Journal of the Nigerian Association of Mathematical Physics
***Volume 31*, (July, *2015*), pp 379 – 390**
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Statistical Analysis of Natural Radionuclides Obtained From Sediments in Ogun River, Nigeria.

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Abstract

Basic statistics were used to describe statistical characteristics of radionuclides in Ogun river sediments. Conventional and multivariate statistical procedures for data treatment were performed using SPSS (version 16.0) for Windows. Descriptive statistics was used to analysis the characteristics of these radionuclides in the sediments. Variational tests and lcation effects size measures were conducted on the concentrations of the radionuclides. Also Pearson correlation andhierarchical cluster analysis have been applied in order to clarify the relationship among the variables.It was observed that the radionuclides did not have any correlation with one another in the upper region but in the middle and lower regions, although ^{40}K did not correlate with the other radionuclides but ^{226}Ra correlated fairly well with ^{232}Th.The upper region of the river indicated no location effect, but in the middle and lower regions, significant locationeffects were observed and these were attributable to industrial activities in the locations.

Keywords: Radionuclides, Ogun River, Stasitical Analysis

1.0 Introduction

Outdoors External exposure arises from terrestrial radionuclides that are present in trace proportions in all soil/sediments. Radiation emitted by these radionuclides within 15-30cm of the topsoil gets to the earth surface [1]. Human exposure to ionizing radiation from natural sources is an unending and unpreventable phenomenon on earth [2]. Human beings are exposed to ionizing radiation whether he is aware or not and at high doses or prolonged low doses there could be some radiation effects. The knowledge of the concentrations of these radionuclides in sediments/soil and estimations of their radiological implications as well as the statistical characteristics of these radionuclides are very important, therefore, the aim of this study is to use basic statistics to describe characteristics of radionuclides in Ogun river sediments using Conventional and multivariate statistical procedures.

2.0 Materials and Methods

Ogun river flows southwards covering a distance ofabout 400 km. For the ease of sampling to cover the long stretch course of the river and for ease analysis, the river course was divided into three: Upper, Middle and Lower regions. Sediment samples were collected at each sampling point in the dry season around January through late April, 2007. The surface sediment was collected [3,4] packed in a nylon made of non-radioactive material sealed and labeled to avoid contaminations. A total of 320 sediment samples were collected. It was composed of 10 sediment samples from each of the 32 sampling locations along the entire course of the river. The distance between each location was about 300–500m depending on accessibility and local terrain.Figure 1 shows the locations where the sediment samples were collected along the course of the river.The location of each sampling point was taken by means of a Global Positioning System.

A76x76mm^{2}NaI(TI)scintillationdetectorBicron(Modelno.3142)wasusedforthemeasurementsof ^{226}Ra, ^{232}Th and ^{40}K in the sediments. The detector was coupledtoaCanberraseries100 multichannel analyzer(MCA) through a photo multiplier tube/ preamplifier/amplifier base. The detector was placed in a 5cm thick lead shield toreducetheeffectsofnaturalbackground

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radiation. Sampleswereplacedsymmetricallyontopofthedetector and measuredforacountingperiodof10h.Thenetareaunder the correspondingpeaksintheenergyspectrumwascomputed. Measurement ofeachsamplewasrepeatedthreetimesandthe mean netareawas determined.Fromthenet area, theactivityconcentrationsoftheradionuclidesinthe samples wereobtainedfrom Equation (1)[5].

$$C(Bq/kg) = KC_n \ \{\text{where } K = \frac{1}{\varepsilon P_\gamma M_s}\} \quad (1)$$

Where C is the activity concentration of the radionuclide in the sample in (Bq/kg). ε is the detector efficiency at the specific gamma energy, P_γ is theabsolutetransitionprobabilityofthe specific gamma-rayand Ms is themassofthesample(kg).C_n is thecountrateunder the correspondingpeak. Following all standard procedures and equations, the activity concentrations obtained have been published in the literature [6].

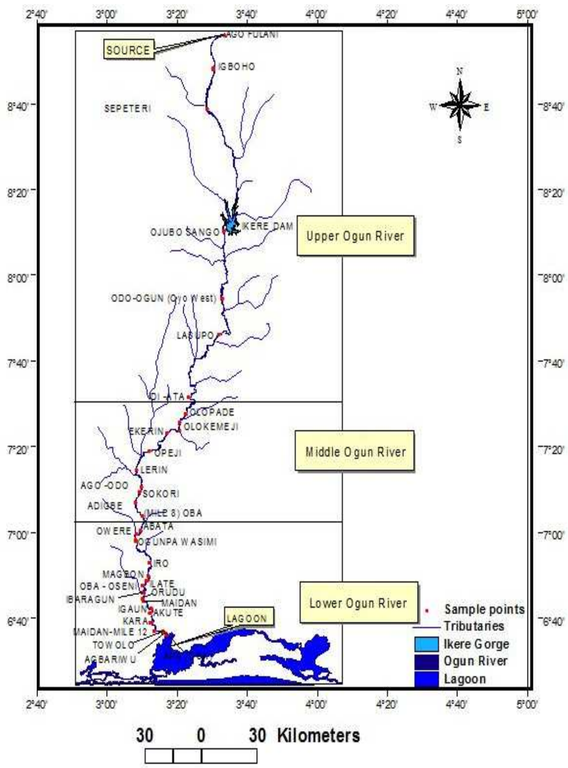

Fig 1: The study area [6]

3.0 Results and Discussions

The results of the statistical analysis are displayed and discussed below.

3.1 Descriptive Statistics

The descriptive statistical results are as shown in Table 1. i.e. the range, minimum, maximum, standard deviation and the mean values of the radionuclides concentrations. The skewness and Kurtosis of the distributions were also shown. The skewness obtained for the distribution of the concentrations of ^{40}K was negative while for ^{226}Ra and ^{232}Th were positive i,e the distribution for ^{40}Kwas negatively skewed, this is the skewness in which the mean are less than the mode showing negative asymmetric nature. While for ^{226}Ra and ^{232}Th, the skewness is such that the mode are less than the mean showing positive asymmetric nature.

Kurtosis is a measure of the peakedness of the probability distribution of a real-valued random variable. It characterizes the relative peakedness or flatness of a distribution compared with the normal distribution [7]. The concentrations of the three radionuclides have negative values and negative kurtosis values indicate relatively flat topped distribution [7], showing a platykurtic distribution.

Table 1: Descriptive Statistical Results

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
Radionuclides	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
POT 40	32	237.05	370.97	608.02	4.99E+02	59.16741	3.50E+03	-0.017	0.414	-0.413	0.809
RAD 226	32	14.83	5.57	20.4	12.6486	3.47609	12.083	0.176	0.414	-0.54	0.809
TH 232	32	18.06	5.04	23.1	11.7743	5.12577	26.274	0.956	0.414	-0.292	0.809

3.2 Frequency Distribution

Histogram plot of the frequency distribution of the concentrations of ^{40}K, ^{226}Ra and ^{232}Th in the sediments of Ogun river was also analysed, Figures 2.The three radionuclides showed some deviations from normal distributions and they all displayed some degrees of multi modal features. The multi modal features suggested complexity of minerals in sediment samples [7].

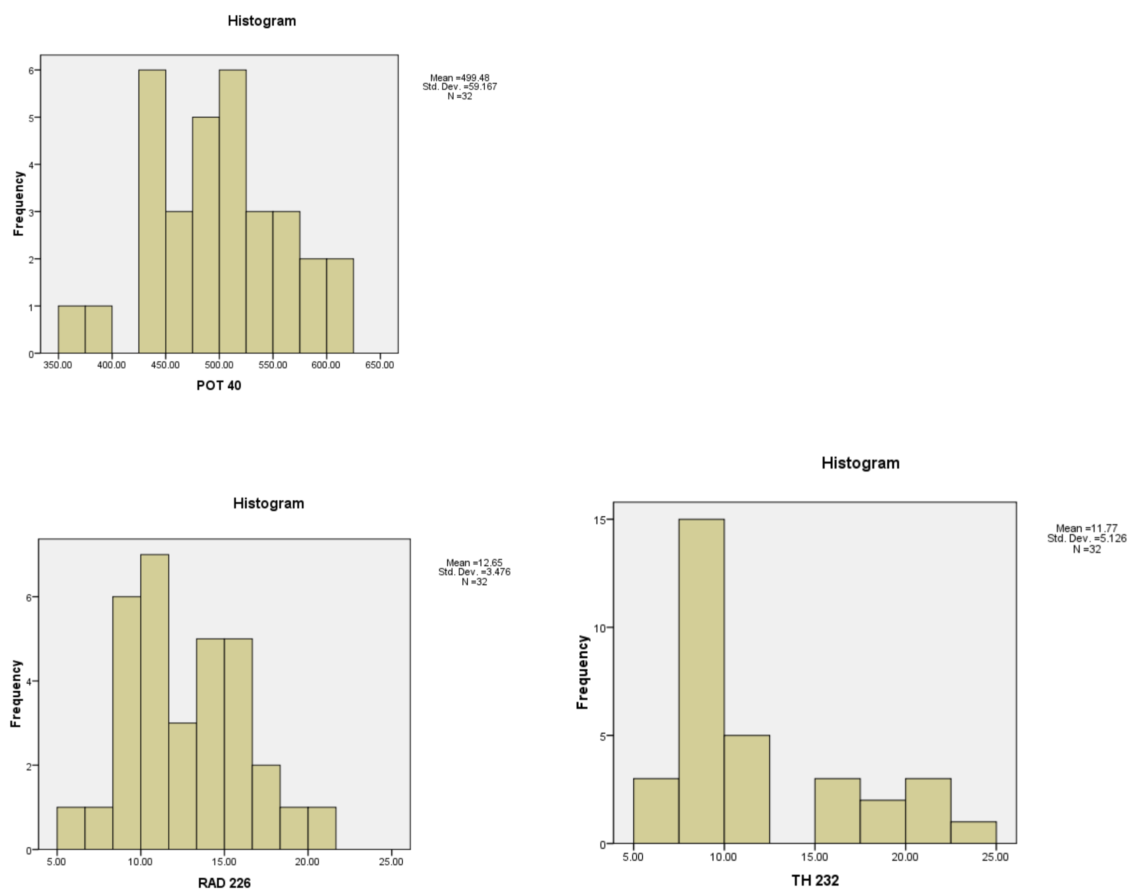

Figure 2: Histogram plots of the frequency distributions of ^{40}K, ^{226}Ra and ^{232}Th of sediments from Ogun river respectively

3.3 Variational Tests on the Concentrations of Radionuclides in the Upper, Middle and Lower Regions of the River

The analysis of variance (ANOVA) technique was carrierd out using SPSS for Windows 16.0 software. In this analysis, the three radionuclides in each of the ten sites together across the thirty – two locations were considered.This was done to see if there would be a significant difference in the means of the measured parameters in each location between the groups and within the groups. If the P-Value is less than (α) = 0.05, there is significant difference in their means, but if the P-value is greater than 0.05, 5 percent level of significance, then there is no significant difference in their means. It was observed that in the upper region of the river, Table 2, the P-values for the three radionuclides were greater than 0.05. Specifically, P = 0.062 for ^{40}K, P = 0.097 for ^{226}Ra and P = 0.824 for ^{232} Th. Therefore in the upper region of the river, there were no significant differences in the means of the three radionuclides. From Tables 3 and 4 it was observed that the P-values of the three radionuclides were less than 0.05.

Table 2: Analysis of Variance for the Upper Region

		Sum of Squares	df	Mean Square	F	(P)Sig.
K_40	Between Groups	117243.876	5	23448.775	2.258	0.062
	Within Groups	560653.494	54	10382.472		
	Total	677897.370	59			
Ra_226	Between Groups	138.360	5	27.672	1.973	0.097
	Within Groups	757.407	54	14.026		
	Total	895.767	59			
Th_232	Between Groups	17.988	5	3.598	.433	0.824
	Within Groups	448.977	54	8.314		
	Total	466.965	59			

*df= degree of freedom, F= F- ratio of the F- distribution (F= MS_B/MS_W, where MS_B is mean square between groups and MS_W is mean square within groups) and (p) sig. = exact significant level of the analysis.

Table 3: Analysis of Variance for the Middle Region

		Sum of Squares	df	Mean Square	F	(P) Sig.
Pottasium-40	Between Groups	378843.869	8	47355.484	4.979	0.000
	Within Groups	770349.834	81	9510.492		
	Total	1149193.703	89			
Radium-226	Between Groups	1600.591	8	200.074	7.393	0.000
	Within Groups	2192.161	81	27.064		
	Total	3792.752	89			
Thorium-232	Between Groups	2034.167	8	254.271	12.895	0.000
	Within Groups	1597.202	81	19.719		
	Total	3631.369	89			

Table 4: Analysis of Variance for the Lower Region

		Sum of Squares	df	Mean Square	F	(P) Sig.
Pottasium-40	Between Groups	541937.452	16	33871.091	8.576	0.000
	Within Groups	604277.831	153	3949.528		
	Total	1146215.283	169			
Radium-226	Between Groups	1883.258	16	117.704	2.516	0.002
	Within Groups	7158.229	153	46.786		
	Total	9041.487	169			
Thorium-232	Between Groups	5045.895	16	315.368	12.299	0.000
	Within Groups	3923.236	153	25.642		
	Total	8969.130	169			

Hence in the middle and lower regions there were significant differences in the means of the concentrations of radionuclides estimated. This could be attributed to the fact that there are more human activities going on in the middle and lower regions compared to the upper region.

3.4 The Location Effects Size Measuresfor the Three Regions

As the statistical significance of the mean differences of the radionuclides' concentrations had been established, it was necessary to look at the location effect size on the radionuclides' concentrations, so that the strength of location effects on the radionuclides' concentrations in each region could be compared. The analysis was done using same package.
Multivariate general linear model was used to compute the location effects index. The location effect size index is the Eta Squared.
Eta squared varies between 0 and 1 and it is interpreted in the usual way i.e 0 – 0.1 is a weak effect, 0.1 – 0.3 is a modest effect, 0.3 – 0.5 is a moderate effect and > 0.5 is a a strong effect.
The location effects size measure for the three regions is presented in Table 5.
For the upper region, it was observed that the three radionuclides were statistically not significant at 0.05 level in this region. The effect of locations on the concentrations of ^{40}Kwas modest (partial eta squared was 0.173), that of^{226}Ra in the upper region was also modest (partial eta squared was 0.154) and that of^{232}Th in that region was a weak effect (partial eta squared was 0.039). Hence there was no significant location effects on the measurements of the concentrations of radionuclides taken at the lower region.

Table 5: The Location Effects Size measures on the Concentrations of the Radionuclides in the upper, middle and lower regions

Source	Dependent Variable	Sig.	Partial Eta Squared
Intercept	Pottasium-40	0	0.967
	Radium-226	0	0.919
	Thorium-232	0	0.918
Upper Locations	Pottasium-40	0.062	0.173 Modest
	Radium-226	0.097	0.154 Modest
	Thorium-232	0.824	0.039 Weak
Intercept	Pottasium-40	0	0.965
	Radium-226	0	0.855
	Thorium-232	0	0.859
Middle Locations	Pottasium-40	0	0.330 Modest
	Radium-226	0	0.422 Moderate
	Thorium-232	0	0.560 Str. Effect
Intercept	Pottasium-40	0	0.986
	Radium-226	0	0.806
	Thorium-232	0	0.887
Lower Locations	Pottasium-40	0	0.473 Str. Eff.
	Radium-226	0.002	0.208 Modest
	Thorium-232	0	0.563 Str. Eff.

*sig. = exact significant level of the analysis.

In the middle region, Table 5, it was observed that the three radionuclides were statistically significant at 0.05 level of significant, since their P- values were less than 0.05. The effect of locations on the concentrations of ^{40}K, was modest, for ^{226}Ra, it was moderate and it was strong for ^{232}Th. Hence there was significant location effects on the measurements of the concentrations of radionuclides taken at the middle region.
Considering the lower region,Table 5, it was seen that the three radionuclides were statistically significant at the 0.05 level, since their P- values were less than 0.05.
The effect of locations on the concentrations of ^{40}K was a strong effect, for^{226}Ra it was modest and for^{232}Th,it was a strong effect. Hence there was significant location effects on the measurements of the concentrations of radionuclides taken at the lower region too.
It could be seen that it was majorly ^{232}Th that had significant location effect in the middle and lower regions, ^{40}K also added some effects to the lower region. Therefore it may imply that some activities that enhance ^{232}Th and ^{40}K are done in these locations. This may be an indication that the radionuclides might have been accumulated in ionic and particulate form from agricultural drains and also as drifted pariculates from long shore currents and accredition processes.

3.5 Pearson Correlation Analysis between Concentrations of Radionuclides and Hazard Indices of the Sediments.

Pearson Correlation analysis was carried out using same software package. The analysis was done to determine the inter – relation and strength of association between the concentrations of radionuclides and the hazard indices.

Table 6: Pearson Correlation Matrix of Measured Parameters in Upper Ogun River

^{40}K	1									
^{Ra}226	-0.24	1								
^{232}Th	0.04	0.64	1							
Ra Equiv.	0.81	0.35	0.53	1						
Indoor Gamma	0.86*	0.28	0.47	1.00**	1					
In. Effect.	0.86*	0.28	0.47	1.00**	1.00**	1				
Repr. Gamma	0.87*	0.24	0.45	0.99**	1.00**	1.00**	1			
ELCR	-0.14	0.64	0.34	0.17	0.14	0.14	0.12	1		
Ext. Hazard	0.81	0.35	0.53	1.00**	1.00**	1.00**	0.99**	0.19	1	
Int. Hazard	-0.52	0.60	0.57	-0.09	-0.16	-0.16	-0.18	0.27	-0.09	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 7: Pearson Correlation matrix of Measured Parameters in middle Ogun River

^{40}K	1									
^{226}Ra	-0.55	1								
^{232}Th	-0.05	0.71*	1							
Ra Equiv.	0.23	0.62	0.94**	1						
Indoor Gamma	0.28	0.58	0.92**	0.99**	1					
In. Effect.	0.33	0.55	0.90**	1.00**	0.99**	1				
Repr. Gamma	0.35	0.52	0.90**	0.99**	0.99**	1.00**	1			
ELCR	0.33	0.55	0.90**	1.00**	0.99**	1.00*	1.00**	1		
Ext. Hazard	0.23	0.62	0.94**	1.00**	0.99**	1.00**	0.99**	1.00**	1	
Int. Hazard	0.05	0.80*	0.95**	0.97**	0.95**	0.94**	0.93**	0.94**	0.97**	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 8: Pearson Correlation Matrix of Measured Parametersin lower Ogun River

40-K	1									
Ra-226	0.08	1								
Th-232	0.05	0.66**	1							
Ra Equiv.	0.44	0.77**	0.89**	1						
Indoor Gamma	0.52*	0.76**	0.85**	1.00**	1					
In. Effect.	0.52*	0.76**	0.85**	1.00**	1.00**	1				
Repr. Gamma	0.51*	0.74**	0.86**	1.00**	1.00**	1.00**	1			
ELCR	0.45	0.74**	0.85**	0.96**	0.96**	0.96**	0.96**	1		
Ext. Hazard	0.44	0.77**	0.89**	1.00**	1.00**	1.00**	1.00**	0.96**	1	
Int. Hazard	0.15	0.78**	0.80**	0.83**	0.81**	0.81**	0.80**	0.79**	0.83**	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

In the upper region of the river (Table 6), none of the radionuclides had any significant correlation with each other, at the level of significance considered.

^{40}Ksignificantly correlated positively with indoor gamma dose rate having (0.86) correlation coefficient, indoor effective dose rate(0.86) and representative gamma index (0.87) all at 0.05 level of significant.^{232}Thdid not correlate significantly with any of the parameters considered at the levels of significance.^{226}Radid not correlate significantly with any of the parameters considered at the levels of significance. Although, Majorities of the hazard indices parameters correlated well with one another.

In the middle region,Table7shows that only ^{40}K did not correlate with any of the measured parameters considered at the levels of significance. ^{226}Ra correlated positively (0.71)at 0.05 level of confidence with^{232}Th.^{226}Ra also showed positive significant correlation (0.80) at 0.05 with indoor hazard index.^{232}Th showed positive significant correlations with all the parameters considered except ^{40}K. Most of the hazard indices parameters correlated very well with one another better than the relationships in the upper regions.

For the inter relationship in the lower region of the river, it was observed from Table 8that ^{40}K positively correlated although weakly (0.52) with indoor gamma dose rate, weakly (0.52) with indoor effective dose rates and also weakly(0.51) with representative gamma index at 0.05 level of significance.^{226}Ra showed fair positve significant correlations with all the parameters considered, except with ^{40}K, all at 0.01 level of significance. Their correlation coefficience ranged between 0.66(^{232}Th) and 0.78 (internal hazard).

^{232}Th showed positve significant correlations with all the parameters considered, except with ^{40}K, all at 0.01 level of significance. Their correlation coefficience ranged between 0.66(^{226} Ra) and 0.89(Radium equivalent and external hazard index).

Buttressing the location effect result, looking specifically at the inter-relationship of the natural radionuclides' concentration with one another, using Pearson correlation analysis, it could be seen that, in the middle and lower regions ^{232}Th mostly correlated well with ^{226}Ra since radium and thorium decay series occurtogether in nature [8], but ^{40}K did not correlate with any of the two because its origin is in a different decay series [8]. ^{232}Th had most significant effect followed by^{226}Ra which is having weak effect in the regions.The presence of one may enhance the other in an area and also enhances any parameterthat depends on either of them. Lastly, the lower region has almost the same relationship as the middleregion.

3.6 Cluster Analysis of the Radionuclides Distribution

Cluster analysis is one of the multivariate techniques used to identify and classify groups with similar radiometric character in a new group of observations [9,10]. Each observation in a cluster is mostly like others in the same cluster. Cluster analysis, (single linkage, using the method of Euclidean distances- nearest neighbour was applied to the sample activity concentrations (^{40}K, ^{226}Ra and ^{232}Th), usingsame softwarepackage in the light of identifying locations with similar characters. Figures3a-c, showsdendrogram of classifying sample locations as groups according to the radionuclides concentrations in the sediments from ogun river.

40 –K Dendrogram using Single Linkage

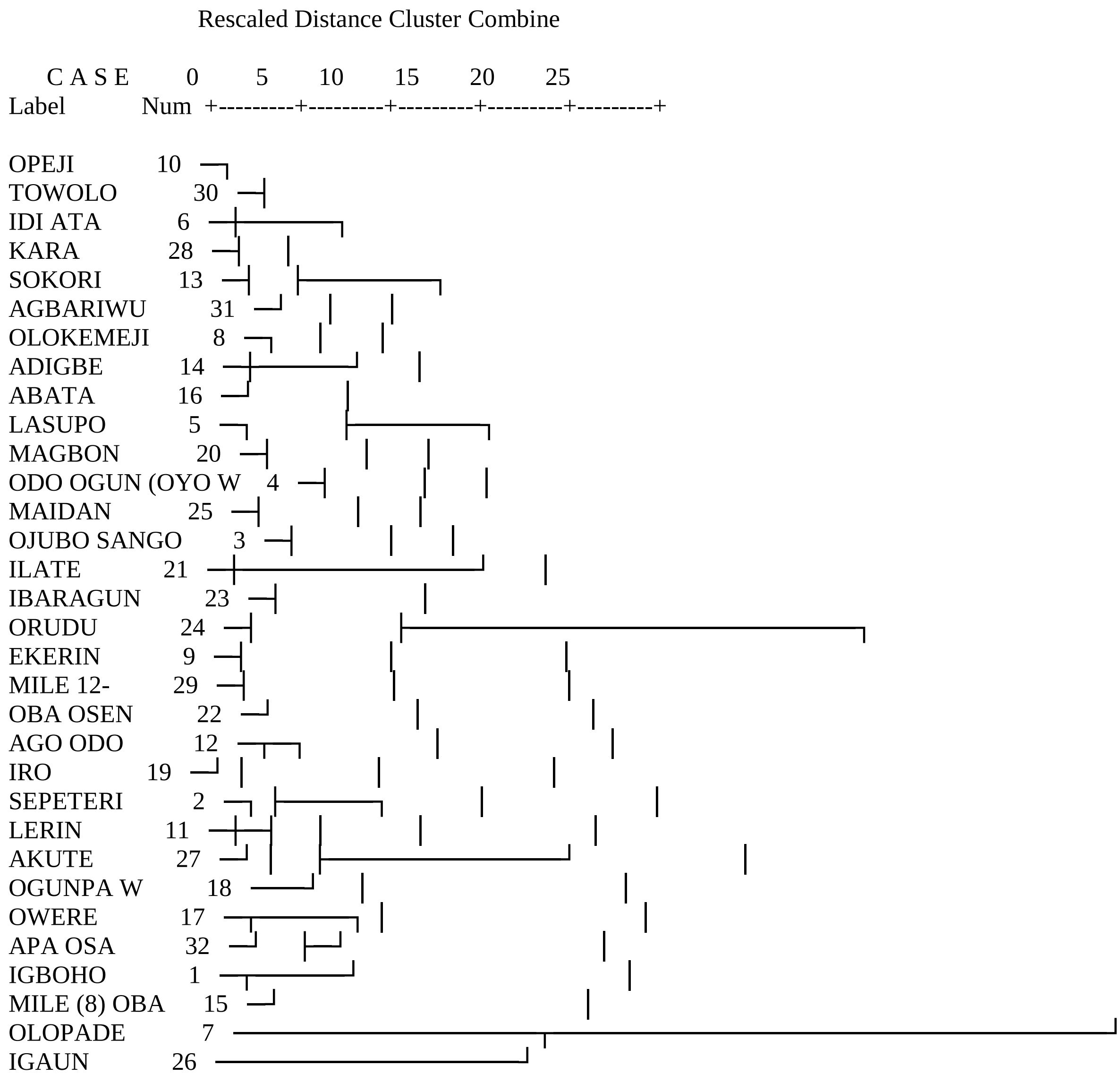

Fig.3a: Dendrogram for classifying sample locations as groups according to the concentrations of ^{40}K in the sediments from Ogun River.

Th-232

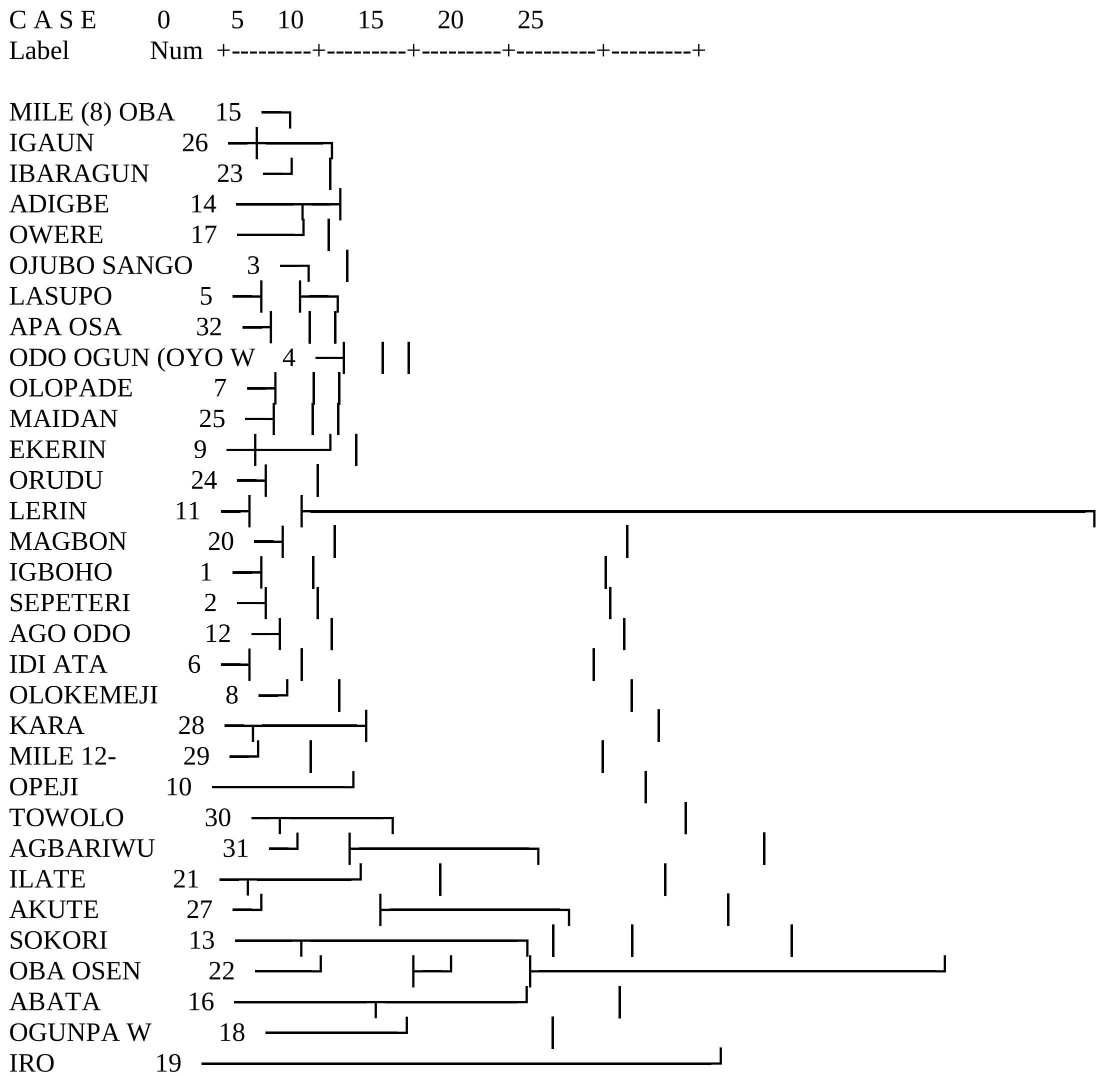

Figure 3b: Dendrogram for classifying sample locations as groups according to the concentrations of ^{232}Th in the sediments from Ogun river.

Ra -226
Dendrogram using Single Linkage

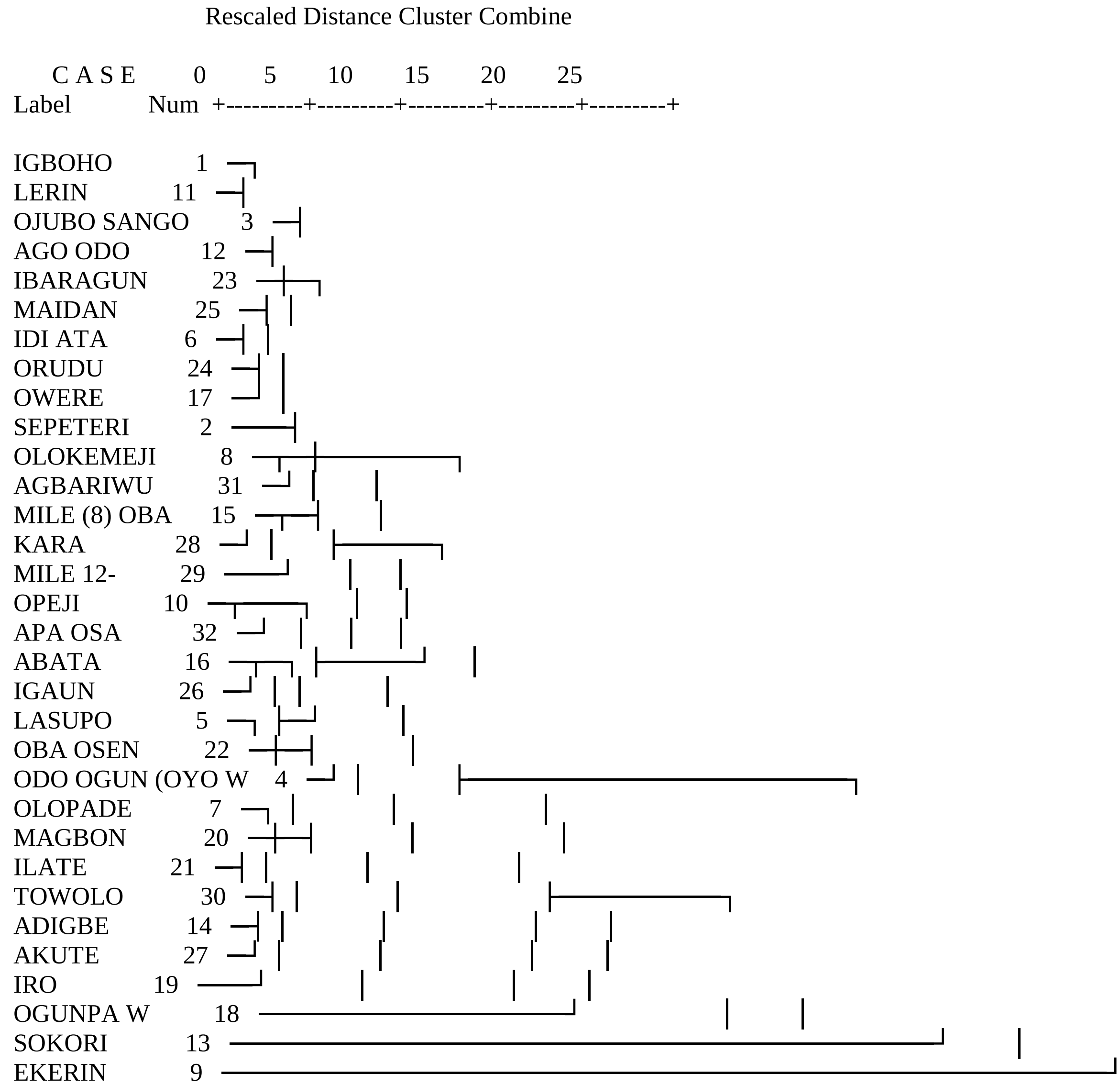

Figure 3c: Dendrogram for classifying sample locations as groups according to the concentrations of ^{226}Ra in the sediments from Ogun river

The Cluster analysis was carried out on the concentrations of the radionuclides to identify and classify groups with similar characters in a new group of observations.

The dendrogram was used to give a pictorial representation of the groups having similar characters just like what a contour map will do, connecting parameters of similar values.

Igaun, Iro and Ekerin were observed to exist as unique locations considering the concentrations of ^{40}K, ^{232}Th and ^{226}Ra respectively. From Figure 3a, Olopade was classified as a unique location, this can be deduced from the relatively high distance at which its cluster was joined perhaps it was due to the fact that Olopade had the least value of ^{40}K in the whole region (370.97 ± 19.26). Igaun too was classified as a unique location on its own, the location was also the second least location with ^{40}K concentration value (393.19± 19.83), although its group was relatively at the forth highest distance, its cluster was not joined to any group.

The closest locations in their characters were Opeji, Towolo, Idi – Ata, Kara, Sokori and Agbariwu in one group.From figure 3b, for^{232}Th, the closest locations in their characters were Mile (8) Oba, Igaun and Ibaragun. Pair of combinations had been identified in the groups,Kara, Mile -12 Maidan, Towolo, Agbariwu, Ilate and Akute.Adigbe, Owere and Sokori, Oba Oseni, also formed Pair of combinations but in a higher order.

Iro exists as a unique location on its own, perhaps because it was the only location having ^{232}Th concentration value of 15.0 ±3.9Bq/kg.From figure 3c for ^{226}Ra, the closest locations in their characters were Igboho, Lerin, Ojubo Sango, Ago Odo, Ibaragun, Maidan, Idi – Ata, Orudu and Owere.

Ogunpa Wasimi and Sokori were classified as unique locations, this can be deduced from the relatively high distances at which these clusters were joined. Ekerin was observed to exist as a unique location on its own, perhaps because it had the least value of ^{226}Ra. Olokemeji , Agbariwu, Mile (8) Oba, Kara, Opeji, Apa Osa, Abata, Igaun, all had Pair of combinations and were connected in a higher group. The cluster analysis had been able to show ways of seeing pictorially, relationship within the radionuclides concentrations along the course of Ogun river.

4.0 Conclusion

The Analysis of Variance showed that there was no significant differences in the means of the radionuclides concentrations in the upper region, but in the middle and lower regions, there were significant differences in the means of the concentrations of the radionuclides estimated.

The location effects size measures showed that there was no significant location effect on the measurements of the concentrations of radionuclides taken at those locations in the upper region, but there were significant location effects on the measurements of the concentrations of radionuclides taken at the middle and lower regions of the river. This may be attributed to the fact that more human activities are going on in the middle and lower regions compared to the upper region.

Pearson correlation analysis was carried out on the concentrations of the radionuclides to determine the inter – relation and strength of association between the concentrations of radionuclides and parameters of hazard indices.It was observed that the radionuclides did not have any correlation with one another in the upper region. In the middle and lower regions, although ^{40}K did not correlate with the other radionuclides but ^{226}Ra correlated fairly well with ^{232}Th and most of the hazard indices parameters correlated well in the middle and lower regions of the river.

Cluster analysis was carried out on the concentrations of the radionuclides to identify and classify groups with similar characters in a new group of observations. Igaun, Iro and Ekerin were observed to exist as unique locations considering the concentrations of ^{40}K, ^{232}Th and ^{226}Ra respectively. They are disjointed.

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