



EVALUATION OF HAZARD INDICES OF BACKGROUND RADIATION IN SOME MAJOR TOWNS OF GOMBE STATE, NIGERIA

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ABSTRACT

Interest for the determination of naturally occurring radiation and environmental radioactivity has led to the interest of extensive surveys in many countries including Nigeria. This work was carried out to ascertain the indoor and outdoor background ionizing radiation in Gombe state as a precautionary measure due to recent development of radioactive activities in the State. RDS-31 Survey meter placed 1m above the earth surface was used for taking readings. The measured average exposure rates ranged from 0.007 to 0.017 mR/h for indoor and 0.007 to 0.015 mR/h for outdoor with a total mean of 0.010 ± 0.003 mR/h, which are within the limit of world average of 0.013 mR/h. The indoor absorbed dose rate ranged from 61.34 ± 7.52 nGy/h in Kwami to 149.21 ± 57.35 nGy/h in Billiri with a total mean value of 88.47 ± 32.64 nGy/h, which is higher than World's average of 84.00 nGy/h, while the outdoor ranged from 61.34 ± 17.45 nGy/h in Shongom to 134.42 ± 38.61 nGy/h in Kaltungo with a mean total value of 90.24 ± 29.88 nGy/h, which is 31.24 nGy/h higher than the standard average of 59.00 nGy/h. Equivalent dose rate was calculated to be in the range of 0.59 ± 0.07 mSv/yr to 1.44 ± 0.55 mSv/yr with a total mean of 0.86 ± 0.32 mSv/yr, which is within the International Commission on Radiological Protection(ICRP)recommended limit of 1 mSv/yr. The AEDE shows a range of 0.33 ± 0.08 to 0.73 ± 0.28 mSv/yr for indoor and 0.08 ± 0.02 to 0.16 ± 0.05 mSv/y for the outdoor respectively. The sum is found to be 0.54 mSv/yr which is 0.02 mSv/yr higher than the world's average of 0.52 mSv/yr. Estimated life-time cancer risk ranges from 1.20×10^{-3} to 2.56×10^{-3} mSv/yr, while outdoor ranges from 0.30×10^{-3} to 0.58×10^{-3} mSv/yr with a total mean of 2.08×10^{-3} mSv/yr which is larger compared with the resulting worldwide average of 1.45×10^{-3} . The excess lifetime cancer risk values indicated that the probabilities of contracting cancer for residents of Gombe, Kwami, Dukku, Yamaltu Deba, Bajoga, Shongom, Balanga, Funakaye, Kaltungo are low but higher in Billiri, and Akko (Mai-Ganga). These values may not constitute any immediate health risk to the residents of Gombe state but precaution should be taken in order to avoid stochastic effect.

Keywords: Background ionizing radiation, hazard indices, Gombe state

INTRODUCTION

Gombe State popularly referred to as the 'Jewel in the Savannah' comprised of sandstones, clay and silt, while the vegetation of the state is that of savannah

woodland comprising scattered shrubs and trees (Mayomi *et al.*, 2016).

Radioactivity is a natural phenomenon and natural sources of radiation are features of the environment. Radiation and radioactive substances have many beneficial



applications, ranging from power generation to uses in medicine, industry and Agriculture. The radiation risks to workers and the public and to the environment that may arise from these applications have to be assessed and, if necessary, controlled (IAEA, 2012). Radionuclides in natural environment may be acquired into the body unintentionally through inhalation, ingestion or absorption (IAEA, 1989).

Human beings are exposed to natural background radiations from cosmos, earth stratum, building materials, food, air, and even elements that constitute their own body. Although influence of cosmic rays and cosmogenic radionuclides (^{14}C , ^3H , ^7Be etc) cannot be ignored, the real threat to public health is imposed by naturally occurring radionuclide materials known as primordial radionuclides. Almost 90% of the radiation exposure for the population arises from natural sources and the other 10% is derived from medical exposure and miscellaneous sources with an artificial origin (Abadat, *et al.*, 2014).

Research has shown that exposure to ionizing radiation can cause cancer and mental retardation in children of mothers exposed to radiation during pregnancy. Background Ionization Radiation (BIR) can be considered to be a form of environmental contamination especially when it exceeds safe occupational and public health limits.

External background ionizing radiation comes from three major sources: Terrestrial, Cosmic and Anthropogenic origin (Agbalagba, 2017).

External exposures outdoors arise from terrestrial radionuclides present at trace levels in all soils. The specific levels are related to the types of rock from which the soils originate. Higher radiation levels are associated with igneous rocks, such as

granite, and lower levels with sedimentary rocks. There have been many surveys to determine the background levels of radionuclides in soils, which can in turn be related to the absorbed dose rates in air (UNSCEAR, 2000).

There are regions in the world where the outdoor terrestrial radiation exceeds substantially the average value due to the enrichment of certain radioactive materials leading to the formation of what are known as high background areas. The presence of high background areas has been reported in several countries such as China, Iran, Germany, USA, Brazil and India (Monica, *et al.*, 2016).

We are exposed to ionizing radiation from natural sources through cosmic rays entering the earth's atmosphere from outer space and internal exposure from radioactive elements which we take into our bodies through food, water and air we breathe. In addition, we have radioactive elements (Potassium 40, Carbon 14, Radium 226) in our blood or bones (IAEA, 2019).

Indoor exposure to gamma rays, mainly determined by the materials of construction, is inherently greater than outdoor exposure if earth materials have been used; the source geometry changes from half-space to a more surrounding configuration indoors. When the duration of occupancy is taken into account, indoor exposure becomes even more significant. Buildings constructed of wood add little to indoor exposures, which may then be comparable to outdoor exposures (UNSCEAR, 2000).

The Health impact of exposure to radon (^{222}Rn) inhalation by humans in indoor environment is a major public concern worldwide especially granite building materials (Monica, *et al.*, 2016).

Additionally, we are exposed to varying amounts of radiation from sources such as dental and other medical X-rays, industrial uses of nuclear techniques and other consumer products such as luminized wrist watches, ionization smoke detectors, etc. We are also exposed to radiation from radioactive elements contained in fallout from nuclear explosives testing, and routine normal discharges from nuclear and coal power stations (IAEA, 2019).

A very large dose delivered to the whole body over a short time will result in the death of the exposed person within days. Much has been learned by studying the health records of the survivors of the bombing of Hiroshima and Nagasaki. We know from these that some of the health effects of exposure to radiation do not appear unless a certain quite large dose is absorbed. However, many other effects, especially cancers are readily detectable and occur more often in those with moderate doses. At lower doses and dose rates, there is a degree of recovery in cells and in tissues. (IAEA, 2019).

Levels of natural background radiation vary over a range of concentrations and exposure rates from different causes. The magnitude of variation can be significant over a short distance and also can vary in the same place from time to time. The most significant changes with time are associated with variations in the amount of snow cover and soil moisture and in the atmospheric concentration of ^{222}Rn decay products (Nahla, 2012).

The cooling and differentiation of molten magma results in the formation of silicate minerals. Igneous rocks are formed in the latter stages of this magmatic cooling and differentiation. These rocks contain mostly silicon and aluminum and are rich in elements such as uranium, thorium, and

potassium. The concentrations of these radionuclides are related to the amounts of silicates present during the formation of igneous rock. Acidic rock will contain the highest concentrations of radionuclides, while ultrabasic rock will contain the lowest concentrations of radionuclides (Robert, 1999).

Terrestrial radionuclides are distributed throughout the crust of the earth. Outdoor exposures from sources of terrestrial radiation originate predominantly from approximately the top 1 ft layer of the soil (Nahla, 2012).

The recent development in diagnostic and other radioactive activities (natural and artificial) will put the public health and environment in danger if proper investigation is not carried out to manage and control the level of exposure to the public. The rate at which cancer disease increases around the world and Nigeria in particular need to be taken into consideration. The commonest cancers in Nigeria in 2009 to 2010 were breast and cervical cancer among women and prostate cancer among men (Elima *et al.*, 2012) and precaution to that effect is what stimulate the other part of this research with a view to ensure that exposure to ionizing radiation is kept As Low As Reasonable Achievable (ALARA) in Gombe State. The age standardized incidence rates for breast cancer in the period 1960 – 1969 was 13.7 per 100,000 and it rose to 24.7 per 100,000 by 1998 – 1999 more or less a doubling of incidence over four (4) decades or approximately 25% increase in incidence per decades (Elima *et al.*, 2012).

Very few works were reported in the background radiation in Gombe State. Seydou and Shitu (2016), determined the radiation background in the vicinity of groundnuts milling machines in Gombe

Metropolis of Gombe State of Nigeria using a Geiger Mueller counter. The measured average background radiation levels ranged between 1.72 $\mu\text{R/hr}$ (0.0185 mSv/yr) to 3.3 $\mu\text{R/hr}$ (0.0355 mSv/yr) in the study area. The average dose equivalents obtained for most locations within the study area is above the standard background radiation of 0.013 mSv/yr given by ICRP, but is within the safe radiation limit of 1.04 mSv/yr. However, results obtained do not indicate any immediate health side effects on the workers and the host communities as the highest radiation exposure level of 0.0355 mSv/yr recorded is below the limit value of 10.43 mSv/yr set by Texas Regulation for Control of Radiation and Protection of Public Health. Seydou and Ibrahim (2016), measured the background ionizing radiation in some farmland of Kwadon, Gombe State, Nigeria. They reported that farmers working in the study area were not in danger going by their results. The mean value of radiation dose rate 0.53 mSv/yr close to world limit average value of 0.5 mSv per year.

This work was carried out in order to enlarge the existing data and see also if the high rate of Cancer diseases in the State can link to the amount of ionizing radiation present in the environment.

MATERIALS AND METHODS

This research adopted a cross-sectional review of the study area. Emphasis was placed in a crowded area, rocky settlements, buildings and a visit to various houses for the measurement of indoor gamma radiation. The outdoor gamma radiation was categorized into two (2), industrial zone because of the concentration of industrial activities in the area and non-industrial area. A RDS-31 survey meter as shown in Figure 3.12 was used to take the readings. Its measuring range goes from 0.01 $\mu\text{Sv/h}$ to 0.1 Sv/h or 1 $\mu\text{rem/h}$ to 10 rems/h and it has a

configurable unit for Sv (/h), R(/h), Gy(/h), cps, cpm, dpm and Bq. It can operate at a temperature of $-25\text{ }^{\circ}\text{C}$ to $+60\text{ }^{\circ}\text{C}$. The tube of the radiation monitoring metre was raised to a standard height of 1.0 m above the ground with its window facing the suspected source. Gombe State is one of the 36 states of the Federal Republic of Nigeria, located in the center of the north east of the country on latitude $9\text{ }^{\circ}\text{ }30'$ and $12\text{ }^{\circ}\text{ }30'$ North, Longitude $8\text{ }^{\circ}\text{ }5'$ and $11\text{ }^{\circ}\text{ }45'$ East. It is bordering Borno, Yobe, Adamawa, Taraba, and Bauchi States, with a land area of 20,265 sqkm. The State climate is generally warm exceeding $40\text{ }^{\circ}\text{C}$ during the hottest month but not exceeding $300\text{ }^{\circ}\text{C}$ during the months of March-May considered to be the hottest months. The state was carved out from defunct Bauchi State on the 1st October, 1996 by the former Head of State and Commander in chief of Armed Forces, Federal republic of Nigeria, Late General Sani Abacha GCFR. It has a population projected as 2,857,042 with a land area of about 20,265sqkm. Topography mainly mountainous, undulating and hilly to the South-East and flat open plains in the Central, North, North-East, West and North-West. Gombe state is located at Latitude $9\text{ }^{\circ}\text{ }30'$ and $12\text{ }^{\circ}\text{ }30'$ N, Longitude $8\text{ }^{\circ}\text{ }5'$ and $11\text{ }^{\circ}\text{ }45'$ E. The state lies in the center of North East Geopolitical Zone of Nigeria. It shares common boundaries with Adamawa and Taraba State to the South, Bauchi State to the West, Borno State to the East and Yobe State to the North. The major towns are; Gombe the capital, Bajoga, Billiri, Kaltungo, Kumo, Dukku and Deba. Ethnic Composition Multi-ethnic, mainly made up of Fulani, Tangale, Waja, Bolawa, Tera, Jukun, Jara, Pero, Tula, Cham, Lunguda, Dadiya, Kamo, Awak, Kanuri, Hausa, Yoruba and Igbo. Language Spoken English is the official language, but as much as Hausa remain the commercial language

amongst the people of the state, Fulfulde, Tangale, Tera, Waja, and Kanuri are commonly spoken. Vegetation Gombe is generally a Guinea Savannah grassland with concentration of wood lands in the South East and South West. The rainfall annual average is 850mm (Gombe seeds Technical committees).

The data were sourced from the background measurements of the indoor and outdoor gamma radiation in various local government area in Gombe State. Latitude and longitude measurement of the particular location were taken to avoid duplication in future research. The mapped study areas in the eleven (11) Local Government Areas in Gombe State are shown in Figure 1 (map of Nigeria States and Gombe State).

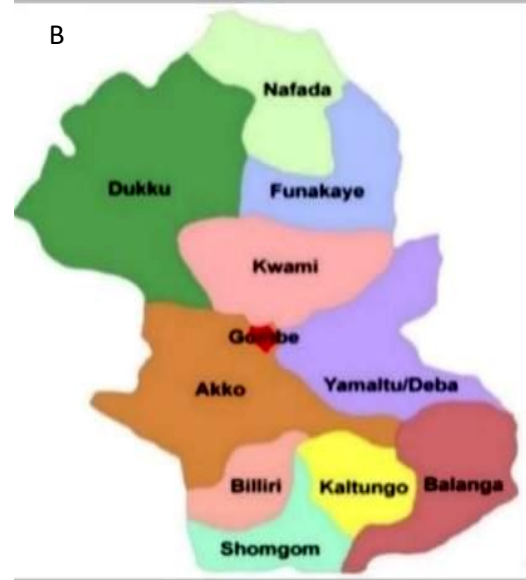
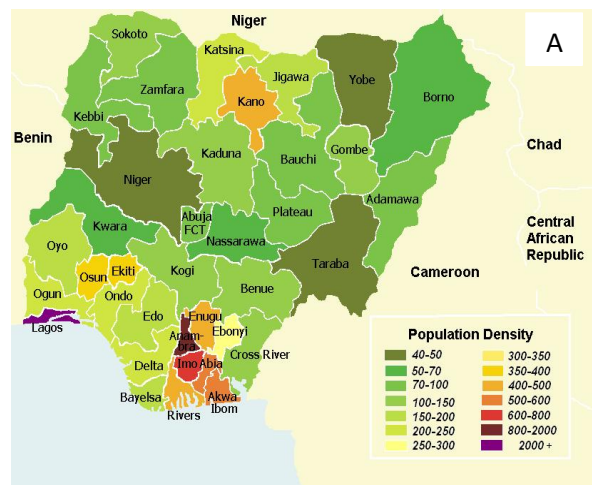


Figure 1: Map of A) Nigeria States and B) Gombe State.



Data Collection

The sample size for this research was distributed across the major towns in Gombe state. Measurements were taken in twenty (20) locations within Gombe town and ten (10) in other strategic locations across the remaining communities in the State. In areas

where there is mining activities and quarry site, measurements were taken some kilometers away from the site and close to the site.

Data Evaluation

Calculation of Absorbed Dose Rate

The absorbed dose rate is divided into two (2), Indoor (D_{in}) and outdoor (D_{out}). The readings were taken in $\mu\text{Sv/h}$ then converted to mR/h . The data obtained for the indoor and outdoor rate in Rh^{-1} were also converted into absorbed dose rates nGyh^{-1} using the conversion factor (Rafique *et al.*, 2014)

$$1\mu\text{R/h} = 8.7 \text{ nGyh}^{-1}\text{and}$$

$$1\text{mR/h} = 10\mu\text{Sv/h} \tag{1}$$

given that 1 roentgen = 0.00877 Sieverts

Background Ionizing Radiation Level (BIR)

The average background ionizing radiation level will be converted from $\mu\text{Sv/h}$ to mR/h using equation 1 above.

2.5.3 Equivalent Dose Rate

To estimate the whole body equivalent dose rate over a period of one year, the National Council on Radiation Protection and Measurement's recommendation reported by Agbalagba, 2017 will be used.

$$1 \text{ mR h}^{-1} = \frac{0.96 \times 24 \times 365}{100} \text{ mSv y}^{-1}$$

Annual Effective Dose Equivalent (AEDE)

The computed absorbed dose rates will be used to calculate the Annual Effective Dose Equivalent (AEDE) received by residents living in the study area. The annual effective dose equivalent is of two types. The annual indoor effective dose (E_{in}) and annual outdoor effective dose (E_{out}) with their standard deviation calculated. The following formulae was used to evaluate the (E_{in}) and (E_{out}) dose in μSv .

$$E_{in} = D_{in} (\text{nGy/h}) \times 8760 \text{ h} \times 0.7 (\text{Sv/Gy}) \times 80\%$$

$$E_{in} = D_{in} \times 4.905 \mu\text{Sv} \quad (3)$$

where E_{in} is the Annual Indoor Effective Dose and D_{in} is the indoor dose with Occupancy factor of 80% (0.8)

$$E_{out} = D_{out} (\text{nGy/h}) \times 8760 \text{ h} \times 0.7 (\text{Sv/Gy}) \times 20\%$$

$$E_{out} = D_{out} \times 1.2264 \mu\text{Sv} \quad (4)$$

where E_{out} is the Annual Outdoor Effective Dose and D_{out} is the outdoor dose.

2.5.5 Lifetime Cancer Risk (LCR)

Lifetime cancer risk is the likelihood that a person who is free of a certain type of cancer will develop or die from that type of cancer during his or her lifetime. The

lifetime cancer risk (LCR) will be estimated based on the computed values of AEDE, using the equations:

$$\text{LCR (indoor)} = E_{in} \times \text{Life Expectancy (LE)} \times \text{RF} \quad (5)$$

$$\text{LCR (outdoor)} = E_{out} \times \text{LE} \times \text{Risk Factor (RF)} \quad (6)$$

where E_{in} and E_{out} are the annual effective dose equivalent for indoor and outdoor respectively, LE is the life expectancy (70 years) and FR is the fatal risk factor per Sievert, for low-dose background radiation, which is considered to produce stochastic effects. ICRP-60 (2006) uses a fatal cancer risk factor value of 0.057 for public exposure used by ICRP as reported by Agbalagba, 2017 will also be used in this work.

Effective Dose

The following equation will be used to calculate the full-body dose which is also known as effective dose.

$$D_{organ} (\text{mSv/y}) = 0.8 \times \text{AEDE} \times F \quad (7)$$

where 0.8 is the occupancy factor and AEDE is the Annual Effective Dose Equivalent and F is the conversion factor for organ dose from ingestion.

RESULTS AND DISCUSSION

Background Ionizing Radiation (BIR)

Exposure Level

Measurements of natural background radiation have been carried out in many parts of the world using a variety of techniques, involving the use of gas filled detectors, Scintillometers, survey meters, spectrometers as well as laboratory analyses of radioactive element in soil and rock samples from which estimates of the average radiation exposures are obtained (Abiye, 2005). In this work, the background readings were measured in $\mu\text{Sv/h}$ with the survey

Table 1: Measured exposure rate meter

S/N	Town	Exposure Rate	
		Average BIR level (mR/h)	
		Indoor	Outdoor
1	Gombe	0.009±0.004	0.010±0.004
2	Kaltungo	0.012±0.004	0.015±0.004
3	Billiri	0.017± 0.01	0.015± 0.004
4	Kwami	0.007± 0.001	0.008± 0.001
5	Funakaye	0.011± 0.004	0.010± 0.004
6	Dukku	0.009± 0.002	0.008± 0.003
7	Nafada	0.009± 0.003	0.011± 0.003
8	Yemaltu Deba	0.008± 0.002	0.010± 0.005
9	Akko	0.012± 0.008	0.010 ± 0.005
10	Balanga	0.009± 0.004	0.009± 0.002
11	Shongom	0.009± 0.003	0.007± 0.002

The results of the measured BIR exposure levels of some major towns in Gombe State are presented in Table 1. Analyses using different known radiation health hazard indices are used in radiation studies to arrive at a more reliable assessment of the health risks to an irradiated person. To assess the radiation hazards associated with the gamma radiation levels in Gombe state, the following radiation hazard indices were used: Absorbed Dose Rate (ADR), Annual Effective Dose Equivalent (AEDE), Lifetime Cancer Risk (LCR) and Equivalent Dose Rate (EDR) to different organs.

The residences visited are mostly made of zinc roofing and cement floor while others were tiled. Other study areas are made up of mold house with paper ceiling. The houses are in different geographical formation which may affect the usual standard of indoor \geq outdoor and some are close to Quarry sites, mountain, rocky surroundings etc.

The Background readings were measured in $\mu\text{Sv/h}$ (Table 1). The results of the background level measured in the eleven major towns in Gombe state that make up

the study area shows that in the Gombe Metropolis, the BIR levels of the indoor and outdoor have mean values of 0.009 ± 0.004 mR/h and 0.010 ± 0.004 mR/h respectively. The mean values BIR in Kaltungo are 0.012 ± 0.004 and $0.015 \text{ mR/h} \pm 0.004 \text{ mR/h}$ for indoor and outdoor respectively. This high values compared to the previous might be due to mountainous nature of the environment.

In Billiri town, the BIR was found to be 0.017 ± 0.01 mR/h and 0.015 ± 0.004 mR/h for indoor and outdoor respectively while in Kwami we obtained 0.007 ± 0.001 mR/h for indoor and 0.008 ± 0.001 mR/h for outdoor.

In Funakaye which is an industrial area, where the Ashaka Cement Company was located, the BIR readings were taken 1kilometer away from the production site and that is where the residents live. It was found that the background indoor to be 0.010 ± 0.004 mR/h while the outdoor is 0.006 to 0.019 mR/h.

The BIR values in Dukku were 0.009 ± 0.002 mR/h and 0.008 ± 0.003 mR/h for indoor and and outdoor respectively. Dukku is a dried area in terms of water content and most of the buildings were made of clay which made the indoor and outdoor readings almost similar. Nafada is located on a latitude of $N11^{\circ}5'46''$ and longitude of $E11^{\circ}20'6''$ with BIR indoor and outdoor values of 0.008 ± 0.002 mR/h and 0.010 ± 0.005 mR/h respectively.

Another industrial area located at kumo community which is popularly known as *Mai-Ganga*, where the indoor background reading was found to be a bit higher than the previous readings in other areas due to the materials the company used to build the houses and the activities round the area. The BIR has mean values of 0.009 ± 0.004 mR/h and 0.009 ± 0.002 mR/h for indoor and 0.007

± 0.002 mR/h outdoor. The World's standard for background ionizing radiation is 0.013mR/h (Agbalagba, 2017), which is

in order in some towns but higher in Akko and Billiri.

Table 2: Absorbed dose rate and hazard indices in some major towns of Gombe State

Mapped Area	Absorbed Dose rate (nGy/h)		Hazard indices				
			Annual Effective Dose Equivalent (mSv/yr)		Lifetime Cancer Risk (LCR) $\times 10^{-3}$		EDR (mSv/yr)
	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor	
Gombe	77.21 \pm 34.85	90.92 \pm 31.87	0.38 \pm 0.17	0.11 \pm 0.04	1.33 \pm 0.60	0.39 \pm 0.14	0.75 \pm 0.34
Kaltungo	106.14 \pm 36.58	134.42 \pm 38.61	0.52 \pm 0.18	0.16 \pm 0.05	1.82 \pm 0.63	0.58 \pm 0.17	1.03 \pm 0.35
Billiri	149.21 \pm 57.35	129.63 \pm 33.31	0.73 \pm 0.28	0.16 \pm 0.04	2.56 \pm 0.98	0.56 \pm 0.14	1.44 \pm 0.55
Kwami	61.34 \pm 7.52	71.34 \pm 12.17	0.30 \pm 0.04	0.09 \pm 0.01	1.20 \pm 0.15	0.35 \pm 0.06	0.59 \pm 0.07
Funakaye	93.96 \pm 37.54	90.48 \pm 36.33	0.46 \pm 0.18	0.11 \pm 0.04	1.84 \pm 0.73	0.44 \pm 0.18	0.91 \pm 0.36
Dukku	74.82 \pm 18.20	72.21 \pm 26.12	0.37 \pm 0.09	0.09 \pm 0.03	1.46 \pm 0.36	0.35 \pm 0.13	0.72 \pm 0.18
Nafada	80.78 \pm 26.60	92.22 \pm 27.42	0.40 \pm 0.13	0.11 \pm 0.03	1.58 \pm 0.52	0.45 \pm 0.13	0.78 \pm 0.26
Yamaltu Deba	67.86 \pm 15.51	85.26 \pm 41.28	0.33 \pm 0.08	0.10 \pm 0.05	1.33 \pm 0.30	0.42 \pm 0.20	0.66 \pm 0.15
Akko	105.27 \pm 68.80	84.83 \pm 43.56	0.52 \pm 0.34	0.10 \pm 0.05	2.06 \pm 1.35	0.42 \pm 0.21	1.02 \pm 0.67
Balanga	79.61 \pm 31.51	80.04 \pm 20.53	0.39 \pm 0.15	0.10 \pm 0.03	1.56 \pm 0.62	0.39 \pm 0.10	0.77 \pm 0.30
Shongom	77.00 \pm 24.87	61.34 \pm 17.45	0.38 \pm 0.12	0.08 \pm 0.02	1.51 \pm 0.49	0.30 \pm 0.09	0.74 \pm 0.24
Total Mean	88.47 \pm 32.67	90.24 \pm 29.88	0.43 \pm 0.16	0.11 \pm 0.04	1.66 \pm 0.61	0.42 \pm 0.14	0.86 \pm 0.32
World Standard	84.00	59.00	0.41	0.07	E _{in} + E _{out} = 0.54 LCR _{in} + LCR _{out} = 2.08		1.00
			E _{in} + E _{out} = 0.52		LCR _{in} + LCR _{out} = 1.45		

Seydou (2014) measured exposure rate in Zaria, Kaduna State to be 0.563 mSv/year while in Gombe state it was found to be 0.86 \pm 0.32 mSv/year, but in Ibrahim Babangida University it was found to range from 0.967 mSv/hr to 1.814mSv/hr (Oladipupo *et al.*,2005).

Indoor Absorbed Dose Rate (D_{in})

The mean values calculated for Funakaye, Dukku, Nafada, Yamaltu Deba local government areas were found to be 93.96 \pm 37.54, 74.82 \pm 18.20, 80.78 \pm 26.60 and 67.86 \pm 15.51 nGy/h respectively. Other mean values obtained were 105.27 \pm 68.80, 79.61 \pm 31.51 and 77.00 \pm 24.87 for Akko, Balanga and Shongom respectively, resulting to the overall mean absorbed dose

The Indoor absorbed dose rate (D_{in}) results of the gamma radiation in some major towns of Gombe state are presented in Tables 2. The results obtained using equation (1) above indicate mean values of 77.21 \pm 34.85, 106.14 \pm 36.58, 149.21 \pm 57.35 and 61.34 \pm 7.52 nGy/h for Gombe metropolis, Kaltungo, Billiri and Kwami local government areas

respectively. rate for the eleven major cities in Gombe state of 88.47 \pm 32.63 nGy/h for indoor absorbed dose rate which is 4.47 nGy/h higher than the worlds average of 84 nGy/h for indoor absorbed dose rate (European Commission, 1999).

Outdoor Absorbed Dose Rate (D_{out})

The results obtained for the outdoor absorbed dose rates (D_{out}) indicate mean values of 90.92 ± 31.87 , 134.42 ± 38.61 , 129.63 ± 33.31 and 71.34 ± 12.17 nGy/h for Gombe metropolis, Kaltungo, Billiri and Kwami local government areas respectively. Funakaye, Dukku, Nafada, Yamaltu Deba areas mean values were found to be 90.48 ± 36.33 , 72.21 ± 26.12 , 92.22 ± 27.42 and 85.26 ± 41.28 nGy/h respectively. Other mean values were 84.83 ± 43.56 , 80.04 ± 20.53 and 61.34 ± 17.45 nGy/h for Akko, Balanga and Shongom respectively, which resulted to an overall total mean value of 90.24 ± 29.88 nGy/h for outdoor absorbed dose rate. This value is 31.24 nGy/h higher than the worlds average of 59.00 nGy/h.

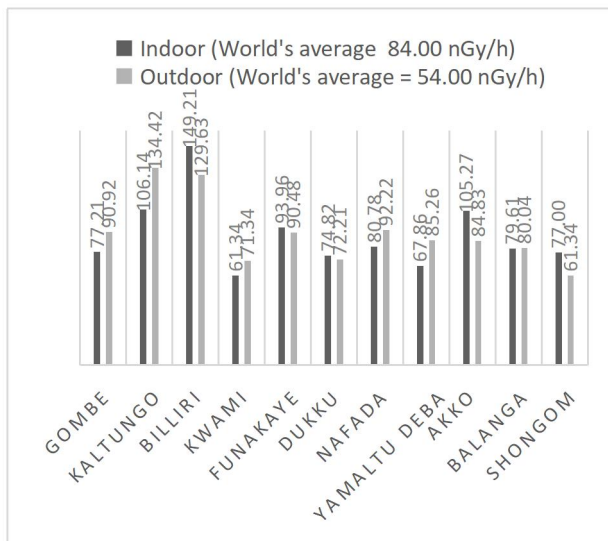


Figure 2: The Indoor and outdoor Absorbed dose rate (nGy/h) for some major towns in Gombe State.

Figure 2 shows the indoor and outdoor absorbed dose rate in nGy/h for some major towns in Gombe State. Kaltungo, Billiri and Akko happened to have higher indoor absorbed dose rate due to the materials used in their buildings. The *Mai-Ganga* area of Akko Local government area was surrounded by the coal mining site for the

Ashaka cement company and activities over there may affect the environment architecture of that particular settlement. Kaltungo is occupied by mountains and rocks which may results to radon emission to the environment. The total mean values for some major parts of Gombe state ranged from 61.34 to 149.21 nGy/h as shown in Table 2 with a grand mean value of 88.47 ± 32.67 as the absorbed dose rate which is 4.47 nGy/h higher than the worlds standard of 84.00 nGy/h.

Annual Indoor Effective Dose (E_{in})

The (E_{in}) is the dose which a person receives in the indoor environment. The (E_{in}) depends on the indoor dose (D_{in}) that is the γ -ray dose within the buildings. We used a dose conversion factor of 70% (0.7 Sv/Gy) and the occupancy factor (OF) of 80% as the time of stay in the indoor in a year. The annual indoor effective dose (E_{in}) was calculated using equation (2) above. The summary of the E_{in} calculated in some major towns of Gombe state as shown in Table 2 shows that Gombe metropolis has a mean value of 0.38 ± 0.17 mSv/yr. Kaltungo, Billiri and Kwami has 134.42 ± 38.61 , 129.63 ± 33.31 and 71.34 ± 12.17 mSv/yr respectively. Other parts of the local government areas had a total Indoor annual effective dose mean values of 0.46 ± 0.18 , 0.37 ± 0.09 and 0.40 ± 0.13 mSv/yr for Funakaye, Dukku and Nafada respectively. Yamaltu Deba, Akko, Balanga and Shongom calculated E_{in} was found to be 0.33 ± 0.08 , 0.52 ± 0.34 , 0.39 ± 0.15 and 0.38 ± 0.12 mSv/yr respectively.

The total mean values of E_{in} ranges from 0.30 to 0.73 mSv/yr with a grand mean total value of 0.43 mSv/y which is 1.05 times higher than the world's average of 0.41 mSv/yr (UNSCEAR, 2000).

Annual Outdoor Effective Dose (E_{out})

The (E_{out}) is estimated from the outdoor external dose rate (D_{out}), which is the dose a person receives outside his building. We used the conversion factor of 0.7 mSv/yr with an occupancy factor of 20% for outdoor exposure. The annual outdoor effective dose was calculated using equation (3). The annual outdoor effective dose equivalents (E_{out}) indicate mean values of 0.11 ± 0.04 , 0.16 ± 0.05 , 0.16 ± 0.04 , 0.09 ± 0.01 and 0.11 ± 0.04 mSv/yr for Gombe Metropolis, Kaltungo, Billiri, Kwami and Funakaye respectively, while the mean values for Dukku, Nafada Yamaltu Deba, Akko, Balanga and Shongom are 0.09 ± 0.03 , 0.11 ± 0.03 , 0.10 ± 0.05 , 0.10 ± 0.05 , 0.10 ± 0.03 , 0.08 ± 0.02 mSv/yr respectively. The total mean values of E_{out} ranges from 0.08 to 0.16 mSv/y with an average of 0.11 mSv/y which is 0.04 higher than the worlds average of 0.07 mSv/y. The sum of total annual effective dose ($E_{in} + E_{out}$) was estimated to be 0.54 mSv/y which is 1.04 times higher than the world's average of 0.52 mSv/yr but lower than the criterion limit of 1 mSv/y according to ICRP-60 (2006). The ($E_{in} + E_{out}$) value shows a slight increase compared to some part of Aboekuta annual effective dose as reported by Farai and Vincent (2006). It is lower than that reported by Ramchandran (2011) in India as shown in Table 3 below.

Table 3: Annual effective dose values obtained in this work compared with values reported by Monica (2016)

Region	Annual Effective Dose	Reference
India	2.3 mSv/year	Ramachandran, 2011
Iran	1.73 mSv	Sadegh <i>et al.</i> , 2012
Jos, Nigeria	2.063 mSv /year	Jwanbot <i>et al.</i> , 2012
Abeokuta, Nigeria	0.19 – 1.64 mSv/year	Farai and Vincent, 2006
Yazd Province	1.03 mSv/year	Bouzarjomehri <i>et al.</i> , 2005
Abeokuta, Nigeria	68.74 μ Sv/year	Okeyode <i>et al.</i> , 2010
Gombe State, Nigeria	0.54 mSv/year	Present Study

The values obtained in this study are slightly above the world average annual effective dose level for indoor and outdoor environments, which is an indication of a minor radiological contamination in some major towns of Gombe state. Figure 3 gives the summary of the indoor and outdoor annual effective dose equivalent for each local community in the state.

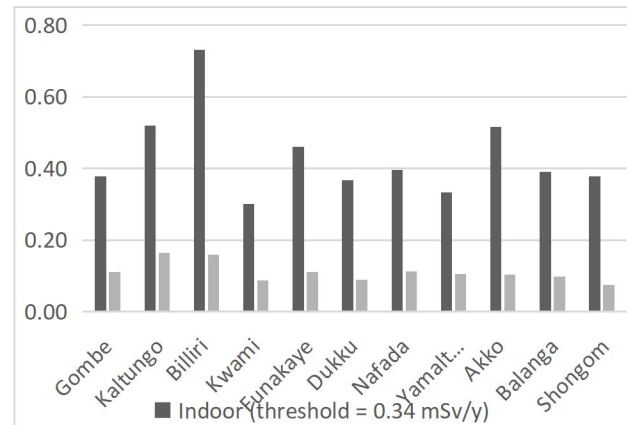


Figure 3: Indoor and Outdoor Annual Effective Dose Equivalent (mSv/y) of some major towns in Gombe State

Lifetime Cancer Risk (Indoor and Outdoor)

Using the values of annual effective dose, lifetime cancer risk (LCR) for the indoor and outdoor was calculated using equation (4) and (5) above respectively. The indoor

lifetime cancer risk (LCR_{in}) estimated for some major towns in Gombe state as shown in Table 2 ranged from 1.20×10^{-3} to 2.56×10^{-3} with an average of 1.66×10^{-3} which is 1.05×10^{-3} high than the report from Warri City of Delta state Nigeria by Agbalagba (2017), while the outdoor lifetime cancer risk (LCR_{out}) exposure ranged from 0.30×10^{-3} to 0.58×10^{-3} with an average value of 0.42×10^{-3} . The total $LCR_{in} + LCR_{out}$ ranges from 1.5×10^{-3} to 3.15×10^{-3} with an average of 2.08×10^{-3} which is 1.13×10^{-3} less than the Northern Pakistan by Aziz (2014). The total lifetime cancer risk reported ELCR from estimated shows that it is 1.43×10^{-3} times higher than the world's average value of 1.45×10^{-3} . Figure 4 shows the variation of values for the indoor and outdoor lifetime cancer risk in which Billiri town shows high value of 2.56×10^{-3} for indoor and 0.56×10^{-3} for the outdoor exposure.

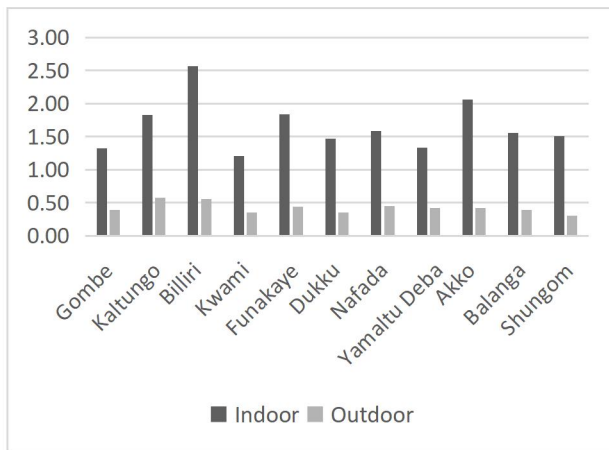


Figure 4: Indoor and Outdoor Lifetime Cancer Risk of some major towns in Gombe State.

The total average LCR value obtained in the current study area is higher than the world average value of 1.45×10^{-3} . This LCR value indicates that the chance of contracting cancer by residents of the study area who will spend all of their lives in the specific area of study is likely from Background

Ionizing Radiation exposure (i.e. Stochastic effect).

Equivalent Dose Rate (mSv/y)

The EDR of some major towns in Gombe state as shown in Table 2 ranged from 0.59 ± 0.07 to 1.44 ± 0.55 mSv/y with a total average of 0.86 mSv/y. This shows a close value to the worlds standard of 1 mSv/y. Figure 5 below shows a comparison of the overall EDR values obtained in some major towns of Gombe state.

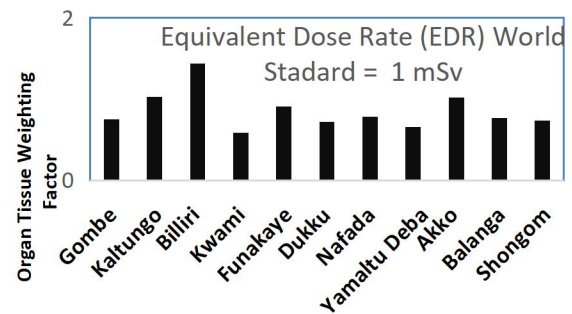


Figure 5: The Equivalent Dose Rate in major towns of Gombe State.

It was observed that Billiri town has an increase in EDR with a value of 1.44 mSv/y while Akko and Kaltungo have a slight increase in EDR if compared to the recommended limit of 1.0 mSv/y by UNSCEAR (2000).

Our results show an elevation of the radiation exposure level, equivalent dose rate, absorbed dose rate, effective dose equivalent rate and lifetime cancer risk in the study area especially in towns of Billiri, Kaltungo, Akko and Funakaye respectively.

However, these values may not constitute any immediate health hazard to the particular community of Gombe state but there may be likelihood of future, long term health risk for the populace living in the study area for a long period of time.

CONCLUSION



These work findings have shown that the background ionizing radiation levels of the areas investigated are at the normal background radiation level except for Billiri town which has shown high values. This can be linked to the topography (hills and valleys) of the area and human activities. The indoor absorbed dose rate at Kaltungo, Akko, Billiri and Funakaye showed a need for regular monitoring to present future hazards of background ionizing radiation. The excess lifetime cancer risk values indicated that the probabilities of contracting cancer for residents of Gombe, Kwami, Dukku, Yamaltu Deba, Bajoga, Shongom, Balanga, Funakaye, Kaltungo are low but higher in Billiri, and Akko (*Mai-Ganga*). These elevated values may not constitute any immediate health risk to the residents of a particular area but long term exposure may have some desirable consequences on the populace.

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