Original Research Article

Modelling Groundwater Quality of Aba in Abia State Using Principal Component Analysis and Multiple Linear Regression

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ABSTRACT

The aim of this study was to model the groundwater quality of Aba in Abia state. To achieve the aim, thirty-two water samples were taken from sixteen boreholes during the rainy and dry seasons and analysed in the laboratory for pH, Electrical Conductivity, Total Hardness, BOD_5, COD, Pb, Cd, Cr, NH3, TDS, SO_4, NO_3 and PO_4. Principal Component Analysis (PCA) and Multiple Linear Regression (MLR) were employed to extract the principal factors and develop a model for predicting water quality index for Aba, Abia State. In the dry season, water quality index could be estimated using the Water Quality Index (WQI) model with pH, PO_4, COD, SO_4 and Pb with Adjusted $R^2 = 0.999999999938$ and standard error of 0.043868872. Meanwhile, in the rainy season, WQI could be estimated using the WQI model with Turbidity, PO_4, NO_3, COD, SO_4 and Pb with Adjusted $R^2 = 0.999999997469$ and standard error of 0.066697494. The one-way ANOVA for the parameters in the dry season with $p = 0.000 < 0.05$ indicated that leachate had a large effect on groundwater quality. During the rainy season, one-way ANOVA result with $p = 0.000 < 0.05$ asserted that leachate had a large effect on groundwater quality.

Keywords: [Water quality index, Aba, groundwater quality, Principal Component Analysis, Multiple Linear Regression]

1. INTRODUCTION

Water is one of the most requested of all human necessities and the most basic and critical requirement for biota [1]. Water also plays a vital role in the earth's ecosystem, as it is the principal component of the earth and an integral part of several natural resources. Water exists substantially either as surface or groundwater. Groundwater is water found in all voids of a geologic stratum [2]. It is considered as the most important source of freshwater especially for the arid and semi-arid regions attributable to the low precipitation rates in those regions [3]. Freshwater which is the form of water available for human consumption, exist in the more feasible form as rivers, streams and groundwater. Groundwater serves as the main reserve of freshwater and the main sources of water in the urban environment, which is used for drinking, industrial, agricultural and domestic purposes [4]. Groundwater is important to the entire world's population, but more important to semi-arid and arid regions where there is insufficiency of surface water[5].

Throughout the world, water is recognized as the most fundamental and indispensable of all natural resources. The demand for groundwater supply for drinking, domestic, agricultural, and industrial use has been on a steady increase owing to global population surge. Although not the largest source of water, groundwater is the largest available source of freshwater, making it an essential component of the water supply chain and a valuable natural resource[1].

Groundwater is a renewable resource, recharged by precipitation. It is often the first alternative choice of many consumers attributable to its perceived cleanness and safeness, since it is recharged, recycled and filtered through biological, natural processes that keeps it free from contamination and pollution. Groundwater becomes polluted from natural and anthropogenic sources, regardless. The safety of groundwater be it shallow or deep groundwater source, depends on the geology of the area, human activities/land use activities of the area, environmental processes and meteorological condition of the area. It is for this reason that groundwater is assessed systematically and monitored continually, applying proven scientific methods, to ascertain its quality so as to ensure that it can be used for domestic purposes, and that no adverse effects are experienced attributable to its use.

Groundwater pollution is a big quandary especially in developing countries where there is inadequate infrastructure to treat and distribute water to the populace [6]. This is compounded by waste management challenges, which brings about groundwater pollution particularly by leachate from dumpsites.

Therefore, finding appropriate locations for suitable groundwater for drinking reasons is a significant difficulty for satisfying water demands. Groundwater quality declines for a variety of reasons, such as natural reversals in the flow of rivers, improper management of water bodies, climate variability, and human activities [7].

According to [8] , people in rural areas of developing nations like Nigeria have access to cleaner water sources than those who reside in cities, where the issue of poor water quality is made worse by industrial effluents, municipal refuse dumps, and the disposal of toxic, metallic, and organic wastes.

The quality, quantity and accessibility of groundwater is requisite for holistic, sustained socio-economic and environmental development since it caters to the water needs of sectors across spheres of life [9].An analytical tool and composite indicator known as a water quality index (WQI) gives end users information based on predetermined water content factors that are then transformed into a single unitless value. WQI offers the benefit of determining the condition of water quality without having to interpret each parameter separately. Nonetheless, more than 20 water quality indices were created and revived across the world until 1970. Because of its simplicity of use and scientific basis, several studies used various WQIs to assess water quality. As a result of this research, a considerable amount of data on water quality is created, which must be gathered in order to determine the water quality status in a specific region [10].Water quality indices (WQIs) are essential for making simpler the reportage of complex and technical water quality data, on a scientific bases of communication, using models that are capable of converting multi-variable water quality data to produce a single unitless digit score that describes overall quality of water, which is important for providing a structured platform to appraise and compare water quality of various water resources [11].

2. MATERIALS AND METHODS

2.1 Study Area

The study area, Aba city in Abia state is the main economic nerve centre of Abia State, Nigeria (Figure 1). It serves the commercial needs of important cities in the south-eastern, and south-southern geopolitical regions of Nigeria. Over one million people are estimated to be living in the 236km^2 area. The vegetation and climate conditions are humid equatorial rainforest, with annual mean rainfall ranging from 2150 to 2460 mm, and mean daily temperatures ranging between 22 ^{o}C and 33^{o}C for the average minimum and maximum daily temperatures [12].

Aba lies approximately within longitude 7°19′ E to 7°37′ E and latitude of 5°3′ N to 5°12′ N in the Niger Delta Basin and is underlain by the Benin Formation that is highly aquiferous.The aquifer type is mostly unconfined and the water table elevation range 26m –33m below ground level, with an average elevation depth of 28.6m [13, 12].

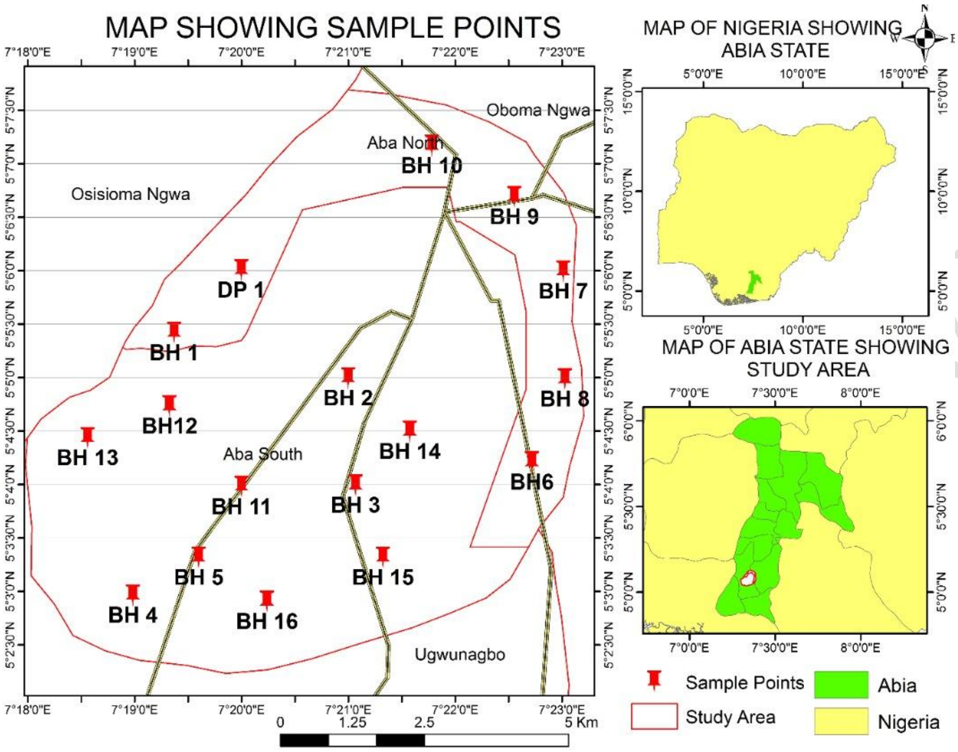

Figure 1: Map of the study area showing sampling points

2.2 Sample Collection

Thirty-twoSamples were taken from boreholes in Aba during the dry and rainy seasons, at evenly distributed sampling points by inserting a grid on the map of Aba using ArcGIS software and taking water samples from boreholes on the nodes of the grid for laboratory analysis. Borehole locations were selected based on spatial distribution on the grid of the map of Aba. Leachate sample was taken from the existing dumpsite in Aba.

The water samples were taken in properly sterilized bottles that had been thoroughly cleaned. Before obtaining a water sample, the bottles were rinsed three times with the groundwater sample. Following that, the obtained samples were put in an ice bag and transferred to the laboratory.

Other equipment and materials used during the study are as follows:

i. Global Positioning system device (GPS App on mobile phone) was used to obtain the geographical position of the sampled boreholes and dumpsite.

ii. Turbidity meter was used to read the in-situ turbidity of the groundwater samples.

iii. pH Meter was used to determine the pH level of the groundwater samples.

iv. Thermometer was used to read the temperature of the groundwater samples.

2.3 Sample Analysis

The concentrations of quality parameters (pH, Electrical Conductivity, TDS, Turbidity, PO_4, NO_3, COD, SO_4, Total Hardness, BOD_5 and Pb) were analysed. All analyses were carried out in accordance with established methods and as described in the literature [14]. The study employed drinking water quality standards provided by the World Health Organization drinking water guideline to detect excessive quantities of these parameters.

2.4 Calculation of Water Quality Index

The physicochemical parameters (pH, EC, TDS,BOD, COD, TH, SO_4, NO_3,Turbidity, Pb and PO_4) were used to calculate the WQI in this study.The Water Quality Index (WQI) was calculated using the Weighted Average Water Quality Index (WAWQI) method [15, 5] which involved:

Step 1:Gathering information on the water quality metrics that will be used to calculate the WQI.

Step 2: Computation of k

Using Equation (1) to compute k.

$$k = \left(1/\ \textstyle\sum_{i=1}^{n} \frac{1}{s_i}\right) \tag{1}$$

where: k = proportionality constant

Si = Standard permissible limit

Step 3: Compute the nth parameter's quality rating, using Equation(2).

$$q_n = 100\left(\frac{(v_n - v_{io})}{(s_i - v_{io})}\right) \tag{2}$$

where: vn = estimated concentration of the nth parameter of the given sampling location.

vio = ideal value of the nth parameter in pure water.

Si = standard permissible limit of the nth parameter.

Step 4: Using Equation (3), determine the unit weight of the nth parameter.

$$W_n = \left(\frac{k}{S_i}\right) \tag{3}$$

Step 5: Using Equation (4), calculate the Water Quality Index.

$$WQI = \left(\frac{(\sum w_n * q_n)}{\sum w_n}\right) \tag{4}$$

The water quality index rating, graded A – E, is shown on Table 1.

Table 1: Water Quality Index (WQI) Ratings

WQI value	Water Quality Rating	Grade
0 - 25	Excellent	A
26 - 50	Good	B
51 – 75	Poor	C
76 - 100	Very Poor	D
Above 100	Unsuitable for drinking purpose	E

Source:[16, 5]

2.5 Statistical Analysisand Model Development

The one-way analysis of variance (ANOVA) was utilized, to see if the parameter concentrations altered considerably[17].Principal Component Analysis (PCA) and Multiple Linear Regression (MLR) were used to extract the principal factors and develop a model for predicting water quality index of the study area.

The Multiple Linear Regression model was given as shown below:

$$\text{Outcome} = \text{model} + \text{Error} \quad (5)$$

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \varepsilon \quad (6)$$

$$Y = \beta_0 + \sum_{i=1}^{n} (\beta_i X_i) + \varepsilon \quad (7)$$

where β_0 is the sample intercept, β_1 is the sample slope parameter for X_1, β_2 is the sample slope parameter for X_2 and so forth, ‘ε’ represents the sample errors/residuals.

3. RESULTS AND DISCUSSION

The Water quality parameters measured included: Temperature, pH, Turbidity, Electrical Conductivity, Nitrate, Phosphate, Total Hardness, Carbonate, Sulphate, BOD, COD, Ammonia, Lead, Cadmium, Chromium and TDS.Table 2 presents the location of the sampled boreholes in the study area.

Table 2: Location of sampled boreholes and Ariaria dumpsite

BOREHOLE	LATITUDE	LONGITUDE
BH1	5° 6' 30.528" N	7° 19' 41.952" E
BH2	5° 4' 59.412" N	7° 20' 59.928" E
BH3	5° 3' 59.256" N	7° 21' 4.032" E
BH4	5° 2' 57.588" N	7° 18' 59.004" E
BH5	5° 3' 18.756" N	7° 19' 35.976" E
BH6	5° 4' 12.216" N	7° 22' 43.032" E
BH7	5° 5' 59.424" N	7° 23' 0.708" E
BH8	5° 4' 58.908" N	7° 23' 1.608" E
BH9	5° 6' 41.148" N	7° 22' 33.348" E
BH10	5° 7' 9.804" N	7° 21' 46.98" E
BH11	5° 3' 58.5" N	7° 20' 0.06" E
BH12	5° 4' 43.752" N	7° 19' 19.524" E
BH13	5° 4' 25.932" N	7° 18' 33.588" E
BH14	5° 4' 29.532" N	7° 21' 34.56" E
BH15	5° 3' 18.756" N	7° 21' 19.44" E
BH16	5° 2' 54.096" N	7° 20' 14.352" E
DP1	5° 6' 34.02" N	7° 19' 41.628" E

3.1 Water Quality Indices for Dry and Rainy Season

Water quality index (WQI) was calculated using eleven parameters (pH, Electrical Conductivity, TDS, Turbidity, PO_4, NO_3, COD, SO_4, Total Hardness, $BOD_5$and Pb). The calculated water quality indices for dry and rainy seasons are presented in Table3.

Table 3: Water quality index for dry and Rainy season interpretation

Loc_ID	WQI - Dry season	Interpretation	WQI - Rainy season	Interpretation
BH1	21,531	Unsuitable for drinking purpose	5,545	Unsuitable for drinking purpose
BH2	3,847	Unsuitable for drinking purpose	352	Unsuitable for drinking purpose
BH3	2,492	Unsuitable for drinking purpose	851	Unsuitable for drinking purpose
BH4	1,518	Unsuitable for drinking purpose	1,020	Unsuitable for drinking purpose
BH5	3,562	Unsuitable for drinking purpose	198	Unsuitable for drinking purpose
BH6	12,628	Unsuitable for drinking purpose	86	Very poor
BH7	242	Unsuitable for drinking purpose	176	Unsuitable for drinking purpose
BH8	8,773	Unsuitable for drinking purpose	612	Unsuitable for drinking purpose
BH9	835	Unsuitable for drinking purpose	938	Unsuitable for drinking purpose
BH10	2,279	Unsuitable for drinking purpose	1,200	Unsuitable for drinking purpose
BH11	850	Unsuitable for drinking purpose	31	Good
BH12	1,236	Unsuitable for drinking purpose	194	Unsuitable for drinking purpose
BH13	5,120	Unsuitable for drinking purpose	185	Unsuitable for drinking purpose
BH14	1,219	Unsuitable for drinking purpose	242	Unsuitable for drinking purpose
BH15	3,075	Unsuitable for drinking purpose	359	Unsuitable for drinking purpose
BH16	3,105	Unsuitable for drinking purpose	253	Unsuitable for drinking purpose

3.2 Developedmodel for groundwater quality index

The principal component analysis and multiple linear regression model development are presented in the Tables 4– 12 and in the Figures 2 - 5.The model efficiency is validated by the coefficient of determination, R^2 and the Adjusted R^2. The effectiveness is computed by regression coefficient and the standard error [10]. The selected dry season model had a coefficient of determination, $R^2 = 0.999999999958541$, Adjusted $R^2 = 0.999999999938$ and standard error of 0.043868872 as shown on Tables 12 and 13. This implies that 99.99999999% of the water quality index is explained by the model. The selected rainy season model had a coefficient of determination, $R^2 = 0.99999999848$, Adjusted $R^2 = 0.999999997469$ and standard error of 0.066697494 as shown on Tables 12 and 13. This implies that 99.99999975% of the water quality index is explained by the model. A plot of the observed and the predicted water quality indices can be seen to overlap and align with each other on visual validation.

From Tables 9 and 11, the models developed asserts that lead is quite significant and has a large impact on WQI. The presence of heavy metals such as lead in drinking water is a major public health concern, and water treatment techniques such as activated carbon filtration at the point of use can be used to limit its consumption [18].

Table 4: Eigenvalues of Extracted factors of the water quality parameters for dry season

Component	Eigenvalues	% of Variance	Cumulative %
F1	4.489	40.813	40.813
F2	2.420	21.997	62.810
F3	1.268	11.530	74.340
F4	.966	8.779	83.119
F5	.701	6.374	89.493
F6	.466	4.233	93.726
F7	.433	3.940	97.665
F8	.183	1.668	99.333
F9	.073	.666	99.999
F10	.000	.001	100.000

Table 5: Varimax Rotated Component Matrix showing loadings of water quality parameters for dry season

Parameter	Component		
	VF1	VF2	VF3
SO_4	.961	.217	.041
PO_4	.958	.238	.041
COD	.723	-.445	.134
Pb	.717	.488	-.061
pH	-.552	.047	.227
EC	-.016	.963	.048
TDS	-.016	.963	.048
NO_3	.559	.647	.081
TH	.362	.645	-.212
Turbidity	-.064	-.164	.840
BOD_5	-.020	-.113	-.661

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

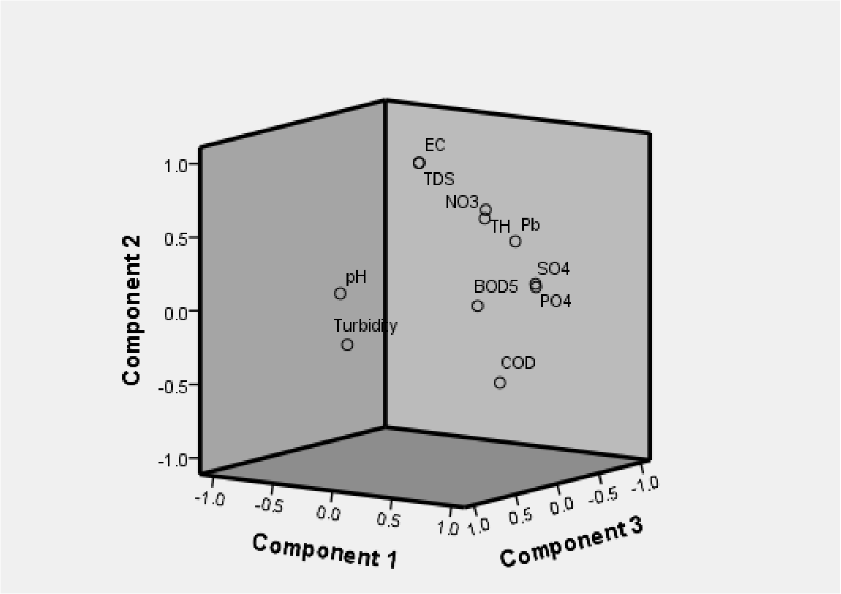

Figure 2: Component plot in rotated space using PCA for dry season

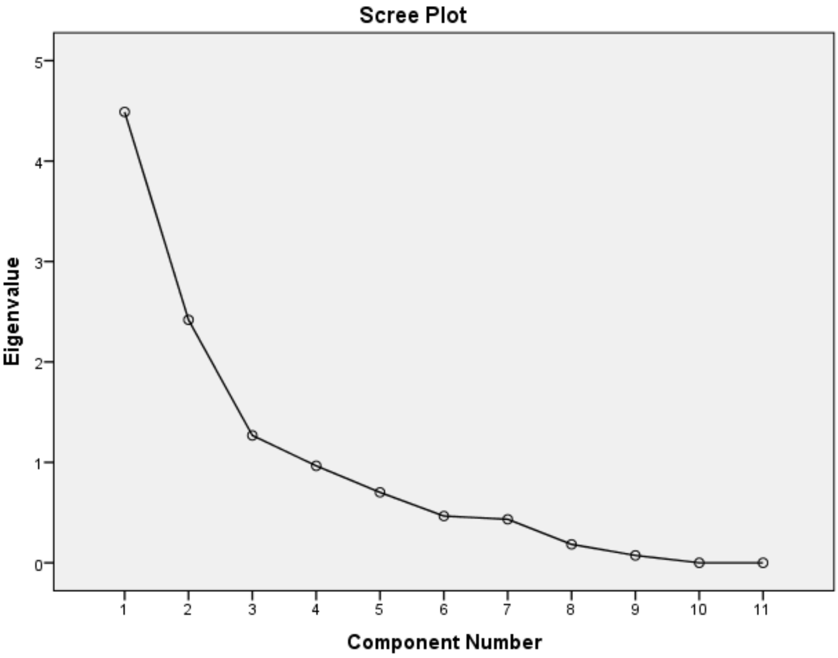

Figure 3: Scree plot for dry season Eigenvalues using PCA

Table 6: Eigenvalues of Extracted factors of the water quality parameters for rainy season

Component	Eigenvalues	% of Variance	Cumulative %
F1	6.326	57.505	57.505
F2	1.631	14.830	72.335
F3	1.058	9.614	81.949
F4	.795	7.225	89.174
F5	.610	5.543	94.716
F6	.371	3.376	98.092
F7	.159	1.443	99.535
F8	.049	.442	99.978
F9	.002	.020	99.997
F10	.000	.003	100.000

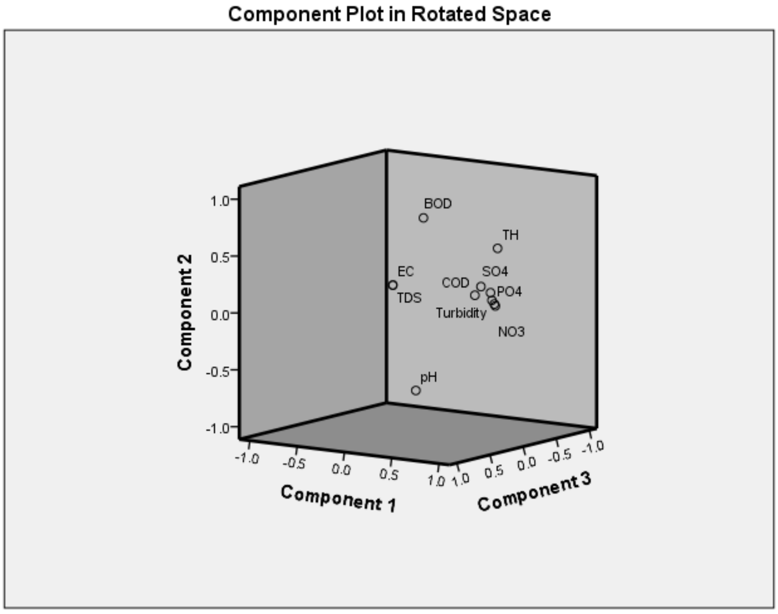

Figure 4: Component plot in rotated space using PCA for rainy season

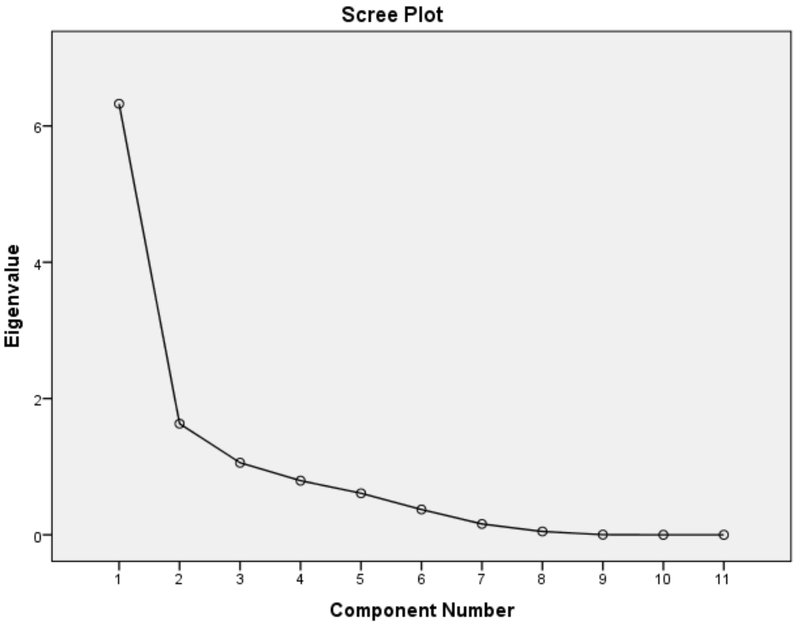

Figure 5: Scree plot for rainy season Eigenvalues using PCA

Table 7: Varimax Rotated Component Matrix showing loadings of water quality parameters for rainy season

Parameter	Component		
	VF1	VF2	VF3
PO_4	.957	.139	.199
NO_3	.950	.156	.205
Turbidity	.940	.191	.227
Pb	.903	.249	.195
SO_4	.773	.284	.154
COD	.569	.159	-.046
BOD_5	.198	.837	.200
pH	-.216	-.791	-.275
TDS	.321	.350	.838
EC	.321	.350	.838
TH	.459	.488	-.546

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Table 8: Observed vs Predicted WQI using MLR for dry season

Location	Observed WQI	VF1 Predicted WQI	VF2 Predicted WQI	VF3 Predicted WQI
BH1	21,531	21,531	14,206	4,793
BH2	3,847	3,847	3,046	5,142
BH3	2,492	2,492	381	4,735
BH4	1,518	1,518	2,086	2,038
BH5	3,562	3,562	8,120	4,425
BH6	12,628	12,628	7,170	4,851
BH7	242	242	1,788	4,634
BH8	8,773	8,772	4,310	4,363
BH9	835	835	5,973	5,221
BH10	2,279	2,279	4,481	4,390
BH11	850	850	6,344	5,690
BH12	1,236	1,236	7,030	4,063
BH13	5,120	5,120	- 981	5,530
BH14	1,219	1,219	1,665	3,370
BH15	3,075	3,075	3,090	3,856
BH16	3,105	3,105	3,603	5,209

Table 9: Coefficients of multiple linear regression for dry season model

	Coefficients	Standard Error	t Stat	P-value
Intercept	2.1876	0.2206	9.9181	0.0000
pH	-0.2992	0.0315	-9.5007	0.0000
PO_4	0.8921	0.4882	1.8273	0.0976
COD	0.0007	0.0012	0.5822	0.5733
SO_4	0.0015	0.0096	0.1605	0.8757
Pb	9843.0373	0.0444	221749.1848	0.0000

Table 10: Observed vs Predicted WQI using MLR for rainy season

Location	Observed WQI	VF1 Predicted WQI	VF2 Predicted WQI	VF3 Predicted WQI
BH1	5545	5545	1805	2943
BH2	352	352	1662	1631
BH3	851	851	1040	919
BH4	1020	1020	1379	550
BH5	198	198	580	1103
BH6	86	86	823	1944
BH7	176	176	399	-493
BH8	612	612	807	152
BH9	938	938	880	1175
BH10	1200	1200	1363	714
BH11	31	31	1029	-4
BH12	194	194	920	478
BH13	185	185	-229	-73
BH14	242	242	581	1051
BH15	359	359	-165	122
BH16	253	253	-633	31

Table 11: Coefficients of multiple linear regression for rainy season model

	Coefficients	Standard Error	t Stat	P-value
Intercept	0.035254272	0.088981796	0.396196	0.701189199
Turbidity	3.195065622	2.362583817	1.352361	0.209258699
PO_4	0.220138224	0.977805336	0.225135	0.826903007
NO_3	-0.021404109	0.124790785	-0.17152	0.867609487
COD	-0.000107496	0.002708228	-0.03969	0.969204995
SO_4	0.000597849	0.001027713	0.581727	0.575029755
Pb	9843.911771	0.539270088	18254.14	2.26266E-35

Table 12: Simulated water quality index models

Extracted Factors	**Model**	**Goodness of fit Statistics**	**Decision**
Dry Season			
VF1	f (x_1, x_2, x_3, x_4, x_5)	R^2 = 0.999999999958541 Adjusted R^2 = 0.999999999938 Standard Error = 0.043868872	Model Accepted
VF2	f (x_1, x_2, x_3, x_4)	R^2 = 0.429934250051281 Adjusted R^2 = 0.131728522797 Standard Error = 4904.7360388	Model Rejected
VF3	f (x_1, x_2)	R^2 = 0.0262076314606923 Adjusted R^2 = -0.123606579 Standard Error = 5896.72690736	Model Rejected
Rainy Season			
VF1	f (x_1, x_2, x_3, x_4, x_5, x_6)	R^2 = 0.999999998481656 Adjusted R^2 = 0.999999997469427 Standard Error = 0.066697494	Model Accepted
VF2	f (x_1, x_2)	R^2 = 0.2585765 Adjusted R^2 = 0.14451135 Standard Error = 1226.32953	Model Rejected
VF3	f (x_1, x_2, x_3)	R^2 = 0.440177 Adjusted R^2 = 0.2771276 Standard Error = 1065.6124	Model Rejected

3.3 Validation of model for groundwater quality index

The selected water quality index modelswith the coefficient of determination, R^2 and its adjusted $R^2$are presented in Table 13. The plots of the visual validation of WQI model for dry and rainy seasons arepresented in Figures 6 and 7. The plots indicate a perfect fit of the observed and predicted WQI for both seasons.

Table 13: Selected water quality index models

Model Equation	R^2	Adjusted R^2
Dry Season		
$y = 2.1876 - 0.2992\ x_1 + 0.8921\ x_2 + 0.00067\ x_3 + 0.001544\ x_4 + 9843.037\ x_5$ where y = Water quality index (WQI), x_1 = pH, x_2 = PO_4, x_3 = COD, x_4 = SO_4 and x_5 = Pb	0.999999999958541	0.999999999937812
Rainy Season		
$y = 0.03525 + 3.1951\ x_1 + 0.22014\ x_2 - 0.021404\ x_3 - 0.0001075\ x_4 + 0.000598\ x_5 + 9843.912\ x_6$ where y = Water quality index (WQI), x_1 = Turbidity, x_2 = PO_4, x_3 = NO_3, x_4 = COD and x_5 = SO_4, x_6 = Pb	0.999999998481656	0.999999997469427

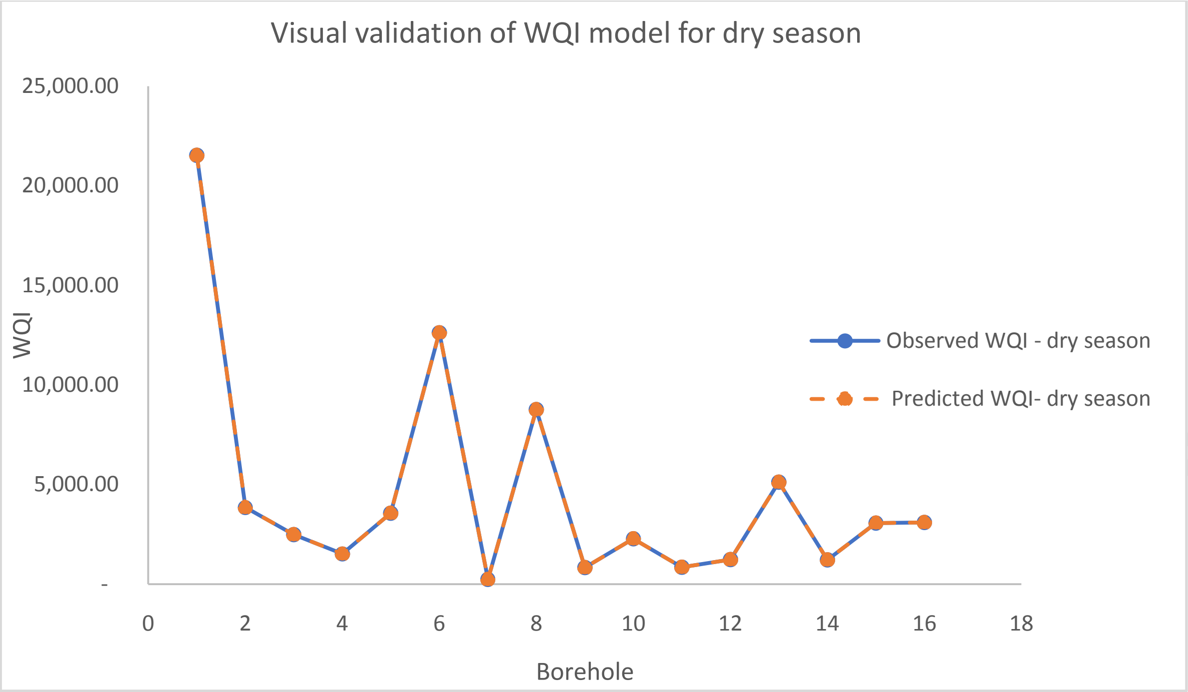

Figure 6: Visual validation of WQI model for dry season

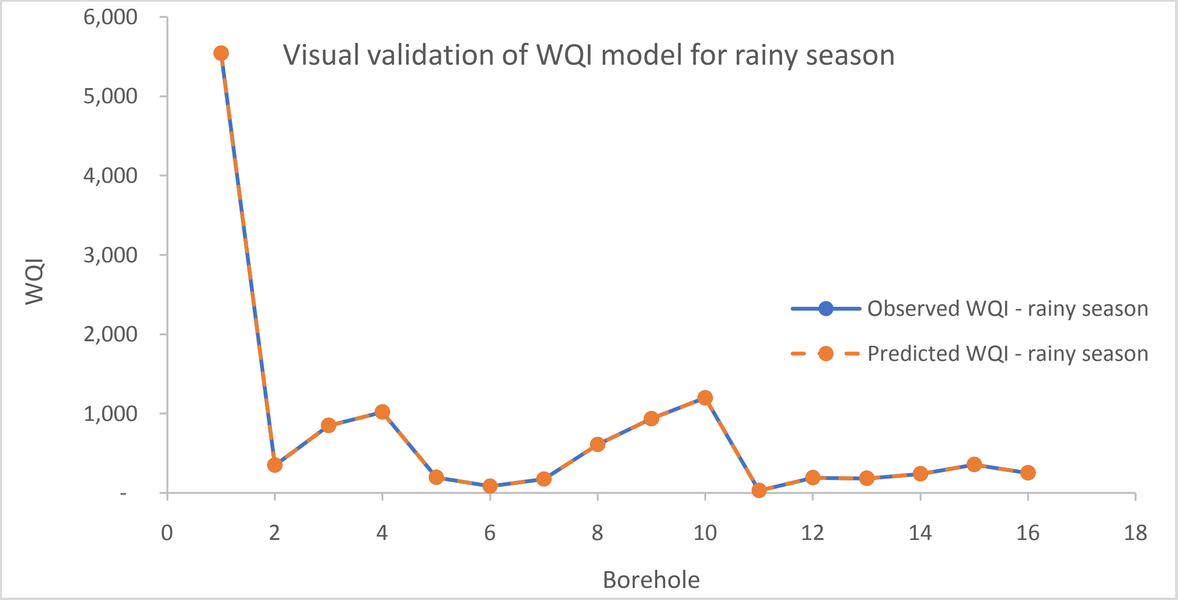

Figure 7: Visual validation of WQI model for rainy season

3.4 Effect of Leachate on Water quality parameters

The influence of leachate on the different borehole characteristics may be understood from the Analysis of Variance of water quality parameters in the dry and rain seasons, as illustrated in Tables 14 and 15. The analysis of variance showed that during the dry season, $p = 0.000 < .05$. The consequence is to reject H_0, which asserts that leachate has no substantial effect on groundwater quality, and accept H_1, which indicates that leachate has a large effect on groundwater quality.

During the rainy season, ANOVA results were $p = 0.000 < .05$. The consequence is to reject H_0, which asserts that leachate has no substantial effect on groundwater quality, and accept H_1, which indicates that leachate has a large effect on groundwater quality.

Table 14: One-Way ANOVA for dry season water quality parameters

ANOVA: Single Factor

Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
pH	16	103.46	6.46625	0.178665
Temp.	16	388.8	24.3	5.42
EC	16	3400.01	212.5006	19976.04
TDS	16	2176.006	136.0004	8182.187
Turbidity	16	6.299	0.393688	0.114718
NH_3	15	3.556	0.237067	0.073562
PO_4	16	4.606	0.287875	0.685022
NO_3	16	80.986	5.061625	56.06293
COD	16	951.6	59.475	283.8588
SO_4	16	170.479	10.65494	1808.973
Total Hardness	16	1532.71	95.79438	2439.972
BOD_5	16	43.69	2.730625	0.91734
Pb	16	5.15847	0.322404	0.114408
Cd	16	0.166556	0.01041	0.000101
Cr	16	15.76931	0.985582	0.302964

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	904168	14	64583.43	29.44432	4.2E-43	1.736146
Within Groups	491323.5	224	2193.408			
Total	1395491	238				

Table 15: One-Way ANOVA for rainy season water quality parameters

ANOVA: Single Factor

Summary

Groups	*Count*	*Sum*	*Average*	*Variance*
pH	16	110.73	6.920625	0.03574
Temp.	16	358.6	22.4125	3.743833
EC	16	4331.3	270.7063	26604.02
TDS	16	2772.032	173.252	10897.01
Turbidity	16	0.767	0.047938	0.013408
NH_3	16	0.951	0.059438	0.000692
PO_4	16	2.368	0.148	0.21115
NO_3	16	23.859	1.491188	23.28919
COD	16	624.51	39.03188	111.9083
SO_4	16	735.25	45.95313	882.3156
Total Hardness	16	1337.66	83.60375	1982.661
BOD_5	16	41.51	2.594375	0.55868
Pb	16	1.24332	0.077708	0.018131
Cd	16	1.724082	0.107755	0.1785
Cr	16	4.45798	0.278624	0.06681

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1385633	14	98973.8	36.6515	3.53E-50	1.735948
Within Groups	607590.5	225	2700.402			
Total	1993224	239				

4. Conclusion

This researchwas undertaken to perform the modelling of groundwater quality of Aba in Abia state. Groundwater samples were analysed in the laboratory for pH, EC, Total Hardness, BOD_5, COD, Pb, Cd, Cr, NH_3, TDS, SO_4, NO_3 and PO_4.Principal Component Analysis (PCA) and Multiple Linear Regression (MLR) were used to extract the principal factors and develop a model for predicting water quality index of Aba.In the dry season, water quality index can be estimated using the WQI model with pH, PO_4, COD, SO_4 and P_b. Meanwhile, in the rainy season, water quality index can be estimated using the WQI model with Turbidity, PO_4, NO_3, COD, SO_4 and P_b.Though there were parameters with minimal concentrations, they could contribute to the deterioration of water quality in the future.

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APPENDIX

Table A1: WHO Drinking Water Standard for Water quality parameters.

Parameters	*WHO*
pH	6.5 – 8.5
EC	1000
TDS	500
Turbidity	5
PO_4	1
NO_3	50
COD	250
SO_4	250
TH	250
BOD_5	5
Pb	0.01

Table A2: Measured water quality parameters from sampled boreholes for dry season

Borehole	Ph	Temp. $^{\theta}$c	EC (S/cm)	TDS (mg/l)	Turbidity (NTU)	NH$_3$ (mg/l)	PO$_4$ (mg/l)	NO$_3$ (mg/l)	COD (mg/l)	S0$_4$ (mg/l)	Total Hardness (mg/l)	BOD$_5$ (mg/l)	Pb (mg/l)	Cd (mg/l)	Cr (mg/l)
BH1	5.74	22.3	315.7	202.048	0.315	1.863	3.39	23.14	96.41	170.15	183.01	2.53	2.18741	0.01631	6.03985
BH2	6.35	22	100.1	64.064	0.133	0.762	0.07	-0.075	67.84	0.009	84.1	3.01	0.39081	0.00427	0.32011
BH3	6.49	21	37.4	23.936	0.183	0.056	0.07	0.041	61.44	0.006	50.4	3.91	0.25314	0.00431	0.81973
BH4	6.65	22	190.8	122.112	1.392	0.527	0.056	0.83	55.68	0.014	54.1	1.98	0.15424	0.01203	0.91031
BH5	6.57	26.2	269.4	172.416	0.284	0.072	0.079	12.02	53.76	0.05	181.3	4.03	0.36182	0.00894	0.84391
BH6	6.31	26.8	558.9	357.696	0.365	0.143	0.14	10.53	17.68	0.023	150.4	1.89	1.28294	0.0362	0.52413
BH7	5.97	22.5	123.5	79.04	0.249	0.078	0.073	1.252	47.36	0.015	98.3	3.65	0.02451	0.01386	2.00317
BH8	6.82	27	255.9	163.776	0.241	0.814	0.056	0.751	60.16	0.019	79.6	4.62	0.89121	0.03102	1.93115
BH9	6.48	23.7	315.2	201.728	0.174	0.126	0.126	13.7	45.44	0.031	120.5	2.38	0.08475	0.00178	1.02131
BH10	6.74	26.4	254.3	162.752	0.428	0.089	0.056	0.625	62.72	0.009	77.6	2.85	0.23149	0.00394	1.25231
BH11	6.32	26.9	196.2	125.568	0.118	0.073	0.07	1.295	65.28	0.011	147.6	1.33	0.08631	0.00658	1.5231
BH12	6.93	23.6	311.2	199.168	0.591	0.112	0.112	16.35	75.52	0.031	52.6	2.47	0.12558	0.00821	1.42874
BH13	6.24	22.1	19.11	12.2304	0.187	0.056	0.056	0.112	52.87	0.012	44.2	1.24	0.52016	0.009346	0.98533
BH14	5.77	27	78.3	50.112	0.802	0.098	0.098	0.256	75.52	0.057	26.9	2.87	0.12374	0.00173	0.42103
BH15	7.35	22.3	58.2	37.248	0.713	0.511	0.056	-0.071	62.72	0.007	118.9	2.06	0.31238	0.01187	0.74987
BH16	6.73	27	315.8	202.112	0.124	0.039	0.098	0.23	51.2	0.035	63.2	2.87	0.31539	0.01247	1.03511

Table A3: Measured water quality parameters from sampled boreholes for rainy season

Borehole	pH	Temp. $^{\theta}$c	EC (µS/cm)	TDS (mg/l)	Turbidity (NTU)	NH$_3$ (mg/l)	PO$_4$ (mg/l)	NO$_3$ (mg/l)	COD (mg/l)	S0$_4$ (mg/l)	Total Hardness (mg/l)	BOD$_5$ (mg/l)	Pb (mg/l)	Cd (mg/l)	Cr (mg/l)
BH1	6.64	20.4	586.19	375.1616	0.480	0.035	1.870	19.57	57.13	130.93	150.96	3.54	0.56317	1.692082	0.00396
BH2	6.78	20.2	590.21	377.7344	0.043	0.074	0.029	0.284	52.72	64.25	45.30	3.87	0.03572	0.00115	0.25167
BH3	6.81	19.8	470.3	300.992	0.015	0.056	0.035	0.162	29.63	51.94	28.9	2.68	0.08641	BDL	0.11851
BH4	6.77	20.3	318.1	203.584	0.023	0.042	0.018	0.157	35.11	22.63	50.6	3.22	0.10365	0.00593	0.36973
BH5	6.83	24.7	286.4	183.296	0.01	0.084	0.062	0.139	48.39	19.84	105.2	1.79	0.02014	0.00167	0.84202
BH6	6.89	23.5	410.6	262.784	0.036	0.042	0.014	0.820	32.05	24.11	130.4	2.58	0.00873	0.00256	0.34516
BH7	6.88	20.0	153.8	98.432	0.018	0.028	0.033	0.402	22.69	52.69	22.8	1.63	0.01784	0.00487	0.10803
BH8	6.86	25.0	210.3	134.592	0.008	0.118	0.051	0.360	41.82	63.72	55.1	2.41	0.06213	BDL	0.08917
BH9	6.91	22.0	94.3	60.352	0.014	0.042	0.021	0.087	45.31	58.23	175.3	2.79	0.09524	0.00172	0.02635
BH10	6.87	25.1	177.2	113.408	0.021	0.056	0.068	0.565	27.03	42.91	110.9	3.64	0.1219	0.00163	0.52718
BH11	6.93	24.2	83.7	53.568	0.036	0.041	0.037	0.48	50.94	74.86	85.2	3.2	0.00315	0.00201	0.20963
BH12	6.86	23.0	182.6	116.864	0.027	0.098	0.026	0.466	24.13	13.22	90.3	2.65	0.01971	0.00658	0.01781
BH13	7.20	21.6	110.9	70.976	0.011	0.028	0.051	0.017	47.04	17.39	70.6	1.74	0.01877	0.00275	0.1931
BH14	6.94	23.6	250.1	160.064	0.003	0.084	0.013	0.144	36.17	29.18	113.2	2.29	0.02457	BDL	0.35178
BH15	7.13	21.2	186.2	119.168	0.017	0.052	0.018	0.097	40.51	43.63	60.8	1.56	0.03648	0.00113	0.19001

BH16	7.43	24.0	220.4	141.056	0.005	0.071	0.022	0.109	33.84	25.72	42.1	1.92	0.02571	BDL	0.81387

*BDL -Below Discoverable Level