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Estimation of Annual Effective Dose Equivalent and Excess Life Cancer Risk Across Major Markets in Northern Cross River State Nigeria

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Abstract: Human exposure to ionizing radiation from natural and artificial sources is an unpreventable phenomenon on Earth. Radiation profile and dose rate for some markets in northern Cross River State, Nigeria have been ascertained using a 451p ion chamber survey meter, and the following parameters of radiation were calculated, absorb dose, annual effective dose equivalent, and excess life cancer risk. The dose rates measured within five major markets are as follows; Obanliku, 0.07μsv/h to 0.18μsv/h, Obudu, 0.03μsv/h to 0.17μsv/h, Bekwara, 0.06μsv/h to 0.78μsv/h Ogoja, market 0.05μsv/h to 0.15μsv/h, Okuku, 0.06 μsv/h to 0.25 μsv/h, The mean value for the dose rate was 0.122 $\pm$ 0.031 for Obanliku, 0.120 $\pm$ 0.031 for Obudu, 0.164 $\pm$ 0.159 for Bekwara, 0.097 $\pm$ 0.030 for Ogoja, 0.117 $\pm$ 0.043 μsv/h for okuku, Mean values of 0.194 $\pm$ 0.072msvy^{-1}, 0.184 $\pm$ 0.045msv/y, 0.250 $\pm$ 0.244msv/y, 0.147 $\pm$ 0.047msv/y, and 0.179 $\pm$ 0.067msv/y, for AEDE were observed respectively for Obanliku, obudu, bekwara, ogoja, and okuku within the markets. Similarly, 0.622 $\pm$ 0.238 x 10^{-3}, 0.643 $\pm$ 0.158 x 10^{-3}, 0.876 $\pm$ 0.853 x 10^{-3}, 0.514 $\pm$ 0.167 x 10^{-3},and 0.628 $\pm$ 0.233 x 10^{-3}, were recorded for ELCR, within the markets. The AEDE values are within the permissible limit as recommended by the international bodies, the ELCR values are also within the permissible limit. The AEDE & ELCR values imply that the market sides are radiation safe for any radiological health burdens that might arise due to absorbing doses from background ionizing radiation, but the probability of occupants developing cancer over a lifetime exposure in marketplaces is high. It is recommended that periodic background ionizing radiation monitoring and evaluation, and radioactive concentration of nuclides in soil and rocks of the are been carried out by local authority.

Keyword: *Gamma Radiation, Dose Rate, Markets, Excess Lifetime Cancer Risk (ELCR), Annual Effective Dose Equivalent (AEDE).*

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I. INTRODUCTION

It is imperative that the level of background gamma radiation levels is monitored and checked to avoid public exposure. (mojisola et al, 2023) everywhere in the world man generally is expose to background gamma radiation, and the radiation can come from different sources. Background radiation is that which is naturally and inevitably present in our environment. Human beings are exposed to background radiation that stems both from natural and man-made sources. In general, approximately 85% of the annual total radiation dose of any person comes from natural radionuclides of both terrestrial and cosmogenic origin (Belivermis et al. 2010; UNSCEAR 2000). The worldwide annual effective dose from natural sources is estimated to be 2.4mSv (UNSCEAR 2000).

The earth crust contains various radioactive isotopes such as uranium, thorium, radon, tritium, carbon and potassium among others. These isotopes and their decay products have differences in their half- life, which emits various types of radiation such as alpha, beta, and gamma rays additionally, cosmic radiation from the sun, contributes to

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gamma rays surrounding the human body. Conversely, the controlled man-made artificial background radiations result from several sources such as fall out of weapon testing, radioactive waste, and the use of radioisotopes in radio-therapy. Both controlled and uncontrolled sources of radiation may have undesired biological effect of living species (orwa et al 2012). Small traces of many naturally occurring radioactive materials are present in the human body. These comes mainly from naturally occurring radioactive nuclides present in the food we eat and in the air we breathe. And this isotope includes tritium (^{3}H), carbon-14 (^{14}C), and potassium-40 (^{40}K) (oyeyinka et al 2012).

II. MATERIALS AND METHOD

➢ *Study Area*

This research work was carried out in a Cross River State, in the south-south geopolitical zone of Nigeria, with the coordinates 5 ^{0}45' N, and 8^{0} 30E. Cross River State is made up of three senatorial districts. northern cross river, southern cross river, and Central Senatorial District. Observations were made in the northern senatorial district which comprises five local government areas, with five major markets across the senatorial district.

➢ *Field Measurement*

In-situ measurement of the background gamma radiation level was done by making use of a portable well-calibrated 451p ion chamber survey meter capable of detecting beta, gamma, and x-ray particles with a high sensitivity µSv/hr measurement of rate and dose simultaneously from various radiation sources. Readings were taken within the hours of 11 am and 4 pm hours. The survey meter was used to measure the dose rate of gamma radiation in µSv/hr within the five markets and a total of 20 sampling points were taken from each market. Measurement was done 1m above the ground level, three measurements for each point were taken and then averages were calculated for each point.

III. RESULTS AND DISCUSSION

➢ *Radiological Parameters.*

- *Absorbed Dose Rate (ADE)*

➢ *Absorbed Dose Rate*

The absorbed dose rate is calculated from the exposure rate using the conversion factor

$$1\mu Sv/h = 1000 nGy/h \ldots\ldots (1)$$

- *Annual Effective Dose Equivalent (AEDE)*

To compute the annual effective dose equivalent (AEDE) absorbed by the people or workers around the study area, the already estimated absorbed dose rate was used. in calculating AEDE, a dose conversion factor for the outdoors of 0.25 (6 hours out of 24 hours) was used. the occupancy factor for the outdoors was determined based on interaction with people. In the market (traders) it was discovered that they spend approximately 6 hours in the course of their daily activities within the study environment. The annual effective dose was calculated using the following relation.

$$\text{AEDE (outdoor) (mSvy}^{-1}) = \text{Absorbed dose (nGyh}^{-1}) \times 8760\text{h} \times \frac{0.7Sv}{Gy} \times 0.25 \ldots (2)$$

- *Excess Life Cancer Risk (ELCR)*

The possibility of contacting cancer by the traders, buyers, sellers, and residents of the study area throughout their lifetime in this environment can be approximately obtained using the excess lifetime cancer Risk (ELCR). The estimation is given as;

$$\text{ELCR} = \text{AEDE} \times \text{Average duration of life} \times \text{Risk factor} \ldots (3)$$

Where AEDE, DL, and RF are the annual effective dose equivalent, duration of life (70 yrs) and risk factor (SV^{-1}) fatal cancer risk per Sievert are considered to produce stochastic effects. ICRP 60 uses values of 0.05 for the public.

➢ *Results*

The in-situ measurement of radiation dose rating of five major markets in Cross River North Nigeria is represented in Tables 1 to 5.

Table 1 Radiation Dose Rate Measured in Ogoja Market

Location	Dose rate µSv/h	Absorbed Dose Rate ($nGyh^{-1}$)	AEDE ($msvy^{-1)}$)	ELCR X 10^{-3}
I_1	0.073	73	0.11	0.39
I_2	0.073	73	0.11	0.39
I_3	0.05	50	0.07	0.25
I_4	0.087	87	0.13	0.46
I_5	0.093	93	0.14	0.49
I_6	0.053	53	0.08	0.23
I_7	0.113	113	0.17	0.59
I_8	0.063	63	0.10	0.35
I_9	0.077	77	0.12	0.42
I_{10}	0.107	107	0.16	0.56
I_{11}	0.106	106	0.16	0.56
I_{12}	0.133	133	0.20	0.70

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I_{13}	0.143	143	0.22	0.77
I_{14}	0.08	80	0.12	0.42
I_{15}	0.143	143	0.22	0.77
I_{16}	0.13	130	0.19	0.67
I_{17}	0.09	90	0.14	0.49
I_{18}	0.15	150	0.23	0.81
I_{19}	0.08	80.00	0.12	0.42
I_{20}	0.097	97	0.15	0.53
Mean ±SD	0.122±0.031	121.500.±30.483	0.1940±0.072	0.622±0.238

Table 2 Radiation Dose Rate Measured in Obudu Market

Location	**Dose rate**	**Absorbed Dose Rate**	**AEDE**	**ELCR**
	μSv/h	**(nGyh^{-1})**	**(msvy$^{-1)}$**	**X 10^{-3}**
O_1	0.03	30	0.05	0.18
O_2	0.11	110	0.17	0.59
O_3	0.09	90	0.14	0.49
O_4	0.12	120	0.18	0.63
O_5	0.13	130	0.20	0.70
O_6	0.17	170	0.26	0.91
O_7	0.14	140	0.21	0.74
O_8	0.09	90	0.14	0.49
O_9	0.17	170	0.26	0.91
O_{10}	0.12	120	0.18	0.64
O_{11}	0.14	140	0.21	0.74
O_{12}	0.11	110	0.17	0.59
O_{13}	0.14	140	0.21	0.74
O_{14}	0.14	140	0.21	0.74
O_{15}	0.12	120	0.18	0.63
O_{16}	0.10	110	0.17	0.59
O_{17}	0.13	130	0.199	0.69
O_{18}	0.10	100	0.15	0.53
O_{19}	0.13	130	0.20	0.70
O_{20}	0.12	120	0.18	0.63
Mean ±SD	0.120±0.031	120.500.±30.345	0.184±0.045	0.643±0.158

Table 3 Radiation Dose Rate in Bekwara Markets

Location	**Dose rate μSv/h**	**Absorbed Dose Rate (nGyh-1)**	**AEDE (msvy-1)**	**ELCR X 10-3**
B_1	0.14	140	0.21	0.74
B_2	0.78	780	1.19	4.17
B_3	0.12	120	0.18	0.63
B_4	0.097	97	0.14	0.49
B_5	0.143	140	0.21	0.74
B_6	0.12	120	0.18	0.63
B_7	0.17	170	0.26	0.91
B_8	0.1	100	0.15	0.53
B_9	0.167	167	0.26	0.91
B_{10}	0.097	97	0.15	0.53
B_{11}	0.08	80	0.12	0.42
B_{12}	0.32	320	0.49	1.72
B_{13}	0.06	60	0.09	0.32
B_{14}	0.103	103	0.16	0.56
B_{15}	0.06	60	0.09	0.32
B_{16}	0.06	60	0.09	0.32
B_{17}	0.14	137.00	0.21	0.74
B_{18}	0.08	80	0.12	0.42
B_{19}	0.2	200	0.31	1.09
B_{20}	0.25	250	0.38	1.33
Mean ±SD	0.164±0.159	164.050±159.215	0.250±0.244	0.876±0.853

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Table 4 Radiation Dose Rate Measured in Okuku Market

Location	Dose rate	Absorbed Dose Rate	AEDE	ELCR
	µSv/h	(nGyh^{-1})	(msvy$^{-1)}$	X 10^{-3}
O_1	0.13	130	0.20	0.70
O_2	0.1	100	0.15	0.53
O_3	0.09	90	0.14	0.49
O_4	0.08	80	0.12	0.42
O_5	0.13	130	0.20	0.70
O_6	0.20	200	0.31	1.09
O_7	0.11	110	0.17	0.59
O_8	0.11	110	0.17	0.59
O_9	0.12	120	0.18	0.63
O_{10}	0.09	90	0.14	0.49
O_{11}	0.06	60	0.09	0.32
O_{12}	0.10	100	0.15	0.53
O_{13}	0.11	110	0.17	0.59
O_{14}	0.25	250	0.38	1.33
O_{15}	0.1	100	0.15	0.53
O_{16}	0.13	130	0.20	0.70
O_{17}	0.10	100	0.15	0.53
O_{18}	0.11	110	0.17	0.59
O_{19}	0.07	70	0.11	0.39
O_{20}	0.15	150	0.23	0.81
Mean ±SD	0.097±0.030	97.050±30.313	0.147±0.047	0.514±0.167

Table 5 Radiation Dose Rate Measured within Obanliku Market

Location	Dose rate	Absorbed Dose Rate	AEDE	ELCR
	µSv/h	(nGyh^{-1})	(msvy$^{-1)}$	X 10^{-3}
R_1	0.13	130	0.20	0.70
R_2	0.08	80	0.37	0.12
R_3	0.10	100	0.15	0.53
R_4	0.16	160	0.25	0.88
R_5	0.11	110	0.17	0.59
R_6	0.13	130	0.19	0.67
R_7	0.10	100	0.15	0.53
R_8	0.14	140	0.21	0.74
R_9	0.11	110	0.17	0.59
R_{10}	0.07	70	0.01	0.04
R_{11}	0.16	160	0.25	0.89
R_{12}	0.18	180	0.28	0.98
R_{13}	0.10	100	0.15	0.53
R_{14}	0.11	110	0.17	0.59
R_{15}	0.15	150	0.23	0.81
R_{16}	0.13	130	0.20	0.70
R_{17}	0.16	160	0.25	0.89
R_{18}	0.10	100	0.15	0.53
R_{19}	0.13	130	0.20	0.70
R_{20}	0.08	80	0.12	0.42
Mean ±SD	0.117±0.043	117.00±43.420	0.179±0.067	0.628±0.233

Assessment of radiation profile and dose rate from major markets in northern senatorial district of cross river state, Nigeria has been carried out using a well calibrated ionization chamber survey meter. The mean dose was measured across the five markets which range from 0.043 ± 0.017µSv/h in bekwara market to 0.110 ± 0.036µ/h in ogoja market.

➢ *Discussion*

Assessment of radiation profile and dose rate for the five major markets across the northern senatorial district of Cross River State has been obtained using a well-calibrated ionization chamber survey meter. The dose rate measured ranges from 0.02µSv/h to 0.30 µSv/h with a mean value of 0.043±0.017 µSv/h to 0.110±0.036 µSv/h which is lower than the world standard value of 1mSv/y for members of the public (ICRP, 1991) the location that recorded the highest dose rate,

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absorbed dose rate, annual effective dose equivalent, and excess life cancer risk is bekwara market, this may be due to the increase in economic activities, presence of rocks, and the building material present in the market.

The absorbed dose measured ranges from 70Gy/hr to 200Gy/hr with a mean value of 42.500±17.130Gy/hr to 110.0±36.419nGy/hr. the location with the highest value of absorbed dose is also Bekwara market. This value can be attributed to the radon gases trapped by building and building materials in the market.

The annual effective dose equivalent measured ranges from 0.14msv/y to 0.30msv/y with a mean value of 0.067±0.029msv/y to 0.223±0.654msv/y. this is far lower than the world standard value of 0.48mSv/y. the excess life cancer risk measured ranges from 0.39×10^{-3} to $0.16\times10^{-3.}$ With a mean value of $0.259\times10^{-3.}$ To $0.558\times10^{-3.}$ Which is higher when compared to the world standard value of $0.29\times10^{-3.}$

This ELCR estimated from the annual effective dose in some markets like Obudu, and Yala exceeded the world weighted average of $0.29\times10^{-3.}$ We can say that there's a probability of this accumulated dose resulting in cancer for long-term exposure. This suggests further studies to be carried out on soil, water from the area.

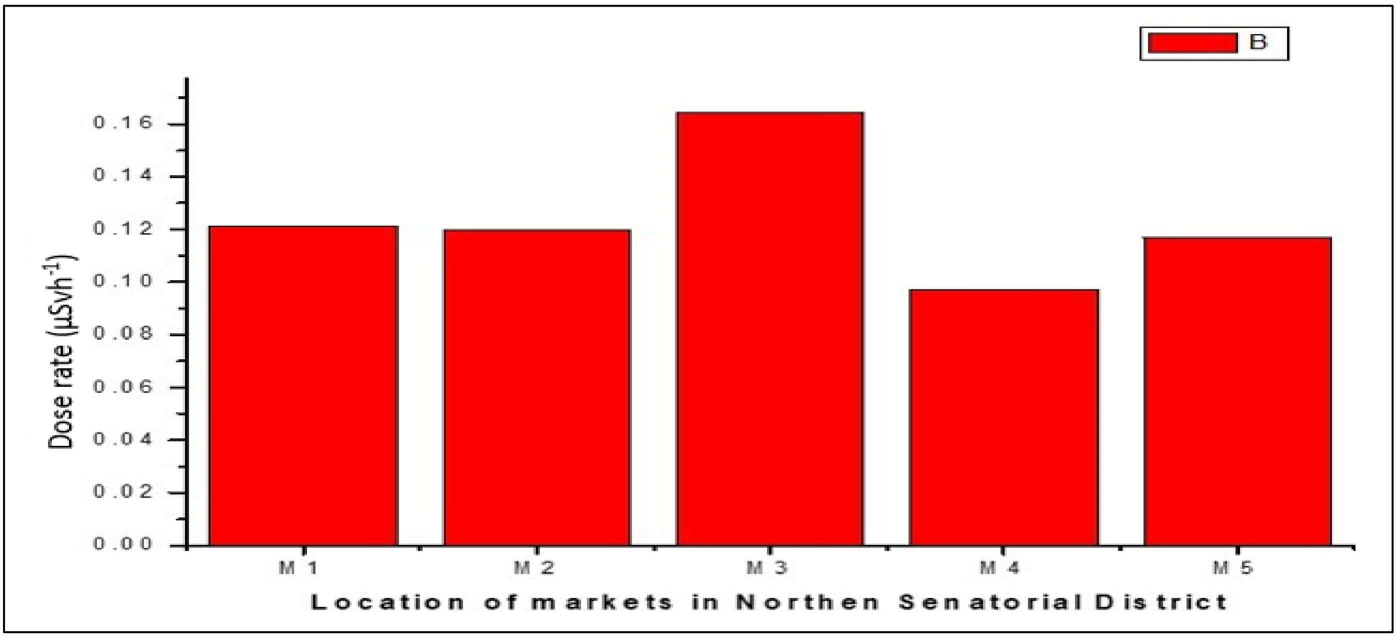


Fig 1 Bar Chart showing Dose Rate in the Northern Senatorial District

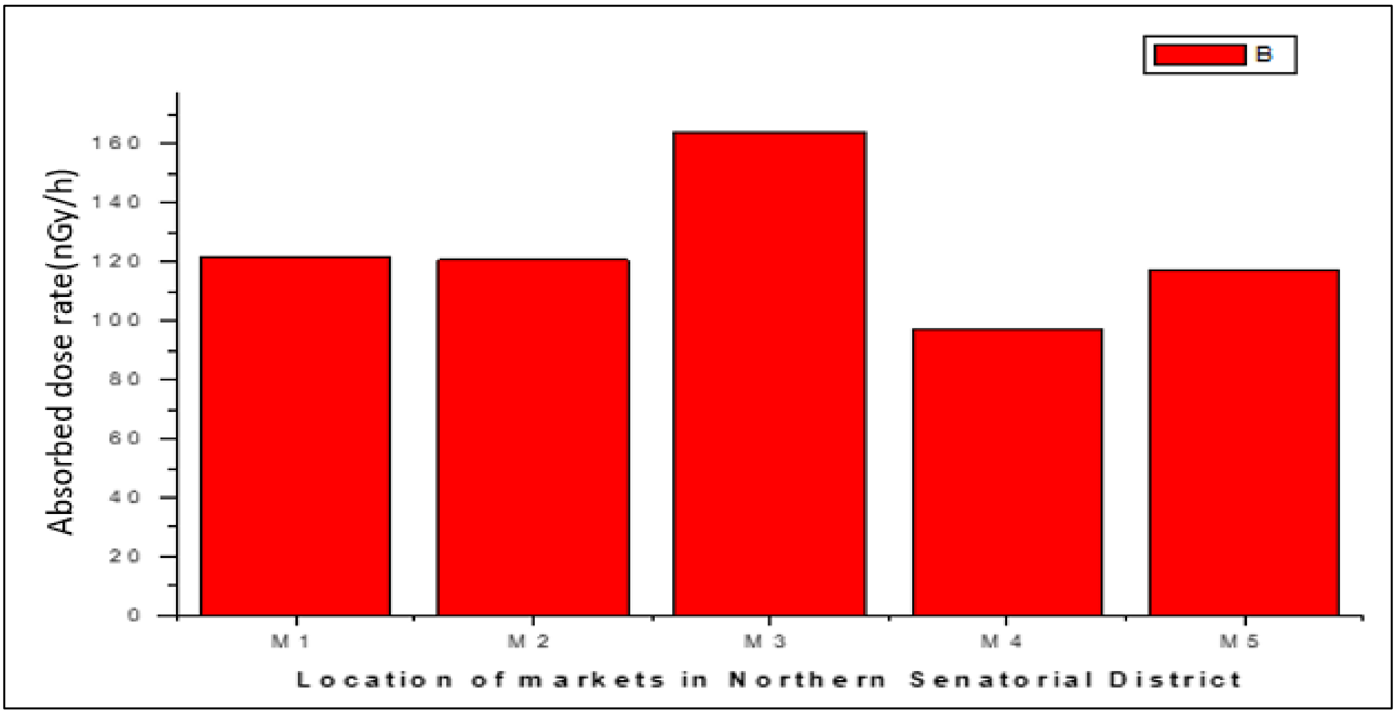
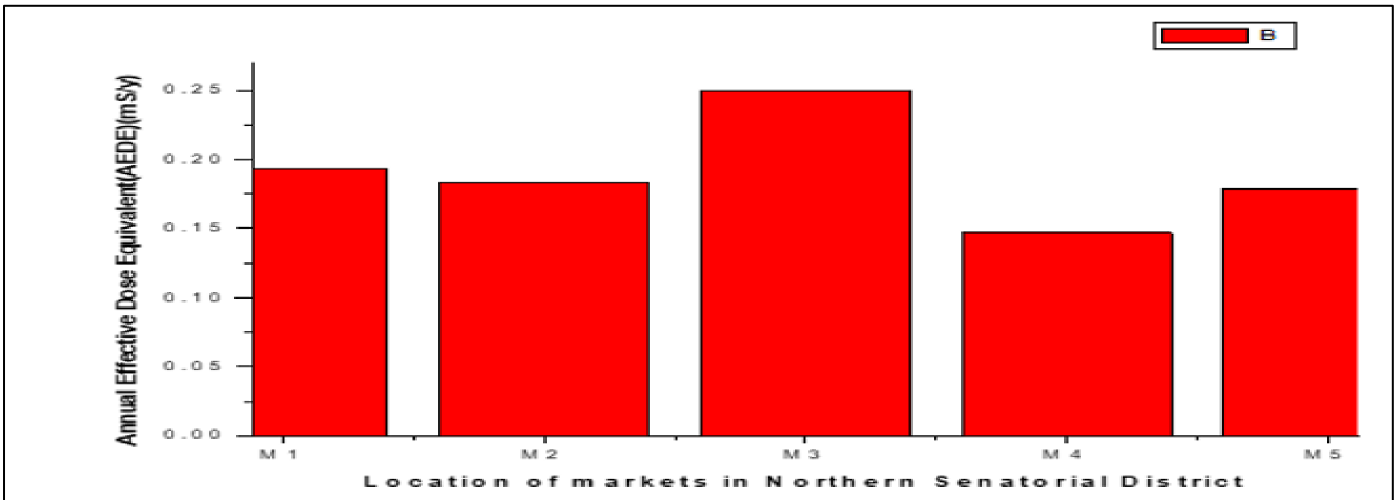


Fig 2 Bar Chat Showing Absorbed Dose Rate of Gamma Radiation in Northern Senatorial District



Bar chart showing the Annual effective dose equivalent(AEDE) of background gamma radiation in the Northern Senatorial District

Fig 3 Bar Chart Showing Annual Effective Dose Equivalents in Northen Senatorial District

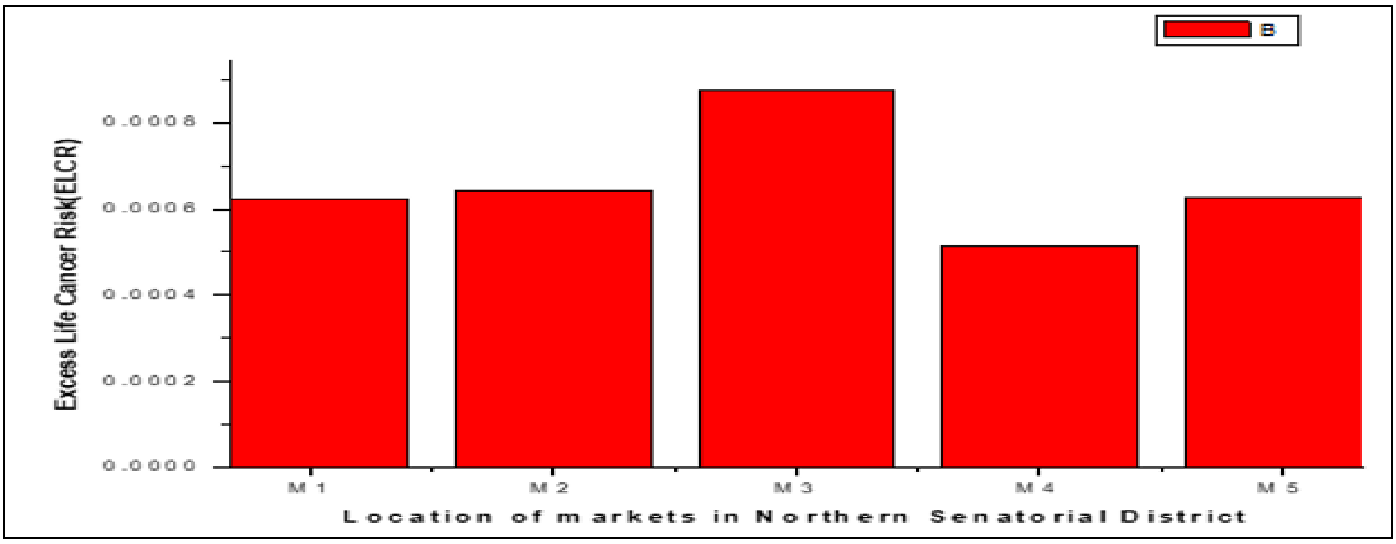


Fig 4 Bar Chart Showing Excess Life Cancer Risk in Northen Senatorial District

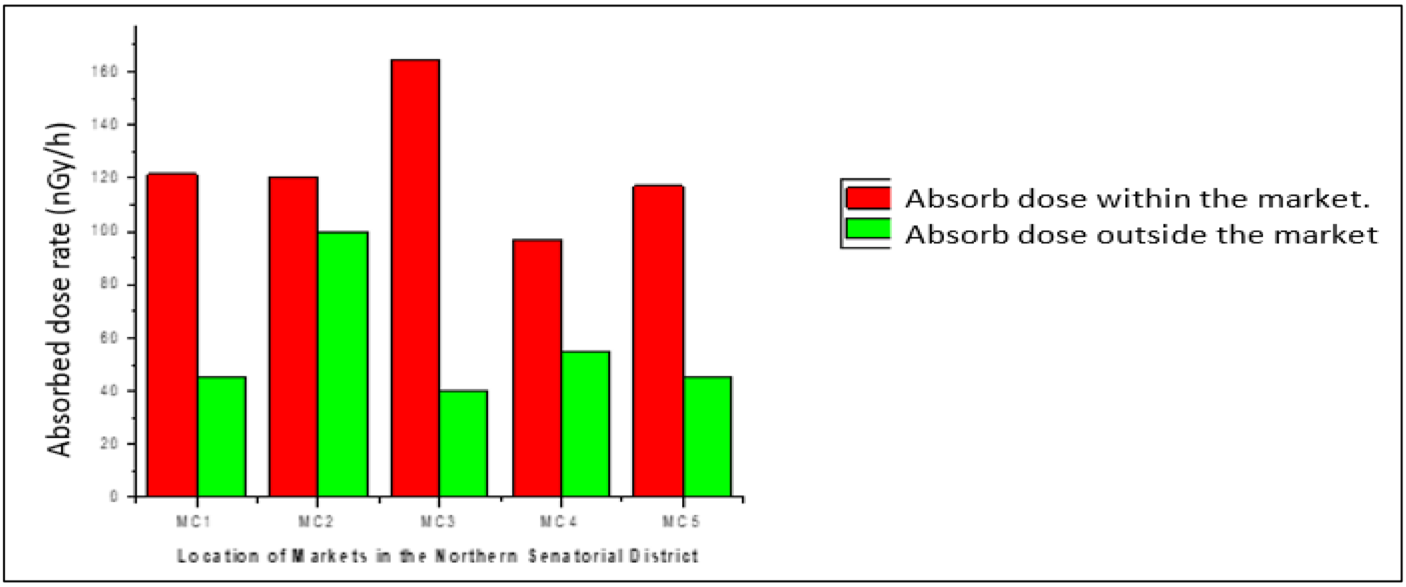


Fig 5 Bar Chart Showing Absorbed Dose within and Outside the Market in the Northen Senatorial District

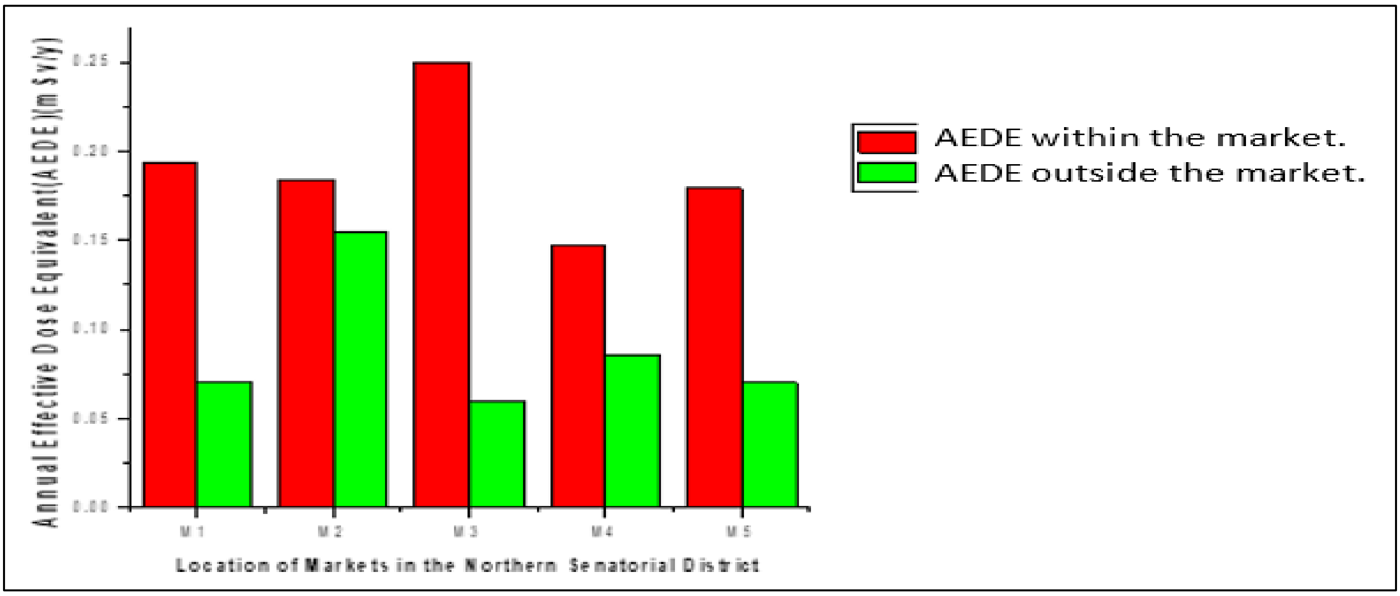


Fig 6 Bar Chart Showing AEDE in and Outside the Market in the Northen Senatorial District

Fig 7 Bar Chart Showing Absorbed Dose in and Outside the Market in the Northen Senatorial District

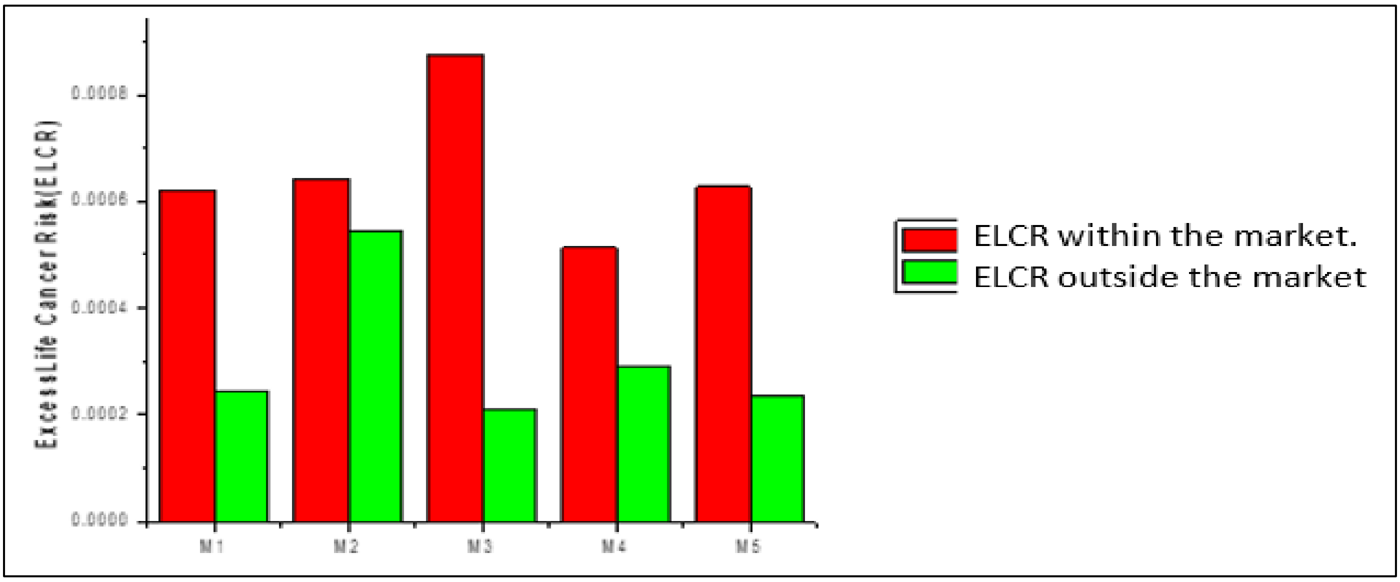


Fig 8 Bar Chart Showing ELCR in and Outside the Market in the Northen Senatorial District

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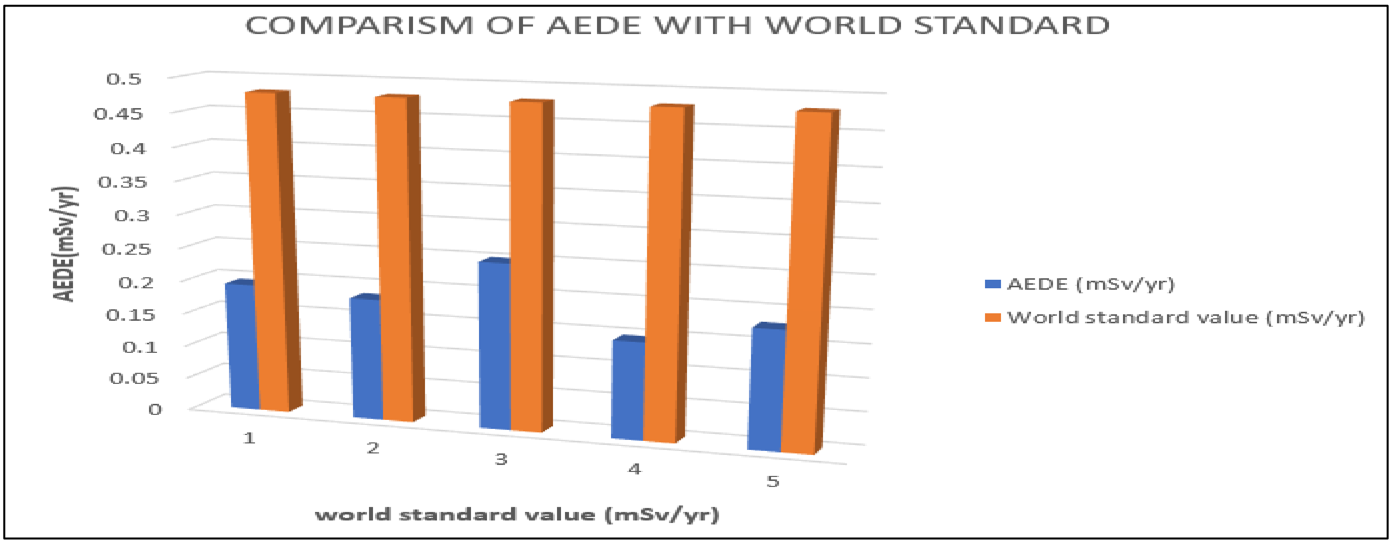

Fig 9 Comparison of AEDE with World Standard

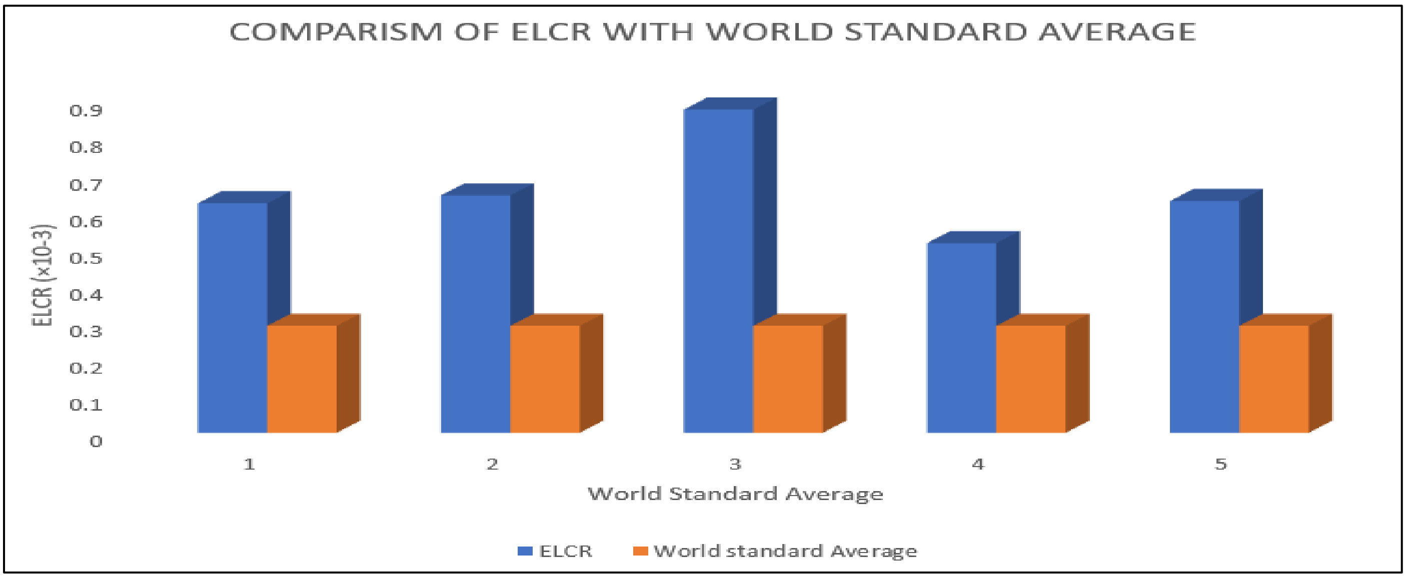

Fig 10 Comparison of ELCR with World Standard Average

IV. CONCLUSION

The background ionizing radiation of the five major markets in northern senatorial district of Cross River State Nigeria, have been measured, the dose level are low both in the market and outside the market, this further informs us that sellers, buyers and nearby occupants are safe. Though the dose rate measured inside the markets all exceed those measured outside the market, therefor sellers and buyers in this market are within the internationally accepted safe limit for members of the public. Also we noticed from our measurement carried out that the calculated values of the excess lifetime cancer risk was higher in some markets than the safe internationally accepted value, this may not lead to immediate health problem but has to be checked for long term exposure.

➢ *Ethics*

The article is original and has not been previously published. All the authors read and approved the manuscript without ethical issues.

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