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Radioactivity Measurements of Soil Samples from the Excavation Sites at Onyeama Hill (Ugwu – Onyeama) Enugu, Enugu State, Nigeria

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ABSTRACT

The use of materials from the earth's crust for building and other purposes such paint making is a source of concern due to natural radiations emanating from them. This exposes human dwellers to worrisome levels of radiation and cause a lot of health risks when the permissible limit is exceeded. This study assessed the radioactivity level of the Onyeama hill excavation sites by measuring the activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th in soils sourced from six excavation sites at Onyeama hill, using gamma – ray spectrometry with Sodium Iodide (NaITl) detector. The soil samples were randomly collected at six excavation locations and taken to the laboratory for preparations and measurements. Results showed average activity concentrations in Bq/kg ranges from (125.08±5.8 – 158.4±5.8 Bq/kg) for ^{40}K, (18.9± 3.4 - 39.3±3.3 Bq/kg) for ^{226}Ra and (22.1±1.7 – 36.8±1.6 Bq/kg) for ^{232}Th, with mean radioactivity level of less than unity, showing that soils from the sites are safe when used for building construction and other purposes.

Keywords:
Concentration,
Excavation Soil,
Gamma ray,
Radioactivity levels.

INTRODUCTION

The use of sharp sand and other earth's crust materials for building houses and other purposes such as paint making, is a source of concern due to natural radiation emanating from them. When permissible concentration levels are exceeded in these materials, human dwellers in houses built with these sands/other users of the sand are exposed to dangerous health risks.

This study is focused on the radioactivity measurement of the soil samples excavated for building and other purposes. Building materials derived primarily from earth's crust contain traces of naturally occurring radioactive materials which decay spontaneously to a more stable forms emitting alpha (α), beta (β) and gamma (γ) radiations during the process (Omeje *et al.,* 2011, Omeje *et al.,* 2009, and Ewa *et al.,* 2000). According to Ewa *et al.* (2000), these emitted radiations are of serious concerns in view of their radiological implications to humans and environment, with these materials also being the primary sources of external exposure of natural radionuclides to human population.

Omeje *et al.* (2009) reported that the occupant's residence time, nature of ventilation within the building, location of the building, type of material used and type of house constructed are among the factors which expose man to worrisome radiations from buildings. Continuous inhalation of the emitted radiations build up in the human body and affect the organs posing health risks.

Globally, various studies have been carried out on radioactivity measurements in soils and other building materials which include: Al Hamarneh *et al.* (2009), Omeje *et al.* (2011) and Rosabianca *et al.* (2024), to mention a few. Rosabianca *el al.* (2024), reported that Europe has created an inventory characterized on the basis of activity concentration of the main natural radionuclides (^{40}K, ^{226}Ra and ^{232}Th) which makes calculation of the activity concentration index, (I) easy for many building materials in Europe.

Previous studies (Babatunde *et al.,* 2004; Usikalu *et al*., 2014, Mbonu, *et al.,* 2021 and Yusuf *et al.,* 2023) done in Nigeria on radioactivity measurements have been mainly on top soils and they all reported low levels of radiation indices or radioactivity levels. However, this work has appreciable depth below the sea level which makes it different from the previous works reported in Nigeria. The excavation sites at Onyeama Hill (Ugwu – Onyeama) Enugu, Enugu State is a major source of sand for building construction in Enugu and its environs and even some parts of towns in Abakaliki, Ebonyi State, Nigeria. This study is therefore a good environmental assessment for the entire populace of these states, to

know how safe their buildings and paint products made from sands from these locations are for people using them.

The main aim of this work is to measure the natural radioactivity levels in soil samples excavated from Onyeama hill (Ugwu – Onyeama) Enugu, Enugu State; and specifically determine the activity concentrations of naturally occurring radionuclides: (^{40}K, ^{226}Ra and ^{232}Th) using gamma – ray spectrometry measurements and determine the radioactivity levels of the radionuclides in soil samples. Studies have been conducted in various parts of the world on the impact caused by the radionuclides occurring naturally in building materials such as wood, soil, cement, bricks, tiles and gravel/stone. In Nigeria, many studies (Babatunde *et al.,* 2004; Usikalu *et al*., 2014, Mbonu *et al.,* 2021 and Yusuf *et al.,* 2023) has been carried out on radioactivity measurements of soil samples which showed the presence of these radionuclides (^{40}K, ^{226}Ra and ^{232}Th) in the soil samples but however at a permissible limit. The soil samples used in the above works were mostly sampled at a level not so deep. Omeje *et al.* (2011) reported that measurement of natural radioactivity in soil is very important to determine the amount of change of the natural background activity with time as a result of any radioactive release (UNSCEAR, 1988; Sroor *et al.*, 2001). This work is aimed at measuring the natural radionuclides because the earth crust is radioactive (Ewa *et al.*, 2000; Kebwaro *et al.*, 2011) and constantly emitting radiation, and specifically to create awareness on the levels of radiation within our environment, especially when the permissible limit is high.

Radioactive substances can be dangerous to the body if one is exposed to it for a long time or even short time when it is of high dose since the penetrating power of α-particle is small, they do not penetrate the skin appreciably, but β-rays and γ-rays which have more penetrating power than that of α-particle, if allowed to penetrate the body in large quantities, or even in small quantity for a long period of time, can destroy the cells in the tissue and upset natural chemical reactions (Omeje *et al.*, 2011). Therefore, it is important to know the radioactivity level of the natural radionuclides in the soil samples of these sites used in building of houses and other purposes in Enugu and its environments.

MATERIALS AND METHODS

Site Description

The study area covers some of the excavation sites in Onyeama hill situated at about latitudes N6^{0}30'27.21" – N6^{0}26'59.93" and longitudes E7^{0}31'16.08" – E7^{0}25'40.84" in Enugu, Enugu State, Nigeria. Figures 1 to 6 below show the different sampling points A to F at the Onyeama hill excavation sites.

Figure 1: Sampling point A

Figure 2: Sampling point B

Figure 3: Sampling point C

Figure 4: Sampling point D

Figure 5: Sampling point E

Figure 6: Sampling point F

Sample Collection

The soil samples were collected randomly at the excavation sites, figures (1 – 6). Four samples were collected at an interval of about 20 cm in each of the six sites at the Onyeama hill. They were packaged and labelled clearly in a polythene bags.

A total of twenty four (24) soil samples were collected from these locations. They were packaged in a polythene bag and taken to the laboratory at the Centre for Energy Research and Training (CERT) ABU, Zaria, Kaduna State, Nigeria for preparation and measurements. The first set of soil samples were collected on 31st October, 2024, while the second set were collected on 12th November, 2024, when the soils were almost dried. For easy identification, the soil samples were labeled as OA1 – OA4, OB1 – OB4, OC1 – OC4, OD1 – OD4, OE1 – OE4 and OF1 – OF4; where 1 – 4 represents number of samples at each site; while A, B, C, D, E and F represents the six excavation sites. These samples were collected at the point where the sand is loaded into the Lorries for onward distribution to the end users.

Sample preparations for gamma spectrometry

The representative samples collected from the field were air-dried and crushed into near uniform grain sizes. Then, known weights of these crushed soil samples were properly sealed in plastic containers each of known weights using candle wax and masking tape and left to equilibrate for thirty days to allow for secular equilibrium to be established among the radium progeny which is necessary to ensure that radon gas is confined within the volume and that the daughters will also remain in the sample (Sroor *et al.*, 2001; Ewa *et al.*, 2006).

The soil samples were analyzed using γ-ray spectrometry technique after the detector calibration, where each of the soil samples were counted for a period of 29000 seconds with a NaI(Tl) detector; manufactured by Canberra USA, model 727, Serial no. 1191416.

Gamma–ray detection mechanism and analysis

The Gamma-ray Spectrometer is an in-situ detection system used for the measurement of the energy spectrum of the emitted gamma rays. The system consists of a NaI(Tl) detector coupled with a Canberra multi-channel analyzer (MCA). Energy calibration of the detector is done using a gamma line (661.70 keV) of ^{137}Cs and two gamma lines (1173.20 keV and 1332.5 keV) of ^{60}Co after which a standard reference material (IAEA mixed standard – RGKUTh) is used to ensure proper calibration. Spectrum of every sample were collected for 29,000 seconds. Finally, data acquisition and spectrum analysis were performed with the MAESTRO - 32 computer software and subsequently, activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th determined.

RESULTS AND DISCUSSION

The analyses of the soil samples from the six excavation sites at Onyeama hill identified the presence of three naturally occurring radionuclides (^{40}K, ^{226}Ra and ^{232}Th) at varying activity concentrations. Table 1 shows the activity concentrations of these radionuclides investigated in this work. Average activity concentrations and the corresponding radioactivity levels (column six) for each of the samples were also shown in Table 1.

The values presented for the sample ID: OA, OB, OC, OD, OE and OF are respectively mean values of the four samples from each of the six locations. The result presented in Table 1 shows the activity concentrations of the radionuclides and the evaluated radioactivity level in the analyzed soil samples from the six excavation sites in Onyeama Hill. The specific activity concentration values are in the ranges of (125.08±5.8 – 158.4±5.8 Bq/kg) for ^{40}K, (18.9± 3.4 - 39.3±3.3 Bq/kg) for ^{226}Ra and (22.1±1.7 – 36.8±1.6 Bq/kg) for ^{232}Th, which indicates that the specific activities differ from one radionuclide to another in the sites. These variations could be attributed to the different levels of concentration in radionuclides in the excavation sites.

Table 1: The Activity Concentration of ^{40}K, ^{226}Ra and ^{232}Th and the Radioactivity level

S/No	Sample ID	^{40}K (Bq/kg)	^{226}Ra (Bq/kg)	^{232}Th (Bq/kg)	Radioactivity level (Bq/kg)
1	OA	134.495±9.054	26.146±2.603	36.758±1.605	0.2406
2	OB	158.376±5.833	25.784±2.471	34.005±2.575	0.2339
3	OC	143.249±6.139	34.120±3.438	22.126±1.681	0.2074
4	OD	130.053±5.319	39.302±3.292	27.842±2.862	0.2408
5	OE	133.544±8.891	27.352±1.765	23.134±2.021	0.1910
6	OF	125.075±5.790	18.906±3.400	35.373±2.117	0.2137

The risk of exposure to people using the soils/sharp sands from these sites for building construction and other purposes were considered by evaluating the radioactivity level expression given in equation (1) as stated by Ruixiang (1986): $\frac{A_{Ra}}{370}+\frac{A_{Th}}{259}+\frac{A_K}{4810}\leq 1$ (1) Where A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg, respectively.

The radioactivity level presented in Table 1 (column 6) was found to be less than unity for all the locations. There is no course for alarm as less than unity implies that permissible limit is not exceeded, therefore, soils/sharp sands from these sites are safe for building constructions, paint making and other useful purposes. The result of this work is therefore in agreement with other researchers (Babatunde, *et al.* 2004; Usikalu, *et al*. 2014, Mbonu, *et. al.* 2021 and Yusuf, *et al.* 2023) in Nigeria who worked on top soils and reported radioactivity levels at permissible limit. However, the low level of radioactivity obtained in this work could be attributed to the fact that the soil samples were collected at the point where the sand is being loaded into the Lorries for onward distribution to the end users even though it is at some depth below the sea level.

CONCLUSION

This research and the results obtained has provided useful information on the radioactivity level of the soils from the Onyeama hill which revealed the activity concentrations for the three natural occurring radionuclides: ^{40}K, ^{226}Ra and ^{232}Th and showed that the radioactivity level is within the permissible limit.

We, therefore, recommend that the use of soils/sharp sands from these locations are safe and do not expose the user(s) to some doses of radiation that could be threatening to human health.

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