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Groundwater Characterization and Ecological Assessment: A Case Study of Lagos State University, Ojo, Lagos

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Abstract: The only source of water supply in Lagos State University Ojo, Lagos State is sub surface water. Despite being under possible threats (natural and anthropogenic), the water is used for irrigation, domestic, recreation and drinking purposes, hence the need for quality verification so as to be sure of the safety of man. Therefore, this study sought the physicochemical quality assessment of groundwater in Lagos State University, main campus, employing standard procedures of American Public Health Association. Groundwater samples collected bimonthly from twenty five (25) wells were chemically investigated for pH, acidity, alkalinity, electrical conductivity, total dissolved solids, total hardness, anions and trace metals. Groundwater data generated from chemical laboratory were subjected to factor and cluster analyses. Six principal components (PCs) extracted 79.3 % of the total variance and five clusters of wells with distinct characteristics were also revealed. The order of exceedance of some quality parameters above WHO limits was NO_3^{2-} > Mg > Fe > SO_4^{2-} >TH, raising the question of safety on its potability. The sodium adsorption ratio (SAR), however showed that over 95% of the water samples analyzed are fit for irrigation purposes, thus portends safety for human health. The impact of agricultural activities among others are apparent on the quality of groundwater, hence the need for regular monitoring by relevant agency, in order to safeguard the safety of man and ensure sustainability of the environment.

Keywords: Groundwater, Factor Analyses, Cluster Analyses, Lagos State University, Sodium Adsorption Ratio

1. Introduction

Water remains a vital substance upon which quality lives rest on [1]. The global supply water is sourced from either surface water including rivers, streams, and oceans or groundwater including hand dug shallow and deep well as well as borehole.

There are various factors that account for the preference of groundwater as a choice source of water supply. These factors include, its excellent natural quality (adequate for potable need with little or no treatment), convenient availability of source of water close to where it is needed and the relatively low capital cost for its development [2]. Groundwater is also less vulnerable to various sources of pollutions unlike surface water, possibly as a results of less direct interference with human induced activities [3]. United Nation Environmental Pollution (UNEP) [4], reported, that fresh water occupies about 3.0 % of the entire global water and two-third (2/3) of the fresh water is groundwater or under groundwater. Water covers about seventy one percent of the Earth's surface. Groundwater accounts for over 40 percent of public water supplies in the USA, and 96 percent of domestic water supplies to the rural areas [5]. Some major cities in Latin America and Europe depends totally on groundwater. UNEP, [6] listed various developed countries that depend largely on groundwater resources. Hundreds of millions of people in Africa and Asia, rely solely on underground source of water [7].

Lagos State of Nigeria through Lagos State Water Corporation (LSWC) abstracts over 220 million liters of water daily which covers about 37% of its population [8]. Over 8.3 million of Lagos residents do not have access to municipal water, hence they rely solely on groundwater (shallow, privately hand dug wells and boreholes) for their domestic and industrial use. Lagos State University (LASU) was established in 1984 and started water production in 2005 with her micro water works that has maximum production capacity of 100000 liters/ per day. The Water quality status is a way to appraise the condition of water in respect of the human need or a purpose. The quality status of the groundwater abstracted from shallow, hand dug wells and boreholes is often dictated by various threats from pollution sources including urban runoff, leachate from municipal solid wastes, industrial discharge, and application of chemical and fertilizer on agricultural farms [9–11]. The geological formation of an area also contributes to the quality of its aquifer, particularly the unconfirmed aquifer which is more vulnerable to contamination from surface pollutions. Water researchers have reported extensively on groundwater characterization using various methods and techniques. The goals of this characterization remain measuring several quality parameters that reveal the characteristics and profile status of natural water samples from both surface and ground sources. The most popular description of water quality is "it is the physical, chemical, and biological characteristics of water" [12]. Water chemical analytical techniques commonly used to measure and monitor all the natural elements encompassing inorganic compounds and a very wide range of organic chemical species include physicochemical, experimental determination of contaminants [13], chromatographic and spectrophotometric method [14, 15], the use of mathematical modeling and simulation [16, 17], application of models including PhreeqC model [18] to predict the impact of discharge on water quality and this may be achieved by use of simple models. Various simple models have been reportedly used in predicting the pollutant fate and exposure concentration: WQAM, QUAL2E, WASP, CE-QUAL-RIV1 and HEC-5Q [19, 20], geophysical and electrical resistivity methods [21, 22] multidimensional data statistical techniques such as cluster analysis (CA), factor analysis (FA), and discriminant analysis (DA). [23, 24].

Since Lagos State University, Ojo was established, 35 years ago there is still paucity of report on the status of groundwater that serves as a main water supply to the University community as well as the potential ecological risks associated. This study was therefore designed to seek the physicochemical characterization and ecological assessment of groundwater in Lagos State University so as to enable proper health and environment policies towards the safety of man and sustainability of the environment in line with goals three, six and eleven of Sustainable Development Goals (SDG).

2. Experimental

2.1. Study Area

This research was carried out at Lagos State University' Ojo campus Lagos State, Established in 1984. It is located at 6.26°N 3.11°S and 6.467° W3.183°E with the location map (Figure 1.). Grasses and trees characterize the area.

The study area is also characterized by various shallow and deep wells. The study area houses many vegetable farm lands. The main campus consist of nine Faculties, and staff residential quarters whose water supply is from groundwater processed and supplied by a micro water works.

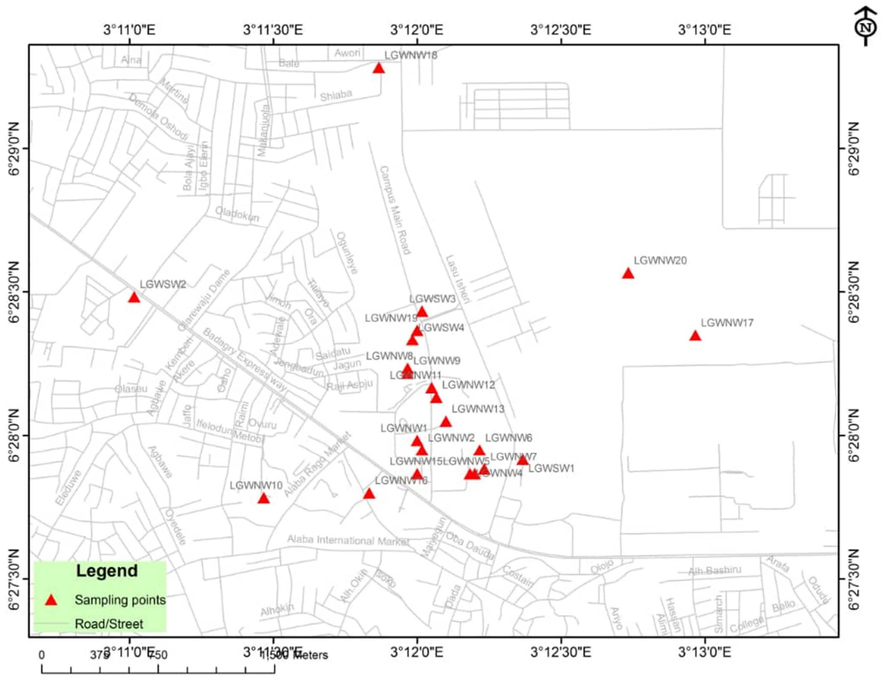

Figure 1. Map of study area showing sampling locations.

2.2. Samples and Sampling Collection

A total of fifty (50) groundwater samples were collected from twenty five (25) wells (deep and shallow). Sampling was carried out bimonthly for a period of four (4) months (July –October). Groundwater samples collected were represented by LSW1 – LSW25. Two samples were collected from each location into acid pre-washed high-density 1.5 L and 0.75 L polyethylene sampling bottles [25].

The 0.75 L water samples (preserved with 1.5 ml of concentrated HNO_3 (Analar grade) and 1.5 L samples were for trace metals and physico - chemical parameters and respectively. Control samples were also analyzed [26] just as the real samples.

2.3. Physicochemical Analytical Procedure

The temperature, pH, electrical conductivity (EC) and total dissolved solids (TDS) were determined as libel parameters. Temperature was measured with mercury in bulb thermometer, pH and EC measured with pH meter (HANNA HI 98107) and conductivity meter (Mettler Toledo) respectively. The total dissolved solids (TDS) was measured gravimetrically. Alkalinity and acidity were determined titrimetrically; total hardness by complexomertric method; chloride by titrimetry, sulphate by turbidimetry [26] phosphate, colorimetrically and nitrate by phenoldisulphonic acid method [27]. Na^+ and K^+ were determined by flame photometry and other trace metals by flame atomic absorption spectrophotometry (Buck scientific 210VGP model).

2.4. Data Treatment and Statistical Analysis

Software package Statistics SPSS 20, 0 was employed in analyzing water quality data generated (descriptive statistics). Multivariate analyses; factor analysis (FA), and cluster analysis (CA) were carried out while Correlations efficiency was performed in a pair wise fashion employing Pearson correlation procedure. Sodium adsorption ratio (SAR), Ca/Cl, Na/Cl ratio concepts and exceedance were also deployed in the analyses.

$$\text{Exceedance} = \frac{\text{Concentration of a quality parameter}}{\text{WHO acceptance limit}}$$

$$\text{SAR} = \frac{\text{Na}}{[(\text{Ca+ Mg}) / 2]1/2} \text{ [28]}$$

3. Results and Discussion

Descriptive statistics of physicochemical parameters and trace metals in the groundwater analysed is shown in Table 1. The pH values observed in this study ranges from 5.1 to 8.1 with the mean value of 6.76 ± 0.83. About 40% of the water samples investigated are lower than the WHO pH allowable range of 6.5 – 8.5 for drinking water. The acidic pH has been implicated in a number of health conditions such as acidosis, leading to neuromuscular disorders, Chest deformities (such kyphosis) and Chest muscle weakness. Lagos water is reported to be of acidic nature as a result of high volume of CO_2 indicating heavy population and industrialization. Water samples in this study with pH values above 7.0 is over 40%, this could be linked with the agricultural practices in the study area. Alkalinity and pH are important water quality parameters that dictate the primary usage of a water samples. Total alkalinity is the sum of all the titrable bases which include hydrogen carbonate (HCO_3^-), carbonate (CO_3^-) and hydroxide (OH^-) in the water sample. Alkalinity values observed in this study range from 2.0 to 85.1 mg/L with average of 35.6 ± 5.7 mg/L.

Most times, alkalinity of groundwater tends to be high particularly in high populated and industrialized areas [29]. Phenolphthalein alkalinity was zero in all the samples collected in the study area, hence all alkalinity values were only due only to bicarbonate. About 20 % of the water samples investigated is suitable for drinking, going by the classification water based on alkalinity [30], while about 40% of the water analyzed are not suitable for drinking purposes.

The electrical conductivity (EC) is a water quality parameter that measures the capacity of a water sample to allow passage of conducting electrons. Hence, it affects the users' acceptance of the potability of water [31]. It has a significant impact on the users' acceptance of potability of water under investigation. The average value of electrical conductivity of groundwater in this study is 268.6 ±26.0 µS /cm and ranges from 118.9 to 744.0 µS /cm. All the water samples analysed had EC values lower than WHO allowable limit of 1.4 mS /cm for drinking water, this may point at the potability of the water being investigated**,** despite that the level some parameters like pH is off the allowable range. TDS varies considerably in different geological regions owing to differences in the solubility of minerals. The potability of water with TDS concentration lower than 500 mg/L is good, while water concentration above 1000 mg/L, the WHO allowable limit for drinking water is rejected to consumer as it affects because taste. The total dissolved solids values in this study range from 50.2 to 447 mg/L with average value of 161.5 ±78. 0 mg/L. All water samples analysed had TDS values below 1000 mg/L, hence, they are categorized as fresh water.

Total hardness is another important quality parameter, for it helps in defining the usage of water. Hardness can be caused by the presence of calcium and magnesium, occurring maturely at a concentration below those of which toxic effect may occur. A number of analytical, ecological, and epidemiological research have demonstrated significant inverse relationship between hardness of water and heart related health condition.

Total hardness ranges from 25 to 225 mg/L with the average value of 103.8 ± 60.5 mg/ L Water is classified into very soft, moderately soft, moderately hard and very hard [30]. The entire water samples investigated in this study is made up of very soft (4%), moderately.

ANIONS: Chloride, sulphate, nitrate and phosphate are all primary negative ions that were investigated in the groundwater collected from this area following standard procedure [26].

Table 1. *Descriptive Statistics of parameters in the groundwater in LASU Ojo, Lagos.*

	Min	Maximum	Mean	SD	% Exceedance	WHO
pH	5.10	8.40	6.75	.84	0.9	6.5 – 8.5
Temp.	29.30	35.40	30.68	1.40		
Electrical conductivity	84.00	744.0	268.60	130.0	0.19	1400 µS /cm
Total Dissolved Solids	50.20	447.00	161.45	78.07	0.16	1000 mg/L
Alkailinity	2.000	85.10	35.57	27.46		
Acidity	14.50	58.70	32.10	12.63		
Chloride	10.90	72.70	27.84	13.68	0.11	250 mg/L
Total Hardness	25.00	225.0	103.80	60.47	0.21	500 mg/L
Phosphate	.022	.112	.042	.018	0.009	5 mg/L
Nitrate	6.68	44.72	29.47	15.23	2.95	10
Sulphate	26.49	274.86	109.28	84.35	0.27	400 mg/L
Potassium	1.32	28.32	18.74	7.793		
Sodium	7.110	52.140	38.58	14.59	0.19	200 mg/L
Calcium	6.810	94.80	24.14	21.03		
Magnesium	.369	1.752	1.22	.3165	2.4	0.5 mg/L
Iron	.000	4.680	1.42	1.269	1.42	0.3 mg/L
Copper	.000	.136	.045	.038	0.03	1.5 mg/L

Chloride affects the aesthetic characteristics of water including taste and renders it unsuitable for drinking purposes when the concentration is high. Chloride values in this study ranges from 10.9 to 72.1 mg/L with average value of 27.8 ±13.7 mg/L.

All water samples analyzed are with chloride values within the WHO allowable value of 250 mg/L for potable water. Various sources of chloride in groundwater include; domestic discharge, seepage from septic tanks, agricultural practices, urban runoff and sea water intrusion [32]. Chloride level of 40 mg/L has been reported to indicate sea water intrusion while groundwater with chloride level above 100 mg/L imply zone of diffusion [33-35]. Hence, 16% of the entire water samples analyzed could be linked to salt water impact. [36] Tindal *et al.,* (1995) suggested some diversified sources of chloride as retention of ions from salt trapped at the time of deposition from solution of minerals and chemical constituents from infiltration of clay as well as recharge atmospheric precipitation containing ion. Ca/Mg; Ca/Cl and Na/Cl coefficients are geochemical term (ratio) presented in table 2. The coefficients help in establishing the possible salinization in an area [37].

Table 2. *Ratio of Ca/Cl and Na/Cl in groundwater around LASU area.*

Sample code	Na/Cl	Ca/Cl
lgw1	1.8	0.83
lgw2	0.5	0.4
lgw3	1.6	1.5
lgw4	2.1	4.67
lgw5	2.4	0.7
lgw6	0.57	0.26
lgw7	0.45	0.21
lgw8	1.8	0.6
lgw9	0.63	0.63
lgw10	1.34	1.4
lgw11	0.28	0.26
lgw12	0.23	0.22
lgw13	3.9	4.6
lgw14	1.6	0.8
lgw15	0.82	0.26
lgw16	2.6	0.7
lgw17	2.1	0.5
lgw18	2.4	1.1
lgw19	1.5	4.1
lgw20	2.7	0.8
lgw21	2.7	0.8
lgw22	1.6	0.34
lgw23	1.6	0.65
lgw24	1	0.3
Igw25	1.8	0.59

Over 28% and 72% of water samples collected showed Na/Cl and Ca/Cl ratios respectively are below sea water (0.86) indicatiive of salt- water intrusion [38]. The average concentration of sulphate was 109.2 ±84.3 mg/L with a minimum concentration of 24.6 mg/L and maximum concentration of 272.3 mg/L in this study

The SO42^{-} values observed in groundwater investigated are lower than the WHO acceptable limit of 400 mg/L of SO_4^{2-} in drinking water. Sources of SO4^{2-}in groundwater include Geological formation of an area, agricultural practices, urban runoff etc. Vehicular emission can also contribute to the SO_4^{2-} concentration in an environment [31].

High concentration of SO_4^{2-} can cause laxative effect to unaccustomed consumers [39] (WHO, 2006). Excessive intake of SO_4^{2-} can also lead to diarrhea and hydration, though no health based guideline has been set for SO_4^{2--} but ingestion of high concentration of sulphate may cause intestinal irritation.

Nitrate is health related quality parameter in groundwater, with sources include agricultural practices, leachate from dumpsites, and urban runoff. When the level of nitrate exceed the WHO maximum value of 10 mg/L, it is with health effects including shortness of breath and blue-baby syndrome and death of infant as reported [40].

The groundwater samples investigated in this study range from 6.60 to 45.7 mg/L with the average value of 29.5±15.2 mg/L.

The nitrate level observed in about 85% of the water samples analyzed is beyond 10 mg/L portending health effect. Tindal *et al.,* [36] also suggested low level of nitrifying bacteria could implicate low nitrate under aerobic condition, consequently the high farming activities including application of chemicals and fertilizers stands the major source of nitrate in this study.

Phosphate level ranges from 0.022 to 0.112 mg/L with the mean value of.042 ± 0.02 mg/L The possible sources of phosphate in groundwater include dumpsite, urban runoff, agriculture activities and infiltration from surface water as well as seepage from disnature source [41]. Generally, the phosphate concentrations in groundwater in the study is lower than that of groundwater study around Solous dumpsite [42].

3.1. Trace Metals

Sodium, calcium, potassium and magnesium are metals of nutritional importance, otherwise called essential metals. They contribute to metabolic functioning of body system [36].

The level of sodium (Na) in the groundwater samples in this study ranges from7.11 to 52.1 with the mean 38.5 ± 2.9. All the concentration of Na observed are within the acceptable level in drinking water. Sources of sodium in groundwater are geochemical formation of an area, farming activities and urban runoff..

Sodium in the body acts as electrolyte that carry an electric charge when dissolved in body fluids such as blood. When sodium consumption is higher than the acceptable limit, it causes a condition known as hypernatremia and hypornatremia when sodium is too low.

Calcium (Ca) concentration in the water analyzed ranged from 6.81 to 94.8 mg/L and average value of 24.1± 4.2 mg/L. About 4% of the water samples analyzed is classified as moderately hard while 96 % categorized as soft water. Calcium is naturally present in water. It may infiltrate from rocks including marble, dolomite, limestone, gypsum, fluorite, calcite, and apatite. Calcium is a dietary mineral and is responsible for the hardness of water. Hardness of water has been linked to significant etiological factor which can cause a number of health conditions such as reproductive failure cardiovascular problems, renal dysfunction and diabetes [43, 44]; Calcium causes hardness in water along with magnesium [43].

The minimum value 0.37 and maximum 1.75 mg/L of magnesium were obsreved in the water analyzed average value of 1.22 mg/L. Leachate is major source of magnesium in groundwater. Ion exchange of minerals in rocks and soils by water is other source [36, 45] Potassium is a major cation that is involved in control of diuretic balance in human body system, though no limit is set for ion in drinking water The values of potassium concentration ranged between 1.32– 23.8 mg/L with mean value of 18.7 ±7.7. Very strong positive inter chemical relationship was observed between potassium and sodium k/Na (0.943) as well as magnesium k/Na (0.785).

Iron and Copper are essential elements that helps in functioning of human body system and could be toxic if the concentration in the human system is very high. Cu aids some enzymatic reactions while Iron helps in helps in formation of hemoglobin, However, Iron is abundant in Earth crust. The maximum copper concentration observed in this study was 0.136 while the minimum was ND mg/L with the mean value as 0.044 mg/L. All water samples investigated had cu concentration lower than the WHO acceptable limit of 1.5 mg/L Cu in water for drinking purpose water. High concentration of Cu can cause gastrointestinal irritation in man.

Copper is always associated with groundwater having CO_2 concentration above 5.0 mg/L for this always result in corrosion. $CuSO_4$. $5H_2O$ is added to surface water to control growth of algae. Agricultural activity, urban runoff and geochemical composition of the soil/rock holding the water are possible potential sources of Cu in the environment. Other sources include leachate from dumpsite. The levels of iron in the water in this study range from ND to 4.68 mg/L with mean value of 1.42 mg/L. Some of the water samples analysed had non-detectable value, for Cu and Fe as a result of very low detection limit (0.001mg/L) of the instrument.

Over 68% of water investigated had Fe concentration higher than WHO allowable limit of 0.3 mg/L Fe in potable water, this portend health risks. The unit less concept, exceedance of some quality parameters are presented in Table 1. The decreasing order of exceedance of some water quality parameters was NO_3^{2-} > Mg > Fe > SO_4^{2-} > total hardness. The SAR calculated from the groundwater data is shown in Table3. and grading of water based on SAR is shown in Table 4.

Table 3. *Sodium Adsorption Ratio of LASU groundwater.*

Sample code	SAR	Sample code	SAR	Sample code	SAR	Sample code	SAR
lgw1	13.9	lgw8	14.8	lgw15	16.1	lgw22	18.3
lgw2	4.73	lgw9	4.3	lgw16	17.2	lgw23	16.6
lgw3	10.6	lgw10	9.5	lgw17	17.6	lgw24	15.4
lgw4	5.0	lgw11	4.1	lgw18	13.4	lgw25	16.8
lgw5	15.9	lgw12	3.7	lgw19	9.2		
lgw6	8.6	lgw13	8.4	lgw20	15.9		
lgw7	10.3	lgw14	14.3	lgw21	13.7		

Table 4. *Classification of groundwater for irrigation based on (SAR).*

Excellent	< 10
Good	10 – 18
Doubtful	18 – 26
Unsuitable	>26

The SAR helps in establishing the grades of water for irrigation purpose. About 36% of the water samples investigated are in excellent condition for irrigation purpose, 60 % are in good conditions and 4% in doubtful. Consequently the water samples analysed are fit for irrigation purposes, thus portend safety of human health.

3.2. Correlation Coefficient

Interchemical relationship among the water physiochemical parameters investigated were established with correlation coefficients values for LASU groundwater are presented in Table 5.

Correlations among the parameters in the groundwater sample was analyzed using Hatva scales, reveal coefficient (P < 0.05) varying among quality parameters investigated. The pH has strong interrelation with alkalinity (r2 = 0.659) and weak correlations with CND (0.335), TDS (0.338) and chloride (0.330) and negative chemical association with some other variables as shown in Table 5. This is similar to what Helena et al. [46] described as aggressiveness towards water containing rock and soil.

Acidity also maintain strong correlation alkalinity (r2 =0.607), TDS (r2 =0.507) and EC (r2 = 0.509). Indicating a common source to all these quality variables and anthropogenity of the source [47]. Sodium element correlate strongly with K (r2 = 0.943) and with Mg (r2 = 0.760). There was also a positive strong chemical association between potassium and magnesium (r^2 = 0.789) as well as between iron and copper (r^2 =.518**).

3.3. Multivariate Analysis

The factor analysis (FA) carried out extracted six major PCs (eigenvalues greater than 1) accounted for 79.3 % of variance of the original data complex structure (Table 6). PC 1 accounted for 20.9 % of the total variance which is contributed by pH, acidity, TDS, alkalinity, electrical conductivity and chloride. This according to [48] is an indication that variables are related to the hydro chemical originating from mineralization of groundwater. High level of EC and TDS is probably as a result of involvement of ions in the groundwater. The only anion that contribute significantly in PC1 is Chloride pointing at pollution from domestic source. PC2 accounted for 18.3% of the variance, with significant contributions from variables such as potassium, sodium and magnesium. Anions such as nitrate, phosphate and calcium, also played role in the PC2.

Table 5. *Correlation coeficence in groundwater samples.*

	pH	Temp.	CND	TDS	Alkal	Acid	Cl	TH	PO4	NO3	SO4	K	Na	Ca	Mg	Fe	Cu
pH	1																
Temp.	-.072	1															
Electrical conductivity	.335	.102	1														
Total Dissolved Solids	.338	.101	1.000**	1													
Alkalinity	.659**	-.292	.245	.246	1												
Acidity	.174	-.095	.506**	.509**	.607**	1											
Chloride	.330	.114	.723**	.725**	.161	.316	1										
Total Hardness	.268	.194	.024	.023	.411*	-.010	.133	1									
Phosphate	.203	-.085	-.011	-.010	.121	-.017	.107	-.057	1								
Nitrate	.093	-.349	.105	.097	.278	.069	.038	.001	.146	1							
Sulphate	.225	-.214	.161	.157	-.265	-.367	.199	-.249	-.011	.041	1						
Potassium	.095	.321	.028	.027	-.012	.132	-.009	-.334	.285	.079	-.063	1					
Sodium	-.044	.315	-.051	-.052	-.060	.100	-.083	-.233	.335	.077	-.199	.943**	1				
Calcium	.212	-.064	-.014	-.017	.359	.181	-.214	.062	.313	.239	-.185	.297	.281	1			
Magnesium	.152	-.034	.040	.040	.159	.122	-.047	-.275	.371	.458*	-.164	.789**	.760**	.296	1		
Iron	-.139	-.118	-.108	-.103	-.193	-.064	-.181	.105	.046	-.438*	-.077	-.298	-.227	.190	-.251	1	
Copper	.034	-.332	-.157	-.151	.013	-.005	-.312	-.114	-.189	-.390	.042	-.090	-.108	.171	-.186	.518**	1

Table 6. *Factor loading and eigenvalue of principal component analysis for LASU groundwater.*

	Principal component					
	1	**2**	**3**	**4**	**5**	**6**
pH	.535	-.204	.289	.086	.211	.546
Temp.	.004	.264	-.626	.149	-.520	.344
Electrical conductivity	.789	-.396	-.288	.180	.040	-.139
Total Dissolved Solids	.789	-.399	-.286	.186	.039	-.139
Alkailinity	.650	.019	.684	-.031	-.098	.061
Acidity	.647	-.057	.231	.331	-.218	-.473
Chloride	.685	-.393	-.397	-.035	-.024	.125
Total Hardness	.175	-.180	.355	-.253	-.598	.468
Phosphate	.218	.379	.029	.123	.278	.393
Nitrate	.383	.321	.214	-.580	.321	-.220
Sulphate	-.033	-.337	-.349	-.167	.708	.279
Potassium	.270	.790	-.325	.337	.120	.023
Sodium	.186	.824	-.279	.333	.003	.000
Calcium	.217	.379	.474	.372	.158	.224
Magnesium	.254	.714	.230	-.240	.015	-.102
Iron	-.391	-.335	.177	.595	-.007	.035
Copper	-.350	-.237	.385	.604	.232	-.053
Eigenvalues	3.562	3.104	2.254	1.792	1.508	1.508
TV (%)	20.951	18.260	13.261	10.540	8.872	7.441
CV (%)	20.951	39.211	52.472	63.012	71.884	79.325

About 11.5 % of the total variance was accounted for by PC3. Only alkalinity (HCO3 -) played major role in the PC3, an indication that the water samples analyzed is polluted mainly by CO_3^{2-} substances. Calcium, copper and nitrate participated in the PC3. Sulphate ion maintained inverse involvement in the principal component, though sulphate is related from geological formation of the aquifer. PC4 explained the 10.54 % of the total variance. Iron and copper are the major contributor in PC4, along with Mg, k and Ca. There are different sources of the trace metals, pointing at anthropogenic influence on the quality of water under investigation. PC5 and PC6 accounted for 8.87 and 7.44% respectively of the entire variance. Sulphate is the only anion that contributed positively in PC 5, along with the participation from nitrate and phosphate. The pH is the only main contributor in PC6 along with participation from temperature, total hardness, PO_4^{3-} and SO_4^{2-}. The detergent based pollution is suspected due to the involvement of PO_4^{3-}. The participation of NO_3^{2-} in PC 1, PC 2, PC 3 and PC5 distinguished them from other PCs.

Nitrate is has been implicated in methemoglobinemy, a baby syndrome involving serious disturbance blood-oxygen exchange. This also cause carcinogenic cells in adult [49]. PC5 and PC6 are influenced by sulphate indicating the impact of geological formation of the study area. Generally, trace metals contamination is suspected from anthropogenic effect [48]. However, these elements have no positive chemical correlation, indicating divergent origin. Therefore, aside the usual contribution of geochemical formation of the aquifer under study, the probability of pollutant from agricultural is also strongly suspected.

3.4. Cluster Analysis

Cluster analysis was performed using wizard linkage through SPSS 2.0 to identify groundwater with similar water chemical quality characteristics. Cluster analysis helps reveal some inherent common trends in pictorial forms. Twenty five (25) wells were sampled in this study. The wells are into two classes based on depth and the age of the wells; (i). **Special** wells, five in number consisting well Nos 21-25, part of the old wells and deeper (>20 meters) dug to deal with the scarcity in the University in the earlier period of the institution, they are always with rings. (ii). Normal wells, they are hand dug wells of shallow wells 5 - 50 cm depth, twenty in number consisting well Nos 1-20. The dendrogram of hierarchical cluster analysis as presented in Figure 2. showing five clusters at 2.7 index of dissimilarities. The clustering of wells as shown in figure 2. reflect influence of both natural and anthropogenic sources particularly agricultural activities Cluster I involve sampling points (six wells) divided into two sub groups; A with lone sub cluster 20 and B with sub cluster 13, 23, 5, 19 and 24. They are located not too far from main road that bound northern part of the University. The clustered points (wells) have relatively high concentration of Fe, Cu., nitrate, sulphate and TDS. The low level of Ca and Mg characterized the cluster.

Cluster II is made up of four sub groups; A with three sub clusters; 11, 16 and 6, B with four sub clusters; 21, 22, 9 and 10, C with four sub clusters; 2, 15, 14 and 25, and D with three sub clusters; 1, 4 and 8. This cluster has varying differential quality parameters probably due to large size of the cluster. Each sub group has differential. However, some common distinguish qualities include the pH around neutral (7.0), while A sub group has more acidic pH. Also common to all members of the cluster is nitrate concentration higher than the WHO acceptable limit of 10mg/L.

Cluster III consists of three clusters of 17, 18 and 12. The Cluster Is characterized with high Cu, Fe, Na, and Mg. These elements possibly account for high level of total dissolved solids.

Cluster IV is a lone cluster of well 3 with so many distinguished variables. Moderately hard water with high total dissolved solids, and electrical conductivity. The cluster is with high acidic water. The high TDS perhaps explain the high concentration of sodium observed in the cluster.

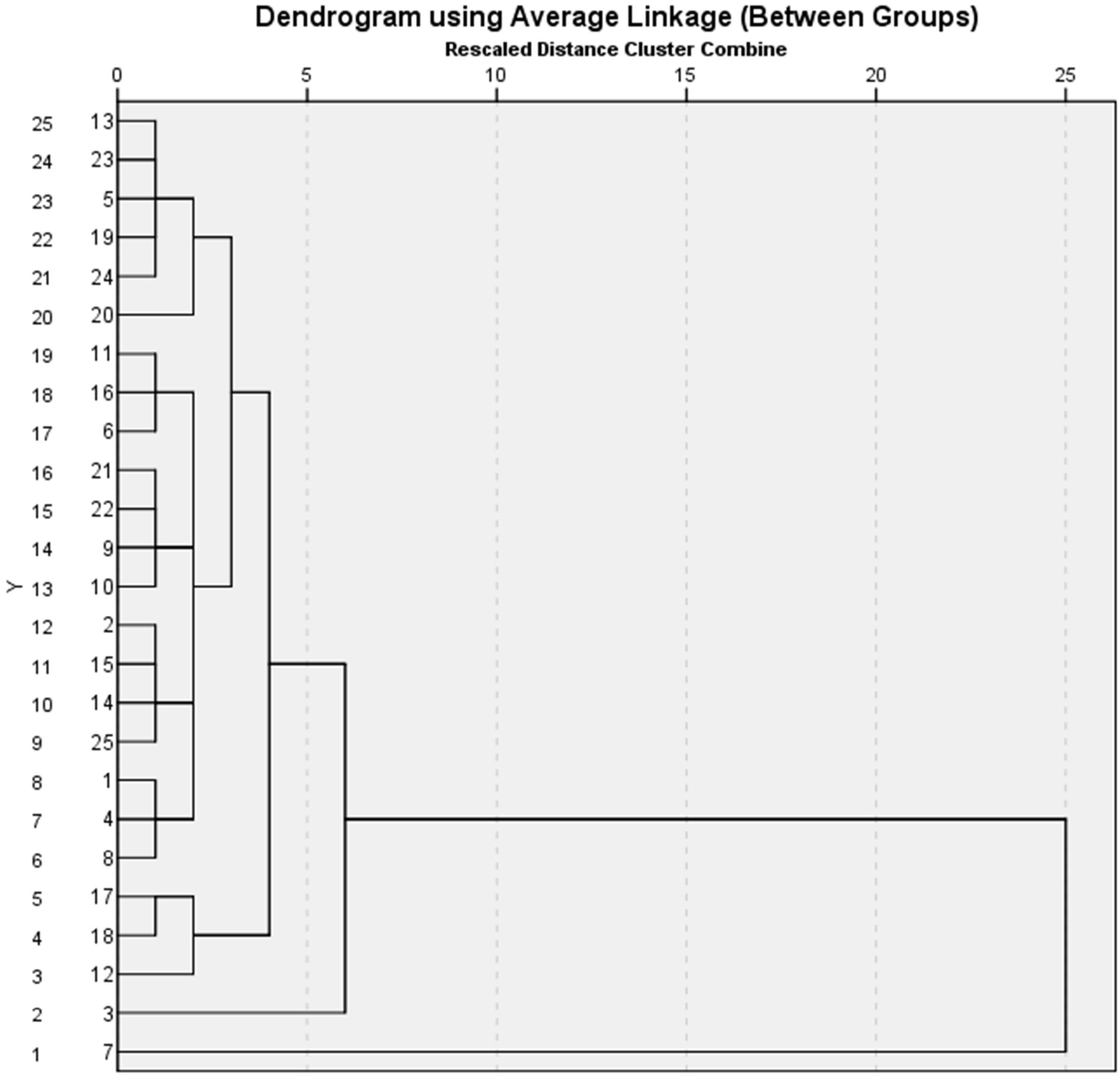

Figure 2. *Dendrogram groundwater samples in LASU area.*

Cluster V is also a lone cluster of well 7, located in the bank arena in the main campus. This is a wetland and not too far from an open market (Iyana Iba) across the university fence. The sampling point is also under serious impact of farming activities. The well 7 has highest chloride and nitrate level as well as highest electrical conductivity which may the pointer to very high concentration of Ca observed in the cluster.

4. Conclusion

This study investigated the level of physicochemical quality parameters in groundwater of Lagos State University, Ojo, Lagos, as a way of assessing the impact of agriculture activities among others on of the groundwater quality in the study area. Quality parameters investigated include pH, TH, EC, alkalinity, acidity, TS and TDS; Anions and some trace metals ware also analyzed. The acidic nature of the groundwater indicates a high concentration of atmospheric carbon dioxide in Lagos from various anthropogenic sources consequently injurious to health of man, The increasing order of quality parameters exceeding WHO limits for drinking water was NO_3^{2-}> Mg > Fe > SO_4^{2-} > TH indicating the need for some treatment before the water under investigation is potable. The SAR helps in establishing the suitability of water for irrigation purpose. However, SAR revealed that more than 95% of the water samples analyzed are fit for irrigation purposes, thus portend safety of human health. The application of multivariate statistical techniques (factor and cluster analysis) reveal six different factors extracted, which account for 79.3% of the total variance of the water with quality five distinct clusters of wells based on hydro chemical dissimilarities.

The impacts of agricultural activities are apparent on the quality of groundwater among others, hence the need for regular monitoring on the farming activities of so as to safeguard human health and environment.

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