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Water Quality Assessment of the Bontanga Reservoir.

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Abstract

The water quality assessment of Bontanga reservoir in Northern Region of Ghana has been carried out and results obtained were based on samples collected from three sampling points monitored over a period of four years. Many of the parameters analysed were within the World Health Organisation's (2008) permissible levels for drinking water, and the Ghana Water Resources Commission target raw water quality range for domestic water use, with an exception of microbiological quality. The physico-chemical parameters ranged from 6.77 to 8.52 (pH unit), 0.43 to 39.40 NTU (turbidity), 2.50 to 30.00 colour units (colour), 44.50 to 135.00µS/cm (electrical conductivity), 24.20 to 39.10 mg/l (total dissolved solids), 20.00 to 88.00 mg/l (total hardness), and dissolved oxygen levels of 9.32 to 10.36mg/l.

The mean concentration of sulphate in the dry season was 4.33mg/l and 8.07mg/l in the wet season. Nitrate-N and phosphate ranged from 0.01 to 4.00mg/l and 0.015 to 0.024mg/l respectively. The heavy metals concentration ranged from 0.017 to 0.025mg/l (Cu); 0.15mg/l to 0.20mg/l (Fe), 0.01 to 0.03mg/l(Cr), 0.12 to 0.21mg/l(Mn), 0.010 to 0.014mg/l(Pb), 0.001 to 0.227mg/l (As) and 0.002 to 0.003 mg/l for Cd. The silica ranged 4.70mg/l to 23.90mg/l (SiO_2).

Total coliform counts ranged from 3,500 to 15,000 cfc/100ml with an overall mean of 9,250 cfc/100ml. The reservoir exhibited an overall ionic dominance pattern of Na > K > Ca > Mg and SO_4 > HCO_3 > Cl.

Keywords: Bontanga Reservoir, Water quality, Physico-chemical analysis, Microbial analysis**.**

1. Introduction

Observations of our environment tell us that water and life are associated with one another. Without water, many organisms, including human beings, would cease to exist.

Freshwater resources in Ghana, as well as in many developing countries, have not been effectively and efficiently managed over the years because water has been traditionally perceived as a free commodity. The result has been that of widespread pollution and wasteful use of freshwater resources that tend to threaten the aquatic environment and the life it supports. The projection of water demand, as envisaged under the Ghana government's economic programmes with regard to available water resources, indicates that within the next decade, water could become a scarce resource in the country (WARM, 1998).

Water quality monitoring is an essential tool used by environmental agencies to gauge the quality of surface water and to make management decisions for improving or protecting the intended uses. Poor water quality has many economic costs associated with it, but increasing access to safe drinking water and basic sanitation and promoting hygiene have the potential to improve the quality of life of billions of individuals and are critical for the achievement of the goals to reduce child mortality and reduce the burden of waterborne disease (UNESCO 2012). Also, changes in water quality have a variety of economic impacts, effects on human health, ecosystem health, agricultural and fisheries productivity, and recreational and amenity uses (Andrew, M., 2012). Experience has also shown that interventions in improving access to safe water favour the poor in particular, whether in rural or urban areas, and can be an effective part of poverty alleviation strategies (WHO, 2011).

The Bontanga reservoir was constructed between the years1978-1983. Water quality in the Bontanga Reservoir is important because much of the population of the area relies on the reservoir as a drinking-water source and for fishing and agricultural activities. Given the rate and extent of anthropogenic activities impacting on the water quality of the reservoir, it is important to carry out water quality assessments for sustainable management.

The main purpose of this study was to determine the physico-chemical and bacteriological characteristics of the water in the Bontanga reservoir, and to contribute towards the limnological knowledge of the reservoir.

Conclusions drawn for the water-quality studies conducted in the Reservoir were the results of samples collected at three sampling sites (Sites 1, 2 and 3).

2. Materials and Methods

2.1 Study area

The Bontanga Reservoir lies between latitude 9°34' 15.75"N and longitude 1°01' 21.13"W, in the northern region of Ghana (Fig 1). The reservoir is fed by the White Volta. The catchment area is about 165 km^2 with a length of about 1900m, dam crest height of 12m, reservoir area of 25km^2, and reservoir volume of 106m^3 (Gordon, 2006).

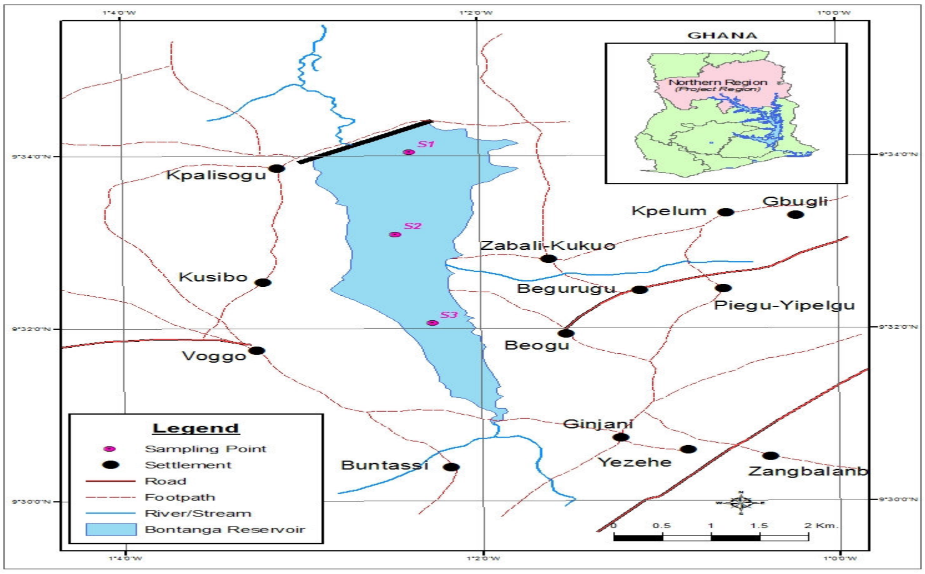

Fig 1: A map of the Bontanga Reservoir

The reservoir has an irrigable area of about 370 ha operated by the Ghana Irrigation Development Authority of the Ministry of Food and Agriculture.

The climate of the Bontanga reservoir catchment area is relatively dry, with a single rainy season that begins in May and ends in October. The amount of rainfall recorded annually varies between 750 mm and 1050 mm. The dry season starts in November and ends in March/April with maximum temperatures occurring towards the end of the dry season (March-April) and minimum temperatures in December and January.

The harmattan winds, which occur during the months of December to early February, have considerable effect on the temperatures in the region, which may vary between 14°C at night and 40°C during the day. Humidity, however, which is very low, mitigates the effect of the daytime heat.

The main vegetation is classified as vast areas of grassland, interspersed with the guinea savannah woodland, characterized by drought-resistant trees such as the acacia, baobab, sheanut, dawadawa, mango, neem etc (Dickson and Benneh, 1985).

2.2 Water sampling

Three sites on Bontanga reservoir were selected and monitored over a period of four years, from June 2003 to August 2007. The first site was located near the main tributary (White Volta) known as Site S1. The other two sampling sites were located about 100 km from the upstream (Site S2) and downstream (Site S3) of the reservoir (Fig 1).

Surface water samples for physico-chemical analyses were collected at depth 20-30 cm directly into clean acid-washed 1-litre plastic bottles. Samples for bacteriological analyses were collected into sterilized screw-capped 250 ml glass bottles. Samples for trace metal analyses were acidified by adding 0.5 ml concentrated HNO_3. All samples were stored in an icebox and transported to the CSIR-Water Research Institute's Laboratory in Tamale for analyses.

2.3 Water quality analyses

The methods outlined in the Standard Methods for the Examination of Water and Wastewater (APHA, 1998) was followed for the analyses of all the physico-chemical parameters. pH was measured in-situ using portable pH meter.

Conductivity was measured with Jenway model 4020 conductivity meter, and turbidity with a Partech model DRT 100B Turbidimeter. Sodium and potassium were measured by flame emission photometry; calcium and magnesium by EDTA titration; trace metals by atomic absorption spectrophotometer; sulphate by the turbidimetric method; colour by colour comparator and chloride by argentometric titration. Other analyses included alkalinity by strong acid titration method and silica by Molybdosilicate Method.

Nitrate-nitrogen was analysed by hydrazine reduction and spectrometric determination at 520nm, and phosphate by reaction with ammonium molybdate and ascorbic acid, and measured at 880 nm. Fluoride by SPADNS method and total dissolved solids, and suspended solids were measured gravimetrically after drying in an oven to a constant weight at 105°C. Total and faecal coliforms were determined by membrane filtration method using M-Endo-Agar Les (Difco) at 37°C and on MFC Agar at 44°C, respectively.

Statistical analysis- SPSS (version 16.0 for Windows) was used for the analyses of variance (ANOVA). The SPSS was also used to show that the data were normally distributed and hence the Pearson's correlation coefficient measures the linear association among the parameters. Significantly correlated parameters are those with very small (less than 0.05) significance level (or p-value). All tests were two-tailed.

3. Results and Discussion

3.1 Physical characteristics

The pH ranged from 6.77 to 8.52 (Table 1). The mean and range of pH values of all the sampling locations were within the Ghana Raw Water Criteria and Guidelines of 6.0-9.0 for domestic water use. There was no significant difference in the pH along the river course. There were negative correlations between pH and turbidity, colour and sulphate, with pH recording high values whenever turbidity, colour and sulphate recorded low values.

Turbidity ranged from 0.43 to 39.40 NTU (Table 1). The mean of turbidity along the course of the reservoir was significantly higher than the recommended range of 0-1 NTU for domestic water use (WRC, 2003). Thus, the reservoir may not be suitable for drinking or aesthetic use without further treatment. This implies that the water carries an associated risk of disease due to infectious disease agents and chemicals adsorbed onto particulate matter. A chance of disease transmission at epidemic levels exists at this level of turbidity. The high turbidity values can be attributed to runoff of organic and inorganic matter (especially soil particles) from the feeder streams. There was no significant difference in the mean turbidity along the course of the reservoir.

The correlation matrix showed that turbidity was negatively correlated with calcium, nitrate-nitrogen, bicarbonates, total alkalinity and total hardness. There was however, positive correlation between turbidity, colour and sulphates.

The mean colour along the river course was not significantly different. Colour ranged from 2.50 to 30.00 colour units (Table 1). The mean (13.97 colour units) fell within the World Health Organization colour limit for domestic water use of 15.00 colour units for no risk (WHO, 1984). Colour recorded negative correlations with calcium, nitrate-N, bicarbonates, total alkalinity and total hardness. It recorded positive correlations with sulphates and iron.

The mean electrical conductivity ranged from 44.50 to 135.00µS/cm (Table 1). Mean electrical conductivity values (60.53 µS/cm) fell within the WRC (2003) target water quality range of 0-70µS/cm. Electrical conductivity indicates presence of minerals but it does not give an indication of which element is present but higher value of EC is a good indicator of the presence of contaminants such as sodium, potassium, chloride or sulfate (Orebiyi et al 2010).The means were not significantly different along the course of the reservoir. Positive correlations were recorded between electrical conductivity and calcium, nitrate-N, bicarbonates, total alkalinity and total hardness.

The means of the Total Dissolved Solids (TDS) was not significantly different along the river course. The mean TDS ranged from 24.20 to 39.10 mg/l (Table 1), which is well within the target water quality range of 0-450mg/l (WRC, 2003), and according to WHO (2008), there is no health based limit for TDS in drinking water, as TDS in drinking water at concentrations well below toxic effects may occur.

Total alkalinity averaged 36.46mg/l (Table 1). There was no significant difference in the mean total alkalinity along the river course and it was positively correlated with total hardness. Total hardness ranged from 20.00 to 88.00 mg/l. The water at all the sampled locations can be described as soft to moderately soft as it falls within the target water quality range of 0-100 mg/l to be so described (WRC, 2003). The means of the total hardness was not significantly different along the course of the river.

The Bontanga reservoir is well oxygenated, with mean Dissolved Oxygen (DO) levels of 9.32, 9.98, and 10.36mg/l for Sites 1, 2, and 3 respectively (Table 1). DO concentrations in unpolluted water are normally about 8.0–10 mg/l at 25^{o}C (DFID, 1999). There were no significant differences in the means of DO along the course of the reservoir.

Table 1: Results of physical parameters of the Bontanga Reservoir

	Site 1		**Site 2**		**Site 3**		**Total**	
	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range
pH (pH unit)	7.76±0.41	7.24-8.52	7.74±0.44	6.77-8.34	7.70±0.42	7.14-8.34	7.74±0.41	6.77-8.52
Turbidity (NTU)	10.42±7.94	0.50-28.90	10.79±6.09	0.47-20.80	12.12±10.38	0.43-39.40	11.07±8.09	0.43-39.40
Colour (Colour units)	12.50±7.07	2.50-20.00	13.33±7.69	2.50-20.00	16.50±10.55	2.50-30.00	13.97±8.06	2.50-30.00
Conductivity (µS/cm)	63.73±23.57	44.50-135.00	60.56±15.78	45.00-102.00	57.31±10.84	45.20-81.00	60.53±17.36	44.50-135.00
TDS (mg/l)	28.81±4.46	24.20-37.60	29.79±4.57	24.60-38.10	28.51±4.98	24.20-39.10	29.04±4.47	24.20-39.10
T. Alkalinity (mg/l)	38.88±13.47	26.00-82.00	36.13±10.39	24.00-64.00	34.38±6.16	22.00-44.00	36.46±10.39	22.00-82.00
T. Hardness (mg/l)	34.63±17.12	20.00-74.00	33.63±17.32	20.00-88.00	32.75±10.45	20.00-56.00	33.67±14.99	20.00-88.00
DO (mg/l)	9.32±1.74	7.60-11.90	9.98±1.23	8.30-11.70	10.36±1.44	9.00-12.30	9.89±1.44	7.60-12.30

3.2 Ionic dominance Pattern

The Bontanga reservoir exhibited an overall ionic dominance pattern of Na > K > Ca > Mg and SO_4 > HCO_3 > Cl. This pattern is in contrast to the ionic dominance pattern of Ca > Mg > Na > K and HCO_3 > SO_4 > Cl for fresh water bodies (Stumm and Morgan, 1981). The anionic dominance pattern was, however, similar to that of freshwater bodies.

Table 2. Results of ionic parameters of the Bontanga Reservoir

	Site 1		Site 2		Site 3		Total	
	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range
Sodium	5.32±1.81	2.90-9.30	5.26±1.77	2.90-9.20	5.97±3.11	2.90-13.40	5.52±2.26	2.90-13.40
Potassium	3.12±0.73	1.90-4.20	3.10±0.76	2.00-4.20	3.17±0.71	2.00-4.40	3.13±0.71	1.90-4.40
Calcium	8.86±6.25	3.20-26.50	7.30±4.32	4.00-21.60	7.60±3.02	4.00-14.40	7.92±4.67	3.20-26.50
Magnesium	3.31±1.99	1.00-7.80	3.88±2.12	1.50-8.30	3.28±1.63	0.50-6.30	3.49±1.90	0.50-8.30
Chloride	6.33±1.75	1.50-9.00	6.86±1.00	5.00-8.00	6.92±1.55	4.00-10.00	6.70±1.46	1.50-10.00
Sulphate	7.27±3.12	2.41-13.30	7.10±3.04	2.29-14.00	7.03±2.75	2.18-11.30	7.13±2.91	2.18-14.00
Bicarbonate	47.43±16.42	31.72-100.00	44.08±12.67	29.28-78.10	41.93±7.53	26.84-53.70	44.48±12.67	26.84-100.00

Although mean values of sodium and potassium were within the target raw water quality range for domestic use (WRC, 2003), their relatively high values can be attributed to the fact that with re-use or recycling of water, the sodium concentration will tend to increase with each cycle or addition of sodium to the water. For this reason, sodium concentrations are elevated in runoffs or leachates from irrigated soils (WRC, 2003). Hence the large irrigated areas around the reservoir could account for the high levels of sodium. Also, the high levels of potassium could also be due to runoff from irrigated lands and from fertilized farms and domestic wastes.

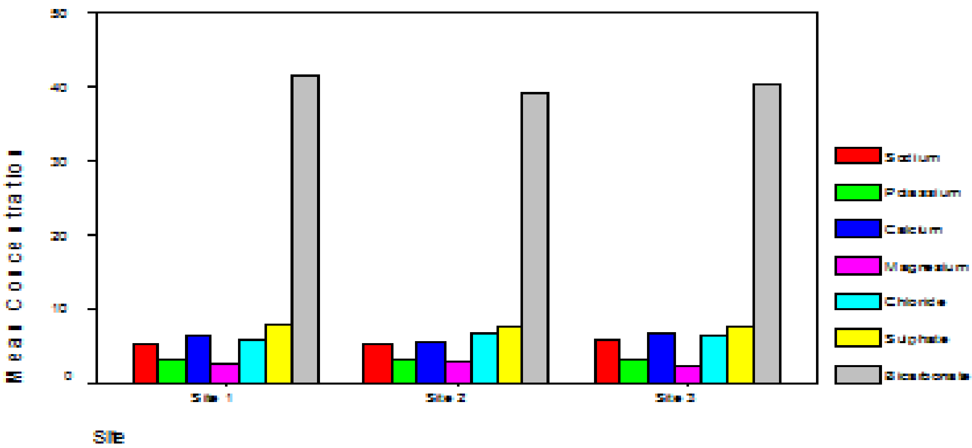

Figure 2: Graph of mean concentration of ionic parameters against site

Calcium was negatively correlated with iron but was positively correlated with nitrate-N, bicarbonates, total alkalinity, and total hardness. Also, Sulphates were negatively correlated with nitrate-N and total hardness. As expected, bicarbonates also recorded positive correlations with total alkalinity and total hardness.

3.3 Nutrients

The results of nutrient parameters measured are presented in the box plots in Figures 3. The means of nitrate-N in the reservoir ranged from 0.01 to 4.00mg/l, which is within the target raw water quality range of 0-6.00 mg/l for domestic use (WRC, 2003). The means of nitrate-N at Sites 1, 2 and 3 did not differ significantly. Nitrate-N recorded positive correlations with bicarbonates, total alkalinity and total hardness.

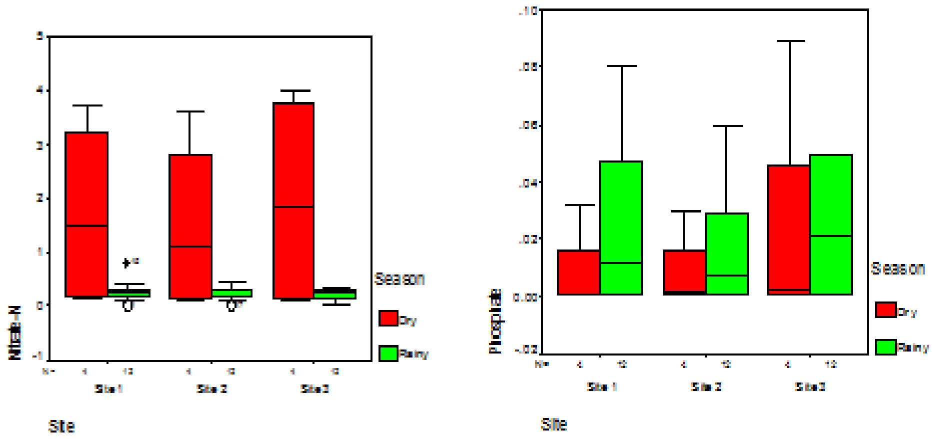

Fig.3: Seasonal Nitrate-N and Phosphate variation of the Bontanga Reservoir

Mean levels of phosphates were 0.020mg/l at Site 1, 0.015mg/l at Site 2 and 0.024mg/l at Site 3. The overall mean was 0.020mg/l and according to Chapman (1992), in most natural surface waters, phosphorous ranges from 0.005 to 0.020 mg/l PO_4-P. This connotes that the reservoir was free from pollution from phosphate sources. Mackenzie L. et al (2004) estimated that the phosphorus concentration should be below 0.010-0.015 mg/l to limit algae blooms.

The mean silica values observed in the reservoir ranged from 4.70mg/l to 23.90mg/l, and falls within 1-30 mg/l range for most rivers and lakes (Chapman, 1992). The means of the silica did not differ significantly along the course of the reservoir.

3.4 Trace metals

Mean levels of iron measured were 0.20mg/l, 0.15mg/l, and 0.16mg/l at Sites 1, 2 and 3 respectively. These values fell outside the raw water quality target of 0-0.10mg/l for domestic water use (WRC, 2003) but fell within the range of no adverse health effects and the water is well tolerated. However, there will be very slight adverse taste effects and marginal other aesthetic effects. The concentration of dissolved iron in water is dependent on the pH, redox potential, turbidity, suspended matter, the concentration of aluminium and the occurrence of several heavy metals, notably manganese (WRC, 2003). Hence, the high values recorded can be attributed to the high turbidity recorded in the same period. The means did not differ significantly along the course of the reservoir. Iron was positively correlated with colour but correlated negatively with sulphates.

Mean manganese levels ranged from 0.12 to 0.21mg/l, which is outside the target water quality range of 0-0.05mg/l for domestic use. The mean manganese levels fell within the no adverse health effects range of 0.1 – 0.15mg/l, but were at the threshold for significant staining and taste problems (WRC, 2003). The means did not differ significantly along the course of the reservoir.

Copper concentrations in reservoir ranged from 0.017 to 0.025mg/l; the overall mean was 0.021mg/l. These values fell within the raw water quality target of 0-0.1mg/l. The means did not differ significantly along the course of the reservoir.

No standard has been established for nickel concentration in drinking water in Ghana. The Maximum Allowable Concentration (MAC) in drinking water set by the European Economic Community (EEC) is 0.05 mg/l WHO (1991). The mean nickel concentration of 0.029 mg/l was within the EEC limit. The means did not differ significantly along the course of the reservoir.

The mean concentrations of Zinc were 0.007mg/l, 0.006mg/l and 0.006mg/l at Sites 1, 2 and 3 respectively. The means fell within the Ghana's raw water quality target range of 0-3mg/l (WRC, 2003). The means did not differ significantly along the course of the reservoir.

The mean range of values of Chromium concentrations for all the sampled locations was from 0.01 to 0.03mg/l. Ghana's raw water quality target for Chromium is 0-0.05mg/l (WRC, 2003). This implies that all the values fell within the target range.

The mean concentrations of Lead measured were 0.010mg/l, 0.003mg/l and 0.014mg/l at Sites 1, 2 and 3 respectively. The overall mean range of lead was 0.010 to 0.014mg/l, which is within the Ghana's raw water quality target of 0-15mg/l (WRC, 2003).

The mean range of values of Arsenic concentrations for all the sampled locations was from 0.001 to 0.227mg/l. Ghana's raw water quality target for chromium is 0-10mg/l (WRC, 2003). This implies that all the values fell within the target range.

Cadmium was also within the Ghana's target water quality range of 0-5mg/l with a range of 0.002 to 0.003 mg/l for all the sampled points.

Table 3. Level of some trace metals in water samples from Bontanga Reservoir.

	Site 1		**Site 2**		**Site 3**		**Total**	
	Mean±SD	**Range**	**Mean±SD**	**Range**	**Mean±SD**	**Range**	**Mean±SD**	**Range**
Iron	0.204±0.095	0.114-0.303	0.149±0.035	0.110-0.179	0.161±0.068	0.113-0.209	0.173±0.066	0.110-0.303
Manganesse	0.139±0.001	0.138-0.140	0.162±0.066	0.115-0.208	0.141±0.000	0.141-0.141	0.148±0.035	0.115-0.208
Copper	0.023±0.004	0.020-0.025	0.019±0.002	0.017-0.020	0.021±0.000	0.021-0.021	0.021±0.003	0.017-0.025
Nickel	0.020±0.013	0.010-0.029	0.019±0.013	0.010-0.028	0.068±0.000	0.068-0.068	0.029±0.024	0.010-0.068
Zinc	0.007±0.002	0.005-0.008	0.006±0.001	0.005-0.006	0.006±0.000	0.006-0.006	0.006±0.001	0.005-0.008
Cromium	0.020±0.014	0.010-0.030	0.020±0.000	0.020-0.020	0.030±0.000	0.030-0.030	0.022±0.008	0.010-0.030
Lead	0.010±0.001	0.009-0.011	0.003±0.003	0.001-0.005	0.014±0.000	0.014-0.014	0.008±0.005	0.001-0.014
Arsenic	0.227±0.000	0.227-0.227	0.001±0.000	0.001-0.001	0.178±0.000	0.178-0.178	0.135±0.119	0.001-0.227
Cadmium	0.003±0.000	0.003-0.003	0.002±0.000	0.002-0.002	-	-	0.003±0.001	0.002-0.003

All units are in mg/l unless otherwise stated

3.5 Bacteriological quality

The results of bacteriological quality are presented in Table 4. Total coliform counts ranged from 3,500 to 15,000 cfc/100ml with an overall mean of 9,250 cfc/100ml. All the values recorded fell well out of the "no effect" range of 0-5 cfc/100ml for domestic water use (WRC, 2003). These values indicate significant and increasing risk of infectious disease transmission when the water is used for domestic purposes. Similar project conducted on water from shallow dugouts in five (5) districts of the region were found to contain coliform bacteria (Cobbina et al 2009), which makes the region notable for waterborne-related diseases such as guinea worm infestation, cholera, dysentery etc. The high coliform counts can be as a result of accumulation of human and animal wastes and wastes discharges.

Table 4. Results of Bacteriological Water Quality (cfc/100ml) of Bontanga Reservoir

	Site 1		**Site 2**		**Site 3**		**Total**	
	Mean±SD	Range	Site	Range	Mean±SD	Range	Mean±SD	Range
Total Coliforms	15000±0.00	15000-15000	Site	3500-3500	N/A	N/A	9250±8132	3500-15000
Faecal Coliforms	10±0.00	10-10	Site	10-10	N/A	N/A	10±0	10-10

The overall mean of faecal coliform counts was 10 cfc/100ml which is above the target of 0 cfc/100ml (WRC, 2003). The high counts of faecal coliforms can be attributed to the indiscriminate defecation along the banks of the reservoir by both humans and other animals that graze along the banks. The large flocks of birds that are present around the reservoir could also account for the large counts of faecal coliforms as Jones and White (1984) reported that birds "pollute" more faecal indicators than humans. The counts of faecal coliforms in almost all occasions of sampling indicate significant and increasing risk of infectious disease transmission. As faecal coliform levels increase beyond 20cfc/ 100ml, the amount of water ingested or required to cause infection decreases (WRC, 2003).

3.6 *Seasonal variations*

Statistically significant seasonal variations were observed in some of the parameters measured. The mean of pH was observed to be high in the dry season with a value of 7.98, and 7.65 in the wet season. Similar trends were observed in electrical conductivity, calcium, nitrate-N, bicarbonate, total alkalinity, and total hardness (fig 4).

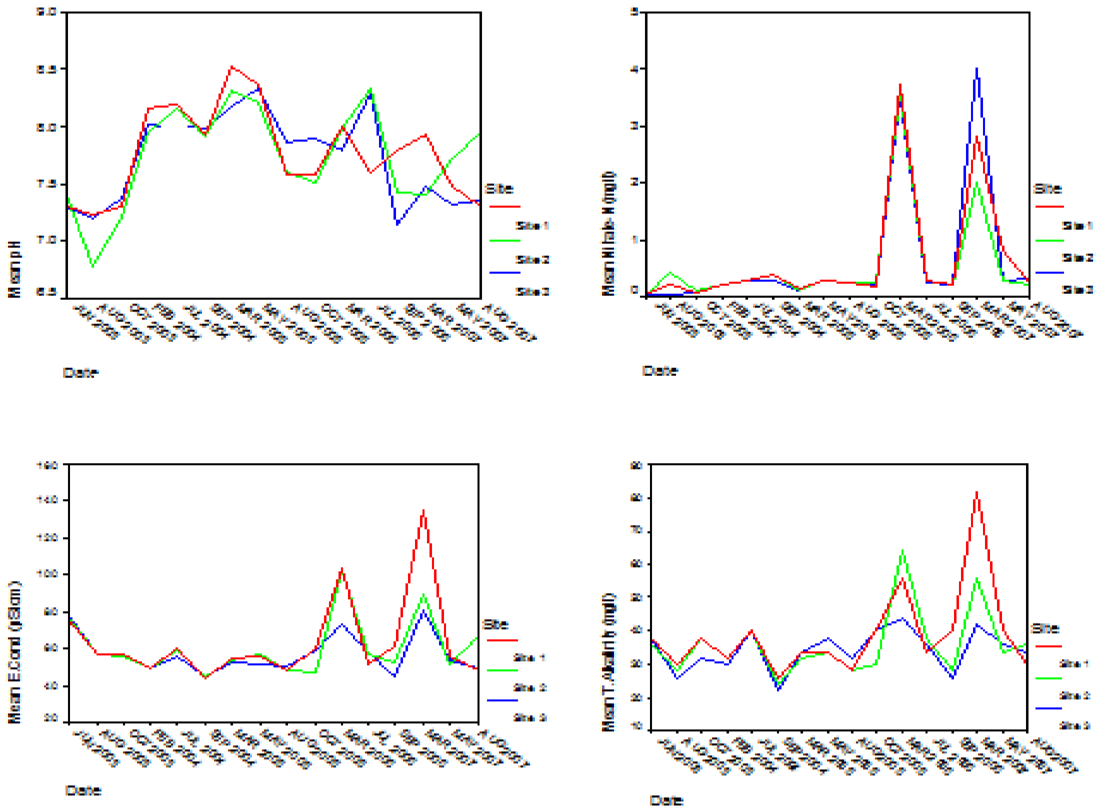

Fig 4. Mean monthly pH, Nitrate-N, EC and T. Alkalinity variation of the Bontanga Reservoir

The generally higher values of the pH in the dry season could be due to the release of acid-forming substances such as sulphates, phosphates, nitrates, etc into the water. These substances might have altered the acid-base equilibrium and resulted in the reduced acid-neutralizing capacity and hence raising the pH.

The high levels of nitrate recorded in dry season might have been because of accumulation of nitrate-containing substances from surface run-off from farms and animal pens into the river during the rainy season.

The high values of electrical conductivity in the dry season were expected since very little of salts are removed from water by precipitation or natural processes (WRC, 2003). In the absence of sufficient carbonic acid, the bicarbonate ion in the water dissociates to form additional carbon dioxide (Baird, 2000). Algae readily exploit this carbon dioxide for their photosynthetic needs, at the cost of allowing a build-up of hydroxide ions to such an extent that the water becomes quite alkaline. This can account for the high alkalinity values recorded. The solubility of salts is a function of temperature. Hence, the high mean total alkalinity values for the dry season since the salts might have been solubilized at the time when temperature is high.

The solubility of calcium in water is usually governed by the carbonate/bicarbonate equilibrium and is thus strongly influenced by pH and temperature.

The mean concentration of sulphate in the dry season was 4.33mg/l and 8.07mg/l in the wet season. The mean values of turbidity, colour, and iron were all higher in the wet season than the dry season values.

Sulphates, when added to water, tend to accumulate to progressively increasing concentration (WRC, 2003). This could account for the high levels recorded in the rainy season.

The relatively higher mean Turbidity values recorded in the rainy season can be attributed to runoff of organic and inorganic matter (especially soil particles) from the feeder streams. Soil particles constitute a major part of the suspended matter contributing to Turbidity (WRC, 2003). Higher mean values of Colour were expected, as Turbidity is strongly associated with apparent water Colour (WRC, 2003).

The concentration of dissolved iron in water is dependent on the pH, redox potential, turbidity, suspended matter, the concentration of aluminium and the occurrence of several heavy metals, notably manganese (WRC, 2003). Hence, the high values recorded in the rainy season can be attributed to the high turbidity levels recorded in the same period. This implies that iron and turbidity were from similar pollution source.

3.7 Water quality index

Water Quality Index (WQI) was used to assess water quality relative to the standard for domestic use and to provide insight into the degree to which water quality is affected by human activity. Using the WQI Calculator 1.0 (CCME, 2001) and water quality classification (Table5), the WQI for the Bontanga Reservoir was calculated to be 42.6% for Site 1, 49.4% for Site 2 and 68.2% for Site 3. The overall WQI for the reservoir was 45.2%. The WQI indicates that water quality in the Bontanga Reservoir was Poor at Site 1. Site 2 fell under the marginal water quality category whilst Site 3 was under the fair WQI category. The CCME WQI for the entire reservoir indicates that the water quality was marginal for the period of the study. This implies that the water quality is usually protected but occasionally threatened or impaired and conditions sometimes depart from natural or desirable levels (CCME, 2001).

Table 5: Classification of Water Quality

Class	WQI Range
Excellent	95-100
Good	80-94
Fair	65-79
Marginal	45-64
Poor	0-44

Source: CCME, 2001

4. Conclusions

This study has provided useful baseline information on the water quality of the Bontanga reservoir for the management of the catchment's ecosystem.

The results indicated that most of the physico-chemical quality parameters of the Bontanga reservoir were within the WRC (2003) target raw water quality criteria for domestic use. However, turbidity, iron, manganese, total coliform, and faecal coliform exceeded target raw water quality criteria for domestic use. The high turbidity observed in the reservoir is attributable to runoff of organic and inorganic matter (especially soil particles) from the feeder streams. The high values of iron recorded can be attributed to the high turbidity recorded in the same period.

The CCME WQI for the entire reservoir indicates that the water quality was marginal for the period of the study, which implies conditions sometimes depart from natural or desirable levels.

The ionic dominance pattern observed were Na > K > Ca > Mg and SO_4 > HCO_3 > Cl. The anionic dominance pattern was similar to that of freshwater bodies. Sodium and potassium recorded relatively higher values than normal freshwater.

Statistically significant seasonal variations were observed in some of the parameters measured. The mean pH was observed to be higher in the dry season than in the wet season. Similar trends were observed in electrical conductivity, calcium, nitrate-N, bicarbonate, total alkalinity, and total hardness. On the other hand, the mean values of turbidity, colour, sulphate and iron were all higher in the wet season than the dry season values.

5. Recommendations

There is the need to educate the public on efficient water use methodologies and the intensification of the educational awareness as to how to handle and locally treat water for domestic use.

In view of the importance of the Bontanga reservoir ecosystem, stringent efforts should be made to, on regular basis, monitor the water quality of the river as well as the landscape in order to conserve the ecosystem.

Further research is needed on pesticide residue analyses for better management of the pesticides used in the farms around the reservoir.

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