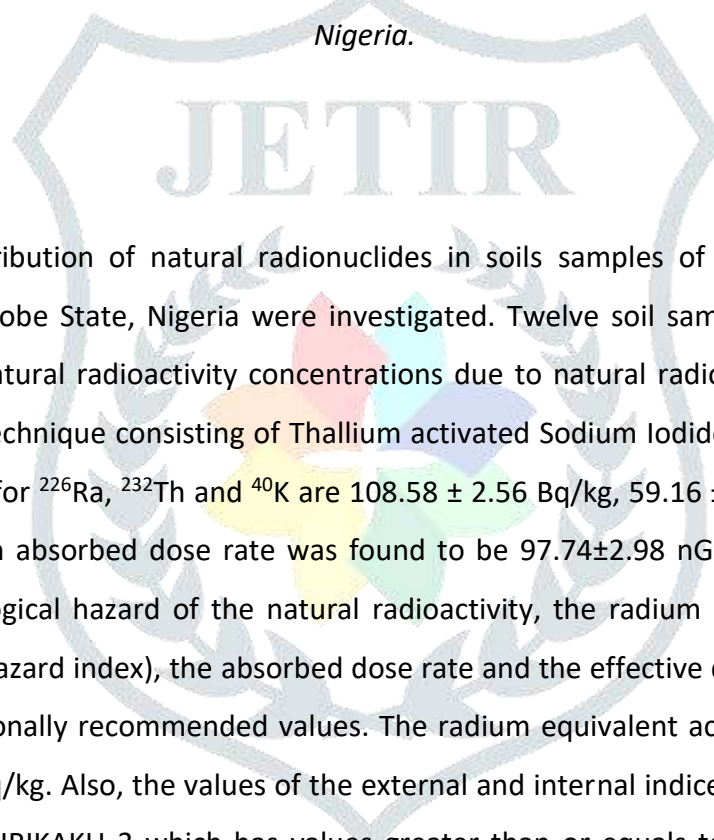


DETERMINATION OF *RADIOACTIVITY* CONCENTRATION IN SOIL SAMPLES OF SOME POTASH MINING AREAS IN YUNUSARI LOCAL GOVERNMENT AREA, YOBE STATE, NIGERIA.

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Abstract

The concentrations and distribution of natural radionuclides in soils samples of some Potash mining areas in Yunusari local government, Yobe State, Nigeria were investigated. Twelve soil samples were collected from four locations to measure their natural radioactivity concentrations due to natural radionuclides (^{226}Ra , ^{232}Th and ^{40}K) using gamma spectrometry technique consisting of Thallium activated Sodium Iodide (NaI (TI)) detector. The mean activity concentration values for ^{226}Ra , ^{232}Th and ^{40}K are 108.58 ± 2.56 Bq/kg, 59.16 ± 3.08 Bq/kg and 284.32 ± 1.37 Bq/kg respectively. The mean absorbed dose rate was found to be 97.74 ± 2.98 nGy/h, which is above the safety limit. To evaluate the radiological hazard of the natural radioactivity, the radium equivalent activity, the hazard index (external and internal hazard index), the absorbed dose rate and the effective dose rate were been calculated and compared with internationally recommended values. The radium equivalent activity values of all samples are lower than the limit of 370 Bq/kg. Also, the values of the external and internal indices are less than unity, except at locations MOZOGUN 1 and KIRIKAKU 3 which has values greater than or equals to unity for the internal hazard indices that is 1 and 1.08 respectively. The mean annual effective dose rate was 0.119mSv/y and is less than 1mSv/y safety limit recommended for the public by International Commission on Radiological Protection (ICRP).

Keywords: Potash Mining, Hazard Index, Natural Radionuclides, Safety Limit, Gamma Spectrometry,

1. Introduction

Natural radioactive mineral deposits are found in suitable geological environments (Bhaumik et al., 2004). Their occurrences in outcrop enhance the background radiation of the area, exposure to high radiation level may be harmful for people residing in the region. According to the United Nations Scientific Committee on Effects of Atomic Radiation Report (UNSCEAR, 2000), the greatest contribution to mankind's exposure comes from natural

background radiation, and the worldwide average annual effective dose from natural sources is 2.4mSv(According to the United Nations Scientific Committee on Effects of Atomic Radiation Report (UNSCEAR, 2000),). However, much higher levels of exposure are usual for inhabitants of natural high background radiation areas (HBRAs). Background radiation is mainly due to naturally occurring radioactive elements in the earth's crust such as Uranium (^{238}U), Thorium (^{232}Th) and Potassium (^{40}K). Areas at high altitudes are also more affected by cosmic radiations (NCRP, 1987; UNSCEAR, 1993; Bennett, 1997). Human beings have always been exposed to ionizing radiations of natural origin, namely terrestrial and extra -terrestrial radiation. Radiation of extra-terrestrial origin is from high energy cosmic ray particles estimated to be 30 nGyh^{-1} at sea level (UNSCEAR, 2000), while that of terrestrial origin is due to the radioactivity of ^{238}U , ^{232}Th and ^{40}K . These radionuclides have half-life which is comparable to the age of the earth The level at which man is being exposed to radiation solely depends on the concentration of these radionuclides in soil of an area which is related to the types of rock that formed the soil. Higher radiation levels are associated with igneous rocks such as granite and lower levels with sedimentary rocks (NCRP Report, 1993).

The research aimed to establish the reference data on the level of natural background radiation globally, several studies have been conducted around the world to measure natural radioactivity concentration in the soil/sediment of certain areas. These include, radioactivity concentration of natural radionuclides was determined in sediments samples for the coast of Accra Ghana(Amekudzie et. al 2011), measurement of natural radioactivity levels in soil samples along the bank of river, kaduna, Nigeria(Abdullahi et al 2013), Natural

radioactivity levels of Australlian building materials was determined in industrial waste and by-products(Beretka and Mathew, 1983), Natural radioactivity levels in environmental samples was determined in northwestern Desert of Egypt(El Daly and Hussain, 2008)

The research aimed to assess natural radioactivity concentration in the soil/sediment of certain Potash mining areas in Yunusari local government area of yobe state. The study area is blessed with varieties of solid minerals which make it to have several Potash mining areas; Potash mining is among the major activity of the inhabitants. The people of Yunusari local government area are likely to face radiation exposure risk due to the presence of naturally occurring radioactive materials (NORM) in the earth and in the mining by-products, and wastes derived from mining operations.

2. Material and Method

Study Area

Yunusari local government is one of the seventeen local government areas of Yobe State. Its headquarters is in the town of Kanamma in the northeast of the area along Burun Gana river at [13°06'15"N 12°04'20"E](#).It shares border to the north with The Republic of Niger, It has an area of 3,790 km² and a population of 125,821 as of 2006 census. The major climatic seasons are rainy season which begins in March or April and ends in October and the dry season

using a wooden pestle and mortar and packed to fill different cylindrical plastic containers of diameter 7 cm by 6 cm height which satisfy the selected optimal sample container height. The sample containers also undergo three stages of sealing to prevent ^{222}Rn escape. Then, before counting activities the sample has been stored for a 30days, to attain secular equilibrium between the radium and thorium and their progenies.

4. Sample Analysis

The soil samples collected from four locations has been analysed to measure their natural radioactivity concentrations due to natural radionuclides (^{226}Ra , ^{232}Th and ^{40}K) using gamma spectrometry technique.

5. Calculation of Radiological Hazard

To represent the activity levels of natural radionuclides (^{226}Ra , ^{232}Th and ^{40}K) by a single quantity, which would account for the radiation hazards associated with NORMs in soils of the study area, a common radiological index has been introduced. This index is called Radium equivalent (Ra_{eq}) activity (UNSCEAR, 2000), and is mathematically defined by

$$Ra_{eq}(\text{Bq/kg}) = A_{Ra} + 1.43A_{Th} + 0.077A_K, \quad (1)$$

where, A_{Ra} , A_{Th} and A_K are the activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K , respectively.. This assumption works only with the external hazard due to gamma rays in building materials. It is recommended that the maximum value of Ra_{eq} in raw building materials must be less than 370 Bq/kg for safe use. This implies that the external gamma dose must be less than 1.5 mSv^{-1} . To estimate the gamma ray related to natural radionuclides in building materials, a widely used hazard index (reflecting the external exposure) called the external hazard index H_{ex} has been used and is defined as follows (UNSCEAR, 2000),

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (2)$$

where, A_{Ra} , A_{Th} and A_K are the activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K , respectively. In addition to external hazard index, radon and its short-lived products are also hazardous to the respiratory organs. The internal exposure to radon and its daughter products is quantified by the internal hazard index H_{in} , which is given by the equation (3) below:

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (3)$$

The values of the indices (H_{ex} , H_{in}) must be less than unity for the radiation hazard to be negligible.

6. Absorbed Dose Rate

To evaluate the health risk associated with naturally occurring radionuclides (^{226}Ra , ^{232}Th and ^{40}K), the calculation of absorbed dose rates (D) due to gamma radiations in air at 1 m above the ground surface is very necessary. The

calculations has been done based on the guide lines provided by (UNSCEAR) 2000. We assumed that the contributions from other naturally occurring radionuclides were insignificant. Therefore, D been calculated according to United Nations Scientific Committee on the Effect of Atomic Radiation (UNSCEAR) 2000.

$$D(nGy/h) = 0.462A_{Ra} + 0.604A_{Th} + 0.0417A_K, \quad (4)$$

where A_K , A_{Ra} and A_{Th} are the activity concentrations (Bq/kg) of ^{40}K , ^{226}Ra and ^{232}Th present in the soil samples.

0.462, 0.604 and 0.0417 are dose conversion factors of radionuclides (^{226}Ra , ^{232}Th and ^{40}K) recommended by (UNSCEAR) 2000.

7. Annual Effective Dose Equivalent

To estimate the annual effective dose rates, one needs to take into account the conversion coefficient from absorbed dose in air to effective dose (0.7 Sv/Gy) received by adults and outdoor occupancy factor (0.2) proposed by UNSCEAR report Therefore, the annual effective dose rate (mSv/yr) is calculated using the formula below

$$\text{Effective Dose Rate}(mSv/y) = D(nGy/h) \times 8760h/y \times 0.2 \times 0.7Sv/Gy \times 10^{-6}, \quad (5)$$

8. Result and Discussion

Table 1. Mean activity concentrations of natural radionuclides (^{40}K , ^{226}Ra and ^{232}Th) in soil samples measured in this work

Sample ID	K-40(Bq/kg)	Ra-226(Bq/kg)	Th-232(Bq/kg)
GONIRI 1	352.74 ± 1.20	131.87 ± 2.99	45.17 ± 3.50
GONIRI 2	231.76 ± 1.34	104.66 ± 3.76	45.33 ± 2.79
GONIRI 3	209.94 ± 1.07	93.36 ± 1.59	56.38 ± 3.81
MOZOGUN 1	285.82 ± 1.45	99.39 ± 2.68	72.42 ± 3.02
MOZOGUN 2	370.01 ± 1.61	124.64 ± 2.44	66.68 ± 2.63
MOZOGUN 3	370.33 ± 1.50	101.43 ± 2.35	63.42 ± 1.69
KIRIKAKU 1	257.77 ± 1.43	83.09 ± 2.56	53.47 ± 2.52
KIRIKAKU 2	261.58 ± 1.28	82.49 ± 2.72	54.06 ± 2.79
KIRIKAKU 3	257.77 ± 1.42	140.16 ± 2.68	74.78 ± 2.87
KANAMMA 1	251.07 ± 1.51	104.94 ± 2.72	57.60 ± 4.68
KANAMMA 2	247.31 ± 1.32	114.29 ± 2.30	70.85 ± 3.58
KANAMMA 3	315.69 ± 1.29	122.64 ± 1.92	49.77 ± 3.03
Mean	284.32 ± 1.37	108.58 ± 2.56	59.16 ± 3.08

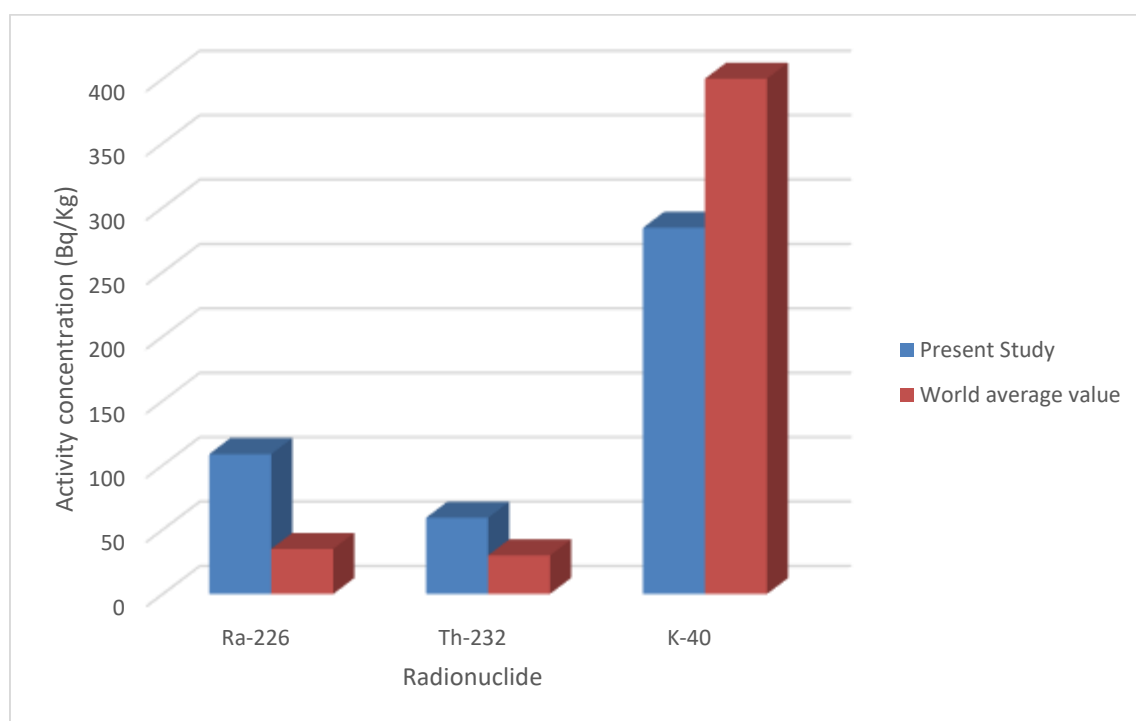


Figure 1. Comparison of the world average values of activity concentration with the present study

Table 2. The absorbed dose rate (D), annual effective dose rate (H_E), Radium equivalent (Ra_{eq}) and Hazard index (H_{ex} , H_{in}) of soil samples measured in this work

Sample ID	D(nGy/h)	H_E (mSv/y)	Ra_{eq} (Bq/kg)	H_{ex}	H_{in}
GONIRI 1	102.92±3.55	0.126±0.004	223.62±8.08	0.60±0.02	0.96±0.02
GONIRI 2	85.39±3.47	0.104±0.004	187.22±7.85	0.50±0.02	0.78±0.03
GONIRI 3	85.94±1.73	0.105±0.002	190.14±7.06	0.51±0.01	0.76±0.02
MOZOGUN 1	101.57±3.12	0.124±0.003	224.95±7.11	0.60±0.01	0.87±0.02
MOZOGUN 2	113.28±2.78	0.138±0.003	248.48±6.32	0.67±0.01	1.00±0.02
MOZOGUN 3	100.60±2.16	0.123±0.002	220.63±4.88	0.59±0.01	0.87±0.01
KIRIKAKU 1	81.43±2.76	0.099±0.003	200.19±6.27	0.48±0.01	0.70±0.02
KIRIKAKU 2	81.67±2.99	0.100±0.003	179.93±6.80	0.48±0.01	0.70±0.02
KIRIKAKU 3	120.67±3.03	0.147±0.003	266.94±6.89	0.72±0.01	1.08±0.02
KANAMMA 1	93.74±4.14	0.114±0.005	206.64±9.52	0.55±0.02	0.84±0.03
KANAMMA 2	105.90±3.27	0.129±0.004	234.64±7.52	0.63±0.02	0.94±0.02
KANAMMA 3	99.88±2.77	0.122±0.003	218.11±6.35	0.58±0.01	0.92±0.02
Mean	97.74±2.98	0.119±0.003	216.79±7.05		

Table 1 present the results of the mean activity concentrations of natural radionuclides obtained from gamma spectrometry measurements for soil samples collected around four locations of Yunusari potash mining areas. The highest concentration value $370.33 \pm 1.50 \text{ Bq/kg}$ for ^{40}K was obtained at location MOZOGUN 3, sample at location KIRIKAKU 3 recorded the highest value $140.16 \pm 2.68 \text{ Bq/kg}$ for ^{226}Ra and also, the highest value $74.78 \pm 2.87 \text{ Bq/kg}$ of ^{232}Th was obtained at location KIRIKAKU 3 respectively.

Figure 1 show the comparison between the world wide average values for activity concentration of natural radionuclides with that of the present study. The activity concentrations of natural radionuclides (^{40}K , ^{226}Ra and ^{232}Th) in the various samples location are also presented in Figure 2. The bar charts showing the deduced activity concentrations

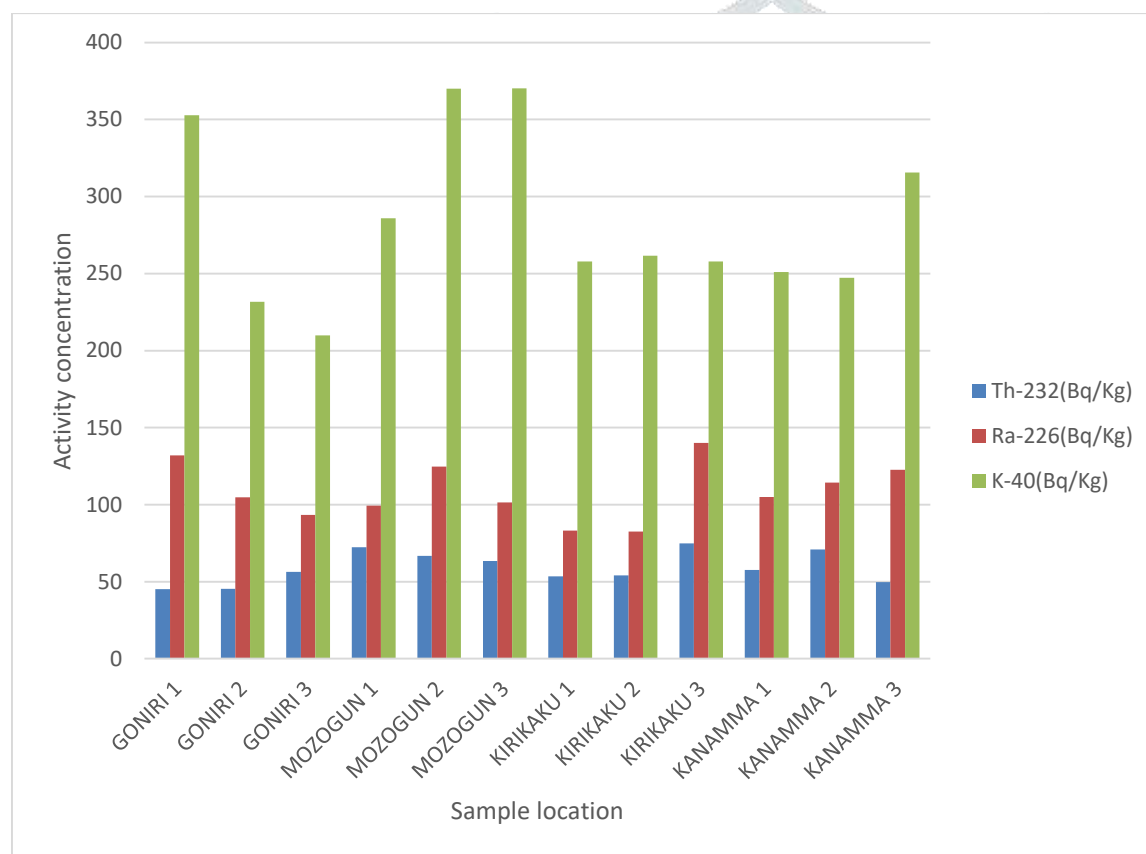


Figure 2. The results of the activity concentrations of the natural radionuclides in the soil sample of the study area verses sample location

9. Conclusion

In view of worldwide concern about the contents of radionuclides (^{40}K , ^{232}Th and ^{226}Ra) in soil/sediments, experimental measurements of the activity concentrations of natural radionuclide in soil samples in Yunusari potash mining areas were conducted. The measured average values of the activities concentration of ^{40}K , ^{226}Ra and ^{232}Th was found to be 284.32 ± 1.37 , 108.58 ± 2.56 and $59.16 \pm 3.08 \text{ Bq/kg}$, respectively. The values of ^{40}K is beyond the world

average values of 400Bq/kg except that ^{226}Ra and ^{232}Th which are above the recommended values(37Bq/Kg and 33Bq/Kg) respectively. Meanwhile, slight variation in the radioactivity content in soil observed with different locations worldwide, was basically due to soil type, formation and transport process involved. This could be the reason for the variation observed in the results. The mean absorbed dose rate obtained in this research (97.74 ± 3.28 nGy/h) which is higher than the world average (55 nGy/h). The calculated average annual effective dose (0.119 mSv) is lower than the world average value 0.480 mSv. All the values obtained for radium equivalent activity are less than 370 Bq/kg, which are acceptable for safe use as recommended by the IAEA. The measured values of external and internal hazard indices values were found to be lower than unity, which means that the study area is safer for the workers and general public as well, except at locations MOZOGUN 2 and KIRIKAKU 3 which has values for internal hazard indices as 1.00 and 1.08 respectively, which slightly above the safety limit.

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