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Assessment of urban groundwater quality using Piper trilinear and multivariate techniques: a case study in the Abuja, North-central, Nigeria

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Abstract

Background: Groundwater pollution ensuing from ion exchange, weathering, agricultural and anthropogenic activities is on the rise in Nigeria. Since groundwater is used for domestic purposes, there is need for routine investigation. Findings on hydrochemistry of the groundwater components is essential for efficient and viable management. As a result, 25 Abuja water samples were collected for microbial and chemical analyses using standard methods. The cations, anions, soluble ions, trace elements, and heavy metal were obtained and compared with WHO standards.

Results: The Discriminant analysis results shown that the parameters such as hydrogen ion concentration (pH), temperature (T), alkalinity (Alk), dissolve silica (SiO_2), and cations such as calcium (Ca^{2+}), potassium (K^+), as well as anions such as carbonates ($CO_3{}^{2-}$), fluoride (F^-), nitrates ($NO_3{}^-$), and heavy metal (Mn) were within the WHO guideline values for drinking water in all the samples for both seasons. Na^+, $SO_4{}^{2-}$, EC, Mg^{2+}, TDS, Fe^{2+}, $HCO_3{}^-$, F^-, TH and Cl^- contents exhibited the most violation of drinking water standards with percent violations of 100, 76, 64, 56, 56, 44, 40, 40, 36 and 24%, respectively. The highest level of significant correlation was found to exist between K^+ and EC ($r = 0.77$, $\alpha = 0.05$). Four hydro chemical clusters were identified from Hierarchical cluster analysis (HCA) with clearly partitioned water quality. Series and time series plot reveals TDS concentration value between 1200 and 2100 mg/l, has the highest with the mean and SD are 1433.76 and 459.38, respectively. Further analysis revealed that 16, 36 and 48% of the samples were the Ca–Cl, Na–Cl, and Mixed types, respectively.

Conclusion: Groundwater in the Abuja district is mainly hard to very hard, slightly acidic in nature, polluted by ion exchange, agricultural activities, anthropogenic activities, and weathering. Therefore, there is also need for routine monitoring of groundwater in Abuja.

Keywords: Discriminant analysis, Chloride, Violation, Anthropogenic, Abuja, Nigeria

Introduction

Groundwater is the main source of water for drinking, domestic, industrial and agricultural purposes in many nations. The population growth of many countries has led to enormous scale of groundwater developments in some regions. Likewise, municipal development also triggered a great demand on groundwater resources in semi-arid as well as arid zones of the world and Nigeria, whereas putting these resources at high risk to contagion (Li 2016; Etteieb et al. 2017). Therefore, there is need for studies on how groundwater will be managed. For effectiveness, the management and assessment of groundwater resources need an understanding of hydrogeochemical and hydrogeological features of the aquifer (Azhar et al. 2015). Since, Hydrogeochemical procedures that are responsible for inconsistent of the chemical composition of groundwater fluctuate with respect to space and time, thus the chemical

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physiognomies of groundwater which plays an essential role in classifying and evaluating the water quality need to be constantly scrutiny (Cao et al. 2016; Li et al. 2013). Groundwater quality depends on several factors such as recharge water quality, geology, grade of chemical weathering of the different rock types, and water–rock interface (Emenike et al. 2017; Aly 2015). Additionally, several recent studies on groundwater quality have been conducted. Many of the study centered on evaluating the natural concentrations of several metals and ions in groundwater, to segregate natural and anthropogenic sources that interrupt groundwater quality, and found interfaces that take place in the aquifer (e.g., Chen et al. 2016; Cao et al. 2016; Ehya and Marbouti 2016; Gu et al. 2015). The findings of groundwater previous studies (Arulbalaji and Gurugnanam 2017; Cao et al. 2016; Ojekunle et al. 2016; Li et al. 2015) concludes that quick population growth, unplanned municipal development, agricultural activities, insufficient hydrogeochemical knowledge, and poor groundwater quality management, are some major factors responsible for groundwater quality control.

Nevertheless, the hydrogeological and hydrogeochemical features of the aquifer has not been carefully studies. Despite, groundwater serve as only source of water to both rural and cities for drinking, agriculture, domestic, industrial and irrigation uses in Abuja, a city in North-central Nigeria. In study area, agriculture is the most significant commercial activity affecting the changes in groundwater quality by anthropogenic effect. Hence, hydro chemical analysis of the groundwater has become a high priority issue. The findings of this study will heighten public understanding of the groundwater composition, which can contribute to effective management of groundwater by water management authorities. Thus main aims of the present study is (1) to ascertain the main hydro geochemical procedures (2) to determine the groundwater quality and (3) to delimit areas where groundwater is unsuitable or fit for drinking, cooking, irrigation, industrial and agricultural purpose.

Materials and methods

Study area

The sampling sites for the study were in Abuja—the centre and capital of Nigeria. Abuja is defined by Aso rock, a 400-m monolith at the center, and near Zuma Rock, a 792-m monolith, north of the city on Kaduna express road. It lies between latitude 9.4° N and longitude 7.29° E. The population of Abuja is estimated at 6000,000 with an annual growth rate of 35%, retain position as the African fastest growing city (Enitan et al. 2018). The city is served by the Nnamdi Azikiwe International Airport, and is the administrative and political centre of Nigeria. Other neighboring cities that share common boundaries with Abuja include Kaduna, Lokoja, Keffi, and Mandalla.

Sample collection

In this study, to evaluate the quality of groundwater, 25 groundwater samples were collected from different locations (P1–P25) in Abuja North-central (Fig. 1) during March to July 2018, analyzed for various chemical parameters as described by the American Public Health Association (APHA 2005), examined and compared with World Health Organization (WHO) water quality standards (WHO and UNICEF 2014). These parameters include hydrogen ion concentration (pH), total hardness (TH), temperature (T), electrical conductivity (EC), alkalinity (Alk), total dissolved solids (TDS), dissolve silica (SiO_2), and significant cations such as sodium (Na^+), calcium (Ca^{2+}), potassium (K^+), magnesium (Mg^{2+}), and iron (Fe^{2+}) as well as anions such as sulphate ($SO_4{}^{2-}$), carbonates ($CO_3{}^{2-}$), chloride (Cl^-), bicarbonates ($HCO_3{}^-$), fluoride (F^-), nitrates ($NO_3{}^-$), and heavy metal (Mn). Sensitive water quality parameters such as pH and EC were measured on site using multiparameter Hanna edge ®HI2031 conductivity metre and a Hanna HI98131 probe. Fe and Mn concentration was measured with the flame absorption spectrophotometer (FAAS) (Phung et al. 2015). $NO_3{}^-$ and $SO_4{}^{2-}$ was measured with spectrophotometer. The F^- concentration in the samples was quantified using a calibrated potentiometric ion- selection electrode (HANNA–HI5315) in connection with a specialized water-resistant filtered ORP/pH/ISEmeter (HANNA–HI98191). Cl^- levels was measured using argentometric titration while HCO3$^-$, TH, Ca^{2+}, TA and $CO_3{}^{2-}$ were analyzed by volumetric method. SiO2, Na^+, Mg^{2+}, and K^+ were estimated using standard method laid out by the American Public Health Association (APHA 2005). The correlation of the analytical data were attempted by plotting graphical representation of various kind for the classification of water and to examine the groundwater fitness for utilitarian purposes by discovering different elements on which the chemical physiognomies of water depend. The groundwater fitness for irrigation, drinking, agricultural, industrial and, domestic purposes was assessed by equating the values of various water quality parameters with those of the World Health Organization (WHO and UNICEF 2014) recommendation values for drinking water. Moreover, Standard sampling techniques were employed throughout the study and samples collected were kept, in accordance with stipulated techniques used for clean water before analysis was carried out. Laboratory quality control techniques

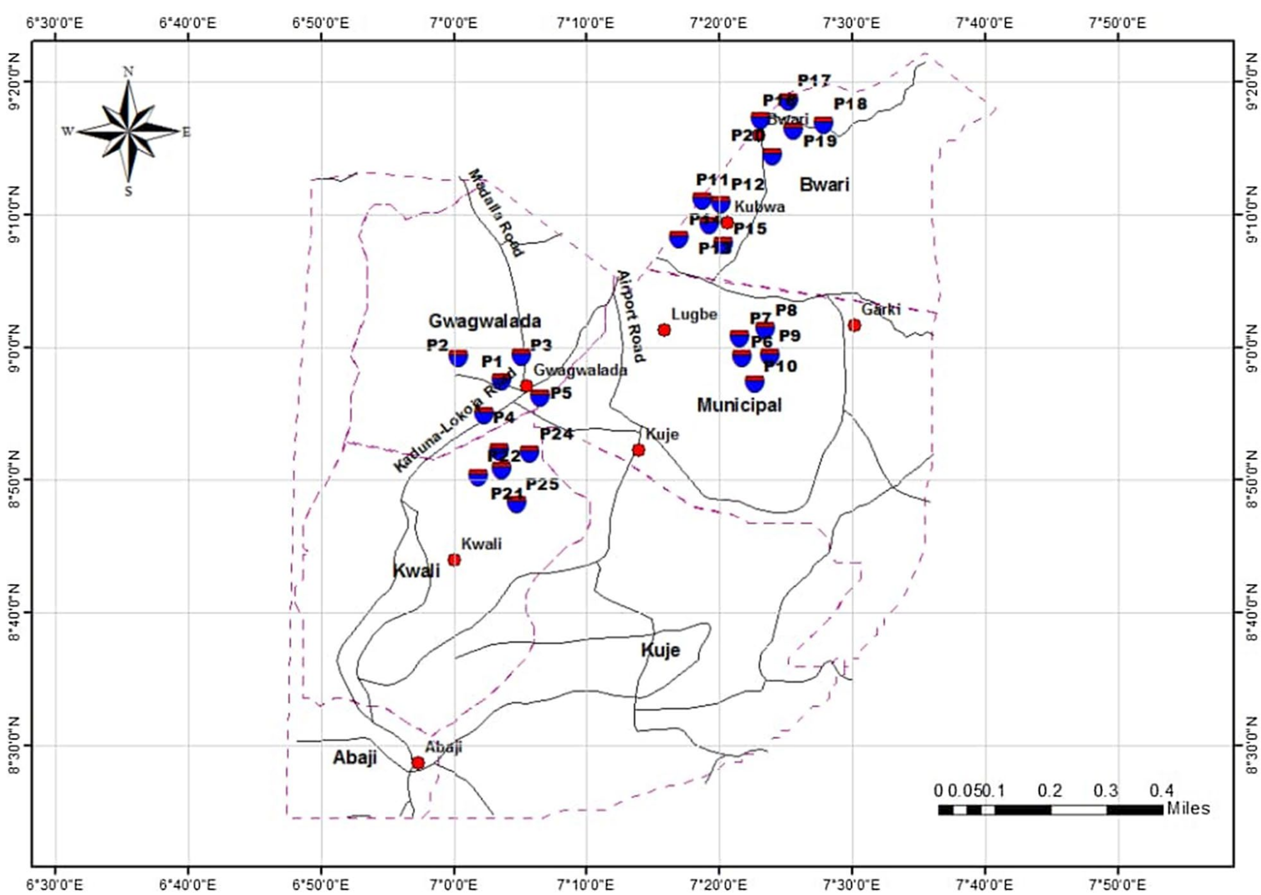

Fig. 1 Map of study area displaying sampling points

with standard operating processes, standards calibration, and analysis of replicates were applied to guarantee all data quality.

Data treatment and statistical analysis

Laboratory results were subjected to descriptive statistical analyses. The degree of violation of each water quality parameter was estimated by considering the number of times it exceeded the WHO water quality guidelines. Correlation between parameters was also performed using Pearson's pairwise correlation at 0.05 level of significance. HCA was applied to the parameters as well as the sampling points to classify objects into groups according to their similarity (nearness). Cluster group (CG) of sampling points were used for spatial delineation of water quality. HCA is the most widely used method for classifying a group of data into similar subgroups, beginning with two of the most similar objects and developing higher clusters in a stepwise manner (Khound and Bhattacharyya 2016; Al-Murairi and Abahussain 2014; Jalal et al. 2012). In this paper, Ward's method of linkage and squared Euclidean distance were employed. The Hierarchical cluster analysis (HCA) method was applied to the 25 water quality parameters using the Statistical Package for Social Sciences (SPSS). Next, Discriminant analysis (DA) was applied to the parameters as well as the sampling points to classify objects into groups according to their similarity (nearness). Clustering of sampling points were employed for spatial delimitation of water quality. HCA is the most common technique for classifying a group of data into related subgroups, starting with two of the most related objects and developing higher clusters in a stepwise manner (Fijani et al. 2017; Jalal et al. 2012). In this study, squared Euclidean distance and ward's method of connection were used. A hydro-chemical classification of the water samples was attempted by using Piperplot-QW for plotting Piper trilinear.

Results and discussion

Physicochemical parameters of groundwater

Descriptive statistics of 19 measured variables at 25 sampling sites for the whole sampling period are summarized in Table 1. The results shows that pH (mean range, 6.60–7.45 mg/l), NO_3^- (mean range, 0.00–6.16 mg/l), K^+

(mean range, 2.06–9.31 mg/l), Ca^{+} (mean range, 22.01–226.56 mg/l) and Mn (mean range, 0.01–0.10 mg/l) is within the permissible levels, while all other parameters exceed average levels set by national guidelines for residential use and other purposes. The non-compliance of water quality parameters degree and WHO drinking water quality standards was calculated as a percentage (%) of the total number of times a parameter surpassed specified standards shows in Table 2. It was establish that Na^{2+}, $SO_4{}^{2-}$ EC, TDS, Mg^{2+}, Fe^{2+}, $HCO_3{}^{-}$, F^{-}, TH and Cl^{-} displayed the most violation of drinking water standards with percent violations of 100, 76, 64, 56, 56, 44, 40, 40, 40, 36 and 24%, respectively.

These results are consistent with (Emenike et al. 2017) who reported that Na^{2+}, Mg^{2+}, Fe^{2+} and EC, exhibited the most violation of drinking water standards with percent violations of 100, 52.4, 47.6, and 47.6%, respectively. High levels of Na + can possibly be outcome of groundwater pollution by sewage, irrigation and salt deposits erosion and sodium-bearing rocks (Achieng et al. 2017). Cl^{-} is a minor constituent earth's crust constituent with a major dissolved constituent of most natural waters can percolate into the groundwater from road salting, agricultural runoff and rocks. F^{-} can occur either artificially or naturally in portable water, and are fascinated to some degree in the bone structure of the tooth enamel and entire body. High level of F^{-} can cause oxidization of water treatment equipment and piping. The high levels of Fe^{2+} in the Abuja groundwater samples is most likely due to the low water pH ensuing from the oxidization of water delivery pipes. Though Fe^{2+} is an important element in human being and is of slight health concern, its existence in water constitutes an irritant (Achieng et al. 2017; Li 2016) noted that high TDS and EC can be ascribed to rainwater infiltration, ion exchange, sediment dissolution and evaporation. TDS level in water reliant on the chemical nature of the water and the aquifer materials solubility through which the water is flowing. The high levels of TDS in the groundwater samples examined should be a great source of anxiety. It has been attested that high levels of TDS could lead to laxative effects and gastrointestinal irritations (Cao et al. 2016; Li et al. 2015). $SO_4{}^{2-}$ can formed artificially from runoff of fertilized agriculture lands and naturally through soil or rock and other common minerals. High levels of Mg^{2+} and $SO_4{}^{2-}$ has been reported causing dehydration (Fingl 1980).

Correlation of physicochemical parameters

Pearson's correlation coefficients were calculated for each hydrogeological parameters as displayed in Table 3. A significant correlation was found to occur between Cl^{-} and Alk ($r = 0.85$, $\alpha = 0.05$). Positive and significant correlation was also achieved between K^{+} and EC ($r = 0.77$, $\alpha = 0.05$), F^{-} and T ($r = 0.66$, $\alpha = 0.05$), Ec and Alk ($r = 0.62$, $\alpha = 0.05$), and anions, such as $HCO_3{}^{-}$ and $SO_4{}^{2-}$ ($r = 0.56$, $\alpha = 0.05$).

But when compared with coastal aquifer of Khulna District, Bangladesh (Islam et al. 2017); Rapur area, Andhra Pradesh, South India (Sreedhar et al. 2016); Dongsheng coalfield, Ordos Basin, China (Li et al. 2013). The high correlation coefficient was between Na^{+} and Cl^{-}, Ca^{2+} and SO_4 2 while Potassium (K^{+}) and NO^{3-} were not significantly correlated to any other ions expect each other ($r = 0.511$, $\alpha = 0.05$).

Emenike et al. (2017) observed that contaminations in limestone, such as $SO_4{}^{2-}$, SiO_2, and Cl^{-}, become exposed to the water solvent action, as carbonates are liquefied they also pass into solution. This relatively explains the high positive correlation between $HCO_3{}^{-}$ and $SO_4{}^{2-}$. Similar correlations were obtained (Phung et al. 2015; Jalal et al. 2012) found that the EC finds higher level correlation significance with the water quality parameters, like K^{-} and Alk. Raman and Geetha (2005) discovered that the ground water quality can be projected with sufficient precision just by the measurement of EC only. This offers a means for quicker and easier monitoring of water quality in an area.

Cluster analysis

Hierarchical cluster analysis (HCA) rendered a dendrogram which classified the 25 sites into four clusters in a convincing way (Fig. 2). The analysis produced four hydro chemical clusters of the study area with physiognomies shown in Table 4. The means concentrations of water quality parameters were compared with WHO standard for drinking water displays in Table 5. Cluster 1 (C1) comprises parameters (pH, Temp, Alk, $CO_3{}^{2-}$, NO^{3-}, F^{-}, K^{+}, Fe^{2+}, Ca^{2+}, Mg^{2+}, Mn, SiO_2) in two districts (Kubwa and Bwari), which are mixed urban and rural regions.

F^{-} forms cluster with pH which is primarily interrelated to the iron-phosphate cluster which is in agreement with findings made by Das and Nag (2017).

Cluster 2 (C2) is a small cluster comprising only one parameter (TDS) in Kwali district where agricultural land use is predominant. Cluster 3 (C3) comprises 5 parameters (EC, $SO_4{}^{2-}$, $HCO_3{}^{-}$, Na^{+}, TH) in Lugbe district where urban and industrial sectors are predominant. As reported by Das and Nag (2017), hardness factors such as TH, Ca^{2+}, Mg^{2+} are clubbed with EC and TDS. This denotes that for rapid evaluation of water quality, abridged number of monitoring sites in each cluster can serve for spatial evaluation of the water quality of the entire network. Cluster 4 (C4) is also small cluster comprises only one parameter (Cl^{-}) at Gwagwalada district where natural chlorination is a widespread phenomenon in all kinds of soils of the region. The evidence

Table 1 Descriptive statistics of water samples collected from the study site ($n^d = 25$)

	pH	T (°C)	Alk (mg/l)	TDS (mg/l)	EC (µS/cm)	Cl^- (mg/l)	SO_4^{2-} (mg/l)	CO_3^{2-} (mg/l)	NO_3^- (mg/l)	HCO_3^- (mg/l)
Mean	6.75	25.68	35.17	1068.24	1796.87	236.41	447.23	19.50	4.20	480.58
Min	5.60	23.08	10.05	468.40	497.34	32.56	34.56	0.00	0.00	278.28
Max	7.45	27.38	56.00	2122.32	3310.11	564.12	890.65	28.78	6.16	666.25
SD	0.63	1.44	15.17	577.44	857.13	178.23	307.84	8.40	2.33	159.94
V	0.39	2.06	230.18	333,431.44	734,672.28	31,764.28	94,764.32	70.54	5.40	25,582.18
Kurtosis	−0.59	−0.47	−0.41	0.74	−0.10	0.88	0.03	−1.51	−0.97	0.70
Skewness	−0.99	−1.13	−0.92	−0.62	−0.82	−0.48	−1.35	1.46	−0.61	−1.89
Q1	6.19	24.54	27.39	493.78	1162.40	169.01	172.40	15.73	3.11	324.17
Q3	7.34	27.04	45.65	1178.77	2352.98	323.73	765.71	24.66	6.08	655.38
WHO	6.5–8.5			1000	1500	250	250		50	500
	F^- (mg/l)	**K^+ (mg/l)**	**Na^{2+} (mg/l)**	**Fe^{2+} (mg/l)**	**Ca^{2+} (mg/l)**	**Mg^{2+} (mg/l)**	**Mn (mg/l)**	**TH (mg/l)**	**SiO_2 (mg/l)**	
Mean	1.28	6.15	260.19	1.02	66.58	83.48	0.03	592.15	3.99	
Min	0.47	2.06	55.98	0.01	22.01	21.34	0.01	208.30	0.41	
Max	1.84	9.31	515.45	2.95	226.56	346.56	0.10	1739.89	8.02	
SD	0.45	2.69	195.77	1.19	71.70	100.93	0.02	526.88	3.20	
V	0.21	7.22	38,324.82	1.42	5140.39	10,185.79	0.00	277,599.93	10.22	
Kurtosis	−0.96	−1.41	−1.78	−1.58	1.28	3.77	4.90	1.45	−1.69	
Skewness	−0.32	−0.53	0.27	0.62	1.66	2.23	2.10	1.70	0.23	
Q1	1.02	3.33	57.40	0.08	22.99	23.18	0.01	223.01	0.62	
Q3	1.77	8.58	483.39	2.40	78.01	0.04	77.73	567.99	7.94	
WHO	1.5	12	50	0.3	300	50	0.4	500		

Table 2 Different samples violation values

Parameter	Unit	WHO limit	Violation number	Violation (%)	Within (%)
pH		6.5–8.5	0	0	100
T	°C	NA			
AlK	mg/l	NA			
TDS	mg/l	1000	14	56	44
EC	μS/cm	1500	16	64	36
Cl^-	mg/l	250	6	24	76
$SO_4{}^{2-}$	mg/l	250	19	76	24
$CO_3{}^{2-}$	mg/l	NA			
$NO_3{}^-$	mg/l	50	0	0	100
$HCO_3{}^-$	mg/l	500	10	40	60
F^-	mg/l	1.5	10	40	60
K^+	mg/l	12	0	0	100
Na^+	mg/l	50	25	100	0
Fe^{2+}	mg/l	0.3	11	44	56
Ca^{2+}	mg/l	300	0	0	0
Mg^{2+}	mg/l	50	14	56	44
Mn	mg/l	0.4	0	0	100
TH	mg/l	500	9	36	64
SiO_2	mg/l	NA			

also proposes an opportunity for designing a prospective spatial sampling stratagem in an ideal manner, leading to a more affordable water monitoring scheme in the Abuja area. The outcomes of this current study tally with the successful application of this method in water quality programs described from previous studies (Achieng et al. 2017; Al-barakah et al. 2017; Ehya and Marbouti 2016; Gu et al. 2015; Phung et al. 2015).

Discriminant analysis (DA)

Temporal DA was conducted with the same raw data set comprising 19 parameters after grouping into four clusters as obtained through the CA technique. All the measured parameters were the independent variables, while season were the dependent variable. Table 6, displays the statistical features of DA compare with WHO standard. The results shown that the parameters such as EC, $SO_4{}^{2-}$, and Na^+ were not within the WHO guideline values for drinking water in all the samples for both seasons. Also, the parameter such as Cl^-, Fe^{2+}, Mg^{2+}, and TH as well as parameter like EC and $HCO_3{}^-$ are not within limit during dry and raining season, respectively. Table 7 shows the discriminant classification, matrix and canonical function. The pH demonstrates a high altitude during the dry likened with the wet season, while there are significantly high value of $CO_3{}^{2-}$ during the wet. pH is very significant since it can affect the solubility and toxicity of metals in the groundwater system. Though high pH can possible be washing out of $SO_4{}^{2-}$ and Cl^- from soil layer surface and their replacement with $CO_3{}^{2-}$ in the matrix of the soil. The seasonal variation of pH values observed in this study is in agreement with the outcomes of a previous related study by Aly (2015).

Table 8 exhibits mean comparative analysis using Anova and sample T test from the water quality parameters. One-way ANOVA indicated the nutritive parameters (TDS, NO_3, F, Mn, TH and SiO_2) are not significantly to different season ($p < 0.05$). The spatial variation in water quality also was conducted to test the significance of discriminant functions obtained and to determine the most significant variables connected with differences among the spatial clusters (Fig. 3). The major features of this function are a canonical correlation of 0.998, an eigenvalue of 325.67, and being significant (Wilk's lambda = 0.03, DF = 19, $p < 0.05$). Regression and X plot was also employed for further analysis (Fig. 4). EC forecast from selected ionic compositions was equally good. The independent variables such as TDS, pH, AlK, $HCO_3{}^-$ and $SO_4{}^{2-}$ were significant in predicting EC value. The multiple *R2* value and standard errors of 0.997 and 0.56, respectively indicates that 99.7% of the variability in EC could be attributed to the combined effect of TDS, pH, AlK, $HCO_3{}^-$ and $SO_4{}^{2-}$.

Meanwhile, all the independent variables were observed to have a significant effect with't' value from partial regression test at 5% level of probability on the equivalent dependent variable. In order to enhance the interpretation of these Regression and X plot groundwater model which can be used to predict the impacts of hydrological changes on the aquifer behavior was applied to the water quality parameters (Fig. 5). EC, TDS, $HCO_3{}^-$ and TH has significance minimum series of sequence length for which are 497.34, 468.40, 278.28 and 208.30, respectively. Season model major features are predictor number of 3, stationary R squared 0.89, and being significant (DF = 18, $p > 0.05$).

Water quality assessment

The Piper-trilinear plot shows the classification of water samples from various lithological environment. It also demonstrates the chemical character of the water samples using the dominant cation and anion to tell the dissimilarities and similarities of the groundwater samples. The study area water analysis result is plotted in piper diagram (Fig. 6), According to the piper diagram, the towns Kubwa and Bwari are dominant in sodium chloride type of water. The town Lugbe are dominant in the Calcium–chloride type of water. The towns Gwagwalada and Kwali are dominant in mixed type of water, which means no cations and anions exceeds 50%. Also, the

Table 3 Pearson coefficient

P	pH	T	Alk	TDS	EC	Cl^-	SO_4^{2-}	CO_3^{2-}	NO_3	HCO_3^-	F	K	Na^+	Fe	Ca	Mg	Mn	TH	SiO_2
pH	1.00																		
T	0.31	1.00																	
Alk	−0.67	−0.31	1.00																
TDS	−5.69	−0.64	0.27	1.00															
EC	−0.22	−0.23	0.62	0.29	1.00														
Cl	−0.68	−0.57	0.85	0.67	0.64	1.00													
SO_4^{2-}	0.03	0.16	0.33	−0.23	0.07	0.08	1.00												
CO_3	−0.09	−0.02	0.06	−0.09	−0.48	0.05	−0.08	1.00											
NO_3	0.22	0.54	−0.45	−0.42	−0.27	−0.58	−0.15	−0.20	1.00										
HCO_3	0.09	0.55	−0.01	−0.65	−0.31	−0.40	0.56	0.05	0.27	1.00									
F	0.53	0.66	−0.53	−0.53	−0.23	−0.57	−0.24	−0.01	−0.46	0.17	1.00								
K	0.03	−0.05	0.51	−0.05	0.77	0.40	0.46	−0.48	−0.23	0.06	−0.09	1.00							
Na	0.20	0.62	−0.40	−0.54	−0.69	−0.65	0.18	0.22	0.38	0.64	0.38	−0.47	1.00						
Fe	0.16	0.28	−0.74	0.07	−0.45	−0.53	−0.53	−0.11	0.36	−0.11	0.47	−0.46	0.24	1.00					
Ca	−0.05	−0.27	−0.34	0.28	−0.34	−0.15	−0.63	−0.04	−0.23	−0.27	0.07	−0.55	−0.06	0.49	1.00				
Mg	0.08	0.09	−0.23	0.18	0.37	−0.11	−0.19	−0.85	0.31	−0.21	0.20	0.29	0.25	0.33	0.23	1.00			
Mn	−0.03	0.07	−0.05	−0.09	−0.13	−0.12	0.11	−0.07	0.18	0.10	−0.21	−0.26	0.07	−0.19	0.03	0.13	1.00		
TH	−0.08	0.22	−0.15	−0.05	0.18	−0.13	−0.14	−0.45	0.39	0.05	0.38	0.26	−0.08	0.40	0.01	0.48	−0.28	1.00	
SiO_2	−0.17	−0.01	−0.35	0.26	−0.65	−0.20	−0.40	0.50	0.14	−0.89	−0.1	−0.84	0.37	0.41	0.45	−0.25	0.06	−0.29	1.00

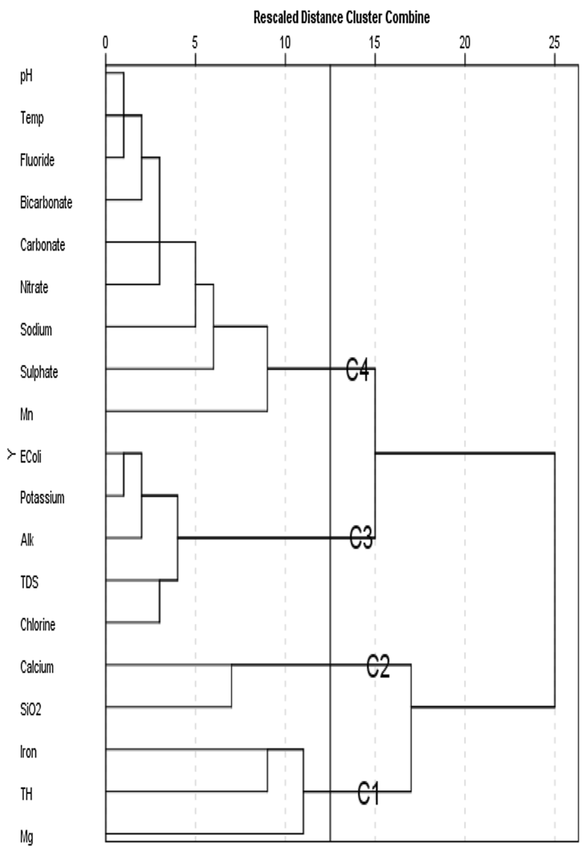

Fig. 2 Cluster grouping based on ground water parameters

Table 4 Cluster grouping of the water quality parameters

Cluster 1	Cluster 2	Cluster 3	Cluster 4
pH	TDS	EC	Cl^-
Temp		$SO_4{}^{2-}$	
AlK		$HCO_3{}^-$	
$CO_3{}^{2-}$		Na^+	
$NO_3{}^-$		TH	
F^-			
K^+			
Fe^{2+}			
Ca^{2+}			
Mg^{2+}			
Mn			
SiO_2			

results revealed that 16% of the samples could be classified as Ca–Cl type, 36% of the samples as Na–Cl type, and 48% as Mixed type. Studies including Aly (2015) and Al-Omran et al. (2015) also found comparable results by

Table 5 Hydro-chemical features of cluster grouping

Parameter	Cluster 1	Cluster 2	Cluster 3	Cluster 4	WHO limit
pH	7.35	6.40	6.93	6.42	6.5–8.5
Temp	27.34	23.12	26.22	24.70	NA
AlK	11.01	55.01	29.27	45.67	NA
TDS	987.32	2112.32	807.74	1531.35	1000
EC	497.34	3310.11	1343.29	2603.24	1500
Cl^-	32.59	564.12	136.26	414.46	250
$SO_4{}^{2-}$	567.89	567.34	468.40	409.59	250
$CO_3{}^{2-}$	24.98	15.79	20.29	18.08	NA
NO^{3-}	6.05	0.00	4.94	2.89	50
HCO^{3-}	656.43	326.78	549.09	358.79	500
F^-	1.81	0.47	1.40	1.07	1.5
K^+	2.07	8.70	5.30	7.66	12
Na^+	515.45	55.98	358.51	85.38	50
Fe^{2+}	2.34	0.07	1.32	0.49	0.3
Ca^{2+}	67.56	23.87	75.31	51.08	300
Mg^{2+}	56.43	21.36	65.73	115.03	50
Mn	0.04	0.01	0.03	0.02	0.4
TH	231.67	213.56	641.16	505.01	500
SiO_2	8.02	0.67	4.56	2.99	NA

Table 6 Statistical characteristics of discriminant grouping and WHO limit

Parameters	Discriminant analysis		
	Mean and standard deviation		WHO limit
	Dry season	Raining season	
pH	6.67 ± 0.67	6.87 ± 0.57	6.5–8.5
Temp	25.25 ± 1.57	26.32 ± 0.94	
AlK	31.20 ± 18.55	41.13 ± 3.56	
TDS	1433.76 ± 459.38	519.96 ± 64.71	1000
EC	1789.31 ± 1040.08	1811.21 ± 526.37	1500
Cl^-	253.27 ± 221.27	211.14 ± 85.83	250
$SO_4{}^{2-}$	359.99 ± 297.47	578.08 ± 288.70	250
$CO_3{}^{2-}$	17.74 ± 9.88	22.14 ± 4.85	
$NO_3{}^-$	4.13 ± 2.64	4.31 ± 1.87	50
$HCO_3{}^-$	403.66 ± 141.64	595.97 ± 111.17	500
F^-	1.23 ± 0.54	1.36 ± 0.29	1.5
K^+	5.61 ± 3.00	6.97 ± 2.01	12
Na^+	211.53 ± 189.41	333.17 ± 191.13	50
Fe^{2+}	1.51 ± 1.23	0.29 ± 0.65	0.3
Ca^{2+}	90.95 ± 83.85	30.04 ± 17.24	300
Mg^{2+}	118.80 ± 118.05	30.49 ± 16.90	50
Mn	0.03 ± 0.02	0.03 ± 0.03	0.4
TH	676.92 ± 668.83	464.99 ± 120.27	500
SiO_2	4.88 ± 3.44	2.65 ± 2.36	

Table 7 Matrix, function coefficient and canonical discriminant based on water quality parameters

Parameters	Discriminant function classification			
	Function		Canonical	Structure matrix
	Dry season	Rain season		
pH	1429.90	1350.94	1.41	− 0.04
Temp	112.59	79.71	− 1.27	− 0.11
AlK	41.07	51.86	− 4.47	− 0.04
TDS	1.19	− 0.03	12.42	0.16
EC	− 0.25	− 0.16	− 2.00	0.04
Cl^-	0.73	1.46	− 3.71	0.06
SO_4^{2-}	− 0.29	− 0.49	1.64	− 0.05
CO_3^{2-}	74.03	81.57	− 1.77	− 0.10
NO_3^-	34.19	7.78	1.77	− 0.31
HCO_3^-	0.99	0.96	0.14	0.13
F^-	− 1229.57	− 1451.05	2.87	− 0.13
K^+	− 281.56	− 1451.05	− 2.45	0.12
Na^+	0.91	1.38	− 2.53	0.04
Fe^{2+}	140.10	137.63	0.07	− 0.20
Ca^{2+}	− 2.59	− 1.28	− 2.46	0.14
Mg^{2+}	8.39	8.01	0.99	0.06
Mn	− 7644.05	− 8120.77	0.30	− 0.28
TH	0.66	0.53	1.85	0.03
SiO_2	− 161.00	− 163.48	0.22	0.04

identified major water types and their ionic composition of different groundwater water samples.

The sodium–chloride and calcium–chloride are rich in these regions because the parent rock are of Fissile Hornblende Biotite gneiss and Charnockite, which have composed of sodium and calcium rich minerals (Arulbalaji and Gurugnanam 2017).

Series and time series plot, are data visualization tools that demonstrates data points at successive intervals of time. The vertical and horizontal points on the chart corresponds to quality and time, respectively, as well as quickly identify spot, trend in cyclical pattern over a given period of time. Water analysis result from the study area is plotted in (Figs. 7 and 8), According to the piper diagram during dry season, TDS concentration has highest time series value between 1200 and 2100 mg/l, while the mean and SD are 1433.76 and 459.38, respectively. Hence, this component possible represents the influence of high organic and inorganic substances in molecular or ionized suspended form, from percolation of man-made products such as pesticides and fertilizers into the soil, road salt, toxic chemicals from underground storage tanks, used motor oil, and untreated waste from septic tanks. This in turn reduces water utility for drinking, irrigation as well as agriculture purposes.

Table 8 Mean comparative analysis obtained from the water quality parameters

Parameters	Mean comparative test					
	One way Anova			One sample T test		
	Unstandardized coefficients	t	Sig.	t	95% interval differences	
					Lower	Upper
pH	0.18 ± 0.51	0.36	0.73	53.91	6.49	7.01
Temp	0.03 ± 0.03	1.05	0.33	89.36	25.08	26.27
AlK	0.01 ± 0.00	3.29	0.02	11.59	28.91	41.44
TDS	− 0.00 ± 0.00	− 12.71	0.00	9.25	829.89	1306.60
EC	5.71E−05 ± 0.00	1.11	0.31	10.48	1443.07	2150.68
Cl^-	0.01 ± 0.00	1.96	0.10	6.63	162.85	309.98
SO_4^{2-}	0.00 ± 0.00	− 1.56	0.17	7.26	320.16	574.30
CO_3^{2-}	0.01 ± 0.01	1.54	0.17	11.61	16.03	22.96
NO_3^-	− 0.02 ± 0.01	− 2.23	0.07	9.04	3.24	5.16
HCO_3^-	1.49E−05 ± 0.00	0.08	0.94	15.03	414.56	546.61
F^-	− 0.23 ± 0.10	− 2.36	0.06	14.16	1.09	1.47
K^+	0.01 ± 0.02	0.74	0.49	11.44	5.04	7.26
Na^+	0.00 ± 0.00	2.34	0.06	6.65	179.38	341.00
Fe^{2+}	0.01 ± 0.03	0.23	0.83	4.28	0.53	1.51
Ca^{2+}	0.01 ± 0.00	2.36	0.06	4.64	36.99	96.18
Mg^{2+}	5.82 E−05 ± 0.00	0.12	0.91	4.14	41.82	125.14
Mn	− 0.70 ± 1.21	− 0.58	0.59	5.73	0.02	0.03
TH	− 7.42E−05 ± 0.00	− 1.77	0.13	5.62	374.66	809.63
SiO_2	− 0.01 ± 0.02	− 0.54	0.61	6.24	2.67	5.31

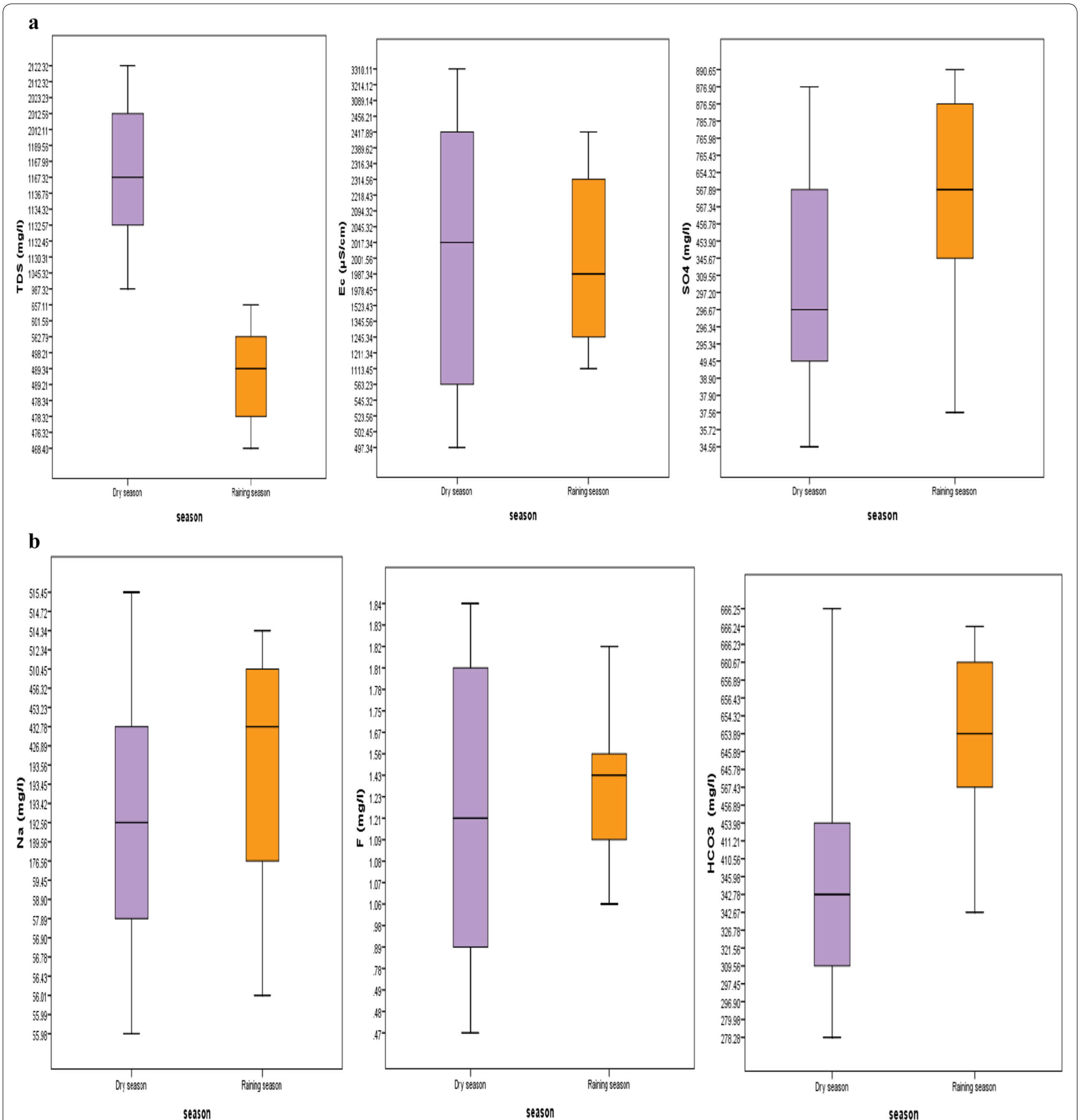

Fig. 3 **a** Spatial variations of TDS, EC and SO_4^{2-}. **b** Spatial variations of Na^+, F^- and HCO_3^-

Conclusions

This study reported the microbial and chemical analyses parameters of twenty-five samples used for cooking, agricultural, drinking and domestic purposes in Abuja, Nigeria. The results revealed that the water quality parameters showed wide spatial variations with pH and temperature having the least variability of 5.9 and 4.5, respectively. Majority of the water samples (64%) is within the slightly acidic range signifying dissolution of composite basement rocks. The very high concentration of EC in the Abuja water samples were identified as a serious source of health concern. Violations of water standards were in order of $Na^+ > SO_4^{2-} > EC > Mg^{2+} > TDS > Fe^{2+} > HCO_3^- > F^- > TH > Cl^-$, which proposes interface among sodium bearing rocks.

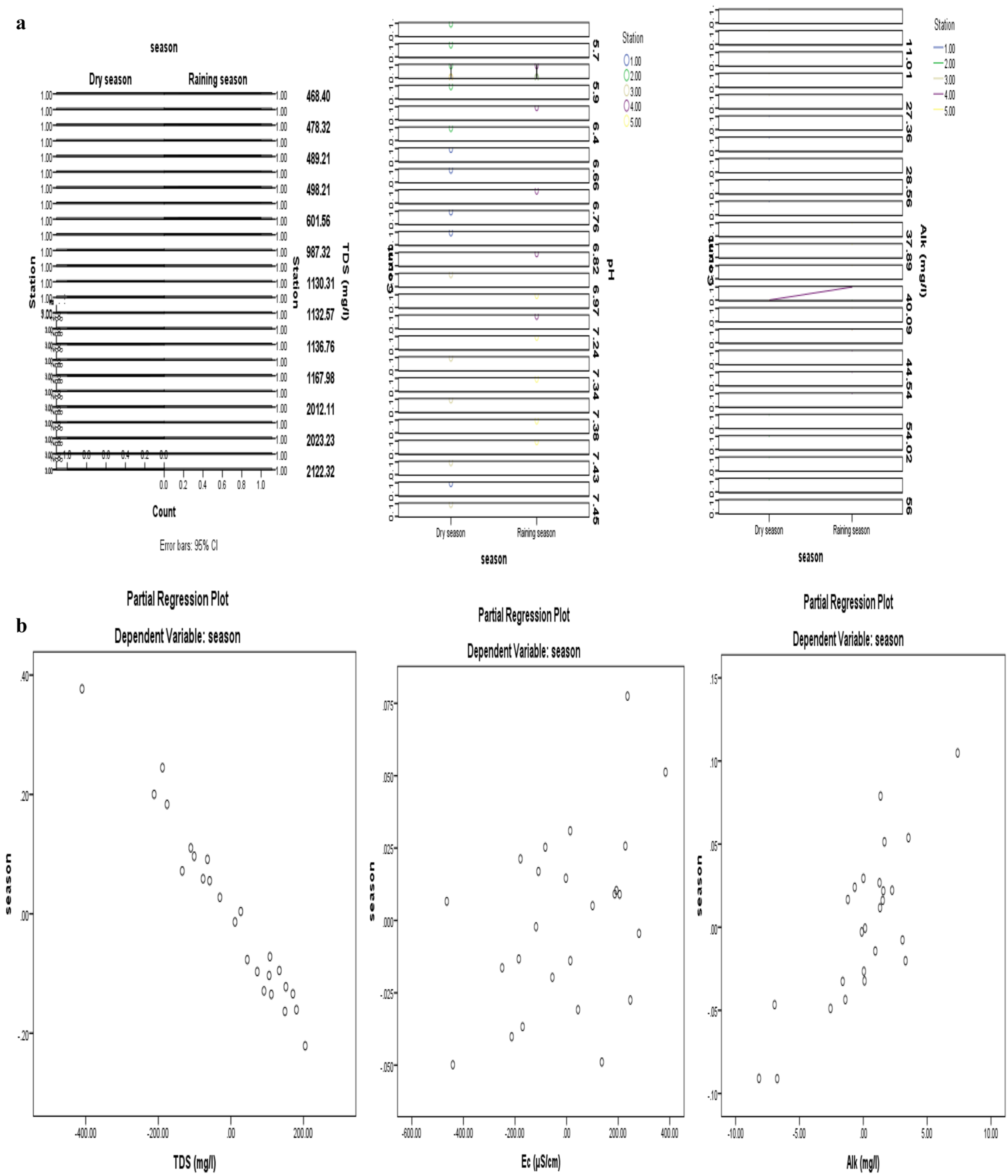

Fig. 4 **a** X graph of TDS, TH and Alk. **b** Partial regression plot of TDS, EC and Alk

The groundwater classifications can be ranked as Ca–Cl < Na–Cl < Mixed types demonstrating general mixed type. Weathering, anthropogenic activities, such as waste management and agriculture as well as ion exchange, were the main sources of hydro-chemical dissimilarity in the study area. The findings of this study will be of

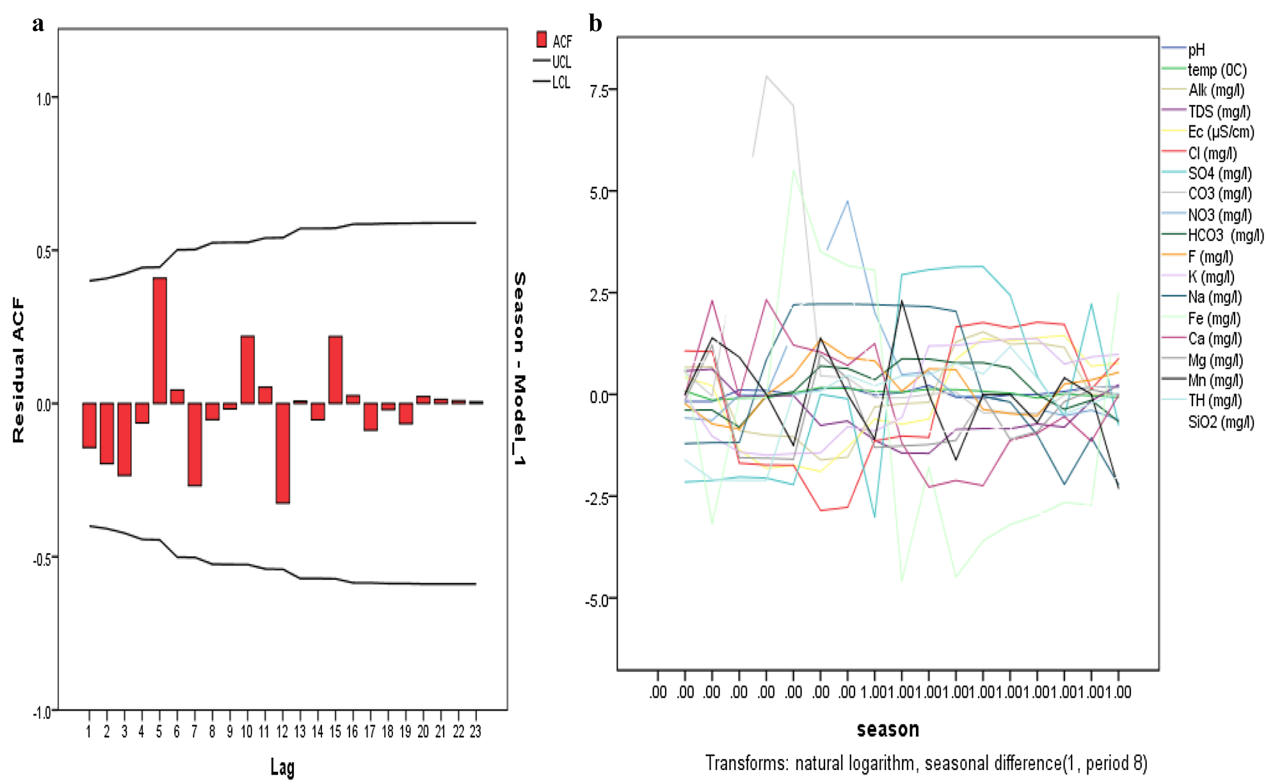

Fig. 5 Season: **a** Model. **b** Sequence plot in the ground water quality of Abuja

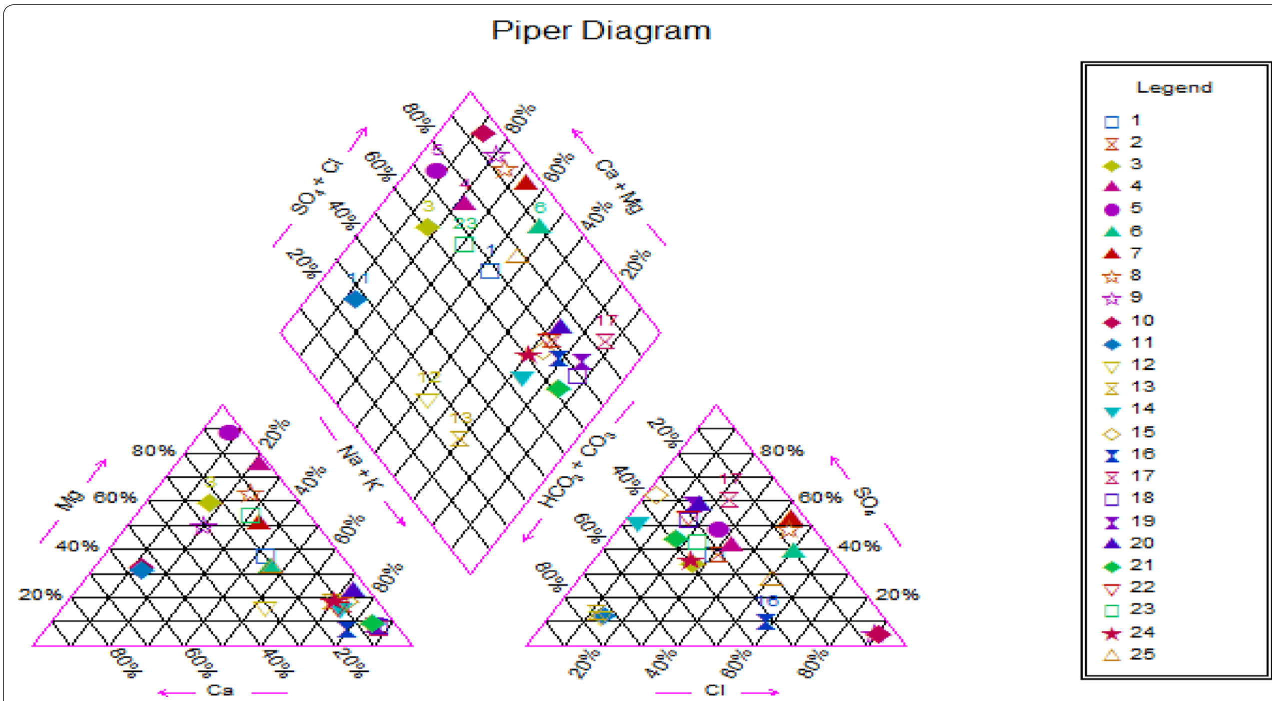

Fig. 6 Piper diagram displaying the hydrological facies of the borehole samples

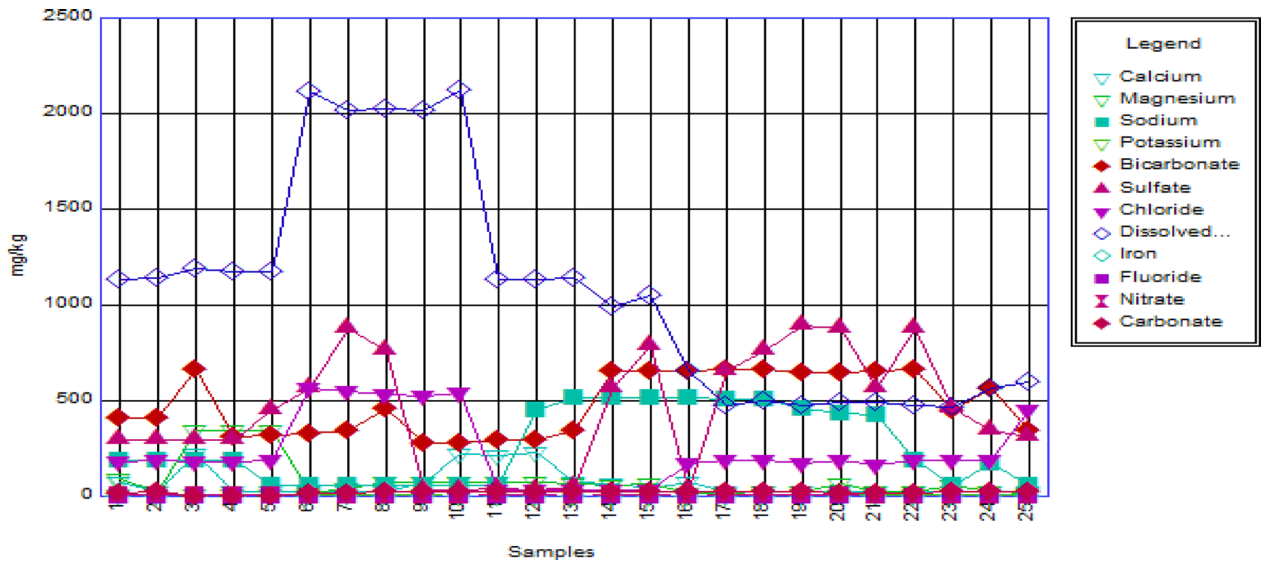

Fig. 7 Series plot showing the hydrological facies of the borehole samples

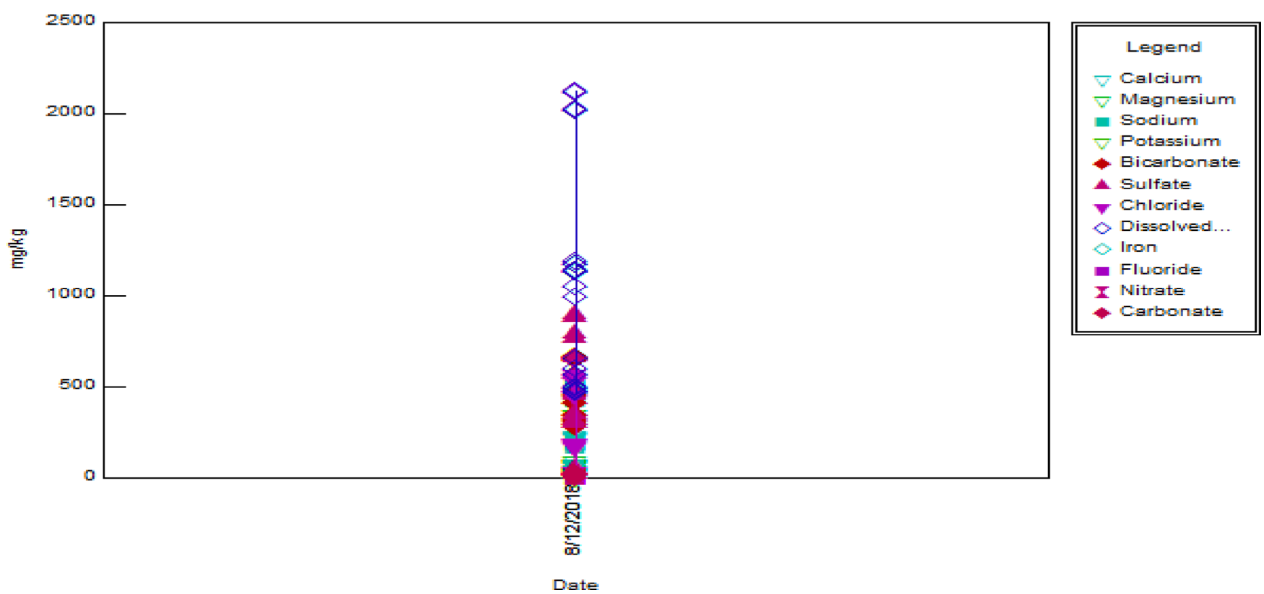

Fig. 8 Time series plot display the hydrological facies of the borehole samples

important to the water management authorities to comprehend the hydrochemistry of the groundwater components in the area for efficient and viable management.

Authors' contributions
Main author contribution about 70%. Both authors read and approved the final manuscript.

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