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# OUTDOOR BACKGROUND GAMMA RADIATION LEVELS IN RURAL ENVIRONMENTS OF ENUGU EAST, NIGERIA.

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## ABSTRACT

*The human populace is constantly irradiated both in the indoor and outdoor environment, as such, estimating the doses of radiation circulating in the environment is key in examining the health exposure to the populace. In this regard, in-situ measurements of outdoor radiation exposure rates in five rural communities of Enugu East local government area of Enugu State, Nigeria were made in this present study using a portable factory calibrated GQ GMC-320 PLUS radiation survey meter held at 1.0 m above ground level alongside a GPS for geographical location. The exposure rates in mRh$^{-1}$ were converted to radiation hazard indices using well established relations. The results revealed that the mean background radiation exposure levels for Akpoga, Nchetanche, Obinagu and Onuogba are generally lower than ICRP reference level of 0.013 mRhr$^{-1}$ for outdoor environments while that of Nkwubor exceeded the limit by 7.7%. The radiation absorbed dose, equivalent dose, annual effective dose equivalent and excess lifetime cancer risks were calculated. The purpose is to assess the radiological risk due to radiation exposure in the communities. The terrestrial gamma radiation levels at some locations in the communities are somewhat low and high. The radiation dose values are generally below the values considered to cause immediate harmful effects and thus do not pose any immediate health hazards to the residents at this present moment. However, continuous exposure and accumulation of low radiation doses may pose radiological health risks to the people living in the areas in future.*

***KEYWORDS:*** *Background radiation; dose levels; health effect; rural communities*

## INTRODUCTION

There has been great interest worldwide by environmental radiation protection scientists and agencies for the study of naturally radioactivity and background radiation assessment and monitoring. It is believed that radioactivity monitoring in Nigeria started about late 1959 and the early 1960s. This was in reaction to ‘the atmospheric weapons test’ which was reportedly carried out by France at Reganne a town located in central Algeria (Olomo, 1990; Mokobia and Balogun, 2004). Several investigation on the natural radioactivity as well as the background radiation levels have since then been carried out in different environments in the country. Background radiation mainly originates from natural sources of both terrestrial and extraterrestrial sources. The terrestrial component is due to the radioactive nuclides termed primordial radionuclides because they have existed since the creation of the earth. The most important of these are $^{238}U$ and $^{232}Th$ and their decay products as well as non-series $^{40}K$. These are found in air, soil, rock, water and building materials. Their specific concentrations vary significantly depending on the geological and geographical characteristics of the environment (Gholami *et al*., 2011). The extraterrestrial component is due to cosmic rays from outer space whose contribution to background radiation changes with elevation and solar cycle (UNSCEAR, 2000). In addition to these natural sources, anthropogenic or man-made activities have contributed to increased radiation levels in the environment. Exploration of the environment for the total benefit of man has led to some increase in radiation exposure of the general public and occupational mine workers.

The human populace is constantly irradiated both in the indoor and outdoor environment and as such, estimating the doses of radiation circulating in the environment is key in examining the health exposure to a populace (Obed *et al*., 2005). Such investigations can be useful for both assessment of public dose rates and the performance of epidemiological studies, as well as keeping reference data records to ascertain possible changes in the environmental radioactivity due to nuclear, industrial, and other human activities (Tzortzis *et al*., 2004). For some of the inhabitable environments, no radiological assessment and monitoring has been carried out, consequently baseline data about the gamma radiation dose in such environments are not available and no attempt made to assess the health risk associated with it. In this present study, the background gamma radiation levels at 1.0 m above the ground level are measured in five rural communities located in Enugu East local government area (LGA) of Enugu State, Nigeria. The purpose of these measurements is to provide a baseline data on background radiation level in the rural communities and to assess the radiological health parameters associated with it. The data is expected to form part of the already existing radiation dose databank in the country (Mokobia and Balogun, 2004) which will be of importance to the regulation formation activities of the Nigeria Nuclear Regulatory Authority (NNRA).

## MATERIALS AND METHODS

### Study area

The background radiation level measurements were carried out in the outdoor environments of Akpoga Nike, Nchetanche, Nkwubor Nike, Obinagu and Onuogba. These are all located in Enugu east local government area of Enugu State, South Eastern Nigeria. Figure 1 shows the map of the Enugu State indicating the study area. Enugu east lies on the Campano-Maestrichtian sediment of South-Eastern Nigeria, called Enugu shale and falls within the Anambra Basin. The Enugu shale is composed of dark grey, fissile shale with occasional thin beds of clay, siderite and Mudstone (Okamkpa *et al*., 2018). Similar to other areas in Nigeria, the study area is characterized by both wet and dry seasons.

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The people in the area are involved in farming and business activities.

**Measurement of background gamma radiation level**

The measurements were made using a factory-calibrated portable GQ GMC-320 PLUS nuclear radiation survey meter (from GQ Electronics LLC, USA). The radiation meter contains a Geiger-Muller detector tube capable of detecting α, β, γ and x-rays. It has gamma radiation energy range of 0.1 to 1.25 MeV and sensitivity of 0.1 ~ 1 MeV.

Measurements were carried out in 10 sampling points in each of the community. These locations were chosen based on factors such as residential location/population density, educational institution, primary health care center, market, etc. The precise locations of the points were determined using a geographical positioning system (GPS). The radiation exposure levels of each community were monitored for one year (September 2017 to September 2018 at two months interval). This was done to account for any variation in the environmental parameters due to seasonal condition. To account for the fluctuating nature of radiation, the radiation meter was switched on for 600 seconds with its window facing any suspected radiation sources. The meter was placed 1.0 m above ground level. The reading indicated by the meter at the end of the time limit was recorded for that point. A total of 10 measurements were made in each sample point and the average recorded.

Measurements were made between 1300 and 1600 hours being the periods that the meter is known to have a maximum response to environmental radiation (National Council Radiation Protection and Measurements NCRP, 1993). The average exposure rates obtained were used to quantify the radiation health parameters using well established mathematical relationships. The values obtained were then used to evaluate the radiological health compliance of the studied environments.

***Calculation of equivalent dose rate***

To estimate the whole body equivalent dose rate over a period of one year, the recommendation of the NCRP was adopted (NCRP, 1993; Avwiri *et al*., 2013; Mokobia *et al*., 2016);

$$1mRh^{-1} = \frac{0.96 \times 24 \times 365}{100} mSvy^{-1} \qquad (1)$$

***Calculation of absorbed dose rate***

The absorbed dose was estimated using equation 2 (Rafique *et al*., 2014; Agbalagba *et al*., 2016a; Agbalagba, 2017).

$$1\mu Rh^{-1} = 8.7nGyh^{-1} = \frac{8.7 \times 10^{-3}}{(1/8760y)} \mu Gyy^{-1} \qquad (2)$$

This implies that;

$$1mRh^{-1} = 8.7nGyh^{-1} \times 10^{3} = 8700\eta Gyh^{-1} \qquad (3)$$

***Calculation of annual effective dose equivalent (AEDE)***

The AEDE was calculated using the values of the absorbed dose according to the equation (Rafique *et al*., 2014; Agbalagba *et al*., 2016a; Agbalagba, 2017).

$$AEDE\left(mSvy^{-1}\right) = ADR\left(nGyh^{-1}\right) \times 8760h \times 0.7Sv/Gy \times 0.2 \quad (4)$$

Where ADR is the absorbed dose rate in $nGyh^{-1}$, 8760 is the total hours in a year, 0.7Sv/Gy is the dose conversion factor from absorbed dose in air to the effective dose and 0.2 is the occupancy factor for outdoor exposure as recommended by UNSCEAR (UNSCEAR, 2000, 2008).

***Calculation excess life cancer risk (ELCR)***

The ELCR was evaluated using the annual effective dose values using Equation 5 (Taskin *et al*., 2009; Rafique *et al*., 2014; Agbalagba, 2017).

$$ELCR = AEDE\left(mSvy^{-1}\right) \times DL \times RF \quad (5)$$

Where DL is average duration of life (70 years) and RF is the fatal cancer risk factor per sievert ($Sv^{-1}$). For low-dose background radiation, which is considered to produce stochastic effects, ICRP 103 uses a fatal cancer risk factor value of 0.05 for public exposure (ICRP, 2007).

## RESULTS

Tables 1 to 5 show the results of the in-situ measurement of background radiation exposure rates within the period of investigation for Akpoga, Nchetanche, Nkwubor, Obinagu and Onuogba respectively while the average background radiation exposure level and the related radiological parameters evaluated for the five communities are summarized in Tables 6 to 10 respectively. In Table 11, the obtained radiation levels as well as the health indices in the communities in comparison with the world average recommended value are shown.

## DISCUSSION

The background radiation exposure rates within the studied periods ranged from 0.006 – 0.017 $mRh^{-1}$ in Akpoga and Nchetanche; 0.008 – 0.022 $mRh^{-1}$ in Nkwubor, 0.006 – 0.021 $mRh^{-1}$ in Obinagu and 0.008 – 0.018 $mRh^{-1}$ in Onuogba. Figure 2 shows the variation of radiation exposure level of the communities within the study periods as compared with the permissible limit. The average exposure radiation levels for Akpoga range from 0.007 – 0.015 $mRh^{-1}$ with mean value of 0.012±0.003 $mRh^{-1}$, that for Nchetanche range from 0.009 – 0.015 $mRh^{-1}$ with mean value of 0.012±0.002 $mRh^{-1}$, for Nkwubor it is 0.010 – 0.019 $mRh^{-1}$ with mean of 0.014±0.003 $mRh^{-1}$, for Obinagu it is 0.008 – 0.019 $mRh^{-1}$ with mean value of 0.012±0.003 $mRh^{-1}$ and that for Onuogba range from 0.011 – 0.014 $mRh^{-1}$ having a mean value of 0.012±0.001 $mRh^{-1}$. The lowest average radiation exposure level 0.007 $mRh^{-1}$ was noticed at location AKP7 in Akpoga community while the highest exposure level of 0.019 $mRh^{-1}$ was measured at locations NKW4 and NKW7 in Nkwubor and OBI5 in Obinagu. The mean radiation absorbed dose, equivalent dose and annual effective dose are 100.92±23.98 $nGyh^{-1}$, 0.975±0.232 $mSvy^{-1}$ and 0.124±0.029 $mSvy^{-1}$ respectively for Akpoga community; 100.05±17.52 $nGyh^{-1}$, 0.967±0.169 $mSvy^{-1}$ and 0.123±0.021 $mSvy^{-1}$ respectively for Nchetanche; 123.54±26.83 $nGyh^{-1}$, 1.194±0.259 $mSvy^{-1}$ and 0.152±0.033 $mSvy^{-1}$ respectively for Nkwubor Nike; 107.88±29.35 $nGyh^{-1}$,

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1.043±0.284 $mSvy^{-1}$, and 0.132±0.036 $mSvy^{-1}$ respectively for Obinagu Nike and 107.88±10.21 $nGyh^{-1}$, 1.043±0.099 $mSvy^{-1}$, and 0.132±0.013 $mSvy^{-1}$ respectively for Onuogba community.

The obtained exposure rates are found to vary slightly with the periods of study as well as with locations. Although the variation does not follow a definite pattern however, the average exposure rates in the communities tend to peak in December except for Obinagu which have its peak in March. This may plausibly be due to the dry season in Nigeria, which basically stretches from October to march, with slight variation depending on the location. This period is characterized of intense sun rays (solar radiation) and dry harmattan breeze. Due to the tilting of the earth, the sun's ray and cosmic radiation impact the earth's surface more during this period. This result is consistent with the reports of Saghatchi *et al*. (2008), Eslami *et al*. (2016) and Hashemi *et al* (2018) who had observed higher background radiation values during the spring (December to March) than winter (June to August) periods. Furthermore, gaseous radionuclides, radon and thoron, and their progenies are more dispersed during this season as they readily mix up with the air and dust particles carried by the harmattan breeze. The mean radiation exposure levels for Akpoga, Nchetanche, Obinagu and Onuogba appeared to be generally low ranging when compared with permissible safe limit of 0.013 $mRh^{-1}$ for general public (UNSCEAR, 2000, 2008; Rafique *et al*., 2014; Agbalagba, 2017). The low mean radiation exposure levels are indication that the outdoor environments of these four communities are radiologically safe for the general public. On the other hand, the mean exposure level for Nkwubor exceeded the safe limit by 7.7%. An inspection of the Nkwubor environment was done for possible contributing factors to the radiation levels of the area and it was found that the area is characterized of sandstone and surrounded by laterite. Lateritic soils are soils that have undergone a serious weathering process. They are enriched with oxides of aluminum, iron or both and usually contain high quantities of kaolinite and quartz and usually lack the primary silicates and their bases (Enaworu *et al*., 2017). These materials undoubtedly contain some levels of naturally occurring radioactive materials (NORMs).

The mean absorbed doses for the five communities are higher than the world average value of 59.00 $nGyh^{-1}$ reported by UNSCEAR (2008) from different countries of the world in the range of 18- 93 $nGyh^{-1}$ and the recommended safe limit of 84.0 $nGyh^{-1}$ (UNSCEAR, 2008; Ononugbo and Mgbemere, 2016). This is clearly shown in Figure 3. The mean values are also higher than values of 77.20 $nGyh^{-1}$, 93.96 $nGyh^{-1}$ and 92.22 $nGyh^{-1}$ in coastal communities of Aboh, Asemuku and Agwe-Etiti respectively in Delta State, Nigeria (Ononugbo and Nte, 2017) and also value of 81.61 $nGyh^{-1}$ in Muzaffarabad, Pakistan (Rafique, 2013). They are also higher than values reported in some part of the world like New Zealand (20 $nGyh^{-1}$), United States (38 $nGyh^{-1}$), United Kingdom (60 $nGyh^{-1}$), Poland (67 $nGyh^{-1}$), Norway (80 $nGyh^{-1}$), China (100 $nGyh^{-1}$), Portugal (102 $nGyh^{-1}$), Italy (105 $nGyh^{-1}$) as documented in UNSCEAR (2000). Those of Akpoga and Nchetanche are lower than the values in Portugal and Italy. The mean exposure level and radiation doses in

Onuogba and Obinagu communities are the same as that of Abalagada community of Delta State (Ononugbo and Nte, 2017). The dose levels in this present study are lower than 135.2 $nGyh^{-1}$ in Loktak Lake environment of Manipur, India (Sharma and Singh, 2018), 147.9 $nGyh^{-1}$ in Okpara mines and its environs (Agbalagba *et al*., 2016b), 139.2 $nGyh^{-1}$ in Bunker coal mineral mining sites of Enugu State (Agbalagba *et al*., 2016b), 132.16 $nGyh^{-1}$ in Ughelli metropolis (Agbalagba *et al*., 2016a). The variation in the absorbed dose in the present study with other parts of the world shows the spatial variation in the natural background radiation level as depended on the geological and geophysical settings of the environment. The absorbed dose values presented in this study have been reported to be below dose values considered to cause any immediate harmful effects (Sharma *et al*., 2014). In this regard, some researchers have proposed that exposures from low dose radiation might be beneficial for human health (Cuttler, 2013).

The annual effective dose equivalent values for the communities shown in column six of Tables 6 to 10 are found to be within ICRP (2007) and UNSCEAR (2008) recommended permissible limits of 1.00 $mSvy^{-1}$ for general public (Figure 4) but are higher than reported world average value of 0.07 $mSvy^{-1}$ (UNSCEAR, 2008; Agbalagba, 2017). The mean AEDE for the five communities which range from 0.123 to 0.152 $mSvy^{-1}$ is similar to mean range of 0.119 to 0.153 $mSvy^{-1}$ in populated motor parks area within Enugu town (Benson and Ugbede, 2018). The low AEDE values further confirmed that the gamma absorbed doses at this present level is not detrimental and may not cause any harmful biological effects to exposed individuals. When compared with other values within Nigeria, the mean AEDE values in this present study are lower than values of 0.25±0.04 and 1.29±0.13 $mSvy^{-1}$ in Keffi and Akwanga towns of Nassarawa State (Termizi-Ramli *et al*., 2014), 0.45±0.27 $mSvy^{-1}$ in Abeokuta in Ogun State (Farai and Vincent, 2006), 0.17±0.04 $mSvy^{-1}$ in Warri city (Agbalagba, 2017), 0.193 $mSvy^{-1}$ in Ikare (Asere and Ajayi, 2017), 0.160 $mSvy^{-1}$ in Aboh (Ononugbo and Nte, 2017), 0.16±0.03 $mSvy^{-1}$ in Ughelli (Agbalagba *et al*., 2016a) and 0.1426 $mSvy^{-1}$ in Uyo unity park (Etuk *et al*., 2017). Slight significant variations have been observed in the radiation levels of the communities but no significant changes in gamma radiation level due to seasonal variations were observed when compared to similar study conducted in Hyderabad, India (Reddy *et al*., 2010).

The calculated values of ELCR for the communities were found to vary from $0.263\times10^{-3}$ to $0.711\times10^{-3}$. The estimated mean values are $0.433\times10^{-3}$, $0.430\times10^{-3}$, $0.531\times10^{-3}$, $0.464\times10^{-3}$ and $0.467\times10^{-3}$ in Akpoga, Nchetanche, Nkwubor Nike, Obinagu Nike and Onuogba respectively. These mean values are higher than reported world average value of $0.29\times10^{-3}$ (UNSCEAR, 2000; Taskin *et al*., 2009). The mean ELCR values report here are lower than values in industrial areas of Warri, Nigeria (Agbalagba, 2017) and also lower than those in Okposi Okwu and Uburu salt lakes environments in Ebonyi State, Nigeria (Avwiri *et al*., 2016).

Though the terrestrial gamma radiation levels at some locations in the communities

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are somewhat above the world average permissible limits, all the values are well below the world background radiation level of 2.4 mSv annually (UNSCEAR, 2000). This, therefore, has reaffirmed that the radiation levels in these communities may not pose any immediate health hazards to the residents at this present moment. However, continuous exposure and accumulation of low radiation doses may pose radiological health risks to the people living in the areas in future as suggested by the ELCR values.

**Table 1: Measured background radiation exposure rates for different months in Akpoga Nike**

| Location code | Geographical Location | Outdoor background radiation exposure rates (mR/h) | | | | | Average Exposure Reading (mR/h) |
|---|---|---|---|---|---|---|---|
| | | Sept. 2017 | Dec. 2017 | March 2018 | June 2018 | Aug. 2018 | |
| AKP 1 | N6º27' 31.51"; E7º36' 56.18" | 0.007 | 0.008 | 0.008 | 0.010 | 0.006 | 0.008 |
| AKP 2 | N6º27' 36.70"; E7º37' 0.36" | 0.012 | 0.014 | 0.011 | 0.013 | 0.011 | 0.012 |
| AKP 3 | N6º27' 27.26"; E7º37' 1.58" | 0.015 | 0.013 | 0.014 | 0.012 | 0.016 | 0.014 |
| AKP 4 | N6º27' 34.27"; E7º37' 10.64" | 0.014 | 0.012 | 0.015 | 0.011 | 0.011 | 0.013 |
| AKP 5 | N6º27' 35.19"; E7º37' 24.99" | 0.013 | 0.016 | 0.015 | 0.017 | 0.012 | 0.015 |
| AKP 6 | N6º27' 49.37"; E7º37' 31.28" | 0.010 | 0.011 | 0.008 | 0.010 | 0.014 | 0.011 |
| AKP 7 | N6º27' 58.34"; E7º36' 17.38" | 0.005 | 0.008 | 0.008 | 0.010 | 0.016 | 0.007 |
| AKP 8 | N6º27' 46.06"; E7º36' 26.69" | 0.015 | 0.017 | 0.016 | 0.011 | 0.013 | 0.014 |
| AKP 9 | N6º27' 48.77"; E7º36' 31.79" | 0.008 | 0.012 | 0.009 | 0.006 | 0.010 | 0.009 |
| AKP 10 | N6º27' 39.90"; E7º36' 33.98" | 0.012 | 0.016 | 0.015 | 0.010 | 0.014 | 0.013 |
| **Monthly Average** | | **0.011** | **0.013** | **0.012** | **0.011** | **0.012** | **0.012±0.003** |

**Table 2: Measured background radiation exposure rates for different months in Nchetanche**

| Location code | Geographical Location | Outdoor background radiation exposure rates (mR/h) | | | | | Average Exposure Reading (mR/h) |
|---|---|---|---|---|---|---|---|
| | | Sept. 2017 | Dec. 2017 | March 2018 | June 2018 | Aug. 2018 | |
| NCH 1 | N6º27' 32.52"; E7º36' 15.38" | 0.014 | 0.017 | 0.016 | 0.014 | 0.013 | 0.015 |
| NCH 2 | N6º27' 30.49"; E7º36' 23.70" | 0.008 | 0.010 | 0.009 | 0.010 | 0.011 | 0.010 |
| NCH 3 | N6º27' 19.92"; E7º36' 26.41" | 0.008 | 0.011 | 0.010 | 0.010 | 0.009 | 0.014 |
| NCH 4 | N6º27' 28.35"; E7º36' 17.09" | 0.010 | 0.011 | 0.009 | 0.010 | 0.008 | 0.010 |
| NCH 5 | N6º27' 27.88"; E7º36' 17.38" | 0.011 | 0.014 | 0.012 | 0.012 | 0.012 | 0.012 |
| NCH 6 | N6º27' 21.99"; E7º36' 12.46" | 0.011 | 0.015 | 0.010 | 0.011 | 0.016 | 0.013 |
| NCH 7 | N6º27' 12.35"; E7º36' 4.66" | 0.013 | 0.010 | 0.008 | 0.010 | 0.010 | 0.010 |
| NCH 8 | N6º27' 23.33"; E7º36' 4.14" | 0.011 | 0.015 | 0.010 | 0.012 | 0.011 | 0.012 |
| NCH 9 | N6º27' 26.95"; E7º35' 54.91" | 0.006 | 0.008 | 0.013 | 0.009 | 0.009 | 0.009 |
| NCH 10 | N6º27' 36.56"; E7º36' 10.79" | 0.009 | 0.013 | 0.008 | 0.011 | 0.010 | 0.010 |
| **Monthly Average** | | **0.010** | **0.012** | **0.011** | **0.011** | **0.011** | **0.012±0.002** |

**Table 3: Measured background radiation exposure rates for different months in Nkwubor Nike**

| Location code | Geographical Location | Outdoor background radiation exposure rates (mR/h) | | | | | Average Exposure Reading (mR/h) |
|---|---|---|---|---|---|---|---|
| | | Sept. 2017 | Dec. 2017 | March 2018 | June 2018 | Aug. 2018 | |
| NKW 1 | N6º29' 59.85"; E7º35' 59.20" | 0.013 | 0.017 | 0.011 | 0.012 | 0.013 | 0.013 |
| NKW 2 | N6º30' 4.86"; E7º35' 59.66" | 0.009 | 0.010 | 0.011 | 0.009 | 0.012 | 0.010 |
| NKW 3 | N6º30' 9.98"; E7º35' 57.76" | 0.016 | 0.017 | 0.016 | 0.016 | 0.014 | 0.016 |
| NKW 4 | N6º30' 16.25"; E7º35' 55.25" | 0.020 | 0.021 | 0.020 | 0.017 | 0.018 | 0.019 |
| NKW 5 | N6º30' 21.18"; E7º35' 50.28" | 0.017 | 0.014 | 0.014 | 0.015 | 0.014 | 0.015 |

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| NKW 6 | N6º30' 17.95"; E7º35' 52.37" | 0.011 | 0.013 | 0.011 | 0.013 | 0.013 | 0.012 |
| NKW 7 | N6º30' 18.17"; E7º35' 49.73" | 0.017 | 0.020 | 0.022 | 0.018 | 0.018 | 0.019 |
| NKW 8 | N6º30' 4.24"; E7º36' 3.61" | 0.015 | 0.015 | 0.011 | 0.013 | 0.014 | 0.014 |
| NKW 9 | N6º30' 3.89"; E7º36' 6.90" | 0.010 | 0.011 | 0.017 | 0.010 | 0.015 | 0.013 |
| NKW 10 | N6º30' 2.48"; E7º36' 13.94" | 0.013 | 0.011 | 0.009 | 0.012 | 0.008 | 0.011 |
| **Monthly Average** | | **0.014** | **0.015** | **0.014** | **0.014** | **0.014** | **0.014±0.003** |

**Table 4: Measured background radiation exposure rates for different months in Obinagu Nike**

| Location code | Geographical Location | Outdoor background radiation exposure rates (mR/h) | | | | | Average Exposure Reading (mR/h) |
|---|---|---|---|---|---|---|---|
| | | **Sept. 2017** | **Dec. 2017** | **March 2018** | **June 2018** | **Aug. 2018** | |
| OBI 1 | N6º27' 30.74"; E7º36' 4.46" | 0.010 | 0.008 | 0.012 | 0.007 | 0.008 | 0.009 |
| OBI 2 | N6º27' 38.08"; E7º36' 0.93" | 0.012 | 0.013 | 0.017 | 0.010 | 0.011 | 0.013 |
| OBI 3 | N6º27' 48.66"; E7º35' 53.48" | 0.010 | 0.012 | 0.012 | 0.008 | 0.014 | 0.011 |
| OBI 4 | N6º27' 36.62"; E7º35' 51.94" | 0.014 | 0.018 | 0.016 | 0.015 | 0.016 | 0.016 |
| OBI 5 | N6º27' 26.65"; E7º35' 48.57" | 0.018 | 0.017 | 0.021 | 0.018 | 0.020 | 0.019 |
| OBI 6 | N6º27' 46.81"; E7º36' 6.50" | 0.014 | 0.013 | 0.013 | 0.013 | 0.012 | 0.013 |
| OBI 7 | N6º27' 53.49"; E7º35' 55.48" | 0.010 | 0.010 | 0.018 | 0.015 | 0.011 | 0.013 |
| OBI 8 | N6º27' 57.43"; E7º35' 59.72" | 0.006 | 0.011 | 0.009 | 0.010 | 0.008 | 0.009 |
| OBI 9 | N6º28' 2.63"; E7º36' 3.14" | 0.014 | 0.014 | 0.016 | 0.011 | 0.011 | 0.013 |
| OBI 10 | N6º28' 1.23"; E7º36' 1.05" | 0.009 | 0.011 | 0.008 | 0.006 | 0.007 | 0.008 |
| **Monthly Average** | | **0.012** | **0.013** | **0.014** | **0.011** | **0.012** | **0.012±0.003** |

**Table 5: Measured background radiation exposure rates for different months in Onuogba**

| Location code | Geographical Location | Outdoor background radiation exposure rates (mR/h) | | | | | Average Exposure Reading (mR/h) |
|---|---|---|---|---|---|---|---|
| | | Sept. 2017 | Dec. 2017 | March 2018 | June 2018 | Aug. 2018 | |
| ONU 1 | N6º28' 12.13"; E7º36' 33.55" | 0.014 | 0.012 | 0.010 | 0.008 | 0.009 | 0.011 |
| ONU 2 | N6º28' 13.34"; E7º36' 41.29" | 0.018 | 0.014 | 0.012 | 0.012 | 0.013 | 0.014 |
| ONU 3 | N6º28' 6.25"; E7º36' 40.69" | 0.012 | 0.014 | 0.011 | 0.010 | 0.016 | 0.013 |
| ONU 4 | N6º28' 5.79"; E7º36' 33.85" | 0.015 | 0.012 | 0.015 | 0.013 | 0.016 | 0.014 |
| ONU 5 | N6º28' 19.33"; E7º36' 46.18" | 0.014 | 0.013 | 0.012 | 0.012 | 0.012 | 0.013 |
| ONU 6 | N6º28' 26.75"; E7º36' 53.42" | 0.012 | 0.011 | 0.011 | 0.011 | 0.010 | 0.011 |
| ONU 7 | N6º28' 26.12"; E7º36' 57.62" | 0.011 | 0.012 | 0.010 | 0.013 | 0.012 | 0.012 |
| ONU 8 | N6º28' 21.94"; E7º36' 50.83" | 0.013 | 0.014 | 0.014 | 0.012 | 0.012 | 0.013 |
| ONU 9 | N6º28' 19.99"; E7º36' 55.05" | 0.009 | 0.010 | 0.014 | 0.010 | 0.012 | 0.011 |
| ONU 10 | N6º28' 18.89"; E7º37' 2.34" | 0.014 | 0.014 | 0.010 | 0.012 | 0.012 | 0.012 |
| **Monthly Average** | | **0.013** | **0.013** | **0.012** | **0.011** | **0.012** | **0.012±0.003** |

**Table 6: Radiation level of Akpoga Nike in Enugu East LGA**

| Location Code | Geographical Location | Average Exposure Reading $mRh^{-1}$ | Equivalent dose $mSvy^{-1}$ | Absorbed dose $nGyh^{-1}$ | AEDE $mSvy^{-1}$ | ELCR$\times10^{-3}$ |
|---|---|---|---|---|---|---|
| AKP 1 | N6º27' 31.51"; E7º36' 56.18" | 0.008 | 0.673 | 69.60 | 0.085 | 0.298 |
| AKP 2 | N6º27' 36.70"; E7º37' 0.36" | 0.012 | 1.009 | 104.40 | 0.128 | 0.448 |
| AKP 3 | N6º27' 27.26"; E7º37' 1.58" | 0.014 | 1.177 | 121.80 | 0.149 | 0.522 |
| AKP 4 | N6º27' 34.27"; E7º37' 10.64" | 0.013 | 1.093 | 113.10 | 0.139 | 0.487 |
| AKP 5 | N6º27' 35.19"; E7º37' 24.99" | 0.015 | 1.261 | 130.50 | 0.160 | 0.560 |
| AKP 6 | N6º27' 49.37"; E7º37' 31.28" | 0.011 | 0.925 | 95.70 | 0.117 | 0.410 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| AKP 7 | N6º27' 58.34"; E7º36' 17.38" | 0.007 | 0.589 | 60.90 | 0.075 | 0.263 |
| AKP 8 | N6º27' 46.06"; E7º36' 26.69" | 0.014 | 1.177 | 121.80 | 0.149 | 0.522 |
| AKP 9 | N6º27' 48.77"; E7º36' 31.79" | 0.009 | 0.757 | 78.30 | 0.096 | 0.336 |
| AKP 10 | N6º27' 39.90"; E7º36' 33.98" | 0.013 | 1.093 | 113.10 | 0.139 | 0.487 |
| **MEAN** | | **0.012±0.003** | **0.975±0.232** | **100.92±23.98** | **0.124±0.029** | **0.433±0.103** |

## Table 7: Radiation level of Nchetanche in Enugu East LGA

| **Location Code** | **Geographical Location** | **Average Exposure Reading $mRh^{-1}$** | **Equivalent dose $mSvy^{-1}$** | **Absorbed dose $nGyh^{-1}$** | **AEDE $mSvy^{-1}$** | **ELCR×$10^{-3}$** |
|---|---|---|---|---|---|---|
| NCH 1 | N6º27' 32.52" ; E7º36' 15.38" | 0.015 | 1.261 | 130.50 | 0.160 | 0.560 |
| NCH 2 | N6º27' 30.49" ; E7º36' 23.70" | 0.010 | 0.841 | 87.00 | 0.107 | 0.375 |
| NCH 3 | N6º27' 19.92" ; E7º36' 26.41" | 0.014 | 1.177 | 121.80 | 0.149 | 0.522 |
| NCH 4 | N6º27' 28.35" ; E7º36' 17.09" | 0.010 | 0.841 | 87.00 | 0.107 | 0.375 |
| NCH 5 | N6º27' 27.88" ; E7º36' 17.38" | 0.012 | 1.009 | 104.40 | 0.128 | 0.448 |
| NCH 6 | N6º27' 21.99" ; E7º36' 12.46" | 0.013 | 1.093 | 113.10 | 0.139 | 0.487 |
| NCH 7 | N6º27' 12.35" ; E7º36' 4.66" | 0.010 | 0.841 | 87.00 | 0.107 | 0.375 |
| NCH 8 | N6º27' 23.33" ; E7º36' 4.14" | 0.012 | 1.009 | 104.4 | 0.128 | 0.448 |
| NCH 9 | N6º27' 26.95" ; E7º35' 54.91" | 0.009 | 0.757 | 78.30 | 0.096 | 0.336 |
| NCH 10 | N6º27' 36.56" ; E7º36' 10.79" | 0.010 | 0.841 | 87.00 | 0.107 | 0.375 |
| **MEAN** | | **0.012±0.002** | **0.967±0.169** | **100.05±17.52** | **0.123±0.021** | **0.430±0.075** |

**Table 8: Radiation level of Nkwubor Nike in Enugu East LGA**

| Location Code | Geographical Location | Average Exposure Reading $mRh^{-1}$ | Equivalent dose $mSvy^{-1}$ | Absorbed dose $nGyh^{-1}$ | AEDE $mSvy^{-1}$ | ELCR×$10^{-3}$ |
|---|---|---|---|---|---|---|
| NKW 1 | N6º29' 59.85"; E7º35' 59.20" | 0.013 | 1.093 | 113.10 | 0.139 | 0.487 |
| NKW 2 | N6º30' 4.86"; E7º35' 59.66" | 0.010 | 0.841 | 87.00 | 0.107 | 0.375 |
| NKW 3 | N6º30' 9.98"; E7º35' 57.76" | 0.016 | 1.346 | 139.20 | 0.171 | 0.599 |
| NKW 4 | N6º30' 16.25"; E7º35' 55.25" | 0.019 | 1.598 | 165.30 | 0.203 | 0.711 |
| NKW 5 | N6º30' 21.18"; E7º35' 50.28" | 0.015 | 1.261 | 130.50 | 0.160 | 0.560 |
| NKW 6 | N6º30' 17.95"; E7º35' 52.37" | 0.012 | 1.009 | 104.40 | 0.128 | 0.448 |
| NKW 7 | N6º30' 18.17"; E7º35' 49.73" | 0.019 | 1.598 | 165.30 | 0.203 | 0.711 |
| NKW 8 | N6º30' 4.24"; E7º36' 3.61" | 0.014 | 1.177 | 121.80 | 0.149 | 0.522 |
| NKW 9 | N6º30' 3.89"; E7º36' 6.90" | 0.013 | 1.093 | 113.10 | 0.139 | 0.487 |
| NKW 10 | N6º30' 2.48"; E7º36' 13.94" | 0.011 | 0.925 | 95.70 | 0.117 | 0.410 |
| **MEAN** | | **0.014±0.003** | **1.194±0.259** | **123.54±26.83** | **0.152±0.033** | **0.531±0.116** |

**Table 9: Radiation level of Obinagu Nike in Enugu East LGA**

| Location Code | Geographical Location | Average Exposure Reading $mRh^{-1}$ | Equivalent dose $mSvy^{-1}$ | Absorbed dose $nGyh^{-1}$ | AEDE $mSvy^{-1}$ | ELCR×$10^{-3}$ |
|---|---|---|---|---|---|---|
| OBI 1 | N6º27' 30.74"; E7º36' 4.46" | 0.009 | 0.757 | 78.30 | 0.096 | 0.336 |
| OBI 2 | N6º27' 38.08"; E7º36' 0.93" | 0.013 | 1.093 | 113.10 | 0.139 | 0.487 |
| OBI 3 | N6º27' 48.66"; E7º35' 53.48" | 0.011 | 0.925 | 95.70 | 0.117 | 0.410 |
| OBI 4 | N6º27' 36.62"; E7º35' 51.94" | 0.016 | 1.346 | 139.20 | 0.171 | 0.599 |
| OBI 5 | N6º27' 26.65"; E7º35' 48.57" | 0.019 | 1.598 | 165.30 | 0.203 | 0.711 |
| OBI 6 | N6º27' 46.81"; E7º36' 6.50" | 0.013 | 1.093 | 113.10 | 0.139 | 0.487 |
| OBI 7 | N6º27' 53.49"; E7º35' 55.48" | 0.013 | 1.093 | 113.10 | 0.139 | 0.487 |
| OBI 8 | N6º27' 57.43"; E7º35' 59.72" | 0.009 | 0.757 | 78.30 | 0.096 | 0.336 |
| OBI 9 | N6º28' 2.63"; E7º36' 3.14" | 0.013 | 1.093 | 113.10 | 0.139 | 0.487 |
| OBI 10 | N6º28' 1.23"; E7º36' 1.05" | 0.008 | 0.673 | 69.60 | 0.085 | 0.298 |
| **MEAN** | | **0.012±0.003** | **1.043±0.284** | **107.88±29.35** | **0.132±0.036** | **0.464±0.127** |

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**Table 10: Radiation level of Onuogba in Enugu East LGA**

| Location Code | Geographical Location | Average Exposure Reading $mRh^{-1}$ | Equivalent dose $mSvy^{-1}$ | Absorbed dose $nGyh^{-1}$ | AEDE $mSvy^{-1}$ | ELCR×$10^{-3}$ |
|---|---|---|---|---|---|---|
| ONU 1 | N6º28' 12.13"; E7º36' 33.55" | 0.011 | 0.925 | 95.70 | 0.117 | 0.410 |
| ONU 2 | N6º28' 13.34"; E7º36' 41.29" | 0.014 | 1.177 | 121.80 | 0.149 | 0.522 |
| ONU 3 | N6º28' 6.25"; E7º36' 40.69" | 0.013 | 1.093 | 113.10 | 0.139 | 0.487 |
| ONU 4 | N6º28' 5.79"; E7º36' 33.85" | 0.014 | 1.177 | 121.80 | 0.149 | 0.522 |
| ONU 5 | N6º28' 19.33"; E7º36' 46.18" | 0.013 | 1.093 | 113.10 | 0.139 | 0.487 |
| ONU 6 | N6º28' 26.75"; E7º36' 53.42" | 0.011 | 0.925 | 95.70 | 0.117 | 0.410 |
| ONU 7 | N6º28' 26.12"; E7º36' 57.62" | 0.012 | 1.009 | 104.40 | 0.128 | 0.448 |
| ONU 8 | N6º28' 21.94"; E7º36' 50.83" | 0.013 | 1.093 | 113.10 | 0.139 | 0.487 |
| ONU 9 | N6º28' 19.99"; E7º36' 55.05" | 0.011 | 0.925 | 95.70 | 0.117 | 0.410 |
| ONU 10 | N6º28' 18.89"; E7º37' 2.34" | 0.012 | 1.009 | 104.40 | 0.128 | 0.448 |
| **MEAN** | | **0.012±0.001** | **1.043±0.099** | **107.88±10.21** | **0.132±0.013** | **0.467±0.044** |

**Table 11: Comparison of Radiation level in rural communities of Enugu East LGA**

| Rural community | Mean Exposure $mRh^{-1}$ | Mean Equivalent $mSvy^{-1}$ | Mean Absorbed dose $nGyh^{-1}$ | Mean AEDE $mSvy^{-1}$ | Mean ELCR×$10^{-3}$ |
|---|---|---|---|---|---|
| Akpoga | 0.012±0.003 | 0.975±0.232 | 100.92±23.98 | 0.124±0.029 | 0.433±0.103 |
| Nchetonche | 0.012±0.002 | 0.967±0.169 | 100.05±17.52 | 0.123±0.021 | 0.430±0.075 |
| Nkwubor | 0.014±0.003 | 1.194±0.259 | 123.54±26.83 | 0.152±0.033 | 0.531±0.116 |
| Obinagu | 0.012±0.003 | 1.043±0.284 | 107.88±29.35 | 0.132±0.036 | 0.464±0.127 |
| Onuogba | 0.012±0.001 | 1.043±0.099 | 107.88±10.21 | 0.132±0.013 | 0.467±0.044 |

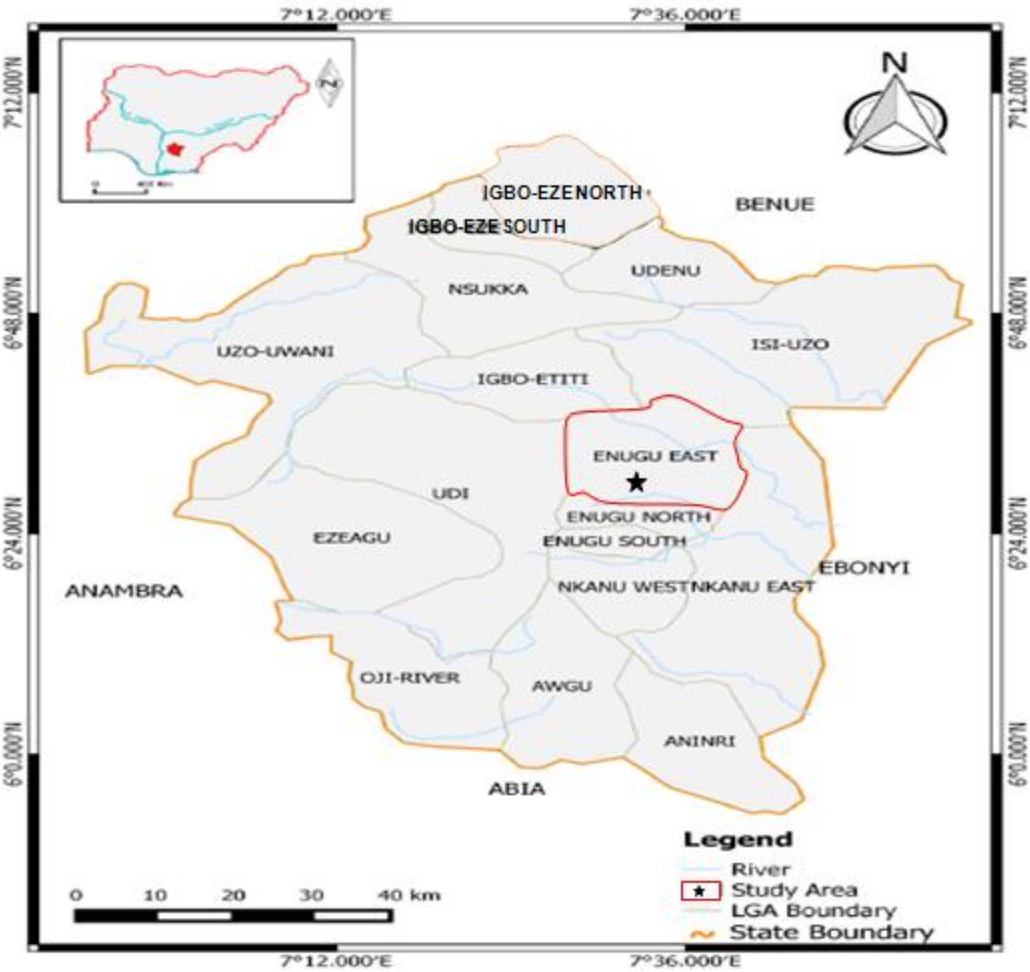


**Figure 1: Map of Enugu State showing the study area**

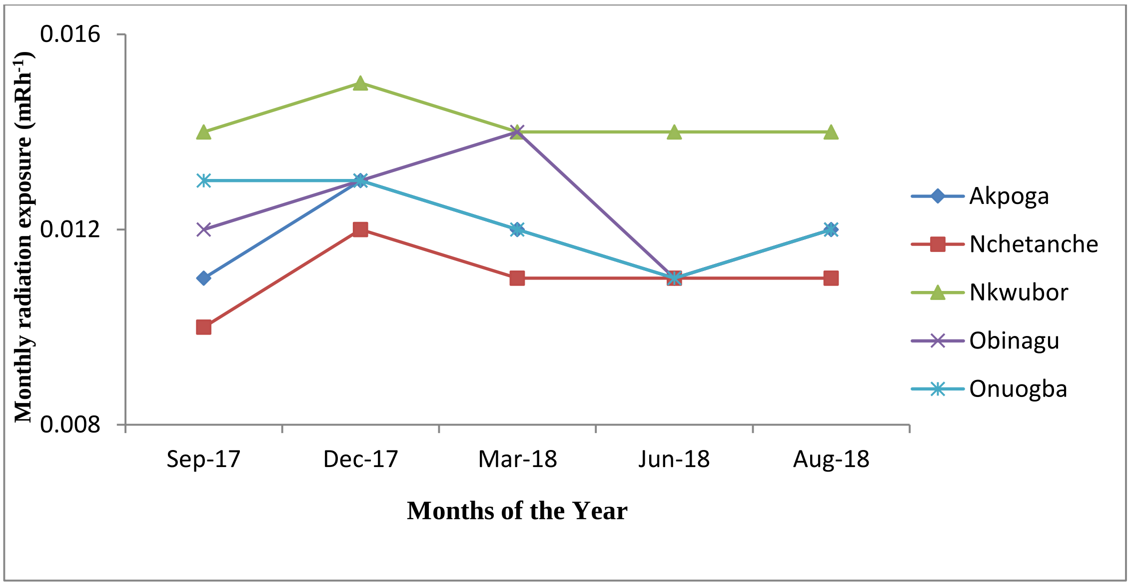


**Figure 2: Monthly variation of background radiation exposures**

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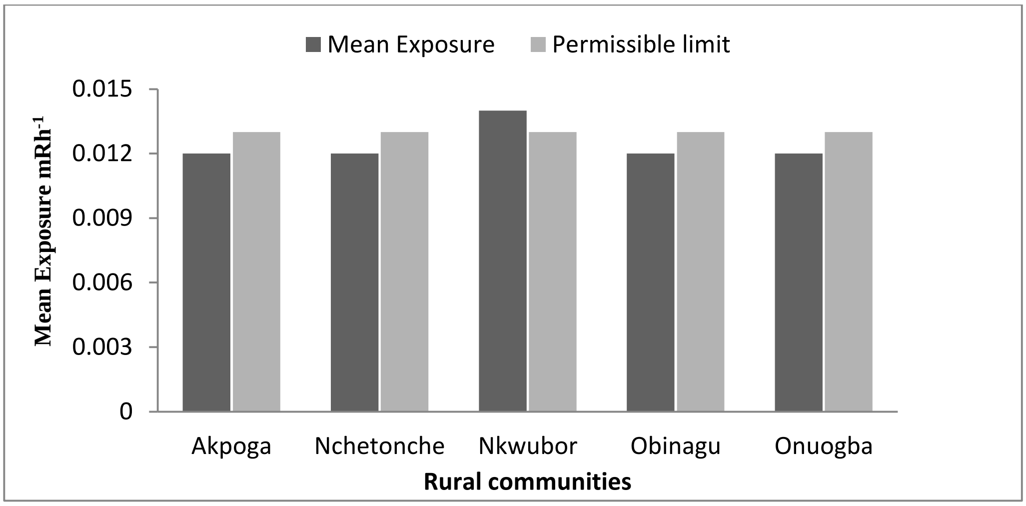


**Figure 3: Comparison of the mean exposure rate with recommended permissible limit**

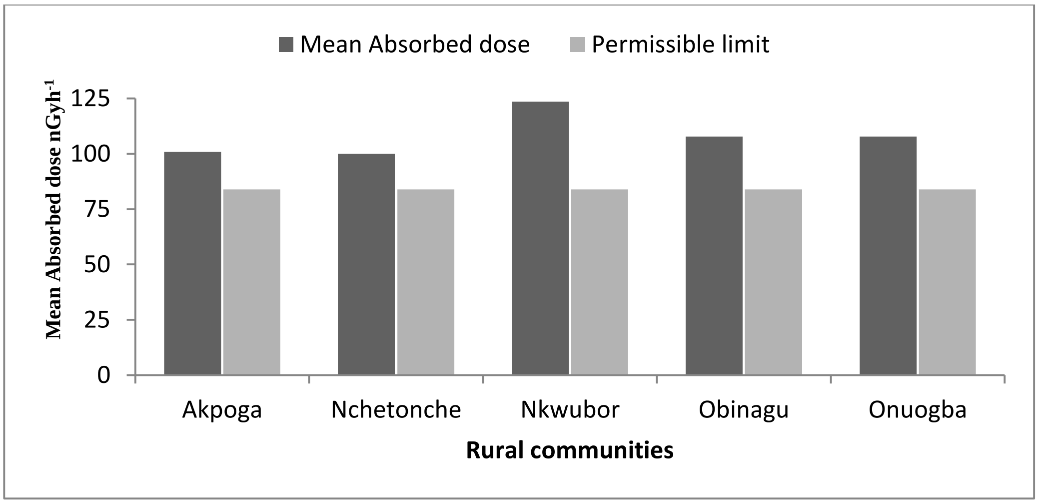


**Figure 4: Comparison of the mean absorbed dose rate with recommended limit**

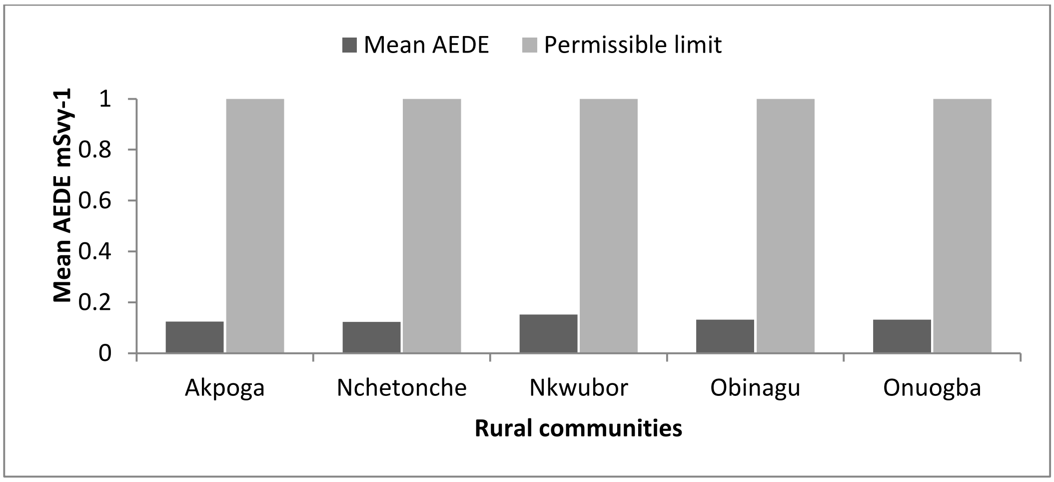


**Figure 5: Comparison of the mean annual effective dose equivalent with recommended limit**

## CONCLUSION

Direct *in-situ* measurements of terrestrial outdoor gamma radiation exposure rates and the consequent radiological health hazards assessment in the rural communities of Enugu east LGA has been concluded in this study. The terrestrial gamma radiation levels at some locations in the communities are somewhat low and high. The dose values are generally below the values considered to cause immediate harmful effects. It is therefore concluded that the radiation levels in the communities do not pose any immediate health hazards to the residents at this present moment.

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