

# Radionuclides Concentrations in Soil and Excess Lifetime Cancer Risk Due to the Gamma Radioactivity in Kogi Central District, Kogi State, Nigeria

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## ABSTRACT

The activity concentrations of the natural radionuclides  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  were measured for eight soil samples collected from different location of high activity across the district, using high resolution gamma ray spectroscopy. The concentration of  $^{226}\text{Ra}$  in the soil in Kogi central district varied from  $27.9914 \pm 3.1965$  to  $73.5054 \pm 0.7592$  Bq/kg with average of  $48.9128 \pm 2.4373$  Bq/kg. The minimum value was obtained in Itakpe1 and a maximum value at Steel complex. For  $^{232}\text{Th}$ , the measured activity ranged from  $32.5168 \pm 2.0446$  to  $128.8090 \pm 2.0053$  Bq/kg with an average of  $90.0606 \pm 2.0495$  Bq/kg. The minimum value was also obtained in Kuroko and a maximum value obtained at Itakpe2. The activity concentration of  $^{40}\text{K}$  ranged from  $114.3884 \pm 3.0568$  to  $448.4904 \pm 10.1357$  Bq/kg with an average of  $254.4176 \pm 4.6723$  Bq/kg. The minimum value obtained in Kuroko and a maximum value obtained at Itakpe1. The calculated radium equivalent activity ( $Ra_{eq}$ ) values are within and less than the permissible limits of 370 Bq/kg and the determined values of external and internal hazard index are less than unity, however, all the values of gamma representative index is greater than unity except at Kuroko. The calculated absorbed dose rates due to the presence of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in each of the soil samples varied from 48.327 to 119.794 (nGy/h), with an average value of 91.446 (nGy/h). this is about 2 times higher than the world average of 43nGy/h. The calculated annual effective dose rate in all the soil samples varies from 0.059 mSv/y to 0.146 mSv/y with an average value of 0.11 mSv/y and it remains within the criterion of 1.0 mSv/y recommended. The range of Excess Lifetime Cancer Risk (ELCR) is  $0.207 \times 10^{-3}$  to  $0.511 \times 10^{-3}$  with an average value of  $0.392 \times 10^{-3}$  which less than world average value of  $1.45 \times 10^{-3}$ .

**keywords:** Radionuclides, concentrations, soil, excess lifetime cancer risk, Kogi central, radium equivalent, hazard indices.

## 1.0 INTRODUCTION

Radiation can be referred to as the energy in motion in the form of waves or particles. Radiation is present everywhere around us in many forms. Radiation includes: radio waves, microwaves, infrared, visible light, ultraviolet rays, X-rays and  $\gamma$ -rays (Rajan, 2017). Radiation has been part of the environment since the creation of the earth and as such, humans are continually and unavoidably exposed daily to varying doses of ionizing radiation (Ugbede and Echeweozo, 2017). The radioactive elements and their radiations are indispensable part of nature. Investigations and measurement of natural environmental radiation and radioactivity are of immense importance and of interest in health physics because it can be useful for assessment of public dose exposure rates and keeping reference data records to ascertain possible changes in the environmental radioactivity over time (Salawu, Osita & Anikoh, 2025). Radionuclides exist in almost every part of the earth's surface. They are present in air, soil and water depending on the geological and geographical features of a region, therefore; radiation measurement and protection require a highly knowledge of their distribution in soils and rocks (Alaboodi *et al.* 2020; Peter, Olanrewaju & Victor 2021). In many instances the human body system adapts to this background radiation level without suffering adverse health effects but any exposure beyond this level may come with certain health problems. The penetration of radiation into matter can pose biological hazard which may later show clinical symptoms (Rilwan, Rufai & Yahaya, 2021). The mode and extent of these symptoms and the time they take to appear depends on the amount of radiation absorbed and the rate at which it is received (Rilwan, Ugwu &

Alkasim, 2022). When assessing the current levels of natural radiation, it is essential to consider the contribution of the sources to the ongoing background exposure. The increase in naturally occurring background radiation, primarily from natural sources of ionizing radiation, is becoming more concerning (Al-Othmany, 2022; Mbonu & Ben, 2021). Human activities such as mining, milling, quarrying operation, soil tillage and ridge making activities have the capability of redistributing 20-40 cm down layered soil to the top surface and radioactive elements initially associated with the soil also reach the top surface (Rilwan., *et al.* 2020; Ugbede, 2018). These operations bring large amounts of buried material containing natural occurring radionuclides to the surface of the environment thereby enhancing the exposure rate. Therefore, radiation protection greatly depends on understanding of their existence, distribution, contamination, interaction and activity with many elements such as air, soil, water, plants, tissue and food species, hence the top soil are where most exposure to natural terrestrial radiation comes from (Isa, Salawu & Abuh, 2024). Reliable estimations of the radiation dose that the public receives from different exposure pathways, such as natural background radiation, environmental radionuclide ingestion, and indoor radon exposure, are necessary to satisfactorily estimate the risks from ionizing radiation (Abdoun, Al-Amri, & Al-Ghamdi, 2020)

### 1.1 Geology of the Study Area

The geological setting of Kogi State is unique in view of the occurrence of the two major components of Nigerian geology (Basement Complex and Sedimentary Basin). Approximately, half of the State is covered by crystalline

Basement Complex while the other half is covered by Cretaceous to Recent sediments. The Basement Complex are predominantly underlain the western flank of the State. They are made up of Migmatite- Gneiss Complex which include rocks of migmatites, gneisses and granite-gneisses; the Schist Belts (metasedimentary and metavolcanic rocks) which include phylites, schists, pelites, quartzites, marbles and amphibolites; and the Pan-African Older Granites consisting of granites, granodiorites, syenites, monzonites, gabbro and charnockites. The crystalline complex contained economic minerals such as iron ore, gemstones, quartz, feldspar and other associated minerals, while the Pan-African Older Granite contained cassiterite, tantalite, columbite, gemstones and other associated minerals (KSMSMD, 2004).

Review of Some Radiation Studies within the state:

Assessment of radiation hazard in soil from Ajaokuta, north central Nigeria. Investigation revealed that the calculated average concentration of the radionuclides ranged from  $12 \pm 1 \text{ Bqkg}^{-1}$  to  $59 \pm 2 \text{ Bqkg}^{-1}$  for  $\text{U}^{238}$ ,  $14 \pm 1 \text{ Bqkg}^{-1}$  to  $78 \pm 5 \text{ Bqkg}^{-1}$  for  $\text{Th}^{232}$  and  $49 \pm 2 \text{ Bqkg}^{-1}$  to  $1272 \pm 23 \text{ Bqkg}^{-1}$  for  $\text{K}^{40}$ , the estimated radium equivalent (Ra eq) ranges from  $\text{Bqkg}^{-1} 55.7$  at Steel Complex to  $253.3 \text{ Bqkg}^{-1}$  obtained from forest samples. The mean absorbed dose rate, annual effective dose and gamma radiation index evaluated were  $66.2 \text{ nGyh}^{-1}$ ,  $81.2 \mu\text{Svy}^{-1}$  and 1.05 respectively which are higher than the recommended limit for normal background radiation. Thus, people living in these locations may be exposed to higher radiation. (Usikalu *et al.*, 2017).

Daniel *et al.*, (2013) carried out Radiological Effects of Iron-Ore Mining and Processing at Itakpe, Kogi State. It was observed that the mean measured activity concentrations of  $^{40}\text{K}$ ,  $^{226}\text{Ra}$ , and  $^{232}\text{Th}$  were  $207.6 \pm 39.4$  (ND-515.0),  $17.6 \pm 2.4$  (ND-31.5), and  $31.7 \pm 8.6$  (ND-118.0)  $\text{Bqkg}^{-1}$ , respectively, which are all less than the world mean of 370.0, 25.0, and  $25 \text{ Bqkg}^{-1}$  for  $^{40}\text{K}$ ,  $^{226}\text{Ra}$ , and  $^{232}\text{Th}$ , respectively and calculated outdoor mean effective doses for the sites were respectively  $74.8 \pm 20.0 \mu\text{Sv}$ ,  $47.0 \pm 7.0 \mu\text{Sv}$  and  $17.0 \pm 1.0 \mu\text{Sv}$  for industrial plant, mining waste and mill tailing deposit sites. These values are comparable to the control mean value of  $74.3 \pm 46.2 \mu\text{Sv}$  (obtained from unmodified environment soil samples) which in turn is comparable to the world mean of  $60 \mu\text{Sv}$ , thus suggesting that the mining company does not constitute radiological problem to its workers and the public. The calculated activity index, I, for the company mill tailings is 0.122, the value which is equivalent to an excess gamma dose of  $0.122 \text{ mSv/yr}$  over that received outdoors if used as a building material.

Sequel to Salawu *et al.*, (2025) in the study of Assessment of Background Gamma Radiation and Development of Radiation Contour Map for Kogi Central District, Kogi State, Nigeria, it was found that the background radiation exposure level in some of the locations studied within the five local Government Area were above the recommended safe limit and some of the determined radiological parameters were above world average values and recommended safe limit, as such it is necessary to carry out radiological concentration of soil samples from such

locations of high background radiation to ascertain the radionuclides concentrations of the soil samples from such locations. This study aimed at determining the activity concentrations of radionuclides in the soil samples, having high exposure rate and the possible radiological implications of exposure in the area.

## 2.0 MATERIALS AND METHODS

### 2.1 Materials

Soil auger, polyethylene sampling bag, gamma spectroscopy “sodium iodide thallium” drifted (NaI (TI)) detector type, Vaseline jelly, sieve

### 2.2 Methods

This is the main analysis to measure quantitatively and qualitatively the radionuclide present in the soil sample collected from area of relatively high activity in terms  $^{238}\text{U}$ ,  $^{40}\text{K}$  and  $^{232}\text{Th}$ .

#### i. Soil sampling

The samples were collected by digging the ground to at least 10 cm then take the soil from there and at each sample point, soil sample as much as 500 g was taken for gamma spectroscopy using sodium iodide thallium drifted (NaI (TI)) detector type. Five soil samples were taken from different points at each location making a total of forty samples collected using composite sampling method for better sampling. Each sample collected was put into a polyethylene sampling bag, tied and labelled appropriately. Double bags were used for each sample to prevent breakage and cross contamination of samples.

#### ii. Soil Sample Preparation

Each of the soil samples collected were dried and crushed to fine powder with the use of pulverizer. Packaging of the samples into radon-impermeable cylindrical plastic containers which were selected based on the space allocation of the detector vessel which measures 7.6 cm by 7.6 cm in dimension (geometry) was also carried out. To prevent radon-222 escaping, the packaging in each case was triple sealed.

The sealing process included smearing of the inner rim of each container lid with Vaseline jelly, filling the lid assembly gap with candle wax to block the gaps between lid and container, and tight-sealing lid-container with masking adhesive tape. Radon and its short-lived progenies were allowed to reach secular radioactive equilibrium by storing the samples for 30 days prior to gamma spectroscopy measurements.

#### iii. Evaluation of Radioactivity of Samples

The radionuclide analysis was carried out at Centre for Energy Research and Training Zaria The analysis was carried out using a 76x76 mm NaI (TI) detector crystal (model No. 727 and serial No. 11914167 by CANBERRA) optically coupled to a photomultiplier tube (PMT). The assembly has a preamplifier incorporated into it and a 1kilovolt external source. The detector is enclosed in a 6cm lead shield with cadmium and copper sheets. This arrangement is aimed at minimizing the effects of background and scattered radiation.

The data acquisition software is Maestro by Canberra Nuclear Products. The samples were measured for a period of 29000 seconds, for each sample. The peak area of each energy in the spectrum was used to compute the activity concentrations in each sample by the use following equation:

$$A \text{ (Bq/kg)} = \frac{C_n}{C_{fk}} \quad (1)$$

where

A is the activity concentration of the radionuclides in the sample given in  $Bqkg^{-1}$

$C_n$  is the count rate (counts per second)

$$\text{Count per second (cps)} = \frac{\text{Net Count}}{\text{Live Time}} \quad (2)$$

(2)

**Table 1:** Spectral energy windows used in the Analysis

Isotope	Gamma Energy (KeV)	Energy Window (KeV)
Ra-226	1764.0	1620-1820
Th-232	2614.5	2480-2820
K- 40	1460.0	1380-1550

**Table 2:** Energy Calibration for quantitative Spectral Analysis

Isotope	Calibration Factors		Conversion Factors (Bq/kg)	Detection Limits	
	$10^{-3}$ (cps/ppm)	$10^{-4}$ (cps/ppm)		ppm	Bq/kg
$^{40}\text{K}$	0.026	6.431	0.032	454.54	14.54
$^{226}\text{Ra}$	10.500	8.632	12.200	0.32	3.84
$^{232}\text{Th}$	3.612	8.768	4.120	2.27	9.08

## 2.2.1 Radiological Parameter

### i. The Radium Equivalent Activity ( $Ra_{eq}$ )

The concentration and distribution of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in the soil is not uniform throughout the world. For the purpose of comparing the radiological parameter or the activity of materials that contain  $^{226}\text{Ra}$  and  $^{232}\text{Th}$  and  $^{40}\text{K}$  by a single quantity, which takes into account the radiation hazards associated with them, a common index termed the radium equivalent activity ( $Ra_{eq}$ ) is used. The  $Ra_{eq}$  index represent weighted sum of activities of natural radionuclides and is based on the estimation that 1  $Bqkg^{-1}$  of  $^{226}\text{Ra}$ , 0.7  $Bqkg^{-1}$  of  $^{232}\text{Th}$  and 13  $Bqkg^{-1}$  produces the same gamma radiation dose rates. The Radium equivalent ( $Ra_{eq}$ ) is expressed mathematically by

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

where  $A_{Ra}$ ,  $A_{Th}$  and  $A_K$  are the activity concentration of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  respectively (Zarma., *et al.* 2023; UNSCEAR 2000).

### ii. The Absorbed Dose rate

The absorbed dose rate ( $D_r$ ) in air at average gonad height of one meter above the surface of ground due to the natural radionuclides  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  was estimated using the formula given as

$$D_r = (DCF_{Ra} \times A_{Ra}) + (DCF_{Th} \times A_{Th}) + (DCF_K \times A_K) \quad (4)$$

where  $DCF_{Ra} = 0.427$ ,  $DCF_{Th} = 0.662$  and  $DCF_K = 0.043$  are the dose conversion factor for  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in

$C_{fk}$  is the Calibration factor of the detecting system.

### iv. Calibration and Efficiency Determinations

Calibration of the system for energy and efficiency were done with two calibration point sources, **Cs-137** and **Co-60**. These were done with the amplifier gain that gives **72% energy** resolution for the 66.16 KeV of Cs-137 and counted for 30 minutes. Table 7 and 8 present the Spectral energy windows used in the Analysis and Energy Calibration for quantitative Spectral Analysis respectively.

### v. Standards

The standards used to check for the calibration are the **IAEA** Gamma Spectrometric reference materials RGK-1 for K-40, RGU-1 for Ra-226 (Bi-214 peak) and RTG-1 for Th-232 (Ti-208).

$nSv/h/Bqkg^{-1}$  The effective dose rate is calculated from the absorbed dose rate by applying the dose conversion factor of 0.7  $SvGy^{-1}$  and an outdoor occupancy factor of 0.2 (Mohammed *et al.* 2025; UNSCEAR 2000). It is given by  $E_r (\mu Sv/yr) = [D_r (nGy/h) \times 0.2 \times 8760 \times 0.7 Sv/Gy] \times 10^{-3}$  (5)

Where  $E_r$  is the average annual effective dose and  $D_r$  is the absorbed dose rate in air. This calculation takes into account that the people spend 20% of their time outdoors.

### iii. The Annual Effective Dose Equivalent

The annual effective dose equivalent (AEDE) to the population can be calculated using the conversion coefficient from absorbed dose (0.7  $SvGy^{-1}$ ) the indoor and outdoor ratio (1.4), the outdoor occupancy factor of 0.2 and the indoor occupancy factor of 0.8. Therefore, the annual effective doses outdoor and indoor equivalent are obtained by using this relation (Ugbede, Osahon, & Agbalagba, 2021).

$$D_{outdoor} (mSv/yr) = [D_r (mGy/hr) \times 8760 \times 0.2 \times 0.7 Sv/Gy] \times 10^{-6} \quad (6)$$

$$D_{indoor} (mSv/yr) = [D_r (mGy/hr) \times 8760 \times 1.4 \times 0.8 \times 0.7 Sv/Gy] \times 10^{-6} \quad (7)$$

The corresponding worldwide values of  $D_{out}$ ,  $D_{in}$  and  $D_{tot}$  are 0.08, 0.42 and 0.50  $mSvyr^{-1}$  respectively (UNSCEAR, 2000; Popoola *et al.*, 2025).

### iv. The External and Internal Hazard Index

The external ( $H_{ex}$ ) and internal ( $H_{in}$ ) hazard index due to the emitted  $\gamma$ -rays of the soil samples can be calculated and examined according to the following criterion: (Berekta and Mathew, 1985).

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (8)$$

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (9)$$

The value of  $H_{ex}$  and  $H_{in}$  should be less than  $1mSv\cdot y^{-1}$  in order for the radiation hazard to be considered acceptable to the public and to have negligible hazardous effects to the respiratory organs of the public.

An additional hazard index so called the representative (radioactivity) level index can be calculated by using this relation (Berehta and Mathew, 1985; Bilici *et al.* 2023).

$$I_\gamma = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \leq 1 \quad (10)$$

The value of  $I_\gamma$  must be less than unity in order to keep the radiation hazard insignificant (Bilici *et al.* 2023)

v. **Excess Lifetime Cancer Risk**

Excess Lifetime Cancer Risk (ELCR) is calculated using the equation below (Dankawu., *et al.* 2021).

$$ELCR = AEDE \times DL \times RF \quad (11)$$

where AEDE, DL and RF are the total annual effective dose equivalent (in  $\mu Sv\cdot y^{-1}$ ), duration of life (70 years) and risk factor ( $Sv^{-1}$ ), fatal cancer risk per Sievert. For stochastic effect, ICRP 60 uses values of 0.05 for the public (Ugbede and Echeweozo, 2017).

### 3.0 RESULTS AND DISCUSSION

#### Gamma Spectroscopy Results

The specific activities of natural of radionuclides present in the soil samples of the selected areas of Kogi Central Senatorial District measured by direct gamma ray spectrometry are given in Table 3 below.

**Table 3:** Activity concentration of radionuclides in soil sample from Kogi central

Sample ID	K-40 (Bq/kg)	Ra-226 (Bq/kg)	Th-232 (Bq/kg)
Okene-Eba	189.5747±5.4700	48.8996±2.5972	64.5225±0.3932
Ogori	165.3885±5.2019	67.0616±0.4795	104.5885±1.8087
Kuroko	114.3884±3.0568	51.2463±0.8391	32.5168±2.0446
Ajaokuta	130.0477±5.5237	32.0853±3.9557	74.9813±1.4548
Steelcomplex	313.9915±5.6846	73.5054±0.7592	89.4507±0.6291
Geregu	413.3105±10.2966	35.8629±6.1933	111.5519±6.9595
Itakpe1	448.4904±10.1357	27.9914±3.1965	114.0644±1.1009
Itakpe2	260.1491±2.3060	54.6500±1.4781	128.8090±2.0053
Average	254.4176±4.6723	48.9128±2.4373	90.0606±2.0495

The result of analysis of activity concentration of  $^{226}Ra$ ,  $^{232}Th$  and  $^{40}K$  are reported in  $Bq\cdot kg^{-1}$  on dry weight basis. The range of measured activity of  $^{226}Ra$  in the soil in Kogi central district was  $27.9914\pm 3.1965$  to  $73.5054\pm 0.7592$   $Bq/kg$  with average of  $48.9128\pm 2.4373$   $Bq/kg$ . The minimum value obtained in Itakpe1 and a maximum value at Steel complex. For  $^{232}Th$ , the measured activity ranged from  $32.5168\pm 2.0446$  to  $128.8090\pm 2.0053$   $Bq/kg$  with an average of  $90.0606\pm 2.0495$   $Bq/kg$ . The minimum value obtained in Kuroko and a maximum value obtained at Itakpe2. The activity concentration of  $^{40}K$  ranged from  $114.3884\pm 3.0568$  to  $448.4904\pm 10.1357$   $Bq/kg$  with an average of  $254.4176\pm 4.6723$   $Bq/kg$ . the minimum value obtained in Kuroko and a maximum value obtained at Itakpe1.

Therefore, as far as the radioactivity from natural radionuclides is concern, the results clearly indicate that

$^{232}Th$  and  $^{40}K$  are the major radionuclide detected in significant amount in all soil samples. The radionuclide  $^{226}Ra$  is in nominal concentrations.  $^{232}Th$  and  $^{40}K$  are the major radionuclide detected in soil sample from Itakpe1, Itakpe2 and Geregu, while  $^{40}K$  is the major radionuclides in soil sample from steel complex. The high value  $^{226}Ra$  concentration is obtain from soil samples collected from steel complex and kuroko. The concentrations of these radionuclide in the soil were not uniform and but varied from soil to soil and location to location depending upon the geological, geochemical composition and topographic character of the area under study.

Table 4 presents the radiological effects such as: the radium equivalent ( $Ra_{eq}$ ), external ( $H_{ex}$ ) and internal ( $H_{in}$ ) hazard index and radioactivity level index ( $I_\gamma$ ) of the soil samples collected from region under investigation.

**Table 4:** The radium equivalent ( $Ra_{eq}$ ), internal ( $H_{in}$ ) and external ( $H_{ex}$ ) hazard index and radioactivity level index ( $I_\gamma$ ) of the soil samples collected from Kogi central district.

Sample ID	$Ra_{eq}$ (Bq/kg)	$H_{in}$	$H_{ex}$	$I_\gamma$
Okene-Eba	155.764	0.55	0.42	1.09
Ogori	229.358	0.80	0.62	1.60
Kuroko	106.553	0.43	0.29	0.74
Ajaokuta	149.322	0.49	0.40	1.05
Steel complex	225.597	0.81	0.64	1.59
Geregu	227.207	0.71	0.61	1.63
Itakpe 1	225.637	0.68	0.61	1.63
Itakpe 2	258.878	0.85	0.70	1.83
Average	197.290	0.67	0.54	1.40

Using the equations (3), (8), (9) and (10), ( $RA_{eq}$ ), ( $H_{ex}$ ), ( $H_{in}$ ) and ( $I_{\gamma}$ ) are calculated as shown in Table 4.

The radium equivalent ( $RA_{eq}$ ) calculated value for the soil samples vary from 106.553 Bq/kg to 258.878 Bq/kg with an average value of 197.290 Bq/kg. it is inferred that for all the samples analysed, The radium equivalent activity ( $RA_{eq}$ ) value is within and less than the permissible limits of 370 Bq/kg (UNSCEAR, 2000).

The ultimate use of the activity measured in the soil samples is to measure the radiation dose delivered externally in the form of gamma dose. The external hazard indices ( $H_{ex}$ ) were calculated and the values vary from 0.29 to 0.70 with an average value of 0.54, the calculated values were less than the acceptable value (1.5 mGy/y). the internal hazard index ( $H_{in}$ ) vary from 0.43 to 0.85 with an average value

Of 0.67 and less than 1. The radioactivity level index ( $I_{\gamma}$ ) vary from 0.74 to 1.83 with an average value of 1.40. The highest values of external and internal hazard indices have been found to be less than unity as shown in Table 4. However the radioactivity level index ( $I_{\gamma}$ ) of all except for soil sample collected from Kuroko were greater than 1, this implies that the radiation hazard is significant. Therefore based on these results of radium equivalent activity, internal and external hazard indices and the radioactivity level index, one can conclude that there is relatively low health hazard from the soil samples collected from area of high activity in Kogi central senatorial district.

The calculated absorbed dose rates, Annual effective dose rate and Excess lifetime cancer risk due to the presence of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in each of the soil samples

**Table 5:** Absorbed dose rate (nGy/h), Annual effective dose equivalent and Excess lifetime cancer risk

Sample ID	Absorbed dose rate (nGy/h)	Annual Effective Dose rate (mSv/yr)	Excess Lifetime Cancer risk $\times 10^{-3}$
Okene-eba	71.7460	0.088	0.308
Ogori	104.985	0.128	0.448
Kuroko	48.3270	0.059	0.207
Ajaokuta	68.9300	0.084	0.294
Steel complex	104.105	0.127	0.445
Geregu	106.933	0.131	0.459
Itakpe 1	106.748	0.130	0.455
Itakpe 2	119.794	0.146	0.511
Average	91.4460	0.112	0.392

The calculated absorbed dose rates due to the presence of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in each of the soil samples varied from 48.327 to 119.794 (nGy/h), with an average value of 91.446 (nGy/h). this is about 2 times higher than the world average of 43nGy/h (UNSCEAR, 2000). The measured absorbed dose in air were higher than the calculated absorbed dose rates for the soil samples. This may be attributed to the fact that the measured absorbed dose rates may not have come wholly from the sampled soil, they may include the dose rates due to terrestrial sources.

The calculated annual effective dose rate in all the soil samples varies from 0.059 mSv/y to 0.146 mSv/y with an average value of 0.11 mSv/y and it remains within the criterion of 1.0 mSv/y recommended by (UNSCEAR, 2000, ICRP 1990). The range of Excess Lifetime Cancer Risk (ELCR) is  $0.207 \times 10^{-3}$  to  $0.511 \times 10^{-3}$  with an average value of  $0.392 \times 10^{-3}$  which less than world average value of  $1.45 \times 10^{-3}$ . According to these results, the risk of cancer is negligible (Dankawu., et al. 2021).

#### 4.0 CONCLUSION

Therefore, as far as the radioactivity from natural radionuclides is concern, the results clearly indicate that  $^{232}\text{Th}$  and  $^{40}\text{K}$  are the major radionuclide detected in significant amount in all soil samples. The values of the activity concentration of the radionuclides were used to evaluate the radiological effect of the radionuclides and it is found that based on these results of radium equivalent activity, internal and external hazard indices, one can conclude that there is relatively low health hazard from the

soil samples collected from area of high activity in Kogi central senatorial district.

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