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Effective dose from natural background radiation in Keffi and Akwanga towns, central Nigeria

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ABSTRACT

***Background*:** Human is exposed to radiation in their environment with or without their consent; and the exposure to natural background radiation is an unpreventable event on earth. ***Materials and Methods*:** An in situ assessment of the indoor and outdoor background radiation in Akwanga and Keffi towns of Nasarawa state Nigeria was carried out using a halogen-quenched Geiger Muller (GM) detector (Inspector alert Nuclear radiation monitor SN: 3544). Each of these towns was divided into at least 20 sampling areas where at least ten readings were taken in order to have a reliable data. ***Results*:** The mean indoor and outdoor annual effective dose of Akwanga were 1.29± 0.13mSv/yr and 0.31±0.04 mSv/yr respectively; and that of Keffi were 1.08± 0.15mSv/yr and 0.25±0.04 mSv/yr respectively. The radiation levels in both highly populated towns were found to be within the safe limit for areas of normal background set by UNSCEAR (2.4 mSv/yr). ***Conclusion*:** These results would serve as a baseline upon which other exposures would be assessed and in the future, serve as reference for dosimetry and decontamination in situations of radiation poisoning of these towns.

Keywords: *Indoor, outdoor, background radiation, effective dose, Keffi.*

INTRODUCTION

Human is exposed to radiation in their environment with or without their consent; and the exposure to natural background radiation is an unpreventable event on earth. Atomic radiation has no boundaries; and the injuries and clinical symptoms induced by exposure to ionizing radiation include; direct chromosomal transformation, indirect free-radical formation, radiation cataractogenesis, cancer induction, bone necrosis, etc. (1). The practice has been to ensure that human exposure to radiation is as low as reasonably achievable known as the *ALARA* principle.

The main sources of natural radiation are; cosmic rays, primordial radionuclides in the earth's crust, ingested radionuclides and lung irradiation due to radon (^{222}Rn) and thoron (^{220}Rn) in air; which are classified into external and internal sourcese (2-4).

Man's exposure to natural radiation exceeds that from all technologies put together(5); and the International Atomic Energy Agency (IAEA) estimate of the dose contribution to the environment shows that, over 85% of background radiation received by man is derived from natural radio-nuclides, while the remaining 15% is from cosmic rays and nuclear process(6).

Previous studies have shown that areas with high background radiation are found in Yangjiang, China; Kerele, India; and Ramsar, Iran (7); and in Asia, maximum outdoor measurement was recorded in Malaysia and the maximum indoor measurement was recorded in Hong

Kong and Iran [8].

In Nigeria, studies have been conducted in different areas to measure the natural radiation level in the areas. For instance, it is reported that the equivalent dose due to outdoor exposure to radiation in Abeakuta, Nigeria ranged from 0.19 to 1.64 mSv /y with the mean of 0.45 mSv /y [9]. A nationwide study of the terrestrial radiation in Nigeria indicates that the mean annual effective dose equivalent is 0.27mSv /y [10], Sadiq *et al.* [11] measured the background radiation in the mines of Nasarawa state; results indicated that Alizaga Quarry has the maximum reading of 2.60 mSv/y. While the effective dose equivalent at the Maloney Hill Quarry in Keffi is 1.75 mSv /y. A survey of gamma terrestrial radiation in Nigerian coal mine indicated mean outdoor readings of 10.4 nGy /h and 11.7 nGy /h for the Okaba and Okpara mines respectively[12].

Table 1 shows the natural radiation dose in some Nigerian towns. These readings were obtained by pilot measurement of the absorbed dose rate.

The present work aims at extending the survey to measure the dose equivalent for towns in the northern region of Nigeria; especially areas that are marked for mining of solid minerals (in Nasarawa state). The result of this survey would serve as base line data for future references.

Study area

Geographically, Keffi is located at Latitude 8^0 50' 23'' Nand Longitude 7^{0}52'12''E. It has an area of 138 Km^2 while Akwanga is located at Latitude 8^0 54' 36'' N and Longitude 8^0 54' 36'' E and has an area of 996 Km^2; and it is 60 Km away from Keffi. Figures 1 and 2 shows the locations of Nasarawa state, Nigeria and its two towns Keffi and Akwanga. The towns are local government head quarters in the Nasarawa state, Nigeria that is widely known to be the home of Nigeria's solid minerals. Nasarawa state has a sedimentary basin with the potential to add to the national oil reserve assets; both towns are characterized by younger granite and are on the basement complex [13].

Geological survey in Keffi area has indicated the availability of rare metals (Ta-Sn-Li-Be) at commercial scale in the area [14, 15].

Table 1. Natural radiation in some Nigerian cities[4]*.

City	Dose Equivalent (µSv /y)
Lagos	943.2±35.9
Ijebu Ode	1279.0±14.0
Ibadan	1146.9±20.1
Awka	976.0±42.7
Benin city	1249.8±78.8
Oweri	1009.8±28.1
Port-Harcourt	1073.6±39.1
Enugu	1026.6±148.6

*This table only accounts for cities in Southern Nigeria.

MATERIALS AND METHODS

A new factory calibrated Inspector Alert Nuclear radiation meter (SN:35440, by SE international, Inc. USA) was used in the assessment. The meter's sensitivity 3500 CPM/ (mR h^{-1}) referenced to Cs-137 and its maximum alpha and beta efficiencies are 18% and 33% respectively. It has a halogen-quenched Geiger-Muller detector tube of effective diameter of 45 mm and a mica window density of 1.5-2.0 mg cm^{-2} (Inspector alert operation manual).

Twenty four sample areas (A_1, ...,A_{24}) were arbitrarily selected in Keffi and twenty areas in Akwanga. Outdoor background radiation readings were taken in open fields that are away from buildings. Indoor measurements were conducted in buildings and city halls. To account for errors in the data, 20 different readings were taken for both indoor and outdoor radiation in each sample area and the standard deviation of each data was obtained.

The meter was held at 1 m above the ground level for both the indoor and outdoor radiation measurements.

Figure 1. Map of Nasarawa State showing the two towns where assessments were conducted.

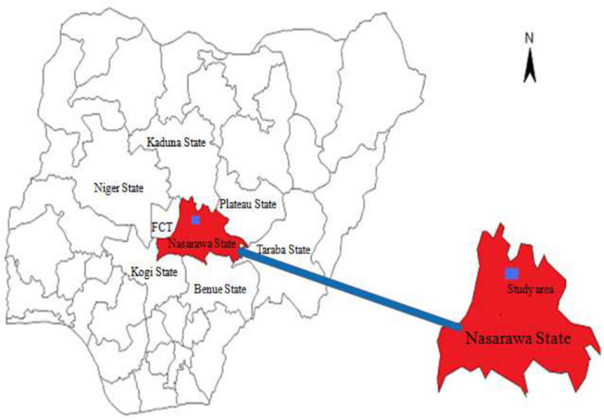


Figure 2. Map of Nigeria showing Nasarawa state [15].

RESULTS

Table 2 presents the equivalent dose rate (meter mean readings) and the annual effective dose equivalent for the areas in Keffi. The table presents both the indoor and outdoor background radiation in the town. Table 3 presets the same parameters for the town of Akwanga. Measurements were repeated ten times in order to obtain the average reading as well as the standard deviation (SD).

The annual effective dose rate for both the indoor and outdoor data from each area were computed using equation (1) and (2) [16].

$$E_i = \chi(\mu Sv/hr) \times 8760 hrs/yr \times 0.8 \quad (1)$$

$$E_0 = \eta(\mu Sv/hr) \times 8760\ hrs/yr \times 0.2 \quad (2)$$

Where:

E_0 is the outdoor annual effective dose equivalent (mSv/y)

E_i is the indoor annual effective dose rate equivalent (mSv/y)

χ is the indoor meter reading (mSv/h) = Indoor absorbed dose rate

η is the outdoor meter reading (mSv/h) = Outdoor absorbed dose rate

0.8 and 0.2 are the indoor and outdoor occupancy factors respectively.

The indoor-to –outdoor ratio was computed for each of the sample areas from which the mean indoor-to-outdoor ratio for the cities, was computed for comparison with the 1.5 set by UNSCEAR (UNSCEAR, 1993). Data from tables (2, and 3) are presented in graphical forms for easy interpretation.

Table 2. Indoor and outdoor background radiation in Keffi town.

Area Code	Name of Area	χ (µSv/hr)	η (µSv/hr)	E_i (mSv/yr)	E_0 (mSv/yr)	(R = χ / η)[a]
A1	G.S.S Yalwa	0.149 (0.02)	0.135 (0.02)	1.04 (0.14)	0.24 (0.04)	1.10
A2	AngwanTofa	0.154 (0.03)	0.148 (0.03)	1.08 (0.20)	0.26 (0.06)	1.04
A3	Tudunwada	0.142 (0.04)	0.144 (0.02)	0.99 (0.28)	0.25 (0.05)	0.99
A4	GangarenTudu	0.147 (0.02)	0.134 (0.02)	1.03 (0.14)	0.21 (0.04)	1.10
A5	YaranMaji	0.160 (0.02)	0.142 (0.03)	1.12 (0.14)	0.25 (0.05)	1.13
A6	YaranZana	0.142 (0.02)	0.132 (0.02)	0.99 (0.14)	0.23 (0.04)	1.08
A7	SabonKasuwa	0.145 (0.02)	0.134 (0.02)	0.89 (0.14)	0.21 (0.04)	1.08
A8	Makwalla	0.156 (0.01)	0.132 (0.02)	1.09 (0.07)	0.26 (0.04)	1.18
A9	SabonGareji	0.147 (0.02)	0.135 (0.02)	1.03 (0.14)	0.24 (0.04)	1.09
A10	KofanGoriya	0.149 (0.02)	0.130(0.02)	1.05 (0.07)	0.23 (0.04)	1.15
A11	TudunAmama	0.147 (0.02)	0.128 (0.02)	1.03 (0.14)	0.22 (0.04)	1.15
A12	AngwanKwara	0.128 (0.04)	0.134 (0.02)	0.89 (0.28)	0.21 (0.04)	0.96
A13	G.R.A	0.152 (0.01)	0.143 (0.03)	1.07 (0.07)	0.25 (0.04)	1.06
A14	Kadarako	0.181 (0.03)	0.126 (0.02)	1.27 (0.21)	0.22 (0.04)	1.44
A15	Pada	0.141 (0.02)	0.134 (0.02)	0.99 (0.14)	0.21 (0.04)	1.05
A16	AngwanNufawa	0.143 (0.01)	0.127 (0.02)	1.00 (0.07)	0.22 (0.04)	1.13
A17	GangarenTudu	0.140 (0.02)	0.138 (0.02)	0.98 (0.14)	0.24 (0.04)	1.01
A18	KofanPada	0.142 (0.02)	0.135 (0.02)	0.99 (0.14)	0.24 (0.04)	1.05
A19	TsohonKasuwa	0.161 (0.03)	0.160 (0.03)	1.13 (0.21)	0.28 (0.05)	1.01
A20	AngwanKwara	0.139 (0.02)	0.140 (0.02)	0.97 (0.14)	0.25 (0.04)	0.99
A21	Karofi	0.144 (0.01)	0.144 (0.02)	1.01 (0.14)	0.25 (0.05)	1.00
A22	Makera	0.156 (0.03)	0.160 (0.03)	1.09 (0.21)	0.28 (0.04)	0.98
A23	GagarenAboki	0.133 (0.02)	0.134 (0.02)	0.81 (0.14)	0.21 (0.04)	0.99
A24	KauranSarki	0.163 (0.02)	0.140 (0.02)	1.14 (0.14)	0.25 (0.04)	1.16
	Mean	0.148 (0.02)	0.139 (0.02)	1.08 (0.15)	0.25 (0.04)	1.06

[a]The ratios of indoor-to-outdoor background radiation were computed in order to compare with the UNSCEAR standard 1.5 for normal background [16].

Table 3. Indoor and outdoor background radiation in Akwanga town.

Area code	Name of Area	η (µSv/hr)	χ (µSv/hr)	E_0 (mSv/yr)	E_i (mSv/yr)	R = χ / η
A1	General Hospital	0.253 (0.03)	0.172 (0.02)	0.44 (0.05)	1.21 (0.14)	0.68
A2	ST. P Cat.Church	0.217 (0.04)	0.226 (0.02)	0.38 (0.04)	1.58 (0.14)	1.04
A3	Mbokishoping comp.	0.173 (0.02)	0.179 (0.02)	0.30 (0.04)	1.25 (0.14)	1.03
A4	Main market	0.175 (0.02)	0.169 (0.02)	0.31 (0.04)	1.18 (0.14)	0.97
A5	C.O.E Akwanga	0.182 (0.02)	0.190 (0.01)	0.32 (0.02)	1.33 (0.07)	1.04
A6	AngwanSarkinandaha	0.160 (0.03)	0.169 (0.02)	0.28 (0.04)	1.18 (0.14)	1.06
A7	Fake filling station	0.159 (0.02)	0.148 (0.02)	0.28 (0.04)	1.04 (0.14)	0.93
A8	Akwanga shopping plaza	0.160 (0.03)	0.169 (0.02)	0.28 (0.04)	1.18 (0.14)	1.06
A9	Akwanga main market	0.136 (0.01)	0.150 (0.02)	0.24 (0.04)	1.05 (0.14)	1.10
A10	AngwanTivi	0.145 (0.01)	0.164 (0.03)	0.26 (0.02)	1.15 (0.20)	1.13
A11	Low cost	0.158 (0.02)	0.149 (0.02)	0.28 (0.04)	1.04 (0.14)	0.94
A12	AgwanAttah	0.147 (0.01)	0.168 (0.02)	0.26 (0.04)	1.18 (0.14)	1.14
A13	AngwanKPpandom	0.175 (0.02)	0.193 (0.02)	0.31 (0.04)	1.35 (0.14)	1.10
A14	AngwanTsako	0.172 (0.01)	0.220 (0.02)	0.30 (0.04)	1.54 (0.14)	1.28
A15	Angwanmada	0.165 (0.01)	0.185 (0.01)	0.29 (0.02)	1.30 (0.07)	1.12
A16	medical center Alushi	0.220 (0.04)	0.250 (0.01)	0.44 (0.02)	1.75 (0.07)	1.14
A17	Kurmintagwaye	0.180 (0.02)	0.193 (0.01)	0.34 (0.02)	1.35 (0.07)	1.07
A18	G.R.A	0.187 (0.03)	0.182 (0.02)	0.32 (0.04)	1.29 (0.14)	0.97
A19	Akpata	0.175 (0.01)	0.184 (0.02)	0.32 (0.04)	1.28 (0.14)	1.05
A20	Tsakpe	0.172 (0.02)	0.180 (0.02)	0.32 (0.04)	1.26 (0.14)	1.05
	Mean	0.176 (0.02)	0.155 (0.02)	0.31 (0.04)	1.29 (0.13)	0.88

The results indicate that in Keffi, the areas with maximum indoor and outdoor radiations are A_{14} and A_{19} respectively (figure 3). Another area, which has high outdoor background radiation, is A_{22}. In the Kadarko area (A_{14}) houses are built closely; and this could result in high concentration of radon in the buildings. A_{19} is located on elevated ground; it is just some few meters away from the Maloney Hill, where a major quarry activity is taking place. In comparison, the annual effective doses in these areas are below the 2.4 mSv limit set by UNSCEAR; and do not pose any significant health risk to the inhabitants.

Nevertheless, the radon levels in areas (e.g. A_{14} in Keffi and A_{16} in Akwanga) with a significantly higher radiation level should be checked in order to minimize the risk of any type of radiation-induced injuries in these areas.

Sample areas with maximum indoor and outdoor radiation in Akwanga are A_{16} and A_1 (figure 4). These areas are on elevated ground; and are surrounded by rocky hills (Younger Granite).

Figure 5 provides a vivid comparison between the results of this research and the international accepted limits. The indoor-to-outdoor background radiation ratio in the two towns are lower than the UNSCEAR limit with the mean effective dose equivalents less than the 2.4 mSv annual effective dose for areas of the normal background. These indicate that the natural background radiation level in the two cities does not pose any significant health risk to the inhabitants.

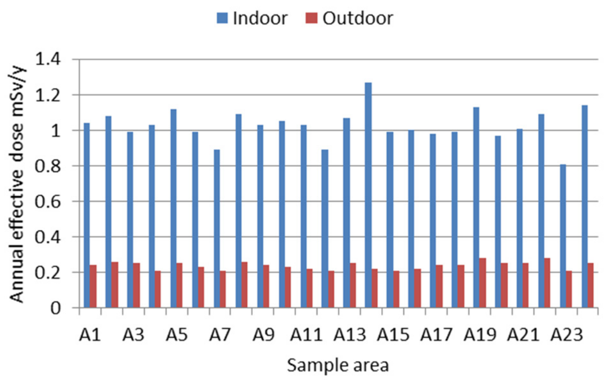


Figure 3. Indoor and outdoor Annual effective dose equivalent in Keffi.

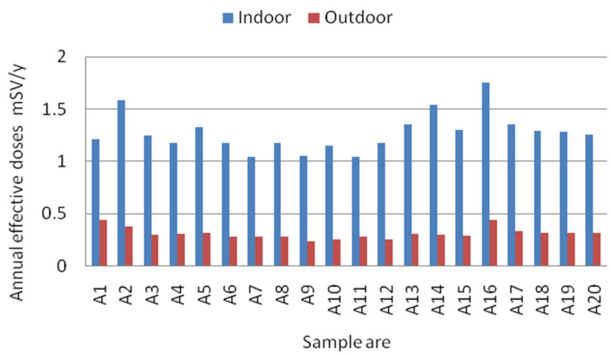
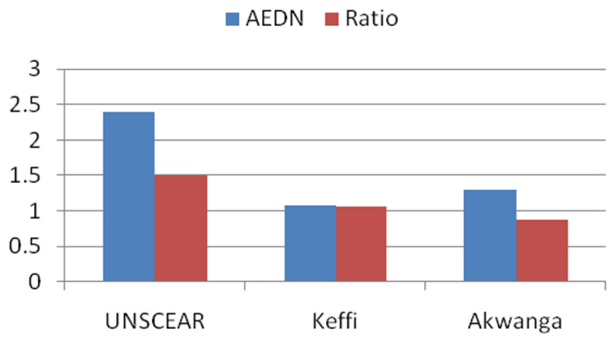


Figure 4. Indoor and outdoor Annual effective dose equivalent in Akwanga.



AEDN = Annual effective dose for normal background area [17].
Ratio = Indoor-to-outdoor ratio

Figure 5. Comparison between the UNSCEAR limits and the results.

The results are in consonance with previous works carried out in some Nigerian cities reported in (2, 4, 6, 9 and 11).

As for the areas with higher indoor radiation, it is recommended that the radon level in buildings around these areas be measured using the technique specified for radon gas measurement in buildings. It's hoped that the result of this work would serve as a reference in the future; as well as serve as a benchmark for future solid mineral exploration in these towns.

CONCLUSION

Our study has presented the natural background radiation levels in Akwanga and Keffi towns for the first time. The radiation level are within the regulatory limits and are within the range of the average readings of radiation limits reported in literatures [2, 4, 6, 9,11] cities in the southern Nigeria. The average equivalent dose rates for both indoor and outdoor radiation exposure in Akwanga and Keffi towns have been measured using a halogen-quenched GM detector. These results provide the essential baseline information for the assessment of any environmental radioactive contamination of the area in foreseeable future.

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