INDOOR AND OUTDOOR *IN-SITU* GAMMA-RAY AND RADIOLOGICAL ASSESSMENT OF SOILS OF OLABISI ONABANJO UNIVERSITY MAIN CAMPUS, SOUTHWESTERN NIGERIA

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Abstract: Olabisi Onabanjo University situated on basement complex has witnessed excavation of ground for purpose building constructions in the recent past. The excavation of ground and the use of building materials in constructions may enhance the level of natural ionizing radiation exposure of the environment. The study, therefore, aims at measuring the radioactivity levels in the environment of the University. Thirty grids were randomly mapped out in the campus and soil samples were collected from 4 or 5 points in each grid and mixed to form a representative sample. The activity concentrations of the soil samples were measured using a NaI(Tl) detector and the outdoor and indoor *in-situ* gamma survey was carried out using a Mirion RDS-30 survey meter. The mean radioactivity levels of the soils were 393.1±63.1 Bqkg^{-1}; 17.6±3.0 Bqkg^{-1} and 12.5±1.7 Bqkg^{-1} for ^{40}K, ^{238}U and ^{232}Th, respectively. The mean absorbed dose rate was 32.1±3.6 nGyh^{-1}and the mean outdoor effective dose rate was 39.3±4.4 μSvy^{-1}. The mean outdoor *in-situ* effective dose rate was 124.8±64.3 μSvy^{-1} and the highest mean indoor *in-situ* effective dose rate of 271.8±32.8 μSvy^{-1} was measured at the University Health Centre. The gamma and effective dose rates measured in the soils from the study area are lower than the world average values 50 nGyh^{-1} and 70 μSvy^{-1}, respectively. The high values of indoor *in-situ* effective dose rate compare to outdoor *in-situ* effective dose may be attributed to the radiation emission from the materials used for the construction of buildings with cramped offices without cross ventilations.

Keywords: *In-situ* gamma-ray, survey meter, radiological assessment, soil samples, Nigeria

Introduction

The existence of naturally occurring radionuclides (NORs) dated back to the time the earth was formed had been the major source of radiation exposure. The world radiation exposure emanates from the naturally occurring radionuclides (NOR) including extra-terrestrial (cosmic) and terrestrial (primordial), and artificial radionuclides (man-made radionuclides) (Mustapha *et al.*, 1999). The major primordial radionuclides, ^{238}U, ^{232}Th and their progenies; and ^{40}K found in the earth crust continuously undergo decay, release gamma-rays to the environment (UNSCEAR, 1993). The levels of exposure of the environment to ionizing radiation are associated with the distribution and level of naturally occurring radionuclides (NOR) in the earth's crust (Gbadebo, 2011; Okedeyi *et al.*, 2012). About 85% of the natural radioactivity comes from the primordial radionuclides (Alausa, 2014) implying that only an estimate of 15% comes from cosmic rays continuously produce cosmogenic radionuclides. The geological and geographical settings together with the distribution of the natural radionuclides in the earth crust pre-determine the radiation exposure level of an environment Jibiri *et al.*, 2009; Gyuk *et al.*, 2017).

Studies have shown that high radioactivity in an area is linked to the presence of igneous rocks such as granite that contains abundant ^{238}U, ^{232}Th and ^{40}K radionuclides (Lopez *et al.*, 2004; Yan *et al.*, 2005) and low radioactivity is associated with sedimentary rocks with exception of phosphate rocks (Alausa and Omotosho, 2017). However, the basement complex rocks of the pre-Cambrian age made up of granites, and the sedimentary rocks of tertiary and secondary ages are the two famous rocks in Nigeria (Lawal *et al.*, 2017).

Materials and Methods

Study location

Ago-Iwoye is underlain by migmatite gneiss (porphyroblastic gneiss, banded gneiss and granite gneiss), granites (quartz-rich granitoid and granodiorite) and pegmatite (Omosanya *et al.*, 2012) with the soil colour varying through yellowish, blackish and brownish as freely observed. It covers a mass area of 10 square km within the coordinate of latitude N6° 56'-6° 58' and longitude E3° 56'-4° 00' with a population of about 110,000 (estimated value using 3% growth rates on the 2006 census figures of Nigerian) (NPC, 2006). Olabisi Onabanjo University's main campus sited in Ago-Iwoye is a higher institution with about 30,000 students (natives and foreigners), 840 staff and 5,300 frequent visitors including contractors, small scale businessmen and women within the school perimeters. With the advent of Tertiary Education Trust Fund (TET-FUND) intervention in infrastructural development in the University systems in Nigeria, Olabisi Onabanjo University's main campus has been witnessing the construction of many new buildings in the last four or five years. The construction activities in the campus involved ground excavations that may cause imminent elevated natural ionizing radiation exposure. Besides some building materials used for constructions may be attenuators of gamma rays and if such building materials are used, the radiation exposure of the environment may be enhanced (Righi and Bruzzi, 2006). Consequently the populace in and around the campus are likely subjected to continuous ionizing radiation exposure. Therefore, the study aims at carrying out an *in-situ* survey and measuring the radioactivity levels of the top soils to create awareness and determine the likely health effect on the populace of the two campuses and their immediate environs.

Soil sample collection

The study area is shown as an inset of the map of Ogun State in Fig. 1. The soil samples were collected at different locations in the environment of the University. A total of thirty (30) sampling grids mapped within the campus. Each mapped grid was 3 m by 4 m and about 4 or 5 soil samples were then collected from each grid and mixed thoroughly to form a representative sample (Alausa, 2012). At each sampling point, the soil was collected to a depth between 2 and 3cm with the aid of hand auger. A The soil samples were then packed into polythene bags, labeled properly and taken to Physics Laboratory located at Olabisi Onabanjo University Ago-Iwoye main campus for preparation.

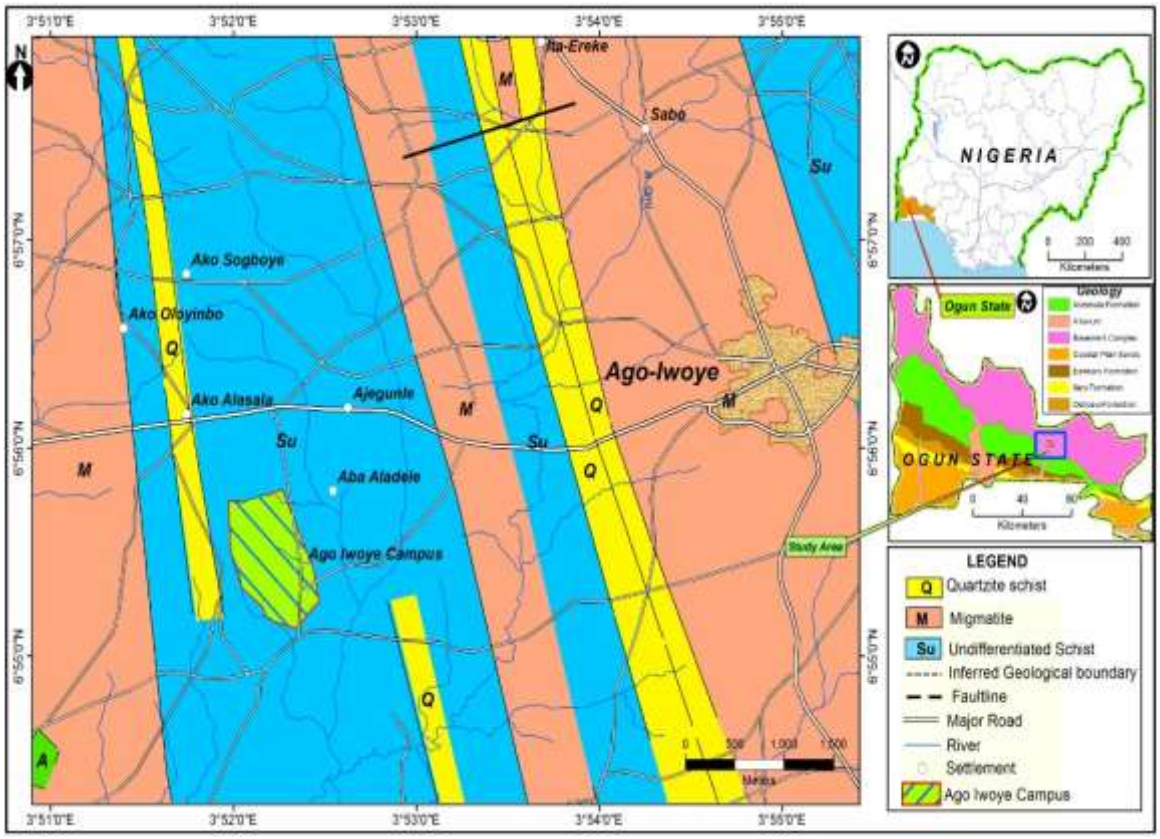

Fig. 1: Geological map of Ogun State showing the study area (Alausa & Odusote, 2013)

In-situ survey

Mirion RDS-30 survey meter was used to measure and record the outdoor *in-situ* emission of γ- ray directly from the soil at each sample grid before soil samples were collected. The indoor *in-situ* measurements were also carried out across various offices, workshops and laboratories in the University. The survey meter used was a digital hand-held dose rate meter designed for a wide range measurement of ionizing radiation. RDS-30 survey meter graduated in mrem/h or μSvh^{-1}, has a microprocessor controller with an interface consists of one push-button and an easy-to-use menu structure that displays information by the LCD on a meter. The six-digit display on the meter shows the dose rate and other messages with different alarm situations.

Soil sample preparation

The soil samples were sun-dried for about 20 days in the open until a constant mass was attained. Thereafter, the soil samples were crushed and pulverized, and the powdered soil samples were sieved with a 2.0 mm sieve to attain the same matrix with the reference standard soil sample obtained from Rocket-dyne Laboratories, California USA. The standard or reference soil sample is traceable to a mixed standard gamma source (Ref. No.48722-356) by Analytic Inc., Atlanta Georgia. 200 g of the powdered soil sample from each grid was packed into a clean and radon-impermeable plastic container of uniform size labeled and sealed for about 30 days to allow for a secular equilibrium between ^{222}Rn and its respective progenies before gamma spectroscopy. The prepared samples were transported from the Physics Laboratory in Olabisi Onabanjo to Radiation and Health Physics Laboratory at the Ladoke Akintola University of Technology Ogbomosho for spectrometry measurements.

Radioactivity determination

A well-calibrated and shielded NaI(Tl**)** detector coupled to a computer resident multichannel analyzer (Quantum MCA 2100R) was used to analyze the soil samples. All calibrations and qualitative analysis were made through software embedded in the MCA. A reference standard mixed source traceable to analytical quality control services (AQCS, USA) was used for the efficiency calibration of the detector. The standard source has the certified activities of the selected radionuclides and geometrical configuration identical to soil samples. The energy calibration was done using the peaks of the radionuclides present in the standard sources. The channel number is proportional to the energy; therefore, the channel scale was converted to an energy scale. The γ-ray energy 1.460 MeV of ^{40}K was used to determine the activity concentration of ^{40}K in the sample. While the gamma transition energy of 1.764.5 MeV (^{214}Bi) was used to determine the concentration of ^{238}U (^{226}Ra), the gamma transition energy of 2614KeV (^{208}TI) was used to determine the concentration of ^{232}Th. To ensure reproducibility, each plastic container of soil sample was placed on top of the detector housed tightly inside a shield and counting took 36,000 seconds. However, the activity concentrations of the radionuclides in each sample were measured with the aid of the Quantum MCA software. Jibiri *et al.* (2011) expressed the relationship between activity concentration and the count rate under the photopeak as shown in Equation (1):

$$C(Bqkg^{-1}) = kC_n \qquad (1)$$

Where:

$k = \dfrac{1}{\varepsilon P_\gamma M_s}$; C= activity concentration of the radionuclide in the sample ($Bqkg^{-1}$); C_n = count rate under the corresponding peak; ε = detector efficiency at the specific γ-ray energy; P_γ = absolute transition probability of the specific γ-ray; M_s = mass of the sample (kg).

External absorbed dose rate

The absorbed dose rate is an important quantity necessary to determine the level of radiation risk to a bio-system. According to Taskin *et al.* (2009), the model for calculating the absorbed gamma dose rate, D ($nGyh^{-1}$) in the air at 1.0 m above the ground level due to the concentration of ^{40}K, ^{238}U and ^{232}Th and ^{137}Cs in soil matrices is:

$$D_R = a.C_{Ra} + b.C_{Th} + c.C_K \qquad (2)$$

Where: a = dose rate per unit ^{238}U activity concentration ($4.61 \times 10^{-10} Gy\ h^{-1}/Bq\ kg^{-1}$); C_{Ra} = concentration of ^{238}U in the sample ($Bq\ kg^{-1}$); b = dose rate per unit ^{232}Th activity concentration ($6.23 \times 10^{-10} Gy\ h^{-1}/Bq\ kg^{-1}$); C_{Th} = the concentration of ^{232}Th in the sample ($Bqkg^{-1}$); c = dose rate per unit ^{40}K activity concentration ($0.417 \times 10^{-10} Gy\ h^{-1}/Bqkg^{-1}$); C_K = concentration of ^{40}K in the sample ($Bqkg^{-1}$)

Effective dose rate due to soil samples

Two other factors in addition to external absorbed dose are necessary for assessing the outdoor effective dose rate to the populace from the calculated absorbed gamma dose rate. The first factor which accounts for the biological effectiveness of the dose in causing damage in human tissue converts Gy to Sv. The second which specifies the proportion of the total time spent outdoors is the occupancy factor. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) recommended 0.7 $SvGy^{-1}$ as the first factor and 0.2 outdoor and indoor occupancy factors, respectively. This second factor implies that the average individual spends only 4.8 h (approximately 5 h per day) outdoors. The effective dose rate H_R due to soil samples from the farmlands in each site was calculated using the equation (Alshasri, 2019):

$$H_R = D_R \times 0.2 \times 0.7 \times 8760 \qquad (3)$$

Where: D_R = absorbed gamma dose rate in ($nGy\ h^{-1}$); 0.2 = occupancy factor; 0.7 = conversion factor ($SvGy^{-1}$); 8760 = hours in one year (yh^{-1})

Results and Discussion

Activity concentration in the soils

The activity concentrations of ^{40}K, ^{238}U and ^{232}Th in the soil samples from the environment of Olabisi Onabanjo University were measured and the results are presented in Table 1. As could be seen from the table the activity concentrations ranged from 275.6-512.2 $Bqkg^{-1}$ with a mean value of 393.1±63.1 $Bqkg^{-1}$ for ^{40}K; 12.6-24.4 Bqg^{-1} with a mean value of 17.6±3.0 $Bqkg^{-1}$ for ^{238}U and 8.4-15.9 $Bqkg^{-1}$ with a mean value of 12.5±1.7 $Bqkg^{-1}$ for ^{232}Th. The mean activity concentrations obtained in the study are higher than 367.9±74.1$Bqkg^{-1}$, 16.4±4.6 $Bqkg^{-1}$and 3.3±2.0 $Bqkg^{-1}$for ^{40}K, ^{226}Ra and ^{232}Th, respectively reported for Ijebu North Ogun State Nigeria (Alausa and Odusote, 2013). The respective mean activity concentrations of 396.1±70.9 and 17.7±4.6 Bqkg-1 for ^{40}K and ^{226}Ra (Jibiri *et al.,* 2009) are similar to the results obtained in the present study. However, the results in the present study are lower than the world average values of range 100-700 $Bqkg^{-1}$ with a mean of 420 $Bqkg^{-1}$; 8-160 $Bqkg^{-1}$ with a mean of 32 $Bqkg^{-1}$ and 4-130 $Bqkg^{-1}$ with a mean of 40$Bqkg^{-1}$ for ^{40}K; ^{238}U and ^{232}Th, respectively (UNSCEAR, 2000).

Table 1: Activity concentrations of ^{40}K, ^{238}U, ^{232}Th; external absorbed and effective dose rates

Samples	^{40}K ($BqKg^{-1}$)	^{238}U ($BqKg^{-1}$)	^{232}Th ($BqKg^{-1}$)	Gamma Absorbed Dose (Lab) ($nGyh^{-1}$)	Effective Dose (Lab)(μSvy^{-1})	Effective Dose (*In-situ*) (μSvy^{-1})
Grid 1	414.2±36.7	17.2±3.2	13.5±1.8	33.4	41.0	114.0
Grid 2	328.1±41.2	19.4±2.1	14.0±1.3	31.1	38.2	376.9
Grid 3	297.4±30.2	20.0±3.8	15.2±2.4	30.8	37.8	96.4
Grid 4	491.2±51.3	13.3±1.2	11.2±2.1	33.4	41.0	105.2
Grid 5	325.4±27.8	19.4±5.2	15.9±1.9	32.1	39.4	96.4
Grid 6	312.2±29.7	15.2±1.7	11.1±2.3	26.7	32.8	105.2
Grid 7	511.1±60.2	14.3±4.2	11.6±3.3	34.9	42.9	131.5
Grid 8	420.1±25.3	12.6±1.9	10.9±2.2	29.9	36.7	122.7
Grid 9	410.3±31.2	24.4±2.3	14.9±3.1	37.4	45.9	96.4
Grid 10	372.4±18.7	16.2±3.1	11.8±1.9	30.1	37.0	289.3
Grid 11	397.4±36.4	22.2±2.7	13.9±5.3	35.2	43.2	105.2
Grid 12	413.4±51.2	19.4±3.5	10.8±2.7	32.7	40.2	96.4
Grid 13	419.4±37.1	21.4±1.9	14.3±3.9	36.0	44.2	105.2
Grid 14	365.7±41.8	18.9±6.3	12.2±2.5	31.4	38.5	96.4
Grid 15	417.2±19.9	19.9±1.2	13.5±4.1	34.7	42.6	140.3
Grid 16	371.0±41.3	17.7±3.1	11.3±2.9	30.5	37.4	122.7
Grid 17	449.2±36.4	16.3±2.6	13.6±3.7	34.5	42.3	70.1
Grid 18	381.4±33.8	14.4±3.1	11.1±1.9	29.3	35.9	201.6
Grid 19	443.8±55.4	20.5±3.7	14.5±2.2	36.7	45.1	105.2
Grid 20	512.2±67.1	21.3±2.5	12.1±1.8	38.5	47.3	87.7
Grid 21	347.6±38.3	19.8±3.3	13.3±3.0	31.7	38.9	87.7
Grid 22	412.2±47.0	16.2±1.9	11.9±2.1	31.9	39.1	122.7
Grid 23	382.5±18.9	14.3±3.2	13.7±3.2	30.8	37.8	78.9
Grid 24	290.5±35.3	16.6±1.6	10.9±3.7	26.4	32.4	157.8
Grid 25	275.6±17.9	13.9±2.8	10.7±2.9	24.4	29.9	96.4
Grid 26	312.4±23.9	12.6±3.7	8.4±3.1	23.9	29.4	166.6
Grid 27	478.6±37.8	16.3±2.9	12.8±2.4	35.2	43.2	78.9
Grid 28	398.4±41.9	15.4±3.5	11.0±2.1	30.4	37.3	105.2
Grid 29	414.3±38.9	19.2±4.2	14.2±2.9	34.7	42.6	70.1
Grid 30	429.2±45.3	18.2±3.9	10.6±3.3	32.7	40.1	114.0
Mean±σ	**393.1±63.1**	**17.6±3.0**	**12.5±1.7**	**32.1±3.6**	**39.3±4.4**	**124.8±64.3**

External absorbed dose

Equation 2 was used to calculate the external absorbed dose related to the activity concentrations measured in the soil samples from the study area and the results are presented in Table 1. As shown in the table, the mean absorbed dose from the study area was 32.1±3.6 $nGyh^{-1}$. This value is higher than the values of 27.6±5.5 $nGyh^{-1}$ (Alausa, 2014) reported for Ijebu-Ode but lower than the world average value of 59.0$nGyh^{-1}$ as reported by (Jibiri *et al.*, 2009; Taskin *et al.*, 2009).

Outdoor effective dose rates

The outdoor effective dose rates were determined using Equation 3 and the results are presented in Table 1. As could be seen from the table, Grid 26 exhibited the least value of 29.4 μSvy^{-1} and Grid 20 exhibited the highest value of 47.3 μSvy^{-1}). The varied values of effective doses for the Grids may be attributed to the activity concentrations and the distribution of natural radionuclides in the soil. The mean effective dose rate obtained in soils from the study was about 1.8 times lower than the world average value of 0.07 $mSvy^{-1}$ as reported by Qureshi *et al.* (2014).

Outdoor in-situ effective dose rates

The outdoor *in-situ* effective dose rates were measured with the Mirion RDS-30 survey meter and results are presented in Table 1. The minimum value was exhibited in Grid 17, the highest in Grid 2 and the mean value was 124.8±64.3 μSvy^{-1} which was 1.8 times higher than the world average value reported by Qureshi *et al.*, (2014). Fig. 2 shows the correlation between outdoor effective dose rates and outdoor *in-situ* effective dose rates. The correlation (R^2 = 0.077) shows a negative poor relationship and not a good predictor of individual values of measured outdoor *in-situ* effective dose rates.

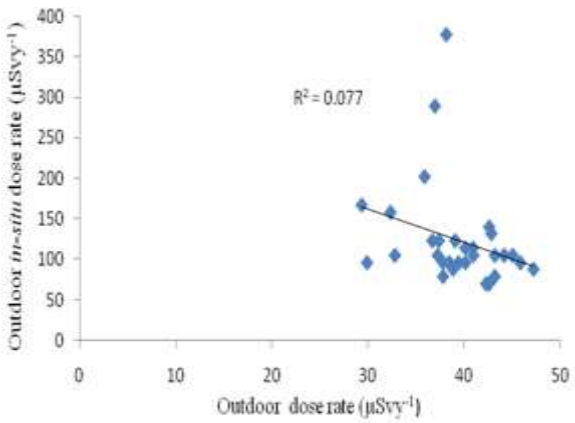

Fig. 2: Correlation between outdoor effective dose rates and outdoor *in-situ* effective dose rates

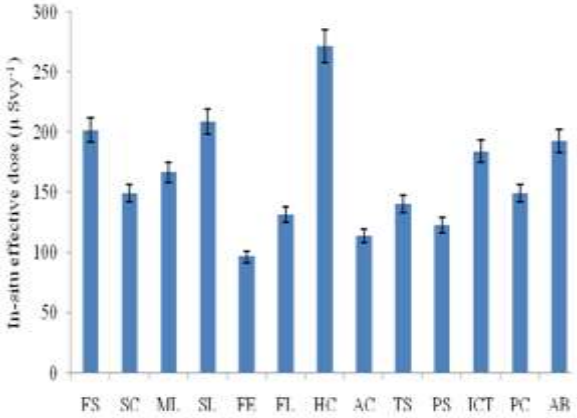

Fig. 3: Bar charts for the indoor *in-situ* effective dose rates

Indoor in-situ effective dose rates

The indoor *in-situ* effective dose rates measurement of the offices in thirteen buildings was carried out and the results are presented in Table 2. Except at the Faculty of Education and Postgraduate School, the mean indoor *in-situ* effective dose rate in each of the remaining buildings was higher than the mean outdoor *in-situ* effective dose rate. Fig. 3 shows the bar chats with 5% vertical error in two directions for the indoor *in-situ* effective dose rate. The mean highest dose level was measured in the Health Centre (HC) and this may be attributed to the presence of medical materials in some wards and offices. Also, leakages from the x-ray and other medical equipment may have caused elevated *in-situ* effective dose rates in the Centre.

Conclusion and Recommendations

The *in-situ* and soil radioactivity of the environment of the Olabisi Onabanjo University has been measured. The activity concentrations of the natural radionuclides (^{40}K, ^{238}U and ^{232}Th), outdoor gamma absorbed and effective dose rates were within the world average limits. But the indoor *in-situ* measurements were higher than the outdoor *in-situ* measurements. This may be attributed to radiation emission from the building materials and poorly ventilated office spaces.

It is therefore recommended that spacious offices with good cross ventilation be considered in the future building constructions so that emitted radiation in the offices could continuously be easing out.

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Conclusion

Based on obtained results it could be concluded that investigated maize lines showed high variability in concentration of important mineral elements (Fe, Zn and Mg). The information presented should be of value to nutritionists.

Conflict of Interest

Authors declare that there is no conflict of interest related to this study.

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