicarbonate high concentrations is in irrigation as it can decrease the lime requirement for plant production thereby causing adverse plant growth by excessively raising the pH of the soil or potting media.

The Nigerian Standard has no stated limit for bicarbonate concentration in water but the WHO (2011) put it at 100mg/l. The concentrations of bicarbonate in the water samples result all fall within the permissible limit of WHO (2011) as the minimum value of 2.59mg/l and highest value of 4.42mg/l were recorded.

Sodium (Na+): Sodium is sourced from rocks and soils washed by moving water ending up in oceans, rivers and lakes. According to sodium can also be sourced from deposited wastes. Sodium is a dietary mineral for animals but plants hardly use it. In humans, it is partially responsible for nerve functions. It regulates extra cellular fluids, acid-base balance and membrane potential, partially together with potassium. Sodium overdose may cause increased blood pressure, arteriosclerosis, oedema, hyperosmolarity, and confusion. Sodium shortages may lead to dehydration, convulsion, muscle paralysis, decreased growth and general numbness. People suffering from diarrhea require a higher dietary amount of sodium than usual while people with heart and kidney diseases are recommended a sodium poor diet.

The maximum permissible limit for sodium according to both NSDWQ (2007) and WHO (2011) standards is 200mg/l and the result above clearly shows that all the water samples have concentration of sodium far below the maximum limit as 1.66mg/l lowest value and 10.55mg/l as highest value were recorded respectively.

Potassium (K^+): Potassium is a dietary mineral with vital functions in nerve stimulus, muscle contractions, blood pressure regulation and protein dissolution. It also protects the heart and arteries and may even prevent cardiovascular diseases. Potassium shortages are rare but may lead to depression, muscle weakness, heart rhythm disorder and confusion. High concentration of potassium may be particularly harmful example, high doses of potassium chloride interferes with nerve impulses, which interrupts with virtually all bodily functions and mainly affects heart functioning. Potassium may be removed from water by means of reverse osmosis.

Potassium occurs in various minerals from which it may be dissolved through weathering process. It is also sourced from fertilizers and plants. Being an essential element, it is present in the tissues of all plants and animals. Potassium is applied in many industrial processes such as in alloy and organic synthesis, fertilizer production, glass making, soap making etc. Waste generated from these production processes is hazardous when discharged on surface water and it is difficult to purify. Concentration of potassium in the water samples in the result in tables 4.6 and 4.7 below ranges from 16.9mg/l to 36.4mg/l with a mean of 27.63mg/l for dry season and 1.66mg/l to11.75mg/l and a mean of 4.758mg/l for rainy season sampling. This indicates that the concentration of all the rainy season samples fall within the WHO (2011) permissible limit of 12mg/l, while all the dry season samples are above the WHO (2011) permissible limit. This could be attributed to the run-off with high suspended particles and heavy rainfall.

Calcium (Ca^{2+}): Calcium occurs in water naturally as it may be dissolved from rocks such as limestone, marble, calcite, dolomite, gypsum, fluorite and apatite. Calcium is a dietary requirement for all organisms apart from some insects and bacteria. It is a building stone of skeletons of most marine organisms, and eye lenses. The surest source of calcium is in drinking water as the body is most easily able to absorb calcium carried along in the mineral drinking water. Together with magnesium, calcium is an important determinant of water hardness and functions as a pH stabilizer because of its buffering qualities. It also gives water a better taste. Lack of calcium is one of the main causes of osteoporosis, a disease in which the bones become extremely porous, and subjected to fracture and heal slowly.

The NSDWQ (2007) stated no limit for calcium concentration in drinking water but the WHO (2011) has its maximum permissible limit at 75mg/l. From the result in Tables 4 and 5 below, calcium composition in the water samples range between 0.31 to 1.65mg/l in dry season and 2.5 to 4.7mg/l in the rainy season and is therefore within the permissible limit of WHO (2011) standards.

Magnesium (Mg^{2+}): Magnesium is a dietary mineral for humans, one of the micro elements that are responsible for membrane function, nerve stimulant transmission, muscle contradiction, protein construction and Deoxyribonucleic acid (DNA) replication. It is also an ingredient of many enzymes. Together with calcium, they often perform the same functions within the human body and are generally antagonistic. Studies have shown that it is unusual to introduce legal limits for magnesium in drinking water because there is no scientific evidence of magnesium toxicity instead water deficient in magnesium and calcium is susceptible to causing cardiovascular diseases in humans.

Contrary to non-scientific evidence of magnesium toxicity NSDWQ (2007) and WHO (2011) standard for drinking water allows for a maximum permissible limit of 0.2mg/l and 30mg/l respectively for magnesium in drinking water. All the water samples for both dry and rainy season are above the NSDWQ (2007) standard maximum permissible limit of 0.2mg/l. This might accounts for the hardness of the water. In some location can attribute to bedrock dissolution and chemical weathering of ferromagnesian mineral.

Cadmium (Cd): Cadmium metal is used in the steel industry and in plastics. Cadmium compounds are widely used in batteries. Cadmium is released to the environment in wastewater, and diffuse pollution is caused by contamination from fertilizers and local air pollution. Contamination in drinking-water may also be caused by impurities in the zinc of galvanized pipes and solders and some metal fittings WHO (2011).

Absorption of cadmium compounds is dependent on the solubility of the compounds. Cadmium accumulates primarily in the kidneys and has a long biological half-life in humans of 10–35 years. There is evidence that cadmium is carcinogenic by the inhalation route, and International Agency for Research on Cancer (IARC) has classified cadmium and cadmium compounds in Group 2A (probably carcinogenic to humans). However, there is no evidence of carcinogenicity by the oral route and no clear evidence for the genotoxicity of cadmium. The kidney is the main target organ for cadmium toxicity.

The maximum permissible limit for cadmium according to both NSDWQ (2007) and WHO (2011) standards is 0.003mg/l and the result above clearly shows that the rainy season water sample which ranges from 0mg/l to 0.07mg/l and a mean value of 0.0035mg/l and dry season water samples ranges from 0mg/l to 0.558mg/l and a mean value of 0.17mg/l. this indicates that all the rainy season samples are above the permissible limit of 0.003mg/l expect for location GR7. The dry season samples locations GD1 and GD2 are above the permissible limit while all other locations are which in the permissible limit. This might be as a result of wastewater, and diffuse pollution is caused by contamination from fertilizers and local air pollution from other water bodies flowing into the reservoir from the catchment areas WHO (2011).

Lead (Pb): Lead is used principally in the production of lead-acid batteries, solder and alloys. The organolead compounds tetraethyl and tetramethyl lead have also been used extensively as antiknock and lubricating agents in petrol, although their use for these purposes in many countries has largely been phased out. Owing to the decreasing use of lead-containing additives in petrol and of lead-containing solder in the food processing industry, concentrations in air and food are declining; in most countries, lead levels in blood are also declining unless there are specific sources, such as dust from leaded paint or household recycling of lead-containing materials (WHO, 2011).

Exposure to lead is associated with a wide range of effects, including various neurodevelopment effects, mortality (mainly due to cardiovascular diseases), impaired renal function, hypertension, impaired fertility and adverse pregnancy outcomes. Impaired neurodevelopment in children is generally associated with lower blood lead concentrations than the other effects the weight of evidence is greater for neurodevelopmental effects than for other health effects and the results across studies are more consistent than those for other effects. For adults, the adverse effect associated with lowest blood lead concentrations for which the weight of evidence is greatest and most consistent is a lead-associated increase in systolic blood pressure.

The maximum permissible limit for lead according to both NSDWQ (2007) and WHO (2011) standards is 0.01mg/l and the result above clearly shows that the rainy season water samples in location (GR2, RR8 and LR9), for dry season water samples (GR2, RR8 and LR9) above the permissible limit for both NSDWQ(2007) and WHO(2011) standards, it might attribute to production of lead-acid batteries, solder, alloys and lubricating agents in petrol found in surface water through surface water flow and runoff from other rivers, streams and lakes in catchment area. All other water samples for both dry and rainy season are within the standards.

Iron (Fe^{2+}): Iron is one of the earth's most plentiful resources. Rainwater dissolves this element as it infiltrates the soil and underlying geological formations. Although iron is not hazardous to health, it is considered a secondary or aesthetic contaminant. It is essential for good health as it helps transport oxygen in the blood. Iron causes taste and odour problem in water and may result in red water when it exceed the maximum permissible limit of 0.3mg/l NSDWQ (2007) and WHO (2011) has a permissible limit of 0.1mg/l.

Iron concentration in the water samples are generally high for both rainy and dry season and are above the permissible limit of 0.30mg/l WHO (2011).Water samples in location GD3 and GD5 of the dry season and have values of 0.024mg/l and 0.28mg/l are within the NSDWQ (2007) recommended standard of 0.3mg/l while all other locations are therefore above the NSDWQ (2007) recommended standard. This might be as a result rainwater dissolving elements from rock formation as it infiltrates the soil and water bodies.

Escherichia coli: Escherichia coli (E. coli) is the major species in the faecal coliform group and the best indicator of faecal pollution and possible presence of pathogens. Most coliform bacteria do not cause disease but however, some rare strains of E. coli can cause serious illness, such as urinary tract infections, bacteraemia and meningitis.

The maximum permissible limits NSDWQ (2007) and WHO (2011), standards for Escherichia coli in drinking water are 0 cfu/100ml.

From the result in table 4.6 and 4.7, above: the E. coli value for both rainy season and dry season is 0mg/l

Seasonal Variation of Water Quality of the Two Dams

- The Gurara Dam water is more acidic than the lower Usuma Dam water as shown in tables 3 and 2 above.
- The water in the lower Usuma Dam is more contaminated than that of Gurara dam as shown in table 4 and 5 above for parameters such as TDS, COD, conductivity, turbidity, total hardness, sulphate, carbonate, potassium, calcium, and iron content.

There is no significant difference the water samples taken at pre-determined depths of the Gurara Dam reservoir expect that the pH at the bottom was the lowest with a value of 5.10 during the rainy season and 6.14 during the dry season.

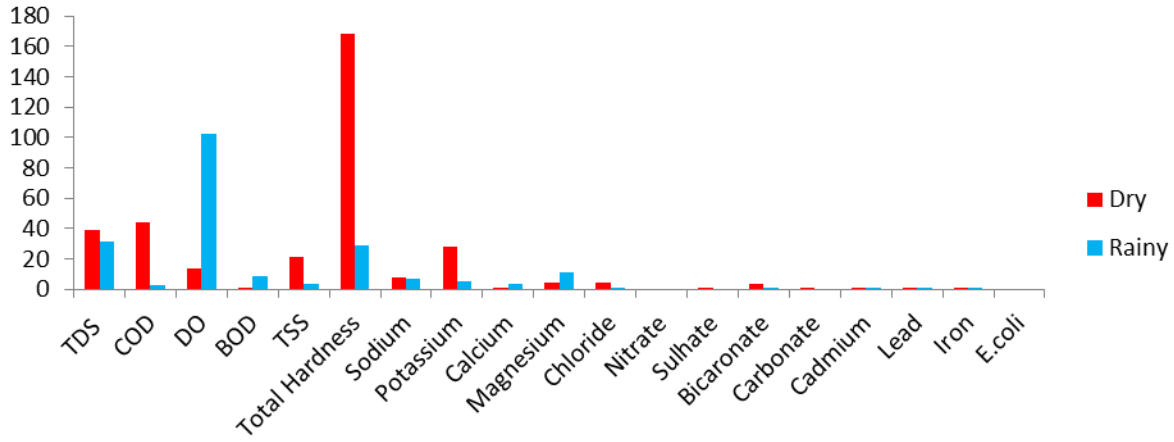


Figure 7: Dilution effect on sample

Chemical parameters in Dam water tend to have higher concentrations during the dry season when water level decreases and have lower concentrations due to higher water level in the wet or rainy season as a result of dilution of the chemical parameters with more water, expect for BOD, DO, magnesium and calcium which is more in the rainy season. This dilution effect was observed on a number of parameters when comparing the chemical analysis results of the rainy and dry seasons as shown in figure 3 above.

V. CONCLUSION

The study was to assess the water quality of the Gurara Water Transfer to FCT. The aim is to compile geological, hydrogeological, hydrological, geochemical and microbiological baseline data of Gurara Dam and Lower Usuma Dam for application in environmental geological issue (e.g. environmental health, agricultural, industrial recreational and other surface water usage).

There are few human activities going on around the Dams such as skeletal fishing but most of the contaminants are from the dissolution of the rocks and soil type and also from the surface water flow from different river and steam flow from catchment area that were already contaminated with anthropogenic wastewater upstream.

Geologically, the study area is basement complex and its characterised by three major outcrops, granite, gneiss and migmatite.

A total of twenty water samples were collected from different sampling location at different depth interval and analysed for physical, chemical and microbiological parameters during the rainy and dry season, using standard analytical methods. The result was also compared with water quality standards provided by NSDWQ (2007) and WHO (2011). It was found that a number of individual samples location have some parameters like

- High concentration of COD and BOD above the maximum permissible limits, the sources of contamination might be attributed to increase in salinity, temperature and biological activity.
- Turbidity above the maximum permissible limits might be as a result of the presence of organic matter pollution, other effluents, run-off with high suspended particles and heavy rainfall.
- High concentration total hardness above the maximum permissible limits mightbe due to the presence of dissolved calcium and magnesium ions.
- High concentration of cadmium above the maximum permissible limits in some locations might be as a result of wastewater, and diffuse pollution caused by contamination from fertilizers and pollution from other water bodies flowing into the reservoir from the catchment areas.
- High concentration of lead above the maximum permissible limitsit might be attributed to production of lead-acid batteries, solder, alloys and lubricating agents in petrol found in surface water through surface water flow and runoff from other rivers, streams and lakes in catchment area.
- The recorded high concentration of iron might be as a result of laterization process of parent rocks (granite, granite gneiss, schist and migmatite) and release of iron oxides.

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AUTHORS

First Author – Shuaibu Ahmed Mahi, Geology Department, Federal University Gusau, Zamfara - Nigeria

Second Author – Shuaibu Isah, Geology Department, Federal University Gusau, Zamfara - Nigeria