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Full Length Research Article

ASSESSMENT OF RADIOACTIVITY CONCENTRATION IN SOIL OF SOME MINING AREAS IN CENTRAL NASARAWA STATE, NIGERIA

[1]Ibrahim, U, [2]Akpa, T.C., and [3]Daniel, I.H.

[1,2] Nasarawa State University Keffi, Nigeria
[3]Kaduna State University Kaduna, Nigeria.

[3]Corresponding author email: Isaac.daniel@kasu.edu.ng

ABSTRACT
A study was conducted to determine 226Ra, 232Th, and 40K natural activity concentrations in surface soils/sediments of some mining areas in Central Nasarawa State Nigeria, using Sodium Iodide-Thallium Gamma Spectroscopy. Seven major sites were identified from the highly mining areas of the zone and a total of twenty (21) samples were collected throughout the whole accessible areas. From the analyzed samples, mean natural activity concentrations were determined and the results show 403.963±7.29 Bq/kg, 32.52±4.65 Bq/kg and 56.23±2.30 Bq/kg for 40K, 226Ra and 232Th respectively. The results obtained were a bit lower compare to the World average value, except for 232Th which is higher than the World average value with a difference of 20.23 Bq/kg. The evaluated annual mean effective dose is 0.04±2.7 mSv/yr. This is far less than the annual dose limit for members of the public. The mean Radium equivalent activity is 141.56±7.2Bqkg-1. The average background radiation absorbed doses at the two spots are 5.81 ±0.08 mSv/y and 8.45±0.56 mSv/y. This is higher compare to worldwide average of 1mSvy-1 given by IAEA (1996) and UNSCEAR (2000). This implies that the people near the mining sites are likely to receive little or no radiation dose when the stay outside or inside their houses.

Keywords: Effective Dose, Background Radiation, Gamma Spectroscopy, Public, Mining Spot.

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. This high exposure 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 is 2.4 mSv. However, much higher levels of exposure are usual for inhabitants of natural high background radiation areas (HBRAs). High level of radiation above the earth is mainly due to naturally occurring radioactive elements in the earth's crust such as Uranium (238U), Thorium (232Th) and Potassium (40K). 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 extraterrestrial radiation. Radiation of extra-terrestrial origin is from high energy cosmic ray particles and at sea level it is about 30 nGyh-1 (UNSCEAR, 2000), while that of terrestrial origin is due to the presence of naturally occurring radionuclides; mainly potassium, rubidium and the radionuclides in the decay chains of thorium and uranium. These radionuclides have half-life which is comparable to the age of the earth. Natural radioactivity in geological materials, mainly rocks and soil, comes from 232Th and 238U series and natural 40K. Artificial radionuclides such as 137Cs which result from weapon testing and nuclear accident could also be present (UNSCEAR, 2000). The levels due to the terrestrial background radiation are related to the types of rock from which the soils originate. Higher radiation levels are associated to igneous rocks such as granite and lower levels with sedimentary rocks. There are some exceptions however, since some shale and phosphate rocks have a relatively high content of radionuclides (NCRP Report, 1993).

The mandate to control nuclear and radiation generating sources in Nigeria is vested with the Nigerian Nuclear Regulatory Authority which is authorized by law to ensure that radiation protection and safety regulations are adhered to. Several studies have been conducted around the world to assess natural radioactivity levels in the soil/sediment of certain areas. Among the recent ones are; Natural radioactivity concentrations and dose assessment in shore sediments along the coast of greater Accra, Ghana (Amekudzie et al., 2011). Measurement of natural radioactivity levels in soil along the bank of river Kaduna, Nigeria (Abdullahi et al., 2013), natural radioactivity levels of Australian building materials, industrial wastes and by-products (Beretka and Mathew, 1985) and natural radioactivity levels in environmental samples in North Western Desert of Egypt (El-Daly and Hussein, 2008).

In recent years there has been rampant dumping of mining tailings in the near-by neighborhood of mining sites in the zone. Nasarawa central is blessed with varieties of solid minerals which make it to have hundreds of mining sites; mining is the second major activity of the inhabitants. The people of Nasarawa central 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. The objective of this study is to assess natural radioactivity levels in the soil/sediment of certain mining areas in Nasarawa central coupled with the fact that structural development is fast moving close to both active and inactive mining areas in the zone. This assessment revealed the air absorbed external gamma-radiation exposure, annual effective radiation dose, and external radiation hazard index. The data generated in this study will provide base line values of exposure to radiation in an environment where mining activities is taking place and may be useful for authorities in the implementation of radiation protection standards for the general population in the country, as well as to conduct further studies on this issue.

MATERIALS AND METHODS

Three major sites were identified from the highly mining areas of Central Nasarawa State. The areas are: Nasarawa Eggon,Wamba and Farin Ruwa.

A total of nine (9) surface soil/sediments samples were collected from the actively mining areas. A 50cm by 50cm area was marked at four to six points in each sampling site by gridding, depending on the size of sites. Soil/sediment samples were collected from an auger hole in each mining site at few centimeter depths (0.2m = 20cm) from the ground so as to get the natural soil. At each mining site, surface soil/sediments were collected from different point at random so that it gives a representative sample of the area. Surface soil/sediments samples were collected from the mining spot, 100m away from the mining site (control area) and at closed by running water or water body around the mining site. The soil/sediments samples collected were packed and labeled according to the mining site and location.

The background gamma dose rate at 1m above the ground was also measured using an Inspector Alert Nuclear Monitoring meter. Readings were taken in count per second (cpm) at sea level at both the mining spot and at the control area (100m away).

Samples Preparation

The major nuclear technique employed in the analysis of samples for background activity is the Gamma spectrometry using NaI(Tl) detector.

The collected samples (i.e. soil or sediment) brought into the laboratory are left open (wet) for a minimum of 24hrs to dry under ambient temper. They were grounded to fine powder and packed into cylindrical plastic containers of height 7cm b 6cm diameter. This satisfied the selected optimum sample container height (Ibeanu, 1999). Each container accommodated approximately 300g of sample. They were carefully sealed (using vaseline, candle wax and masking tape) to prevent random escape and you stored for a minimum of 24 days. This is to allow radium attain equilibrium with the daughters.

Dose Calculations

In order to assess any radiological hazard, the absorbed dose rate (nGyh-1) in air at 1 m above the ground surface due to the mean specific activities of 40K, 226Ra, and 232Th (Bqkg-1) in the collected samples, can be calculated using the following formula reported by (UNSCEAR Report, 2000).

$$D\ (nGyh^{-1}) = DCF_k C_k + DCF_{Ra} C_{Ra} + DCF_{Th} C_{Th} \quad (1)$$

where D is air absorbed dose rate, DCF_k (0.0417), DCF_{Ra} (0.462) and DCF_{Th} (0.604) are the dose rate conversion factors (Saito, and Jacob,1995) and C_k, C_{Ra} and C_{Th} are the concentrations of ^{40}K, ^{226}Ra, and ^{232}Th in the materials respectively.

It is assumed that the contribution from other radionuclides, such as ^{137}Cs, ^{235}U, ^{87}Rb, ^{90}Sr, ^{138}La, ^{147}Sm and ^{176}Lu to the total dose rate are negligible. UNSCEAR reported that the world average absorbed gamma dose rate mean is $55nGyh^{-1}$.

Annual Effective Dose

The annual effective dose rate from outdoor gamma radiation can be estimated by taking into account the conversion coefficient from the absorbed dose in air to the effective dose in air to the effective dose ($0.7Sv\ Gy^{-1}$) and an outdoor occupancy factor of 0.2 received by adults. Under these assumptions, the annual effective dose equivalent can be calculated by the following equation (UNSCEAR, 2000).

$$E(mSvy^{-1}) = D(nGh^{-1}) \times 8760(h) \times 0.2 \times 0.7\ (mSvy^{-1}) \times 10^{-6} \quad (2)$$

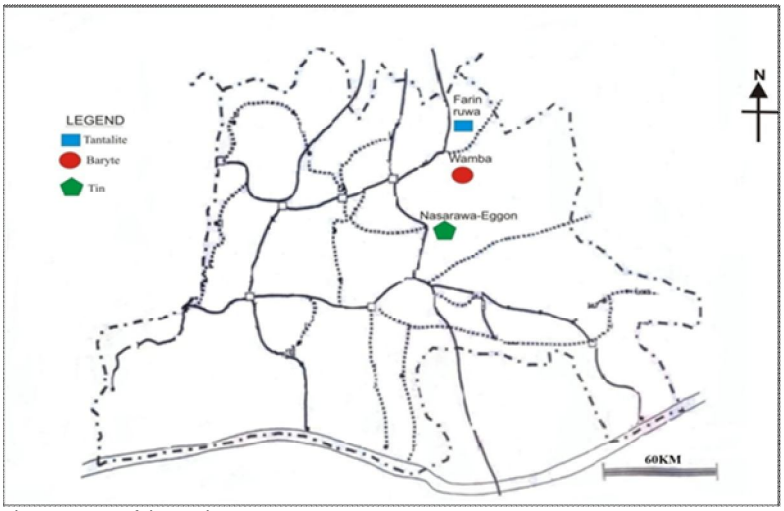

Figure 1: Map of the study area

RESULTS

Activity Concentrations of ^{226}Ra, ^{232}Th and ^{40}K from Samples Collected

Table 1 Activity Concentration from the Soil/Sediments from Nasarawa central Mining Spot

S/N	Sample ID	K-40 (Bq/Kg)	Ra-226 (Bq/Kg)	Th-232 (Bq/Kg)	Temperature	Coordinates		
						Elevation	Longitude	Latitude
1.	NN1 Spot	313.06±10.10	19.11±7.76	62.48±1.02	36°c	502m	N08°32'58.6''	E08°05'19.1"
2.	NN2 Spot	613.06±7.93	60.12±6.60	54.04±2.28	24°c	446m	N08°42'03.8"	E08°39'07.0"
3.	NN3 Spot	271.22±7.93	50.74±5.32	35.91±1.25	21°C	194m	N08°32'53.6"	E08°40'52.4"
MEAN		399.11±8.63	43.32±6.56	50.81±3.71				

Table 2: Activity Concentration from the Soil/Sediments from Nasarawa North 100m away from Mining Spot

S/N	Sample ID	K-40 (Bq/Kg)	Ra-226 (Bq/Kg)	Th-232 (Bq/Kg)	Temperature	Coordinates		
						Elevation	Longitude	Latitude
1.	NN1 100M AWAY	613.06±7.93	60.12±6.60	54.04±2.28	36°c	502m	N08°32'58.6''	E08°05'19.1"
2.	NN2 100m away	234.05±3.57	11.35±1.73	56.55±2.62	24°c	446m	N08°42'03.8"	E08°39'07.0"
3.	NN3 100m away	177.13±2.33	19.46±0.57	48.68±1.17	21°C	194m	N08°32'53.6"	E08°40'52.4"
MEAN		314.42±4.61	30.31±2.96	53.09±2.02				

Table 3: Activity Concentration from the Soil/Sediments from Nasarawa North Water ways around the Mining Spot

S/N	Sample ID	K-40 (Bq/Kg)	Ra-226 (Bq/Kg)	Th-232 (Bq/Kg)	Temperature	Coordinates		
						Elevation	Longitude	Latitude
1.	NN1 water ways	317.88±6.53	10.19±1.96	40.59±1.84	36°c	502m	N08°32'58.6''	E08°05'19.1"
2.	NN2 water ways	583.51±9.95	10.19±3.59	81.75±1.02	24°c	446m	N08°42'03.8"	E08°39'07.0"
3.	NN3 water ways	590.66±9.48	51.43±7.76	72.06±0.79	21°C	194m	N08°32'53.6"	E08°40'52.4"
MEAN		497.35±8.65	23.93±4.43	64.80±1.22				

Where NN_1 stands for Farin ruwa, NN_2 stands for Wamba and NN_3 stands for Nasarawa-Eggon

Table 4: Mean Dose Evaluation from the Soil/Sediments samples

S/N	Sample ID	K-40 (Bq/Kg)	Ra-226 (Bq/Kg)	Th-232 (Bq/Kg)	Absorbed dose rate ($nGyh^{-1}$)	Annual Effective dose ($mSvy^{-1}$)	Radium Equivalent Activity (Bq/kg)	External hazard index	Internal hazard index
1.	Mining Spot	399,11±8.6	43.32±6.5	50.82±3.7	67.35±4.3	0.04±2.6E-3	143.93±9.3	0.41±3.2E-2	0.496±3.6E-2
2.	100m away	314.42±4.6	30.31±2.9	53.09±2.0	60.31±2.7	0.03±3.6E-3	130.14±5.4	0.357±3.6 E-2	0.439±4.8E-2
3.	water ways	497.35±8.6	23.93±4.4	64.80±1.2	70.94±3.1	0.04±1.9E-3	151.42±6.7	0.41±2.3E-2	0.4±2.97E-2

Table 5: Background Radiation Measurement and mean dose evaluation

S/No.	Code	Mean Count (cpm)	Dose (mSv/y)	Dose (nGy/h)	Annual Effective Dose (mSv/y)
1.	Mining Spot	72.8±3.6	8.45±0.56	728±36	0.574±0.04
2.	100m away	66.4±0.8	5.81±0.08	655±44	0.407±0.01

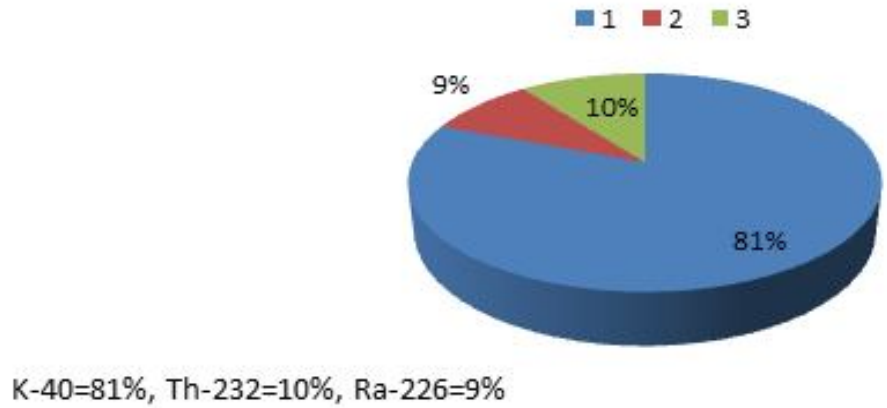

Figure 1: Percentage activitycConcentration of K-40, th-232 and Ra-226 in mining spot

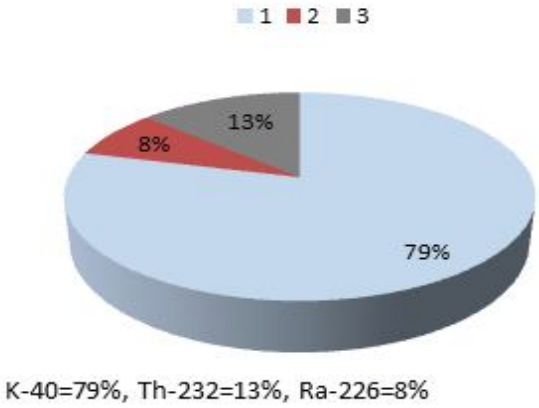

Figure 2: Percentage activity concentration of K-40, Th-232 and Ra- 226100m away from mining spot

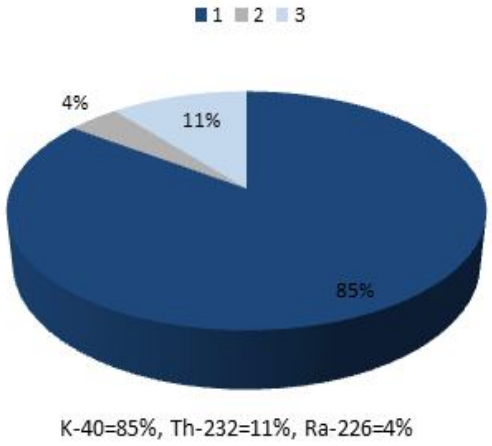

Figure 3: Percentage Activity Concentration of K-40, Th-232 and Ra-226 in water ways around mining areas

Table 6: Comparison of activity concentrations obtained in present study with that reported for Other Countries

Country	^{226}Ra	^{232}Th	^{40}K	Reference
India (Punjap)	19.7	220.5	920.2	(Kolo *et al*.,2012)
Thailand	68.0	45.0	213.0	,,
Vietnam (South-East)	19.6	31.0	34.6	,,
Madagascar	29.0	95.0	294.0	,,
Botswana	34.8	41.8	432.7	,,
Turkey	115.0	1192.0	1207.0	,,
China	112.0	71.5.0	672.0	,,
Jordan	84.0	82.0	560.0	,,
World average	33.0	36.0	474.0	(UNCEAR, 2000)
Nigeria(Nasarawa Central)	32.52±4.65	56.23±2.3	403.63±7.2	Present Study

DISCUSSION

The mean activity concentration at 100m away from the mining spot is higher compare to the other locations; this might be due to altitude or temperature variation. The measurement showed that 40K has the largest contribution to the specific activities in all the samples analyzed in the area.

The average activity concentrations level is lower than the corresponding worldwide mean value for soils which is 40 Bq/kg for ^{226}Ra and ^{232}Th, 370 Bq/kg for ^{40}K reported by UNSCEAR in 2000 except for **^{232}Th** which is above 36 Bq/kg.
The mean annual effective doses evaluated in Table 4, is less than the annual dose limit for members of the public as reported by NiBIRR in 2003.

The average γ-radiation hazards associated with the soil samples presented in Table 4 are less than the upper limit of 370 Bq/kg as reported by UNSCEAR in 1988 and 2000.

The results in table 4, revealed that both H_{ex} and H_{in} are less than one (1) in all locations and can be considered as low since the value is less than 1 (Krieger, 1981; Beretka & Mathew, 1985).

The background radiation doses revealed the minimum effective dose of 0.4073693±0.01 mSv/y in 100m away from mining spot and the maximum effective dose of 0.446614±0.02 mSv/y in the mining spot. This could be attributed to the elevation, temperature and radioactive half lives.

The results revealed that almost all the mining sites and their surroundings had effective doses less than 6mSv per year. Therefore, the mining area should not be regarded as a controlled area from radiation protection point of view (NIBIRR, 2003).

CONCLUSION

Any mining or minerals processing operation has the potential to increase the radiation dose received by individuals owing to the fact that minerals and raw materials contain radionuclide of natural or terrestrial origin.
Regarding public and occupational exposure measurements, the results obtained in this work indicated the existence of atmospheric radioactive heavy metals in the environment where mining activities is taken place, most especially where effective doses were averagely higher or closed to the recommended limits.
The measurement showed that ^{40}K has the largest contribution to the specific activities in all the soil samples analyzed. This suggests that mining activities needs to be continuously monitored and workers occupancy in the mining areas need to be controlled. Members of the public residing around the industries may in time to come likely to receive significant doses greater than what they are supposed to receive.

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