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Multivariate Statistical Analysis for Assessment of Groundwater Quality around Dumpsites in Bauchi metropolis, Bauchi State, Nigeria

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ABSTRACT: Groundwater is an important source of drinking water and the protection of groundwater is a major environmental issue as the importance of water quality to human health. Hence, the objective of this study was to assess the groundwater quality around dumpsites in Bauchi metropolis, Bauchi State, Nigeria using standard analytical techniques and multivariate statistical analysis methods such as correlation analysis (CA), principal component analysis (PCA), and hierarchical cluster analysis (HCA). The mean concentration of the parameters in ground water samples ranged from pH 7.55 to 9.06, temperature 32.55 to 34.25 ºC, conductivity 54.80 to 65.38 µS/cm, salinity 0.20 to 0.29 mg/L, TSS 0.36 to 1.93 mg/L, TDS 57.53 to 59.95 mg/L, HCO_3 26.80 to 31.00 mg/L, PO_4^{3-} 1.05 to 2.06 mg/L, SO_4^{2-} 2.25 to 3.26 mg/L, NO_3^- 1.40 to 4.50 mg/L, NO_2^- 0.01 to 0.03 mg/L, and Cl^- 2.14 to 8.31 mg/L. The result shows that the investigated parameters were below the WHO, permissible limit, except PO_4^{3-}. The concentration of the parameters were in following trend; TDS > conductivity > temperature > HCO_3> pH > NO_3> SO_4>Cl> PO_4> TSS > salinity > NO_2. Multivariate analysis revealed that the main sources of water quality parameters might be related to dumpsites around the study area. According to the HCA, and PCA, the parameters were divided into three groups; the first group correlated with Salinity, TSS, SO_4, NO_3 and NO_2; the second group correlated with TDS and HCO_3, and the third with pH, temperature, and conductivity. The hydrochemistry of groundwater from the area reveals that the water could be applied to irrigation.

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Groundwater is a major source of water supply for domestic and industrial purposes in most of the Nigerian cities (Sulaiman *et al.*, 2019a). Contamination of this groundwater has a detrimental on human health, particularly in small communities and developing countries like Nigeria, where groundwater is often the ideal source of water for domestic purposes (Udiba *et al.*, 2019; Sulaiman *et al.*, 2020). However, the increase in urbanization, industrialization, and agricultural activities deteriorated the quality of groundwater (Li *et al.*, 2020). Deterioration of water quality is due to the introduction of foreign substances into the water across the water body (Sulaiman *et al.*, 2021). These contaminants are introduced into the water bodies in several ways, such as weathering of rocks, dissolution of aerosol particles from the atmosphere, mining, and leaching from dumpsite soils (Sulaiman *et al.*, 2019b). Dumpsites have been recognized as the major threats to groundwater receiving a mixture of municipal, commercial and mixed industrial wastes, which leachates to groundwater sources (Parvin *et al.*, 2021).

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Several studies reported that the effects of unlined waste dumps on the swarm soil and underlying shallow aquifers can be polluted due to poorly designed waste disposal facilities (Amadi *et al.*, 2012; Aromolaran *et al.*, 2023). The major problem related to the dumpsite is the infiltration of leachates into the surrounding environment, with subsequent contamination of groundwater (Alao *et al.*, 2023a). Uncontrolled dumpsite threatens the groundwater supply as the movement of leachates from dumpsites through the soil and the aquifers pose a risk to the environment and human health (Igboama *et al.*, 2022). It has been reported that about 80% of all human health issues are caused by water (Lin *et al.*, 2023). The adverse health effects of water contaminants are due to their toxic properties, and bioaccumulation nature (Sharma *et al.*, 2021). It is essential to protect surface and groundwater contamination due to leachate percolation in and around the dumpsite (Alkalay *et al.*, 1998; Alao *et al.*, 2023b). Moreover, the protection of groundwater is a major environmental concern due to the importance of water quality on human health (Longe *et al.*, 2010; Li *et al.*, 2022). It is, therefore, necessary to evaluate the water quality for the protection of public health. This present study aims to determine the quality of groundwater samples around dumpsites in the Bauchi metropolis using multivariate statistical analysis.

MATERIALS AND METHODS

Study area: The study area is Bauchi metropolis, the capital of Bauchi State, situated in the North-Eastern part of Nigeria. It is located between longitude 10.10^0N-10.33^0N and latitude 9.40^0E-10.13^0E. It occupies an estimated land area of 3,687 km^2 and its altitude is 690.2 m above sea level. The climate is tropical with two distinct seasons; dry/harmattan (November-April) season and wet (May-October) and season, with a temperature ranging between 23 ^oC and 40 ^oC. The annual rainfall ranged from 894 to 960mm, with an average of 928 mm. The daily humidity increases to 94% in the middle of the rainy season but falls to less than 10% during the dry season (Barambu *et al.*, 2020; Sulaiman *et al.*, 2021).

Sample collection: Water samples were collected from ten different boreholes around the dumpsites in the Bauchi metropolis. The samples were collected for three months into 500 ml sterile bottles. Before taking water samples, the plastic containers were rinsed twice. A total of thirty different samples were collected for the study. All the samples were taken to the laboratory and stored under at 4 ^oC temperature until analysis. The water samples are chemically analyzed and the analysis of the water sample was done using the procedure of standard methods as presented in Table 1.

Table 1 Methods used, description, and reference guidelines

S/N	Parameters	Methods	Description	Reference Guidelines	
				NSDWQ	WHO
1	pH	Field(pHep)	pH meter	6.5-8.5	6.5-8.5
2	Temperature	Field (DK-MsG01)	Temp/Salinity-meter	Ambient	Ambient
3	Conductivity	Field (DIST)	EC/TDS- meter	1000	1000
4	Salinity	Field (DK-MsG01)	Temp/Salinity-meter	0.5	0.5
5	TSS	Field (DIST)	EC/TDS- meter	500	500
6	TDS	Field (DIST)	EC/TDS- meter	500	1000
7	HCO_3	Laboratory	Titration	200	250
8	PO_4^{3-}	Laboratory	AC	0.2	0.2
9	SO_4^{2-}	Laboratory	IC	200	250
10	NO_3^-	Laboratory	AC	50	50
11	NO_2^-	Laboratory	AC	0.5	0.5
12	Cl^-	Laboratory	Titration	250	250

To study the differences between the sampling stations among the water quality parameters, the ANOVA (one-way) was employed using the equation 1.

$$F = \frac{MS_{bg}}{MS_{wg}} \quad (1)$$

Where MS_{bg} =mean square of the between group and MS_{wg} = mean square of the within group.

One of the important tools of the employed analysis was determining Pearson's correlation coefficient to estimate the correlation between two parameters. The Pearson's coefficient was evaluated using the Equation 2:

$$r = \frac{\sum_{1=1}^{n}(x_1-\bar{x})\,(y_1-\bar{y})}{\sqrt{\sum_{1=1}^{n}(x_1-\bar{x})}\sqrt{\sum_{1=1}^{n}(y_1-\bar{y})}} \quad (2)$$

Where xi and yi mark the measured values for which the correlation coefficient is to be attained, x and y are the corresponding average values, and n denotes the number of data pairs.

As a sophisticated tool of cluster analysis, the principal component analysis is used in situations where a large set of data needs to be manipulated and rearranged so that grouping (clustering) patterns can be easily identified. Using PCA, one can reduce the dimensionality of the multidimensional data set while keeping most of the variation contained in the original data set. This is achieved by finding the so-called principal components of the data set. The principal components are computed as a linear combination of the independent variables, in this case, the water quality parameters. The procedure for the computation of the principal components is as follows:

1. Normalization of the measured data set using Eq3.
2. Calculation of the covariance of the normalized dataset using Eq4.
3. Computing the eigenvalues of the matrix using Eq5.

$$Z = \frac{x-\mu}{\sigma} \quad (3)$$

$$Cov\,(\varkappa,y) = \frac{1}{n-1} \cdot \sum_{1=1}^{n}(x_1 - \bar{x}) \cdot (y_1 - \bar{y}) \quad (4)$$

$$A\cdot \vec{v} \;=\; \lambda\vec{v}, \vec{v} \cdot (A - \lambda I) = 0, det\,(A - \lambda I) = 0 \quad (5)$$

Where Z represents the new, normalized variable, μ is the median of the original variable, σ stands for the standard deviation of the original variables, and A is the covariance matrix for which the eigenvalues λ are to be computed. These eigenvalues describe the direction of the principal components and the amount of variance contained in the considered principal component.

RESULTS AND DISCUSSION

Water quality parameters: The results for the water quality parameters obtained in the groundwater samples in Bauchi Metropolis are presented in Figure 1.The mean concentration of the parameters in groundwater samples ranged from pH 7.55 to 9.06, temperature 32.55 to 34.25ºC, conductivity 54.80 to 65.38µS/cm, salinity 0.20 to 0.29 mg/L, TSS 0.36 to 1.93 mg/L, TDS 57.53 to 59.95 mg/L, HCO_3 26.80 to 31.00 mg/L, PO_4^{3-} 1.05 to 2.06 mg/L, SO_4^{2-} 2.25 to 3.26 mg/L, NO_3^-1.40 to 4.50 mg/L, NO_2^- 0.01 to 0.03 mg/L, and Cl^- 2.14 to 8.31mg/L. In comparison with the Nigerian Standard for Drinking Water Quality (NSDWQ) and World Health Organization (WHO), the investigated parameters were below NSDWQ and WHO permissible limits, except PO_4^{3-} in some samples. The concentration of the parameters were in the following trend; TDS> conductivity> temperature > HCO_3> pH > NO_3 > SO_4 > Cl > PO_4 > TSS > salinity > NO_2. The data obtained from the chemical analysis was subjected to ANOVA, the test results confirm the normal distribution of the data with a confidence coefficient of 95% (p≥0.05) and the results tests are presented in Table 2. According to the analysis of variance (ANOVA) test, there was no significant difference observed in parameters at different sampling stations (p ≥0.05).

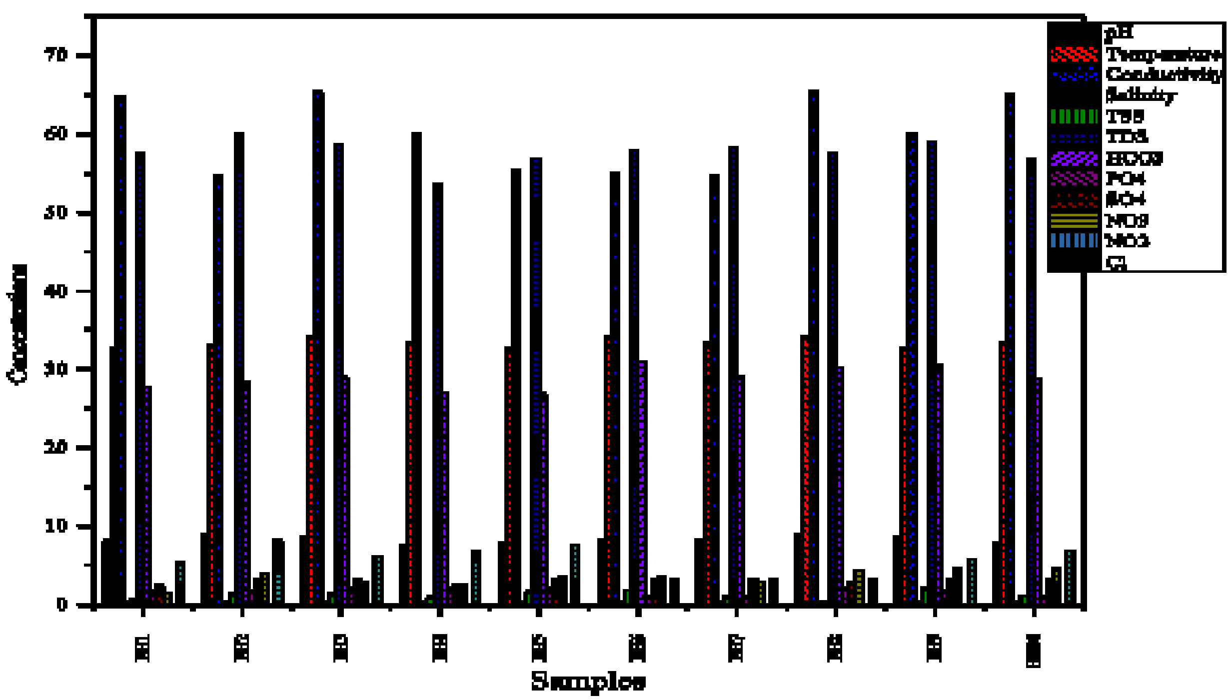

Fig. 1 Mean concentration of water quality parameters of groundwater samples

Table 2: Person's correlation analysis (*r*) for the water quality parameters in the groundwater samples

Parameters	pH	Temp.	Cond.	Salinity	TSS	TDS	HCO_3	PO_4	SO_4	NO_3	NO_2	Cl
pH	1.00	0.72	0.83	0.03	-0.16	0.40	0.52	0.55	-0.67	0.12	0.11	0.50
Temperature		1	0.79	0.67	0.46	0.19	0.04	- 0.174	0.03	0.71	0.38	-0.24
Conductivity			1	0.12	-0.16	-0.14	-0.04	0.16	-0.43	0.55	-0.22	0.19
Salinity				1	.96*	0.21	-0.18	-0.70	0.72	0.71	0.72	-0.81
TSS					1	0.32	-0.10	-0.69	0.80	0.52	0.81	-0.82
TDS						1	.91*	0.46	-0.21	-0.44	0.81	0.27
HCO_3							1	0.78	-0.58	-0.66	0.50	0.64
PO_4								1	-.94*	-0.74	-0.15	.98**
SO_4									1	0.52	0.38	-.971*
NO_3										1	0.03	-0.71
NO_2											1	-0.34
Cl												1

*Key: *. Correlation is significant at the 0.05 level (1-tailed). **. Correlation is significant at the 0.01 level (1-tailed).*

*Correlation analysis***:** The results of (*r*) for water quality parameters of the groundwater samples ($p< 0.01$ and $p< 0.05$) are shown in Table 2. The results show that pair parameters have a positive correlation ($r> 0.9$) with Salinity-TSS, and TDS- HCO_3, at $p< 0.01$ and PO_4-Cl at $p< 0.05$.This signifies their concurrent discharge from a similar source. The PO_4-SO_4 and SO_4-Cl showed a negative correlation ($r> -0.9$), this perhaps has not originated from the same sources.

Table 3 Principal component analysis of the water quality parameters in the groundwater samples

Parameters	Components		
	1	2	3
Ph	-0.370	0.332	**0.868**
Temperature	0.365	0.181	**0.913**
Conductivity	-0.155	-0.198	**0.968**
Salinity	**0.910**	0.262	0.320
TSS	**0.924**	0.377	0.064
TDS	-0.069	**0.997**	0.045
HCO3	-0.471	**0.880**	0.061
PO4	-0.916	0.389	0.098
SO4	**0.940**	-0.130	-0.315
NO3	**0.792**	-0.418	0.488
NO2	**0.847**	0.531	0.032
Cl	-0.975	0.204	0.087
Eigen values	5.638	3.262	3.100
% of Variance	46.984	27.181	25.835
Cumulative %	46.984	74.165	100.000

Principal Components Analysis: Principal Components Analysis (PCA) was evaluated to categorize the source of water quality parameters. Table 3 and Fig 2 showed three components demonstrating 100% cumulative total variance of the different parameters in the samples. Salinity, TSS, SO_4, NO_3 and NO_2 with a total variance of 46.984% correlated with the first component. This might be due to the infiltration of leachates from the dumpsite. The second component correlated with TDS and HCO_3 with a total variance of 27.181%. This could be due to emissions of automobile exhaust and machines used, while the third component correlated with pH, temperature, and conductivity with a total variance of 25.835, which indicated that the third component was attributed to lithogenic origin. The results are in line with the correlation that forecasted thatPO_4 and Cl could not be from the same source.

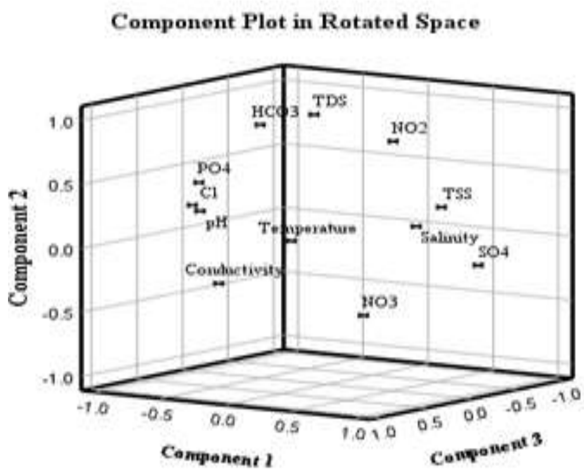

Fig. 2 Rotated component loading plot of component analysis of water quality parameters of groundwater

Cluster analysis: The water quality parameters are grouped into three clusters in Figure 3, where PO_4, Cl, TDS, and HCO_3 are in one group. Salinity, TSS, NO_2, and SO_4 are in the second group, while pH, conducted, temperature and NO_3 are in the second group. The cluster analysis showed that PO_4, Cl, TDS, and HCO_3, which have a related source and are not inclined by Salinity, TSS, NO_2, and SO_4, but the presence of pH, conducted temperature and NO_3 is influenced by Salinity, TSS, NO_2, and SO_4, signifying that they are from a similar source.

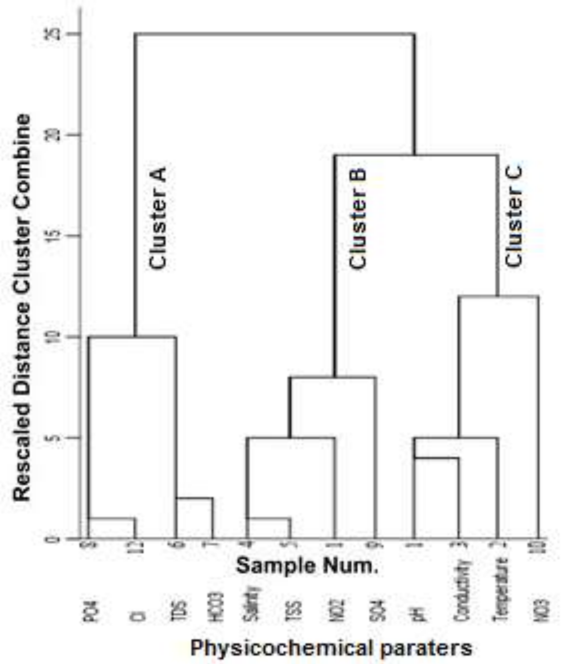

Fig. 3 Dendrograms produced by hierarchical clustering for water quality parameters of groundwater samples

Conclusions: From the result of this study, it can be concluded the concentration of the investigated water quality parameters with the NSDWQ and WHO, the investigated parameters were below NSDWQ and WHO permissible limits, except PO_4^{3-}exceeded the maximum permissible set by NSDWQ and WHO. Furthermore, the lower concentration of the studied parameters indicates the low impact of dump sites around sampling stations. However, regular motoring should be encouraged to detect early warning signs of changes in the parameters to preserved water sources. The implementation of multivariate statistics helps to reduce the dimension of the large data set and extract only a few important determinants to control the groundwater quality.

REFERENCES

Akhtar, N; SyakirIshak, MI; Bhawani, SA; Umar, K (2021). Various Natural and Anthropogenic Factors Responsible for Water Quality Degradation: A Review. *Water*. 13(19): 2660. https://doi.org/10.3390/w13192660

Alao, JO; Lawal, HA: Nur, MS (2023) Investigation of groundwater vulnerability to open dumpsites and its potential risk using electrical resistivity and water analysis. *Heliyon,* 9 (2): e13265.https://doi.org/10.1016/j.heliyon.2023.e13265.

Alao, JO (2023). Impacts of open dumpsite leachates on soil and ground water quality. *Groundwater Susta Dev.* 20:100877. https://doi.org/10.1016/j.gsd.2022.100877.

Aromolaran, OK; Aromolaran, O; Faleye, ET; Faerber, H (2023). Environmental impacts of an unlined municipal solid waste land fill on groundwater and surface water quality in Ibadan, Nigeria. *Environ. Geochem. Health.* 45(6): 3585-3616.

Barambu, AU; Maigari, AU; Sulaiman, MB (2020). Levels of Heavy Metals in a Groundwater around a Municipal Solid Waste Dumpsite in Bauchi, Nigeria: Assessing the Health Impact. *J. Chem. Soc. Nig.* 45(2): 316-323.

Igboama, WN; Hammed, OS; Fatoba, JO (2022). Review article on impact of groundwater contamination due to dumpsites using geophysical and physiochemical methods. *Appl. Water Sci.* 12:130. https://doi.org/10.1007/s13201-022-01653-z

Li, J; Sun, C; Chen, W; Zhang, Q; Zhou S; Lin, R; Wang, Y (2022). Groundwater Quality and Associated Human Health Risk in a Typical Basin of the Eastern Chinese Loess Plateau. *Water*. 14(9): 1371.https://doi.org/10.3390/w14091371

Li, P; Karunanidhi, D; Subramani, T (2021). Sources and Consequences of Groundwater Contamination. *Arch Environ Contam. Toxic.* l80:1–10. https://doi.org/10.1007/s00244-020-00805-z

Lin, L; Yang, H; Xu, X (2022). Effects of Water Pollution on Human Health and Disease Heterogeneity: A Review. *Front. Environ. Sci*. https://doi.org/10:880246.doi:10.3389/fenvs.2022.880246

Parvin, F; Tareq, SM (2021). Impact of land fill leachate contamination on surface and groundwater of Bangladesh: a systematic review and possible public health risk assessment. *Appl. Water. Sci.* 11,100.https://doi.org/10.1007/s13201-021-01431-3

Sharma, S; Bhattacharya, A (2017). Drinking water contamination and treatment techniques. *Appl Water Sci*. 7:1043-1067.

Sulaiman, BA; Sulaiman, MB; Ahmed, A; Maigari, IA; Tijjani, AF (2021). Levels of Heavy Metals in Soil, Water and Vegetables around Industrial area in Bauchi, Northeastern Nigeria. *J. Appl. Sci. Environ. Manage.* 25(8): 1527-1533.

Sulaiman, MB; Asegbeloyin, JN; Ihedioha, JN; Oyeka, EE; Oji, EO (2019b). Trace Metals Content of Soil around a Municipal Solid Waste Dumpsite in Gombe, Nigeria: Assessing the Ecological and Human Health Impact. *J. Chem. Risk.* 9(3): 173-190.

Sulaiman, MB; Yakubu, Y; Akinlotan, OO (2019). Assessment of Seasonal Variation of Groundwater Quality in Bauchi Town, Northeastern Nigeria. *Nig. Res. J. Chem. Sci*. 6: 49-57.