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PHYSICOCHEMICAL AND BACTERIOLOGICAL QUALITY OF WATER COLLECTED FROM DAMS AND RIVERS ALONG GOLD MINING SITES IN ZAMFARA STATE

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ABSTRACT
The physicochemical properties of water such as pH, temperature, conductivity, total dissolved solids, total suspended solid, alkalinity, dissolved oxygen, chloride, turbidity, hardness, sulphate, chemical oxygen demand and biochemical oxygen of the three major dams and rivers in Zamfara State were analyzed using standard analytical methods. The influence of seasonal variability on the parameters was also considered. Bacteriological assessment was also conducted to determine the bacteria load of the water bodies. The total bacterial counts obtained during the wet season (3.6 x 10^6 to 8.9 x 10^6) were generally higher than those obtained in the dry (2.4 x10^5 to 7.9 x 10^5). The microbial values recorded in the dam which ranged from (2.4 x10^5 to 7.4 x 10^6) and rivers (5.2 x10^5 to 8.9 x 10^6) water body represent high bacteria load compared to the recommended standards for drinking water (WHO, 2008; EPA, 2010; USEPA, 2002). The result of the physicochemical parameters revealed marked variations and non-uniform distribution from one season to another for two years of study. The results further showed that pH, temperature, EC, TDS, TSS, alkalinity, DO, BOD, COD, Cl, and SO_4 have values that fall below the USEPA standard limit for drinking water with exception of turbidity (88.67 mg/l) that has a value higher than the recommended standard limit. Analysis of variance on the data collected revealed that there were significant difference ($P < 0.05$) between the parameters based on locations and seasons. Multiple range test conducted on the parameters also showed a significant difference between the wet and dry seasons. A combined mean of the parameters further revealed a significant different between the years.

Keywords: physicochemical parameters, drinking water, microbial and locations

INTRODUCTION
Contamination of the environment usually result from industrial activities, such as mining, electroplating, gas exhaust, energy and fuel production, fertilizer and pesticides application, and generation of municipal waste (Olutiola, 2000). Gold mining and processing have been the main sources of heavy metal contamination in the environment (Duruibe *et al*., 2007; Boamponsem *et al*., 2010; Girigisu *et al*., 2012). The uncontrolled dissemination of waste effluents to large water bodies has negatively affected both water quality and aquatic life (Abdulrahman *et al*., 2008). During the processing of the ores for gold, poisonous substances such as oxides and sulphides of heavy metals are released into the environment (Boamponsem *et al*., 2010). Hence, most of the water sources, particularly in Zamfara State, are gradually becoming polluted due to the addition of these foreign materials from the environment. Certain environmental conditions such as salinity, pH, and water hardness can play an important factor in heavy metals accumulation up to toxic concentrations in living organisms and cause ecological damage (Garba *et al*., 2010). High or low pH values in a river have been reported to affect aquatic life and alter toxicity of other pollutant in one form or the other (DWAF, 1996c). Low pH values in a river for examples impair recreational uses of water and effect aquatic life. A decrease in pH values could also decrease the solubility of certain essential element such as selenium, while at the same time low pH increases the solubility of many other element such as Al, B, Cu, Cd, Hg, Mn and Fe (DWAF, 1996c). Water temperature may cause the differences in metal deposition in various organs. Higher temperatures promote accumulation of cadmium especially in the most burdened organs: kidneys and liver (Chang H, 2005). Increased accumulation of metals by fish at higher temperatures probably results from higher metabolic rate, including higher rate of metal uptake and binding. High water temperature enhances the growth of microorganisms and may increase taste, odour, colour and corrosion problems (WHO, 2008). The effect of temperature, and especially changes in temperature, on living organisms can be critical. Conductivity does not have direct impact on human health. It is determined for several purposes such as determination of mineralization rate (existence of minerals such as potassium, calcium, and sodium) and estimating the amount of chemical reagents used to treat this water (Kavcar *et al*., 2009; Cidu *et al*., 2011; Muhammad *et al.,* 2011; and Khan *et al*., 2013). High conductivity may lead to lowering the aesthetic value of the water by giving mineral taste to the water. For the industrial and agricultural activity, conductivity of water is critical to monitor. Water with high conductivity may cause corrosion of metal surface of equipment such as boiler. It is also applicable to home appliances such as water heater system and faucets. Food-plant and habitat-forming plant species are also eliminated by excessive conductivity (Khan *et al*., 2013 and Kavcar *et al*., 2009). A high DO level in a community water supply is good because it makes drinking water taste better. However, high DO levels speed up corrosion in water pipes. It is also taken as a measure of the concentration of organic matter present in any water. The greater the decomposable matter present, the greater the oxygen demand and the greater the BOD values (Ademoroti, 1996). Natural sources of organic matter include plant decay and leaf fall. When BOD levels are high, dissolved oxygen (DO) levels decrease because the bacteria are consuming the oxygen that is available in the water. Since less dissolved oxygen is available in the water, fish and other aquatic organisms may not survive (Keith *et al*., 1997). Alkalinity, the concentration of bases in water is

composed mainly of bicarbonate, carbonate and hydroxyl ions (WHO, 2008). Alkalinity is affected by variations in flow regimes and its natural unevenness is linked to the presence or absence of carbonate rock (Dladla, 2009). The change in alkalinity depends on carbonates and bicarbonates, which in turn depend upon release of CO_2. Change in carbonates and bicarbonates also depend upon release of CO_2 through respiration of living organisms (Verma *et al*., 2013). Water with high dissolved solid is generally of inferior palatability and may induce an unfavourable physiological reaction in the consumer (ASTM, 2004; APHA, 2004). High concentration of dissolved solid in water is also responsible for hardness, turbidity, odour, taste, colour and alkalinity (ASTM, 2004). The maximum permissible concentration of TDS is 500 mg/L in potable water. Turbidity is also related to the content of diseases causing organisms in water, which may come from soil runoff. The presence of colloidal solid gives water a cloudy appearance which reduces its transparency. The standard recommended maximum turbidity limit, set by WHO and NDWQS, for drinking water is 5 nephelometric turbidity units (NTU) (Kavcar *et al*., 2009; Cidu *et al*., 2011; Muhammad *et al*., 2011).

MATERIALS AND METHODS

Sample area and Sampling Points: Zamfara State is located in the North Western Zone of Nigeria between Latitude 11^0 40' E and Longitudes 70^0 25' E at an altitude of 420 m. The dams are located in Gusau LGA (Gusau dam), Maradun LGA (Bakolori dam), and Maru LGA (Dangulbi dam). The rivers are located in Anka LGA of the state, they are Abare, Sunke and Bagega which are contaminated with lead poisoning coming from extensive gold mining in those villages.

Sample Collection and Analysis

Physicochemical properties: Temperature was measured with the aid of a digital thermometer. Measurements of both the water temperature and the ambient temperature were measured and values recorded in degrees Celsius.

pH, TDS and EC : The pH and total dissolved solids (TDS) and electrical conductivity (EC) of the water samples were measured with HANNA HI 9810 pH-TDS meter. The meter was standardized with a buffer solution (i.e. buffer 7 and 9). The buffer tablet was distilled in water (100 ml) in a beaker (250 ml). The probe of the meter was then placed in the solution and adjusted to read 000 to standardize it. The electrode response was checked by measuring the pH of the test sample, first with distilled water and then with the sample. The system was allowed to stabilize before the final reading was made. **Total suspended solids (Gravimetric method)**: A known amount of the water sample was filtered through a pre weighed filter paper. The filter paper was then dried between 103˚C and 105˚C (APHA, 1995). TSS was determined by using the following formula: Total Suspended Solids (TSS) mg/l = $\frac{(A\text{-}B)\times 10^3}{C}$
Where A = weight of filter plus solids (g); B = weight of filter (g); C = volume of sample filtered (ml).

Turbidity Nephelometric Method: The water sample was gently agitated until air bubbles disappeared from the water sample. About 100 ml of the agitated sample was transferred into a cell and the turbidity was measured directly from the meter display. The turbidity meter (HACH 2100P) was initially calibrated with a turbidity standard reagent before any sample reading was taken. Turbidity was measured in the field with a portable Hach Turbidity Meter (APHA, 1995). **Dissolved oxygen:** A glass stopped bottle (300 ml) was filled with sample and stoppered without trapped air. $MnSO_4$ solution (1.0 ml) and alkaline iodide solution (1.0 ml) were added and the bottle stoppered carefully to exclude air bubbles. The bottle was inverted several times to mix content. The formed precipitate was allowed to settle and H_2SO_4 (sp. gr. 1.84, 1.5 ml) was added, re-stoppered and mixed by inverting several timed. An aliquot (25 ml) was titrated with $Na_2S_2O_3.5H_2O$ solution to a colorless end point using starch indicator. DO was calculated using the expression:

$$\text{DO (mg/L)} = \frac{\text{T cm}^3 \times 100}{\text{Volume (ml) of aliquot}}$$

Where T =volume of titrant used.

Bacteriological Analysis of Water

Total bacterial count: The pour plate method was used for the enumeration of total bacterial count of the water samples.
The estimation of the Coli form counts: The standard multiple tube or most probable number (MPN) technique as suggested by APHA (1995) and modified by Olutiola *et al.* (2000) was used.

Statistical Analysis: Descriptive statistics (such as mean and standard deviation) were performed on all the data. A two way ANOVA was used to compare means of the different parameters measured for two seasons (wet and dry) and for two years (2014 and 2015). Duncan Multiple Range Test was used to separate means where significant. Means were considered significantly different at $P > 0.05$.

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Table 1: The Mean and Standard Deviation of Location and Year of the Physicochemical Parameters of Water Bodies in the Wet Season

Location	Year	pH	Temp ⁰C	EC µs/cm	TDS mg/L	TSS mg/L	Cl mg/L	Alk. mg/L	Tur. NTU
Gusau dam	2014	7.67± 0.03	26.53 ± 0.06	125.00 ± 0.00	196.67 ± 5.77	102.33 ± 1.15	15.93 ± 0.12	16.70 ± 0.46	6.67 ± 0.58
	2015	7.68 ± 0.02	26.50 ± 0.00	123.33 ± 2.89	180.00 ± 0.00	66.53 ± 4.31	15.20 ± 0.20	15.33 ± 0.40	4.67 ± 0.58
Bakolori dam	2014	7.86 ± 0.01	26.60 ± 0.00	200.00 ± 0.00	300.00 ± 0.00	1.64.67 ±0.58	19.40 ± 0.17	18.27 ± 0.12	7.00 ± 0.00
	2015	7.98 ± 0.58	26.50 ± 0.00	211.67 ± 2.87	293.3 ± 1.55	148.33 ± 2.89	18.00 ± 0.00	16.06 ± 0.75	7.67 ± 0.58
Dangulbi dam	2014	7.73 ± 0.04	26.50 ± 0.00	220.00 ± 0.00	350.00 ± 0.00	186.00 ± 1.73	20.07 ± 0.11	17.30 ± 0.00	10.00 ± 0.00
	2015	7.74 ± 0.35	26.57 ± 0.58	206.67 ± 0.00	326.67 ± 5.77	170.67 ± 0.58	21.33 ± 0.40	19.47 ± 0.06	11.67 ± 0.58
Bagega river	2014	7.60 ± 0.03	26.73 ± 0.58	231.67 ± 2.89	360.00 ± 0.00	3.85.33 ±1.15	26.70 ± 0.17	20.04 ± 0.05	72.67 ± 1.35
	2015	7.54 ± 0.03	26.77 ± 0.06	250.00 ± 0.00	346.67 ± 5.73	406.67 ± 2.52	27.67 ± 0.29	21.93 ± 0.40	73.33 ± 1.57
Sunke river	2014	7.52 ± 0.03	26.70 ± 0.00	260.00 ± 0.00	400.00 ± 0.00	430.00 ± 0.00	33.07 ± 0.11	23.47 ± 0.12	76.67 ± 0.35
	2015	7.54 ± 0.03	26.77 ± 0.68	253.33 ± 2.89	396.67 ± 5.77	420.00 ± 0.00	36.00 ± 0.34	20.67 ± 0.12	74.33 ± 1.77
Abare river	2014	7.53 ± 0.03	26.80 ± 0.00	328.33 ± 2.89	500.00 ± 0.00	573.33 ± 2.89	36.60 ± 0.00	23.54 ± 0.22	80.33 ± 1.77
	2015	7.45 ± 0.03	26.87 ± 0.08	330.00 ± 0.00	516.67 ±5.77	573.33 ± 2.89	25.29 ± 0.35	22.33 ± 0.06	77.67 ± 1.35
Nigeria range		6.5 – 8.5	35 - 40	1000	500	-	250		
WHO range		6.5 – 7.5	35 - 37	500	1000	-	250	200	5.0 - 25

n = 3; mean ± S.D.

KEY: E.C = Electronic Conductivity; T.D.S = Total Dissolved Solids; Cl = Chlorine; Alk = Alkalinity; Tur = Turbidity

Table 2: Mean Standard Deviation of Location and Year of the Physicochemical Parameters of Water Bodies in the Dry Season

Location	Year	pH	Temp. ⁰C	E C µs/cm	TDS mg/L	TSS mg/L	Cl mg/L	Alk mg/L
Gusau dam	2014	7.85 ± 0.03	26.80 ± 0.00	186.67 ± 0.09	75.53 ± 0.74	123.00 ± 1.73	16.330 ± 0.26	18.73 ± 0.29
	2015	7.80 ± 0.47	26.67 ± 0.58	156.67 ± 0.77	71.80 ± 1.11	92.00 ± 1.73	15.70 ± 0.26	16.77 ± 0.15
Bakolori dam	2014	7.95 ± 0.21	26.70 ± 0.00	200.00 ± 0.00	246.67 ± 0.34	119.00 ± 0.24	17.30 ± 1.84	18.40 ± 0.05
	2015	7.90 ± 0.08	26.57 ± 0.06	250,00 ± 0.00	300.00 ± 0.00	119.00 ± 0.74	18.73 ± 0.12	17.53 ± 0.12
Dangulbi dam	2014	7.85 ± 0.01	26.73 ± 0.58	230.00 ± 0.00	360.00 ± 0.00	184.66 ± 0.58	21.47 ± 0.58	19.23 ± 0.06
	2015	7.75 ± 0.02	27.00 ± 0.00	233.3 ± 0.87	370.00 ± 0.00	182.00 ± 0.00	20.70 ± 1.00	18.70 ± 0.10
Bagega river	2014	7.50 ± 0.01	27.00 ± 0.00	260.00 ± 0.00	400.00 ± 0.00	431.33 ± 0.58	27.67 ± 0.33	21.82 ± 0.36
	2015	7.40 ± 0.01	27.17 ± 0.15	270.00 ± 0.00	426.67 ± 057	447.33 ± 1.15	27.27 ± 0.42	21.90 ± 0.61
Sunke river	2014	7.55 ± 0.01	27.00 ± 0.00	280.00 ± 0.00	430.00 ± 0.00	470.00 ± 0.00	33.67 ± 0.12	24.47 ± 0.12
	2015	7.52 ± 0.01	27.01 ± 0.01	300.00 ± 0.00	420.00 ± 0.00	450.00 ± 0.00	37.97 ± 0.21	23.40 ± 0.01
Abare river	2014	7.50 ± 0.01	27.20 ± 0.00	350.00 ± 0.00	510.00 ± 0.00	560.00 ± 0.00	36.37 ± 0.58	22.80 ± 0.01
	2015	7.40 ± 0.03	26.73 ± 0.06	330.00 ± 0.00	520.00 ± 0.00	545.00 ± 0.00	32.67 ± 0.12	21.50 ± 0.01

KEY: E.C = Electronic Conductivity; T.D.S = Total Dissolved Solids; Cl = Chlorine; Alk = Alkalinity;

Table 3: The Mean and Standard Deviation of Location and Year of the Physicochemical Parameters of Water Bodies in the Wet Season.

Location	Year	COD (mg/l)	BOD (mg/l)	DO (mg/l)	SO_4 mg/l
Gusau dam	2014	198.00 ± 1.73	10.67 ± 1.10	7.67 ± 0.06	9.56 ± 0.06
	2015	195.33 ± 1.15	09.67 ± 0.81	7.40 ± 0.17	9.21 ± 0.19
Bakolori dam	2014	182.33 ± 1.15	14.40 ± 0.10	7.47 ± 0.06	9.47 ± 0.12
	2015	178.00 ± 1.73	12.50 ± 0.17	7.37 ± 0.06	9.19 ± 0.07
Dangulbi dam	2014	169.07 ± 0.58	11.37 ± 0.23	8.00 ± 0.00	9.52 ± 0.03
	2015	164.33 ± 1.15	10.63 ± 0.29	7.80 ± 0.17	9.30 ± 0.02
Bagega river	2014	241.33 ± 1.31	33.31 ± 0.34	4.03 ± 0.06	14.11 ± 0.18
	2015	240.00 ± 0.00	35.59 ± 0.70	2.37 ± 0.23	14.20 ± 0.17
Sunke river	2014	256.67 ± 1.15	25.57 ± 0.64	3.53 ± 0.12	15.04 ± 0.06
	2015	260.33 ± 0.58	33.47 ± 0.12	2.60 ± 0.17	16.68 ± 0.64
Abare river	2014	266.33 ± 0.82	33.13 ± 0.23	2.60 ± 0.17	17.56 ± 0.07
	2015	272.00 ± 0.46	34.53 ± 0.23	2.73 ± 0.12	12.54 ± 0.29
Nigeria standard					100
WHO standard					200

Tur = Turbidity; SO_4 = Sulphate ; COD = Chemical Oxygen Demand; BOD = Biological Oxygen Demand; TSS = Total Suspended Solid; DO = Dissolved Oxygen

Table 4: The Mean and Standard Deviation of Location and Year of the Physicochemical Parameters of Water bodies in the Dry Season.

Location	Year	COD mg/L	BOD mg/L	DO mg/L	Tur NTU	SO_4 mg/L
Gusau dam	2014	199.67 ± 0.58	8.33 ± 0.21	7.70 ± 0.73	8.00 ± 0.00	10.43 0.02
	2015	182.33 ± 0.15	9.03 ± 0.26	7.30 ± 0.10	7.33 ± 0.58	10.41 ± 0.12
Bakolori dam	2014	194.53 ± 0.61	11.10 ± 0.88	7.67 ± 0.21	8.00 ± 0.00	10.50 ± 0.02
	2015	171.33 ± 0.21	11.47 ± 0.10	7.53 ± 0.06	7.67 ± 0.58	10.12 ± 0.02
Dangulbi dam	2014	170.43 ± 0.15	8.13 ± 0.06	8.50 ± 0.10	12.00 ± 0.01	11.03 ± 0.03
	2015	165.87 ± 0.06	11.70 ± 0.15	7.90 ± 0.01	11.00 ± 0.01	10.96 ± 0.03
Bagega river	2014	243.00 ± 0.00	26.33 ± 0.10	6.67 ± 0.06	81.00 ± 1.00	24.49 ± 0.02
	2015	244.50 ± 0.97	22.37 ± 0.10	6.57 ± 0.15	79.66 ± 0.58	25.76 ± 2.89
Sunke river	2014	270.00 ± 0.00	34.43 ± 0.11	2.83 ± 0.06	81.00 ± 0.00	27.01 ± 0.17
	2015	256.33 ± 0.58	26.33 ± 0.10	3.87 ± 0.06	80.00 ± 0.00	27.16 ± 0.15
Abare river	2014	290.00 ± 0.50	37.34± 0.06	2.76 ± 0.06	88.67 ± 0.58	29.81 ± 0.01
	2015	280.33 ± 0.58	33.60± 0.15	2.90 ± 0.01	85.33 ± 0.58	29.13 ± 0.11

n = 3; mean ± S.D.
KEY: Tur = Turbidity; SO_4 = Sulphate ; COD = Chemical Oxygen Demand; BOD = Biological Oxygen Demand; DO = Dissolved Oxygen;

Table 5: Total Bacterial Count CFU/ml of Water Samples For Dry and Wet Season

Name	Year	Season	
		Wet $x10^5$	Dry x 10^5
Gusau dam	2014	3.6	2.4
	2015	4.5	3.2
Bakolori dam	2014	5.7	4.8
	2015	4.5	4.1
Dangulbi dam	2014	7.4	6.4
	2015	6.2	5.2
Bagega river	2014	7.8	6.4
	2015	7.9	7.4
Sunke river	2014	8.5	7.4
	2015	8.3	7.8
Abare river	2014	8.6	7.9
	2015	8.9	7.8

Table 6: Coliform count Using Multiple Tube for Dry and Wet Water Sample MPN/100ml

Name	Year	Season	
		Wet	**Dry**
Gusau dam	2014	35	25
	2015	42	31
Bakolori dam	2014	41	20
	2015	39	28
Dangulbi dam	2014	60	47
	2015	67	50
Bagega river	2014	45	35
	2015	43	33
Sunke river	2014	67	50
	2015	80	63
Abare river	2014	75	53
	2015	89	67

Table 7: Multiple range tests of pH, temperature and EC for 2014 and 2015 for all locations of water bodies in the wet and dry season

Location	pH		Temperature		EC	
	Wet	Dry	Wet	Dry	Wet	Dry
Gusau dam	7.60 ± 0.02^a	7.70 ± 0.06^a	26.52 ± 0.02^a	26.73 ± 0.02^b	124.17 ± 1.02^a	171.67 ± 4.41^a
Bakolori dam	7.59 ± 0.02^a	7.67 ± 0.06^a	26.60 ± 0.02^b	26.63 ± 0.02^a	205.83 ± 1.02^b	225.00 ± 4.41^b
Dangulbi dam	7.60 ± 0.02^a	7.63 ± 0.06^a	26.53 ± 0.02^a	26.87 ± 0.02^c	213.33 ± 1.02^c	231.67 ± 4.41^b
Bagega river	7.67 ± 0.02^b	7.92 ± 0.06^b	26.73 ± 0.02^c	27.03 ± 0.02^e	240.83 ± 1.02^d	265.00 ± 4.41^c
Sunke river	7.89 ± 0.02^a	7.94 ± 0.06^b	26.75 ± 0.02^c	27.08 ± 0.02^e	256.67 ± 1.02^e	290.00 ± 4.41^d
Abare river	7.70 ± 0.02^b	7.63 ± 0.06^a	26.83 ± 0.02^d	26.97 ± 0.02^d	329.17 ± 1.02^f	325.00 ± 4.41^e

n = 6; mean ± S.D; Values with the same Superscripts are not significantly different (P> 0.05)

Table 8: Combined means of pH, temperature and EC for all locations of Water Bodies for 2014 and 2015 in the Wet and Dry Season

year	pH		Temperature		EC	
	wet	dry	wet	dry	wet	dry
2014	7.69 ± 0.01	7.79 ± 0.04	26.64 ± 0.01	26.91 ± 0.01	227.50 ± 0.59	251.11 ± 2.55
2015	7.66 ± 0.01	7.71 ± 0.04	26.68 ± 0.01	26.87 ± 0.01	229.12 ± 0.59	251.67 ± 2.55

n = 36; mean ± S.D

Table 9: Multiple range tests of TDS, TSS and Cl for 2014 and 2015 for all locations of water bodies in the wet and dry season.

Location	TDS		TSS		Cl	
	Wet	Dry	Wet	Dry	Wet	Dry
Gusau dam	188.33 ± 7.01^a	173.67 ± 20.8^a	84.43 ± 5.86^a	107.50 ± 2.14^a	15.56 ± 7.07 ^{a}	16.00 ± 0.23 ^{a}
Bakolori dam	296.67 ± 7.01^b	273.33 ± 20.8^b	156.50± 5.86 ^{b}	126.17 ± 2.14^b	18.70 ± 7.07 ^{b}	18.01 ± 0.23 ^{b}
Dangulbi dam	338.33 ± 7.01^c	365.33 ± 20.8^c	178.33± 5.86 ^{c}	183.33 ± 2.14^c	20.70 ± 7.07 ^{c}	21.08 ± 0.23 ^{c}
Bagega river	353.33 ± 7.01^c	413.33 ± 20.8^c	396.00± 5.86 ^{d}	439.50 ± 2.14^d	27.18 ± 7.07 ^{d}	27.18 ± 0.23 ^{d}
Sunke river	398.33 ± 7.01^c	425.00 ± 20.8^c	425.00± 5.86^e	460.00 ± 2.14^e	34.54 ± 7.07 ^{e}	35.81 ± 0.23 ^{f}
Abare river	508.33 ± 7.01^d	515.00 ± 20.8^d	558.33± 5.86 ^{f}	552.50 ± 2.14^f	36.00 ± 7.07 ^{f}	34.52 ± 0.23 ^{e}

n = 6; mean ± S.D; Values with the same Superscripts are not significantly different (P> 0.05)

Table 10: Combined means of TDS, TSS and Cl for all locations of Water Bodies for 2014 and 2015 in the Wet and Dry Season.

year	TDS		TSS		Cl	
	wet	dry	wet	dry	wet	dry
2014	227.50 ± 4.08	337.03 ± 12.03	306.94 ± 3.38	314.72 ± 1.23	35.11 ± 4.08	25.46 ± 0.13
2015	229.12 ± 4.08	351.41 ± 12.03	292.59± 3.38	308.28 ± 1.23	34.33 ± 4.08	25.51 ± 0.13

n = 36; mean ± S.D

Table 11: Multiple range tests of Alkalinity, Turbidity and Sulphate for 2014 and 2015 for all locations of water bodies in the wet and dry season.

Location	Alk.		Tur.		SO_4	
	Wet	Dry	Wet	Dry	Wet	Dry
Gusau dam	15.70 ± 0.13^a	17.75 ± 0.11^a	5.67 ± 1.76 ^{a}	7.67 ± 0.23^a	9.38 ± 0.07^a	10.43 ± 0.34^a
Bakolori dam	17.70 ± 0.13^b	17.97 ± 0.11^a	7.33 ± 1.76 ^{a}	7.83 ± 0.23^a	9.33 ± 0.07^a	10.53 ± 0.34^a
Dangulbi dam	18.38 ± 0.13^c	18.97 ± 0.11^b	10.83 ±1.76^a	11.50 ±0.23^b	9.41 ± 0.07^a	10.10 ± 0.34^a
Bagega river	20.99 ± 0.13^d	21.86 ± 0.11^c	73.00 ±1.76^b	80.33 ±0.23^c	14.15 ± 0.07^b	25.13 ± 0.34^b
Sunke river	22.06± 0.13^e	23.93 ± 0.11^d	75.50±1.76^{bc}	80.50± 0.23^c	15.86± 0.07^c	27.08 ± 0.34^c
Abare river	22.93± 0.13^f	22.15 ± 0.11^c	79.00± 1.76^c	87.00± 0.23^d	18.13± 0.07^d	29.47 ± 0.34^d

n = 6; mean ± S.D; Values with the same Superscripts are not significantly different (P> 0.05)

Table 12: Combined means of Alkalinity, Turbidity and Sulphate for all locations of Water Bodies for 2014 and 2015 in the Wet and Dry Season.

year	Alk.		Tur.		SO_4	
	wet	dry	wet	dry	wet	dry
2014	19.78 ± 0.07	20.91 ± 0.07	42.22 ± 1.02	46.44 ± 0.13	12.54 ± 0.04	18.88 ± 0.20
2015	19.30± 0.07	19.97 ± 0.07	41.56± 1.02	45.45± 0.13	12.88± 0.04	19.01± 0.20

n = 36; mean ± S.D

Table 13: Multiple range tests of COD, BOD and DO for 2014 and 2015 for all locations of water bodies in the wet and dry season.

Location	COD		BOD.		DO	
	Wet	Dry	Wet	Dry	Wet	Dry
Gusau dam	196.67±2.54^c	191.00±1.05^c	34.67 ±0.21^f	35.47 ±0.58^e	7.53 ± 0.05^d	7.50 ± 0.04^d
Bakolori dam	180.17±2.54^b	182.93±1.05^b	26.95± 0.21^e	30.37± 0.58^d	7.42± 0.05^d	7.60 ± 0.04^d
Dangulbi dam	166.70±2.54^a	168.15±1.05^a	19.50 ±0.21^d	21.57 ±0.58^c	7.90 ± 0.05^e	8.20 ± 0.04^e
Bagega river	240.67±2.54^d	244.50±1.05^d	11.94± 0.21^c	12.75 ±0.58^b	4.17± 0.05^c	6.62 ± 0.04^c
Sunke river	263.00±2.54^e	267.67±1.05^e	10.51± 0.21^b	11.28 ±0.58^b	2.95± 0.52^b	3.35 ± 0.04^b
Abare river	269.17±2.54^e	285.17±1.05^e	7.83± 0.21^a	8.63 ± 0.58^a	2.17± 0.52^a	2.33 ± 0.04^a

n = 6; mean ± S.D; Values with the same Superscripts are not significantly different (P> 0.05)

Table 14: Combined means of COD, BOD and DO for all locations of Water Bodies for 2014 and 2015 in the Wet and Dry Season.

year	COD		BOD		DO	
	wet	dry	wet	dry	wet	dry
2014	220.46 ± 1.46	220.46 ± 1.46	19.74 ± 0.12	21.41 ± 0.33	5.19 ± 0.03	5.86 ± 0.03
2015	218.33± 1.46	218.33± 1.46	17.40± 0.12	18.62 ± 0.33	5.52±0.03	6.01 ± 0.03

n = 36; mean ± S.D

pH: The pH of all the water bodies of the six locations (table 1 and 2) for the two years (2014 and 2015) tends to be alkaline; this is because it ranged between 7.57 and 7.96. Statistical analysis of variance conducted on the data revealed that there was no significant difference between the interaction of locations and year while the combined mean pH of all the water locations in year 2014 was significantly higher than those of 2015 (table 7 and 8). The pH of aquatic environment can be upset by added acid or alkali from waste water. The maximum pH value recorded in this study is lower than 8.22, and 8.1 reported in similar water bodies in Nigeria (Arimoro, *et al*., 2008; and Davies *et al*., 2006). The lower values recorded during the wet season as against the dry season might be due to deposition of some organic matter into the water bodies from run-off. Partial decomposition of this organic matter by bacteria and fungi has been recognized to produce various organic acids that are capable of lowering the pH of aqueous solution Fakayode, (2005). No health-based guideline value has been proposed for pH, however, an acceptable range for drinking water pH is from 6.5 to 9.5 (EPA, 2010; USEPA, 2002). Corrosion effects may become significant below pH 6.5, and the frequency of incrustation and scaling problems may be increased above pH 8.5. The pH of all the locations was within the 6.0 and 9.5 WHO and USEPA standard limits for drinking water.

Temperature: The relatively high temperature recorded in the dry season is in response to time and period of sample collection (table 1 and 2). The mean temperature of the water bodies for Gusau and Dangulbi dams were significantly the lowest ($p < 0.05$), while that of Abare River was significantly the highest. Also the combined mean temperature of all the water locations in 2014 were higher than those of 2015 (table 7 and 8).Similar observation was reported for some dams and surface waters within the same geographic region with the dam and river under investigation (Aiyesanmi *et al*., 2006; Adefemi *et al*., 2007). Temperature is the most important physical variable affecting the metabolic rate of fish and is therefore one of the most important water quality attributes in aquaculture (WHO, 2008). The highest mean temperature value (27.20°C) recorded in this work fell within the optimal water temperatures (Target Guidelines) of 28°C - 30°C, within which maximal growth rate, efficient food conversion, best condition of fish, resistance to disease and tolerance of toxins (metabolites and pollutants) are enhanced by South African water quality guidelines (SAWQG, 1996).

Electrical conductivity: It is known that electrical conductivity of water is an important parameter of water quality conductivity. Values from this study revealed that Bagega, Sunke and Abare rivers contained some appreciable amounts of dissolved ions than the dams. The mean EC value for both years (2014 and 2015) for Gusau dam was significantly the lowest amongst the three dams' considered while Abare River recorded the highest mean EC value (table 1 and 2). The mean EC value for both wet and dry seasons across all the location is higher in 2015 than in 2014 (table 7 and 8). Water conductivity values measured for the dry seasons were higher than for the wet seasons. This may be attributable to excessive evaporation of water from the dam during the dry season, which might have consequently increased the concentration of dissolved salts, also when compared to the work of Fakayode (2005) who studied Alaro River in Ibadan, values obtained in this study were lower. Generally, Abare River recorded the highest conductivity value which could be as a result of the mining activities and other mineral exploitation done using the river water since it is close to mining sites.

Total dissolved solid: Gusau dam recorded the lowest mean TDS amongst the dams while Abare river recorded the highest mean TDS value amongst the rivers. The mean TDS concentration for both year 2014 and 2015 for all the dams and Bagega rivers, were significantly the lowest ($P < 0.05$), While that of Sunke and Abare Rivers are significantly the highest ($P < 0.05$) (Table 1 and 2). The mean TDS of all the water bodies across all the six location in 2015 are higher than those of 2014 (Table 9 and 10). TDS is most important to water quality when it concerns designated uses and has been listed by the EPA as a secondary ground water and drinking water contaminants (Akpan *et al.*, 2007). The secondary contaminant causes aesthetic, technical, and cosmetic effects. Water high in total dissolved solids may have an unpleasant taste, odour, colour and may have a laxative effect beyond the tolerance level (EPA, 2010). The TDS recorded in the dry season is higher than the wet season; this may be due to evaporation during the dry season which caused some dehydration of aquatic animals (Marini and Piccolo, 2004).

Total suspended solid: Gusau dam recorded the lowest mean TSS value amongst the Dams, while Abare River has the highest mean TSS value. Generally, the values of TSS recorded in the wet season are lower than the dry season, which also indicate the effect of seasonal variation. It was also observed that the TSS levels for rivers are higher than for the dams (Table 1 and 2). The mean TSS of all the water bodies across the six locations under study in 2014 were significantly higher ($p < 0.05$) than that of 2015 (Table 9 and 10). Total suspended solids also affect water clarity. Suspended solids may kill fish and other aquatic fauna by causing abrasive injuries, by clogging the gills and respiratory passages, by blanketing the stream bottom, by destroying the spawning beds and by screening out light necessary for the photosynthetic activity of aquatic plants (Chapman, 1999). From the results of this study, the levels of TSS in the entire sampling locations exceeded the WHO guidelines of 50 mg/l for the protection of fisheries and aquatic life (Chapman, 1999). Higher TSS concentrations in this work may be attributed to discharges from use of the river/dam for mining, agricultural and domestic purposes (Parr *et al*. (1998); Peck and Zinke, 2006).

Chloride: Generally, the concentration of chlorine in Bagega, Sunke and Abare Rivers are higher than those of Gusau, Bakolori and Dangulbi dams during the wet and dry seasons of 2014 and 2015. (Table 1 and 2) The mean concentration of all the water bodies in 2014 was significantly higher than those of 2015 (Table 9 and 10).Chloride is a ubiquitous aqueous anion in all natural waters, the concentrations varying very widely and reaching a maximum in sea water. Natural levels in rivers and other fresh waters are usually in the range 15 - 35 mg/L Cl^- similar to what was recorded in this work, and much below the permissible drinking water standard of < 250 mg/l (EPA, 2010; USEPA, 2002; WHO, 2003).

Alkalinity: The mean alkalinity concentration of all the water bodies in 2014 was significantly higher than that of 2015 (Table 1 and 2). Low concentrations were obtained for alkalinity across all the locations when compared with 880 mg/l reported by Fakayode (2005) from Alaro River in Ibadan. Generally, the dry season recorded higher alkalinity levels than the wet season. Hence seasonal variation is established. The alkalinity levels recorded for the rivers are slightly higher than those of the dams during wet and dry season of 2014 and 2015 period. The mean alkalinity concentrations of all the water bodies in 2014 were significantly higher than that of 2015 (Table 11 and 12). Alkalinity is one of the best measures of the sensitivity of river/dam to acid inputs (Gaballah *et al.,* 2006). The concentrations of alkalinity recorded in this work across all the locations fall below the maximum acceptable standard (WHO, 2003).

Chemical Oxygen Demand: The COD values obtained for this work (Table 3 and 4) were higher than the one in the report of Gaballah *et al*, (2006) for Lome's lagoon with COD of 110 mg/l. COD levels varied significantly in all locations, especially at the rivers (244.50 – 290 mg/l), which suggest that a discharge of Quantum amount of waste into the rivers. The mean COD of all water bodies for 2014 was significantly higher ($P < 0.05$) than that of 2015 (Table 13 and 14). It was generally observed that the COD levels for the rivers are much higher than the levels for the dams. This suggests an influence of seasonal variation on the chemical oxygen demand. The activities around the rivers such as mining, agricultural and domestic uses may account for the high values obtained for the rivers.

Dissolved oxygen: Dissolved Oxygen (DO) is very crucial for the survival of aquatic organisms and is also used to evaluate the degree of freshness of a river or dam. It was generally observed that the dams for both wet and dry seasons have higher DO values than those of the rivers (Table 3 and 4). Seasonal variation is observed in DO concentration, with higher values in the wet seasons, this could be due to increased aeration and continuous recharge of the water bodies as a result of rainfall (Table 13 and 14). Seasonal variation is observed in DO concentration, with higher values in the wet seasons, this could be due to increased aeration and continuous recharge of the water bodies as a result of rainfall, a situation which was also observed by Adefemi (2007) who reported that DO concentration of Asejire Lake attained its peak at the height of rainy season. However, the lower DO in this study especially for the rivers compared to 4.0 – 6.0 mg/l standard limits (USEPA) implies that the river are more polluted, since it is very common to find mining, domestic, agricultural, and waste discharge into the river, this may be the main reason for the high pollution of the water. Also, low DO could be as a result of high TSS, which in a broad sense reflects the pollutant burden in the aquatic system. The ranged of DO in the six sampling locations were above the (USEPA, 2000; WHO, 2002) permissible limit of 4 mg/L and 5 mg/L. Therefore, the parameter does give cause for concern within this portion of dams and rivers.

Bacterial count: The total bacterial count is a reflection of the general purity of the water samples analysed. The total bacterial counts obtained during the wet season (3.6×10^6 to 8.9×10^6) were generally higher than those obtained in the dry (2.4×10^5 to 7.9×10^5). The microbial values recorded in the dam which ranged from (2.4×10^5 to 7.4×10^6) and rivers (5.2×10^5 to 8.9×10^6) water body represent high bacteria load compared to the recommended standards for drinking water (WHO, 2008; EPA, 2010; USEPA, 2002). In all the dams, the total bacterial count obtained during the wet season were generally higher than those obtained in the dry seasons (Table 5), which may be attributable to influx through runoff of microorganisms originating from vegetation decay, municipal sewage, garbage, domestic and faecal waste (GCDWQ, 2006). The microbial values recorded in the dam and rivers water body represent high bacteria load compared to the recommended standards for drinking water (WHO, 2008; EPA, 2010; USEPA, 2002; GCDWQ, 2006). This condition constitutes a threat to end users, thus suggesting adequate disinfection process before distribution for domestic and industrial uses.

Determination of Coliform counts (MPN Method): The result of most probable number (MPN) revealed that during the wet season the coliform counts for the dams ranged between 35-67 coli-form per 100ml, while for the rivers it ranged between 43 – 89 Coliform per 100ml (Table 6). The most probable number (MPN) revealed that the coliform count values for the river are higher than for the dams. The coliform counts for Dangulbi dam was highest amongst the dams which ranged from 60 - 67 coli-form per 100ml. This suggests that the dam has more dead material and runoffs in them. The MPN values revealed that coli form counts for the wet seasons were higher than for the dry seasons; this may be due to run-offs, dead material in water and the more favourable low temperature during the Wet season.

In conclusion the physicochemical parameters revealed high turbidity and low dissolved oxygen particularly of the river values when compared with drinking water standards by WHO and USEPA. The research also revealed a high microbial burden of the dam and river water when compared to the recommended standards by WHO and USEPA for drinking water, thus constituting a serious hazard to public health.

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