Evaluation of Radiological Hazards Indices of Dose Rate Measurement from Akwa Ibom State, South-South Nigeria

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Abstract: ***Sources of radiation like terrestrial, cosmic and anthropogenic activities etc are major contributors of exposures to human and other environmental biota, which raises global apprehensions and likewise the quest for impact mitigation. The dose rate measurement investigation was conducted to create a baseline of radiation and estimate related radiological risk implications in Akwa Ibom State, Nigeria located at 6°42'E, 7°30'N, before siting a proposed nuclear facility in the area. Method of dose rate measurement engaged in the investigation was a systematic grid, with appropriate equipment as ArcGIS software & GIS GARMIN Etrex 10, 7 RDS-31S/R and 2 Polimaster PM 1703 M-01 survey meters. The background radiation obtained with an overall average dose rate of 0.05±0.003, quite lower than the world average of 0.2 µSv/h. Radiological risk implications arising from the dose rate measurement were also evaluated. Absorbed dose rate with mean value of 45.87nGy/hr. The Annual Equivalent dose with mean value of 0.042 mSv/yr was below the world's average of 0.42 mSv/yr. Annual effective dose outdoor with mean value of 0.07 mSv/yr which is below the world's average of 0.42 mSv/yr; and mean Excess Lifetime Cancer Risk factor for the outdoor gamma radiation was seen to be 0.25 x 10^{-3} below the world's average of 0.29x 10^{-3}. The assessed risk implications were below admissible limits, and thus poses no health menace to the rural dwellers. However, continuous monitoring is recommended.***

Keywords: Background Ionizing Radiation,Dose Rate, Hazard Indices, Akwa Ibom State

1. Introduction

Exposures to varied levels of ionizing radiation for people and other biota are inevitable because this radiation has always been present in the environment as background ionizing radiation (BIR) since the earth's formation (Ugbede and Echeweozo, 2017). Therefore, due to component sources like terrestrial (Primordial), cosmogenic (extraterrestrial), and artificial (man-made) radionuclides, humans are constantly exposed to ambient radiation. The terrestrial sourcesusually arise from primordial radionuclides and they emits gamma radiation from Uranium (^{238}U), Thorium (^{232}Th) (i.e. decay series) and Potassium (^{40}K) (i.e. a non decay series). Moreover, the disorganized mining activities, mainly open pit type produces large quantity of mine tailings of technically enhanced Natural Occurrence Materials (NORMs), which normally associates with high concentration of ^{226}Ra, ^{232}Th and ^{40}K depending on the geographical and geological formation, and thus amassing radioactivity concentration in the environment (Njinga et al, 2015).

Cosmogenic radiation interact with atmospheric environments and are set down on earth by means of dry and wet deposition. Also, they are radioactivity in the air, mostly as a result of the presence of gases like Radon (222Rn) and Thoron (220Rn), which are byproducts of the 238U and 232Th decay series, respectively (Okeyode and Oluseye, 2010; UNSCEAR, 2008). Nuclear explosions, nuclear weapon testing, and the leakage of effluent from nuclear facilities can all result in the release of artificial or man-made radionuclides into the environment. Recent human activities such as dumping hospital waste, nuclear waste, and industrial effluents into the environment, among others, have significantly expanded the source of radioactive elements in soil, water, and air (UNSCEAR, 2008). Therefore, exposure to radiation can occur either externally from a nearby source or internally from radioactive material that has already entered the body.

Furthermore, there are enormous detrimental effects of the NORMs to ecology, consequently resulting in radiological health hazards of host community, leading to radiation sicknesses, chromosomal transformation, hence, gene mutation through several pathways of radiological exposures(Conti et al, 1999; Qureshi et al, 2014; Aigbedion & Iyayi 2007). This has led to the practice of keeping one's exposure to ionizing radiation to as low as reasonably achievable, known by the agronomy ALARA principle. The Federal Government of Nigeria is in need to increase electricity capacity generation in the country to meet with it growing population increase. Power generation from hydro sector is grossly inadequate and the nuclear power plant (NPP) has become the next viable option. Recently, a proclamation has been made on choosing some candidate sites for constructing NPP facilities in Nigeria which Geregu, Akwa Ibom State Nigeria amongst others are listed as candidate sites (Youdeowei, 2021; Anuforo, E.; Onyedika, 2021; Ekong et al, 2019). This investigation was however necessitated due to the fact that a comprehensive radiological evaluation is yet to be conducted to establish radiological baseline level in the entire Akwa Ibom State. This will offer a baseline statistics and substitute check for impending build-up of radiation level values intends to emanate from such facility operation and for appropriate decision making.

2. Method / Approach

2.1 Study Area & Measurement Mapping Phase:

The investigation was carried out at the entire 31 LGAs in Akwa Ibom State, Nigeria. The state is located within latitude 6°42′E and longitude 7°30′N (Fig. 1) and was created in 1987 from parts of Cross River State. There are three main ethnic groups and languages in the state and there include Ibibio, Efik and Oron. The geological location of Akwa Ibom State is exceptional in regards of occurrence of the two major constituents of geology which are Basement Complex and Sedimentary Basin. About fraction of the State conceals crystalline Basement Complex whereas other is covered by Cretaceous to Recent sediments. The projected population as at 2013 was put at 161,572 and the major occupation of the people are mainly of farming, fishing and trading. It is bounded by Cross River State in the North, Abia State in the West, Rivers State in the South/West and the Atlantic Ocean by the South. The climate of Akwa Ibom like Nigeria generally is categorized as tropical climate, which is further classified into rainy and dry season. The rainy season could experience averaged 2409 mm annual precipitation with mean air surface temperatures ranging between 25.5 - 28.3°C (Ekong et al, 2019).

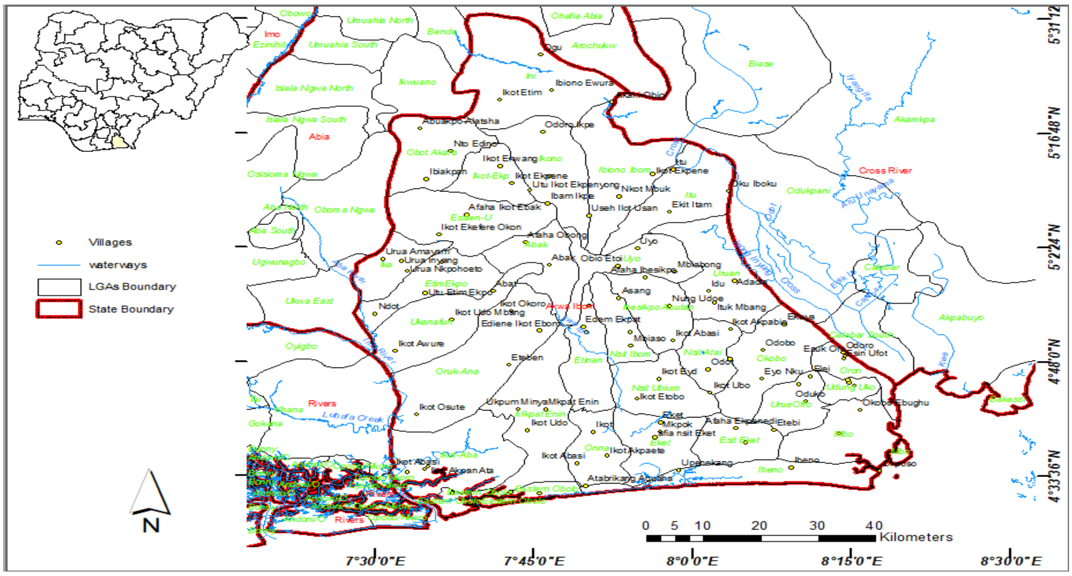

Figure 1: Location of Akwa Ibom State in Nigeria

To measure the BIR of the state, each LGA was divided into grids of 1km by 1km (see Fig. 2). A unique Local Identification Code (LIC) was assigned and recorded, coordinates for measurements were taken at Five (5) points each with a total of 25 points per LGA. A total of 775 measurement points were derived from the 31 LGAs of the State. Geographical Information System (GIS) was involved in mapping the area using ArcGIS and while descriptive statitistics were carried outwith the help of SPSS version 26.0 and python programming language.

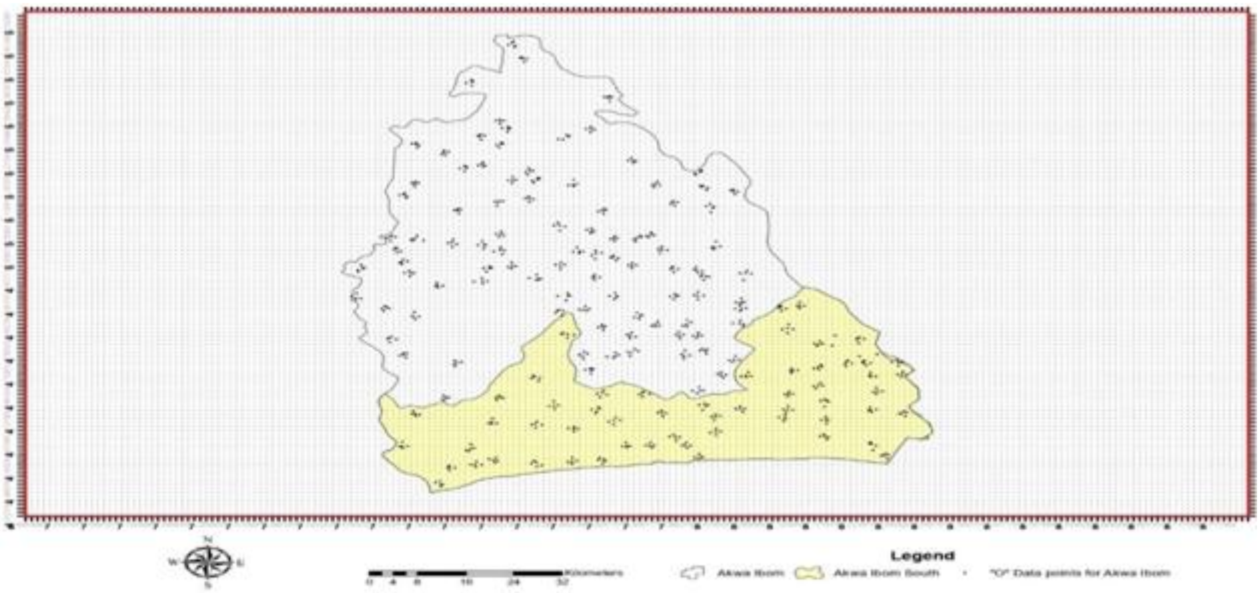

Figure 2: Map of Akwa Ibom State, divided into grids of 1km by 1km (represented by the dots), showing the generated sample points

2.2 Equipment & Dose Rate Measurement Phase

Employed tools in the field investigation were 2 Numbers Polimaster Radiation Detection PM 1703 M-01,7 Numbers RDS-31S/R Multi-purpose survey meters, which measures dose rate in unit of µSv/hr. The survey meters were duly calibrated at the National Institute of Radiation Protection and Research, University of Ibadan.

Dose rate mmeasurement was carried out by conducting radiation survey using survey meters with measurement units of µSv/hr. There was a stepwise process of scanning around 360^0 with survey meter at 1 meter from ground at each data point. A total of 25 readings were obtained per LGA which were average to 5 data points. Therefore, from the total of 775raw readings, 155 readings were obtained from the averages. Its associated standard error was also determined using simple statistical formula that abounds in most statistics text.

2.3 Theory - Evaluation of Hazard Indices

2.3.1 Absorbed Dose (D_o)

The BIR measurements recorded were used to estimate radiological hazard indices as presented in Table 1. Gamma shine due to surface-dwelling gamma rays measured at 1m from the ground was used to determine gamma dose rate by using the expression (Ezekiel, 2017):

$$D = [1_{\mu R/hr} = 8.7_{\frac{nGy}{hr}}] = \frac{8.7x10^{-3}}{1/8760}\mu Gyy^{-1} = 76.212\mu Gyy^{-1} \quad (1)$$

2.3.2 Annual Effective Dose (Outdoor) (AEDEo$_{ff}$Do)

However, the annual effective dose rate estimations are calculated from gamma dose rate with a conversion factor of 0.7 Sv/Gy of absorbed dose in air to effective dose an adults receives and 20% time out-of-doors (80% indoors) using equation 2 (UNSCEAR, 2000; Al-Sulaiti, 2009):

$$AEDE_{\mu Sv} = D_{nGy/h} \times 8760_{h/y} \times 0.2 \times 0.7\ _{Sv/Gy} \times 10^{-3} \quad (2)$$

2.3.3 Excess Lifetime Cancer Risk (ELCR)

In addition, the excess life cancer risk (ELCR) was determined from the annual effective dose rate with duration of life (DL) estimated as 70 years for children and 50 years for adult. The risk factor (RF, 5%) for public exposure considered to produce stochastic effect is given as (ICRP, 1990; Taskin et al, 2009)

$$ELCR_{mSv/y} = AEDE\ _{mSv/y} \times RF \times DL \quad (3)$$

3. Results /Discussion

3.1 Dose Rate Measurement Data Presentation

A total of 775 raw dose rate measurement were conducted from the entire Local Government Areas of Akwa Ibom State. These raw datas were averaged for each LGA and presented in Table 1. The BIR measurement as revealed in Table 1 ranged between **0.04±0.002**µSv/h to **0.06±0.003**µSv/h with an overall average dose rate of **0.05±0.003**. This value quite lower than the world average of 0.2 µSv/h and the average measurements are presented in Tables 1. Figure 3 shows the visualization of the BIR measurements in µSv/hand mR/hr.

Table 1: The average BIR measurement from all LGAs of Akwa Ibom State

Location	Lat.	Long.	BIR(µSv/hr)	BIR (mR/hr)
Esit Eket	4.65	8.02	0.05±0.003	$0.005±3E^{-4}$
Eket	4.65	7.94	0.06±0.004	$0.006±4E^{-4}$
Eastern Obolo	4.49	7.60	0.04±0.002	$0.004±2E^{-4}$
Abak	5.02	7.69	0.06±0.004	$0.006±4E^{-4}$
Urue OffongOruko	4.75	8.17	0.06±0.004	$0.006±4E^{-4}$
Mbo	4.64	8.19	0.05±0.003	$0.005±3E^{-4}$
Essien Udim	5.13	7.70	0.06±0.004	$0.006±4E^{-4}$
Ika	5.06	7.58	0.04±0.002	$0.004±2E^{-4}$
Ikono	5.07	7.84	0.06±0.004	$0.006±4E^{-4}$
Ikot Ekpene	5.19	7.72	0.06±0.004	$0.006±4E^{-4}$
Ini	5.47	7.73	0.05±0.003	$0.005±3E^{-4}$
Obot Akara	5.29	7.67	0.04±0.002	$0.004±2E^{-4}$
Ukanafun	4.88	7.57	0.05±0.003	$0.005±3E^{-4}$
Uyo	5.03	7.94	0.06±0.004	$0.006±4E^{-4}$
Udung Uko	4.77	8.24	0.05±0.003	$0.005±3E^{-4}$
Oruk Anam	4.77	7.63	0.06±0.004	$0.006±4E^{-4}$
Onna	4.66	7.84	0.05±0.003	$0.005±3E^{-4}$
Nsit Ubium	4.74	8.03	0.06±0.003	$0.006±3E^{-4}$
Nsit Ibom	4.88	7.90	0.06±0.004	$0.006±4E^{-4}$
Nsit Atai	4.78	8.05	0.06±0.004	$0.006±4E^{-4}$
Mkpat Enin	4.54	7.69	0.05±0.003	$0.005±3E^{-4}$
Itu	5.05	7.90	0.06±0.003	$0.006±3E^{-4}$
Ikot Abasi	4.57	7.55	0.04±0.002	$0.004±2E^{-4}$
Ibiono Ibom	5.04	7.87	0.04±0.002	$0.004±2E^{-4}$
Ibesikpo Asutan	4.92	7.95	0.06±0.004	$0.006±4E^{-4}$
Ibeno	4.54	7.85	0.05±0.003	$0.005±3E^{-4}$
Etinan	4.85	7.85	0.06±0.004	$0.006±4E^{-4}$
Etim Ekpo	4.99	7.68	0.04±0.002	$0.004±2E^{-4}$
Okobo	4.73	8.06	0.06±0.003	$0.006±3E^{-4}$
Oron	4.82	8.23	0.06±0.004	$0.006±4E^{-4}$
Uruan	4.90	8.06	0.04±0.002	$0.004±2E^{-4}$
Minimum			0.04±0.002	$0.004±2E^{-4}$
Maximum			0.06±0.004	$0.006±4E^{-4}$
Study Average			0.05±0.003	$0.005±3E^{-4}$
World Average			0.2	0.013

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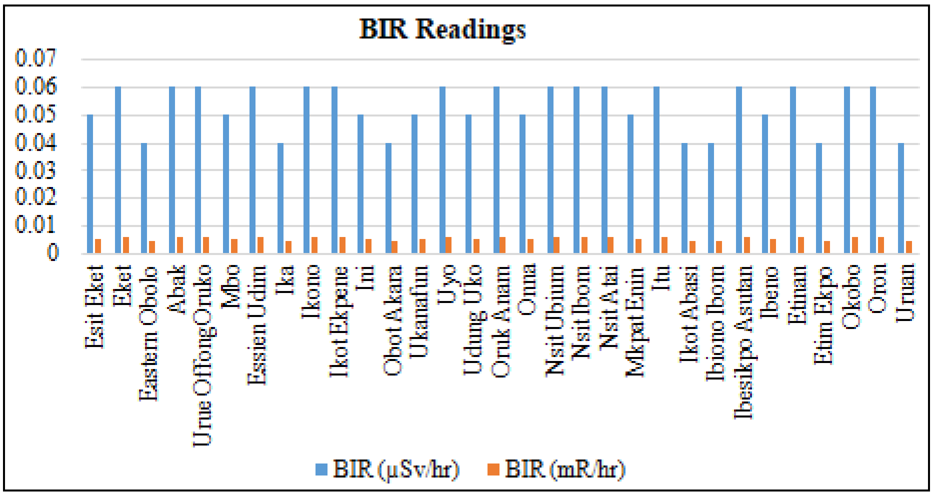

Figure 3: Illustration of BIR measurements

3.2 Radiological Hazards Assessment

The results for the estimated level of this radiological hazards i.e. the Absorbed Dose (D_o), Annual Equivalent Dose ($H_T a$), Annual Effective Dose (Outdoor) ($AE_{ff}Do$), Excess Lifetime Cancer Risk (ELCR) etc are presented in Table 2. It is pertinent to note that there were no resultant effect of radiological hazards indices considered in this investigation as presented herewith. The mean Absorbed dose rate for the entire LGAs of Akwa Ibom State was computed directly was evaluated from the dose rate using Equation (2) to range between 34.80nGy/hr to 52.20 nGy/hr with mean value of 45.87nGy/hrwhich is below the world's average of 59nGy/hr allowable limit (UNSCEAR, 2000 & 2008; NNRA, 2016)

The mean Annual Equivalent Dose rate for the entire LGAs of Akwa Ibom Statewas evaluated from the dose rate using Equation (2). Its value ranged between 0.034 mSv/hr to 0.050 mSv/hr with mean value of 0.042 mSv/hr which is below the world's average of 0.42 mSv/yr **and** less than 1mSv/hr for public as endorsed allowable limit (UNSCEAR, 2000& 2008; Al-Sulaiti, 2009; ICRP 1990). The largely annual effective dose outdoor for the entire LGAs of Akwa Ibom State was evaluated from the annual equivalence dose rate using Equation (4) to range between 0.05 mSv/hr to 0.08 mSv/hr with mean value of 0.07 mSv/hr (see Table 2) which is below the world's average of 0.42 mSv/yr (UNSCEAR, 2000& 2008; Al-Sulaiti, 2009; ICRP 1990). The effect of radiological implications arising from annual effective dose outdoor for the entire Akwa Ibom State translate directly to Excess Lifetime Cancer Risk factor from Equation (5) which has attracted several studies from Radiation Physicists and several medical and environmental practitioners globally. This investigation reveals that the mean Excess Lifetime Cancer Risk (ELCR) factor for the outdoor gamma radiation was seen to be 0.25 x 10^{-3}which is lower than the world's average of 0.29 x 10^{-3} (UNSCEAR, 2000& 2008; Al-Sulaiti, 2009; ICRP 1990).

The average dose rate measurement for each LGAs of Akwa Ibom State, range between 0.04±0.002µSv/h to 0.06±0.003µSv/h with an overall average dose rate of 0.05±0.003 (see Table 2) below the 0.2 µSv/h world average, as well as 0.1 µSv/h which requires no establishment of radiation protection as in the case of radiological facility (UNSCEAR, 2000& 2008; ICRP 1990). Also, the hazard indices were represented diagramatically as shown in Fig.4.

Table 2: Hazard Indices from all LGAs of the State

Location	Ab. DR (nGy/hr)	Eq.D (mSv/yr)	AEDR (o)(mSv/yr)	ELCR* 10^-3
Esit Eket	43.50	0.042	0.07	0.23
Eket	52.20	0.050	0.08	0.28
Eastern Obolo	34.80	0.034	0.05	0.19
Abak	52.20	0.050	0.08	0.28
Urue OffongOruko	52.20	0.050	0.08	0.28
Mbo	43.50	0.042	0.07	0.23
Essien Udim	52.20	0.050	0.08	0.28
Ika	34.80	0.034	0.05	0.19
Ikono	52.20	0.050	0.08	0.28
Ikot Ekpene	52.20	0.050	0.08	0.28
Ini	43.50	0.042	0.07	0.23
Obot Akara	34.80	0.034	0.05	0.19
Ukanafun	43.50	0.042	0.07	0.23
Uyo	52.20	0.050	0.08	0.28
Udung Uko	43.50	0.042	0.07	0.23
Oruk Anam	52.20	0.050	0.08	0.28
Onna	43.50	0.042	0.07	0.23
Nsit Ubium	52.20	0.050	0.08	0.28
Nsit Ibom	52.20	0.050	0.08	0.28
Nsit Atai	52.20	0.050	0.08	0.28
Mkpat Enin	43.50	0.042	0.07	0.23
Itu	52.20	0.050	0.08	0.28
Ikot Abasi	34.80	0.034	0.05	0.19
Ibiono Ibom	34.80	0.034	0.05	0.19
Ibesikpo Asutan	52.20	0.050	0.08	0.28
Ibeno	43.50	0.042	0.07	0.23
Etinan	52.20	0.050	0.08	0.28
Etim Ekpo	34.80	0.034	0.05	0.19
Okobo	52.20	0.050	0.08	0.28
Oron	52.20	0.050	0.08	0.28
Uruan	34.80	0.034	0.05	0.19
Minimum	34.80	0.034	0.05	0.19
Maximum	52.20	0.050	0.08	0.28
Study Average	45.87	0.041	0.07	0.25
World Average	59	0.42	0.42	0.29

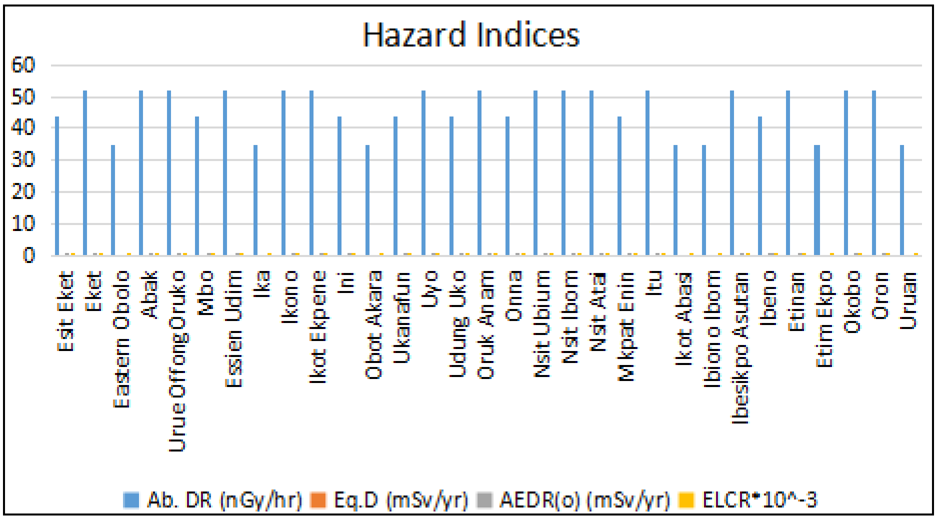

Figure 4: Illustration of Hazard Indices

The average values of this investigation were compared with values reported from other locations within Nigeria and are presented in Table 3. Ekong et al (2019) from Assessment of Radiological Hazard Indices from Exposures to Background Ionizing Radiation Measurements in Itu LGA South-South Nigeria reported a value of 0.04±0.002µSv/h. Also, Isa et al (2022) conducted Measurement of Background Ionizing Radiation in Kogi State, Nigeria with lowest mean readings of 0.096 µSv/hr and highest mean reading of 0.2300µSv/hr and highest annual equivalent dose rates of 0.4030mSv/yr. It is imperative to note that these two sites both in Akwa Ibom and Kogi State are being considered as NPP candidate sites (Youdeowei, 2021; Anuforo, E.; Onyedika, 2021; Ekong et al, 2019). Etuk et al (2017) reported a dose rate of 0.116µSv/yr on Measurement of Outdoor Ambient Radioactive Radiation and Evaluation of Radiation Indices and Excess Lifetime Cancer Risk within Uyo, Unity Park, Uyo, Nigeria. A 0.021 mRh^{-1} mean dose was stated for Outdoor Background Radiation Level and Radiological Hazards Assessment in Lafia, Nasarawa which was above recommended safe limits of 0.013 mRh^{-1} [18]. Likewise, 0.132 ±0.021 $\mu Svhr^{-1}$ (0.015 ± 0.002 mR/hr-1) BIR measurement was reported by Alkasim et al (2017) from a refuse dumpsites in Yola Metropolis, North-Eastern Nigeria also above recommended safe limits.

This present study corroborates with the aforesaid studies which points out low radiation level in Akwa Ibom State, which is considered to be attributed to its geological formation, and also probably no serious anthropogenic activities like mining taking placein the state (Etuk et al, 2017; Ekong et al., 2019). Fig.5 shows the dose rate from these various studies diagrammatically.

Table 3: Comparison of present studies with other locations within Nigeria

Location	Dose Rate	References
Lafia, Nasarawa	0.021 mRh^{-1}	Mustapha et al, (2021)
Park, Uyo, Akwa Ibom	0.116µSv/yr	Etuk et al (2017)
Itu, **Akwa Ibom State**	**(0.10±0.01) µSv/h**	Ekong et al (2019)
Kogi State	0.096 µSv/hr - 0.2300µSv/hr	Sambo et al (2022)
Akwanga town Keffi town	(0.176 ±0.02 and 0.155 ±0.02) $\mu Svhr^{-1}$ (0.148 ±0.02 and 0.139 ±0.02) $\mu Svhr^{-1}$	Ramli, et al 2014
Yola Metropolis, Adamawa	0.132 ±0.021 $\mu Svhr^{-1}$ (0.015 ± 0.002 mR/hr-1)	Alkasim et al (2017)
Akwa Ibom State Range; Average value	**(0.10±0.01 - 0.24±0.02) ; 0.16±0.01 µSv/h**	**Present Study**
World Average	0.2 $\mu Svhr^{-1}$, 0.013 mRh^{-1}	UNSCEAR, (2000& 2008);

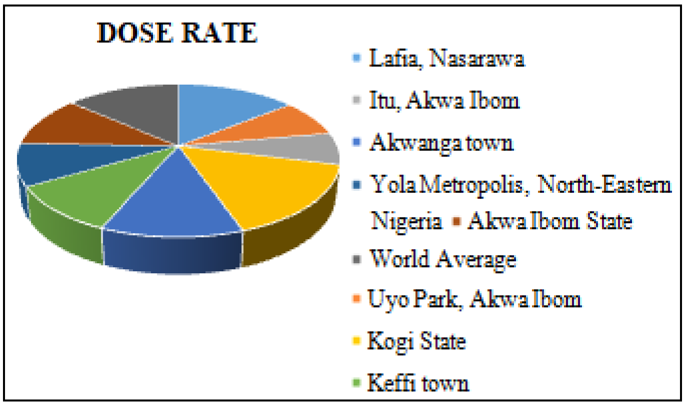

Figure 5: Illustration of Dose rate from different studies

With the help of ArcGIS, more comparisons are shown in the spatial presentation in Fig 6, 7 and 8. Figs. 6 and 7 shows the spatial presentation of bar charts and contour line for all the LGAs respectively.while fig.8 present the Digital Elevation Model (DEM) image of Akwa Ibom state which were interpolated from the average DP and DR1.

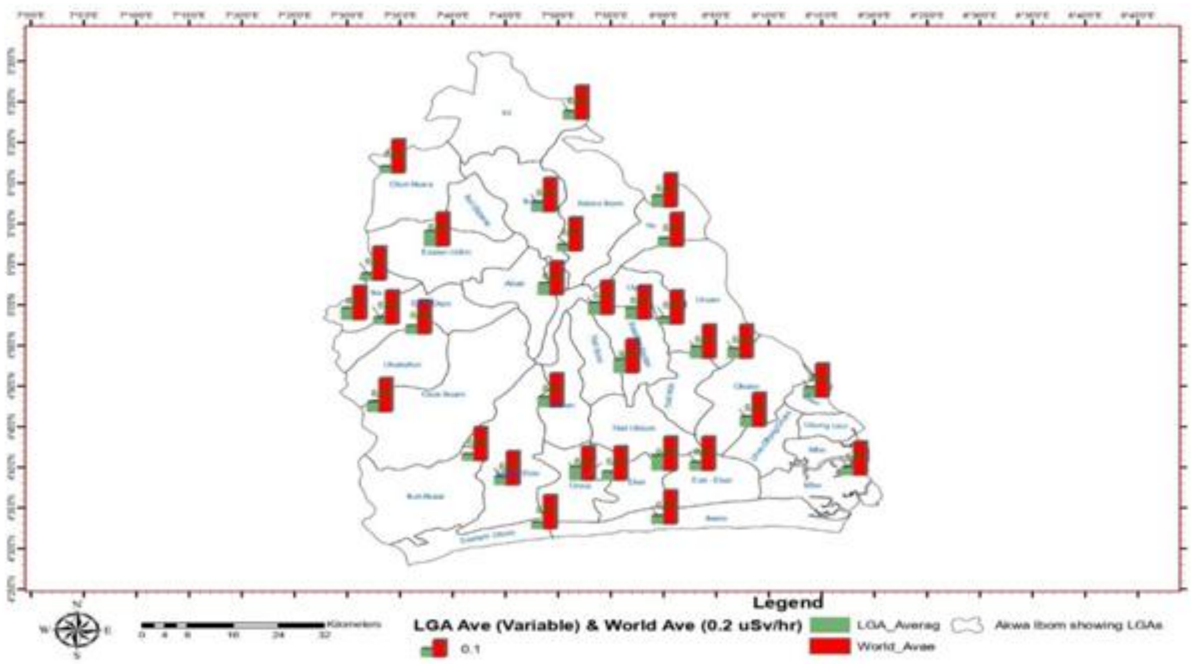

Figure 6: Map of Akwa Ibom State showing the various LGAs and bar charts for LGA Average dose rate compared with the world average Dose rate. (See legend for chart interpretation). Units for the y axis are in measured in uSv/h

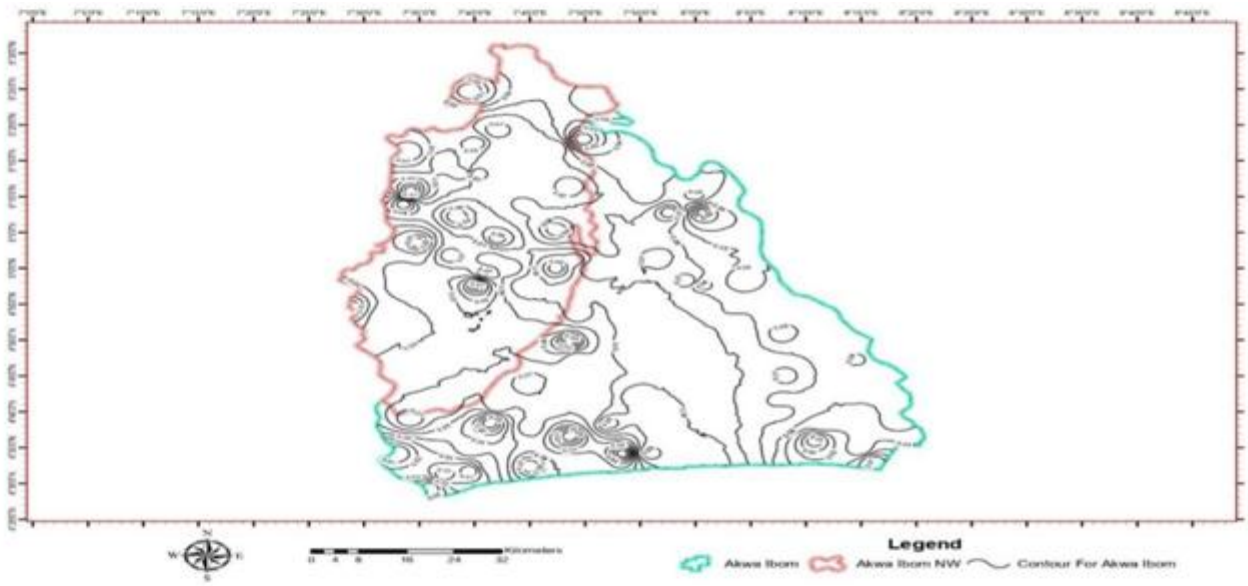

Figure 7: Contour map, generated from the information in map 3. “Z” values used here as shown on the contour line, were measured in uSv/hr, then averaged.

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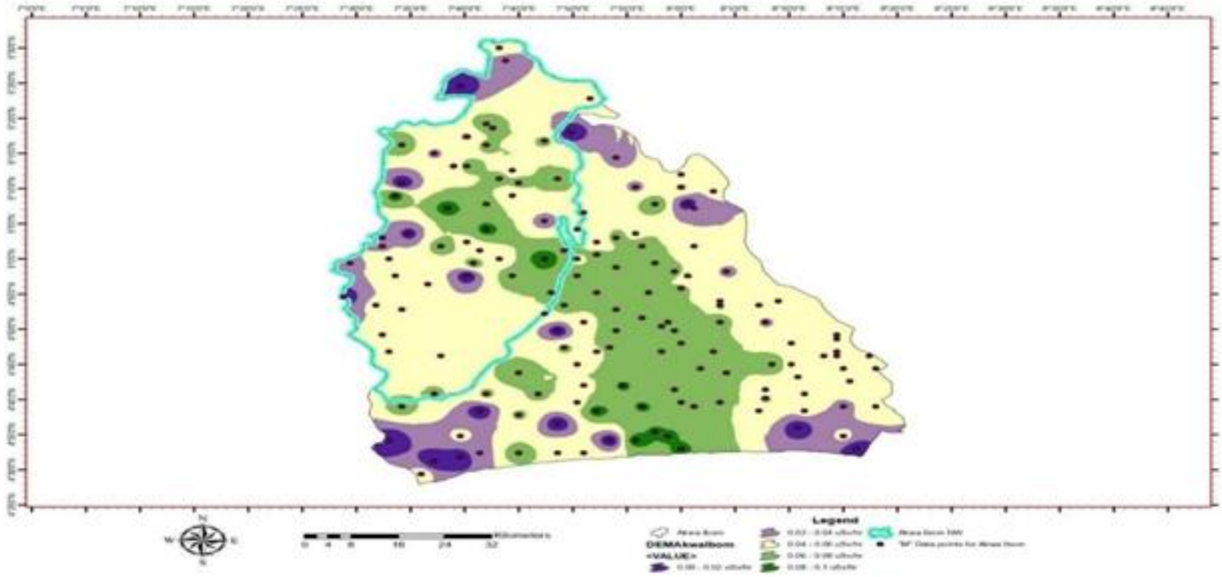

Figure 8: Digital Elevation Model (DEM) image of Akwa Ibom state, interpolated from the average DP and DR1 (as "Z" factor), with Akwa Ibom North West Senatorial district inserted for focus. (See legend for DEM interpretation).

4. Conclusion

The Background Ionizing radiation was conducted in Akwa Ibom State to ascertain the radiation level with a view of establishing baseline for examining future radiation incremental level in event of siting a radiological or nuclear activity. The dose rate measurement level was found below the world average which shows no anthropogenic activities capable of increasing radiation level at the moments. Therefore, there is need to carry out further investigation to determine radioactivity in soil, sediment, and water in the entire Akwa Ibom State, in order to assess the possible long term consequences of radiation to the general public.

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