



## Spatial and Seasonal Variation of Water Quality in Savanna River System

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### Abstract

Using fifteen sampling stations, study was conducted to assess the water quality parameters of samples collected from River Galma, Zaria, Northwestern Nigeria, in wet and dry seasons. This was achieved using analysis of independent samples test (t-test), Hierarchical Cluster Analysis (HCA) and Principal Component Analysis (PCA) techniques. Analysis of the t-test results shows that, out of the 18 water quality parameters analyzed, 9 parameters were statistically significant ( $p < 0.05$ ), while the remaining parameters were statistically significant at  $p > 0.05$  for both seasons and all the concentration of the water quality parameters results increases during dry season, which maybe attributed to water evaporation and absence of rainfall. HCA identified 4 and 3 different groups in wet and dry seasons from 18 water quality parameters, indicates that the variation in water quality are due to natural and anthropogenic processes. Two components resulted from PCA analysis from both WS and DS. PCA explained 79.33% of the total variance in the variables which are included in the component in WS, and 80.09% of the total variance in the variables which are included in the component in DS, in which the major sources of pollution are related to agriculture and other human activities. From this study it shows that application of environmental multivariate techniques are significant to environmental management, and the result will help stakeholders in decision making towards sustainable management support of the river system.

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### INTRODUCTION

As a result of precipitation, weathering processes and human anthropogenic activities such as agriculture, urbanization, industrial exercises, surface waters are helpless against pollution (Carpenter et al 1998, Jarvie et al 1998 and Shahrizim, 2018). Recently, more attention partakes to water quality monitoring because of its strong relationships with human riches (Filik et al 2008 and Zhang et al 2009). River water as a source of inland waters and asset for domestic, agriculture and industrial purposes, control measures are important to the rivers Simeonova et al (2003) so as to have a well-developed data bank on water quality for fruitful management.

Rivers are significant waterways in attaining domestic, industrial and agricultural

water use (Jain, 2009). River Galma water serves as a source for irrigation, fishing and other agricultural activities as well as the main source of raw water to Zaria water works for domestic supply. Physico-chemical properties of river water entails its quality level and suitability for both humans consumption and survival of the living organisms.

In Developing countries, scarcity and water pollution constitute a primary challenge for sustainable water resources management. Despite the World Health Organization's guidelines (WHO) for water quality data sets, water pollution from various sources has been continuously increasing in most countries (Tredoux and Talma, 2006; Eruala et al 2011 and Mkoma and Mihayo, 2012). Thus, ensuring water

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quality must be an issue of scientific and public concern. Scientists and researchers have identified several factors that pose serious threats to water quality. These include, but not limited to, agricultural activities, habitat destruction, invasive species, pollution and human overpopulation (Defersha et al 2012, and Dessu et al 2014). Several studies also shown that many fresh water bodies are continually being disturbed and polluted which influence changes in the hydrologic regime, water quality and biodiversity of water bodies (Dessu et al 2014 and Garabaa and Zielinski, 2015) Contaminated water affects the health of ecosystem and organisms (man, animals and plants) living in or using that particular water.

Water quality refers to the standard chemical, physical, and biological characteristics of water, which measure the condition of water relative to the requirements of one or more biotic species and or to any human need (Patil et al 2012). To assess the water quality, independent samples test (t-test), Hierarchical Cluster Analysis (HCA) and Principal Component Analysis (PCA) are suitable for such studies and used to reveal and interpret useful information from the data set obtained from the samples of interest (Einax et al 1997 and Shahrizim, 2018). Lately, the use of environmetric multivariate techniques to complex datasets has been of great scientific interest (Einax et al 1997), with many related studies carried out using these multivariate techniques to assess surface water quality (Shrestha and

Kazama, 2007; Zhang et al 2009; Zhao and Cui, 2009 and Juahir et al 2010).

Due to increases water pollution in unmanaged rivers and streams either deliberately or accidentally, this study wanted to assess water quality of River Galma using environmetric multivariate statistical techniques. The river receives various pollutant loads from agricultural, sand quarrying, mechanical villages, bathing and domestic activities. These necessitate the need for periodic water monitoring networks for water quality assessment and evaluation. Therefore, the main objective of this research is to make detailed studies to assess water quality of the river Galma.

## MATERIALS AND METHODS

The study was conducted in Zaria city domestic water source, Galma river located southeastern part of the city in the year 2018. As the main drainage channel of other tributaries forming the rivers system it is located on lat. 11.30 N and long. 7.40 E (Nnaji et al 2010) and 128 km and 64 km Southeast of Kano and Northeast of Kaduna respectively. The area falls within the Guinea Savanna climate, with two different distinct seasons (Udo, 1978). The dam was constructed on the Galma river channel in 1975 in Zaria of Kaduna State to support farming, animal and other human activities which has happening even before the advent of the Dam construction era along the river banks (Fig. 1).

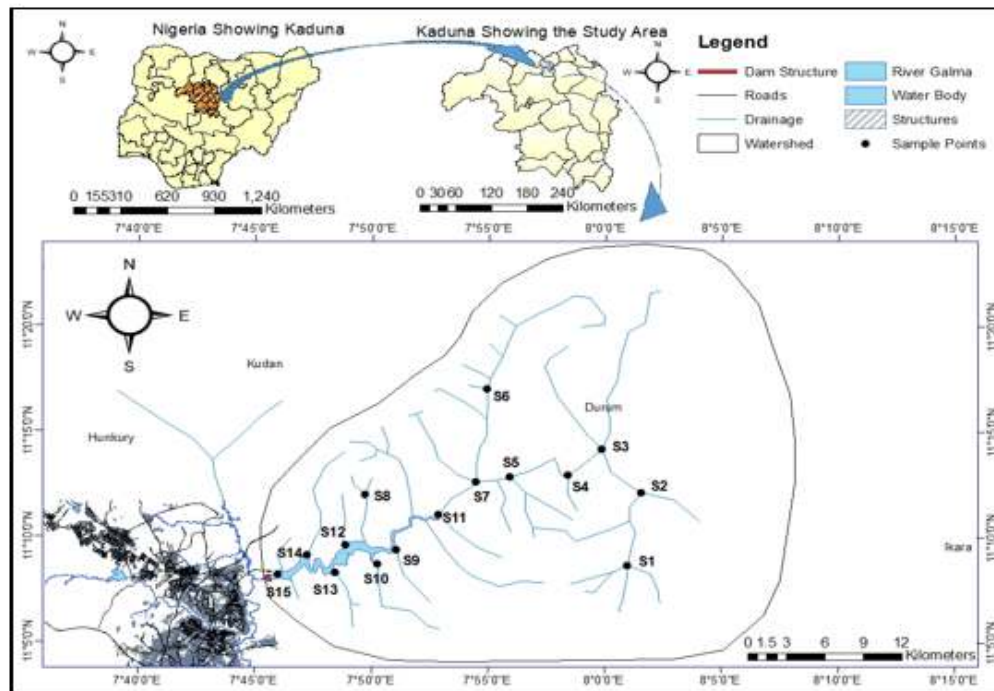


Fig. 1: Geographic location of the study area along with the sampling stations in Galma River, Nigeria.

### Data collection and analysis

Two different set of water sampling of in situ and Ex situ were considered for collection and measurements in the months of June and December of the year 2018 wet and dry seasons respectively.

For water sampling, the site were identified and stratified random sampling scheme was used with objective of arriving at representative water samples in the study area. Fifteen (15) selected stations were chosen and sampled along the river channel (Fig. 1) using both In Situ and the Ex Situ methods. The in-situ involves measuring some parameters onsite using hand held multiparameter (YSI Professional Plus) probe. Whereas in the ex-situ fifteen samples with three replicas having a total of 45 samples were collected for each seasons using clean polyethylene bottles that are pre-treated with deionized water and then brought to the laboratory for analysis. Public Health Laboratory of the Department of Water Resources and Environmental Engineering of Ahmadu Bello

University, Zaria, Nigeria was used for these analyses.

Standardized methods as described by the American Public Health Association (APHA) were used for physicochemical parameters determination and analysis. Parameters of pH, Temperature ( $^{\circ}\text{C}$ ), Turbidity (NTU), Electrical Conductivity (s/m), Total Dissolve Solid (mg/L), Dissolve Oxygen (mg/l) and Salinity (ppt or PSU) were considered for the in situ measurement while Nitrate,  $\text{NO}_3^-$  (mg/L), Nitrite,  $\text{NO}_2^-$  (mg/L), Sulphate,  $\text{SO}_4^{2-}$  (mg/L), Phosphate,  $\text{PO}_4^{3-}$  (mg/L), Magnesium,  $\text{Mg}^{+2}$  (mgL $^{-1}$ ), Calcium,  $\text{Ca}^{+2}$  (mgL $^{-1}$ ), Chloride,  $\text{CL}^-$ (mgL $^{-1}$ ), Sediments, TSS (mgL $^{-1}$ ), Total solids, TS (mgL $^{-1}$ ), Biochemical oxygen demand,  $\text{BOD}_5$  (mgL $^{-1}$ ) and Chemical Oxygen Demand, COD (mgL $^{-1}$ ) for ex situ laboratory analysis. The data were subjected to descriptive statistics using Microsoft Excel, Inferential statistic and Principal Component Analysis (PCA) using statistical Package for Social Science (SPSS statistic 23) and Hierarchical Cluster Analysis (HCA) using Past3 respectively.



## RESULTS AND DISCUSSION

(Table 1 and 2) show the descriptive statistic of wet and dry season water quality parameters in River Galma. While (Table 3 and 4)

shows the minimum and maximum alongside the tested means and standard deviation of the river water quality parameters used in the research.



Table 1: Descriptive statistic of wet season water quality parameters in River Galma

Parameter	Measuring unit	Sp1	Sp2	Sp3	Sp4	Sp5	Sp6	Sp7	Sp8	Sp9	Sp10	Sp11	Sp12	Sp13	Sp14	Sp15
Sal	(mg/L)	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.09	0.09	0.09	0.09	0.09	0.09
BOD5	(mg/L)	4.5	4.6	5	4.3	4	4.2	5.4	5.5	5.7	4.5	5	5.5	5.4	5.7	5.7
DO	(mg/L)	4.7	5.5	6.3	6.8	5.62	6.5	5.1	5	5.3	5.1	5.2	5.1	5.1	5	5.3
NO <sub>2</sub> <sup>-</sup>	(mg/L)	3.43	2.90	2.90	4.53	7.20	3.93	7.10	4.60	5.50	6.37	8.10	8.00	10.50	6.33	8.47
pH	-	6.50	6.40	6.30	6.37	6.40	6.23	6.20	6.23	6.30	6.20	6.20	6.10	6.13	6.10	6.10
Mg <sup>+2</sup>	(mg/L)	8.20	8.35	10.40	15.50	20.70	33.50	37.20	39.50	41.20	31.50	22.10	60.12	66.50	61.20	71.30
SO <sub>4</sub> <sup>2-</sup>	(mg/L)	9.72	9.76	9.21	10.54	12.80	13.74	13.67	10.51	13.80	14.51	15.16	15.51	19.45	16.00	10.53
PO <sub>4</sub> <sup>3-</sup>	(mg/L)	12.80	13.37	11.68	11.69	13.91	11.69	13.32	11.68	16.67	12.77	19.46	17.39	27.81	20.86	24.34
Ca <sup>+2</sup>	(mg/L)	18.00	18.51	19.50	20.00	19.50	18.00	21.50	20.50	23.50	24.00	20.50	25.00	37.50	46.70	58.50
NO <sub>3</sub> <sup>-</sup>	(mg/L)	20.28	22.00	25.52	32.20	36.10	30.74	32.84	30.33	29.01	28.00	34.50	35.30	48.07	34.00	38.00
T	(°C)	28.36	28.06	28.06	28.10	28.13	28.37	28.13	28.36	28.23	28.17	28.03	28.03	28.17	28.23	28.10
Cl <sup>-</sup>	(mg/L)	47.00	68.00	112.00	125.00	172.00	189.00	187.00	190.00	196.00	230.00	200.00	220.00	230.00	220.00	250.00
TSS	(mg/L)	51.33	82.67	50.00	77.33	62.67	92.67	95.00	47.33	30.00	37.00	95.00	64.00	105.00	120.00	145.67
EC	(s/m)	73.67	54.00	71.00	70.00	80.67	70.00	25.33	25.00	71.00	60.33	49.67	23.00	61.00	61.00	51.00
COD	(mg/L)	90.00	91.00	106.67	320.00	251.00	140.00	240.67	120.00	261.67	190.00	179.00	170.00	171.00	100.00	135.00
TDS	(mg/L)	470.67	432.67	265.00	260.00	453.33	320.00	396.67	427.67	415.00	635.00	410.00	652.33	350.00	415.00	480.00
Turb.	(NTU)	420.33	415.00	471.00	398.67	478.00	408.00	443.67	572.33	597.67	587.00	545.00	669.00	675.00	587.33	926.33
TS	(mg/L)	652.33	500.00	442.67	355.67	510.00	420.00	480.00	535.67	460.00	710.00	645.67	825.00	867.33	604.00	644.67



Table 2: Descriptive statistic of dry season water quality parameters in River Galma

Parameter	Measuring unit	Sp1	Sp2	Sp3	Sp4	Sp5	Sp6	Sp7	Sp8	Sp9	Sp10	Sp11	Sp12	Sp13	Sp14	Sp15
Sal	(mg/L)	0.10	0.10	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10
BOD5	(mg/L)	5.2	5.2	5.5	5.7	5.8	4.8	5.8	5.4	5.1	5	4.5	5.8	5.2	5.5	5.8
DO	(mg/L)	5.6	6.2	6.3	6	5.9	5.2	6.6	5.1	5.6	5.3	6.3	5.9	5.2	5.6	6.3
NO <sub>2</sub> <sup>-</sup>	(mg/L)	7.30	4.00	7.10	4.60	5.50	6.40	8.10	8.00	10.50	6.30	8.50	8.00	10.50	9.70	10.80
pH	-	7.50	7.60	7.30	7.40	7.40	7.20	7.20	7.20	7.50	7.20	7.20	7.50	7.80	6.90	7.90
Mg <sup>+2</sup>	(mg/L)	20.70	33.50	37.20	39.50	41.20	31.50	22.10	60.12	66.50	61.20	71.30	76.12	76.50	61.90	77.30
SO <sub>4</sub> <sup>2-</sup>	(mg/L)	14.51	15.16	15.51	19.45	16.80	17.74	17.67	18.51	18.80	20.00	21.11	22.51	22.45	22.00	23.53
PO <sub>4</sub> <sup>3-</sup>	(mg/L)	13.80	13.37	13.32	11.68	16.66	12.77	19.45	17.39	27.81	20.86	24.34	25.39	27.81	26.86	27.34
Ca <sup>+2</sup>	(mg/L)	17.50	20.50	23.50	24.00	20.50	25.00	37.50	46.70	58.50	52.00	55.98	49.00	44.50	46.70	59.50
NO <sub>3</sub> <sup>-</sup>	(mg/L)	30.74	32.84	30.33	29.01	36.10	30.74	34.84	30.33	39.01	32.00	39.50	39.30	48.07	47.00	49.00
T	(°C)	30.02	29.89	30.46	31.56	30.86	31.46	31.57	31.23	30.34	30.19	32.00	30.94	31.45	29.44	30.76
CL	(mg/L)	112.00	125.00	172.00	189.00	187.00	190.00	196.00	230.00	200.00	220.00	230.00	220.00	250.00	251.00	260.00
TSS	(mg/L)	53.00	88.00	55.00	79.00	67.00	97.00	99.00	51.00	33.00	37.00	99.00	69.00	110.00	140.00	156.00
EC	(s/m)	87.00	67.00	71.00	91.00	95.00	78.00	45.00	55.00	81.00	67.00	73.00	32.00	71.00	71.00	96.00
COD	(mg/L)	140.00	241.00	120.00	262.00	190.00	150.00	261.00	180.00	292.00	199.00	189.00	177.00	172.00	140.00	175.00
TDS	(mg/L)	397.00	428.00	415.00	635.00	410.00	652.00	350.00	415.00	480.00	637.00	677.00	687.00	871.00	877.00	871.00
Turb.	(NTU)	572.00	598.00	587.00	545.00	669.00	675.00	578.00	589.00	712.00	716.00	775.00	857.00	877.00	888.00	926.00
TS	(mg/L)	667.00	598.00	489.00	386.00	586.00	470.00	500.00	550.00	480.00	810.00	687.00	889.00	897.58	747.00	858.00



**Table 3:** Descriptive statistic of wet season water quality parameters

Parameter	Unit	Sampled stations (N)	Min.	Max.	Tested mean ± SD
Sal	(mg/L)	15	0.09	0.10	0.10 ± 0.01
BOD5	(mg/L)	15	4.00	5.70	5.00 ± 0.60
DO	(mg/L)	15	6.70	6.80	5.44 ± 0.61
NO <sub>2</sub> <sup>-</sup>	(mg/L)	15	2.90	10.50	5.99 ± 2.27
pH	-	15	6.10	6.50	6.25 ± 0.12
Mg <sup>+2</sup>	(mg/L)	15	8.20	71.30	35.15 ± 21.53
SO <sub>4</sub> <sup>2-</sup>	(mg/L)	15	9.21	19.45	12.99 ± 3.92
PO <sub>4</sub> <sup>3-</sup>	(mg/L)	15	11.68	27.81	15.96 ± 5.08
Ca <sup>+2</sup>	(mg/L)	15	18.00	58.50	26.08 ± 11.99
NO <sub>3</sub> <sup>-</sup>	(mg/L)	15	20.28	48.07	31.79 ± 6.77
T	(°C)	15	28.03	28.37	28.17 ± 0.12
CL <sup>-</sup>	(mg/L)	15	47.00	250.00	175.73 ± 60.74
TSS	(mg/L)	15	30.00	145.67	77.04 ± 32.43
EC	(s/m)	15	23.00	80.67	56.44 ± 18.69
COD	(mg/L)	15	90.00	320.00	171.07 ± 70.25
TDS	(mg/L)	15	260.00	652.33	425.56 ± 110.99
Turb.	(NTU)	15	398.67	926.33	546.29 ± 140.81
TS	(mg/L)	15	355.67	867.33	576.87 ± 147.86

**Table 4:** Descriptive statistic of dry season water quality parameters

Parameter	Unit	Sampled stations (N)	Min.	Max.	Tested mean ± SD
Sal	(mg/L)	15	0.09	0.10	0.09 ± 0.00
BOD5	(mg/L)	15	4.50	5.80	5.35 ± 0.40
DO	(mg/L)	15	5.10	6.60	5.81 ± 0.40
NO <sub>2</sub> <sup>-</sup>	(mg/L)	15	4.00	10.80	7.69 ± 2.11
pH	-	15	6.90	7.90	7.39 ± 0.26
Mg <sup>+2</sup>	(mg/L)	15	20.70	77.30	51.78 ± 20.32
SO <sub>4</sub> <sup>2-</sup>	(mg/L)	15	14.51	23.53	19.05 ± 2.87
PO <sub>4</sub> <sup>3-</sup>	(mg/L)	15	11.68	27.81	19.92 ± 6.20
Ca <sup>+2</sup>	(mg/L)	15	17.50	59.50	38.76 ± 15.39
NO <sub>3</sub> <sup>-</sup>	(mg/L)	15	29.01	49.00	36.59 ± 6.86
T	(°C)	15	29.44	32.00	30.81 ± 0.74
CL <sup>-</sup>	(mg/L)	15	112.00	260.00	202.13 ± 42.92
TSS	(mg/L)	15	33.00	156.00	82.20 ± 35.68
EC	(s/m)	15	32.00	96.00	72.00 ± 17.89
COD	(mg/L)	15	120.00	292.00	192.53 ± 50.38
TDS	(mg/L)	15	350.00	877.00	586.80 ± 187.47
Turb.	(NTU)	15	545.00	926.00	704.27 ± 131.07
TS	(mg/L)	15	386.00	897.58	640.97 ± 167.62

**T-test Analysis**

Detection of seasonal variation in water quality between wet and dry season in River Galma were analysed. It was achieved by comparing the mean differences of the 15 sample locations data from Galma river in both seasons

using independent samples student t-test and the results are presented in Table 5. From the results the two tests can be seen, the first is the Levene's Test for Equality of Variances (LTV) which tests the homogeneity of variance assumption (one of the assumption for parametric test). The null

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hypothesis for this test is that the variance is equal. If the test shows that there is no significant difference between the two variance ( $p > 0.05$ ) the null hypothesis is accepted, the variances can be assumed to be homogeneous and the Equal variances assumed (EVA) t-test value is used. However, if the LTEV is significant the Equal variances not assumed (EVNA) t-test value is used. The second test is t-test for Equality of Means (TTEM). The null hypothesis is that the mean number wet season = dry season.

Table 5 shows a number of statistics of the distribution of differences between the two groups (mean differences). Not only significant is observed but also the mean difference was identified, but certain water quality parameters also shows variation in the data between wet and dry season. However, either increasing, decreasing or constant, the parameters were significant in most of the sampling points between wet and dry season. For instance, temp, pH and TDS parameters indicate a significant at  $p < 0.05$  in LTEV and the EVNA t-test value is used, which also show significant at  $p < 0.05$  in all the three parameters showing temp ( $p = 0.000$ ), pH ( $p = 0.000$ ) and TDS ( $p = 0.009$ ) in TTEM column of Table 5. This indicates that the difference between means is statistically significant. The dry season average shows increase of temp (2.64 °C), pH (15.47) and TDS (161.20) more than average temp, pH and TDS when compared during wet season. However, EC, DO, Turbidity, Salinity, Nitrite, Nitrate, Phosphate, Sulphate, COD, BOD,

TSS, TS,  $Mg^{+2}$ ,  $Ca^{+2}$  and  $Cl^-$  parameters shows that there is no significant difference between the two variances ( $p > 0.05$ ) in LTEV, therefore the null hypothesis is accepted. The variances was assumed to be homogenous and the EVA t-test value is used, which also shows significant with  $p < 0.05$  in EC ( $p = 0.029$ ), Turbidity ( $p = 0.004$ ), Nitrite ( $p = 0.045$ ), Sulphate ( $p = 0.000$ ), BOD ( $p = 0.041$ ),  $Mg^{+2}$  ( $p = 0.038$ ) and  $Ca^{+2}$  ( $p = 0.018$ ) in TTEM column section of Table 5, showing that, the difference between means are statistically significant. The dry season has on average values, about EC (15.47), Turbidity (157.93), Nitrite (1.69), Sulphate (6.06), BOD (0.35),  $Mg^{+2}$  (16.62) and  $Ca^{+2}$  (12.68) higher concentration of the seven parameters when compared to that of the wet season.

On the other hand, the variances in EVA t-test value shows no significant at  $p > 0.05$  in DO ( $p = 0.585$ ), Salinity ( $p = 0.936$ ), Nitrate ( $p = 0.064$ ), Phosphate ( $p = 0.066$ ), COD ( $p = 0.350$ ), TSS ( $p = 0.684$ ), TS ( $p = 0.277$ ) and  $Cl^-$  ( $p = 0.180$ ) in TTEM, which means that the difference between means is statistically not significant, indicating there is increase, decrease or constant which is more or less inconsistent between this 9 parameters. For example, the dry season had on average about DO (0.37), Nitrate (4.79), Phosphate (3.96), COD (21.20), TSS (5.13), TS (64.02), and  $Cl^-$  (26.40) more DO, Nitrate, Phosphate, COD, TSS, TS and  $Cl^-$  compared to wet season (Table 5).

**Table 5:** Independent Samples Test

Group Statistics				Levene's Test for Equality of Variances		t-test for Equality of Means	
Parameter	Season	N	Mean		Sig.	Sig. (2-tailed)	Mean Difference
Temp	Wet	15	28.1687	EVA	0.000	0.000	-2.64
	Dry	15	30.8113	EVNA		0.000	-2.64
pH	Wet	15	6.2467	EVA	0.043	0.000	-1.14
	Dry	15	7.3867	EVNA		0.000	-1.14
EC	Wet	15	56.5333	EVA	0.653	0.029	-15.47
	Dry	15	72.0000	EVNA		0.029	-15.47
DO	Wet	15	5.4413	EVA	0.585	0.079	-0.37
	Dry	15	5.8067	EVNA		0.080	-0.37
Turbidity	Wet	15	546.3333	EVA	0.888	0.004	-157.93

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Salinity	Dry	15	704.2667	EVNA		0.004	-157.93
	Wet	15	0.09460	EVA	0.106	0.936	0.00
TDS	Dry	15	0.09467	EVNA		0.936	0.00
	Wet	15	425.6000	EVA	0.008	0.008	-161.20
Nitrite	Dry	15	586.8000	EVNA		0.009	-161.20
	Wet	15	6.0000	EVA	0.626	0.045	-1.69
Nitrate	Dry	15	7.6867	EVNA		0.045	-1.69
	Wet	15	30.9493	EVA	0.613	0.064	-4.79
Phosphate	Dry	15	41.5873	EVNA		0.064	-4.79
	Wet	15	15.9613	EVA	0.174	0.066	-3.96
Sulphate	Dry	15	19.9233	EVNA		0.066	-3.96
	Wet	15	12.9933	EVA	0.964	0.000	-6.06
COD	Dry	15	19.0500	EVNA		0.000	-6.06
	Wet	15	171.3333	EVA	0.219	0.350	-21.20
BOD	Dry	15	192.5333	EVNA		0.350	-21.20
	Wet	15	5.0000	EVA	0.041	0.069	-0.35
TSS	Dry	15	5.3533	EVNA		0.071	-0.35
	Wet	15	77.0667	EVA	0.759	0.684	-5.13
TS	Dry	15	82.2000	EVNA		0.684	-5.13
	Wet	15	576.9553	EVA	0.469	0.277	-64.02
Mg <sup>+2</sup>	Dry	15	640.9720	EVNA		0.277	-64.02
	Wet	15	35.1513	EVA	0.832	0.038	-16.62
Ca <sup>+2</sup>	Dry	15	51.7760	EVNA		0.038	-16.62
	Wet	15	26.0807	EVA	0.058	0.018	-12.68
Cl <sup>-</sup>	Dry	15	38.7587	EVNA		0.018	-12.68
	Wet	15	175.7333	EVA	0.218	0.180	-26.40
	Dry	15	202.1333	EVNA		0.181	-26.40

On the overall, for all parameters the independent samples t-test shows temp, pH, TDS, EC, Turbidity, Nitrite, Sulphate, BOD, Mg<sup>+2</sup> and Ca<sup>+2</sup> exhibit significant at  $p < 0.05$ , while DO, Salinity, Nitrate, Phosphate, COD, TSS, TS and Cl<sup>-</sup> shows no significant at  $p > 0.05$  between the seasons. Also there is an increase in the concentration of all the water quality parameters on average about temp (2.64 °C), pH (15.47), TDS (161.20), EC (15.47), DO (0.37), Turbidity (157.93), Nitrite (1.69), Sulphate (6.06), Mg<sup>+2</sup> (16.62) Ca<sup>+2</sup> (12.68), Nitrate (4.79), Phosphate (3.96), COD (21.20), TSS (5.13), BOD (0.35), TS (64.02), and Cl<sup>-</sup> (26.40) more in dry season than in wet season in the river. These variations depend on the seasonal weather condition within the river watershed, as the concentration of the water quality parameters were found to increase due to absence of rainfall and high evaporation during the dry season. This is consistent with the

findings of Bhangaonkar and Patel, (2017) on their study on water quality of Vishwamitri River.

#### **Water Pollution Source Identification using HCA and PCA**

HCA and PCA applied in this research to monitor and identify the sources of pollution into the river was considered to be appropriate and useful to provide significant reduction in data dimensionality. To obtain reliable information about the relationships among the environmental variables, HCA and PCA was applied to the datasets to explore the water quality parameters similarities/grouping and the water pollution source identification.

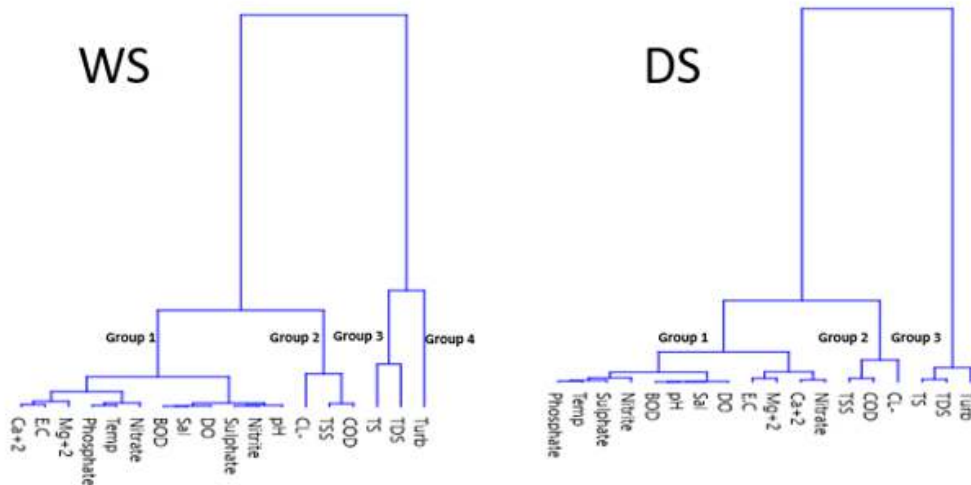
#### **Multivariate Analysis of Hierarchical Cluster Analysis (HCA)**

Multivariate analysis of hierarchical cluster analysis (HCA) using ward method

classification of variables based on their spatial similarities were employed in this study. The water quality parameters were analyzed using HCA technique to identify seasonal pollution sources. Hierarchical cluster analysis yielded a dendrogram (Fig. 2WS) with the eighteen water quality parameters (WQP) in wet season (WS) classified into four major groups, (Willet, 1987) suggested it to be preferred method as it accurately classifies the groups. As shown in dendrogram (Fig. 2WS), group 1 consists of

twelve WQP: pH, Nitrite, Sulphate, DO, Salinity, BOD, Nitrate, Temp, Phosphate,  $Mg^{+2}$ , EC and  $Ca^{+2}$ . WQP in group 1 in WS could be relate to human activities during

the WS. Group 2 consisting of three WQP: COD, TSS and CL- which is more related to agricultural activities. While Group 3 comprises of two WQP: TDS and TS corresponding to sand mining and land clearing for farming. Lastly, group 4 consist of one WQP, Turbidity that is related to agricultural runoff and atmospheric deposition.



**Fig. 2.** Dendrogram (using Ward Method) showing classification of variables based on their spatial similarities produced by cluster analysis

The cluster analysis of the data collected during the dry season (DS) is shown in Fig. 2DS. As indicated in the dendrogram, eighteen WQP were classified into three groups. Group 1 corresponding to Nitrate,  $Ca^{+2}$ ,  $Mg^{+2}$ , EC, DO, Sal, pH, BOD, Nitrite, Sulphate, Temp and Phosphate. This group signifies farming activities and other anthropogenic activities. Group 2 consisting of three WQP, COD, TSS and CL- is related to agricultural activities, and lastly, group 3 consists of three WQP, Turbidity, TDS and TS corresponding to Sand quarrying, agricultural runoff, land clearing and domestic waste.

The HCA technique reveals its capability in offering a acceptable grouping of surface-water physicochemical parameters in the study area. As a tool, will provides objective

interpretations of physicochemical properties of surface-water as well as identify pollution sources, that will help to apportion efforts toward sustainable management of a river basin Venkatramanan et al (2014) as well these clustering results are supportive of the results of the study conducted by (Othman et al 2018).

**Principal component analysis (Pollution Source Identification)**

Principal component analysis (PCA) is a data reduction method which transforms a number of possibly correlated variables into a smaller number of uncorrelated variables called principal components or factors by analyzing the correlation between variables. In this study PCA is used for Pollution Source Identification, were applied to the

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18 WQP. Component loading above 0.50 is considered to be significant (Liu et al 2003). PCA requires that the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO-MSA) be greater than 0.50 for each individual variable as well as the set of variables (Shahrizim, 2018). From anti-image correlation matrices (AICM) column of WSA in Table 6, Temp, EC, TDS, Sulphate, COD and BOD has KMO-MSA of less than 0.50. As it do not fulfil the requirement of PCA, the variables were then removed and the PCA was run again. Also, column WSB in WS of Table 6 revealed that DO, pH and salinity has KMO-MSA value of less than 0.50 still not satisfy PCA requirement, were also removed and PCA was rerun. Going by column WSC, all the variables are greater than 0.50 KMO-MSA, hence fulfilling the PCA requirement. Again, considering the overall KMO-MSA in the raw column section of WS in Table 6, it can be seen that the overall KMO-MSA is increasing from 0.567 to 0.742 and finally to 0.809 which exceeds the minimum requirement of 0.50 for overall KMO-MSA (Shahrizim, 2018). values which satisfied PCA requirement.



**Table 6:** Anti-image matrices, Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO-MSA) and Total

Parameters	Wet Season Anti-image Correlation			Parameters	Dry season Anti-image Correlation		
	WSA	WSB	WSC		DSA	DSB	DSC
Turbidity		0.867 <sup>a</sup>	0.848 <sup>a</sup>	pH		0.841 <sup>a</sup>	0.856 <sup>a</sup>
Nitrite		0.682 <sup>a</sup>	0.770 <sup>a</sup>	DO		0.809 <sup>a</sup>	0.822 <sup>a</sup>
Nitrate		0.762 <sup>a</sup>	0.801 <sup>a</sup>	Turbidity		0.785 <sup>a</sup>	0.786 <sup>a</sup>
Phosphate		0.899 <sup>a</sup>	0.883 <sup>a</sup>	TDS		0.657 <sup>a</sup>	0.663 <sup>a</sup>
TSS		0.601 <sup>a</sup>	0.767 <sup>a</sup>	Nitrite		0.820 <sup>a</sup>	0.817 <sup>a</sup>
TS		0.578 <sup>a</sup>	0.703 <sup>a</sup>	Phosphate		0.774 <sup>a</sup>	0.790 <sup>a</sup>
Mg+2		0.920 <sup>a</sup>	0.833 <sup>a</sup>	Sulphate		0.720 <sup>a</sup>	0.720 <sup>a</sup>
Ca+2		0.801 <sup>a</sup>	0.784 <sup>a</sup>	BOD		0.797 <sup>a</sup>	0.801 <sup>a</sup>
CL-		0.698 <sup>a</sup>	0.790 <sup>a</sup>	Mg+2		0.793 <sup>a</sup>	0.787 <sup>a</sup>
DO		0.236 <sup>a</sup>		Salinity		0.465 <sup>a</sup>	
pH		0.481 <sup>a</sup>		Temp	0.344 <sup>a</sup>		
Salinity		0.498 <sup>a</sup>		EC	0.079 <sup>a</sup>		
Temp	0.313 <sup>a</sup>			Nitrate	0.474 <sup>a</sup>		
EC	0.385 <sup>a</sup>			COD	0.075 <sup>a</sup>		
TDS	0.282 <sup>a</sup>			TSS	0.294 <sup>a</sup>		
Sulphate	0.461 <sup>a</sup>			TS	0.460 <sup>a</sup>		
COD	0.163 <sup>a</sup>			Ca+2	0.450 <sup>a</sup>		
BOD	0.264 <sup>a</sup>			CL-	0.492 <sup>a</sup>		
<b>Overall KMO-MSA</b>		0.567	0.742		0.503	0.765	0.771

variance explain



From AICM column of DSA of dry season, Temp, EC, Nitrate, COD, TSS, TS, Ca<sup>+2</sup> and CL<sup>-</sup> have KMO-MSA value less than 0.50 therefore, were removed and PCA is run again. Salinity from column DSB also exhibit a value less

than 0.05 also was removed and PCA was run again. Lastly column DSC reveals that all the variable satisfied PCA requirement as overall KMO-MSA is 0.771 which exceeds the minimum requirement of 0.50.

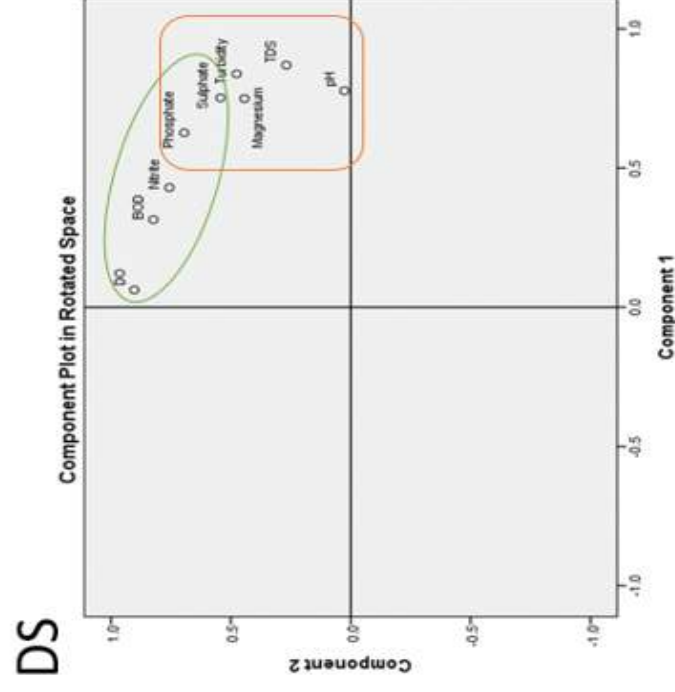
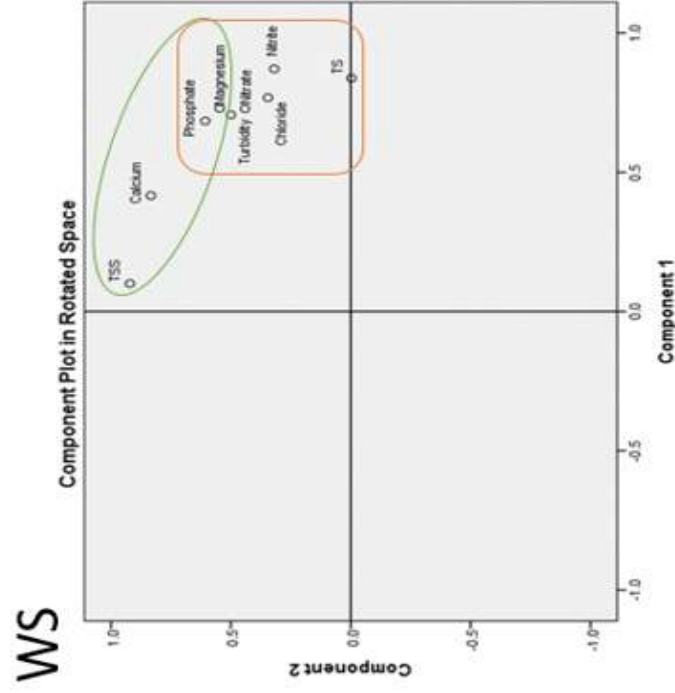
**Table 7.** Factor loadings after Varimax rotation

Variables	Wet Season (WS) Component			Dry Season (DS) Component	
	WS1	WS2		DS1	DS2
Turbidity	<b>0.706</b>	0.499	pH	<b>0.777</b>	0.026
Nitrite	<b>0.871</b>	0.319	DO	0.062	<b>0.903</b>
Nitrate	<b>0.728</b>	0.441	Turbidity	<b>0.838</b>	0.476
Phosphate	<b>0.684</b>	<b>0.607</b>	TDS	<b>0.869</b>	0.268
TSS	0.100	<b>0.921</b>	Nitrite	0.429	<b>0.757</b>
TS	<b>0.838</b>	-0.002	Phosphate	<b>0.626</b>	<b>0.694</b>
Mg <sup>+2</sup>	<b>0.729</b>	<b>0.547</b>	Sulphate	<b>0.752</b>	<b>0.543</b>
Ca <sup>+2</sup>	0.416	<b>0.833</b>	BOD	0.315	<b>0.823</b>
CL <sup>-</sup>	<b>0.768</b>	0.345	Mg <sup>+2</sup>	<b>0.749</b>	0.444
Eigenvalue	6.134	1.005		6.087	1.121
Variability %	68.159	11.166		67.633	12.455
Cumulative%	68.159	<b>79.325</b>		67.633	<b>80.088</b>

The water quality parameters analyzed using PCA to identify seasonal pollution source as in (Fig. 3WS) and Table 7 produced a loading plot in which the eighteen WQP in WS were reduced to nine WQP and two components were extracted. The first component in WS (WS1) explained that 68.16 % of the total variance has a strong positive loading on Turbidity, Nitrite, Nitrate, Phosphate, TS, Mg<sup>+2</sup> and CL<sup>-</sup>. This component signify agricultural and other human activities involvement along the watershed. Nitrite, Nitrate, Phosphate, Mg<sup>+2</sup> and CL<sup>-</sup> may be attributed to originate from fertilizer and pesticides application in the farms that have found their way into the water.

Turbidity and TS were contributed from atmospheric deposition, agricultural runoff, leaching from solid waste disposal sites and sand quarrying along the river bank (Aminu et al 2015). More so, from Table 7 the second component loading in WS (WS2) designated 11.17 % of the total variance with strong positive loading on Phosphate, TSS,  $Mg^{+2}$  and

CL<sup>-2</sup> (Fig. 3WS). This component explained the effects of agricultural and residential runoff, leaching from solid waste disposal sites and point source water pollution discharging from nearby residential and sand quarrying areas along the river bank (Tamer et al 2018).



**Fig. 3.** Loading plot produced by principal component analysis/factor analysis



Fig. 3DS also shows the Principal Component Analysis of the DS data in table 7 and loading plot (Fig. 3DS), having eighteen WQP reduced to nine WQP and two extracted components. The first Component of DS1 explained 67.633% of the total variance with strong positive loading on pH, Turbidity, TDS, Phosphate and Sulphate. This component are sturdily related to farming activities and conductive ions coming from dissolved salts and inorganic materials This may be as a result of salts and other chemicals from non-point sources such as domestic disposal and agricultural runoff that dissolve in water and break down into positively and negatively charged ions (Tamer et al 2018). Component of DS2 showed 12.455% of the total variance with strong positive loading on DO, Phosphate, Sulphate and BOD. These elements clarify agriculture activities and organic loading as pollutant in the river, indeed all these contaminants are of relevance in relation to the point source pollution (How can I use BOD5 as pollution indicator in water quality? 2019). These components loading difference indicate that in DS the pollution is more noticeable due to absence of rainfall as was indicated by Independent Samples Test above (Table 5). These results by principal component analysis are supportive of the results (Aminu et al 2015). Besides, these PCA results are in line with the findings using multivariate statistical techniques (Tamer et al 2018). The study is also consistent with the findings (Venkatramanan et al 2014).

## CONCLUSION

Eighteen water quality parameters for fifteen sampling points were studied for River Galma Zaria, by applying independent samples test (t-test), Hierarchical Cluster Analysis (HCA) and Principal Component Analysis (PCA). t-test result shows that temp, pH, TDS, EC, Turbidity, Nitrite, Sulphate,  $Mg^{+2}$  and  $Ca^{+2}$  exhibit significant with  $p < 0.05$ , while DO, Salinity, Nitrate, Phosphate, COD, BOD, TSS, TS and CL- shows no significant with  $p > 0.05$  between the WS and DS. Also, the concentration of the water quality parameters tends to increase due to absence of rainfall and water evaporation during DS. Analysis of the Hierarchical Cluster Analysis (HCA)

revealed 4 groups in WS and 3 groups in DS and for the both seasons, anthropogenic (human induced ) and natural processes as a major pollution sources. PCA explained 79.33 % of the total variance in the variables which are included in the component in WS and 80.09 % of the total variance in the variables which are included in the component in DS with agriculture and other human activities as major pollution sources which was also identified by HCA above. Considering the loading plots, 9 out of the 18 variables were represented by 2 components in both wet and dry seasons. Thus, application of environmetric multivariate statistical techniques to sustainable environmental management are important tools for studies of this kind.

This investigation study, suggested that precautions could be taken to prevent future surface water pollution which may be dangerous to human health and aquatic life living in the river. it is hoped the information will provide necessary steps if taken into account by both the local communities and concerned authority will significantly improve management of the river ecosystem and reduces pollution risks within the watershed.

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