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# Natural Background Radiation and Associated Radiological Hazard in Yewa Metropolis of Ogun State, Nigeria

**Olowofila O. Inioluwa[1] & Dosunmu G. Oluwaseun[2]**
[1]*Science Laboratory Technology Department, The Federal Polytechnic, Ilaro, Nigeria.*
[2]*Department of Physics, Federal University of Agriculture, Abeokuta*
*Corresponding Author Email: inioluwaolowofila@gmail.com*

## Abstract

*Natural background radiation and associated hazard assessment was carried out in Yewa metropolis area. Twenty-five soil samples were collected from selected towns including Idogo, Ilaro, Itolu, Iweke, and Owode. The collected samples were analyzed by gamma ray spectrometry. The mean activity concentration of the radionuclides $^{226}Ra$, $^{232}Th$ and $^{40}K$ in soil samples collected were 12.9±3.38, 6.40± .37 and 91.45±4.63 Bq/kg, respectively for Idogo; 5.72±0.33, 0.71± 3.60 and 148.40 ± 7.82 Bq/kg respectively for Ilaro; 24.66 ± 2.75, 5.35 ± 1.32 and 80.97 ± 4.12 Bq/kg for Itolu; 7.91 ± 1.02, 4.42 ± 0.28 and 105.25 ± 5.36 Bq/kg for Iweke and 26.20 ± 3.25, 4.84 ± 0.29 and 61.68 ± 3.26 Bq/kg for Owode. The results from the study sites were lower than the world average values of 35 and 30 Bq/kg and 400 Bq/kg for $^{226}Ra$, $^{232}Th$, and $^{40}K$, respectively. The average absorbed dose rates at a height of one meter above the ground delivered to the general public of the study areas were all lower than the international average value of 60 $nGyh^{-1}$. The average values of Ra equivalent ($Ra_{eq}$) for all the selected areas were found to be below the international average of 370 Bq/kg and the computed mean annual effective dose (AED) from the selected study area was below the safety limit of unity. The results showed that no hazardous radiological effects are posed to the populace in the vicinity of the investigated locations.*

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## Introduction

Radiation is energy transport in form of particles e.g., alpha (∝), beta ($\beta$) and waves e.g., gamma ($\gamma$) rays. There are two broad types or radiation: ionizing and non-ionizing radiation. The radiation class referred to as ionizing radiation is that which bears just enough energy capable ionizing the molecule or atom by having an electrons detached from them. They may be in form of high-speed moving atoms and electromagnetic waves usually dwelling at the high-energy tip of the electromagnetic spectrum (Asaduzzaman *et al*., 2014). The electromagnetic radiation energy per quantum possessed by non–ionizing radiation is not strong enough to ionize atoms or molecules but have sufficient energy for excitation (Stallcup, 2006). Ionizing radiation (which is of concern here) can have natural sources, which can either be of terrestrial or cosmic origins. The concentration of the terrestrial radionuclides are localized and depends on the regional geographical and geology of the area under study except in the event radiation fallout and migration of radionuclides through agents of environmental erosion (liquid water, wind and ice). The cosmic component includes radiation originated from space beyond earth's



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atmosphere as cosmic rays as their contributions to background radiation on earth are altered as the latitude and altitude varies. Complimenting these natural sources, a reference region's background radiation level affected by man-made activities which includes but not limited to radionuclides released during normal operations or accidental releases (Kam & Bozkurt, 2007). Isotopes that are unstable due the fact that they possess excess nuclear energy and therefore decay radioactively are referred to as radionuclides and are generated naturally or artificially. The most well-known sources of natural background radiation are radium, thorium and uranium (Manigandan & Sheka, 2014). Radioactivity levels and assessment of the risk of health exposure of background radiation is one of the leading treats to life due to daily interaction of human beings with their environment. (Belyaeva et al., 2021).

Maximum radiological hazard is likely when the doorway for the entry of radionuclides into the body is ingestion of food and water, which is have been earlier contaminated, or through air (UNSCEAR, 2010). Environmental radioactivity and radiation sources are numerous, and they could be natural or due to anthropogenic activities. Regardless of the factors responsible for the availability (natural or artificial) of these radionuclides in the nutrient or food intake of plants and animals, they unavoidably make entrance into the human food chain which later affect human total well-being (Kabir, et al., 2009).

For advisory and regulatory purposes, environment safety, maintaining public health and more importantly safeguarding posterity, it is of utmost importance to have adequate data on environmental radioactivity (UNSCEAR, 2000).

## Materials and Methods

### Study Area

Yewa metropolis, Ogun State, Nigeria boasting of a land mass of 629 km$^2$ and lying at 6°53′00″N 3°01′00″E, Ilaro town serves as the headquarters of this local government area. Some studies have been carried out on the evaluation of radionuclide concentration in soil and radiological hazards in some southwestern parts of Nigeria; none has been done as regards to natural radionuclides evaluation in the study area. Consequently, it is imperative to analyze the soil of Yewa metropolis in order to evaluate and monitor the level of exposure in the environment. Twenty-five (25) samples were collected from selected areas (including include Idogo, Ilaro, Itolu, Iweke and Owode) for the purpose of the analyses and the study.

### Geology

The geology of Yewa metropolis as seen in Figure (1) is made up of the vault complex rocks. Pre-cambian age of the older and younger sandstones in the Northern Province and in the southern province are found the basement complex of sedimentary layers in the coastal basin comprising of deposition sediments of cretaceous, tertiary and quaternary. Topography of Yewa metropolis is characterized by undulating lowland of the coastal sedimentary rock with rivers that traverse southwards joining the main rivers that flow southward into the Atlantic Ocean.

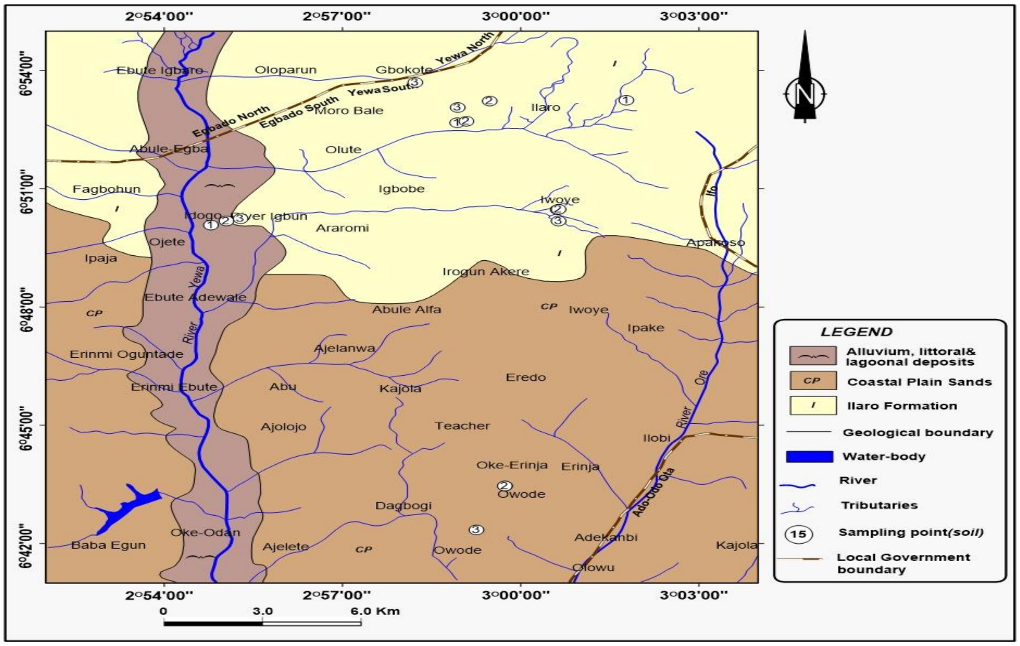


Figure (1): map of the geological feature of the study area

**Sample preparation**

Soil samples were collected 5 cm below the topsoil from different sites in the study area. The procedures for the collection and preparation of samples were done using Jianzhou et al (2022) technique. The soil matrix were oven-dried at 105 °C, pounded and sifted using 60 mesh to obtain fine particles after the removal of superfluous materials. About 400g of the oven dried samples were packed in sealed and stored in plastic cups (75 mm diameter × 70 mm height). The stored samples were left for 30 days to achieve lay equipoise between $^{238}U$ and $^{232}Th$ (Amanjeet et al., 2017)

**Activity Concentrations**

Gamma spectrometer (Sodium Iodide activated with Thallium [NaI(Tl)] detector fixed to a Camberra series 100 multichannel analyzer (MCA) at the NIRPR, university of Ibadan, Nigeria was used to analyzed the radionuclides in the samples.

The detector was retained in a hollow lead block of thickness 5cm to provide a shield in reducing natural external radiation effects. The detector was connected to 100 multichannel analyzer to measure the activity engrossment of radionuclides. The detector used at its peak efficiency of $1.2\times10^{-5}$ at 1.33MeV gamma line of Co-60, consequential to an energy resolution of 662KeV (FWHM) with a relative yield of 7.5% at $^{137}Cs$ energy of 0.662 MeV (Chinyere, Ononugbo & Tutumeni, G. (2016)). This arrangement is usually done to aim at putting the paraphernalia of background and strewn radiation at the barest minimum. The counting of each samples measured was 21,600 seconds and activity engrossment of the radionuclides in the matrice were computed using equations (1) and (2) (Jibiri & Okeyode, 2012, Ademola & Obed 2012).

$$C\left(\frac{Bq}{kg}\right) = KA \qquad [1]$$

Where:

C (Bq/kg): specific activity concentration of the radionuclide in the sample

A: count rate of the corresponding peak,

$K$: conversion factor

$$k = \frac{1}{\varepsilon P_r M_s} \qquad [2]$$

Where:

$P_r$: Absolute transition probability of the specific gamma ray.

$M_s$: Mass of sample in kg

$\varepsilon$: Detector's efficiency at a specifically given energy.

**Absorbed Dose Rate (D)**

This is a measure of the amount of energy from an ionizing radiation deposited in a mass of some material or tissue at 1 m above the ground. D was calculated from equation (3) (Jibiri & Okeyode, 2012):

$$D(nGyh^{-1}) = 0.462\,A_{Ra} + 0.604\,A_{Th} + 0.0417\,A_K \qquad [3]$$

Where $A_{Ra}$, $A_{Th}$, and $A_K$, are the respective activity concentrations of $^{226}Ra$, $^{232}Th$ and $^{40}K$ in Bq/kg with corresponding the dose conversion factors of 0.462, 0.604 and 0.0417 $nGyh^{-1}$ per Bq/kg are for $^{226}Ra$, $^{232}Th$, and $^{40}K$, respectively (UNSCEAR, 2010).

**Radium Equivalent Activity ($Ra_{eq}$)**

This is an estimation done to aid the effective estimation of the precise activities of $^{226}Ra$, $^{232}Th$ and $^{40}K$. This makes it a possibility to represent the radiation hazards, which are associated with the mixture of these radionuclides using a single index (Afzal et al., 2022).

$$Ra_{equivalent} = A_{Ra} + 1.43A_{Th} + 0.007A_k \qquad [4]$$

Where, $A_{Ra}$, $A_{Th}$ and $A_K$ are the activity concentrations of $^{226}Ra$, $^{232}Th$ and $^{40}K$ in the samples correspondingly.

**Annual ED**

This is the risk related with the air absorbed dose rate of radiation in a year by the populace of a given area, which represents the dose quantity for the stochastic effect of low-level radiation on human tissue. AED was computed using equation (5)

$$AED(mSvy^{-1}) = D \times TF \times CF \times T \times 10^{-6} \qquad [5]$$

Where D ($nGyh^{-1}$) is the total absorbed dose rate in air, TF is the time conversion of hour per year 8760 $hry^{-1}$ is representing the number of hours per annual, CF is the conversion factor, which is 0.7 $SvGy^{-1}$, $T$ is the occupancy factor. The occupancy factor used for this study is 0.5 taking the upper band of the time spent outdoor since the occupants of the study area are farmers.

**Annual Gonadal Dose Equivalent (AGDE)**

AGDE is the evaluation of the radiation dose deposited to the reproductive organs due to explicit activities of $^{226}Ra$, $^{232}Th$, and $^{40}K$ is as given in equation (6) (Chandrasekaran et al., 2014).

$$AGDE = 3.09\,A_{Ra} + 4.18\,A_{Th} + 0.314\,A_K \qquad [6]$$

## Results and Discussion

The measured activity concentration and absorbed dose rate are presented in the Tables 1 - 5 below. IDG, ILR, ITL, IWK and OWD denote Idogo, Ilaro, Itolu, Iweke and Owode respectively. The result of the radionuclides activity concentration in the study area relation to the world average values reported by UNCEAR are seen in figures (2) to (4). Likewise, the comparison of the evaluated mean dose rate at the study area in relation to the world's average safe limit is see in figure (5)

**Table 1: Radionuclides concentration in samples collected in Idogo (IDG)**

| Sample ID | $^{226}Ra$ (Bq/kg) | $^{232}Th$ (Bq/kg) | $^{40}K$ (Bq/kg) |
|---|---|---|---|
| IDG 1 | 13.60 ± 1.80 | 6.30 ± 0.37 | 83.17 ± 4.40 |
| IDG 2 | 13.00 ± 1.60 | 6.32 ± 0.37 | 89.40 ± 4.62 |
| IDG 3 | 9.17 ± 0.90 | 6.50 ± 0.37 | 99.03 ± 5.02 |

| | | | |
|---|---|---|---|
| IDG 4 | 12.80 ± 1.56 | 6.48 ±0.38 | 93.50 ± 4.63 |
| IDG 5 | 15.93 ± 2.03 | 6.40 ± 0.38 | 92.15 ± 4.48 |
| Mean | 12.9 ± 3.38 | 6.40 ± 0.37 | 91.45 ± 4.63 |

The concentration of $^{226}$Ra, $^{232}$Th and $^{40}$K for the samples collected in Idogo area ranged from 9.17 ± 0.90 to 15.93 ± 2.03, 6.30 ± 0.37 to 6.50 ± 0.37 and 83.17 ± 4.40 to 99.03 ± 5.02 Bq/kg respectively and average values of 12.9 ± 3.38, 6.40 ± 0.37 and 91.45 ± 4.63 Bq/kg respectively. (Table 1).

**Table 2: Radionuclides concentration in samples collected in Ilaro (ILR)**

| Sample ID | $^{226}$Ra (Bq/kg) | $^{232}$Th (Bq/kg) | $^{40}$K (Bq/kg) |
|---|---|---|---|
| ILR 1 | BDL | 5.72 ± 0.33 | 70.71 ± 3.60 |
| ILR 2 | 7.22 ± 0.95 | 4.40 ± 0.26 | 148.40 ± 7.82 |
| ILR 3 | 6.89 ± 0.69 | 6.13 ± 0.30 | 100.60 ± 4.55 |
| ILR 4 | 7.69 ± 0.89 | 4.00 ± 0.31 | 105.09 ± 6.10 |
| ILR 5 | 14.70 ± 1.42 | 5.10 ± 0.30 | 89.40 ± 4.53 |
| Mean | 7.30 ± 0.79 | 5.07 ± 0.30 | 102.84 ± 5.32 |

For Ilaro area, the computed average activity concentration for $^{226}$Ra, $^{232}$Th and $^{40}$K were 7.30 ± 0.79, 5.07 ± 0.30 and 102.84 ± 5.32 Bq/kg respectively with ranges of BDL to14.70 ± 1.42, 4.40 ± 0.26 to 5.72 ± 0.33 and 70.71 ± 3.60 to 148.40 ± 7.82 Bq/kg respectively. (Table 2).

**Table 3: Radionuclides concentration in samples collected in Itolu (ITL)**

| Sample ID | $^{226}$Ra (Bq/kg) | $^{232}$Th (Bq/kg) | $^{40}$K (Bq/kg) |
|---|---|---|---|
| ITL 1 | 21.72 ± 2.63 | 3.60 ± 0.21 | 26.86 ± 1.42 |
| ITL 2 | 29.30 ± 2.99 | 5.55 ± 1.94 | 101.11 ± 4.04 |
| ITL 3 | 34.14 ± 3.30 | 4.80 ± 3.30 | 86.50 ± 4.40 |
| ITL 4 | 20.01 ± 2.50 | 5.15 ± 0.70 | 60.82 ± 4.20 |
| ITL 5 | 18.13 ± 2.33 | 7.65 ± 0.45 | 129.56 ± 6.54 |
| Mean | 24.66 ± 2.75 | 5.35 ± 1.32 | 80.97 ± 4.12 |

The computed mean values of activity concentration of the radionuclides $^{226}$Ra, $^{232}$Th and $^{40}$K in the samples collected in Itolu were 24.66 ± 2.75, 5.35 ± 1.32 and 80.97 ± 4.12 Bq/kg respectively with ranges from 18.13 ± 2.33 to 34.14 ± 3.30, 3.60 ± 0.21 to 7.65 ± 0.45 and 26.86 ± 1.42 to 129.56 ± 6.54 Bq/kg respectively (Table 3).

**Table 4: Radionuclides concentration in samples collected in Iweke (IWK)**

| Sample ID | $^{226}$Ra (Bq/kg) | $^{232}$Th (Bq/kg) | $^{40}$K (Bq/kg) |
|---|---|---|---|
| IWK 1 | 8.20 ± 1.10 | 0.97 ± 0.08 | 97.90 ± 5.14 |
| IWK 2 | 7.93 ± 1.08 | 4.90 ± 0.30 | 100.31 ± 6.14 |
| IWK 3 | BDL | 6.49 ± 0.40 | 93.64 ± 4.97 |
| IWK 4 | 7.90 ± 0.93 | 3.97 ± 0.27 | 110.20 ± 4.01 |
| IWK 5 | 15.52 ± 1.96 | 5.80 ± 0.35 | 124.20 ± 6.54 |
| Mean | 7.91 ± 1.02 | 4.42 ± 0.28 | 105.25 ± 5.36 |

In the Iweke study area samples, the concentration ranges of $^{226}$Ra, $^{232}$Th and $^{40}$K were from BDL to 15.52 ± 1.96, 0.97 ± 0.08 to 6.49 ± 0.40 and 93.64 ± 4.97to 124.20 ± 6.54Bq/kg respectively having computed average values of 7.91 ± 1.02, 4.42 ± 0.28 and 105.25 ± 5.36 Bq/kg respectively. (Table 4)

**Table 5: Radionuclides concentration in soil sample of Owode (OWD)**

| Sample ID | $^{226}$Ra (Bq/kg) | $^{232}$Th (Bq/kg) | $^{40}$K (Bq/kg) |
|---|---|---|---|
| OWD 1 | 22.13 ± 2.90 | 7.09 ± 0.42 | 35.20 ± 1.86 |
| OWD 2 | 31.20 ± 3.31 | 5.57 ± 0.39 | 63.65 ± 4.02 |
| OWD 3 | 9.60 ± 1.24 | 5.00 ± 0.03 | 69.94 ± 3.69 |
| OWD 4 | 21.20 ± 3.20 | 4.11 ± 0.46 | 59.71 ± 2.51 |
| OWD 5 | 46.87 ± 5.60 | 2.43 ± 0.15 | 79.90 ± 4.22 |
| Mean | 26.20 ± 3.25 | 4.84 ± 0.29 | 61.68 ± 3.26 |

The average activity concentration of the radionuclides $^{226}$Ra, $^{232}$Th and $^{40}$K in the sample of Owode were 26.20 ± 3.25, 4.84 ± 0.29 and 61.68 ± 3.26 Bq/kg respectively with ranges of 9.60 ± 1.24 to 46.87 ± 5.60, 2.43 ± 0.15 to 7.09 ± 0.42 and 35.20 ± 1.86 to 79.90 ± 4.22 Bq/kg respectively (Table 5).

As realized in figure (4), the average activity concentration of $^{40}$K is seen to be significantly higher than the sedated activity concentration values of $^{226}$Ra and the measured activity concentration rate of $^{232}$ Th which means that the soil samples of the study areas being investigated have more abundance of $^{40}$K compared to its other two counterparts i.e., $^{226}$Ra and $^{232}$Th.

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**Radiological Parameters**

The rivetted dose rate in air due to the gamma ray emitted from the soil in the study area is seen in the figure (5), showing the mean variation with the safe limit accepted by UNSCEAR. The figure (5) shows that the highest level of mean absorbed dose rate was found in Itolu study area while the lowest was found in Iweke. All values obtained were below the UNSCEAR safety limit. Table 6 and 7 shows the radiological parameters.

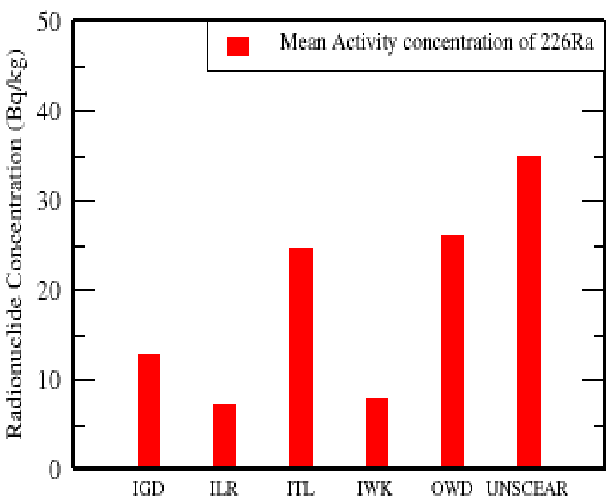



Figure (2)

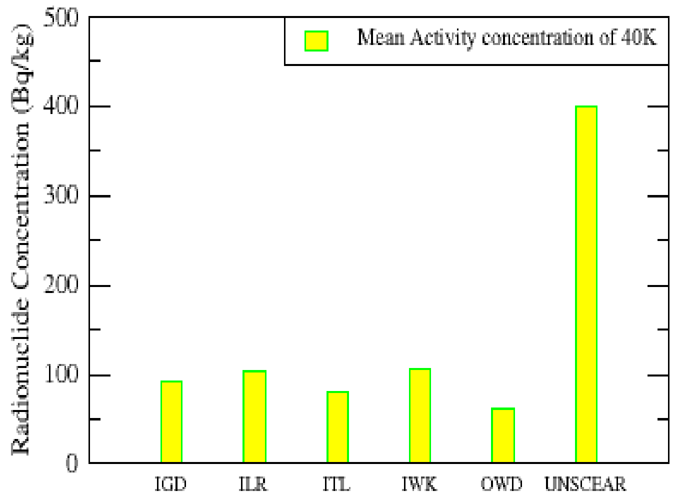



Figure (4)

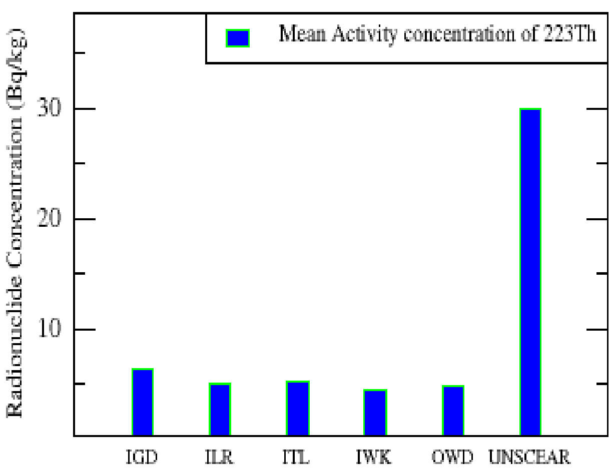
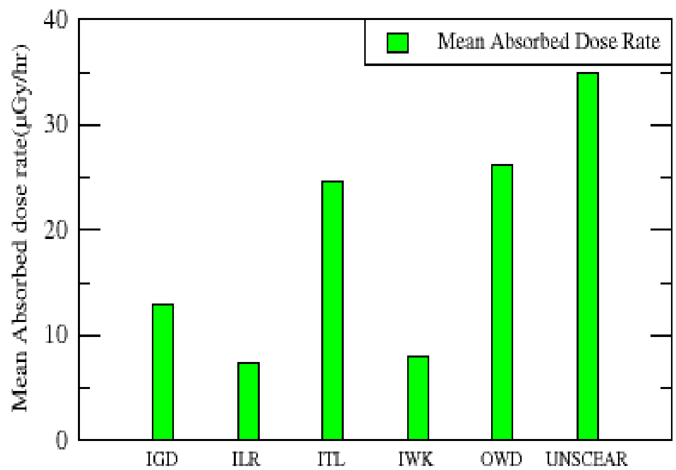



Figure (3)




Figure(5)

Figures 1 to 5: Correlation between mean activity of radium, thorium and potassium mean annual absorbed rate with locations under study when compared UNSCEAR reported world average dose and lithology of the area.

**Table 6: Range of Radiological Parameters in the study areas**

| Study Area | AED ($mSvy^{-1}$) | $Ra_{eq}$ (Bq/kg) | AGDE ($\mu Gyh^{-1}$) |
|---|---|---|---|
| IDG | 0.037 - 0.046 | 26.97 - 32.13 | 86.60 - 104.91 |
| ILR | 0.019 - 0.042 | 13.58 - 28.84 | 46.11 - 94.81 |
| ITL | 0.040 - 0.068 | 28.91 - 47.63 | 90.60 - 15.72 |
| IWK | 0.024 - 0.048 | 16.45 - 33.34 | 56.53 - 111.20 |
| OWD | 0.031 - 0.081 | 22.10 - 56.48 | 72.53 - 109.07 |

**Table 7: Mean values of the Radiological Parameters**

| Study Area | AED ($mSvy^{-1}$) | $Ra_{eq}$ (Bq/kg) | AGDE ($\mu Gyh^{-1}$) |
|---|---|---|---|
| IDG | 0.042 ± 0.004 | 29.06 ± 3.03 | 95.33 ± 9.19 |
| ILR | 0.033 ± 0.011 | 22.44 ± 7.92 | 76.08 ± 26.22 |
| ITL | 0.055 ± 0.013 | 38.51 ± 7.65 | 124.33 ± 31.78 |
| IWK | 0.033 ± 0.013 | 22.30 ± 9.56 | 75.96 ± 30.58 |
| OWD | 0.054 ± 0.024 | 37.84 ± 17.37 | 120.78 ± 55.05 |

The AED rate extended between 0.037 and 0.046 mSv/yr with an average value of 0.042 ± 0.004 mSv/yr in Idogo, 0.019 and 0.042 mSv/yr with an average value of 0.033 ± 0.011 mSv/yr in Ilaro, 0.040 and 0.068 mSv/yr with an average value of 0.055 ± 0.013 mSv/yr in Itolu, 0.024 and 0.048 mSv/yr with an average value of 0.033 ± 0.013 mSv/yr in Iweke and 0.031 and 0.081 mSv/yr with an average value of 0.054 ± 0.024 mSv/yr in Owode. The $Ra_{eq}$ ranged between 26.97 and 32.13 Bq/kg with a mean value of 29.06 ± 3.03 Bq/kg in Idogo, 13.58 and 28.84 Bq/kg with a mean value of 22.44 ± 7.92 Bq/kg in Ilaro, 28.91 and 47.63 Bq/kg with a mean of 38.51 ± 7.65 Bq/kg in Itolu, 16.45 - 33.34 Bq/kg with a mean value of 22.30 ± 9.56 Bq/kg in Iweke and 22.10 - 56.48 Bq/kg with a mean value of 37.84 ± 17.37 Bq/kg in Owode. The annual gonadal dose equivalent ranged between 86.60 - 104.91 $\mu Gyh^{-1}$ with a mean value of 95.33 ± 9.19 $\mu Gyh^{-1}$ in Idogo, 46.11 - 94.81 $\mu Gyh^{-1}$ with a mean value of 76.08 ± 26.22 $\mu Gyh^{-1}$ in Ilaro, 90.60 - 15.72 $\mu Gyh^{-1}$ with a mean value of 124.33 ± 31.78 $\mu Gyh^{-1}$ in Itolu, 56.53 to 111.20 $\mu Gyh^{-1}$ with a mean value of 75.96 ± 30.58 $\mu Gyh^{-1}$ in Iweke and 72.53 to 109.07 $\mu Gyh^{-1}$ with a mean value of 120.78 ± 55.05 $\mu Gyh^{-1}$ in Owode.

## Conclusion and Recommendation

The assessment of the radiation level of Yewa Metropolis was carried out. Twenty-five (25) soil matrix were collected across five towns in the local government area. The concentration of the natural radionuclides $^{226}Ra$, $^{232}Th$ and $^{40}K$ in the samples were then investigated. The conclusions drawn from this study are to concentration of the radionuclide activities for $^{226}Ra$, $^{232}Th$ and $^{40}K$ in soil collected were found to be below the world average values of 35 Bq/kg, 30 Bq/kg and 400 Bq/kg respectively. The average absorbed dose values at 1m above the ground delivered to the public of the study areas were all lower than 60 $nGyh^{-1}$ (UNSCEAR, 2010). The $Ra_{eq}$ mean values obtained from all the research areas were also below the world average of 370 Bq/kg (UNSCEAR, 2000) and the computed mean Annual effective dose from all study sites were also discovered to be below the unity safety limit. There are no radiological hazardous effects posed to the populace domiciling in these investigated locations. This study hence, provides a baseline data for the natural background radiation for future epidemiological studies in Yewa metropolis

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