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Evaluating the Impact of Seasonal Variability on Groundwater Quality using Multivariate Analysis of Variance

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Abstract
Groundwater which constitutes high percent of the global fresh water is one of the most important sources of drinking water. When polluted, groundwater has deleterious effects on its users. Consequently, the quality and pollution of groundwater is a health concern in the world. The focus of the study is to evaluate the impact of seasonal variation on the quality of groundwater within the study areaHundred (100) boreholes spread to cover the study area were sampled. The water samples were analyzed using standard procedures for assessing drinking water qualities in order to determine the condition of groundwater quality within the study area. Statistical analysis of the groundwater quality data was done using weighted average index method to determine the water quality index and multivariate analysis of variance (MANOVA) to assess the impact of seasonal variation. Result of multivariate analysis of variance (MANOVA) which was employed to assess the presence of seasonal variability revealed that the calculated partial Eta squared of the Pillai's trace statistics was 1.00 which indicates 100% variability among the dependent variables occasioned by seasonal change.
Keywords: Multivariate statistics, Seasonal variation, Water quality index, Pillai's trace statistics and Partial Eta squared.
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1. Introduction

Water and its quality are a very serious and vital issue for mankind due to its link with human health and welfare. It is one of the most precious and replenishable natural resources. There is abundance of it on the earth surface but the quality as well as the quantity to serve its intended purpose is where the problem lies. The demand for water has increased over the years and this has led to water scarcity in many parts of the world and the situation is aggravated by the problem of water pollution or contamination (Sundara et al., 2010). The application of different multivariate statistical techniques, such as cluster analysis (CA), principal component analysis (PCA) and factor analysis (FA) help identify important components or factors accounting for most of the variances of a system. They are designed to reduce the number of variables to a small number of indices while attempting to preserve the relationships present in the original data (Simeonov, et al., 2003; Simeonov, et al., 2004). (Iyer et al., 2003) constructed a statistical, model which is based on the PCA for coastal water quality data from the Cochin coast in south west India to explain the relationships between the various physicochemical variables that have been monitored and also to evaluate the impact of environmental fluctuations on the coastal water quality.

MANOVA is the multivariate analogue to Hotelling's T^2. The purpose of MANOVA is to test whether the vectors of means for the two or more groups are sampled from the same sampling distribution. Just as Hotelling's T^2 will provide a measure of the likelihood of picking two random vectors of means out of the same hat, MANOVA gives a measure of the overall likelihood of picking two or more random vectors of means out of the same hat. There are two major situations in which MANOVA is used.

i. The first is when there are several correlated dependent variables, and the researcher desires a single, overall statistical test on this set of variables instead of performing multiple individual tests.
ii. The second, and in some cases, the more important purpose is to explore how independent variables influence some patterning of response on the dependent variables. Here, one literally uses an analogue of contrast codes on the dependent variables to test hypotheses about how the independent variables differentially predict the dependent variables.

MANOVA also has the same problems of multiple post hoc comparisons as ANOVA. An ANOVA gives one overall test of the equality of means for several groups for a single variable. The ANOVA will not tell you which groups differ from which other groups. (Of course, with the judicious use of a priori contrast coding, one can overcome this problem.) The MANOVA gives one overall test of the equality of mean vectors for several groups. But it cannot tell you which groups differ from which other groups on their mean vectors. (As with ANOVA, it is also possible to overcome this problem through the use of a priori contrast coding.) In addition, MANOVA will not tell you which variables are responsible for the differences in mean vectors. Again, it is possible to overcome this with proper contrast coding for the dependent variables Shrestha and Kazama, 2007).

2. Materials and Methods

2.1 Description of study area

The study area for this research is the Niger Delta Basin Development Authority. This study covers the original area of operation of the River Basin Authority, which is Rivers and Bayelsa State alone. The geographical coordinates of Rivers and Bayelsa states are 4.8581˚N and 6.9209˚E and 4.25˚S and 5.37˚W and 6.75˚E respectively (Nwankwoala et al., 2011). The Niger Delta Basin is situated in the south-south geo-political zone of Nigeria. It is located in the rain forest region with relative humidity above 80% having an annual temperature range of 25ºC to 31ºC and annual rainfall of 4700mm on the coast to about 2400mm. The basin is characterized by two alternating climatic conditions of a long period of rainy season spanning from March to November, followed by a dry season spreading from November to March (Nwankwoala, et al., 2011). Figures 1 and 2 shows the Google earth and the study area maps respectively.

Figure 1: Google earth map of study area (Google .com)

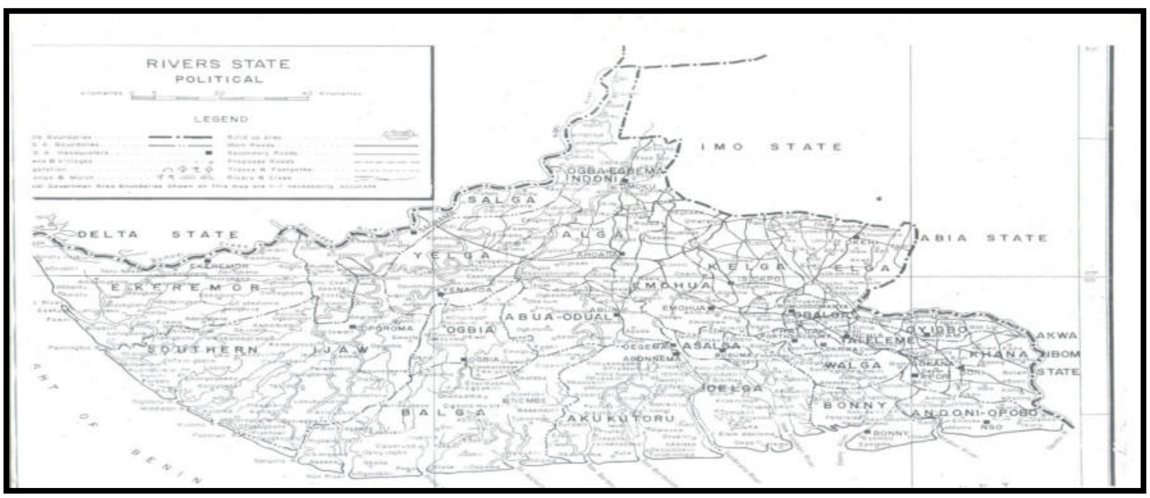


Figure 2: Map of study area ((Bolaji and Tse, 2009)

2.1.1 Geology and Hydrogeology of study area

The Niger Delta Basin is located on the continental margin of the Gulf of Guinea in equatorial West Africa. The Niger Delta lithofacies is made up of the three distinct vertical subdivisions viz. the Benin formation, the Agbada formation and the Akata formation. The Benin formation being the upper delta-top Lithofacies comprises of massive continental sands and gravels. The Agbada formation or facie consists of the pro-delta marine shales, with low stand turbidite fans which are deposited in a deep marine setting. In the Northern Delta Sector during the Oligocene times the Benin formation first occurs (Bolaji and Tse, 2009). Similarly, Paleocene age was established as the occurrence of the Akata formation in the proximal parts of the Delta. The Niger Delta complex geomorphologic features comprise of fresh water swamps, mangrove swamps, beaches, bars, and estuaries (Bolaji and Tse, 2009).

2.2 Sampling location and sample collection

The boundary of built up area (land use) within the study area was digitized and gridded at 2km interval to determine the sampling points and ensure uniform coverage. Water samples was collected systematically so as to have a general overview of the water quality condition within the study area. For accurate geo-referencing of the selected boreholes, Garmin hand held GPS receiver was employed to determine the geographical coordinates of each borehole. A section of the boreholes sampled including their location and geographical coordinates is presented in Table 1. One hundred (100) boreholes were systematically sampled with reference to location points at each season: Wet season (July to October 2018) and dry season (November to December 2018) in order to determine the physico-chemical and biological parameters of the groundwater samples. At every point of collection, the air tight, clean and dried plastic containers were rinsed two to three times with the borehole water to be sampled before collection. The samples were labelled properly and stored in air tight, clean and dried plastic containers before been transported to Water Resources and Environmental laboratory in the Department of Civil Engineering, University of Benin were the analysis were conducted in line with standard procedures and guideline recommended by World Health Organization (WHO). The water samples were analyzed in triplicates to obtain the mean value and standard deviation of each water quality test parameters. For the analysis of biochemical oxygen demand (BOD), the black bottles containing the water samples remained tightly closed prior to analysis in order to prevent photosynthetic and oxygen generation. In-situ parameters, namely; dissolved oxygen (DO), temperature, pH electrical conductivity (EC) and total dissolved solids (TDS) were determined in the field immediately after sample collection to avoid false measurement values (APHA, 2005).

Table 1: Coordinate Data of Sampled Boreholes (RIVERS)

Borehole Codes	Locations	Northings	Easting
1. Sample R1	Igbu Ahaoda	239820	561471
2. Sample R2	Mini Ama	269110	525361
3. Sample R3	Arukwo-Abua	235669	537656
4. Sample R4	Bakana	286341	528043
5. Sample R5	Edeoha-Ahoada	237214	556600
6. Sample R6	Edeoha-Ahoada	236203	556600
7. Sample R7	Okoboh-Abua	235766	540433
8. Sample R8	Buguma	262207	524264
9. Sample R9	Air force Base	280557	534103
10. Sample R10	Trans Amadi	279389	530030
11. Sample R11	Ipo-Ikwerre	274121	532098
12. Sample R12	Woji	286716	533642
13. Sample R13	Rumuokwurushi (1)	283293	536010
14. Sample R14	Amakiri Polo	286238	527163
15. Sample R15	Rukpokwu	289003	534162
16. Sample R16	Aggrey	280451	526634
17. Sample R17	NDBDA	278741	529397
18. Sample R18	Rumuokwurushi (2)	283012	536068
19. Sample R19	Amadi-Ama	279849	530118
20. Sample R20	Owodu	287302	531219
21. Sample R21	Okochiri	307314	519241
22. Sample R22	Trans Amadi (3)	278023	530112
23. Sample R23	Railway	279801	527029
24. Sample R24	Bundu	279684	525973
25. Sample R25	Oyorokoto	325714	496236
26. Sample R26	Kono Town	334047	508598
27. Sample R27	Oyigbo (1)	289245	538032
28. Sample R28	Ngo Town Andoni	323819	495804
29. Sample R29	Yegha Gokona	319044	517018
30. Sample R30	Oyigbo (2)	289599	538240
31. Sample R31	Nyokuru	339050	510170
32. Sample R32	Tegu-Gokana	316831	519746
33. Sample R33	Woji (2)	286421	533116

2.3 Water Quality Analysis

A total of thirty-three (33) physico-chemical parameters and two (2) microbiological parameters were analyzed for each sampled domestic borehole to provide an insight into the overall quality of water within the study area. The physico-chemical parameters include: temperature, odour, colour/clarity, total hydrocarbon content (THC), pH, Electrical conductivity (EC), Turbidity, Total suspended solid (TSS), Salinity, Alkalinity, Total Dissolve Solids (TDS), and Dissolved Oxygen (DO). Others are; Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Bicarbonate (HCO_3), Sodium (Na), Potassium(K), Calcium(Ca), Magnesium (Mg), Chloride(Cl^-), Phosphorus (P), Ammonium(NH_4), Nitrite (NO_2), Nitrate (NO_3), Sulphate (SO_4) and heavy metals, namely; Iron (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu), Chromium (Cr), Cadmium (Cd), Nickel (Ni) and Lead (Pb). The microbiological parameters include: Total Coliform Counts (TCC) and E. Coli

2.3.1 Determination of in-situ parameters; (pH, EC, TDS, DO and Temperature)

For electrical conductivity (EC), total dissolved solids (TDS), pH, temperature and dissolved oxygen (DO), in-situ measurements were carried out since the measurement values of the parameter's changes with storage time (WHO, 2003). pH, electrical conductivity, temperature and total dissolved solids were measured using portable meter's (multi-parameters) while dissolved oxygen was examined using DO meter (Lutron DO-5509, Range 0 – 20mg/l) shown in Figure 3

Figure 3: DO meter and multi portable meter

The multi portable meter probe was submerged in the water at 4cm and pH mode selected. Water sample was stirred gently and pH value displayed on the meter was allowed to adjust and stabilize before recording. Other measurements buttons were pressed successively and values recorded. The procedure was repeated three (3) times and the mean value calculated for each parameter. DO meter was also inserted into the water sample at about 10cm depth using the oxygen probe handle.

UNICAM 969 Atomic Absorption Spectrometer (AAS) shown in Figure 4 was used to determine the concentration of heavy metals such as; Iron (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu), Chromium (Cr), Cadmium (Cd), Nickel (Ni), Lead (Pb), and Vanadium (V) while UV visible spectrophotometer (Thermo Scientific Spectronic 20D+) presented in Figure 5 was used to analyzed the level of phosphorous (P), Nitrate (NO_3), Nitrite (NO_2) and Sulphate (SO_4). Other apparatus utilized included 250ml separating glass funnels, Cuvette, 10ml and 50ml pipette, 250ml conical flask, 50ml burette, 25ml and 50ml volumetric flask, glass beads, refrigerator, oven and whatman filter paper.

Figure 4: UNICAM 969 AA Spectrometer

Figure 5: UV Visible Spectrophotometer

Preparation of reagents and procedures employed in the laboratory for the analysis and determination of all water quality parameters followed the standard methods recommended by relevant authorities such as World Health Organization (WHO).

2.4 Analysis of seasonal variability using MANOVA

To study the seasonal variability of the groundwater quality parameters, multivariate analysis of variance (MANOVA) was employed. The following steps were used to justify the presence of seasonal variability in the water quality parameters

2.4.1 Assessing the suitability of MANOVA based on multivariate outliers

Multivariate alliance is usually calculated through a measure known as the Mahalanobis constant. If the maximum calculated value of the Mahalanobis constant is less than the critical value, then the assumption of multivariate outliers has not been violated. Therefore, if multivariate outliers have not been violated, then we can investigate the concept of seasonal variability using multivariate analysis of variance (MANOVA) otherwise, we must think of another statistical concept to track the presence of seasonal variability (Alkarkhi, 2008; Shrestha and Kazama, 2007). The critical values of the Mahalanobis constant is presented in Table 2

Table 2: Critical values of Mahalanobis constant

S/No	Degree of Freedom	Critical Value
1	2	13.82
2	3	16.27
3	4	18.47
4	5	20.52
5	6	22.46
6	7	24.32
7	8	26.13
8	9	27.88
9	10	29.59

2.4.3 Descriptive Statistics

Descriptive statistics was employed to check the difference in the mean and standard deviation of the sampling group. The mathematical equations for computing the mean and standard deviation are presented as follows.

Mean ($\bar{X}$), = $\frac{1}{n}\sum_{i=1}^{n} X_i$ (1)

Standard Deviation (S) = $\left[\frac{1}{(n=1)}\sum\left(X_i - \bar{X}\right)^2\right]^{0.5}$ (2)

2.4.4 Box Test or Covariance Matrix

In multivariate analysis of variance, we set out to test the null hypothesis that observed covariance matrix of all the dependent variables (water quality parameters) are equal across group (season) that is there is no seasonal variation in the water quality parameters. If the calculated p-value is less than 0.05 ($p < 0.05$) we reject the null hypothesis and conclude that the assumption of equal covariance matrices across group has not been satisfied; an indication that seasonal variability exists among the group (Alkarkhi, 2008; Shrestha and Kazama, 2007).

2.4.5 The Multivariate Test

Different statistical method for computing the F-value for multivariate analysis of variance exits in literature. One of them is the Roy's largest root which is probably the most acceptable and also the most susceptible to deviation in the covariance matrix. The next is the Pillai's Trace followed by Wilk's Lambda. Pillai's Trace is the least sensitive to the violation of the assumption of covariance matrix. If the p-value of the Pillai's Trace is less than 0.05 then we reject the null hypothesis that the water quality parameters are the same for the two groups and conclude that seasonal variability actually exists (Alkarkhi, 2008; Shrestha and Kazama, 2007).

2.4.6 Levene's Test of Equality of Error Variance

If seasonal variability exists, then the calculated error variance for all the dependent variables for the different sampling location must not be the same. To test the null hypothesis that the error variance of the dependent variables is equal across groups, Levene's test of equality of error variance was computed. Since calculated p-value for most of the dependent variables (groundwater quality parameters) is greater than 0.05, then, it was concluded that seasonal variability exists among the group (Alkarkhi, 2008; Shrestha and Kazama, 2007).

3. Results and Discussion

3.1 Analysis of seasonal variability using MANOVA

Variation in season affects the quality of groundwater. For shallow wells which are highly susceptible to infiltration of anthropogenic impurities, seasonal variation is pivotal to the quality of the water. In the Niger Delta region for example, activities of oil exploration and exploitation can affect the quality of groundwater owing to the porous nature of the soil which allows for speedy infiltration of impurities. To study the effect of seasonal variation, twenty one (21) water quality parameters, namely; pH, Electrical conductivity (EC), Salinity, Total Dissolve Solids (TDS), Dissolved Oxygen (DO), Bicarbonate (HCO_3), Sodium (Na), Potassium(K), Calcium (Ca), Magnesium (Mg), Chloride (Cl^-), Phosphate (PO_4), Nitrate (NO_3), Sulphate (SO_4), Iron (Fe), Zinc (Zn), Copper (Cu), Turbidity, Total suspended solid (TSS), Temperature and Alkalinity were monitored using 100 boreholes for wet and dry season. To apply multivariate analysis of variance (MANOVA), in the study of seasonal variability, the following assumptions and conditions were tested.

3.1.1 Testing the normality assumption of the dependent variables

For seasonal variability, it is expected that the dependent variables (water quality parameters) varies with season and do not obey normality. In addition, results of the water quality parameters should not contain outliers and the significant value (p-value) computed based on Kolmogorov smirnov and Shapiro-wilk test must be less than 0.05; i.e. ($p < 0.05$) for all the dependent variables. Results of the computed p-value based on Kolmogorov smirnov and Shapiro-wilk is presented in Table 3 and 4 while the outlier detection test using box plot is presented in Figure 6

Table 3: Testing the assumption of normality for MANOVA

Tests of Normality

	Season	Kolmogorov-Smirnov[a] Statistic	df	Sig.	Shapiro-Wilk Statistic	df	Sig.
pH	Dry Season	.111	100	.004	.967	100	.013
	Wet Season	.099	100	.018	.973	100	.037
Nitrate	Dry Season	.313	100	.000	.528	100	.000
	Wet Season	.111	100	.004	.962	100	.006
Electrical Conductivity	Dry Season	.193	100	.000	.703	100	.000
	Wet Season	.106	100	.008	.977	100	.083
Turbidity	Dry Season	.435	100	.000	.323	100	.000
	Wet Season	.481	100	.000	.201	100	.000
Dissolved Oxygen	Dry Season	.196	100	.000	.885	100	.000
	Wet Season	.193	100	.000	.928	100	.000
Total Dissoved Solids	Dry Season	.251	100	.000	.591	100	.000
	Wet Season	.152	100	.000	.867	100	.000
Sodium	Dry Season	.147	100	.000	.916	100	.000
	Wet Season	.134	100	.000	.817	100	.000
Sulphate	Dry Season	.454	100	.000	.193	100	.000
	Wet Season	.140	100	.000	.957	100	.003
Zinc	Dry Season	.205	100	.000	.897	100	.000
	Wet Season	.097	100	.022	.965	100	.009
Copper	Dry Season	.374	100	.000	.693	100	.000
	Wet Season	.092	100	.038	.958	100	.003
Chloride	Dry Season	.084	100	.075	.970	100	.021
	Wet Season	.157	100	.000	.775	100	.000

Table 4: Testing the assumption of normality for MANOVA

	Season	Kolmogorov-Smirnov[a] Statistic	df	Sig.	Shapiro-Wilk Statistic	df	Sig.
Iron	Dry Season	.402	100	.000	.246	100	.000
	Wet Season	.203	100	.000	.753	100	.000
Carbonate	Dry Season	.214	100	.000	.750	100	.000
	Wet Season	.087	100	.057	.971	100	.028
Total Suspended Solids	Dry Season	.484	100	.000	.249	100	.000
	Wet Season	.496	100	.000	.146	100	.000
Phosphate	Dry Season	.183	100	.000	.922	100	.000
	Wet Season	.214	100	.000	.665	100	.000
Temperature	Dry Season	.092	100	.035	.946	100	.000
	Wet Season	.173	100	.000	.947	100	.001
Alkalinity	Dry Season	.232	100	.000	.780	100	.000
	Wet Season	.090	100	.045	.963	100	.006
Salinity	Dry Season	.452	100	.000	.091	100	.000
	Wet Season	.302	100	.000	.545	100	.000
Magnesium	Dry Season	.308	100	.000	.461	100	.000
	Wet Season	.100	100	.015	.970	100	.021
Potassium	Dry Season	.139	100	.000	.905	100	.000
	Wet Season	.134	100	.000	.959	100	.003
Calcium	Dry Season	.300	100	.000	.463	100	.000
	Wet Season	.131	100	.000	.961	100	.005

a. Lilliefors Significance Correction

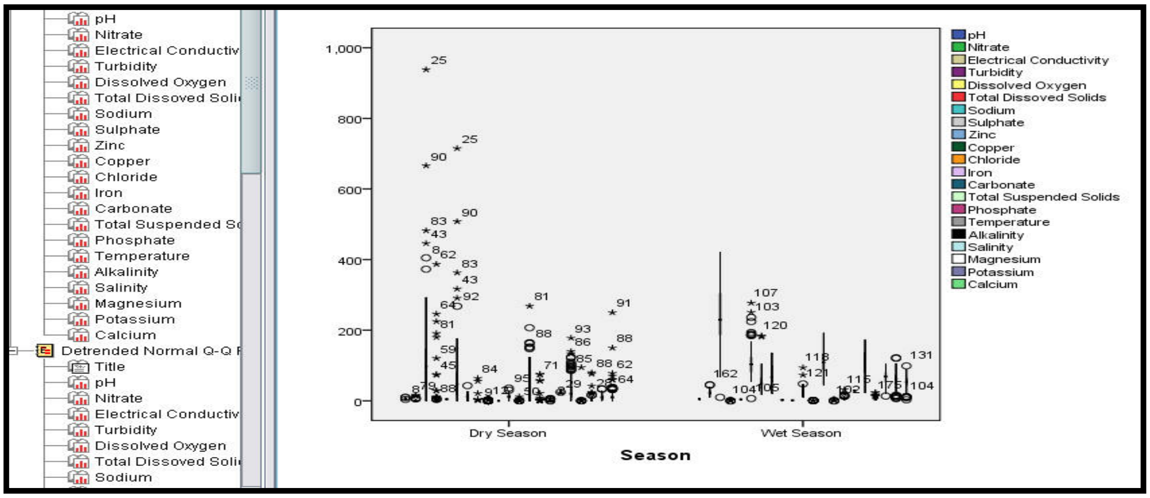


Figure 6: Seasonal box plot for assessing the presence of outliers

From the result of Table 3 and 4, it was observed that most of the dependent variables had p-value less than 0.05 based on Kolmogorov smirnov and Shapiro-wilk test. Since the calculated p-values based on Kolmogorov smirnov and Shapiro-wilk test are less than 0.05, it was concluded that the dependent variables did not obey normality. Non-normally distributed dependent variables indicate the presence of seasonal variation. A further test of normality was done using the detrended normal quantile-quantile (Q-Q) plot presented in Figures 7a and 7b

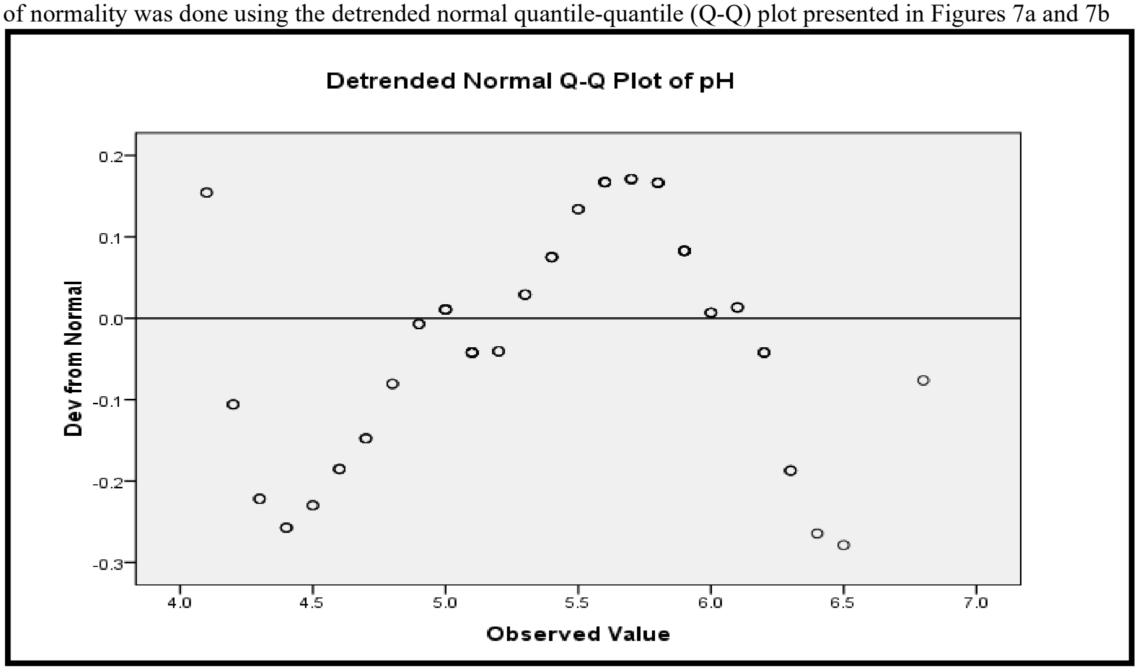


Figure 7a: Detrended normal Q-Q plot of pH

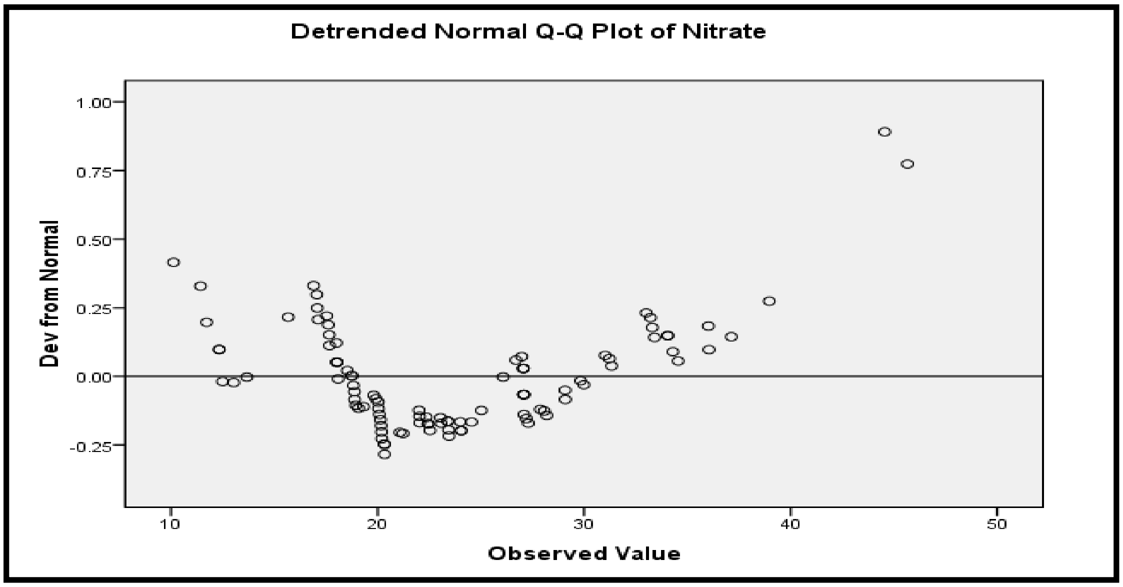


Figure 7b: Detrended normal Q-Q plot of nitrate

Since the dependented variables did follow the detrended normally distributed line, it was concluded that the variables are not normally distributed an indication that there is variation in the water quality parameters occassioned by season. On whether the dependent variables contain any form of outliers, the seasonal box plot presented in Figure 6 was employed. The presence of outlier is normally indicated with a square box or circle containing a number inside it. Since the circles in Figure 6 did not contain any number inside them, it was concluded that the dependent variables are devoid of possible outliers.

3.1.2 Assessing the suitability of MANOVA based on multivariate outliers

Multivariate alliance is usually calculated through a measure known as the Mahalanobis constant. If the maximum calculated value of the Mahalanobis constant is less than the critical value, then the assumption of multivariate outliers has not been violated. Therefore, if multivariate outliers have not been violated, then we can investigate the concept of seasonal variability using multivariate analysis of variance (MANOVA) otherwise, we must think of another statistical concept to track the presence of temporal variability. Results of the calculated Mahalanobis constant using regression analysis is presented in Figure 8

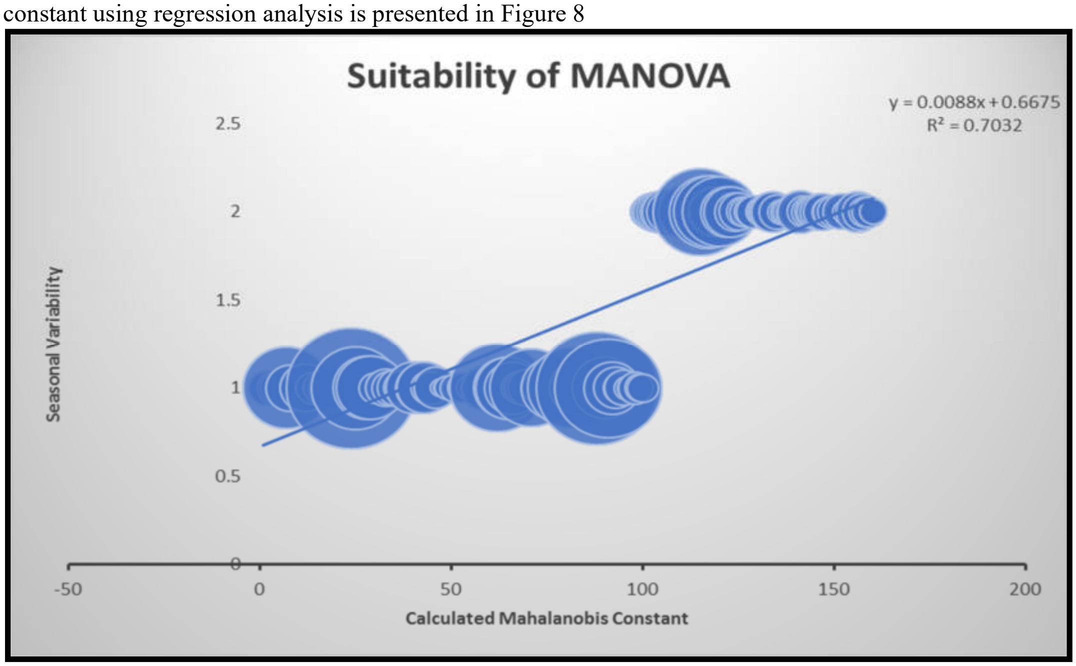


Figure 8: Variation of mahalanobis constant with season

With a coefficient of determination of 0.7032, it was concluded that the maximum calculated value of Mahalanobis constant of 173.1431 was significant and can be employed to justify the use of multivariate analysis of variance in assessing the effect of seasonal variability. With (df > 10) the critical value of Mahalanobis constant was (> 29.59). Since 173.1431 > 29.590, it was concluded that the assumptions of multivariate outliers have not been violated hence the use of multivariate analysis of variance to study the presence of seasonal variability is justified. To assess the degree of reliability of this claim, regression goodness of fit criteria was computed and presented in Table 5

Table 5: Computed regression goodness of fit criteria

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.974[a]	.948	.942	.120

a. Predictors: (Constant), Calcium, Turbidity, Total Suspended Solids, Salinity, Total Dissoved Solids, Temperature, pH, Iron, Zinc, Phosphate, Chloride, Alkalinity, Carbonate, Potassium, Sodium, Copper, Dissolved Oxygen, Nitrate, Sulphate, Magnesium, Electrical Conductivity

b. Dependent Variable: Season

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	47.424	21	2.258	156.029	.000[a]
	Residual	2.576	178	.014		
	Total	50.000	199			

a. Predictors: (Constant), Calcium, Turbidity, Total Suspended Solids, Salinity, Total Dissoved Solids, Temperature, pH, Iron, Zinc, Phosphate, Chloride, Alkalinity, Carbonate, Potassium, Sodium, Copper, Dissolved Oxygen, Nitrate, Sulphate, Magnesium, Electrical Conductivity

b. Dependent Variable: Season

The regression model is highly significant with a p-value < 0.05. Coefficient of determination of 0.948 and Adjusted R-square value of 0.942 were good enuogh to conclude that the assumptions of multivariate outliers has not been violated which justify the use of MANOVA in this study. Since the assumption of multivariate outliers was not violated, multivariate analysis of variance was then applied to explain the seasonal variability in the quality of water at different sampling time (season). The following step by step analysis was employed to study the imaginative variance (seasonal variability in the water quality as a function of season)

3.3.3 Descriptive Statistics

Descriptive statistics was employed to check the difference in the mean and standard deviation of the sampling time (wet and dry season). Tables 6a and 6b shows the descriptive statistics of the dependent variables

Table 6a: Descriptive statistics of dependent variables

	Season	Mean	Std. Deviation	N
pH	Dry Season	6.679	1.0970	100
	Wet Season	5.376	.6318	100
	Total	6.027	1.1062	200
Nitrate	Dry Season	1.36801	2.810711	100
	Wet Season	2.3677E1	7.082085	100
	Total	1.2522E1	12.407173	200
Electrical Conductivity	Dry Season	123.07	137.557	100
	Wet Season	236.58	79.786	100
	Total	179.83	125.767	200
Turbidity	Dry Season	16.6645	57.72555	100
	Wet Season	.0800	.37255	100
	Total	8.3722	41.55627	200
Dissolved Oxygen	Dry Season	4.593	.1076	100
	Wet Season	4.145	.1329	100
	Total	4.369	.2549	200
Total Dissoved Solids	Dry Season	71.50	102.213	100
	Wet Season	109.26	42.501	100
	Total	90.38	80.338	200
Sodium	Dry Season	11.6801	8.60493	100
	Wet Season	53.6573	27.07023	100
	Total	32.6687	29.05390	200
Sulphate	Dry Season	2.0744	8.58674	100
	Wet Season	75.1899	27.24221	100
	Total	38.6321	41.82190	200
Zinc	Dry Season	1.0576	.65330	100
	Wet Season	2.3805	.28970	100
	Total	1.7191	.83294	200
Copper	Dry Season	.355476	.4588976	100
	Wet Season	1.4605E0	.3000701	100
	Total	.908003	.6755586	200

Table 6b: Descriptive statistics of dependent variables

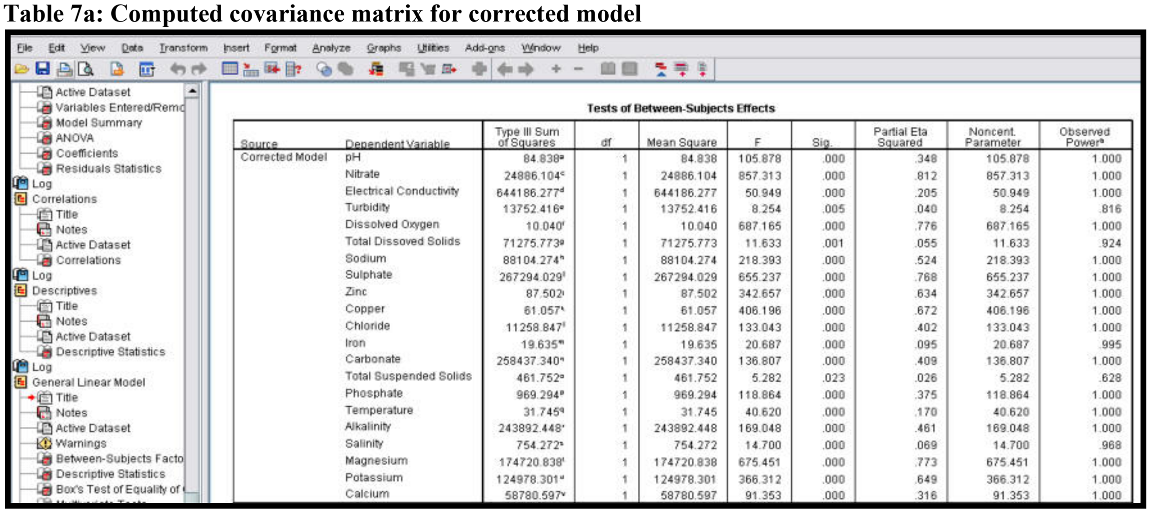
	Total	.908003	.6755586	200
Chloride	Dry Season	12.27	6.730	100
	Wet Season	27.28	11.134	100
	Total	19.78	11.865	200
Iron	Dry Season	.3387	1.36986	100
	Wet Season	.9653	.14742	100
	Total	.6520	1.02128	200
Carbonate	Dry Season	39.923	50.2681	100
	Wet Season	111.817	35.3731	100
	Total	75.870	56.3760	200
Total Suspended Solids	Dry Season	3.14	13.208	100
	Wet Season	.10	.611	100
	Total	1.62	9.450	200
Phosphate	Dry Season	2.4139	1.33825	100
	Wet Season	6.8168	3.81029	100
	Total	4.6154	3.60340	200
Temperature	Dry Season	27.715	1.2197	100
	Wet Season	28.512	.2746	100
	Total	28.114	.9680	200
Alkalinity	Dry Season	34.83	37.516	100
	Wet Season	104.67	38.445	100
	Total	69.75	51.586	200
Salinity	Dry Season	1.1399	9.46159	100
	Wet Season	5.0239	3.61896	100
	Total	3.0819	7.40553	200
Magnesium	Dry Season	6.30	12.019	100
	Wet Season	65.42	19.311	100
	Total	35.86	33.695	200
Potassium	Dry Season	10.2432	7.97401	100
	Wet Season	60.2389	24.87519	100
	Total	35.2411	31.10462	200
Calcium	Dry Season	18.37	30.940	100
	Wet Season	52.66	18.155	100

From the results of Tables 6a and 6b, it was observed that there is a significant difference between the calculated mean and standard deviation of all the dependent variables as a function of sampling time (wet and dry season). For pH, the mean ± standard deviation during dry season was observed to be 6.679 ± 1.0970 and during wet season it was observed to be 5.376 ± 0.6318. For nitrate, the mean ± standard deviation during dry season was observed to be 1.3601 ± 2.810711 and during wet season it was observed to be 2.3677E1 ± 7.082085. For electrical conductivity (EC), the mean ± standard deviation during dry season was observed to be 123.07 ± 137.557 and during wet season it was observed to be 236.58 ± 79.786. For turbidity, the mean ± standard deviation during dry season was observed to be 16.6645 ± 57.7256 and during wet season it was observed to be 0.0800 ± 0.37255. For dissolved oxygen (DO), the mean ± standard deviation during dry season was observed to be 4.593 ± 0.1076 and during wet season it was observed to be 4.145 ± 0.1329. The difference in the mean and standard deviation suggest the presence of imaginative variance which is seasonal variation occasioned by change in sampling time (dry and wet season).

3.3.4 Box Test or Covariance Matrix

In multivariate analysis of variance, we set out to test the null hypothesis that observed covariance matrix of all the dependent variables (water quality parameters) are equal across group (wet and dry season) that is there is no seasonal variation in the water quality parameters. If the calculated p-value is less than 0.05 ($p < 0.05$) we reject the null hypothesis and conclude that the assumption of equal covariance matrices across group has not been satisfied; an indication that seasonal variability exists among the group. The computed covariance matrix for the corrected model and season is presented in Tables 7a and 7b

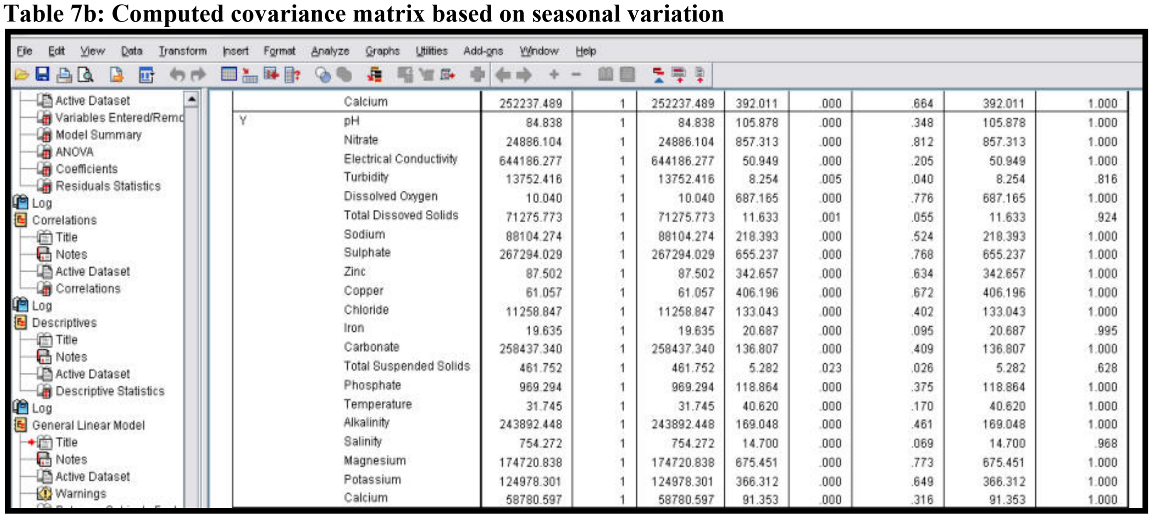
Table 7a: Computed covariance matrix for corrected model



Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Corrected Model	pH	84.838[a]	1	84.838	105.878	.000	.348	105.878	1.000
	Nitrate	24886.104[c]	1	24886.104	857.313	.000	.812	857.313	1.000
	Electrical Conductivity	644186.277[d]	1	644186.277	50.949	.000	.205	50.949	1.000
	Turbidity	13752.416[e]	1	13752.416	8.254	.005	.040	8.254	.816
	Dissolved Oxygen	10.040[f]	1	10.040	687.165	.000	.776	687.165	1.000
	Total Dissoved Solids	71275.773[g]	1	71275.773	11.633	.001	.055	11.633	.924
	Sodium	88104.274[h]	1	88104.274	218.393	.000	.524	218.393	1.000
	Sulphate	267294.029[i]	1	267294.029	655.237	.000	.768	655.237	1.000
	Zinc	87.502[j]	1	87.502	342.657	.000	.634	342.657	1.000
	Copper	61.057[k]	1	61.057	406.196	.000	.672	406.196	1.000
	Chloride	11258.847[l]	1	11258.847	133.043	.000	.402	133.043	1.000
	Iron	19.635[m]	1	19.635	20.687	.000	.095	20.687	.995
	Carbonate	258437.340[n]	1	258437.340	136.807	.000	.409	136.807	1.000
	Total Suspended Solids	461.752[o]	1	461.752	5.282	.023	.026	5.282	.628
	Phosphate	969.294[p]	1	969.294	118.864	.000	.375	118.864	1.000
	Temperature	31.745[q]	1	31.745	40.620	.000	.170	40.620	1.000
	Alkalinity	243892.448[r]	1	243892.448	169.048	.000	.461	169.048	1.000
	Salinity	754.272[s]	1	754.272	14.700	.000	.069	14.700	.968
	Magnesium	174720.838[t]	1	174720.838	675.451	.000	.773	675.451	1.000
	Potassium	124978.301[u]	1	124978.301	366.312	.000	.649	366.312	1.000
	Calcium	58780.597[v]	1	58780.597	91.353	.000	.316	91.353	1.000

Table 7b: Computed covariance matrix based on seasonal variation



	Calcium	252237.489	1	252237.489	392.011	.000	.664	392.011	1.000
Y	pH	84.838	1	84.838	105.878	.000	.348	105.878	1.000
	Nitrate	24886.104	1	24886.104	857.313	.000	.812	857.313	1.000
	Electrical Conductivity	644186.277	1	644186.277	50.949	.000	.205	50.949	1.000
	Turbidity	13752.416	1	13752.416	8.254	.005	.040	8.254	.816
	Dissolved Oxygen	10.040	1	10.040	687.165	.000	.776	687.165	1.000
	Total Dissoved Solids	71275.773	1	71275.773	11.633	.001	.055	11.633	.924
	Sodium	88104.274	1	88104.274	218.393	.000	.524	218.393	1.000
	Sulphate	267294.029	1	267294.029	655.237	.000	.768	655.237	1.000
	Zinc	87.502	1	87.502	342.657	.000	.634	342.657	1.000
	Copper	61.057	1	61.057	406.196	.000	.672	406.196	1.000
	Chloride	11258.847	1	11258.847	133.043	.000	.402	133.043	1.000
	Iron	19.635	1	19.635	20.687	.000	.095	20.687	.995
	Carbonate	258437.340	1	258437.340	136.807	.000	.409	136.807	1.000
	Total Suspended Solids	461.752	1	461.752	5.282	.023	.026	5.282	.628
	Phosphate	969.294	1	969.294	118.864	.000	.375	118.864	1.000
	Temperature	31.745	1	31.745	40.620	.000	.170	40.620	1.000
	Alkalinity	243892.448	1	243892.448	169.048	.000	.461	169.048	1.000
	Salinity	754.272	1	754.272	14.700	.000	.069	14.700	.968
	Magnesium	174720.838	1	174720.838	675.451	.000	.773	675.451	1.000
	Potassium	124978.301	1	124978.301	366.312	.000	.649	366.312	1.000
	Calcium	58780.597	1	58780.597	91.353	.000	.316	91.353	1.000

From the results of Tables 7a and 7b, it was observed that the computed significant values (p-value) for both the corrected model and season were less than 0.05; ($p < 0.05$), hence the null hypothesis was rejected and it was concluded that the covariance matrix assumption was not satisfied. This means that the covariance matrices of the dependent variables are not equal across group an indication that seasonal variability exists. It was concluded based on the covariance matrix that the variation in the dependent variables is due to seasonal variability

3.3.5 The Multivariate Test

Different statistical method for computing the F-value for multivariate analysis of variance exits in literature. One of them is the Roy's largest root which is probably the most acceptable and also the most susceptible to deviation in the covariance matrix. The next is the Pillai's Trace followed by Wilk's Lambda. Pillai's Trace is the least sensitive to the violation of the assumption of covariance matrix hence it was selected for this study. Result of multivariate test statistics computed to study the effect of seasonal variability is presented in Table 8

From the result of Table 8, it was observed that the computed significant value (p-value) based on Roy's largest root, Wilk's Lambda, Hotelling's Trace and the Pillai's Trace was less than 0.05 ($p = 0.00$) hence, the null hypothesis that the water quality parameters are the same for the two groups (wet and dry season) was rejected and it was conclude that seasonal variability actually exist. To calculate the percent variability that is accounted for due to seasonal variation, the partial Eta squared value of the Pillai's trace was employed. From the result of Table 4.11, the calculated partial Eta squared of the Pillai's trace was observed to be 1.00 which indicates 100% variability among the dependent variables occasioned by seasonal change.

In addition, when the null hypothesis of equal variance assumption is rejected, then the observed power function based on Pillai's trace must be between 0.9-1.00. From the result of Table 8, it was observed that the calculated power function based on Pillai's trace is 1.00 for both intercept and season. This validates the initial claim that seasonal variability exists between the dependent variables.

3.3.6 Levene's Test of Equality of Error Variance

If seasonal variability exists among the dependent variables then, the calculated error variance for all the dependent variables for wet and dry season must not be the same. To test the null hypothesis that the error variance of the dependent variables is equal across groups, Levene's test of equality of error variance was computed and presented in Table 9. From the result of Table 9, it was observed that the calculated p-value for most of the dependent variables were less than 0.05; an indication that the error variance of the dependent variables is not equal across group. Since the error variance of the dependent variables varies across group, it was concluded that seasonal variation exists between the dependent variables. Results of parameters estimates based on MANOVA is presented in Tables 10a and 10b

Table 8: Multivariate statistical table

Multivariate Tests[c]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Intercept	Pillai's Trace	1.000	2.159E4[a]	21.000	178.000	.000	1.000	453347.175	1.000
	Wilks' Lambda	.000	2.159E4[a]	21.000	178.000	.000	1.000	453347.175	1.000
	Hotelling's Trace	2.547E3	2.159E4[a]	21.000	178.000	.000	1.000	453347.175	1.000
	Roy's Largest Root	2.547E3	2.159E4[a]	21.000	178.000	.000	1.000	453347.175	1.000
Y	Pillai's Trace	.948	1.560E2[a]	21.000	178.000	.000	.948	3276.617	1.000
	Wilks' Lambda	.052	1.560E2[a]	21.000	178.000	.000	.948	3276.617	1.000
	Hotelling's Trace	18.408	1.560E2[a]	21.000	178.000	.000	.948	3276.617	1.000
	Roy's Largest Root	18.408	1.560E2[a]	21.000	178.000	.000	.948	3276.617	1.000

a. Exact statistic

b. Computed using alpha = .05

c. Design: Intercept + Y

Table 9: Levene's Test Statistics

Levene's Test of Equality of Error Variances[a]

	F	df1	df2	Sig.
pH	12.607	1	198	.000
Nitrate	66.912	1	198	.000
Electrical Conductivity	2.142	1	198	.145
Turbidity	29.918	1	198	.000
Dissolved Oxygen	7.357	1	198	.007
Total Dissoved Solids	8.541	1	198	.004
Sodium	34.701	1	198	.000
Sulphate	159.858	1	198	.000
Zinc	16.788	1	198	.000
Copper	68.028	1	198	.000
Chloride	3.237	1	198	.074
Iron	10.973	1	198	.001
Carbonate	6.012	1	198	.015
Total Suspended Solids	19.944	1	198	.000
Phosphate	15.429	1	198	.000
Temperature	62.678	1	198	.000
Alkalinity	1.585	1	198	.210
Salinity	.001	1	198	.977
Magnesium	41.444	1	198	.000
Potassium	44.837	1	198	.000
Calcium	.975	1	198	.325

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

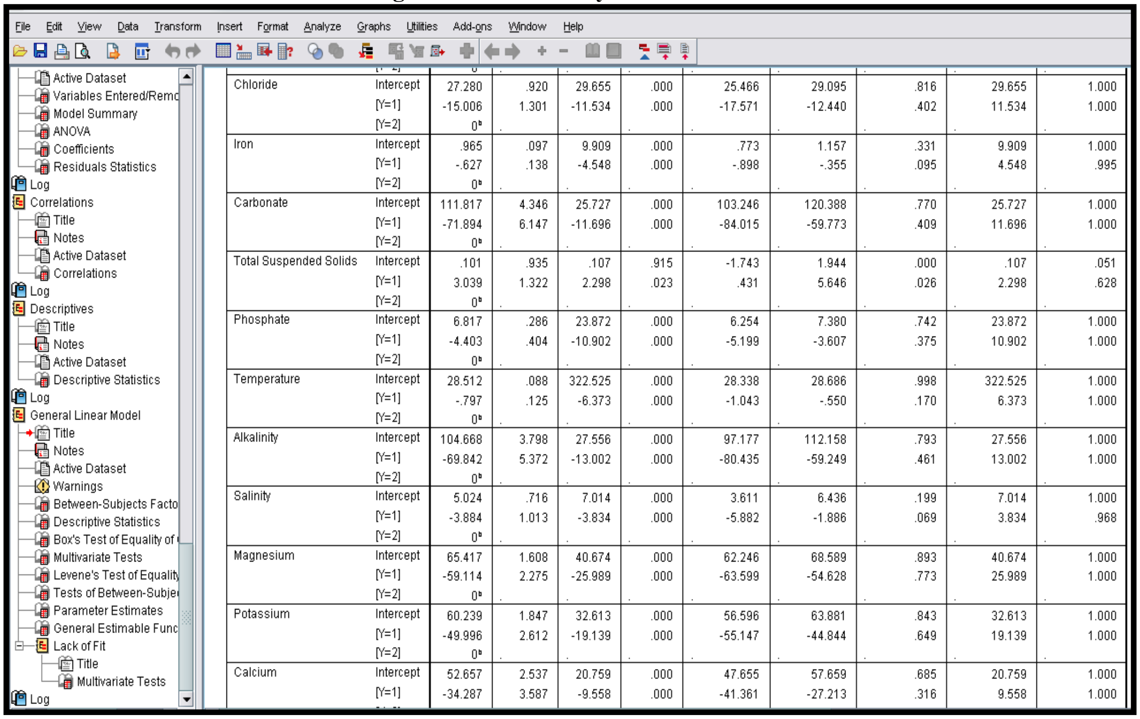
a. Design: Intercept + Y

Table 10a: Parameter estimates using multivariate analysis of variance

Parameter Estimates

Dependent Variable	Parameter	B	Std. Error	t	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
pH	Intercept	5.376	.090	60.057	.000	5.199	5.553	.948	60.057	1.000
	[Y=1]	1.303	.127	10.290	.000	1.053	1.552	.348	10.290	1.000
	[Y=2]	0[b]	.	.	.	.	.	.	.	.
Nitrate	Intercept	23.678	.539	43.947	.000	22.615	24.740	.907	43.947	1.000
	[Y=1]	-22.310	.762	-29.280	.000	-23.812	-20.807	.812	29.280	1.000
	[Y=2]	0[b]	.	.	.	.	.	.	.	.
Electrical Conductivity	Intercept	236.579	11.244	21.040	.000	214.405	258.754	.691	21.040	1.000
	[Y=1]	-113.507	15.902	-7.138	.000	-144.866	-82.147	.205	7.138	1.000
	[Y=2]	0[b]	.	.	.	.	.	.	.	.
Turbidity	Intercept	.080	4.082	.020	.984	-7.970	8.130	.000	.020	.050
	[Y=1]	16.585	5.773	2.873	.005	5.201	27.968	.040	2.873	.816
	[Y=2]	0[b]	.	.	.	.	.	.	.	.
Dissolved Oxygen	Intercept	4.145	.012	342.922	.000	4.121	4.169	.998	342.922	1.000
	[Y=1]	.448	.017	26.214	.000	.414	.482	.776	26.214	1.000
	[Y=2]	0[b]	.	.	.	.	.	.	.	.
Total Dissoved Solids	Intercept	109.260	7.827	13.959	.000	93.824	124.696	.496	13.959	1.000
	[Y=1]	-37.756	11.070	-3.411	.001	-59.586	-15.926	.055	3.411	.924
	[Y=2]	0[b]	.	.	.	.	.	.	.	.
Sodium	Intercept	53.657	2.009	26.715	.000	49.696	57.618	.783	26.715	1.000
	[Y=1]	-41.977	2.840	-14.778	.000	-47.579	-36.376	.524	14.778	1.000
	[Y=2]	0[b]	.	.	.	.	.	.	.	.
Sulphate	Intercept	75.190	2.020	37.228	.000	71.207	79.173	.875	37.228	1.000
	[Y=1]	-73.116	2.856	-25.598	.000	-78.748	-67.483	.768	25.598	1.000
	[Y=2]	0[b]	.	.	.	.	.	.	.	.
Zinc	Intercept	2.380	.051	47.108	.000	2.281	2.480	.918	47.108	1.000
	[Y=1]	-1.323	.071	-18.511	.000	-1.464	-1.182	.634	18.511	1.000
	[Y=2]	0[b]	.	.	.	.	.	.	.	.

Table 10b: Parameter estimates using multivariate analysis of variance



Chloride	Intercept	27.280	.920	29.655	.000	25.466	29.095	.816	29.655	1.000
	[Y=1]	-15.006	1.301	-11.534	.000	-17.571	-12.440	.402	11.534	1.000
	[Y=2]	0a	.	.	.	.	.	.	.	.
Iron	Intercept	.965	.097	9.909	.000	.773	1.157	.331	9.909	1.000
	[Y=1]	-.627	.138	-4.548	.000	-.898	-.355	.095	4.548	.995
	[Y=2]	0a	.	.	.	.	.	.	.	.
Carbonate	Intercept	111.817	4.346	25.727	.000	103.246	120.388	.770	25.727	1.000
	[Y=1]	-71.894	6.147	-11.696	.000	-84.015	-59.773	.409	11.696	1.000
	[Y=2]	0a	.	.	.	.	.	.	.	.
Total Suspended Solids	Intercept	.101	.935	.107	.915	-1.743	1.944	.000	.107	.051
	[Y=1]	3.039	1.322	2.298	.023	.431	5.646	.026	2.298	.628
	[Y=2]	0a	.	.	.	.	.	.	.	.
Phosphate	Intercept	6.817	.286	23.872	.000	6.254	7.380	.742	23.872	1.000
	[Y=1]	-4.403	.404	-10.902	.000	-5.199	-3.607	.375	10.902	1.000
	[Y=2]	0a	.	.	.	.	.	.	.	.
Temperature	Intercept	28.512	.088	322.525	.000	28.338	28.686	.998	322.525	1.000
	[Y=1]	-.797	.125	-6.373	.000	-1.043	-.550	.170	6.373	1.000
	[Y=2]	0a	.	.	.	.	.	.	.	.
Alkalinity	Intercept	104.668	3.798	27.556	.000	97.177	112.158	.793	27.556	1.000
	[Y=1]	-69.842	5.372	-13.002	.000	-80.435	-59.249	.461	13.002	1.000
	[Y=2]	0a	.	.	.	.	.	.	.	.
Salinity	Intercept	5.024	.716	7.014	.000	3.611	6.436	.199	7.014	1.000
	[Y=1]	-3.884	1.013	-3.834	.000	-5.882	-1.886	.069	3.834	.968
	[Y=2]	0a	.	.	.	.	.	.	.	.
Magnesium	Intercept	65.417	1.608	40.674	.000	62.246	68.589	.893	40.674	1.000
	[Y=1]	-59.114	2.275	-25.989	.000	-63.599	-54.628	.773	25.989	1.000
	[Y=2]	0a	.	.	.	.	.	.	.	.
Potassium	Intercept	60.239	1.847	32.613	.000	56.596	63.881	.843	32.613	1.000
	[Y=1]	-49.996	2.612	-19.139	.000	-55.147	-44.844	.649	19.139	1.000
	[Y=2]	0a	.	.	.	.	.	.	.	.
Calcium	Intercept	52.657	2.537	20.759	.000	47.655	57.659	.685	20.759	1.000
	[Y=1]	-34.287	3.587	-9.558	.000	-41.361	-27.213	.316	9.558	1.000

4. Conclusion

The study was conducted to assess the quality of groundwater around the Niger Delta Basin Development Authority and evaluate the impact of seasonal variability (wet/dry season) on the groundwater quality. Results of the study have shown that a high degree of variability exist in the quality of groundwater collected from different locations within the study area. One of the major factors that are responsible for this variability is the influence of climate change occasioned by season. The study also demonstrated the potential of multivariate statistics as a tool for climatic variability studies. The content of this study is not completely exhaustive of the subject matter, but it has provided additional information to the already existing literatures on groundwater variability studies using statistical approach.

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