Geostatistical investigation and ambient radiation mapping of Akure north and south local government areas of Ondo state, Nigeria

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***Abstract*: The need for geostatistical estimation and mapping of ambient radiation prevalence in Akure North and South Local Government Areas of Ondo State, Nigeria prompted dose rate assessment at 166 selected sample locations in these areas. Global Positioning System (GPS) and Geiger-Muller Counter (GMC) were respectively used for location identification and dose rates measurement within an interval of $1 - 1.5$km. The dose rates were measured at 1m above the ground level. The values of Dose Rate (DR) in air, and Annual Dose Rate (ADR) in air ranged from 0.16 ± 0.01 to 0.37 ± 0.04 μSv/h and 1.40 ± 0.09 to 3.24 ± 0.35 mSv/y respectively. The mean dose rate and mean annual dose rate in air are 0.26 ± 0.03 μSv/h and 2.28 ± 0.26 mSv/y. The measured DR and calculated ADR was processed in ArcGIS and Surfer, using Inverse Distance Weighting (IDW) and Kriging interpolation to produce delineation maps of ambient radiation, in 2D and 3D. Only about 1% of the variation in dose rate is explained by spatial data- elevation, latitude and longitude, which suggest very weak correlation between DR and spatial data(s). All dose rates are within the limit of internationally accepted Ambient Radiation levels; it poses no health effect on the general public.**

***Keywords*- Ambient Radiation; Dose Rate; Kriging; Inverse Distance Weighting; Cosmogenic; Akure**

1. Introduction

Background radiation have been captured to primarily consist of primordial radionuclide from terrestrial sources [1], cosmogenic radionuclide which is due to interaction of high energy cosmic ray with the nucleus of an in situ solar system atom [2], and anthropogenic sources [3]. Human exposures to these sources of radiation are incessant and unpreventable [4] [5].

Primordial radionuclides originate from the earth's crust and existed already at the formation of the earth [6]. These nuclides could either occur as a single nuclide and decay into a stable daughter nuclide, such as ^{40}K - potassium, or belong to a decay series, such as ^{238}U - uranium, ^{235}U - actinium, and ^{232}Th - thorium [7]. They are present in soil, rock, water and vegetation; but vary in concentration due to environmental geology [8] [9] [10] [11].

Most nuclear reactions in the atmosphere take place with nitrogen or oxygen [6]. Some of the main cosmogenic radionuclides produced are ^{3}H, ^{7}Be, ^{22}Na and ^{14}C, but the production is generally low [4]. Carbon-14 is the most important of all cosmogenic radionuclides produced in the atmosphere [12], and most relevant to public exposure [6]. The cosmic radiation which formed its basis is of three main sources- galactic, solar and radiation from the earth's radiation belt [13]. The primary cosmic radiation mainly originates from outer space and is produced in e.g. supernova explosions, stella flares, and pulsars [14]. A small fraction also originates from our sun. The primary cosmic radiation mainly consists of protons (87%), α-particles (11%), nuclei of elements with atomic numbers between 4 and 26 (~1%) and high-energetic electrons (~1%) [4] [7] [15]. Variations in cosmic radiation intensity relate primarily to altitude, latitude, and solar activity [7] [16]. The artificial radiation type in the environment is due to medical diagnosis (not therapy), atmospheric nuclear testing, and nuclear fuel cycle [6].

Environmental assessment and monitoring of artificial and natural radioactivity is very important to public health and safety [4] [17]. A number of researchers have proposed the exposures from low dose radiation might be beneficial for human health [18] [19] [20] [21] [22] [23]. However, certain radiation types, at some thresholds pose health problems. It is therefore necessary to monitor ambient radiation level most especially in densely populated areas such as Akure.

Several measurements and evaluations have been carried out in the Southwestern Nigeria on both the background radiation level in air and radiation concentration in soil, water, vegetable, and rock samples respectively [2] [3] [8] [24] [25], visual delineation (mapping and interpolation) of such an assessment would be of help in an emergency situation for quick response and intervention. It will provide an approximate estimation of dose rates of terrains that are difficult to access, and also help relevant health and environmental agencies take certain decisive measure towards adequate preservation of our continuously irradiation environment.

Researchers have established that there is strong correlation between dose rate and geologic background, dose rate and soil types [17] [26]. UNSCEAR, (2008) have also reported that dose rate increases with higher altitude, most especially in upper troposphere, typically 6100m – 12200m where dose rate doubles for every 1830m of increase in altitude. The UNSCEAR, (2000) report said cosmic radiation increase with altitude and geomagnetic latitude; and Gbolami et al., (2011) observed slight correlation between dose rate and altitude range 790m – 1500m in Lorestan province of Iran [27]. Therefore, from the facts provided above, this study will further seek to determine if measured dose rate in Akure is dependent on the three-spatial coordinates (latitude, longitude and elevation) or vis-à-vis.

2. Materials and methods

2.1 Study area

Akure is located in Southwestern Nigeria. It has coordinates 7.25256 [latitude in decimal degrees] and 5.19312 [longitude in decimal degrees], with an average altitude 356 metres above the sea level. The total land area cover is approximately 995 Sq Km. A large vast of thick forest surrounds Akure North and South which extends to other L.G.A. Based on the 2006 census, and data reviewed from National Population Commission the population of Akure North and South is 491,033. Akure South is densely populated being the state capital and commercial hub of Ondo State. The tropical climate of Akure is broadly of two seasons: Rainy season (April - October) and dry season (November - March). The temperature throughout the year ranges from 21^{o}C to 29^{o}C, and humidity is relatively high (about 80%). The annual rainfall is about 1524mm [28].

2.2 Geological features of the study area

The Akure area, which is located in a gently undulating terrain surrounded by inselbergs, is underlain by granites, charnockites, quartzites, granite gneisses and migmatite gneisses [29]. The granites occupy about 65% of the area. The migmatite gneisses, being the oldest rocks in the Nigerian basement, are both litho- and tectonostratigraphically basal to all suprajacent lithologies and orogenic events [30]. The area is flanked to north by Ikere Batholith and to the south by Idanre batholith. The drainage pattern in the area is dendritic and the major rivers are River Ala, River Owena and River Ogburugburu [31]. The geological map of Akure is shown in Figure 1.

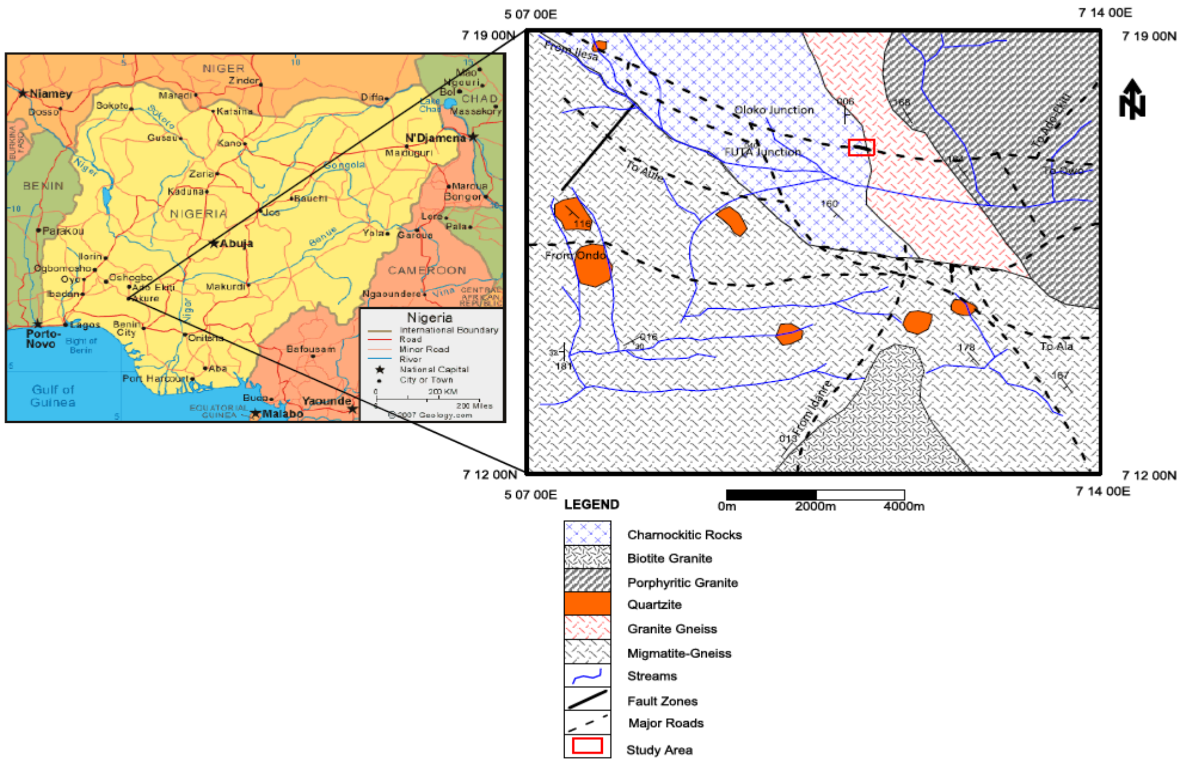

Figure 1: Simplified geological map of Akure, showing the study area [32].
Left: Administrative map of Nigeria.

2.3 Data Collection

The Ambient Radiation (AR) measurement and mapping were achieved using the geographical map of Akure North and South Local Government Areas; measurements were carried out across routes and domains for every 1.0 - 1.5km [33]. The spatial coordinate of each sampling point in Appendix 1 was duly established by a Global Positioning System (Garmin GPSmap 62s). Immediately after location identification via the GPS, the Geiger Muller Counter (Kindenoo blueGeiger PG-15 detector) was initialized to start fresh measurement of dose rate in air. The dose rates were measured at 1m above the ground level, and only six detectable stable logs were recorded in every location at 2 minutes interval after the first stable detection. The average and standard deviation of six stable measurements was specified as outdoor ambient dose rate for the sampled point shown in

Appendix 1. This process was repeated in about 166 geographical locations across Akure North and South Local Government Areas of Ondo State, making a total of 996 detectable stable logs, Figure 2 and Appendix 1.

2.4 Data Analysis Technique

The baseline data [generated in Appendix 1] were subjected to theoretical evaluations using scientific and statistical models such as Regression, ANOVA, and Correlation; with mapping tools such as ArcGIS and Surfer to create a grid-map of interpolated ambient radiation. The radiation map showed radiation distribution within the geographical location of Akure North and South Local Government Areas of Ondo State.

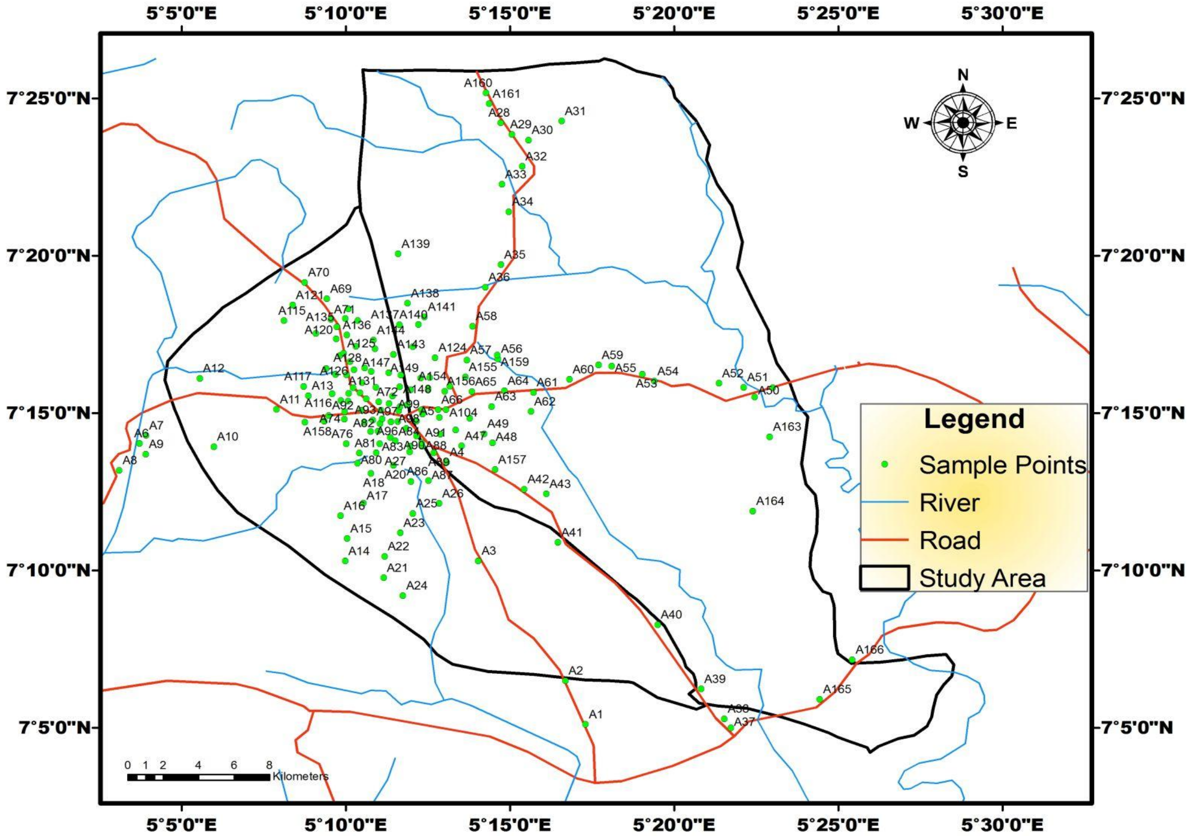

Figure 2: Spatial and AR Sample Points across Akure North and South L.G.A [34].

2.5 Geostatistical Interpolation of Data

In the mathematical field of numerical analysis, interpolation is a method of constructing new data points within the range of a discrete set of known data points. There are different types of interpolation methods such as Kriging, IDW, Spline, Lagrange, Thiessen polygon, etc. All interpolation methods have been developed based on this theory that closer points to each other have more correlations and similarities than farther points. The two common methods are used in this study.

2.5.1 Inverse Distance Weighting (IDW)

Inverse Distance Weighting (IDW) estimates values at un-sampled points by the weighted average of observed data at surrounding points. So, this can be defined as a distance reverse function of each point from neighbouring points [35]. That means by using a linear combination of values at a known sampled point, values at un-sampled points can be calculated. Using this method, the property at each unknown location for which a solution is sought is given by:

$$Z_j = \sum_{i}^{G} Z_i \, . d_{ij}^{-n} \Big/ \sum_{i}^{G} d_{ij}^{-n}$$

where Z_j is the estimated value for the unknown point at location j; Z_i is the value at known point i; d_{ij} is the distance between known point i and unknown point j; G is the number of sampled locations; and n is the inverse-distance weighting power. The value of n, in effect, controls the region of influence of each of the sampled locations. As n increases, the region of influence decreases until, in the limit, it becomes the area which is closer to point i than to any other. When n is set equal to zero, the method is identical to simply averaging the sampled values. As n gets larger, the method approximates the Voronoi tessellation procedure [36] [37].

2.5.2 Kriging interpolation method

Kriging is a geostatistical gridding method that has proven useful and popular in many fields. This method produces visually appealing maps from irregularly spaced data. Kriging attempts to express trends suggested in your data, so that, for example, high points might be connected along a ridge rather than isolated by bull's-eye type contours [38].

Different authors have discussed kriging in their publications, which has formed the basis for kriging analysis in Surfer Software and other geostatistical softwares [39] [40]. Among the various kriging methods, ordinary kriging was used in this study. Its average of spatial random field [Z(x)] is assumed to be stationary and unbiased [17] [41].
The general equation of kriging method;

$$Z(x_0) = \sum_{i=1}^{N} W_i Z(x_i)$$

Here $Z(x_0)$ is unknown but estimated Z value in x_0 point, W_i is weight value for each $Z(x_i)$ which are used for the calculation of $Z(x_0)$ in the experimented data, $Z(x_0)$ is calculated by using point number N [17].

3. Results and Discussion

Table 1: Model Summary of Dose Rate and Elevation

Model	r	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.080[a]	0.006	0.000	0.03838	0.006	1.055	1	164	0.306

a. Predictors: (Constant), Elevation (m)

Table 2: Coefficients[a] of dependent variable Dose Rate and independent variable Elevation

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	0.214	0.041		5.249	0.000	0.134	0.295
	Elevation (m)	0.000	0.000	0.080	1.027	0.306	0.000	0.000

a. Dependent Variable: Dose Rate (µSv/h)

Table 3: Model Summary of Dose Rate and Latitude

Model	r	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.087[a]	0.008	0.001	0.03836	0.008	1.239	1	164	0.267

a. Predictors: (Constant), Latitude (°N)

Table 4: Coefficients[a] of dependent variable Dose Rate and independent variable Latitude

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-0.171	0.384		-0.446	0.656	-0.929	0.587
	Latitude (°N)	0.059	0.053	0.087	1.113	0.267	-0.046	0.163

a. Dependent Variable: Dose Rate (µSv/h)

Table 5: Model Summary of Dose Rate and Longitude

Model	r	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.079[a]	0.006	0.000	0.03838	0.006	1.021	1	164	0.314

a. Predictors: (Constant), Longitude (°E)

Table 6: Coefficients[a] of dependent variable Dose Rate and independent variable Longitude

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	0.504	0.246		2.053	0.042	0.019	0.990
	Longitude (°E)	-0.048	0.047	-0.079	-1.010	0.314	-0.141	0.045

a. Dependent Variable: Dose Rate (µSv/h)

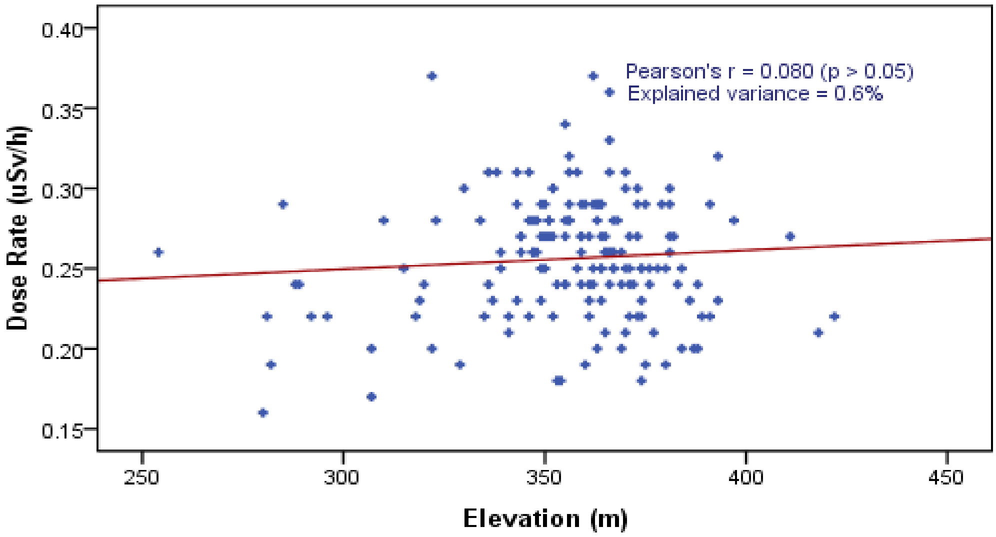

Figure 3: Scatterplot of Dose Rate and Elevation

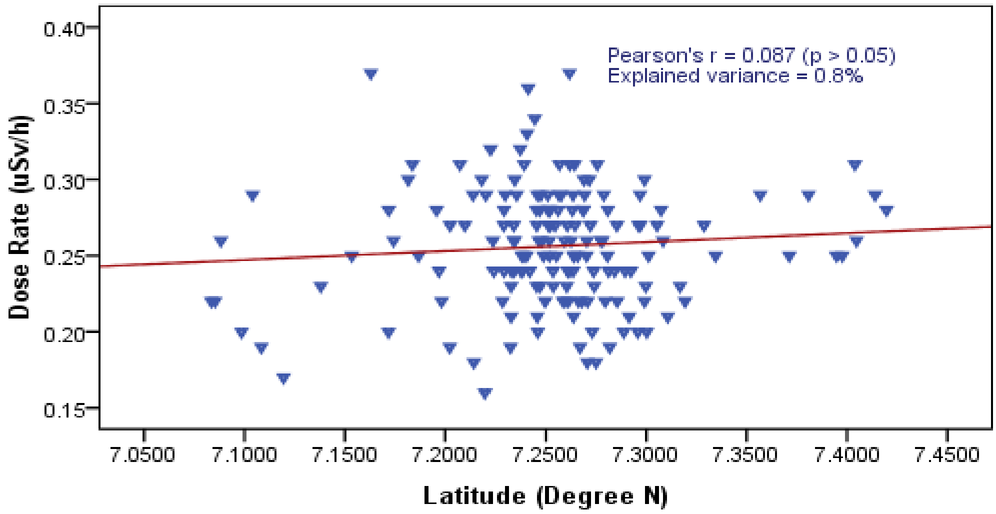

Figure 4: Scatterplot of Dose Rate and Latitude

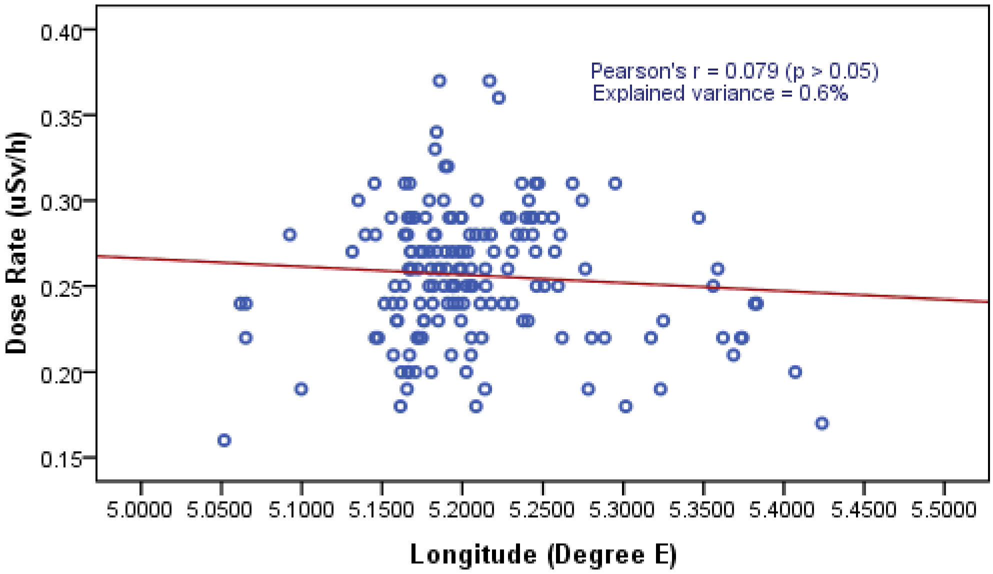

Figure 5: Scatterplot of Dose Rate and Longitude

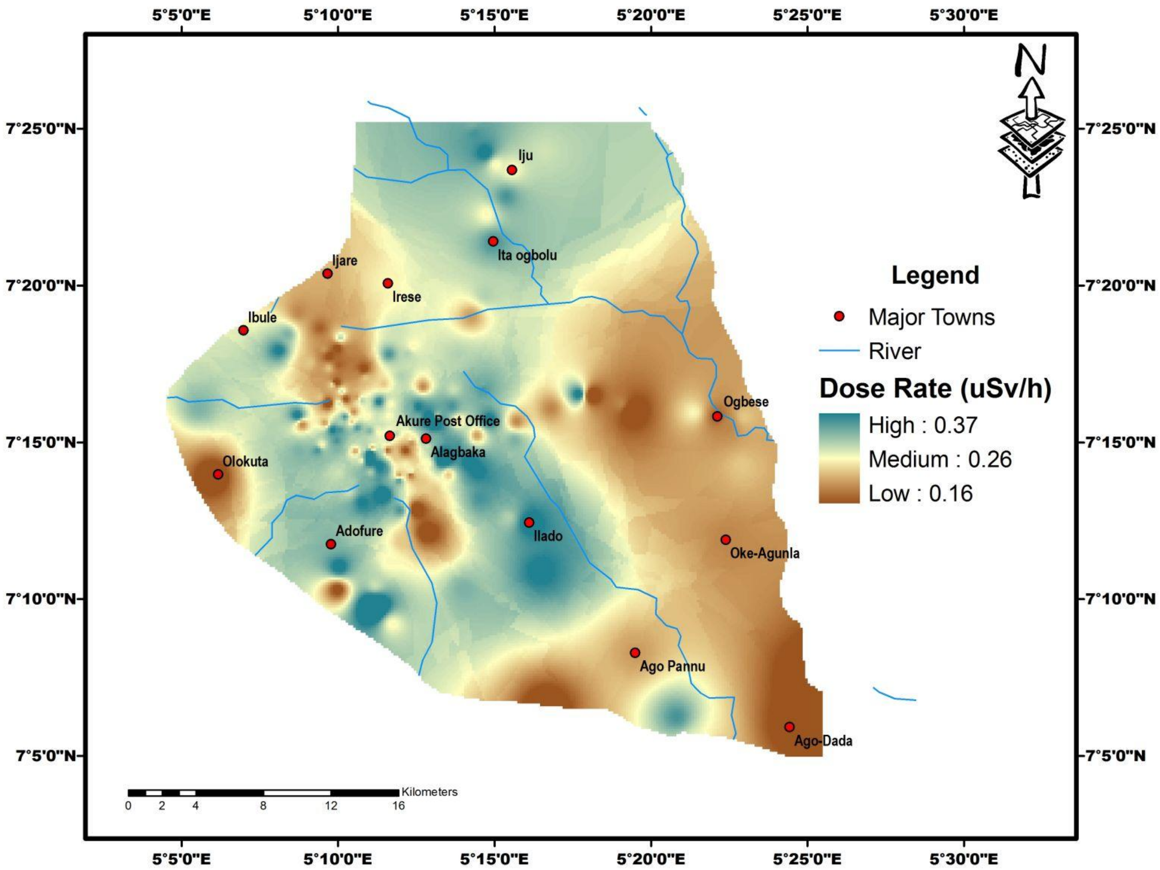

Figure 6: Interpolation map of DR distribution in Akure North and South L.G.A [34].

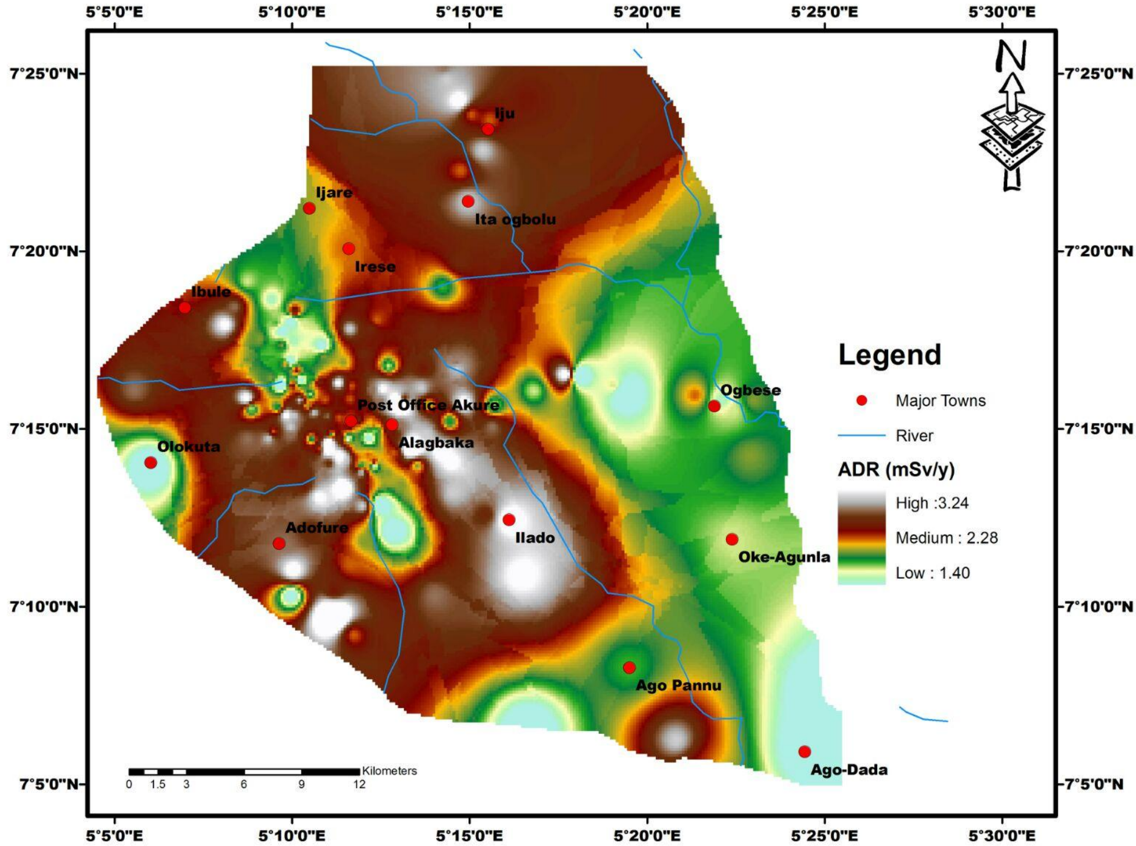

Figure 7: Interpolation map of ADR distribution in Akure North and South L.G.A [34].

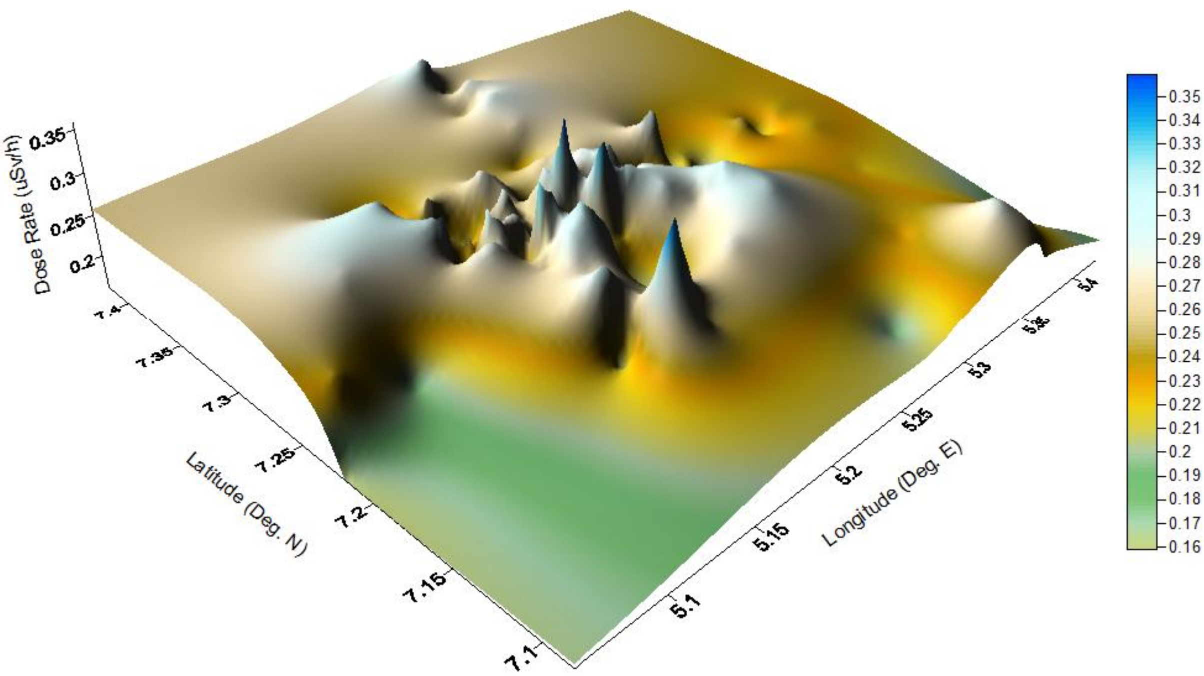

Figure 8: 3D Map of DR Distribution in Akure North and South L.G.A of Ondo State [38].

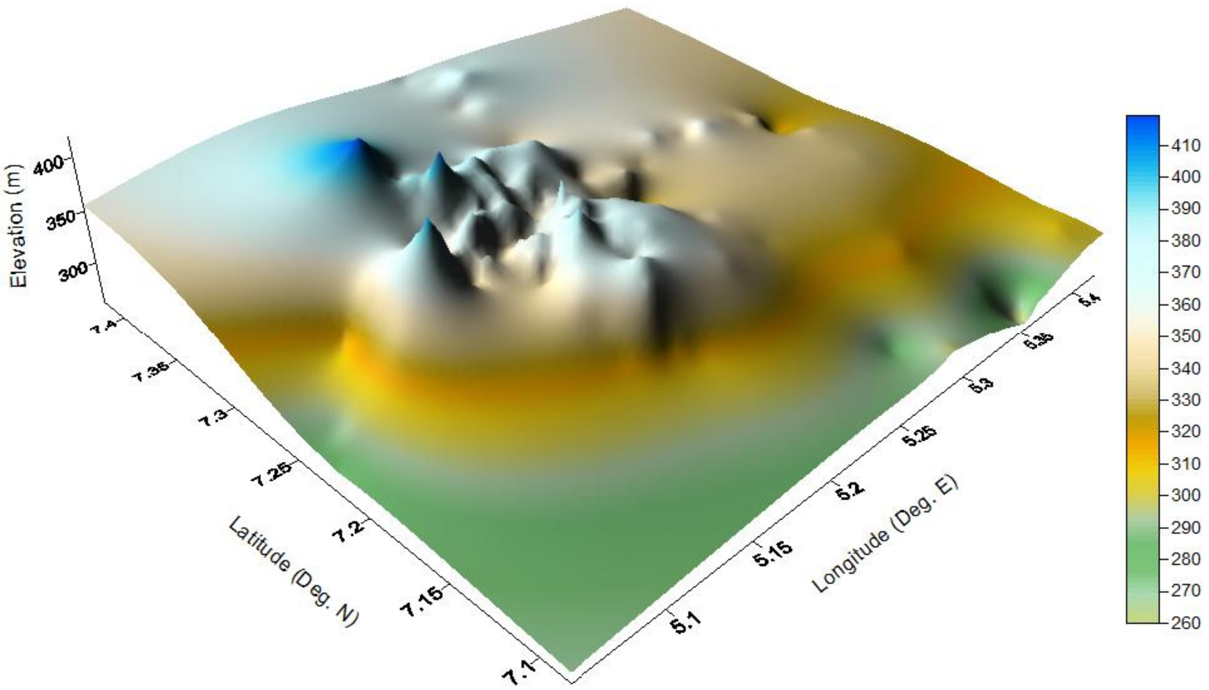

Figure 9: 3D Map of Spatial coordinates in Akure North & South L.G.A of Ondo State [38].

The conceptual mapping of Ambient Radiation (AR) in this study was based on dose rate measurements in 166 sample locations across Akure North and South L.G.A of Ondo State, which fall within the coordinates 7^{o} 05' 00''N to 7^{o} 25' 11''N latitude and 5^{o} 03' 06''E to 5^{o} 25' 25''E longitude (Appendix 1).

The lowest Dose Rate, DR of $0.16 \pm 0.01\, \mu Sv/h$ was recorded at Ondo State Asphalt Company (OSAC) with location identity A8 and elevation of 280 m above the sea level. The highest radiation measurement was taken at location A21, Fakinlede Camp Ijoka; and location A156, Ojomu Famubo Layout, Ijapo, the two sites recorded DR $0.37 \pm 0.04\, \mu Sv/h$ and $0.37 \pm 0.03\, \mu Sv/h$, and elevation 322 m and 362 m respectively. The mean elevation of Akure is 356.22m. The minimum elevation 254m was recorded at Ala Ajagbusi, having location identity A38 and DR $0.26 \pm 0.01\, \mu Sv/h$ while the maximum elevation 422m was measured at Central Market, Ipinsa with identity A70 and DR $0.22 \pm 0.04\, \mu Sv/h$ (Appendix 1).

The Inverse Distance Weighting (IDW) and Kriging interpolation techniques in Figures 6, 7, 8, and 9 was used to estimate the unknown dose rate, and elevation of areas in Akure which falls between areas of known dose rates and elevation, and terrains that are very difficult to access [26] [42] [43]. This estimation technique usually considers distance as a major factor in determining optimum result; for this reason closer distance of 1 – 1.5km was maintained in the metropolis because most routes and domains are reachable, but interpolation map was relied upon for dose rate evaluation of unmeasured areas like vegetation forest and government reserved areas which covers larger areas of Akure North and South. The colours in the maps depict varying and ranging values of radiation and elevation data within the geographical location of Akure North and South, from the lowest value to the peak value. These techniques are mathematically and statistically good, and have its significance but the graphical result (in 2D or 3D) tells which technique best describe the data distribution of the sampled areas. In this particular work IDW showed better result in 2D when compared with other techniques, Fig. 6 and 7, while kriging gave the best result in terms of resolution and quality in 3D, Fig. 8 and 9.

The ambient radiation distribution in Akure is mainly of terrestrial and cosmic sources. The terrestrial source which is most significant is usually characterized by soil type and geology of the terrain. The geology of Akure has certain rock types such as chanockitic rock (metamorphic), biotite granite (igneous), porphyritic granite (igneous), quartzite (metamorphic), granite gneiss (metamorphic) and migmatite gneiss (a composite rock of igneous and metamorphic) [29] [31] [44] [45]. These underlain bedrock types are considered primary sources of terrestrial radiation in the environment since dose rate in air cannot be independently isolated from geological background and soil types [17] [26]. The parent rocks of the metamorphic rocks describe above could possibly be sedimentary or igneous, which may have been responsible for its varying radiation level, although an average dose rate of $0.26\, \mu Sv/h$ may not be extreme. This may have come from the fact that activity concentrations of primordial radionuclide in rocks are usually higher in igneous than in sedimentary types. However, exceptions as certain sedimentary rocks, notably some shale and phosphates, are highly radioactive [46]; and it is worth noting that activity concentration (i.e. amount of radioactivity) in soil are largely determined by the activity concentrations in the source rock, and fairly similar to the radioactivity in the rock underneath [10].

Moreover, the contribution of cosmic rays to public exposure in Akure is believed to be very low (i.e. insignificant) due to the fact that cosmic radiation increase with altitude, geomagnetic latitude, and time in the solar cycle [4]. Akure with an average elevation of 356m on latitude 7 degrees may not experience much of cosmic radiations when compared to the dominance of terrestrial radionuclides.

Correlation and regression analysis was used to determine and estimate the relationship between dose rate and spatial data, the following were deduced:

i. The correlation coefficient, r equals 0.080, 0.087 and 0.079 suggests a very weak linear correlation exist between dose rate and spatial data (elevation, latitude and longitude) in the scatterplots as shown in tables 1, 3, and 5; and Figures 3, 4, and 5.
ii. The R-square(s) in tables 1, 3 and 5 show that less than 1% of the variation in DR data is explained by spatial data.
iii. The p-value(s) 0.306, 0.267 and 0.314 is greater than the selected significance level 0.05 at 95.0% confidence interval in tables 2, 4 and 6.

The values above implies that none of the spatial data are useful predictors of dose rates in Akure North and South L.G.A, meaning that dose rate in Akure is independent of its spatial coordinates. The scatterplots in Figures 3, 4, and 5 shows the graph of dose rate and spatial data(s), and depicts the explained variance(s) in tables 1, 3, and 5. The ambient radiation here is largely due to its geologic features, soil types, and human activities within the immediate environment; and limited contribution from cosmic sources.

The highest dose rate detected at Fakinlede Camp (A21) could be attributed to the soil type, bedrock type and vegetation. The top soil is similar to laterite and the embedded rock comparable to migmatite gneiss rock which covers vast area of Akure South and part of Akure North, Figure 1. Also at Ojomu Famubo Layout, Ijapo (A156) which recorded ambient radiation hike as location A21 has laterite and bush gravel, a family of sedimentary rock covers the whole area [46]. Researchers have carried out geochemical assessment; geologic investigation; and constraint map production for landfill site in Akure, these separate works identified laterite as top soil in some parts of Akure, however, the thickness and depth of this laterite composition varies from location to location [32] [47] [48]. Therefore, radiation contribution from these sources to the environment cannot be neglected, most especially if the source rock contains radionuclide materials. Sample locations around Sasa, Owo-Road axis recorded radiation measurement above the average dose rate in Akure, these are areas of porphyritic granite, and quarry work is a major activity around this area, therefore radionuclide concentration from these sources may have contributed to its radiation hike. On the contrary, the lowest radiation measurement was near the premises of Ondo State Asphalt Company (OSAC) along Owena, a quarry company that hasn't been functioning for over two years. The measurement around this area is generally below $0.26\,\mu Sv/h$ average, this reflects in data recorded at four locations around Owena-Aponmu axis- A6, A7, A8, A9 [33]. Two vital assumptions are inferred from radiation data recorded around Owena-Aponmu axis: the rock and soil type in this area have lower concentration of radionuclide; unlike other quarries and rocky areas along Akure-Owo road with dose rates in the range of an average measurement in Akure, measurement near the quarry suggest family of parent rocks (e.g. igneous rocks) and daughter rocks (e.g. migmatite gneiss) have varying radionuclide concentration. This may be responsible for its low ambient radiation.

Waste Management Recycling, Igbatoro (A157) is another location amongst others that recorded dose rate $0.29 \pm 0.05\,\mu Sv/h$ above average; it is a refuse dump-site filled with organic and inorganic wastes of carbon, nitrogen and other compounds. The decomposition process will definitely elevate background radiation. Other locations around this area such as Ajowa Igunsi (A41), Imafo (A42) and Ilado (A43) also experience dose rates $0.30 \pm 0.03\,\mu Sv/h$, $0.27 \pm 0.02\,\mu Sv/h$ and $0.31 \pm 0.02\,\mu Sv/h$ above average. The high dose rates recorded along some major roads in Akure could be ascribed to the geology of these routes, and elevated contribution from road-construction materials. In general, the radiation potential of building (both local and modern as they comprise different sands, gravels and granites) cannot be undermined in the study area [49]; building materials such as cement components which include limestone, gypsum, clay and laterite also contributes to ambient radiation level of an environment [50], though, it's very low compared to the dominance of primordial radionuclide. Estimation of Annual Dose Rate in air, ADR is given by:

$$ADR(mSv/y) = Dose\ Rate\ (\mu Sv/h) \times 24\ (h) \times 365(days) \times 10^{-3}$$

4. Conclusion

In this study, ambient radiation was measured in some selected locations in Akure North and South L.G.A., Geiger-Muller detector was used for the assessment, map of the sample points and AR interpolation map is presented. The dose rate ranged from $0.16 \pm 0.01\,\mu Sv/h$ in OSAC to $0.37 \pm 0.04\,\mu Sv/h$ in Fakinlede Camp Ijoka, and annual dose rate $1.40 \pm 0.09\,mSv/y$ – $3.24 \pm 0.35\,mSv/y$, respectively. The mean dose rate and mean annual dose rate in air are $0.26 \pm 0.03\,\mu Sv/h$ and $2.28 \pm 0.26\,mSv/y$. The maps, presented in 2D and 3D clearly depict ambient radiation concentration over Akure, which is due to its geologic structure and human activities. The analysis in this study also express negligible relationship between dose rate and spatial data because less than 1% of the variation in dose rate is explained by spatial data. This research work is primarily an outdoor composition of terrestrial sources and presumable low contribution from cosmic radiation fragments as the scope of this study does not include the assessment and evaluation of other sources; it poses no health effect on the general public. Since Geiger-Muller detector doesn't distinguish ionizing radiations, it is assumed that its measurements comprise radiation types other than gamma.

5. Acknowledgement

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Appendix 1: Spatial and Ambient Radiation Data across Akure, Ondo State

Site Code	Lat. (°N)	Long. (°E)	Elevat. (Metre)	Dose Rate ($\mu Sv/h$)	Annual Dose Rate (mSv/y)	Site Code	Lat. (°N)	Long. (°E)	Elevat. (Metre)	Dose Rate ($\mu Sv/h$)	Annual Dose Rate (mSv/y)
A1	7.08527	5.28834	296	0.22±0.02	1.93±0.18	A84	7.23535	5.19170	379	0.29±0.02	2.54±0.18
A2	7.10832	5.27810	282	0.19±0.02	1.66±0.18	A85	7.23259	5.19918	364	0.23±0.02	2.01±0.18
A3	7.17182	5.23390	351	0.28±0.02	2.45±0.18	A86	7.21387	5.19964	364	0.29±0.04	2.54±0.35
A4	7.22400	5.21778	369	0.24±0.02	2.10±0.18	A87	7.21427	5.20854	374	0.18±0.02	1.58±0.18
A5	7.24587	5.20255	369	0.20±0.03	1.75±0.26	A88	7.23258	5.20539	370	0.21±0.03	1.84±0.26
A6	7.23402	5.06193	288	0.24±0.04	2.10±0.35	A89	7.22900	5.21127	362	0.24±0.03	2.10±0.26
A7	7.23827	5.06522	289	0.24±0.03	2.10±0.26	A90	7.23792	5.20253	378	0.25±0.03	2.19±0.26
A8	7.21972	5.05168	280	0.16±0.01	1.40±0.09	A91	7.23441	5.20528	381	0.26±0.03	2.28±0.26
A9	7.22832	5.06508	292	0.22±0.02	1.93±0.18	A92	7.24878	5.15802	349	0.25±0.02	2.19±0.18
A10	7.23228	5.09972	329	0.19±0.02	1.66±0.18	A93	7.24643	5.18026	348	0.26±0.03	2.28±0.26
A11	7.25205	5.13150	411	0.27±0.03	2.37±0.26	A94	7.24440	5.18398	355	0.34±0.04	2.98±0.35
A12	7.26846	5.09255	310	0.28±0.04	2.45±0.35	A95	7.24694	5.18509	343	0.23±0.01	2.01±0.09
A13	7.25929	5.14771	361	0.22±0.02	1.93±0.18	A96	7.24536	5.18950	355	0.27±0.02	2.37±0.18
A14	7.17177	5.16640	322	0.20±0.03	1.75±0.26	A97	7.24564	5.19306	365	0.21±0.02	1.84±0.18
A15	7.18362	5.16724	336	0.31±0.02	2.72±0.18	A98	7.24188	5.19736	366	0.24±0.01	2.10±0.09
A16	7.19570	5.16396	347	0.28±0.06	2.45±0.53	A99	7.24953	5.20554	391	0.22±0.02	1.93±0.18
A17	7.20240	5.17550	361	0.27±0.02	2.37±0.18	A100	7.24783	5.21420	366	0.26±0.02	2.28±0.18
A18	7.21818	5.17945	370	0.30±0.03	2.63±0.26	A101	7.23884	5.21454	371	0.25±0.02	2.19±0.18
A19	7.22905	5.18206	356	0.28±0.03	2.45±0.26	A102	7.24109	5.22245	366	0.36±0.02	3.15±0.18
A20	7.22244	5.19088	393	0.32±0.02	2.80±0.18	A103	7.24739	5.22953	349	0.29±0.01	2.54±0.09
A21	7.16287	5.18586	322	0.37±0.04	3.24±0.35	A104	7.25191	5.21753	351	0.28±0.03	2.45±0.26
A22	7.17423	5.18640	359	0.26±0.03	2.28±0.26	A105	7.25082	5.16597	350	0.29±0.02	2.54±0.18
A23	7.18665	5.19424	376	0.25±0.04	2.19±0.35	A106	7.25641	5.16773	356	0.29±0.02	2.54±0.18
A24	7.15339	5.19564	315	0.25±0.04	2.19±0.35	A107	7.26052	5.16809	373	0.27±0.02	2.37±0.18
A25	7.19688	5.20070	355	0.24±0.01	2.10±0.09	A108	7.26345	5.17027	375	0.29±0.02	2.54±0.18
A26	7.20225	5.21398	375	0.19±0.03	1.66±0.26	A109	7.26080	5.17381	361	0.24±0.03	2.10±0.26
A27	7.22962	5.19908	373	0.29±0.04	2.54±0.35	A110	7.25761	5.17703	359	0.29±0.04	2.54±0.35
A28	7.40390	5.24519	366	0.31±0.02	2.72±0.18	A111	7.25665	5.16410	370	0.31±0.03	2.72±0.26

A29	7.39764	5.25089	367	0.25±0.02	2.19±0.18	A112	7.27057	5.16149	354	0.18±0.01	1.58±0.09
A30	7.39470	5.25936	374	0.25±0.02	2.19±0.18	A113	7.27034	5.16694	369	0.26±0.02	2.28±0.18
A31	7.40474	5.27625	367	0.26±0.02	2.28±0.18	A114	7.28059	5.16385	367	0.25±0.04	2.19±0.35
A32	7.38079	5.25616	381	0.29±0.05	2.54±0.44	A115	7.29904	5.13520	381	0.30±0.03	2.63±0.26
A33	7.37123	5.24588	358	0.25±0.01	2.19±0.09	A116	7.26031	5.15973	386	0.23±0.02	2.01±0.18
A34	7.35675	5.24930	364	0.29±0.03	2.54±0.26	A117	7.26422	5.14529	338	0.31±0.01	2.72±0.09
A35	7.32869	5.24538	349	0.27±0.02	2.37±0.18	A118	7.27369	5.15672	359	0.24±0.02	2.10±0.18
A36	7.31675	5.23752	349	0.23±0.03	2.01±0.26	A119	7.29226	5.15151	372	0.24±0.03	2.10±0.26
A37	7.08342	5.36210	281	0.22±0.02	1.93±0.18	A120	7.28934	5.16178	388	0.24±0.03	2.10±0.26
A38	7.08820	5.35880	254	0.26±0.01	2.28±0.09	A121	7.30730	5.13963	397	0.28±0.02	2.45±0.18
A39	7.10396	5.34697	285	0.29±0.03	2.54±0.26	A122	7.28543	5.17176	389	0.22±0.07	1.93±0.61
A40	7.13800	5.32495	319	0.23±0.03	2.01±0.26	A123	7.28410	5.18148	376	0.24±0.02	2.10±0.18
A41	7.18158	5.27436	330	0.30±0.03	2.63±0.26	A124	7.27945	5.21196	374	0.22±0.05	1.93±0.44
A42	7.20978	5.25723	344	0.27±0.02	2.37±0.18	A125	7.28171	5.16562	380	0.19±0.02	1.66±0.18
A43	7.20731	5.26841	343	0.31±0.02	2.72±0.18	A126	7.27734	5.16874	366	0.26±0.03	2.28±0.26
A44	7.25516	5.18851	370	0.25±0.02	2.19±0.18	A127	7.27297	5.17082	363	0.20±0.02	1.75±0.18
A45	7.25157	5.18449	344	0.26±0.02	2.28±0.18	A128	7.27400	5.17617	374	0.23±0.03	2.01±0.26
A46	7.25126	5.19355	364	0.27±0.03	2.37±0.26	A129	7.26618	5.17498	371	0.22±0.01	1.93±0.09
A47	7.23269	5.22545	371	0.24±0.02	2.10±0.18	A130	7.26367	5.18197	380	0.25±0.02	2.19±0.18
A48	7.23437	5.24116	352	0.30±0.01	2.63±0.09	A131	7.27208	5.17955	352	0.27±0.02	2.37±0.18
A49	7.23908	5.23677	356	0.31±0.02	2.72±0.18	A132	7.30021	5.16635	387	0.20±0.02	1.75±0.18
A50	7.25852	5.37421	318	0.22±0.04	1.93±0.35	A133	7.30530	5.16793	381	0.27±0.03	2.37±0.26
A51	7.26370	5.36865	341	0.21±0.03	1.84±0.26	A134	7.29907	5.17272	373	0.22±0.03	1.93±0.26
A52	7.26586	5.35599	339	0.25±0.05	2.19±0.44	A135	7.29573	5.16204	388	0.20±0.02	1.75±0.18
A53	7.27069	5.31721	346	0.22±0.03	1.93±0.26	A136	7.29138	5.16709	418	0.21±0.04	1.84±0.35
A54	7.26695	5.32315	360	0.19±0.04	1.66±0.35	A137	7.29685	5.19383	391	0.29±0.04	2.54±0.35
A55	7.27492	5.30153	353	0.18±0.05	1.58±0.44	A138	7.30826	5.19800	365	0.26±0.05	2.28±0.44
A56	7.27878	5.24386	343	0.29±0.03	2.54±0.26	A139	7.33445	5.19318	374	0.25±0.05	2.19±0.44
A57	7.27816	5.22809	367	0.26±0.02	2.28±0.18	A140	7.29695	5.20349	371	0.27±0.05	2.37±0.44
A58	7.29609	5.23089	382	0.27±0.03	2.37±0.26	A141	7.30104	5.20653	384	0.25±0.03	2.19±0.26
A59	7.27551	5.29492	358	0.31±0.03	2.72±0.26	A142	7.28528	5.20057	359	0.27±0.03	2.37±0.26
A60	7.26795	5.28013	341	0.22±0.04	1.93±0.35	A143	7.28116	5.19079	383	0.24±0.03	2.10±0.26

A61	7.26104	5.26187	352	0.22±0.02	1.93±0.18	A144	7.28873	5.18065	384	0.20±0.03	1.75±0.26
A62	7.25095	5.26068	323	0.28±0.02	2.45±0.18	A145	7.25915	5.19033	365	0.26±0.02	2.28±0.18
A63	7.25358	5.24062	337	0.23±0.02	2.01±0.18	A146	7.27016	5.19467	362	0.25±0.02	2.19±0.18
A64	7.26187	5.24713	346	0.31±0.02	2.72±0.18	A147	7.27152	5.18841	373	0.30±0.03	2.63±0.26
A65	7.26140	5.23068	353	0.24±0.02	2.10±0.18	A148	7.26406	5.19392	350	0.25±0.06	2.19±0.53
A66	7.25191	5.21355	348	0.28±0.02	2.45±0.18	A149	7.26862	5.20465	363	0.28±0.03	2.45±0.26
A67	7.25178	5.20513	364	0.25±0.02	2.19±0.18	A150	7.26304	5.20843	356	0.28±0.01	2.45±0.09
A68	7.25344	5.19418	355	0.24±0.01	2.10±0.09	A151	7.25450	5.19778	350	0.27±0.02	2.37±0.18
A69	7.31065	5.15707	377	0.21±0.02	1.84±0.18	A152	7.26243	5.19947	347	0.26±0.01	2.28±0.09
A70	7.31923	5.14580	422	0.22±0.04	1.93±0.35	A153	7.26887	5.20914	352	0.30±0.06	2.63±0.53
A71	7.29965	5.15910	393	0.23±0.03	2.01±0.26	A154	7.26438	5.21938	351	0.27±0.02	2.37±0.18
A72	7.25602	5.18328	368	0.28±0.04	2.45±0.35	A155	7.26920	5.22727	360	0.29±0.02	2.54±0.18
A73	7.24570	5.15572	363	0.29±0.04	2.54±0.35	A156	7.26164	5.21679	362	0.37±0.03	3.24±0.26
A74	7.24690	5.16587	346	0.28±0.01	2.45±0.09	A157	7.22018	5.24232	362	0.29±0.05	2.54±0.44
A75	7.25167	5.17463	344	0.27±0.05	2.37±0.44	A158	7.24519	5.14596	334	0.28±0.01	2.45±0.09
A76	7.23377	5.16688	347	0.26±0.02	2.28±0.18	A159	7.28076	5.24354	355	0.28±0.02	2.45±0.18
A77	7.24534	5.17600	361	0.23±0.03	2.01±0.26	A160	7.41962	5.23786	367	0.28±0.02	2.45±0.18
A78	7.24027	5.17921	364	0.25±0.03	2.19±0.26	A161	7.41398	5.23937	363	0.29±0.03	2.54±0.26
A79	7.23389	5.18388	365	0.27±0.03	2.37±0.26	A162	7.26348	5.38331	320	0.24±0.03	2.10±0.26
A80	7.22359	5.17249	339	0.26±0.01	2.28±0.09	A163	7.23751	5.38169	336	0.24±0.02	2.10±0.18
A81	7.22891	5.17354	359	0.27±0.04	2.37±0.35	A164	7.19820	5.37315	335	0.22±0.02	1.93±0.18
A82	7.24049	5.18302	366	0.33±0.03	2.89±0.26	A165	7.09850	5.40718	307	0.20±0.03	1.75±0.26
A83	7.23711	5.18921	356	0.32±0.02	2.80±0.18	A166	7.11940	5.42372	307	0.17±0.01	1.49±0.09

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