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The Effect of Agrochemicals and Leachate on Ground Water Quality in Farmlands using Multivariate Analysis in Minna Niger State, Nigeria

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Abstract:- The multivariate analysis of groundwater quality in farmlands in Minna, Niger State, and its surroundings is evaluated in this work. To conduct this investigation, four research questions and four hypotheses for the study were posed. The groundwater's physicochemical characteristics in four distinct point areas—Chanchaga, Bosso, Kpakungu, and Tudun-Fulani—were studied. From February to November 2019, groundwater was collected from the wells within these study areas. In Minna, Niger State, farmlands were the subject of a multivariate analysis of groundwater quality. The objective of the study was to compare the concentration of the variable under investigation with both the Nigerian Water Quality Control (NWQC) standard and the WHO. Fifteen (15) parameters were investigated for sixteen (16) water samples that were gathered. While electrical conductivity (EC) in K, T, and B was higher than the WHO guideline, EC in C was lower than the 1000 S/cm suggested by the WHO. The study area's groundwater had lower concentrations of heavy metals according to the results. Nonetheless, this study suggests that good agricultural practices (GAP), accurate timing and administration of the precise amount of agrochemicals required by crops, and spill-proof application techniques be maintained.

Biodegradable; leachate; infiltration; biodegradable; landfill; physico-chemical; sanitary; groundwater; borehole.

Keywords:- *Multivariate, Contamination index, Physiochemical Parameters, Groundwater, Water Quality Index.*

I. INTRODUCTION

Groundwater is a vital natural resource, serving as the primary source of drinking water and irrigation for many communities worldwide. However, its quality is constantly under threat due to various human activities, including the use of agrochemicals and the release of leachates. This article explores the impact of agrochemicals and leachates on groundwater in Minna, Niger State, Nigeria, shedding light on the consequences and possible solutions.

Agrochemicals, which encompass pesticides, herbicides, and fertilizers, are commonly used in agricultural practices to enhance crop yields. However, improper application and overuse of these chemicals can lead to the contamination of groundwater. When it rains, these chemicals can be washed into the soil and eventually reach the water table. Once in the groundwater, they can persist for long periods, posing health risks to those who consume the water.

Leachates are liquids that percolate through waste materials, picking up various contaminants along the way. In Minna, the presence of landfills and poorly managed waste disposal sites can lead to leachates infiltrating the groundwater. These leachates can carry harmful substances, including heavy metals and organic pollutants, which compromise the quality of groundwater.

As men’s activities increase, the tendency of increase of these substances in the groundwater is very high and several authors have used several methodologies to show the amount of these substances in the groundwater at different locations.

II. STUDY AREA

Niger State is named after the River Niger. The State borders the Republic of Benin (West) nationally and other states within Nigeria. The Federal Capital Territory (FCT) in the southeast, Zamfara in the north, Kebbi in the north and west, Kwara in the south and west, and Kaduna in the northeast are among them as shown in Figure 1.

The State borders the Republic of Benin (West) nationally and other states within Nigeria. These comprise the Federal Capital Territory (FCT) in the southeast, the northern states of Zamfara, Kebbi, Kwara, and Kaduna, and the eastern states of Kwara and Kebbi.

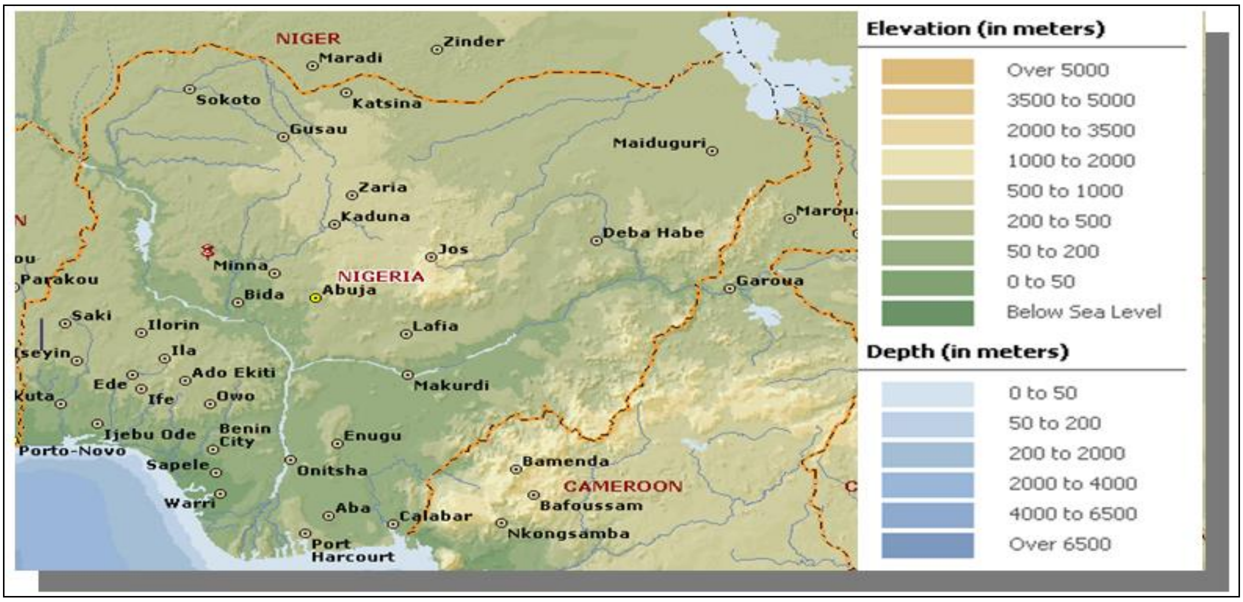

Fig. 1: Map of Nigeria Showing Minna with pushpin (Adapted from Microsoft Encarta)

The largest state in Nigeria is Niger State, which is located in Central Africa (Figure 2). Bida, Kontagora, Suleja, and Minna are the other important cities in the state. When the then-Northwestern State was divided into Niger State and Sokoto State in 1976, it was created [6]. The bulk of Niger State's various indigenous tribes are the Nupe, Gbagyi, Kamuku, Kambari, Dukawa, Hausa, and Koro.

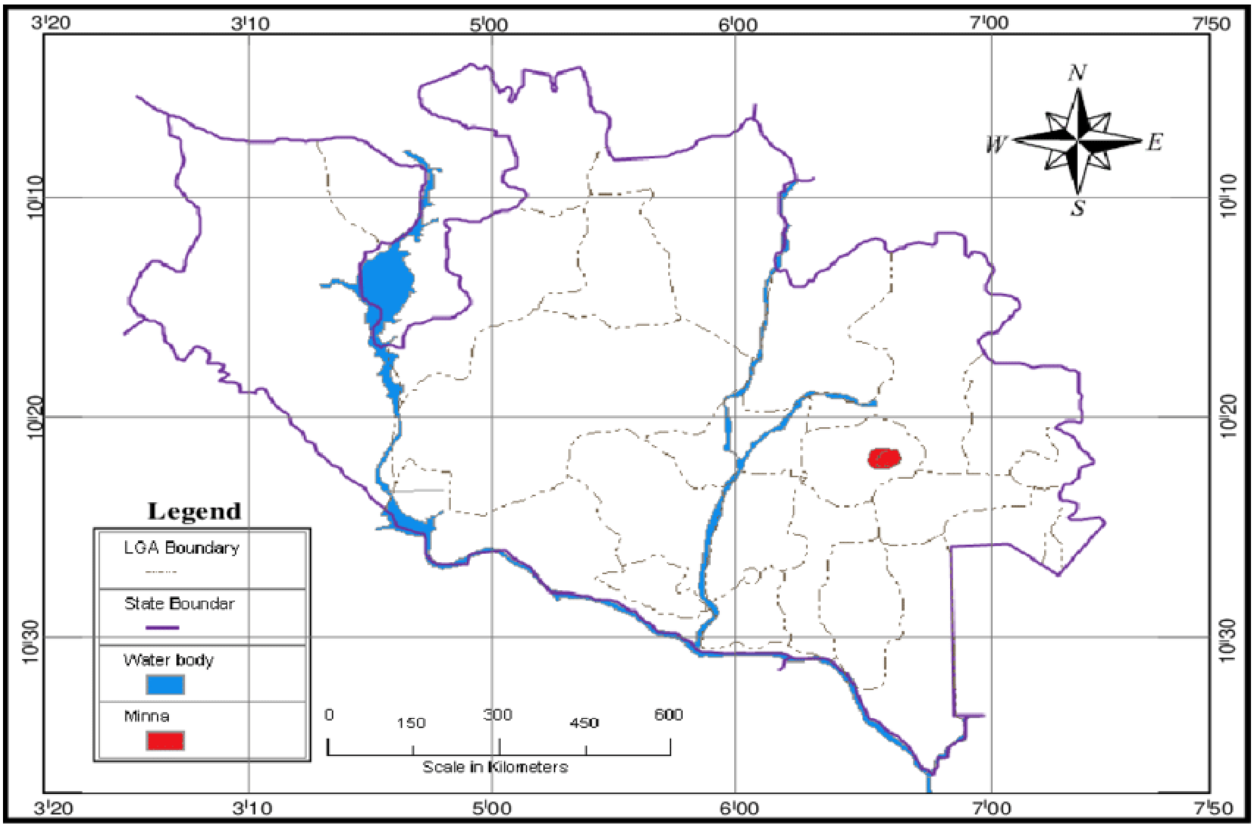

Fig. 2: Map of Niger States showing Minna (Adapted from [6])

Two of Nigeria's major hydroelectric power stations, the Kainjiand the Shiroro Dams, are located in Niger State, The famous Gurara Falls is in Niger State, and Gurara Local Government Area is named after the Gurara River, on whose course the fall is situated. Also situated there is Kainji National Park, the largest National Park in Nigeria Yaradua, (2004), which contains Kainji Lake, the Borgu Game Reserve,and the ZugurmaGame Reserve.

The latitudes of 8°15'–11°15'N and the longitudes of 4°00'–7°15' E comprise Niger State. Kaduna and Kebbi States border it on the north, and Kogi State borders it on the south. Its eastern boundary is shared by the Federal Capital Territory and the state of Kaduna; its westernmost point is shared with Kwara and the Benin Republic. With a size of roughly 80,000.00 square kilometers and a population of 3,920,000 (2006, census), it has been split into twenty-five municipal administrations.

There is a wet season and a dry season, similar to most of West Africa. A longer wet season lasting roughly seven months with an average rainfall of 250 mm and a dry season lasting roughly five months with little to no rain are the results of the seasonal rainfall regime. The subterranean multifaceted rocks occupy approximately half of Niger State's geographical territory, with the other portion being made up of parts of the Sokoto (Iullemeden Basin) and the Bida Basin's Cretaceous sedimentary rocks. The Nigerian geological map in Figures 1 and 2 depicts Niger State following modification [7].

III. SAMPLE AND SAMPLING METHOD FOR PRIMARY DATA

The Site Specifications of Groundwater of four study areasare mainly Minna. The Groundwater was collected from the wells at four different points each located in this study area. The direction of inflow and the collection stations' closeness to the irrigation site guided the selections. For each study area, four sampling points were taken and herein referred to as M_1, M_2, M_3, and M_4 (see Plate 3.1).The selection of a well is based on how far it is from a previously identified well, and the wells were chosen at random to ensure equitable distribution throughout the project area. Each sample was taken in doubles (2) in a specified location, and they were all kept in plastic containers since plastic offers the lowest possible concentration of any contaminants which could influence the composition of water at the proper temperature at the right time.Major physical and chemical variables on water quality, such as pH, electrical conductivity (EC), total dissolved solids (TDS), turbidity, chloride (Cl-), calcium (Ca++), magnesium (Mg++), sodium (Na+), and potassium (K+), were examined in the collected samples. The specifications were chosen using a set of criteria based on the common pollutants found in the groundwater around the dumpsites.

IV. MULTIVARIATE STATISTICAL ANALYSIS (MSA)

Descriptive statistics, correlation analysis, hierarchical cluster analysis (HCA), and Factor analysis (FA) for the selected physic-chemical water quality parameters were carried out. The descriptive statistics is used to understand the distribution of the physiochemical, while the multivariate statistical analysis which is based on Correlation matrix, Hierarchical Cluster Analysis (HCA) and Factor Analysis (FA) were used to evaluate the water quality of the wells and identify potential sources of pollution required the actual position of the wells.

V. RESULTS AND DISCUSSION

Table 1: Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
pH	16	6.80	7.70	7.3275	.21582
Acidity	16	.00	270.00	59.0000	62.28965
Alkalinity	16	10.00	1605.00	158.1250	409.29156
Hardness	16	4.00	86.00	4.1250	23.54535
Cl-	16	.00	121.00	25.4625	35.08365
NO3-	16	1.40	11.90	5.3250	2.37079
PO43-	16	.00	2.12	.7675	.82521
SO42-	16	.00	29.00	5.3963	7.33759
D_Oxygen	16	1.88	5.71	4.9031	1.04104
Mg2+	16	.00	1.43	.2025	.34663
Zn	16	.00	.16	.0100	.04000
Cu	16	.00	.09	.0356	.03140
Mn	16	.00	.01	.0009	.00280
Fe	16	.00	.44	.0506	.10523
Pb	16	.00	.38	.0286	.09390
Valid N	16				

The result in Table 1 above shows the 15-physio-chemical found in the groundwater in Minna Niger State. 4 farming areas were selected, and four (4) distinct wells were also sampled from each of the locations selected making a total of sixteen (16) samples. The pH level of all the sites visited is not too far apart, with a minimum value of 6.80 and a maximum value of 7.70. We can say that they have a steady pH, which according to WHO should be between 7.0 and 8.0 and according to NWQS and it is close to the finding of Amadi et al. (2015), having a pH level of 7.6, it should be within 6.5-8.5. The pH has a mean of 7.33 and a standard deviation of 0.22. Acidity has a mean of 59.0 and a standard deviation of 62.29. The value of the standard deviation shows that the acidity of the sites visited is far different from each other as some site has 0.00 acidity and while some has maximum value of 270.00. Chloride also

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has a mean of 25.46, and standard deviation of 35.08. The high deviation value shows that some site has more chloride concentration than the others, this can be seen with the minimum value of 0.00 and the maximum value of 121.00. According to JurnalTeknolog (2015), the level of chloride in the groundwater in Chanchaga which is one of the sites sampled from varies with season and month. Dissolved Oxygen (D_Oxygen) has a mean of 4.90 and a standard deviation of 1.04. The value of the standard deviation shows that the Dissolved Oxygen of the sites visited are not too far different from each other as some site has as low as 1.88 Dissolved Oxygen and a maximum value of 5.71. Our finding is also similar to the descriptive finding of C. O. Bamigboye1 and T. M. Amina (2018) and that of J. J. Musa et. al.

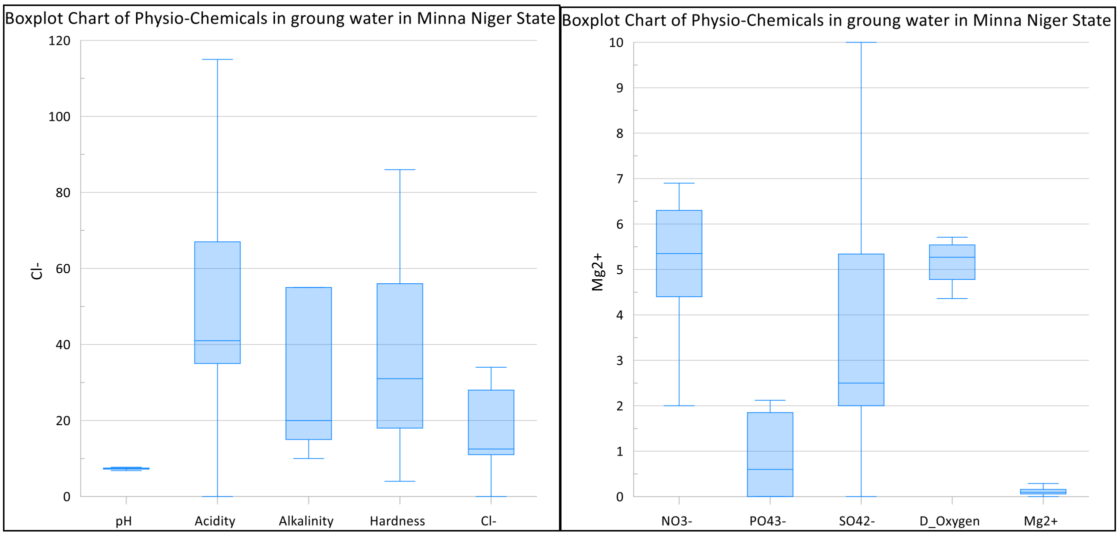

Fig. 3: Box plot of Physio-Chemical Parameters

VI. MULTIVARIATE (CORRELATION MATRIX) ANALYSIS

The correlation matrix is used to find the relationship between the physio-chemical properties of groundwater. A high correlation coefficient (close to 1 or 1) is an indication of a good positive relationship between two variables and a value around zero means no relationship at a significant level of $P < 0.05$. More specifically, the parameters of $r > 0.7$ are strongly correlated while a value $0.5 < r < 0.7$ represents a moderate correlation. The correlation matrix on Table 2 displays the significant value of the relationship between two variables. A value greater than 0.05 show that the relationship is not significant and a value less than 0.05 show that the relationship is statistically significant at 95% confidence interval.

Table 2: Pearson's Correlation Matrix of Physio-chemical Parameters

		pH	Acidity	Alkalinity	Hardness	Cl-	NO3-	PO43-	SO42-	D_O2	Mg2+	Zn	Cu	Mn	Fe	Pb
Sig. (1-tailed)	pH		.303	.452	.269	.124	.233	.023	.255	.467	.308	.362	.124	.004	.442	.305
	Acidity	.303		.419	.071	.327	.300	.318	.000	.144	.000	.364	.400	.346	.243	.383
	Alkalinity	.452	.419		.021	.181	.081	.477	.360	.000	.021	.366	.058	.335	.000	.389
	Hardness	.269	.071	.021		.108	.373	.429	.070	.013	.001	.399	.296	.434	.066	.429
	Cl-	.124	.327	.181	.108		.248	.127	.436	.353	.232	.364	.435	.318	.142	.345
	NO3-	.233	.300	.081	.373	.248		.394	.191	.322	.397	.351	.492	.492	.041	.349
	PO43-	.023	.318	.477	.429	.127	.394		.279	.411	.460	.320	.121	.182	.462	.288
	SO42-	.255	.000	.360	.070	.436	.191	.279		.065	.000	.324	.435	.257	.333	.332
	D_O2	.467	.144	.000	.013	.353	.322	.411	.065		.002	.361	.043	.241	.000	.378
	Mg2+	.308	.000	.021	.001	.232	.397	.460	.000	.002		.322	.154	.279	.137	.348
	Zn	.362	.364	.366	.399	.364	.351	.320	.324	.361	.322		.430	.373	.498	.000
	Cu	.124	.400	.058	.296	.435	.492	.121	.435	.043	.154	.430		.063	.099	.392
	Mn	.004	.346	.335	.434	.318	.492	.182	.257	.241	.279	.373	.063		.379	.434
	Fe	.442	.243	.000	.066	.142	.041	.462	.333	.000	.137	.498	.099	.379		.480
	Pb	.305	.383	.389	.429	.345	.349	.288	.332	.378	.348	.000	.392	.434	.480	

a. Determinant = 3.063E-13

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Table 2 shows correlation matrices prepared using the following parameters: Temperature, pH, Acidity, Alkalinity, Hardness, Cl-, NO3-, PO43-, SO42-, D_O2, Mg^{2+}, Zn, Cu, Mn, Fe, and Pb. The Temperature values indicated a statistically significant relationship with PO_4^{3-}, and Mn. Acidity values indicated a statistically significant relationship with SO_4^{2-}, and Alkalinity has a statistically significant relationship with hardness, D_Oxygen, Mg^{2+}, and Fe. With their P-value less than 0.05 at a 95% confidence interval and the same goes for other physio-chemicals. From previous research, peter Adeoye and Hasfalina Che Man (2015), did compare variables for association. They found out that chlorine has positive relationship with NO3, PO4, Mn, and Zn though only NO3, Mn, and Zn were statistically significant. But from our finding, Cl has positive relationship with NO3 and PO4, and a negative relationship with Mn and Zn and none is statistically significant.

Table 3: Multivariate (Factor) Analysis (Factor AnalysisTotal Variance Explained)

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.246	24.958	24.958	2.246	24.958	24.958	2.010	22.338	22.338
2	1.907	21.188	46.147	1.907	21.188	46.147	1.828	20.311	42.649
3	1.685	18.718	64.865	1.685	18.718	64.865	1.584	17.599	60.248
4	1.329	14.762	79.627	1.329	14.762	79.627	1.507	16.739	76.987
5	1.026	11.396	91.022	1.026	11.396	91.022	1.263	14.035	91.022
6	.528	5.864	96.887						
7	.228	2.533	99.420						
8	.051	.571	99.991						
9	.001	.009	100.000						
Extraction Method: Principal Component Analysis.									

Factor analysis is known for variable dimension reduction. Plotting in all variables (physiochemical components), some of the variables did not load properly having values less than 0.6. Results that show the loadings of the variables that were removed are attached in the appendix. Table 4 shows the loading of nine (9) physiochemical into five factors, explaining 91.02% of the variance in the physiochemical composition. The factor analysis has been able to reduce the physiochemical variables from fifteen (15) to nine (9).

Table 4: Factor Loading Rotated Component Matrix

	Component				
	1	2	3	4	5
Zn	.995	-.066	.026	.043	-.030
Pb	.992	-.055	.034	.082	-.046
Mg2+	-.074	.944	.177	.080	-.076
SO42-	-.050	.924	-.226	-.041	-.034
Fe	-.037	.141	.848	.038	-.183
NO3-	-.091	.176	-.825	.066	.002
PO43-	.093	-.063	.134	.886	.372
pH	-.063	-.125	.206	-.836	.425
Cl-	-.070	-.074	-.197	.029	.949
a. Rotation converged in 5 iterations.					

Table 4 shows how the physiochemical loads on the factors. Zn, Pb load perfectly on Factor One (1), Mg, and SO4 load on Factor (2), Fe, and NO3 load on Factor three (3), PO4 and pH load on Factor four (4), and Cl load on factor five (5).

Table 5: Hierarchical Cluster Analysis

Agglomeration Schedule						
Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	3	10	7.434	0	0	2
2	1	3	9.519	0	1	3
3	1	2	16.622	2	0	6
4	4	8	17.564	0	0	5
5	4	6	23.946	4	0	9
6	1	5	25.763	3	0	7
7	1	16	29.589	6	0	9

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8	11	14	31.861	0	0	11
9	1	4	32.080	7	5	10
10	1	15	48.784	9	0	11
11	1	11	55.935	10	8	13
12	7	12	62.881	0	0	13
13	1	7	117.437	11	12	14
14	1	9	593.983	13	0	15
15	1	13	1547.603	14	0	0

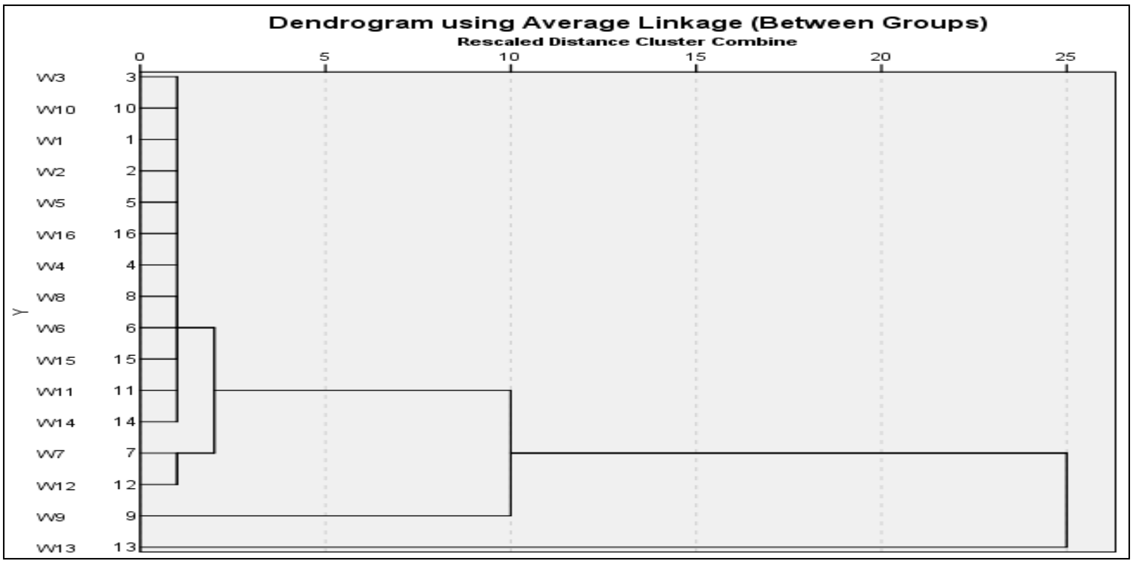


Fig. 4: Dendrogram

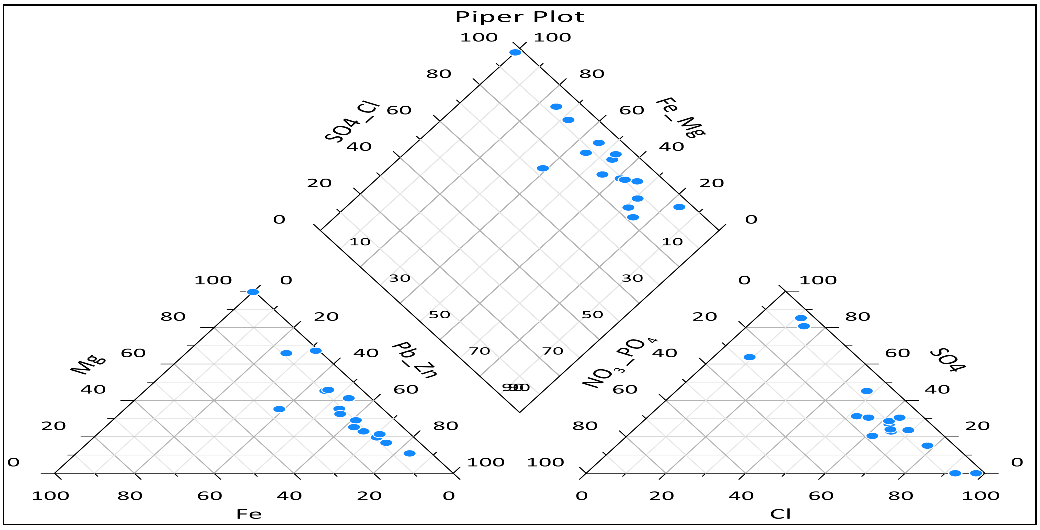
The Hierarchical Cluster Analysis result in Table 5 shows that the physiochemical are classified into two clusters. It shows that the location of the physiochemical is differential betweenthe two clusters. This is also seen in Figure 4 above, as the dendrogram shows two distinct clusters though cluster two seems to have more sites than cluster one.

VII. PIPER DIAGRAM

The chemical components of the groundwater in Minna, Niger State, are shown by a piper diagram. It provides the principal cation and significant anion combinations in a groundwater triangle diagram. The relative composition of groundwater is shown by the organization of the different substances (Thilagavathi et al., 2012; Blake et al., 2016 and Barkat et al., 2021).

Figures 5a and 5b show the results of the chemical analysis of groundwater samples from 15 water bodies around Minna, Niger State, as represented on the Piper diagram. They demonstrate two chemical Sectioning:

- Iron, magnesium, sulfate, and chloride.
- Bicarbonate of iron and magnesium.



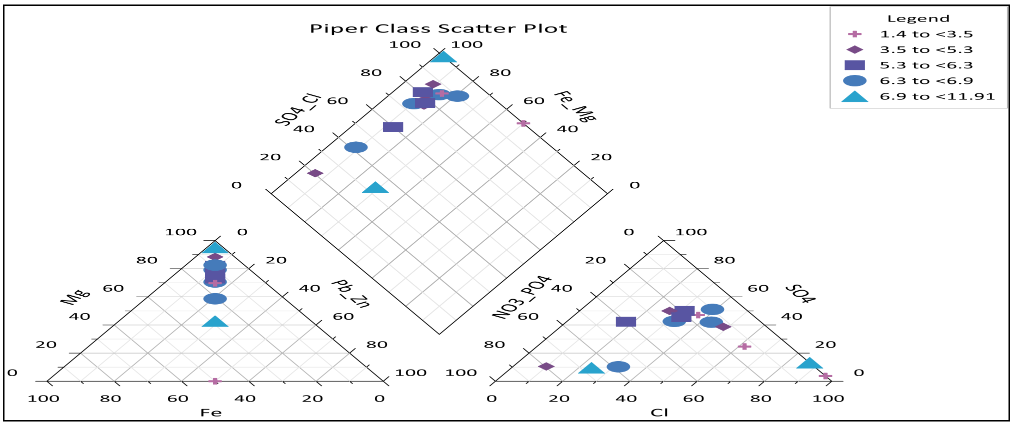


Fig. 5: Piper Plot

VIII. CONCLUSION

Based on the findings of the results, it is however concluded that

- The groundwater at Minna, Niger State, contains very little in the way of physio-chemicals and leachates. The point source of groundwater was found to be the irrigation site's base, where the investigation found a restricted migration of physio-chemicals into leachate. This serves as groundwater for a variety of uses (including household, commercial, and agricultural).
- The World Health Organization's allowable water quality guidelines are met by the groundwater quality in the research region.
- Not all public health-relatedimpairments could be related to contamination of Groundwater in the study area owing to the fact that the degree of the contamination by physio-chemicals and leaches cannot be linked to this ailment. Therefore, groundwater pollution cannot be attributed to different public health-related problems.
- Many of the parameters used as measurements comply with WHO standards and Nigerian Standards. Groundwater in some of the study areas may not require precautionary measures before drinking. Concentrations of many variables were not detected in large quantities.

RECOMMENDATIONS

Based on the findings above, the following recommendations are made:

- A competent agricultural practice procedure, accurate timing and application of the precise amount of physio-chemicals required by crops, and spillage management during application are all important.
- To create a model for forecasting contamination at different times of the year, a system for routine evaluations and monitoring of the concentration levels of agrochemicals in water and wells should be established.
- The government and other organizations ought to help spread the word about the physio-chemical impact on groundwater. Certain crops have a strong phyto-remediation capacity; by absorbing more toxins, they lessen the amount of residue that could seep into groundwater. Constructed wetlands, or such crops, ought to be grown on any catchment that has been contaminated by physio-chemicals.
- Farmers should be educated to change farming practices and adopt sustainable physio-chemical usage.
- In order to better understand how sustainable farming interacts with surface water resources—specifically, the rivers in the study area—and to meet overall environmental quality standards, the government should implement a multitude of environmental policies, research projects, and knowledge gathering initiatives.

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