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Assessment of Guinea Savanna River system to evaluate water quality and water monitoring networks

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ABSTRACT

The analysis of changes in water quality in a monitoring network system is important because the sources of pollution vary in time and space. This study utilized analysis of the water quality index calculation, hierarchical cluster analysis, and mapping. This was achieved by assessing the water quality parameters of the samples collected from Galma River in Zaria, Northwestern Nigeria in wet and dry seasons. The Analysis shows that sampling point number 15 located downstream of the river has the largest number of water quality index of 105.77 and 126.34, while sampling points 1 located upstream of the river has 62.71 and 78.09 in both wet and dry seasons respectively. This indicates that all the monitoring sites were polluted and the water could be utilized for industrial and irrigation specified due to the purposes only. Hierarchical cluster analysis and mapping revealed consistency and variations. For both networks, cluster 1 is located in the middle of the river watershed, while clusters 2, 3 and 4 show variations within the river watershed. 3 sampling points in wet season located at the upstream of the river were specified for Irrigation and Industrial uses, while the rest of the sampling points in both seasons were specified for irrigation purpose only. From this study, water quality index and multivariate techniques for environmental management can be employed in monitoring river resources, and research of this kind can help inadequate planning and management of the river system.

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INTRODUCTION

Water is of great importance to economy, industrial, agricultural and other overall human activities. Man-made pollutions threaten fresh water bodies all over the world and river physico-chemical parameters convey much about its quality and fitness to humans and living biota using it (Animesh and Saxena, 2011; Marimuthu and Rajendran, 2017). In developing countries most especially Nigeria, water pollution creates a primary challenge for sustainable water resources management, thus ensuring water quality must be an issue of scientific and public concern. Scientists and researchers have identified several threaten water quality factors. These include, but not limited to agricultural activities, habitat destruction, invasive species and human population (Eruola *et al.,* 2011; Mkoma and Mihayo, 2012; Defersha *et al.,* 2012; Dessu *et al.,* 2014). Several studies have shown that many fresh water bodies are continually being polluted due to human activities which influence changes in the hydrologic regime, water quality and biodiversity of water bodies (Patil *et al.,* 2012; Dessu *et al.,* 2014; Garabaa and Zielinski 2015). Large watersheds pose many challenges for monitoring and management of water quality, particularly in multinational basins where legislative framework and priorities for water resources management differs (Bloesch *et al.,* 2012). In the savanna area of Nigeria, Galma River is the main drainage channel in Zaria as other rivers and streams discharge and emptied into it. Galma River serves as source of water for irrigation, fishing and other agricultural activities (shitu *et al.,* 2015). With the establishment of Zaria dam in 1975 (Nnaji *et al.,* 2010), It also serves as the main source of drinking water to Zaria community, supply by Zaria water works after treatment. The major land use in the catchment areas is farming, involving vegetables, grains and roots crops production during wet and dry seasons on both sides of the river banks. However, Due to booming of agricultural activities, rapid urban growth coupled with excessive pressure on the land use is continuously changing the water utilization spare in the basin Therefore, Water Quality Index (WQI) is utilized in this research work. WQI is defined as the weight of chemical concentrations determining the quality of water. WQI is a well-known effective tool for examining water quality that handles a stable, simple, reproducible unit of measure and communicate information about water quality to policy makers and concerned citizens. Thus, becomes an effective parameter for the management and evaluation of surface water. Normally, the water quality is linked to water classes. These are quality classification levels of water that determines the stages water needs to attain before being supplied for uses the intended purposes (Haritash *et al.,* 2016; Bora and Goswami 2017; Gor and Shah, 2014; Rajankar *et al.,* 2013; Balan *et al.,* 2012; Sharma and Kansal, 2011; Samantray *et al.,* 2009; Fulazzaky *et al.,* 2010). Horton's method of calculating water quality index developed this method in 1965 is used globally and was adopted and applied in this research. Researchers nowadays are still using the method with some modifications. Horton, (1965) suggested that the numerous water quality data could be combined into an overall index. Also, multivariate data analysis methods have been applied for the groupings of the river monitoring sites according to their similarity of responses to the water quality variables. These methods include Hierarchical cluster analysis (HCA) and Mapping. Hierarchical cluster analysis (HCA) is a multivariate technique commonly used to group similar variables into clusters, where the variance within the groups is reduced to the minimum and the variance between groups is increased (Einax *et al.,* 1997; Osei *et al.,* 2010; CCME, 2015). HCA has been applied to enhance spatial sampling policies by decreasing the number of sampling sites and analysis costs (Kannel *et al.,* 2007; Dominick *et al.,* 2012). Extracted clustering information can therefore be considered in reducing the number of sampling points without significant loss of information (Wang *et al.,* 2014; Juahir *et al.,* 2011). Thus enabling us to identify sampling points that are of great significance to this study. Therefore, the main objective of this research is to make detailed studies to assess water quality and establish water monitoring networks for adequate planning and better management strategy of the river water resources by utilizing various techniques such as WQI, cluster analysis and mapping of Galma River in Zaria, Kaduna State, Nigeria in the year 2018.

MATERIALS AND METHODS

Galma River is the main drainage channel of other rivers and streams in southeastern part of Zaria, in Kaduna State, Nigeria, and is located on latitude

11.3^{0}N and longitude 7.4^{0}E (Nnaji *et al.,* 2010). It is 128 km South-East of Kano and 64 km North-East of Kaduna. Zaria falls into the Guinea Savanna climate, which has distinct wet and dry seasons (Udo, 1978). Zaria is in the North central zone of Kaduna State, Nigeria. Zaria dam is located on the river, which was constructed in 1975. The Foremost activities in the study area are animal rearing and farming activities happening on both sides of the river bank throughout the year.

Data collection and analysis

Two sets of water samples were collected for the analyses during June 2018 and December 2018 distinct wet and dry seasons. Sampling sites were identified based on a stratified random sampling techniques with sole objective of obtaining representative water samples from the study area. Water samples were collected from fifteen sampling points along the river (Fig. 1). Both In Situ and Ex Situ measurements were conducted. In Situ, data were collected from Fifteen samplings points using YSI professional Plus Handheld Multiparameter Probe, while fifteen Ex Situ samples with three replicas were collected from each In Situ sampling locations, making a total of 45 samples each during wet and dry seasons, using clean polyethylene bottles that have been thoroughly cleaned with deionized water. The samples were analyzed in Public Health Laboratory, Department of Water Resources and Environmental Engineering, Ahmadu Bello University, Zaria, Nigeria. Water was analyzed for the following physicochemical parameters; In Situ:- pH, Dissolve Oxygen (mg/l), Temperature(°C), Electrical Conductivity (s/m), Salinity (ppt or PSU), Total Dissolve Solid (mg/L), Turbidity (NTU). While Ex Situ: - Sediments (TSS) (mg/L), biochemical oxygen demand (BOD_5) (mg/L), Nitrate (NO_3^-) (mg/L), Sulphate (SO_4^{2-}) (mg/L), Phosphate (PO_4^{3-}) (mg/L), Chemical Oxygen Demand (COD) (mg/L), Nitrite (NO_3^-) (mg/L), Total solids (TS) (mg/L), Magnesium (Mg^{+2}) (mg/L), Calcium (Ca^{+2}) (mg/L), Chloride (CL^-) (mg/L). All the physicochemical parameters were determined

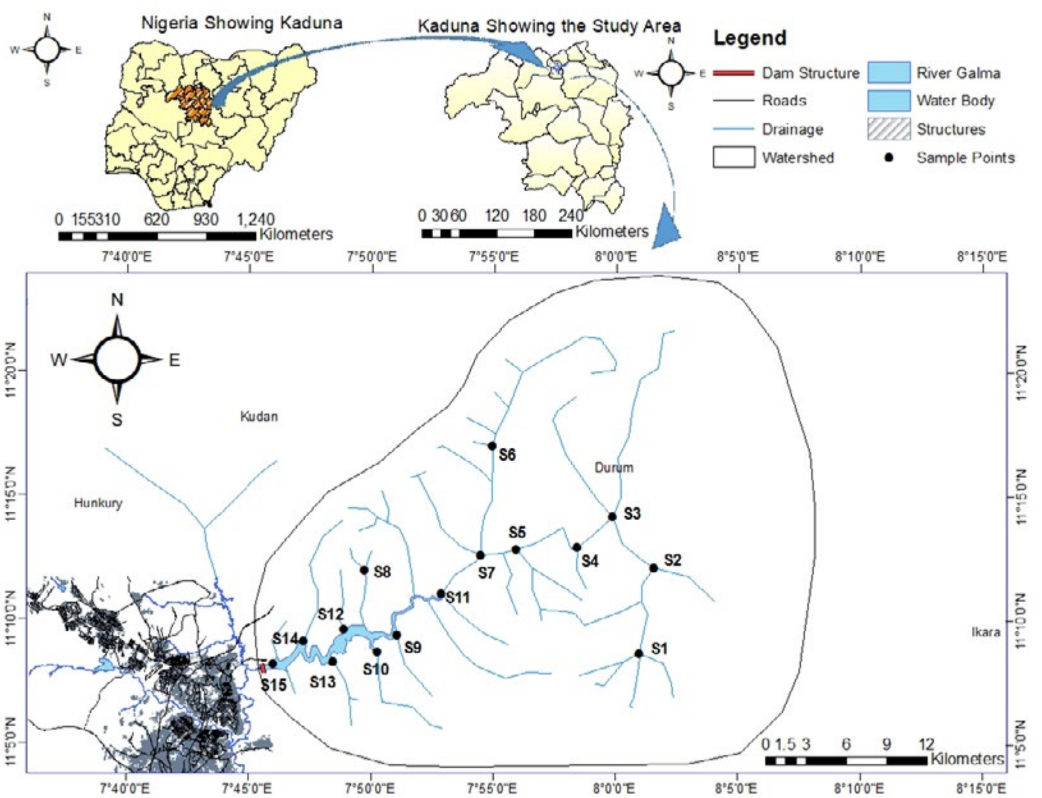

Fig. 1: Geographic location of the study area along with the sampling points in Galma River, Nigeria

using standard methods described by the American Public Health Association (APHA). All data generated were subjected to descriptive statistics. Moreover, the data were subjected to Water quality index test using Horton's method computation with Nigeria or World Health Organization (WHO) standards in Microsoft Excel, Hierarchical cluster analysis using Statistical Package for Social Sciences (SPSS statistic 23) with Past3 and Mapping using ArcMap 10.2.2 respectively.

Water quality index

WQI is a tool for measuring water quality (Al-Janali *et al.,* 2012), which is found helpful for the selection of appropriate treatment technique to meet the concerned issues. (Tyagi *et al.,* 2013) state that WQI measures the amplitude, scope and frequency of water quality which produces a value to indicate the type of the water. The WQI summarized the water quality data for easy reporting of the status of water quality to the public for comparison purposes. The smaller WQI value represents better quality for domestic uses. WQI is calculated by utilizing the standardized parameters provided by the Nigerian Standard alongside WHO Standard and their unit weight parameters, which is also obtained using the standardized parameters. Table 1 is a further use in this study to assist in determining the status of the samples.

Calculation of WQI

Calculation of WQI was carried out using Horton's method as in Eqs. 1 and 2 (Stambuk- Giljanovic, 1999; Mohebbi *et al.,* 2013).

$$WQI = \frac{WQE}{\sum \mathcal{W}_i} \quad (1)$$

$$WQE = \sum q_i w_i \quad (2)$$

Where, q_i is the quality rating of i^{th} parameter
W_i is the unit weight of i^{th} parameter

Quality rating

The quality rating (q_i) is shown in Eq. 3 and (Table 5).

$$qi = \frac{(\mathcal{V}_i - \mathcal{V}_{id})}{(s_i - \mathcal{V}_{id})} \times 100 \quad (3)$$

Where, V_i is the value of i^{th} water quality parameter of the sample V_{id} is the ideal value of i^{th} parameter in pure water.
(Note that V_i for pH is 7 and 0 for other parameters)
s_i is the standardized parameter by Nigerian standard

Unit weight of parameter

The important steps in calculating the unit weight, is to identify the standard maximum allowable concentration, s_i and the constant proportionality, *k*. The value of k depends on the s_i Value of *k* varies on the amount of parameters involve in the study.

The unit weight of parameter, W_i is shown in Eq. 4.

$$\mathcal{W}_i = \frac{k}{S_i} \quad (4)$$

Where, s_i is the standardized parameter by local permissible limit and were is not stated, WHO standard is been applied.

k is constant of proportionality.

The constant proportionality is shown in Eq. 5 by utilizing the s_i. Hence, the calculation is further shown in (Table 4)

$$k = \frac{1}{\sum \frac{1}{s_i}} \quad (5)$$

RESULTS AND DISCUSSION

Table 2 show the descriptive statistic of wet and dry season water quality parameters in Galma River with the minimum, maximum, tested means and standard

Table 1: WQI and corresponding water quality status
(Horton, 1965; Stambuk- Giljanovic, 1999; Mohebbi *et al.,* 2013)

WQI	Status	Possible Usages
0-25	Excellent	Drinking and Industrial
26-50	Good	Domestic and Industrial
51-75	Fair	Irrigation and Industrial
76-100	Poor	Irrigation
101-150	Very Poor	Restricted for Irrigation
Above 150	Unfit for Drinking	Proper treatment required before use.

deviation of the river water quality parameters and (Table 3) shows the water quality standards used in the research.

WQI Calculation

The first step is to calculate the denominator of Eq. 5. The constant proportional, k and the weight, W_i for all the parameters were calculated as in Eq. 6.

$$\sum \frac{1}{s_i} = 3.0338$$

$$\text{Then, } k = \frac{1}{3.0338} = 0.3296 \quad (6)$$

After the k value had been identified, proceed with Eq. 4 and find the Weight, W_i.

Now, $WQE = \sum q_{i}w_i$

Table 2: Descriptive statistic of wet and dry season water quality parameters

Parameter	Unit	Sampled stations (N)	Wet season (WS)			Dry season (DS)		
			Min.	Max.	Tested mean ± SD	Min.	Max.	Tested mean ± SD
Sal	(mg/L)	15	0.09	0.10	0.10 ± 0.01	0.09	0.10	0.09 ± 0.00
BOD5	(mg/L)	15	4.00	5.70	5.00 ± 0.60	4.50	5.80	5.35 ± 0.40
DO	(mg/L)	15	6.70	6.80	5.44 ± 0.61	5.10	6.60	5.81 ± 0.40
NO_2^-	(mg/L)	15	2.90	10.50	5.99 ± 2.27	4.00	10.80	7.69 ± 2.11
pH	-	15	6.10	6.50	6.25 ± 0.12	6.90	7.90	7.39 ± 0.26
Mg^{+2}	(mg/L)	15	8.20	71.30	35.15 ± 21.53	20.70	77.30	51.78 ± 20.32
SO_4^{2-}	(mg/L)	15	9.21	19.45	12.99 ± 3.92	14.51	23.53	19.05 ± 2.87
PO_4^{3-}	(mg/L)	15	11.68	27.81	15.96 ± 5.08	11.68	27.81	19.92 ± 6.20
Ca^{+2}	(mg/L)	15	18.00	58.50	26.08 ± 11.99	17.50	59.50	38.76 ± 15.39
NO_3^-	(mg/L)	15	20.28	48.07	31.79 ± 6.77	29.01	49.00	36.59 ± 6.86
T	(°C)	15	28.03	28.37	28.17 ± 0.12	29.44	32.00	30.81 ± 0.74
CL^-	(mg/L)	15	47.00	250.00	175.73 ± 60.74	112.00	260.00	202.13 ± 42.92
TSS	(mg/L)	15	30.00	145.67	77.04 ± 32.43	33.00	156.00	82.20 ± 35.68
EC	(s/m)	15	23.00	80.67	56.44 ± 18.69	32.00	96.00	72.00 ± 17.89
COD	(mg/L)	15	90.00	320.00	171.07 ± 70.25	120.00	292.00	192.53 ± 50.38
TDS	(mg/L)	15	260.00	652.33	425.56 ± 110.99	350.00	877.00	586.80 ± 187.47
Turb.	(NTU)	15	398.67	926.33	546.29 ± 140.81	545.00	926.00	704.27 ± 131.07
TS	(mg/L)	15	355.67	867.33	576.87 ± 147.86	386.00	897.58	640.97 ± 167.62

Table 3: Water quality standards used in the current study

Parameter	Unit	Maximum allowable concentration (WHO)	Local permissible limit Nigerian standard (NG)	Desirable limit (S_i)
Sal.	(mg/L)	0.5	Not Stated	WHO
BOD5	(mg/L)	5	5	NG
DO	(mg/L)	5	5	NG
NO_2^-	(mg/L)	3	Not Stated	WHO
pH	-	7.0 – 8.0	7.0 – 8.0	NG
SO_4^{2-}	(mg/L)	250	Not Stated	WHO
PO_4^{3-}	(mg/L)	5	Not Stated	WHO
T	(°C)	20 - 32	40	NG
NO_3^-	(mg/L)	5	Not Stated	WHO
EC	(s/m)	1500	1500	NG
TSS	(mg/L)	500	Not Stated	WHO
COD	(mg/L)	80	Not Stated	WHO
TDS	(mg/L)	1000	1000	NG
Turb	(NTU)	5.0	500	NG
TS	(mg/L)	1000	Not Stated	WHO
Mg^{+2}	(mg/L)	30	30	NG
Ca^{+2}	(mg/L)	75	75	NG
CL^-	(mg/L)	250	250	NG

Where, WQE = 59.67 for wet season and WQE = 74.33 for dry season

Then, WQI is calculated by utilizing Eq. 1. The summation of weight, W_i is 0.95182. Sample point 1 (Sp1) of wet season (WS) has WQI = 62.70 and Sample point 1 (Sp1) of the dry season (DS) has WQI = 78.09 the same calculation was performed to find the WQI for the rest of the sampling points that are presented in Table 6 and Fig. 2.

From Table 6 and Fig. 2 above, spatial variation of the water quality in both wet season (WS) and dry season (DS), shows that, the water quality index is increasing from the upstream of the river to the downstream of the river. Galma River has a large number of tributaries toward the southern part of the river watershed (Fig. 1) and these tributaries were influenced by lot of agriculture and domestic activities, which were finally connected to the sampling point 15 (Sp15), in the downstream section of the river. This is why Sp15 has the largest value

Table 4: Calculation of numerator and denominator of unit weight

Parameter	S_i	$s_i - \mathcal{V}_{id}$	Weight, $\mathcal{W}_i$
T	40 °C	40	0.00980
pH	8.0	1.0	0.03922
EC	1500 s/m	1500	0.00021
DO	5 mg/L	5	0.06275
Turb	5NTU	500	0.06275
Sal	0.5 mg/L	0.5	0.62747
TDS	1000 mg/L	1000	0.00031
NO_2^-	3 mg/L	100	0.00314
NO_3^-	5 mg/L	5	0.06275
PO_4^{3-}	5 mg/L	5	0.06275
SO_4^{2-}	250 mg/L	250	0.00125
COD	80 mg/L	80	0.00392
BOD5	5 mg/L	5	0.06275
TSS	500 mg/L	500	0.00063
TS	1000 mg/L	1000	0.00031
Mg^{+2}	30 mg/L	30	0.01046
Ca^{+2}	75 mg/L	75	0.00418
CL^-	250 mg/L	250	0.00125
			0.95182

Table 5: Calculation of numerator and denominator of quality rating

	Wet season (WS)			Dry season (DS)		
Parameter	Value ($\mathcal{V}_i$)	$\mathcal{V}_i - \mathcal{V}_{id}$	Value q_i	Value ($\mathcal{V}_i$)	$\mathcal{V}_i - \mathcal{V}_{id}$	Value q_i
T	28.36	28.36	70.900	30.02	30.02	75.05
pH	6.50	0.50	50.000	7.50	0.50	50.00
EC	73.67	73.67	4.667	87.00	87.00	5.80
DO	4.70	4.70	94.000	5.60	5.60	112.00
Turb	420.33	420.33	84.000	572.00	572.00	114.40
Sal	0.1	0.1	19.000	0.10	0.10	19.00
TDS	470.67	470.67	47.100	397.00	397.00	39.70
NO_2^-	3.40	3.40	3.400	7.30	7.30	7.30
NO_3^-	20.28	20.28	405.600	30.74	30.74	614.80
PO_4^{3-}	12.80	12.80	256.000	13.80	13.80	276.00
SO_4^{2-}	9.72	9.72	3.884	14.51	14.51	5.80
COD	90.00	90.00	112.500	140.00	140.00	175.00
BOD5	4.50	4.50	90.000	5.20	5.20	104.00
TSS	51.33	51.33	10.200	53.00	53.00	10.60
TS	652.33	652.33	65.200	667.00	667.00	66.70
Mg^{+2}	8.20	8.20	27.333	20.70	20.70	69.00
Ca^{+2}	18.00	18.00	24.000	17.50	17.50	23.33
CL^-	47.00	47.00	18.800	112.00	112.00	44.80

of WQI in both WS and DS, 105.77 and 126.34 respectively, which is much higher than Sp1 located upstream of the river with WQI of 62.71 in WS and 78.09 in DS. This indicate that Sp15 is the most polluted and problematic sampling point, a mirror image of strong impact of agricultural and domestic activities within the downstream section of the river. This may be resulting from non-point source pollution such as domestic disposal, agricultural activities and runoff that dissolve pollutants in the river water. This is in line with the work of Ogbozige *et al.* (2017), on evaluation of the Water Quality of River Kaduna, Nigeria Using Water Quality Index. More so, Table 6 shows the samplings in DS to be more polluted than those in WS through all the sampling points. At sampling points (Sp1, Sp2 and Sp3) in the WS, WQI exhibit fair (51-75) water quality status (WQS), in the upstream part of the river, however within the same sampling point it changed to poor status in the dry season (76-100) WQS. This indicates that the concentration of the water quality parameters tend to increase due to absence of rainfall and excessive

Table 6: WQI for all the 15 sampling stations

Sampling points	Wet Season (WS)			Dry Season (DS)		
	WQI	Status	Possible Usages	WQI	Status	Possible Usages
Sp1	62.70	Fair	Irrigation and Industrial	78.09	Poor	Irrigation
Sp2	67.46	Fair	Irrigation and Industrial	81.85	Poor	Irrigation
Sp3	69.82	Fair	Irrigation and Industrial	76.67	Poor	Irrigation
Sp4	78.85	Poor	Irrigation	73.89	Poor	Irrigation
Sp5	88.11	Poor	Irrigation	89.48	Poor	Irrigation
Sp6	77.11	Poor	Irrigation	76.74	Poor	Irrigation
Sp7	82.99	Poor	Irrigation	91.77	Poor	Irrigation
Sp8	76.85	Poor	Irrigation	83.09	Poor	Irrigation
Sp9	81.94	Poor	Irrigation	110.77	Very Poor	Restricted for Irrigation
Sp10	74.80	Poor	Irrigation	89.90	Poor	Irrigation
Sp11	92.15	Poor	Irrigation	105.18	Very Poor	Restricted for Irrigation
Sp12	92.84	Poor	Irrigation	108.52	Very Poor	Restricted for Irrigation
Sp13	144.76	Very Poor	Restricted for Irrigation	124.52	Very Poor	Restricted for Irrigation
Sp14	94.82	Poor	Irrigation	121.54	Very Poor	Restricted for Irrigation
Sp15	105.77	Very Poor	Restricted for Irrigation	126.34	Very Poor	Restricted for Irrigation

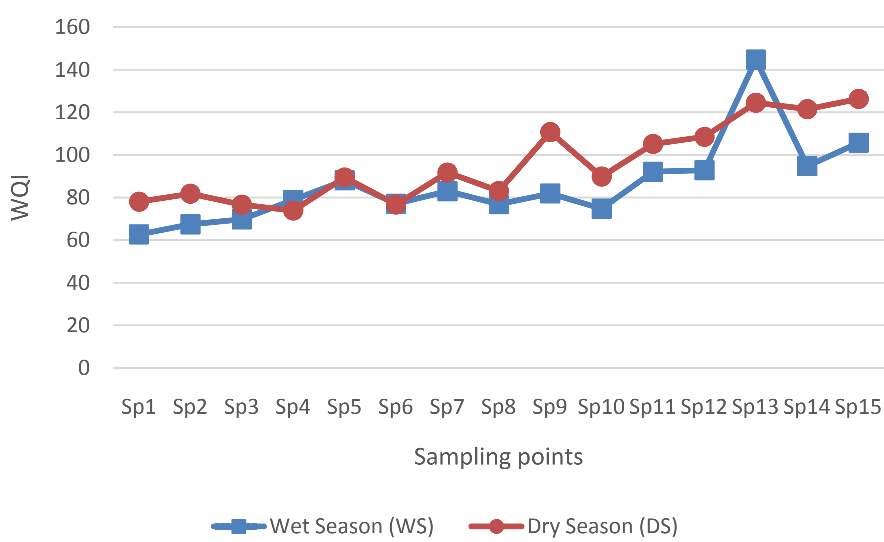

Fig. 2: Spatial and seasonal variation in WQI values along Galma River

water evaporation during DS. Similarly, wet season WQI exhibit poor (76-100) WQS in the middle of the river to very poor (101-150) WQS at the downstream of the river, yet looking at the dry season, it shows a very poor (101-150) WQS from the middle up to the downstream of the river. In general, the results of WQI showed that the monitoring sites were significantly polluted and could be used for Industrial and Irrigation purpose (Table 1). This is in consistent with the findings of Bhangaonkar and Patel, (2017) on water quality zoning of Vishwamitri River to access environmental flow requirements through aggregation of water quality index. The result of the water quality index will provide better understanding of recent water quality status of the river.

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

The water quality parameters were analyzed using a multivariate statistical technique of HCA to determine seasonal variation. Cluster analysis yielded a dendrogram (Fig. 3) for WS and DS, the fifteen sampling points in wet season (WS) were grouped into four major clusters. The grouping procedure highlighted two groups of sampling points at the upstream of the river, which is very convincing as stations in these groups have similar characteristics and types of natural sources. Cluster 1 consists of six sampling points, Sp8, Sp6, Sp7, Sp11, Sp9 and Sp5. These monitoring points are located in the middle of the watershed and are classified as poor WQS in WS portion of Table 6 by Horton's method of calculating the water quality index. Again, cluster2 in WS consist of five sampling points, Sp14, Sp12, Sp13, Sp10 and Sp15 are located in the downstream part of the river with poor (76-100) and very poor (101-150) WQS. Cluster 3 in WS comprised of two stations, Sp1 and Sp2, which were located towards the southern part of the watershed of the river with fair (51-75) WQS. Lastly, cluster 4 consisting of two sampling points Sp3 and Sp4, located at the upstream of the river and it is not surprising that Sp3 has the same water quality status (Fair) with Sp1 and Sp2 because both sampling stations are located in the upstream part of the river sharing some similar characteristics(Fig. 4).

Fig. 3 shows the cluster analysis of the data collected during the dry season (DS). As indicated in the dendrogram, fifteen sampling points are classified into four clusters. Cluster 1 corresponding to the sampling points of Sp6, Sp4, Sp5, Sp9, Sp7 and Sp3, located middle of the watershed, except Sp3 which is located at the upstream of the watershed. These sampling points are in poor status (76-100) WQS, except for Sp9 which falls in vary poor (101-150) WQS as shown in Table 6. More so, Cluster 2 comprises of two sampling points, Sp1 and Sp2, which were located upstream of the watershed with poor (76-100) WQS. Cluster 3 consisting of three sample station, Sp14, Sp13 and Sp15, are located at the extreme end of the downstream of the river (Fig. 4), these stations are in very poor (101-150) WQS. Whereas, cluster 4 contains three sampling points, Sp10, Sp11 and Sp8,

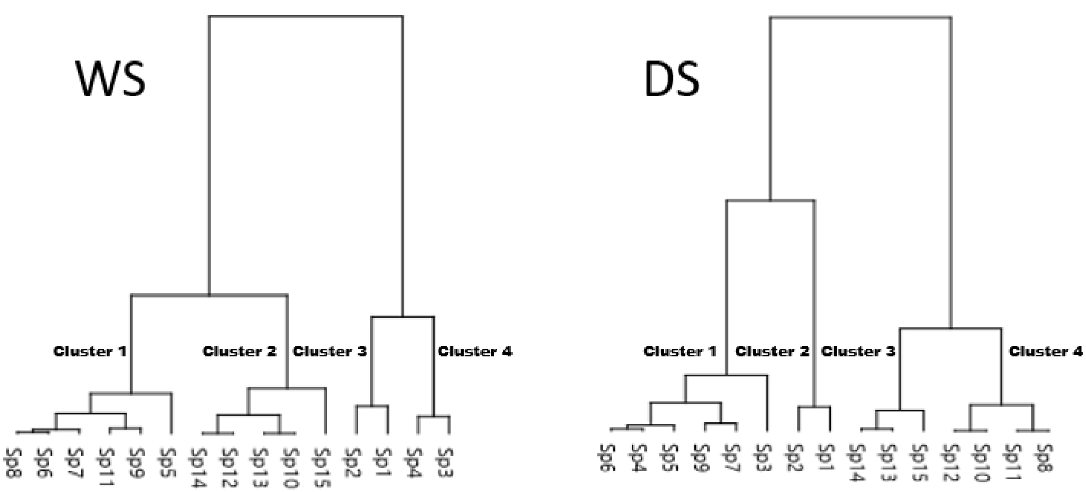

Fig. 3. Dendrogram (using Ward Method) showing spatial similarities of monitoring sample points produced by cluster analysis

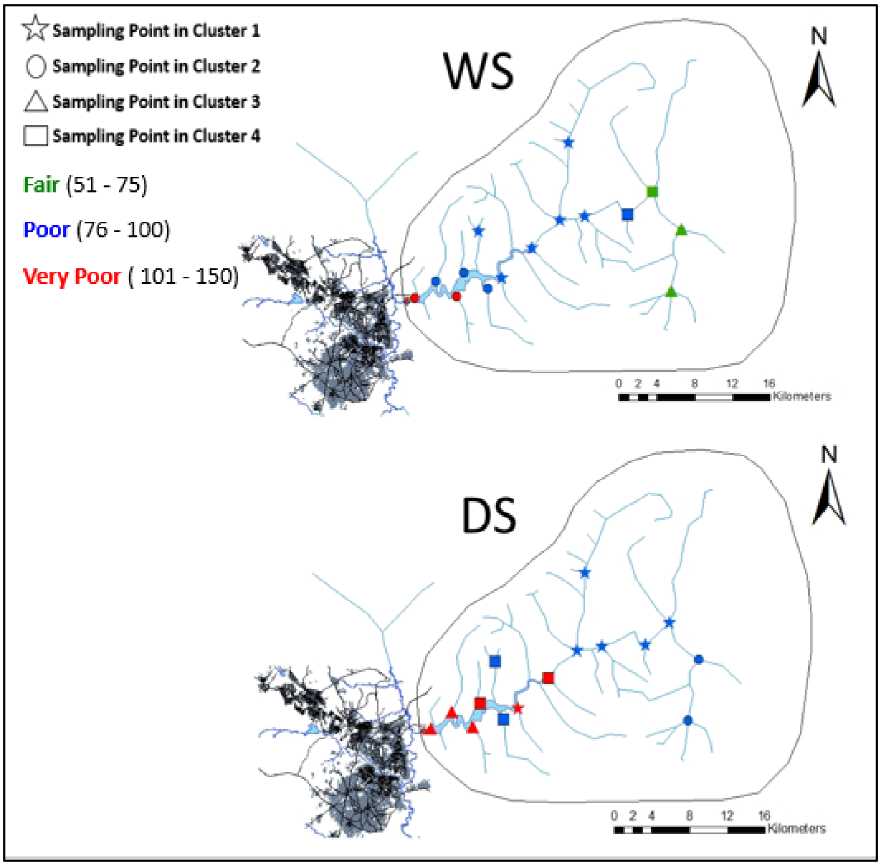

Fig. 4: Cluster of Galma River monitoring sample points

located at the downstream of the river system with poor (76-100) WQS, except Sp11 which exhibit very poor (101-150) WQS (Table 6).

The results of the Hierarchical Cluster Analysis (HCA) for WS and DS showed that there were consistency and variations between the cluster groups of the stations (Fig. 4). For example, in both networks, the first clusters are all located middle of the river watershed, while clusters two, three and four show some variations within the river watershed. More so, Fig. 4WS indicates that the first 3 sampling points in the upstream of the river could be used for the purpose of Irrigation and Industrial activities, which fall in the fair WQS (51-75) in a WS portion of Table 6 by Horton's method of calculating the water quality index. While the middle of the river reveals 10 sampling points with poor (76-100) WQS and 2 sampling points with very poor (101-150) WQS located at the downstream of the river that could be utilized for irrigation purpose only. Again, Fig. 4DS reveal 9 sampling points located at the upstream and middle of the river with poor (76-100) WQS that could be used for the purpose of Irrigation and 6 sampling points with very poor (101-150) WQS at downstream of the river that could be utilized and restricted to irrigation purposes only. The reasons of these variations were related to non-point pollutions, because in WS non-point source pollution generally resulted from land runoff, precipitation, atmospheric deposition, unlike non-point source pollution in DS corresponding to irrigation agriculture, sand quarry, absence of rainfall and water evaporation. These clustering results will provide better understanding of the spatial variation in WQS of the river which will help to understand the most problematic sampling points in both WS and DS within the river watershed. This is similar to findings of Othman, *et al.,* (2018) in clustering the sampling stations for risk assessment and identification of heavy metals sources in Selangor River. The clustering results are in agreement with study results on the spatial assessment of monitoring network in coastal waters: a case study of Kuwait Bay (Al-Mutairi, *et al.,* 2015), and with the findings in assessing the impact of fertilizers to the Selangor River Basin (Santhi and Mustafa, 2013). In general, this results of WQI showed that the monitoring sites are polluted, but could be utilized for Industrial and Irrigation purposes (Table 1).

CONCLUSION

Eighteen water quality parameters for fifteen sampling points were studied for Galma River in Zaria, and by applying WQI, cluster analysis and mapping. WQI result shows that the monitoring sites were polluted and could be specified for the purpose of Industrial and Irrigation usage. Hierarchical Cluster Analysis (HCA) for WS and DS revealed that there were consistency and variations between the clusters of the sampling points. For both wet and dry season networks, Cluster 1 is located at middle of the river watershed, while, cluster 2, 3 and 4 shows some variations within the river watershed, generally 3 Sampling point in WS are located at the upstream of the river and were specified for Irrigation and Industrial usage while the rest of the Sp in both WS and DS were specified for irrigation only. By this investigation, the result will provide better understanding of the spatial variation and recent water quality status of the river in order to implement appropriate strategies to improve water quality management efforts in the river basin. Thus, WQI and multivariate techniques for environmental management should be employed in monitoring as they provides detailed explanation in managing river resources. Further studies should be conducted on other water quality parameters for heavy metals for in-depth understanding of pollution sources in the basin.

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CONFLICT OF INTEREST

The authors declares that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

ABBREVIATIONS

APHA	American Public Health Association
BOD5	Biochemical oxygen demand
COD	Chemical oxygen demand
Ca^{+2}	Calcium
CL^{-}	Chloride
°C	Degree Celsius
DO	Dissolve oxygen
DS	Dry season
Eq	Equation
EC	Electrical conductivity
HCA	Hierarchical cluster analysis
Max.	Maximum
Mg^{+2}	Magnesium
Min.	Minimum
mg/L	milligrams per liter
NG	Nigerian standard
NO_3^-	Nitrate
NO_2^-	Nitrite
NTU	Nephelometric turbidity unit
PO_4^{3-}	Phosphate
pH	Power of hydrogen
PSU	Practical salinity unit
Ppt	Parts per thousand
Sal	Salinity
SD	Standard Deviation
S_i	Desirable limit
SO_4^{2-}	Sulfate
Sp	Sampling point
SPSS	Statistical Package for Social Sciences
S/m	Siemens per meter

T	Temperature
Turb.	Turbidity
TDS	Total dissolve solids
TSS	Total suspended solids
TS	Total solids
UPM	Universiti Putra Malaysia
WS	Wet season
WQI	Water Quality Index
WQS	Water Quality Status
WHO	World Health Organization

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