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Multivariate Analysis of Seasonal Variation in Groundwater Quality within Federal University of Agriculture Abeokuta, Southwestern Nigeria

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Abstract
This research work was aimed at analyzing the data of the seasonal variation of groundwater quality in the Federal University of Agriculture Abeokuta (FUNAAB) environment using descriptive statistics and a covariance matrix analysis of the data set for both rainy and dry seasons to see the effect of the water quality parameters on each other. Cluster analysis was also carried out on the data set to check the level of the Euclidean distance between the water quality parameters. The data used for this analysis was secondary data obtained from groundwater sources (ten wells) within the University environment during the rainy and dry seasons respectively. It was observed that there is a slight variation in the quality of groundwater in the FUNAAB environment as regards the dry season and the rainy season. In the result of the cluster analysis, the water quality parameters are clustered into seven groups for the dry season and eight groups for the rainy season which indicate that the dissimilarities in the data set increase during the rainy season. It was observed that for the dry season covariance data, 36% of the values have a negative relationship within themselves and 64% has a positive relationship, as compared to the rainy season data which possesses a 31% negative relationship and a 69% positive relation. This implies that there is only a 5% variation in the entire data set of the dry season and the raining season as regards the interdependence of the water quality parameters on each other.

Keywords: Groundwater, Physico-Chemical, Water Quality, Wells

INTRODUCTION
Water is one of the essential inputs for the sustenance of all living beings. The need for water for various purposes among which includes; utilization for drinking, irrigation, and industrial purposes, is increasing at a fast rate. This is due to the continual increase in population, rapid urbanization with the lifestyle change, and growing industrialization (Gajbhiye *et al.*, 2014: Sharma *et al.*, 2014).

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The principal sources of water for human use are lakes, rivers, soil moisture, and relatively shallow groundwater basins. Freshwater is renewable only by snow and rainfall, at the rate of about 40- 50, 000 km^3 per year (European Commission, 2003).
The total amount of water available to the earth is infinite and conserved. Although the total volume of water in the global hydrologic cycle remains constant, the distribution of this water is continually changing on continents, in regions, and in local catchments (Han, 2010). With growing populations, changing weather patterns, and increasing pollution of surface water bodies, countries across the world are relying more and more on finite groundwater reserves built up over centuries, for households, agricultural and industrial needs. (International Water Management Institute, 2006).

Groundwater is water that exists in the pore spaces and fractures in rocks and sediments beneath the earth's surface. It originates as rainfall or snow and then makes its way back to surface streams, lakes, or oceans (Han, 2010). Groundwater has become an important source of drinking water worldwide and especially in developing countries according to Christiana and Amobichukwu, (2014). The 2006 population census in Nigeria shows that 49.4% of households sampled depend on groundwater as the main source of water for domestic use (Christiana and Amobichukwu, 2014). This is because groundwater is thought to be free of the pathogens widely found in surface waters (Amini, 2011).

However, groundwater may contain a wide variety of natural and human-induced chemicals (USGS, 2016). Arsenic and Fluoride concentration in groundwater at Ibadan, Oyo state South-West Nigeria has been found to exceed the WHO (2011) recommended concentration for drinking water (Christiana and Amobichukwu, 2014). A Statistical Assessment of Groundwater Quality in Ogbomosho Southwest Nigeria also reveals an overall water quality index corresponding to poor water. Quality parameters (calcium, chromium, copper, fluoride, iron, manganese, nickel, and zinc) exceed their respective maximum permissible limit in some locations according to Olasehinde, *et al.,* (2015).

Water quality plays an important role in groundwater protection and quality conservation. Hence it is very important to assess the water quality not only for its present use but also from the viewpoint of a potential source of water for future consumption. There is a growing concern about the deterioration of water quality due to geogenic and anthropogenic activities. The quality of water is identified in terms of its physical, chemical, and biological parameters. Polluted groundwater cannot achieve a balanced ecosystem, in which living things and the environment interact beneficially with one another. Water quality plays a critical role in this relationship (Ntengwe, 2006), as it is key to the maintenance of a well-balanced environment.

MATERIALS AND METHODS

Description of Study Area

The Federal University of Agriculture, Abeokuta is located at Odeda Local Government of Ogun State, Southwestern Nigeria on latitude 70 30' N and longitude 30 54' E and lies within a forest-savanna transition zone. There is a very distinct climatic feature of a wet season which starts around March and ends in October while the dry season commences from November and ends in February with a mean annual rainfall of 1113.1mm (Badmus and Olatinsu, 2010; Ufoegbune and Fabiyi, 2016). It has a mean monthly temperature that varies from 22.9^{0}C in August to 36.32^{0}C in March. The relative humidity is high ranging from 75.52% in February to 88.15% in July. The University occupies a pre-Cambrian basement complex which is mainly composed of Igneous rocks and has streams/ rivers including rivers Oshinko, Ole/Alakata, Arakanga, and Tigba/Ajigbayin (Jones. 1964; Ufoegbune and Fabiyi, 2016).

Sample Collection and Physico-chemical Analysis

A total of twenty water samples for the physic-chemical analysis were collected from ten sampling stations made up of groundwater (GW) sources such as wells and borehole sources located within the University campus and using tightly closed 1-liter plastic bottles that had been previously washed with ethanol and subsequently rinsed with deionized water. The collections were carried out in August, 2020 and January, 2021, representing the peaks of both the dry and rainy seasons. In-situ measurements were performed on the collected samples to determine ph, electrical conductivity (EC), temperature, and total dissolved solids (TDS). Other tests were conducted in the laboratory including alkalinity, calcium hardness, magnesium hardness, total hardness, potassium and nitrates using measurements described in the standard methods for the Examination of Water and Wastewater (APHA 2005).

Descriptive Statistics

Descriptive statistics of each data set was carried out for both the rainy season and the dry season to obtain the minimum value, maximum value, mean and standard deviation of each set of water quality parameter.

Covariance Matrix;

The covariance matrix was used to identify relationships between all the water quality parameters and their dependence on each other.

Cluster Analysis;

This analysis was used to search for patterns in the data set by grouping the (multivariate) observations into clusters. This was aimed at finding an optimal grouping for which the observations within each cluster are similar.

RESULTS AND DISCUSSION

A total of ten stations were selected for sample collection for the duration of the fieldwork. These locations are listed below in table 1.

Table 1: Location of Sample Stations

Sample Station	Location	Description
Ss1	Umar Kabir hostel	Borehole
Ss 2	Iyalode hostel	Borehole
Ss 3	Civil Engineering building	Borehole
Ss 4	Marble hostel	Borehole
Ss 5	Directorate of University farms 1	Well
Ss 6	Non-Academic Staff Union building	Well
Ss 7	University mosque	Well
Ss 8	College of Environmental Resources Management (COLERM)	Borehole
Ss 9	Directorate of University farms 2	Well
Ss 10	Directorate of University farms 3	Well

In table 2, below, is listed the maximum allowable limits by two selected regulatory bodies; the World Health Organization (WHO) and the Nigerian Standard of Drinking Water Quality (NSDWQ).

Table 2: Water Quality standards

S/no	Water quality parameters	WHO standards	NSDWQ standards
1.	pH	6.5 – 8.5	6.5 – 8.5
2.	Electrical Conductivity (μS/cm)	1250	1000
3.	Temperature (°C)	12 - 25	Ambient
4.	Alkalinity (Mg/l)	-	-
5.	Total Hardness (Mg/l)	50	150
6.	Nitrates (Mg/l)	50	50
7.	Potassium (Mg/l)	20	
8.	Calcium (Mg/l)	75	150
9.	Magnesium (Mg/l)	-	0.20
10.	Total Dissolved Solids (Mg/l)	1000	500

Source: WHO (2011); (NSDWQ, 2007)

The summary of the water quality results for both seasons is presented below in tables 3 and 4.

Table 3: Summary of water quality data for the wet season.

Sample stations	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Water quality Parameters										
pH	7.25	6.91	7.32	6.85	8.01	7.70	6.58	7.71	6.23	7.01
EC (μS/cm)	117	179	431	105	162	360	168	129	224	170
TEMP (°C)	28	27.9	28.2	28.0	28.2	27.8	27.6	27.5	28	28.2
ALKALINITY(Mg/l)	12	11	11	14	12	13	14	11	13	14
TOTAL HARDNESS(Mg/l)	28	63	148	40	48	105	69	58	66	71
NITRATE (Mg/l)	1.69	2.29	2.65	6.10	11.9	3.81	3.51	2.38	2.48	3.00
POTASSIUM (Mg/l)	2.51	4.63	2.77	3.49	1.69	1.59	1.99	1.54	2.76	5.56
CALCIUM (Mg/l)	10.8	11.7	16.7	5.18	1.58	13.4	5.9	9.63	9.04	3.56
MAGNESIUM(Mg/l)	0.58	3.91	2.74	0.62	0.79	7.51	2.63	1.73	3.65	5.92
TDS(Mg/l)	61	96	241	58	94	168	88	86	115	97

Table 4: Summary of water quality data for dry season

Sample stations	1	2	3	4	5	6	7	8	9	10
Water Quality Parameters										
pH	6.24	6.61	6.04	7.29	7.07	6.25	6.63	6.09	6.05	6.44
EC (μS/cm)	108	185	446	110	188	325	184	129	220	172
TEMP (°C)	28.2	28.1	28.2	28.2	28.2	28.2	28.0	28.1	28.1	28.4
ALKALINITY (Mg/l)	12	12	11	11	17	13	16	12	15	15
TOTAL HARDNESS(Mg/l)	26	66	138	34	42	100	66	52	66	68

NITRATE (Mg/l)	1.72	2.09	1.45	5.90	10.92	2.81	3.63	2.36	2.45	2.90
POTASSIUM (Mg/l)	2.52	4.48	26.97	2.49	1.68	1.59	1.99	1.54	2.76	5.56
CALCIUM (Mg/l)	9.85	11.86	17.60	4.18	1.48	19.32	13.4	5.9	9.63	3.56
MAGNESIUM(Mg/l)	0.17	3.86	12.7	0.46	0.49	7.05	2.33	1.73	3.56	5.29
TDS (Mg/l)	52	92	228	52	94	166	83	68	110	79

Descriptive Statistics

Tables 5 and 6 give the descriptive statistics of the water quality data for both wet and dry seasons including the mean of the data, mode, standard variation, the minimum and maximum value of data. It could be seen from the results that during the wet season, pH ranged from 6.23 to 8.01 with a mean value of 7.10 and 6.05 to 7.29 during the dry season with a mean value of 6.47. This is an indication that most of the GW samples were slightly alkaline but were within the maximum permissible limits as stipulated by WHO and NSDWQ for drinking purposes. These values appeared higher than the values obtained from parts of Bayelsa State, South-southern Nigeria (Okiongbo and Douglas, 2013) with values ranging from 5.8 to 6.9 and values lower than the results obtained from Ekiti with a range of values of 8.3 to 9.6 (Talabi and Tijani, 2010).

The temperature values for the wet season ranged from 27.5 °C to 28.2 °C with a mean value of 27.9 °C while in the dry season it ranged from 28.1 °C to 28.4 °C with a mean value of 28.2 °C. These results when compared to the meteorological data reports of the study area, indicates an influence of local weather conditions and could be inferred as ambient.

The mean EC value during the wet season was 204.5 µS/cm and ranged from 105 µS/cm to 431 µS/cm while in the dry season, the mean value was 206.7 µS/cm and ranged from 108 µS/cm to 446 µS/cm. These values were observed to be below the WHO and NSDWQ regulatory limits. The low EC values may have stemmed from the fact that the study area occupies a basement complex that is primarily of igneous rock origin. The low values indicate a low level of salinity within the GW source, thereby inferring the positive suitability as a potable water source (Langeneggar, 1990; Omaka *et al.,* 2015). The values were far below that obtained in GW samples obtained from Ngbo community in Ebonyi State, South-Eastern Nigeria (Nwankwoala and Udom, 2011).

The mean TDS values for the wet season were 110.4 Mg/l and ranged from 58 Mg/l to 241 Mg/l while for the dry season, the mean TDS value was 102.4 Mg/l and ranged from 52 Mg/l to 228 Mg/l. The values were below the accepted tolerable limits as stipulated by WHO and NSDWQ. However, these values were lower than those obtained from GW samples collected from Ngbo community in Ebonyi State with mean values of 336.9 Mg/l (Omaka, 2014).

The Alkalinity values ranged from 11 Mg/l to 14 Mg/l during the wet season and had a mean value of 12.5 Mg/l while its equivalent values during the dry season ranged from 11 Mg/l to 17 Mg/l with a mean value of 13.4 Mg/l. The relatively lower mean concentration may have stemmed from the dissolution of mineral substances during rainfall and its subsequent dilution. The basement complex accounts for the low dissolution of substances in water because of igneous rock origin.

The total hardness had values ranging from 28Mg/l to 148Mg/l with a mean value of 69Mg/l during the wet season and ranged from 26 Mg/l to 138 Mg/l with an average value

of 65.8 Mg/l during the dry season. A large percentage of the GW samples collected exceeded the permissible stipulated by WHO but were all within the NSDWQ limits.
The mean and range values for nitrates, calcium, and potassium in both seasons all fell within the tolerable limits of WHO and NSDWQ. A cursory look at the magnesium concentrations shows that show that some sample locations during both the wet and dry seasons had values exceeding the limit of 0.2 Mg/l as stipulated by NSDWQ regulatory limits.

Table 5: The result for the descriptive statistics analysis for the wet season.

Field	N	MEAN	STD	MIN	MAX	SUM
pH	10	7.10	0.524	6.23	8.01	71.63
EC	10	204.5	107.5	105	431	2045
TDS	10	110.4	55.2	58	241	1104
TEMP	10	27.9	0.249	28.0	28.2	279.4
ALKALINITY	10	12.5	1.269	11	14	125
TOTAL HARDNESS	10	69.6	34.4	28	148	696
NITRATE ION	10	3.98	1.802	1.69	11.9	39.82
POTASSIUM ION	10	2.85	1.432	1.54	4.63	28.49
CALCIUM ION	10	8.81	4.65	1.58	11.7	88.13
MAGNESIUM ION	10	3.01	2.73	0.58	7.51	30.1

Table 6: The result for the descriptive statistics analysis for the dry season.

Field	N	MEAN	STD	MIN	MAX	SUM
pH	10	6.47	0.4327	6.05	7.29	64.7
ELECTRICAL CONDUCTIVITY	10	206.7	104.9	108	446	2060.7
TOTAL DISSOLVED SOLIDS	10	102.4	55	52	228	1020.4
TEMPERATURE	10	28.2	0.11	28	28.4	280.2
ALKALINITY	10	13.4	2.17	11	17	130.4
TOTAL HARDNESS	10	65.8	32.89	26	100	658
NITRATE ION	10	3.62	2.85	1.45	10.92	36.2
POTASSIUM ION	10	5.16	7.86	1.54	26.9	51.6
CALCIUM ION	10	9.68	2.70	1.48	19.3	96.8
MAGNESIUM ION	10	3.77	3.87	0.17	12.74	37.7

Covariance Matrix

This analysis as carried out on the data and identifies the pattern during seasonal variation. It shows the dependence of one water quality parameter on the other. This provides a series of results of both negative and positive values that is arranged in matrix form. A positive covariance value shows that two water quality parameter increases or decreases together but a negative covariance value indicates that as one value increases the other decreases. The covariance matrix table for both the wet season (Table 7) and the dry season (Table 8) is shown below.
Comparing the dependence of the water quality parameters for the covariance matrix for both the dry season and rainy season, we observe that the interdependence level changes in the parameters itself. For example, pH and alkalinity possess a positive relationship for the rainy season data but a negative relationship for the dry season data. This same pattern can also be found in other quality parameter pair. It can also be observed that for the dry season covariance data, thirty-six per cent of the data has a negative relationship within themselves while the rainy seasonal data has a thirty-one per cent negative covariance relationship.

Table 7: Covariance matrix for measured parameters in groundwater samples for wet season

	pH	EC	TDS	ALK	TH	N	K	Ca	Mg
pH	0.275								
EC	8.64	41820							
TDS	5.52	5816.7	12188						
ALK	-0.568	78.03	5.54	156.3					
TH	1.142	3523.7	-0.01	99.5	4844				
N	0.827	-42.11	-23.5	-5.57	-23.6	15.84			
K	0.96	-5.89	5.9	0.358	-2.45	-0.41	8.12		
Ca	-2.41	351.1	176	-0.62	43.5	-9.01	-1.52	77.6	
Mg	-5.04	113.4	54.9	0.98	40.8	-2.3	-0.08	2.92	9.06

Table 8: Covariance matrix for measured parameters in groundwater samples for dry season.

	pH	EC	TDS	ALK	TH	N	K	Ca	Mg
pH	0.187								
EC	11.63	11010							
TDS	-10.75	52649	3025						
ALK	0.185	-17.87	-19.84	4.708					
TH	-7.181	3305	1718.9	73.59	1082				
N	0.953	-57.64	-37.49	3.23	-37.75	2.102			
K	-1.163	639.5	330.5	5.103	197.2	-6.981	61.78		
Ca	-1.383	437.8	257.3	3.28	130.5	-10.91	19.90	7.290	
Mg	-0.703	436.2	184.9	-1.383	117.9	-5.02	24.17	16.80	14.94

Cluster Analysis

The hierarchical tree diagram provides an effective visual condensation of the clustering results. The hierarchical tree diagram is one of the most commonly used methods of determining the number of clusters. It is also useful in spotting outliers, as these will appear as one member clusters that are joined later in the clustering process. The objective of the cluster analysis is to separate the observations into different groups (clusters) so that the members of any one group differ from one another as little as possible, whereas observations across clusters tend to be dissimilar.

The cluster analysis carried out for this data is the single linkage method which employs the Euclidean distance formula that tends to show the minimum distance between cluster groupings as they are linked.

Table 9: Cluster analysis for measured parameters in groundwater samples for wet season.

CLUSTER GROUP	PARAMETER	ECLIDEAN DISTANCE	SPATIAL HETEROGENEITY
CLUSTER 1	pH, N	2	349
CLUSTER 2	C1, Mg	15	336
CLUSTER 3	C2, K	17	334
CLUSTER 4	C3, Ca	21	330
CLUSTER 5	C4, ALK	23	328
CLUSTER 6	TH, TDS	150	201
CLUSTER 7	C5, C6,	194	157
CLUSTER 8	C7, EC	351	0

Table 10: Cluster analysis for measured parameters in groundwater samples for dry season.

CLUSTER GROUP	PARAMETER	ECLIDEAN DISTANCE	SPATIAL HETEROGENEITY
CLUSTER 1	K, Mg	7	333
CLUSTER 2	C1, N	12	328
CLUSTER 3	C2, PH	13	327
CLUSTER 4	C3, ALK, Ca	18	322
CLUSTER 5	C4, TDS	157	183
CLUSTER 6	C5, TH	154	186
CLUSTER 7	C6, EC	340	0

CONCLUSION

It is observed that from the statistical analysis carried out on the data that there is a slight variation in the quality of ground water in FUNAAB environment as regards the dry season and the raining season.

In the result of the cluster analysis, the water quality parameters are clustered into seven groups for the dry season and eight groups for the raining season. This goes to indicate that the dissimilarities in the data set increases during the raining season.

It is observed that for the dry season covariance data, 36% of the values have a negative relationship within themselves and 64% has a positive relationship, as compared to the rainy season data which possesses a 31% negative relationship and a 69% positive relation.

This implies that there is only a 5% variation in the entire data set of the dry season and the raining season as regard the inter dependence of the water quality parameters on each other.

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