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Research Article

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Determination of Natural Radioactivity Concentration Levels in Soil Samples in Odigbo Local Government Area

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Abstract The aim of this study was to evaluate the level of natural radioactivity concentrations of ^{238}U, ^{232}Th and ^{40}K in the surface (0-5cm) soil samples collected from Odigbo in the Southwestern region of Nigeria. The surface soils were collected along the streets of this city. The activity concentrations of naturally-occurring radioactive materials in the ^{238}U, ^{232}Th and ^{40}K were determined by means of a Sodium Iodide (NaI) gamma-ray spectrometry system detector in a low background configuration. The mean activity concentrations of ^{238}U, ^{232}Th and ^{40}K for Odigbo were found to be 179.07±11.36, 152.32 ±32.71 and 1617.43±9.90 Bq kg^{-1}. The results of this current study have been compared with the world mean values of 37, 33 and 400 Bq kg^{-1}, respectively specified by the United Nations Scientific Committee on the Effects of Atomic Radiation. The average annual effective dose obtained from this study is 0.22 mSv y^{-1} for Odigbo, which is still less than the recommended limit of 1 mSv y^{-1} by International Commission on Radiation Protection [ICRP] for non occupational population. Also the mean radium equivalent for Odigbo is 535.56 Bq kg^{-1} and its absorbed dose is 175.21 nGy h^{-1}. It was shown that in most of the locations studied ^{40}K has the highest concentration.

Keywords Annual effective dose, radium equivalent and absorbed dose

Introduction

The naturally-occurring radionuclides, ^{238}U, ^{232}Th and ^{40}K are present in soils, building materials, rocks, oil and gas and food but are not uniformly distributed all over the world. The knowledge of the distribution of these radionuclides in soils and rocks plays an important role in radiation protection measurements [1]. The level of radionuclides in soils is a major cause of external and internal exposure of lumens. Outdoor radiological hazard to human health can be accessed from the determination of radioactivity level in the soil [2]. When these radiations interact with biological system in the body, energy is deposited or absorbed in the material leading to ionization of some of the atoms of the cell. These can lead to a breakdown of the cell structure and its components. The radionuclides disintegrate and release radiations to the environments resulting to radiological hazards or disease condition even death [3].

In this study the concentrations of naturally- occurring radionuclides were measured in the soil samples collected from Odigbo local government area with the aim of assessing the radiological risks to the people living in the area.

Materials and Methods

Odigbo is a Local Government Area in Ondo State, Nigeria. Its headquarters is Ore. It has an area of 1,818 km² and a population of 230,351 at the 2006 census. Its geographical coordinates are **latitude 6.78333 and longitude 4.86667** and its original name (with diacritics) is Odigbo. It is the business nerve of Ondo State.

Samples Collection

The surface of the location in which the soil samples were to be collected was cleared with a spade .With the aid of a metre rule, 1 m^2 location size points was measured and the centre of the square was dug to a depth of about 5cm and the soil samples were collected from the corners and centre of the $1m^2$ land. The square and the diagonal ensures adequate representation of each location, this was done in all the ten (10) locations where samples were collected.

The samples were packed in polythene bags and labelled with paper tape showing the name of each location.

Samples Preparation

The soil samples were sun dried. The soil samples were then transferred to the laboratory to be oven dried at 110 ºC for 2 hrs to remove water content remain in the samples. This was carefully done by using ten dried plates for each sample in the oven dryer. Then each sample was grinded in the laboratory with mortar and pestle. The soil samples were then sieved with 1mm mesh size to remove the larger – size grains. 200 g of each sample measured with analytical weighing balance was packed in each Marinelli beakers of 500 ml capacity previously washed with a diluted hydrogen tetraoxosulphate (VI) acid (H_2SO_4) and dried to avoid contamination. The samples were well sealed with paper tape and stored for thirty (30) days to allow secular equilibrium between ^{226}Radon and its short lived decay products to be attained prior to analysis [4].

Sample Analysis and Activity Concentration Measurement

The samples were prepared for analysis according to the International Atomic Energy Agency (IAEA) procedures and then analyzed at Centre for Energy Research and Development, Radioactivity Measurement laboratory, Obafemi Awolowo University, Ile-Ife, Osun State, using gamma ray spectrometry technique with NaI (Tl) scintillation detector (Canberra Industries Inc.). The energy resolution of the detector is 8% at 0.662 MeV of ^{137}Cs, a value good enough to distinguish the gamma ray energies of most environmental radionuclides present in the samples. The counting assembly was housed in a cylindrical lead castle to shield against environmental background radiation that might interfere with the result. The detector was coupled to the Multichannel Analyzer (MCA) via a 50 Ω coaxial cable. Calibration of the spectrometer system was done by detecting the efficiencies of radionuclides ^{40}K, ^{232}Th and ^{238}U at fixed sample geometry and matrix achievable by keeping the detector-sample arrangement constant throughout the period of assay of the samples over the same counting time. Each of the 10 samples was counted for a standard period of 7 hours (25200 seconds) because of the low gamma counts in the samples. The analysis was performed using a Canberra S-100 (Sampo-100) Multichannel (MCA) computer analyzer. This algorithm subtracts counts due to Compton scattering of higher peaks and other background effects from the total area. A blank counting for background determination was carried out for the same period of time.

Results

Absorbed Dose

This is the amount of energy that ionizing radiation deposit in a unit mass of matter; measured in gray (Gy), where 1 gray is equal to 1 Joule per kilogram. The mean activity concentrations of ^{226}Ra (^{238}U), ^{232}Th, and ^{40}K (Bq kg^{-1}) in the samples are used to calculate the absorbed dose rate given by the following formula [5].

$$D\ (nGy\ h^{-1}) = 0.0417C_U + 0.462C_{Th} + 0.0602C_K \quad (1)$$

where D is the absorbed dose rate in nGy h^{-1}, C_U , C_{Th} and C_K are the activity concentration of ^{226}Ra (^{238}U), ^{232}Th and ^{40}K respectively.

Annual Effective Dose (H)

Annual Effective Dose Rate: Using the dose rate data obtained from the concentration values of natural radionuclides in soil, adopting the conversion factor from the absorbed dose in air to the effective dose (0.7 $SvGy^{-1}$) and outdoor occupancy factor (0.2) proposed by UNSCEAR 1988 [5], the annual effective dose rate was calculated from the formula [5-6].

$$H\ (mSv\ y^{-1}) = D\ (nGy\ h^{-1}) \times 8766\ D\ (h\ y^{-1}) \times 0.2 \times 0.7\ (Sv\ Gy^{-1}) \times 10^{-6} \quad (2)$$

Radium Equivalent Activity (Ra_{eq})

Due to a non- uniform distribution of natural radionuclides in the soil samples, the actual activity level of ^{226}Ra, ^{232}Th and ^{40}K in the samples can be evaluated by means of common radiological index named the radium equivalent activity (Ra_{eq}). It is the most widely used index to assess the radiation hazards and can be calculated using equation given by Beretka and Mathew [7].

Ra_{eq} (Bq kg^{-1}) = C_U + 1.43 C_{Th} + 0.077 C_K ---------- (3)

This estimates that 370 Bq kg^{-1} of ^{226}Ra, 259 Bq kg^{-1} of ^{232}Th and 4810 Bq kg^{-1} of ^{40}K produce the same gamma-ray dose rate. Where C_U, C_{Th} and C_K are the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in Bq kg^{-1}, respectively. The permissible maximum value of the radium equivalent activity is 370 Bq kg^{-1} which corresponds to an effective dose of 1 mSv y^{-1} for the general public.

Discussions

Table 1 and Table 2 show the results of absorbed dose rate of the locations and displayed in fig.3.The absorbed mean value of Odigbo is 175.21 nGy h^{-1} higher than the world average absorbed dose rate of 56 nGy h^{-1} [5].

Table 1 and Table2 show the results of annual effective dose and displayed in fig.1.The mean annual effective dose for Odigbo is 0.22 (mSv y^{-1}). This is lower than the worldwide average of 0.48 (mSv y^{-1}) [8].

The world average value of annual outdoor effective dose for regions of natural radiation background is 0.07 (mSv y^{-1}).

The worldwide annual exposures to natural radiation sources would generally be expected to be in the 1 – 10 mSv y^{-1} range; with being the present value estimated.

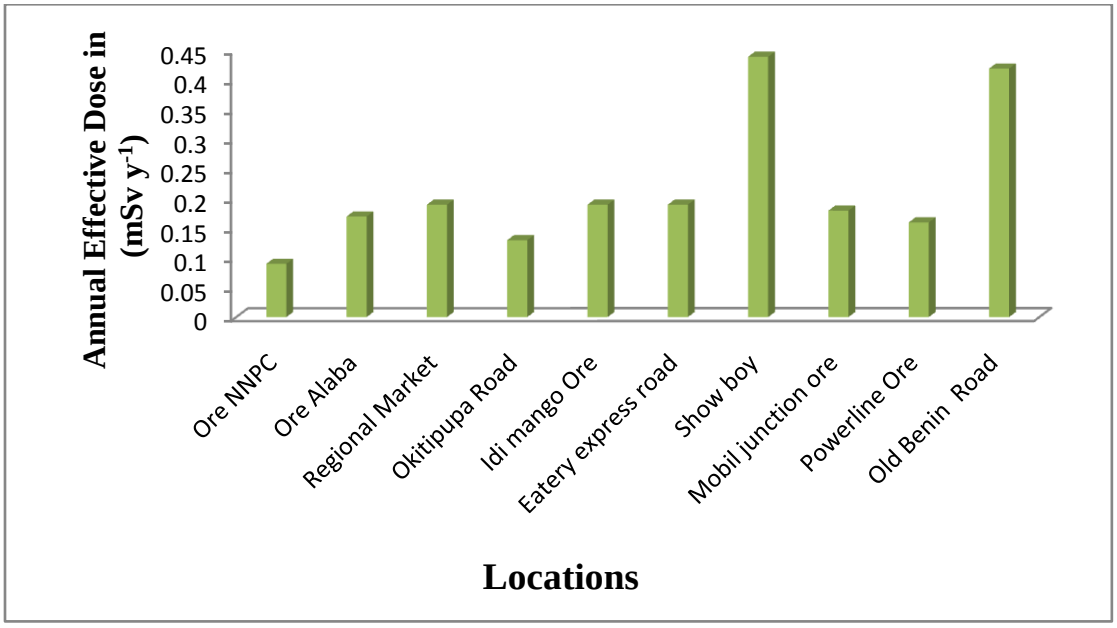

Figure 1: Annual Effective Dose of the soil samples in Odigbo

Figure 1 shows that Ore NNPC has the least effective dose rate of 0.09 mSv y^{-1} while show boy has the highest effective dose rate of 0.44 mSv y^{-1} and an average of 0.22 mSv y^{-1}.

Figure 1 shows that Ore NNPC has the least annual effective dose rate of 0.09 mSv y^{-1} while show boy has the highest effective dose rate of 0.44 mSv y^{-1} and an average of 0.22 mSv y^{-1}.

Radium Equivalent

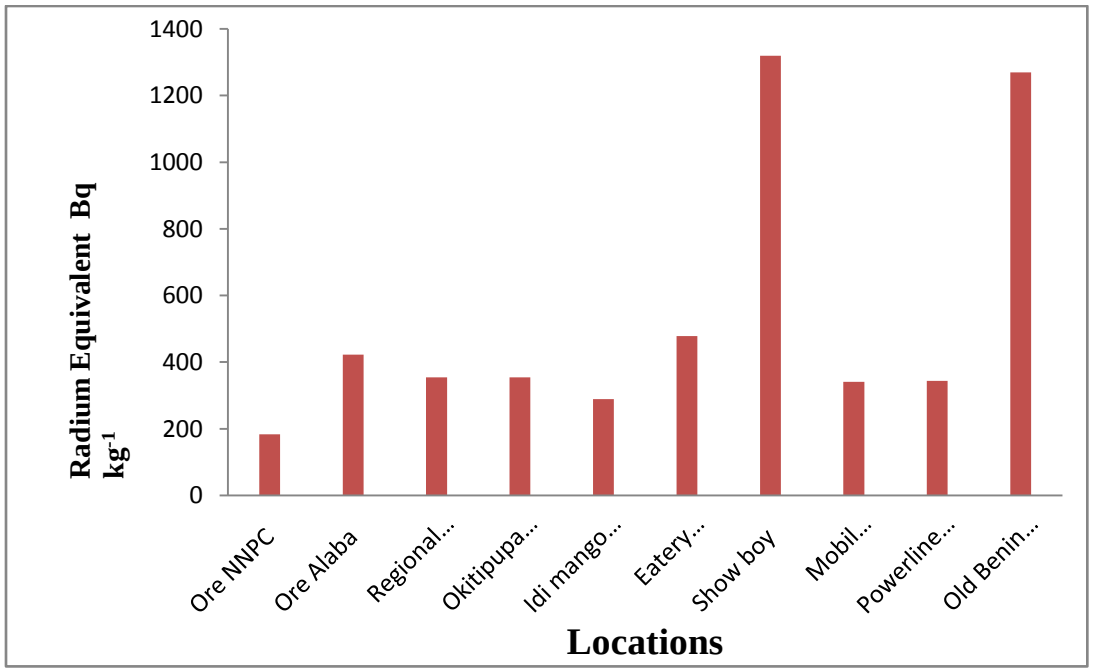

Figure 2: Radium Equivalent of the soil samples in Odigbo

In fig. 2: Show boy has the highest radium equivalent of 1319.21 Bq kg^{-1}. Ore NNPC has the least of 183.81 Bq kg^{-1}. The mean radium equivalent of the area is 535.56 Bq kg^{-1} Odigbo, this is higher than the recommended 370 Bq kg^{-1} value UNSCEAR, 2000 [8].

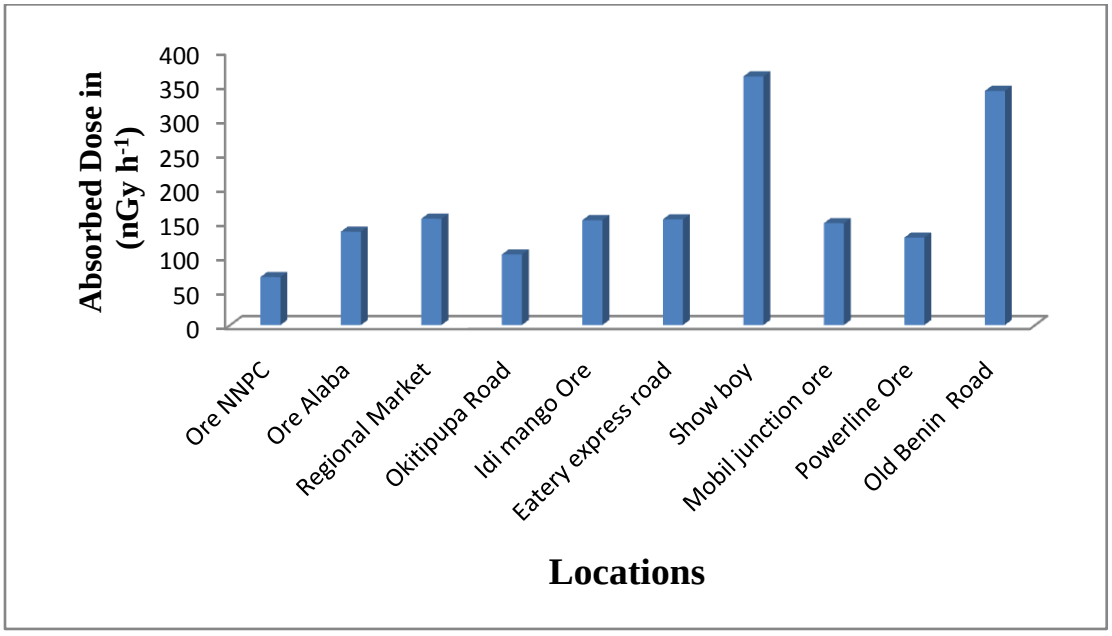

Figure 3: Absorbed Dose of the soil samples in Odigbo.

Figure 3 shows that Ore NNPC has the least absorbed dose rate of 69.96 nGy h^{-1} while show boy has the highest absorbed dose rate of 36.68 nGy h^{-1} and mean of 175.21 nGy h^{-1}. This is higher than the world average 56 nGy h^{-1} [8].

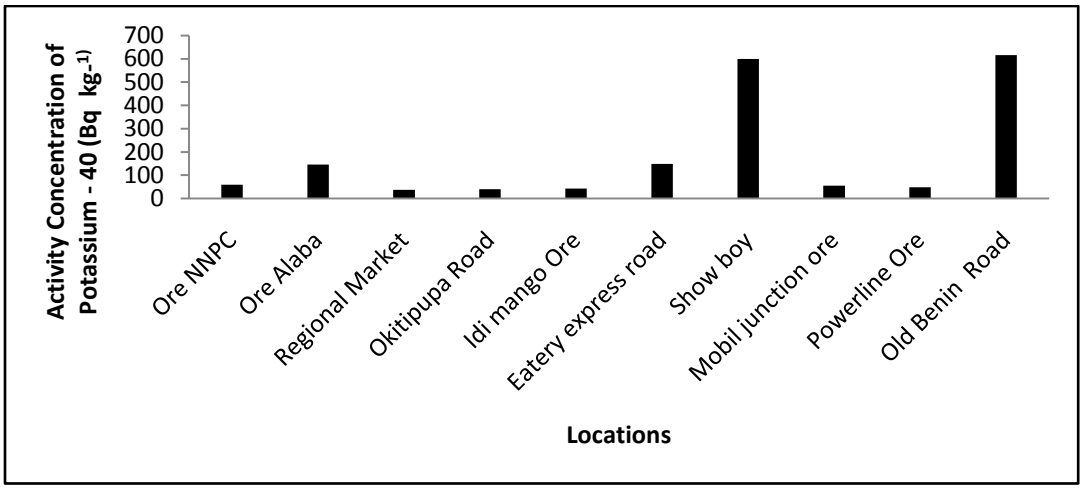

Figure 4: Activity concentration of Potassium - 40 in Odigbo

In fig.4 for ^{40}K show boy has the highest activity concentration with a value of 2973.30±16.13 Bq kg^{-1} and the least with powerline 855.58±6.13 Bq kg^{-1}.

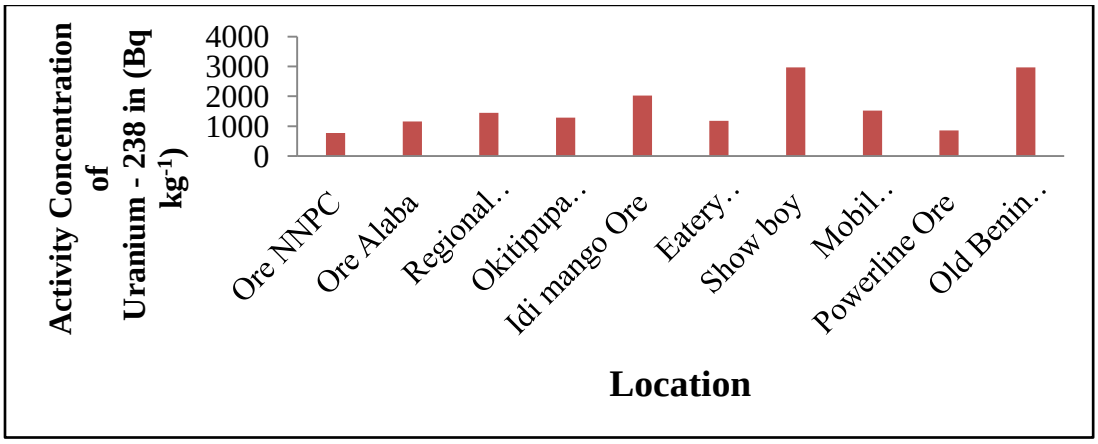

Figure 5: Activity Concentration of Uranium - 238 in Odigbo

In fig. 5 shows that Old Benin road has the highest concentration of ^{238}U with value of 616.28±35.83 Bq kg^{-1} and the least is regional market with a concentration of 36.82±3.42 Bq kg^{-1}.

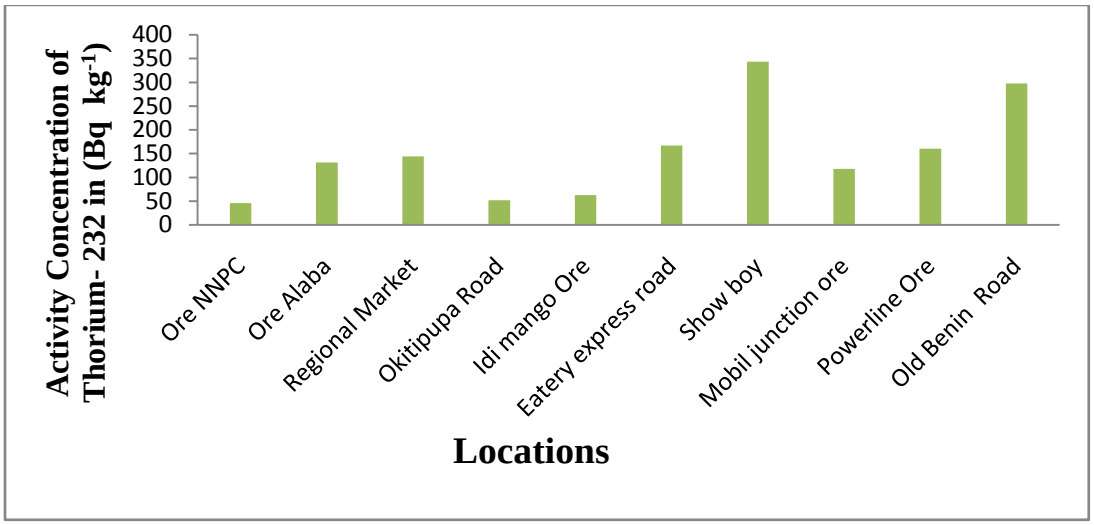

Figure 6: Activity concentration of Thorium – 232 in Odigbo

In fig. 6 reveals that Show boy has the highest concentration 343.57±68.07 Bq kg^{-1} while Ore NNPC has the least concentration of ^{232}Th 46.11±12.53 Bq kg^{-1}.

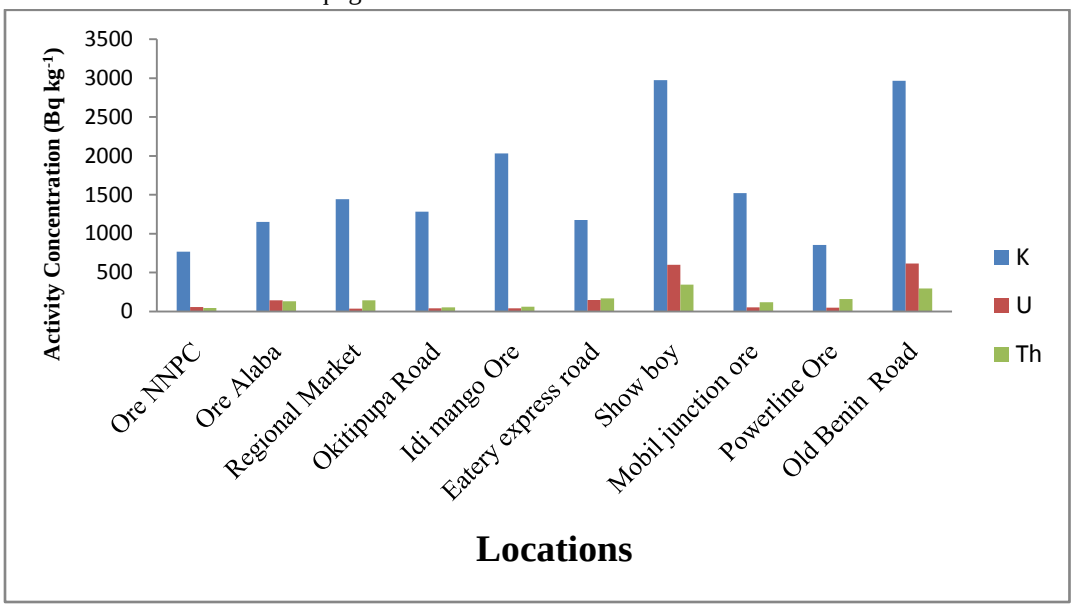

Figure 7: Activity Concentrations of Potassium – 40, Uranium – 238 and Thorium - 232 of the soil samples in Odigbo

Activity Concentrations

K-40 Show boy has the highest activity concentration with a value of 2973.30±16.13 Bq kg^{-1} and the least with powerline 855.58±6.13 Bq kg^{-1}. The mean of K-40 concentration is 1617.43±9.80 Bq kg^{-1} while in U-238 old Benin road has the highest concentration value of 616.28±35.83 Bq kg^{-1} and the least regional market with a concentration of 36.82±3.42 Bq kg^{-1} and average value of 179.07±11.36 Bq kg^{-1}. For Th-232 show boy also has the highest concentration 343.57±68.07 Bq kg^{-1}, while Ore NNPC has the least of 46.11±12.53 Bq kg^{-1} with an average of 152.32±32.71 Bq kg^{-1}as shown in tables 1 and 2 below.

The mean activity concentrations of ^{238}U, ^{232}Th and ^{40}K Odigbo soil samples are 179.07 ±11.36 Bq kg^{-1}, 152.32±32.71 Bq kg^{-1} and 1617.43±9.80 Bq kg^{-1} respectively.

The worldwide average concentrations of these radionuclides were reported by UNSCEAR [9]. ^{238}U, ^{232}Th and ^{40}K as 37 Bq kg^{-1}, 33 Bq kg^{-1} and 400 Bq kg^{-1} respectively.

^{40}K is about 4 times the world average value of 400 Bq kg^{-1} [9].

The mean value of the activity concentration of ^{232}Th is 159.06±33.86 Bq kg^{-1}. Odigbo is 5 times higher than the world average value of 33 Bq kg^{-1} [9].

The mean value of the activity concentrations for ^{238}U is 179.07±11.36 Bq kg^{-1}. This value is about 5 times the world average value of 37 Bq kg^{-1} [9].

It is apparent that ^{40}K exhibited the highest activity concentrations for all measured radionuclides in all of the soil samples measured in the current study.

Table 1: The activity concentrations of ^{238}U, ^{232}Th and ^{40}K measured in different soil in Odigbo metropolis, Ondo state.

S/N	Location Names	K-40 (Bq kg^{-1})	U-238 (Bq kg^{-1})	Th-232 (Bq kg^{-1})
1.	Ore NNPC	767.51±5.67	58.77±4.60	46.11±12.53
2.	Ore Alaba	1152.83±7.59	145.48±9.54	131.54±29.04
3.	Regional Market	1444.58±8.88	36.82±3.42	144.36±31.29
4.	Okitipupa Road	1283.37±8.13	39.59±3.52	52.15±14.28

5.	Idi mango Ore	2031.22±11.97	42.58±3.78	62.75±15.94
6.	Eatery express road	1177.21±7.70	148.67±9.65	166.95±35.16
7.	Show boy	2973.30±16.13	598.96±34.72	343.57±68.07
8.	Mobil junction ore	1523.22±9.51	55.17±4.42	118.04±26.35
9.	Powerline Ore	855.58±6.13	48.39±4.09	160.37±34.56
10.	Old Benin Road	2965.44±16.28	616.28±35.83	297.31±59.86
	MEAN± SD	1617.43±9.80	179.07±11.36	152.32±32.71

Table 2: Activity concentrations, radium equivalent (Bq kg^{-1}), outdoor absorbed dose rate (nGy h^{-1}) and outdoor annual effective dose rate (mSv y^{-1}) for all soil samples from Odigbo

Location Names	**K-40 (Bq kg^{-1})**	**U-238 (Bq kg^{-1})**	**Th-232 (Bq kg^{-1})**	**Ra_{eq} (Bq kg^{-1})**	**Absorbed dose rate (nGy h^{-1})**	**Annual Effective dose rate (mSv y^{-1})**
Ore NNPC	767.51±5.67	58.77±4.60	46.11±12.53	183.81	69.96	0.09
Ore Alaba	1152.83±7.59	145.48±9.54	131.54±29.04	422.29	136.24	0.17
Regional Market	1444.58±8.88	36.82±3.42	144.36±31.29	354.49	155.19	0.19
Okitipupa Road	1283.37±8.13	39.59±3.52	52.15±14.28	354.44	103.00	0.13
Idi mango Ore	2031.22±11.97	42.58±3.78	62.75±15.94	288.72	153.05	0.19
Eatery express road	1177.21±7.70	148.67±9.65	166.95±35.16	478.05	154.20	0.19
Show boy	2973.30±16.13	598.96±34.72	343.57±68.07	1319.21	362.68	0.44
Mobil junction ore	1523.22±9.51	55.17±4.42	118.04±26.35	341.26	148.53	0.18
Powerline Ore	855.58±6.13	48.39±4.09	160.37±34.56	343.60	127.61	0.16
Old Benin Road	2965.44±16.28	616.28±35.83	297.31±59.86	1269.77	341.64	0.42
MEAN±SD	1617.43±9.80	179.07±11.36	152.32±32.71	535.56	175.21	0.22

Conclusion

This research work shows that the activity concentrations for each of the radionuclides were found to be higher than the world average UNSCEAR,2000.Therefore, there may be higher radiological risk hazards for the people living in that area. The calculated mean values of annual effective dose was still within the world average [8-9]. Also, the mean absorbed dose and radium equivalent were higher than the world average [5,8]. respectively. Therefore, the soils in this area may not be suitable for the construction buildings and agricultural purposes.

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