# Radioassay of Geregu Soil North-Central Nigeria

**M. Hassan, [1] J.SKarniliyus, [2] J. M. Egieya, [3]**

[1]Centre for Nuclear Energy Research and Training (CNERT), University of Maiduguri,
[2-3]Nigeria Atomic Energy Commission, NIGERIA.

[1]muhammad59@hottmail.com,[2]justin.salu@nigatom.org.ng, [3] jegieya@gmail.com

## ABSTRACT

*Geregu Area in North Central Nigeria has been selected as a potential site for the location of Nigeria's first proposed nuclear power plant. Siting of a nuclear power plant is a complex process that involves a lot of site survey and characterization. The objective of this study is to evaluate the radiological effects of soil samples from this Geregu Area. Ten soil samples were collected at different locations within the area. The radionuclide concentrations of the soil samples were measured using gamma spectroscopy method. The average values of $^{226}Ra$, $^{232}Th$ and $^{40}K$ obtained are 15.45Bqkg$^{-1}$, 10.64Bqkg$^{-1}$ and 105.60Bqkg$^{-1}$ respectively.The hazard indices and excess lifetime cancer risk were estimated using standard analytical method. The average values obtained for annual effective dose equivalent (AEDE) (Outdoor), annual effective dose equivalent (indoor) and excess lifetime cancer risk (ELCR) for the Geregu Area are 22.26μSv/yr, 89.04μSv/yr and 0.078×10$^{-3}$μSv/yr respectively. Others are annual gonadal equivalent dose (AGED), representative gamma indices (Iγ), external hazard indices ($H_{ex}$) and internal hazard indices ($H_{in}$) obtained for the same area are 125.35mSv/yr, 0.28, 0.11 and 0.15 respectively. All the values obtained when compared with their corresponding world permissible standard values were found to be below the standard limits and as such radiation exposure in the study area will pose no significant health threat to the workers and inhabitants of the place.*

**Keywords:** Geregu, nuclear power plant, hazard Indices, excess lifetime cancer risk

## INTRODUCTION

Unquestionably, power plays a fundamental role in the economic development process. All countries seek to ensure a supply of electricity that is affordable, reliable, and secure in order to sustain modern ways of living. In developing countries like Nigeria the demand for electricity is increasing and to sustain it, long-term planning is needed. Nigeria Atomic Energy Commission (NAEC) is proposing to install a nuclear power plant (NPP) of 1000 MWein a north central state of Nigeria.As part of the process to implementing the nuclear power plant program, radiometric analysis of soil in the proposed site is being studied.

Natural environmental radioactivity and the associated external exposure due to gamma radiation depend mainly on the local geological and geographical conditions and appear at different levels in each region in the World (UNSCEAR, 2000). The natural terrestrial gamma dose rate is an important contributor to the average dose received by the world's population (Senthilkumar et al., 2010). Estimation of the radiation dose distribution is vital in assessing the health risk to a population and serves as a reference for documenting changes in environmental radioactivity due to anthropogenic activities (Obed et al., 2005). Monitoring for radioactive materials are therefore of primary importance for humans, organisms and for environmental protection, but rapid and accurate methods for the quantitative and qualitative analysis of radioactivity is essential.



ISSN: 2223-9944, e ISSN: 2223-9553

When humans are outdoors, they are exposed to natural terrestrial radiation originating predominantly from the upper 30 cm of the soil (Avwiri et al., 2013).Humans are also exposed by contamination of the food chain which occurs as a result of direct deposition of radionuclides on plant leaves, root uptake from contaminated soil, sediment or water (Arogunjo et al., 2004), and from direct ingestion of contaminated water (Avwiri and Agbalagba, 2007). To assess these exposures, radioactivity studies have been previously carried out in soil samples in other parts of the world, some similar to those in Nigeria (e.g.Selvasekarapandian et al., 2005; Kannan et al., 2002; Kirchner et al., 2002; Avwiri et al., 2013; Nour and Abdel, 2005;Obed et al., 2005; Patra et al., 2006; Diab et al., 2008; Senthilkumar et al., 2010; Avwiri et. al., 2013; Agbalagba and Onoja, 2010).

Hence, the aim of this study is to estimate the health hazard indices of the soil samples obtained by evaluating the annual effective dose equivalent (outdoor and indoor), internal and external hazard indices, annual gonadal equivalent dose, radium equivalent activity, representative gamma index and excess cancer exposure risk.

## STUDY AREA

The selected sample area is in Geregu,Kogi state a north central part of Nigeria. The site is not far from the Ajaokuta Steel Complex and the Geregu Gas-Turbinewith longitude $N07^{0}33'51.2''$ and $E06^{0}41'30.8''$. The prevalent occupation of the inhabitants is farming and fishing and it is sparsely populated without any dense population centers nearby. It will appear from field observations and information gathered from inhabitants that flooding usually occurs but with limited overflow of the banks due to the channel morphology (of steep slopes). Mining activities in the area are mainly of marble without the risk of chemical explosives. There is no known drilling or sub-surface extraction.

## MATERIALS AND METHODS

The materials used include NaI(TI) scintillator detector, Dutch auger, samples collected, oven, mortar and pestle, plastic containers and Tetraoxosulphate (VI) acid $H_2SO_4$.

**Table 1. Activity concentration of radionuclides**

| S/No | Sample ID | $^{226}Ra$ (Bq/Kg) | $^{232}Th$ (Bq/Kg) | $^{40}K$ (Bq/Kg) |
|---|---|---|---|---|
| 1 | SAMPLE1 | 15.18±3.94 | 10.72±1.37 | 102.95 ±4.20 |
| 2 | SAMPLE2 | 15.53±3.71 | 10.49±1.60 | 105.44 ±3.73 |
| 3 | SAMPLE3 | 15.41±4.17 | 10.95±1.82 | 108.09 ±3.89 |
| 4 | SAMPLE4 | 14.95±4.40 | 10.38±1.71 | 100.62 ±4.35 |
| 5 | SAMPLE5 | 15.87±3.82 | 11.17±1.25 | 109.02 ±4.82 |
| 6 | SAMPLE6 | 15.99±3.48 | 11.06±1.94 | 106.38 ±3.58 |
| 7 | SAMPLE7 | 14.72±4.52 | 10.83±1.37 | 100.15 ±4.98 |
| 8 | SAMPLE8 | 15.30±3.36 | 10.03±1.48 | 110.57 ±5.13 |
| 9 | SAMPLE9 | 15.64±4.06 | 10.15±1.14 | 104.20 ±4.04 |
| 10 | SAMPLE10 | 15.87±4.29 | 10.60±1.59 | 108.55 ±4.51 |
| | AVERAGE | 15.45±3.98 | 10.64±1.53 | 105.60 ±4.32 |

Each sample was collected randomly from an area of approximately $0.5km^2$ within 10 by 5 km selected site and up to a depth of 40cm to 50cm using the Dutch auger. The samples, collected in black polythene bags, were oven dried at $60^{0}C$ for about 24 hours. The dried



ISSN: 2223-9944, e ISSN: 2223-9553

samples were ground with mortar and pestle and then allowed to pass through a 2mm-mesh sieve, the larger particles discarded, in order to achieve a uniform distribution of radionuclides. The filtered soil was then sealed for 28 days in air tight plastics containers previously washed and rinsed with diluted tetraoxosulphate (VI) acid ($H_2S0_4$) before analysis with the gamma-spectrometer (IAEA, 2003). This was done in order to maintain radioactive equilibrium.

***Sample Analysis***

The samples were analyzed using a thallium activated Canberra vertical high purity 3"x 3"Sodium Iodide [NaI (TI)] detector connected to ORTEC 456 amplifier. The detector was connected to a computer program MAESTRO window that matched gamma energies to a library of possible isotopes. The cylindrical plastic containers holding the samples were put to sit on the high geometry 7.6cm x 7.6cm NaI (TI) detector. High level shielding against the environmental background radiation was achieved by counting in the Canberra 100mm thick lead castle. The $^{232}$Th concentration was determined from the average concentrations of $^{212}$Pb (238.6 keV) and $^{228}$Ac (911.1keV) in the samples, and that of $^{226}$Ra was determined from the average concentrations of $^{214}$Pb (351.9 keV) and $^{214}$Bi (609.3 and 1764.5 keV) decay products 1461keV for $^{40}$K (El-Taher., 2010).

The energy resolution of the detector using $^{137}$Cs from International Atomic Energy Agency (IAEA) is 8% at 662 keV$^{137}$Cs line, while the activity of the standard at the time of calibration is 25.37KBq. The background spectrum measured under the same conditions for both the standard and sample measurements, were used to correct the calculated sample activities concentration in accordance with that proposed by (Arogunjo, et.al. 2004). The activity concentration (C) in Bqkg$^{-1}$ of the radionuclides in the samples was calculated after decay correction using the expression:

$$C_s(Bqkg^{-1}) = \frac{C_a}{\varepsilon_\gamma \times M_s \times t_c \times P_\gamma} \qquad (1)$$

Where $C_s$= Sample concentration, $C_a$= net peak area of a peak at energy, $\varepsilon_\gamma$= Efficiency of the detector for a γ-energy of interest, $M_s$= Sample mass, $t_c$= total counting time, $P_\gamma$is the abundance of the γ-line in a radionuclide.

**Radiation Hazard Indices Calculation**

Different known radiation health hazard indices analysis has been used in radiation studies to arrive at a better and safer conclusion on the health status of a radiated or irradiated personand environment in recent studies (Avwiri*et al.,* 2013; Orgun*et. al.,* 2007; Zarie and Al Mugren, 2010; Senthilkumar*et. al.*, 2010; Agbalagba and Onoja, 2011). To assess the radiation hazards associated with the studied soil samples, the following seven quantities have been defined.

**Absorbed Dose rate (D)**

The absorbed dose rates (D) due to terrestrial gamma rays are calculated from $^{226}$Ra, $^{232}$Th and $^{40}$K concentration in soil or water assuming that other radio nuclides, such as $^{137}$Cs, $^{90}$Sr and the $^{235}$U decay series can be neglected as they contribute very little to the total dose from the environmental background. (UNSCEAR, 2000), has given the dose conversion factors for converting the activity concentrations of $^{226}$Ra, $^{232}$Th and $^{40}$K doses (nGyh$^{-1}$ per Bqkg$^{-1}$) as 0.462, 0.621 and 0.0417, respectively. The absorbed dose rate is important in radiation risk analysis since it measures the amount of radiation deposited per unit time. To avoid any somatic, epidemiological and radiological health side effect, (ICRP, 1999) recommended and



ISSN: 2223-9944, e ISSN: 2223-9553

consequently set the maximum permissible limit for non-radionuclide industrial worker and public as 1.0 $mSvy^{-1}$.

The gamma radiation population doses of those living in the area are given as:

$$D = 0.461C_{Ra} + 0.623C_{Th} + 0.0417C_K \quad (2)$$

Where, $D$ is the dose rate in $nGyh^{-1}$,$C_{Ra}$,$C_{Th}$ and $C_K$are the concentrations of Radium, Thorium and Potassium, respectively.

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

Radium equivalent ($Ra_{eq}$) is a common index used to compare the specific activities of materials containing $^{226}Ra$, $^{232}Th$ and $^{40}K$ by a single quantity, which takes into account the radiation hazards associated with them (Baratta, 1990). The activity index provides a useful guideline in regulating the safety standard dwellings.

The radium equivalent activity represents a weighted sum of activities of the above mentioned natural radionuclides and is based on the estimation that 1Bq/kg of $^{226}Ra$, 0.7Bq/kg of $^{232}Th$, and 13Bq/kg of $^{40}K$ produce the same radiation dose rates.

The radium equivalent activity index is given as (Beratka and Mathew 1985);

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.077C_K \quad (3)$$

Where, $C_{Ra}$, $C_{Th}$ and $C_K$ are the radioactivity concentration in Bq/kg of $^{226}Ra$, $^{232}Th$, and $^{40}K$.

The use of a material whose concentration exceeds 370Bq/kg is discouraged to avoid radiation hazards (Sam and Abbas, 2001)

**Annual Gonadal Equivalent Dose (AGED)**

The gonads, the activity bone marrow and the bone surface cells are considered as organs of interest by (UNSCEAR, 1988) because the most sensitive parts of the human body toradiation. An increase in AGED has been known to affect the bone marrow, causingdestruction of the red blood cells that are then replaced by white blood cells. This situationresults in a blood cancer called leukemia which is fatal. AGED for the resident of a buildingusing a material with given activity concentration of $^{226}Ra$, $^{232}Th$ and $^{40}K$ is calculated usingthe equation below:

$$AGED(Svyr^{-1}) = 3.09C_{Ra} + 4.18C_{Th} + 0.314C_K \quad (4)$$

Where,$C_{Ra}$,$C_{Th}$ and $C_K$are the radioactivity concentration of $^{226}Ra$, $^{232}Th$ and $^{40}K$ in soilsamples.

**Representative Gamma Index (Iyr)**

This is used to estimate the gamma radiation hazard associated with the natural radionuclides in specific investigated samples. The representative gamma index is given as:

$$I_{yr} = C_{Ra}/150 + C_{Th}/100 + C_K/1500 \quad (5)$$

This gamma index is also used to correlate the annual dose rate due to the excess external gamma radiation caused by superficial materials. It is a screening tool for identifyingmaterials that might become a health concern when used for construction (Tufail et al., 2007).

Since, gamma ray can pass through any material; it can cause severe damage to the cells of human beings. Hence, an increase in the representative gamma index greater than the universal standard of unity may result in radiation risk leading to the deformation of



ISSN: 2223-9944, e ISSN: 2223-9553

humancells thereby causing cancer. Values of $I_{yr} \leq 1$corresponds to an annual effective dose ofless than or equal to 1mSv, while $I_{yr} \leq 0.5$corresponds to annual effective dose less or equal to 0.3mSv(Turham et al., 2008).

**Annual Effective Dose Equivalent (AEDE)**

The annual effective dose equivalent received outdoor by a member is calculated from the absorbed dose rate by applying dose conversion factor of 0.7Sv/Gy and occupancy factor foroutdoor and indoor was 0.2(5/24) and 0.8(19/24) respectively (Veiga et al., 2006). AEDE isdetermined using the following equations.

$$AEDE(Outdoor)(\mu Sv/y) = AbsorbeddoseD(nGy/h) \times 8760h \times 0.7\,Sv/Gy \times 0.2 \times 10^{-3} \quad (6)$$

$$AEDE(Indoor)(\mu Sv/y) = AbsorbeddoseD(nGy/h) \times 8760h \times 0.7\,Sv/Gy \times 0.8 \times 10^{-3} \quad (7)$$

The AEDE indoor occurs within a house whereby the radiation risks due to building materials are taken into consideration, which accounts for the higher dose than that of AEDE outdoor. AEDE outdoor involves a consideration of the absorbed doseemitted from radionuclides in the environment such as $^{226}$Ra, $^{232}$Th and $^{40}$K.

**Excess Lifetime Cancer Risk (ELCR)**

This deals with the probability of developing cancer over a lifetime at a given exposure level. It is presented as a value representing the number of cancers expected in a given number of people on exposure to a carcinogen at a given dose.

It is worth noting that an increase in the ELCR causes a proportionate increase in the rate atwhich an individual can get cancer of the breast, prostate or even blood.Excess Lifetime cancer risk (ELCR) is given as (Taskin et. at., 2009):

$$ELCR = AEDE \times DL \times RF \quad (8)$$

Where, AEDE is the Annual Equivalent Dose Equivalent, DL is the average duration of life (Estimated to 70 years), and RF is the Risk Factor ($Sv^{-1}$), i.e. fatal cancer risk per Sievert. For Stochastic effects, ICRP use RF as 0.05 for public (Taskin et. al., 2009). The range of ELCR is 0.071 x $10^{-3}$ to 0.37 x $10^{-3}$ with an average of 0.202 x $10^{-3}$.

**External Hazard Index ($H_{ex}$)**

Many radionuclides occur naturally in terrestrial soils and rocks and upon decay, these radionuclides produce external radiation field to which all human beings are exposed. In terms of dose, the principal primordial radionuclides are $^{232}$Th, $^{238}$U and $^{40}$K. Thorium and Uranium head the series of radionuclides that produce significant human exposure.

The external hazard index ($H_{ex}$) is defines as (Beretka and Mattew, 1985).

$$H_{ex} = C_{Ra}/370 + C_{Th}/259 + C_K/4810 \quad (9)$$

Where, $C_{Ra}$, $C_{Th}$ and $C_K$ are the radioactivity concentration in Bq/kg of $^{232}$Th, $^{238}$U and $^{40}$K. The value of this index must be less than unity for the radiation hazard to be negligible (Beretka and Mattew, 1985).

**Internal Hazard Index ($H_{in}$)**

The internal hazard index is given as (Beretka and Mattew, 1985)

$$H_{in} = C_{Ra}/185 + C_{Th}/259 + C_K/4810 \quad (10)$$



ISSN: 2223-9944, e ISSN: 2223-9553

$H_{in}$should be less than unity for the radiation hazard to be negligible. Internal exposure to radon and its daughter products are very hazardous and can lead to respiratory diseases like asthma and cancer.

**Table 2: Radiation Hazard Parameters**

| S/No | Sample ID | ADR (nG/yr) | AGED (Sv/yr) | $Ra_{eq}$ (Bq/kg) | $H_{ex}$ | $H_{in}$ | $I_{yr}$ | AEDE (Outdoor) | AEDE (Indoor) | ELCR x $10^{-3}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | SAMPLE1 | 17.97 | 124.04 | 38.44 | 0.10 | 0.14 | 0.21 | 22.04 | 88.15 | 0.077 |
| 2 | SAMPLE2 | 18.09 | 124.94 | 38.65 | 0.10 | 0.15 | 0.21 | 22.19 | 88.75 | 0.078 |
| 3 | SAMPLE3 | 18.43 | 127.33 | 39.39 | 0.11 | 0.15 | 0.21 | 22.61 | 90.43 | 0.079 |
| 4 | SAMPLE4 | 17.55 | 121.18 | 37.54 | 0.10 | 0.14 | 0.20 | 21.53 | 86.16 | 0.075 |
| 5 | SAMPLE5 | 18.82 | 129.96 | 40.24 | 0.11 | 0.15 | 0.22 | 23.08 | 92.33 | 0.081 |
| 6 | SAMPLE6 | 18.70 | 129.04 | 40.00 | 0.11 | 0.15 | 0.22 | 22.93 | 91.72 | 0.080 |
| 7 | SAMPLE7 | 17.71 | 122.20 | 37.92 | 0.10 | 0.14 | 0.21 | 21.72 | 86.87 | 0.076 |
| 8 | SAMPLE8 | 17.91 | 123.92 | 38.16 | 0.10 | 0.14 | 0.20 | 21.97 | 87.87 | 0.077 |
| 9 | SAMPLE9 | 17.88 | 123.47 | 38.18 | 0.10 | 0.15 | 0.21 | 21.97 | 87.71 | 0.077 |
| 10 | SAMPLE10 | 18.45 | 127.43 | 39.39 | 0.11 | 0.15 | 0.21 | 22.62 | 90.49 | 0.079 |
| | Average | 18.15 | 125.35 | 38.79 | 0.10 | 0.15 | 0.21 | 22.27 | 89.05 | 0.0779 |

## Annual Gonadal Equivalent Dose (AGED)

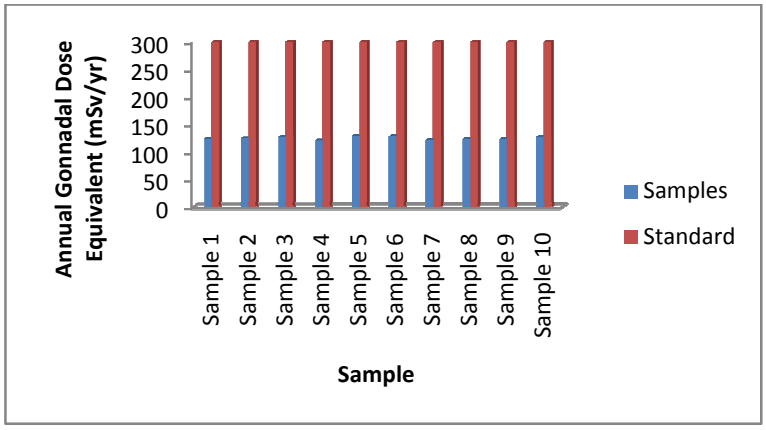


Figure 1.Annual Gonadal Equivalent compared with standard value

## Ra equivalent

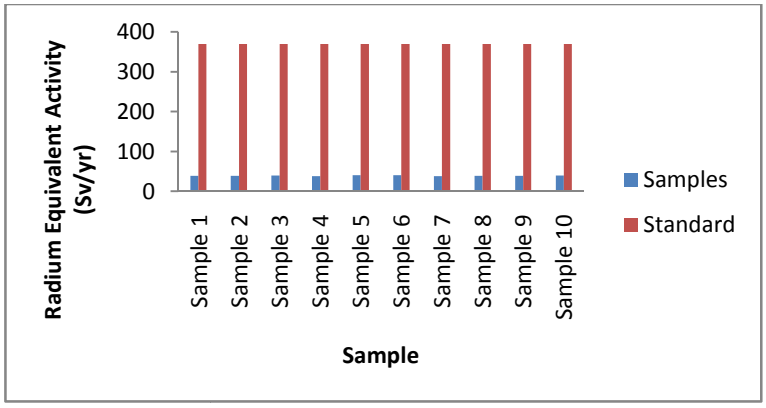


Figure 2: Radium Equivalent Activity compared with standard value


ISSN: 2223-9944, e ISSN: 2223-9553

**External Hazard ($H_{ex}$)**

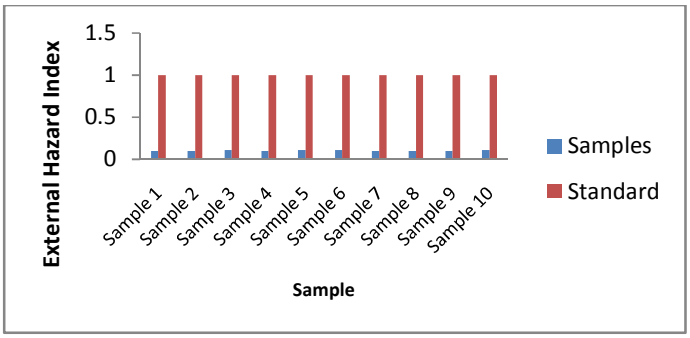


Figure 3: External Hazard Index compared with Standard value

**Internal Hazard Index ($H_{in}$)**

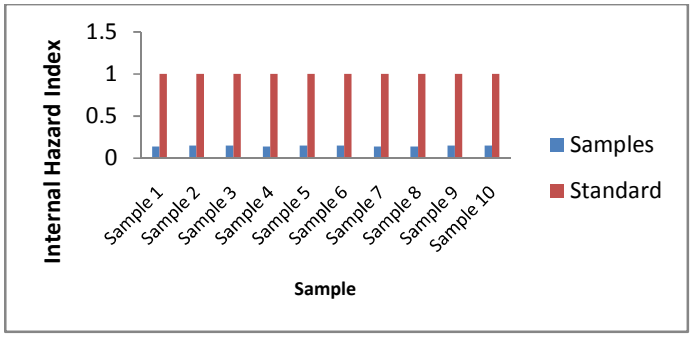


Figure 4. Internal Hazard Index compared with Standard value

**Representative Gamma Index ($I_{yr}$)**

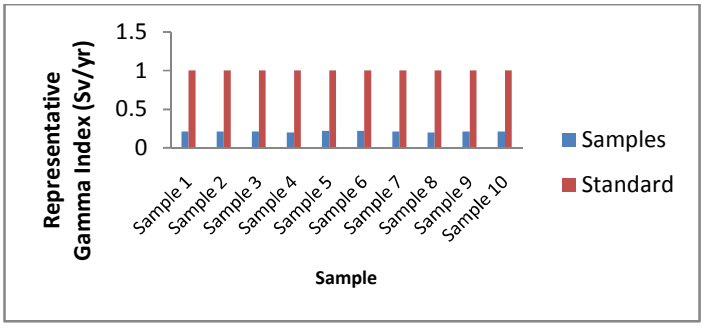


Figure 5.Representative gamma index compared with standard value

**Annual Effective Dose Equivalent (AEDE) outdoor**

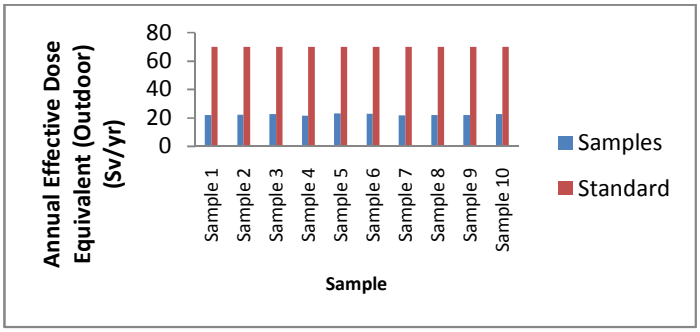


Figure 6. Annual effective dose equivalent (Outdoor) compared with standard value

**Annual Effective Dose Equivalent (AEDE) Indoor**

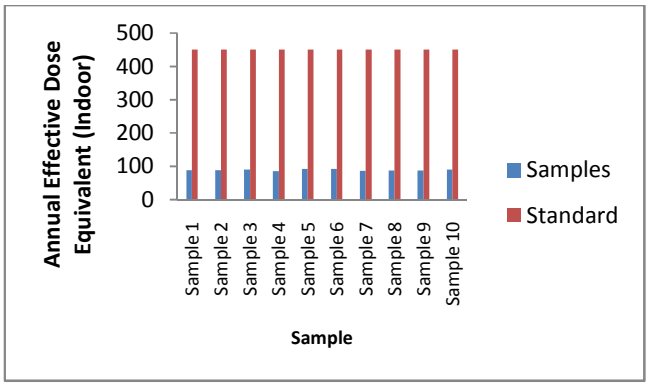


Figure 7. Annual effective dose equivalent (Indoor) compared with standard value

**Excess Lifetime Cancer Risk (ELCR)**

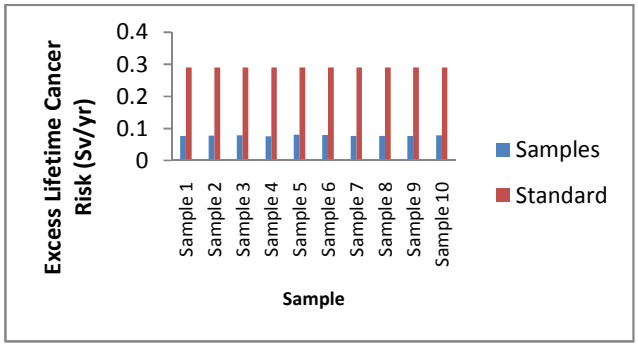


Figure 8. Excess lifetime cancer risk compared with standard value

## DISCUSSION

The specific radioactivity levels together with the natural radionuclides obtained are presented in Tables 1. The mean values of $^{226}$Ra, $^{232}$Th and $^{40}$K are 15.45 ± 3.98 Bqkg$^{-1}$, 10.64 ± 1.53Bqkg$^{-1}$ and 105.60 ± 4.32Bqkg$^{-1}$ respectively for the soil sample. These activity concentration values obtained in the samples are below the world permissible value of 35.0 Bqkg$^{-1}$ for $^{226}$Ra, 30.0 Bqkg$^{-1}$ for $^{232}$Th and 400.0 Bqkg$^{-1}$ for $^{40}$K (UNSCEAR,2000).

The results obtained for the radium equivalent activity and annual gonadal dose equivalent are below the permissible values of 370 Bqkg$^{-1}$ and 300 mSvy$^{-1}$respectively (UNSCEAR, 2000). This implies that the gonadal values may pose no threat to the bone marrow and the bone surface cells of the building workers during construction of the nuclear power plant and community residents in the area of study. Also all values of external hazard index, internal hazard index and representative gamma index are less than the world permissible value of unity (Avwiri et.al. 2013, Avwiri and Ononugbo, 2012 and Orgun et al., 2007). This is an indication that the obtained values will not pose any respiratory tract disease such as asthma and other external diseases such as erythema, skin cancer and cataracts to the users of such soil.In addition, the present value of indoor and outdoor annual effective dose equivalent is lower than the world average values of 70μSvy$^{-1}$ for outdoor and 450 μSvy$^{-1}$for indoor (Avwiri et al., 2013). Average excess lifetime cancer hazard risk (ELCR) for all samples is less than theworld average of 0.29 × 10-3 (Taskin et al., 2009). This implies that the chances of developing cancer by the general populace are insignificant for now but continuous accumulation may pose health.



ISSN: 2223-9944, e ISSN: 2223-9553

## CONCLUSION

The evaluation of radiation hazard indices and excess lifetime cancer risk of soils in Geregu area of Kogi State, Nigeria have been conducted. The values obtained when compared with the various world permissible values were found to be below the standards for such environment and as such exposure will pose no significant health threat to human lives and the environment.

## ACKNOWLEDGEMENT

We express our sincere thanks and gratitude to the Director of the Centre for Nuclear Energy Research and Training (CNERT), for his sincere cooperation and help during this work. The authors are also thankful to the Management of the Nigeria Atomic Energy Commission (NAEC) for providing all logistic support to carry out this work.

## REFERENCES

[1] Agbalagba, E. O., &Onoja, R. A.(2011). Evaluation of natural radioactivity in soil, sediment and water samples of Niger Delta (Biseni) flood plain lakes, *Nigeria. J. Environ. Rad.102*:667-6713

[2] Arogunjo, A. M., Efuga, E. E., & Afolabi, M. A. (2004). Levels of natural radionuclide‘s in some Nigerian cereals and tubes *Journ. Of Environ. Radioactivity 82;* 1-6.

[3] Avwiri, G. O., & Agbalagba, E. O. (2007): Survey of gross alpha and gross beta radionuclide activity in Okpare-Creek Delta State Nigeria. Asian network for Scientific information. *J. Appl. Sci., 7*(22), 3542-3546.

[4] Avwiri, G. O., Egieya J. M., &Ononugbo, C. P. (2013). Radiometric Assay of Hazard Indices and Excess Lifetime Cancer Risk Dose to Natural Radioactivity in Soil Profile in Ogba/Egbema/Ndoni Local Government Area of Rivers State, *Nigeria. Academic Research International, 4*(5) Pg. 54 -65

[5] Avwiri, G. O., &Ononugbo, C. P. (2012). Natural Radioactivity Levels in Surface Soil of Ogba/Egbema/Ndoni Oil and Gas Fields. *CSCanada Energy. Sci. And Technology, 4*(2), pp 92-101

[6] Baratta, E. J. (1990).*Radon, Radium and Uranium in drinking water*. Lewis Publisher, Washington DC, pp. 203-213

[7] Beretka, J., & Mathew, P. J. (1985). Natural radioactivity of Australia Building materials industrial wastes and by-products, *Health Phy, 48*: 87-95

[8] Diab, H. M., Nouh, S. A., Hamdy, A., & El- Fiki, S. A. (2008).Evaluation of natural radioactivity in a cultivated area around a fertilizer factory. J. *Nucl. and Rad. Phys. 3*(1): 53- 62

[9] El-Taher, A. (2010). Gamma spectroscopic analysis and associated radiation hazards of building materials used in Egypt. *J. Radiat. Protect. Dosim 138* (2): 158-165.

[10] IAEA (International Atomic Energy Agency) (2003). *International Basic Safety Standards for Protection against Ionising Radiation andfor safety of Radiation sources* 115. IAEA Vienna.

[11] Kannan, V., Rajan, M. P., Iyengar, M. A., & Ramesh, R. (2002). Distribution of natural and anthropogenic radionuclides in soil and beach sand samples of



ISSN: 2223-9944, e ISSN: 2223-9553

Kalpakkam, using Hyper Pure Germamium (HPGe) Gamma ray spectrometry. *Appl. Radi. Isotopes 57,* 109-119.

[12] Kirchner, T. B., Webb, S. B., Webb, J. B., Arimoto, R., Stewart, B. D., &Schoep, B. D. (2002).Variability in the background levels of surface soil radionuclides in the vicinity of US Department of Energy Waste Isolation plant. *J. Environ. Rad 60*, 275-281

[13] Nour, K. A., & Abdel, G. M. E. (2005). Natural radioactivity in farm soil and phosphate fertilizer and its environmental implications in Qena governorate, Upper Egypt. *J. Environ. Rad. 84* (1), 51-64.

[14] Obed, R. I., Farai, I. P., & Jibiril, N. N. (2005). Population dose distribution due to soil radioactivity concentration levels in 18 cities across Nigeria*. J. Radiol. Prot. 25,* 305-312

[15] Orgun, Y., Altinsoy, N., Sahin, S.Y., Gungor, Y., Gultekin, A. H., Karaham, G., & Karaak, Z. (2007).Natural and anthropogenic radionuclide in rocks and beach sands from Ezine region, Western Anatolia, Turkey.*Applied Radiation and Isotopes*., 65: 739-747.

[16] Patra, A. K., Sudhakar, J., Ravi, P. M., James, J. P., Hedge, A. G., & Joshi, M. I., (2006). Natural radioactivity distribution in geological matrices around Kaiga environment. *J. Radio. Nucl. Chem. 270*, 307-312.

[17] Sam, A. K., & Abbas, N. (2010). Assessment of radioactivity and associated hazards in local and imported cement types used in Sudan. *Radiation protection Dosimetory 88,*225-260, 2000

[18] Selvasekarapandian, S., Sivakumar, R., Manikandan, N. M., Meenakshisundaram, V., Raghunath, V. M., & Gajendran, V., (2005). Natural radionuclide distribution in soilsofGudalore, *India. Appl. Radiat. Isotopes 52,* 299-306.

[19] Senthilkumar, B., Dhavamani, V., Ramkumar, S., & Philominathan, P. (2010). Measurement of gamma radiation levels in soil samples from Thanjavur using gamma-ray spectrometry and estimated of population exposure. *J. Med. Phys.* 2010.

[20] Taskin, H., Karavus, M., Ay, P., Topuzoglu, A., Hidiroglu, S., & Karahan, G. (2009). "Radionuclide concentration in soil and lifetime cancer risk due to the gamma radioactivity in Kirklareli, Turkey*". Journal of environmental radioactivity, 100*, 49-53.

[21] Tufail, M., Akhtar, N., Jaried, S., & Hamid, T. (2007). Natural radioactivity hazards of building bricks fabrication from soil of two districts of Pakistan, *Journal of radiological protection 27*: 481-492

[22] UNSCEAR (1988). *Sources, Effects and Risks of Ionizing radiation, Report to the General Assembly with annexes.* United State Publication E88ix 17 (United Nations) New York.

[23] UNSCEAR (2000). *Sources, Effects and Risks of Ionizing Radiation*, Report to the General Assembly, New York.

[24] Zarie, K. A., & Al MugrenK, S. (2010). Measurement of natural radioactivity and assessment of radiation hazard in soil samples from Tayma area (KSA). *Isotope and Rad. Res.42*(1):1- 9



ISSN: 2223-9944, e ISSN: 2223-9553