

EVALUATION OF NATURALLY OCCURRING RADIONUCLIDE MATERIALS FROM SOLID MINERALS PROCESSING IN ZAMFARA STATE, NIGERIA

A. J. Innocent^{1&2}, M.Y. Onimisi² and S.A. Jonah^{2&3}

¹Department of Preliminary Studies (Science), The Federal Polytechnic, Kaura-Namoda, Nigeria

²Department of Physics, Nigerian Defence Academy, Kaduna, Nigeria

³Centre for Energy Research and Training, Ahmadu Bello University, Zaria, Nigeria

onimisim@yahoo.com

ABSTRACT

This study presents results of activity concentrations and the annual effective dose rates of naturally occurring radionuclides (^{40}K , ^{232}Th and ^{238}U) absorbed in soil samples collected from 10 different mine sites in Zamfara State, northwest-Nigeria.

A laboratory γ -ray spectrometry NaI(Tl) at the Centre for Energy Research and Training (CERT), Ahmadu Bello University Zaria, was employed to carry out the analysis of the soil samples. The values of activity concentration found for ^{40}K , ^{238}U and ^{232}Th range from 227.095 ± 7.541 – 590.444 ± 10.566 , 4.675 ± 3.516 – 18.980 ± 0.839 and 40.577 ± 1.848 – 94.916 ± 2.752 Bq.Kg^{-1} respectively, while absorbed dose rate in the soil samples for ^{40}K , ^{238}U and ^{232}Th range from 9.470 ± 0.314 – 24.621 ± 0.441 , 2.160 ± 1.624 – 8.769 ± 0.388 and 24.509 ± 1.116 – 57.329 ± 1.662 nGy.h^{-1} respectively. The total average absorbed dose rate of the soil samples collected is 59.696 nGy.h^{-1} and the estimated annual effective dose for the study areas range from 52 – 106 $\mu\text{Sv.y}^{-1}$, with an average annual effective dose of 73 $\mu\text{Sv.y}^{-1}$.

These show that the radiation exposure level for members of the public in the study areas is lower than the recommended limit value of 1 mSv.y^{-1} (UNSCEAR, 2000).

Keywords: radionuclides, ^{40}K , ^{232}Th , ^{238}U , soil sample, mining activities, activity concentration, absorbed dose rate, annual effective dose, Zamfara

INTRODUCTION

The world is naturally radioactive and about 90% of human radiation exposures arise from natural sources such as cosmic radiations, exposure to radon gas, and terrestrial radiations. Significant naturally occurring radionuclides present in the soil are ^{238}U , ^{232}Th and ^{40}K (Harb *et al.*, 2010). Since these radionuclides are not uniformly distributed, the knowledge of their distribution in soils and rocks play an important role in radiation protection and measurement. Some of the exposures are fairly constant and uniform for all individual persons everywhere, for example, the dose acquire from ingestion of ^{40}K in foods. However, other exposures vary widely depending on location. Cosmic rays,

for example, are more intense at higher altitudes and concentrations of uranium and thorium in soils are elevated in localized areas. High levels of uranium and its decay products in rock and soil, and thorium in monazite sands are the main sources of high natural background radiations that have been identified in several areas of the world (UNSCEAR, 2000).

Radiation exposures arise in the mining and mineral processing industries through three principal pathways: external gamma radiation from ores, concentrates and the like; inhalation of dusts containing long-lived alpha-emitting radionuclides; and inhalation of the short-lived decay products of radon. Inhalation of radon decay products in poorly ventilated underground mines can lead to exposures in excess of current radiation exposure limits, and this could cause high incidence of lung cancer in the mine workers. There is consequently a need to adopt careful radiological control measures in mining and mineral processing operations involving radioactive ores, in order to protect those involved and to meet dose limits.

Exposure of workers to naturally occurring radioactive material (NORM) continued to be an emerging industrial issue, for example in the extraction of rare earths, the zircon and zirconium industries, coal-fired electricity generation and the phosphate industry (IAEA, 2011). According to United Nations Scientific Committee on the Effects of Atomic Radiation, about 13 million workers are exposed to natural sources of radiation. Historically, such industries have not always been subjected to the same strict regulation regime as is the case with artificial sources. Environmental problems associated with NORM in solid minerals mines and processing occur in the process of drilling, leaching, handling, storage, transportation of mineral ores and the use of contaminated equipment or waste media without controls. These usually lead to the spread of NORM contaminating the environment, resulting in potential radiation exposure of members of the public. An example of negative effect of contaminated environment on humans, as a result of mining activities was that reported by (UNEP, 2010). According to the source, in March 2010, an unusual high number of deaths, primarily among children under age 5 in Bukkuyum and Anka local government areas of Zamfara State, north-western Nigeria, was reported by Médecins Sans Frontières (MSF-Holland) to

state health authorities. Further study on blood samples taken by MSF revealed that the increased mortality was the result of acute lead poisoning, determined to be caused by massive environmental contamination from artisanal mining and processing of gold found in lead-rich ore. The grinding of the ore into fine particles by local miners resulted in extensive dispersal of lead dust in the villages concerned, including within family compounds. Ingestion and inhalation of the fine lead particles was determined to be the major reason for high blood lead levels in victims' bodies. Blood lead levels were found to be unprecedented for human being.

Since radiation is neither visible nor can it be felt by the human sense organs, it is important that the total amount of radiation emitting-NORMs in the area is accurately known and kept to a level as low as reasonably achievable in order to safeguard the live of the people and ensure radiation-pollution free environment. Therefore, the problem this research work sought to find solution to is, the unknown level of NORM associated with solid mineral mining activities in Zamfara, with the hope that results of this study will serve as baseline for future assessment of NORMs level in the study area.

Environmental radioactivity monitoring is believed to have commenced between the late 1959 and early 1960s (Olomo, 1990). The objective in the measurement of the radioactivity in soil is to assess the radionuclides concentration which is helpful in characterising environments in terms of radioactivity level for the purpose of safeguarding the live of people. Furthermore, a good knowledge of the radionuclide concentration may be used to characterise substances and relate the radiometric properties to physical properties of the material. This may be of use in mineral separation for example. The results obtained in this study might compliment the data base of some related studies carried out in other locations within Nigeria. Such studies are determination of terrestrial gamma dose rates and physical-chemical properties of farm soils from ex-tin mining locations in Jos, (Jibiri *et al.*, 2011); Characterization of distribution of gamma-emitting radionuclides in soils around the Centre for Energy Research and Training (CERT) Ahmadu Bello University, Zaria (Muhammad *et al.*, 2010); determination of radiological safety assessment and occurrence of heavy metals in soil from designated waste dumpsites used for building and composting in south-western Nigeria (Faweya *et al.*,

2010); Characterization of distribution of some natural gamma emitting radionuclides in the soils of the coastal areas of Nigeria (Alatise *et al.*, 2008); Estimation of natural radionuclides and elemental composition of chemical fertilizers used in Nigeria (Jonah *et al.*, 2002); baseline measurement of natural radioactivity in soil, vegetation and water in the industrial district of the Federal Capital Territory (FCT) Abuja, Nigeria (Umar *et al.*, 2012); Measurement of activity concentration of ^{40}K , ^{226}Ra and ^{232}Th for assessment of radiation hazards from soils of southern region of Nigeria (Ajayi, 2009) e. t. c.

MATERIALS AND METHOD

Sample collection and preparation

The types of soil samples used for the investigation were soils samples collected from solid mineral processing site at Danba-Gusau and mine sites at other locations within Zamfara state, Nigeria. The soil samples were packed in plastic containers from the areas of surveillance, properly sealed and labelled for easy identification and then transported to the environmental laboratory at Centre for Energy Research and Training (CERT), Ahmadu Bello University, Zaria.

In the laboratory, the soil samples were put in an oven and set to a temperature of 105°C to allow for drying overnight in order to remove any available moisture. After drying, the samples were crushed and sieved with a mesh having holes each of diameter of 2 mm in order to remove organic materials, stones and lumps. Afterwards, the homogenized samples were packed to fill cylindrical plastic beakers of height 7cm by 6cm diameter which is the same as geometry of the counting detector. This satisfies the selected optimal sample container height (Ibeanu, 2000). The samples were carefully sealed using vaseline, candle wax and masking tape in order to prevent trapped radon gas from escape. They were weighed on a digital weighing balance with a precision of $\pm 0.01\text{g}$, each plastic beaker accommodated approximately 300g of the soil sample. The sealed samples were kept for a minimum period of 30 days so as to allow for ^{226}Ra and its short-lived progenies to reach secular radioactive equilibrium before gamma counting.

The experimental set-up and procedure

The gamma-ray spectrometry set-up consists of a 7.62 cm by 7.62 cm NaI (Tl) detector housed in a 6 cm thick lead shield and lined with cadmium and copper sheets in order to assist in the reduction of background radiation (CERTZ, 1999). In addition, a computer based Multichannel Analyser (MCA) Maestro Programme from ORTEC was used for the data acquisition and analysis of gamma spectra. The soil samples were placed on the detector surface and each counted for a lifetime of about 29,000 secs (8 hrs, 3mins) in reproducible sample detector geometry. The configuration and geometry were maintained throughout the analysis, as previously characterized based on well established protocol of the laboratory at the Centre for Energy Research and Training, Zaria. The background count was also measured for the same period of lifetime.

The 1764 KeV γ -line of ^{214}Bi for ^{226}Ra was used in the assessment of the activity concentration of ^{238}U while 2614.5 KeV γ -line of ^{208}Tl was used for investigating the activity concentration of ^{232}Th . The single 1460 KeV γ -line of ^{40}K was used in its content evaluation.

CALCULATION

Net count per second (CPS)

The gross area count G_c is related to the net area count N_c by (Okeyode *et al.*, 2009):

$$N_c = G_c - B_c \quad (1)$$

Where B_c is the background area count, (the area count recorded by the detector in the absence of samples). Table 1 presents the background area counts corresponding to ^{40}K , ^{238}U and ^{232}Th as obtained from the measurements.

**Table 1: Area under the photo peaks
due to background count**

Nuclide	Bgrd count (B_c)	Stat. error
^{40}K	3816	± 338
^{238}U	902	± 307
^{232}Th	3103	± 227

Using equation (1), the net area counts N_c was calculated from the gross area counts G_c generated by the gamma spectroscopy measurements and the results obtained are as tabulated in table 2 for all the soil samples under investigation. Consequently, the net count per second (CPS) was also calculated for all the three radionuclides and table 3 presents the data obtained for the samples.

**Table 2: Gross area counts (G_c) and net area counts (N_c)
under photo peaks for the samples**

Sample ID	Gross count (G_c)			Net count (N_c)		
	^{40}K	^{238}U	^{232}Th	^{40}K	^{238}U	^{232}Th
ZM.G1	14283 $\pm$ 535	1212 $\pm$ 366	5517 $\pm$ 297	10467 $\pm$ 197	310 $\pm$ 59	2414 $\pm$ 70
ZM.G11	14826 $\pm$ 535	1359 $\pm$ 319	4971 $\pm$ 268	11010 $\pm$ 197	457 $\pm$ 12	1868 $\pm$ 41
ZM.G12	13674 $\pm$ 515	1179 $\pm$ 362	4427 $\pm$ 273	9858 $\pm$ 177	277 $\pm$ 55	1324 $\pm$ 46
ZM.H1	10720 $\pm$ 542	1099 $\pm$ 361	4135 $\pm$ 274	6904 $\pm$ 204	197 $\pm$ 54	1032 $\pm$ 47
ZM.L1	11757 $\pm$ 542	1047 $\pm$ 339	4446 $\pm$ 272	7941 $\pm$ 204	145 $\pm$ 32	1343 $\pm$ 45
ZM.L2	12496 $\pm$ 512	1261 $\pm$ 347	4238 $\pm$ 301	8680 $\pm$ 174	359 $\pm$ 40	1135 $\pm$ 74
ZM.H2	10124 $\pm$ 482	1377 $\pm$ 328	4482 $\pm$ 267	6308 $\pm$ 144	475 $\pm$ 21	1379 $\pm$ 40
ZM.L12	7821 $\pm$ 471	1314 $\pm$ 277	4106 $\pm$ 243	4005 $\pm$ 133	412 $\pm$ 30	1003 $\pm$ 16
ZM.L11	8384 $\pm$ 490	1019 $\pm$ 395	4540 $\pm$ 293	4568 $\pm$ 152	117 $\pm$ 88	1437 $\pm$ 66
ZM.G2	12504 $\pm$ 532	1139 $\pm$ 319	5190 $\pm$ 279	8688 $\pm$ 194	237 $\pm$ 12	2087 $\pm$ 52

163

164

Table 3: Net count per second (CPS) calculated for the samples

Sample ID	Net Count Per Second (CPS)		
	⁴⁰ K	²³⁸ U	²³² Th
ZM.G1	0.3609310 ± 0.0067931	0.0106897 ± 0.0020345	0.0832414 ± 0.0024138
ZM.G11	0.3796552 ± 0.0067931	0.0157586 ± 0.0004138	0.0644138 ± 0.0014138
ZM.G12	0.3399310 ± 0.0061034	0.0095517 ± 0.0018966	0.0456552 ± 0.0015862
ZM.H1	0.2380690 ± 0.0070345	0.0067931 ± 0.0018621	0.0355862 ± 0.0016207
ZM.L1	0.2738276 ± 0.0070345	0.0050000 ± 0.0011034	0.0463103 ± 0.0015517
ZM.L2	0.2993103 ± 0.0060000	0.0123793 ± 0.0013793	0.0391379 ± 0.0025517
ZM.H2	0.2175172 ± 0.0049655	0.0163793 ± 0.0007241	0.0475517 ± 0.0013793
ZM.L12	0.1460219 ± 0.0048492	0.0150215 ± -0.0010938	0.0365693 ± 0.0005834
ZM.L11	0.1575172 ± 0.0052414	0.0040345 ± 0.0030345	0.0495517 ± 0.0022759
ZM.G2	0.3297291 ± 0.0073627	0.0089947 ± 0.0004554	0.0792063 ± 0.0019735

165

166 Activity concentrations

167 The activity concentrations for the natural radionuclides in the measured samples were computed using
 168 the following relation (Okeyode *et al.*, 2009).

$$169 \quad A_c = \frac{N_c}{L_t} \sigma^{-1} \quad (2)$$

170 Where L_t is the lifetime of counting. And σ is a conversion factor, it is constant for each radionuclide
 171 at constant geometry and it is a characteristic of efficiency of the NaI(Tl) detector assembly used.
 172 Table 4 presents the values of the conversion factor (σ) for ⁴⁰K, ²³⁸U and ²³²Th (CERTZ, 1999; Umar
 173 *et al.*, 2012) used for converting the raw data into conventional unit data. All the raw data obtained
 174 from the detector were converted to conventional units using calibration factors to determine the
 175 activity concentrations of ⁴⁰K, ²²⁶Ra and ²³²Th respectively.

176 **Table 4: Conversion constants and**
 177 **gamma ray line for each nuclide**
 178

Nuclide	$\sigma(\text{Bq.Kg}^{-1}/\text{CPS})$	Gamma ray line (KeV)
⁴⁰ K	0.000643	1460
²³⁸ U	0.000863	1764
²³² Th	0.000877	2614.5

180

Using equation (2), the activity concentrations were calculated and the results are as presented in table 5 and figure 1.

Table 5: Activity concentrations of the soil samples

	Activity Concentrations (Bq.Kg ⁻¹)			
Sample ID	⁴⁰ K	²³⁸ U	²³² Th	TOTAL
ZM.G1	561.324 ± 10.565	12.387 ± 2.357	94.916 ± 2.752	668.626±15.674
ZM.G11	590.444 ± 10.565	18.260 ± 0.479	73.448 ± 1.612	682.152±12.656
ZM.G12	528.664 ± 09.492	11.068 ± 2.198	52.058 ± 1.809	591.791±13.498
ZM.H1	370.247 ± 10.940	07.871 ± 2.158	40.577 ± 1.848	418.696±14.946
ZM.L1	425.859 ± 10.940	05.794 ± 1.279	52.805 ± 1.769	484.459±13.988
ZM.L2	465.490 ± 09.331	14.345 ± 1.598	44.627 ± 2.910	524.462±13.839
ZM.H2	338.285 ± 07.722	18.980 ± 0.839	54.221 ± 1.573	411.485±10.134
ZM.L12	227.095 ± 07.541	17.406 ± -1.267	41.698 ± 0.665	286.199±6.939
ZM.L11	244.972 ± 08.151	04.675 ± 3.516	56.501 ± 2.595	306.149±14.263
ZM.G2	512.798 ± 11.451	10.423 ± 0.528	90.315 ± 2.250	613.536±14.229
MEAN	426.518 ± 9.670	12.121 ± 1.369	60.117 ± 1.978	498.755±13.017

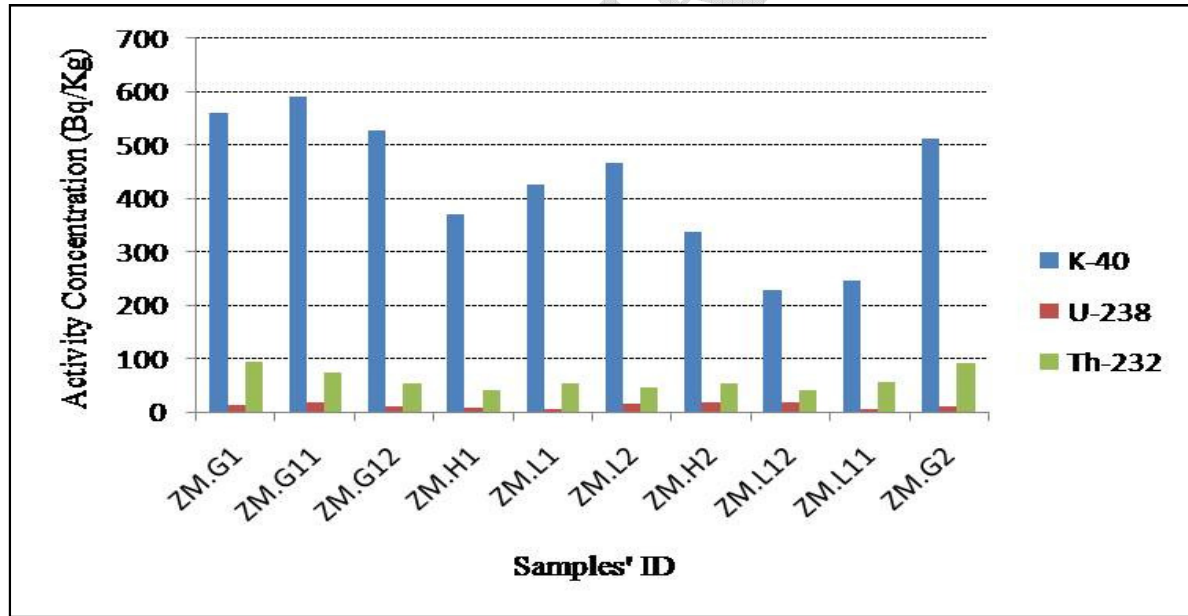


Fig. 1: Activity concentration for the samples

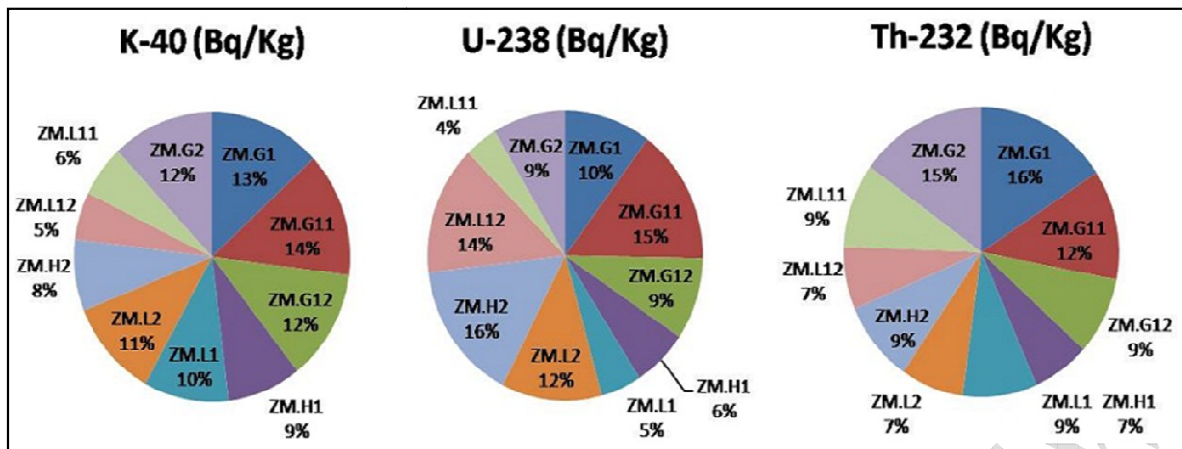


Fig.2: Percentage contribution to activity concentration by samples

Absorbed dose rates (D)

The external absorbed dose rate, $D(nGy.h^{-1})$ in air at 1 m above the ground level due to activity concentrations of ^{40}K , ^{238}U and ^{232}Th for the 10 samples were calculated using equation (3) (UNSCEAR, 2000; Jibiri *et al.*, 2011):

$$D(nGy.h^{-1}) = 0.0417A_K + 0.462A_U + 0.604A_{Th} \quad (3)$$

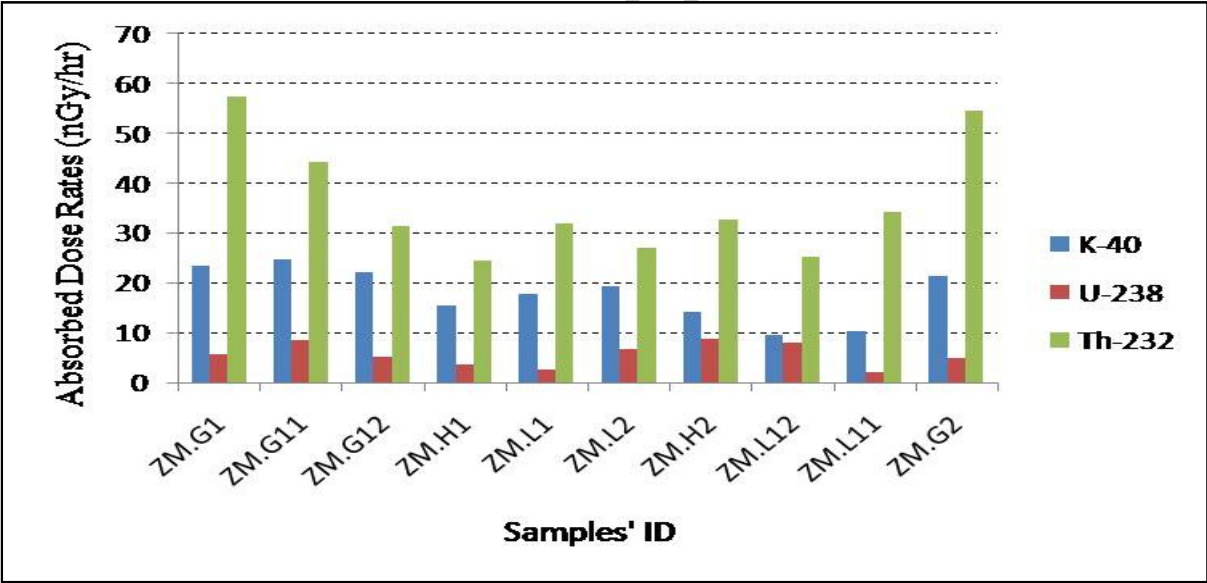
where A_K , A_U and A_{Th} are the activity concentrations of ^{40}K , ^{238}U and ^{232}Th respectively in $Bq.Kg^{-1}$.

The conversion factors 0.0417, 0.462, 0.604 are expressed in $nGy.h^{-1}/Bq.kg^{-1}$. Table 6 and figure 3 present the absorbed dose rates calculated. The absorbed dose rates in air are usually related to human absorbed dose in order to assess radiological implications.

Table 6: Absorbed dose rates of the soil samples

Sample ID	⁴⁰ K (nGyhr ⁻¹)	²³⁸ U (nGyhr ⁻¹)	²³² Th (nGyhr ⁻¹)	TOTAL (nGyhr ⁻¹)
ZM.G1	23.407 ± 0.441	5.723 ± 1.089	57.329 ± 1.662	86.459 ± 3.192
ZM.G11	24.621 ± 0.441	8.436 ± 0.222	44.363 ± 0.794	77.420 ± 1.636
ZM.G12	22.045 ± 0.396	5.115 ± 0.015	31.443 ± 1.092	58.602 ± 2.504
ZM.H1	15.439 ± 0.456	3.637 ± 0.997	24.509 ± 1.116	43.585 ± 2.569
ZM.L1	17.758 ± 0.456	2.677 ± 0.591	31.894 ± 1.069	52.330 ± 2.116
ZM.L2	19.411 ± 0.389	6.627 ± 0.738	26.955 ± 1.757	52.993 ± 2.885
ZM.H2	14.106 ± 0.322	8.769 ± 0.388	32.749 ± 0.950	55.624 ± 1.660
ZM.L12	09.470 ± 0.314	8.042 ± -0.586	25.186 ± 0.402	42.697 ± 0.131
ZM.L11	10.215 ± 0.340	2.160 ± 1.624	34.127 ± 1.567	46.502 ± 3.532
ZM.G2	21.384 ± 0.477	4.815 ± 0.244	54.550 ± 1.359	80.749 ± 2.080
TOTAL	177.858 ± 4.032	55.998 ± 6.322	363.105 ± 11.949	596.961 ± 22.304
MEAN	17.786 ± 0.403	5.600 ± 0.632	36.311 ± 1.195	59.696 ± 2.230

209
210
211
212
213
214



215
216
217
218

219

220

221

222

Fig. 3: Absorbed dose rate

Annual Effective Dose (E_d)

To estimate the annual effective dose rates, the conversion coefficient from absorbed dose in air to effective dose (0.7Sv.Gy^{-1}) and outdoor occupancy factor (0.2) proposed by (UNSCEAR 2000; Harb *et al.*, 2010) were used. Therefore, the annual effective dose rates (mSv.yr^{-1}) were calculated from the following formula:

$$E_d = D(\text{nGy.hr}^{-1}) \times 8760 (\text{hr.y}^{-1}) \times 0.2 \times (0.7 \times 10^3 \text{mSv}) \times (10^9 \text{nGy})^{-1} \quad (4)$$

Equation (4) simplifies into

$$E_d = D \times 1.2264 \times 10^{-3} \quad (5)$$

where E_d is the annual effective dose rate in (mSv.y^{-1}) and D is the value of absorbed dose rate earlier calculated from equation (3). Table 7 and figure 4 present the calculated annual effective dose for the entire samples.

Table 7: Annual effective dose rates

Sample ID	^{40}K (mSv.y^{-1})	^{238}U (mSv.y^{-1})	^{232}Th (mSv.y^{-1})	TOTAL (mSv.y^{-1})
ZM.G1	0.029	0.0070	0.070	0.106
ZM.G11	0.030	0.0103	0.054	0.095
ZM.G12	0.027	0.0063	0.039	0.072
ZM.H1	0.019	0.0045	0.030	0.053
ZM.L1	0.022	0.0033	0.039	0.064
ZM.L2	0.024	0.0081	0.033	0.065
ZM.H2	0.017	0.0108	0.040	0.068
ZM.L12	0.012	0.0099	0.031	0.052
ZM.L11	0.013	0.0026	0.042	0.057
ZM.G2	0.026	0.0059	0.067	0.099
TOTAL	0.220	0.0687	0.445	0.732
MEAN	0.022	0.0069	0.045	0.073

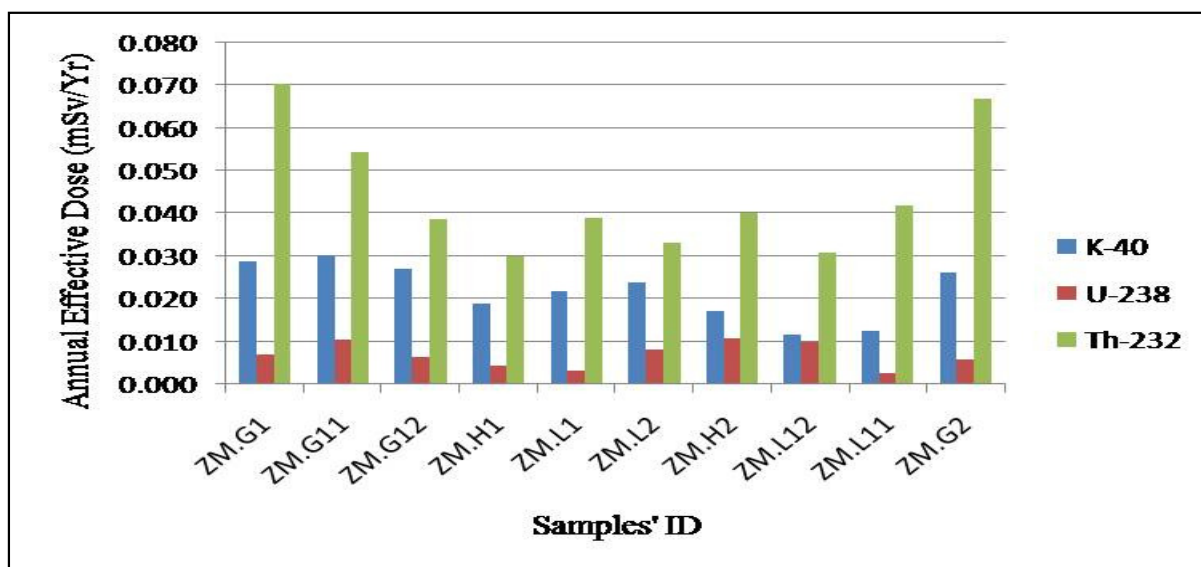


Fig. 4: Annual effective dose for each sample

RESULTS AND DISCUSSION

The highest radioactivity concentration of ^{40}K was found in soil sample ZM.G11 with $590.444 \text{ BqKg}^{-1}$ (Table 5, Fig. 1). This high value could be due to presence of abundant radioactive minerals such as smectite, kaolinite, feldspars and so on in the sample. The radioactivity concentration order was followed by soil sample ZM.G1 with $561.324 \text{ Bqkg}^{-1}$. Samples ZM.G12 and ZM.G2 also had their radioactivity concentrations of ^{40}K as $528.664 \text{ Bqkg}^{-1}$ and $512.798 \text{ Bqkg}^{-1}$ respectively. The least radioactivity concentration of ^{40}K was found in soil sample ZM.L12 with $227.095 \text{ Bqkg}^{-1}$. The highest radioactive concentration of ^{238}U was found in soil sample ZM.H2 with 18.980 Bqkg^{-1} . This high value of ^{238}U concentration could be due to high presence of uranium minerals such as uraninite, zircon, monazite and so on. The radioactivity concentrations orders of ^{238}U were followed by soil samples ZM.G11 and ZM.L12 with 18.260 Bqkg^{-1} , 17.406 Bqkg^{-1} respectively. Soil sample ZM.L11 had the lowest radioactivity concentration of ^{238}U of 4.675 Bqkg^{-1} . Also, Table 5 shows that the highest radioactive concentration of ^{232}Th is found in soil sample ZM.G1 with 94.916 Bqkg^{-1} . This could be due to presence of abundant radioactive thorium minerals such as monazite, zircon and thorianite (Okeyode *et al.*, 2009). Soil samples ZM.G2 and ZM.G11 follow the order with 90.315 Bqkg^{-1} and

73.448 Bqkg⁻¹ respectively. The smallest radioactive concentration of ²³²Th was also found in soil sample ZM.L12 with 41.698 Bqkg⁻¹.

From Table 6 and Fig. 3, it was shown that the absorbed dose rate due to the three radionuclides is highest for soil sample ZM.G1 with dose rate of 86.459 nGy.h⁻¹. This might be due to accumulation of mineral sands from different mine sites at the processing plant. The average absorbed dose rate of the soil samples is 59.696 nGy.h⁻¹. According to Table 6, ²³²Th had the highest value of total absorbed dose rate of 363.105 nGy.h⁻¹ among the three radionuclides detected in the soil samples collected, thus it had the highest dose level in the study areas while ²³⁸U had the least total at 55.998 nGy.h⁻¹.

CONCLUSION

The method of gamma spectrometry had been used to measure the radioactivity concentration of 10 soil samples collected from mine sites in Zamfara State, Nigeria. The result shows that the total concentration of ²³²Th is much higher than that of ²³⁸U by approximately a factor of 5 while ⁴⁰K leads the table of radioactivity concentrations with total value of 4265.178 BqKg⁻¹.

The average annual effective dose rate in air at the study area is 0.073 mSv.y⁻¹ which is the same with the world average outdoors exposure to external terrestrial radiation of 0.07 mSv.y⁻¹ (UNSCEAR, 2000). Thus, the exposure level for the members of general public is within the recommended value of 1 mSv.y⁻¹ (IAEA, 1999). Therefore, this is an indication that the mining activities in the study areas do not appear to have any impact on the radiation burden of the environment. However, it is recommended that proper radiation monitoring exercise be conducted on the processing site (ZM.G1) from time to time in order to checkmate the possible rise in radiation level due to accumulation of mineral sands from various mine sites.

ACKNOWLEDGEMENT

We are grateful to staff and management of Nigerian Defence Academy Kaduna, Nigeria and Centre for Energy Research and Training Zaria, Nigeria for their supports.

REFERENCES

- Ajayi, O.S. (2009): *Measurement of activity concentrations of ^{40}K , ^{226}Ra and ^{232}Th for assessment of radiation hazards from soils of the south-western region of Nigeria*, Journal of Radiation, Environment & Biophysics, vol.48, 323–332.
- Alatise, O.O., Babalola, I.A., Olowofela, J.A. (2008). *Distribution of some natural gamma emitting radionuclides in the soils of the coastal areas of Nigeria*, Journal of Environmental Radioactivity, 99(11), 1746-1749.
- CERTZ (1999): *Operation of Sodium Iodide-Thallium Gamma Spectrometry System Manual*, Centre for Energy Research and Training Manual, Ahmadu Bello University, Zaria, Nigeria.
- Faweya E. B. and Babalola A. I. (2010): *Radiological safety assessment and occurrence of heavy metals in soil from designated waste dumpsites used for building and composting in south-western Nigeria*, The Arabian Journal for Science and Engineering, Volume 35, No. 2A
- Harb S., Salahel Din K., Abbady A. and Mostafa M. (2010): *Activity concentration for surface soil samples collected from Armant, Qena, Egypt. Proceedings of the 4th Environmental Physics Conference, 10-14 March 2010, Hurghada, Egypt.*
- IAEA (1999): *Safety report on radiation protection and the management of a radioactive waste in mine, oil and gas industries*, International Atomic Energy Agency, New York.
- IAEA (2011): *Nuclear Safety Review For the Year 2010*, International Atomic Energy Agency, Publication by the IAEA in Austria.
- Ibeanu, I. G. E., Futua, I. I., Adeyemo, D. J, Bappah, A. I. and Umar, I. M. (2000): *Radiation monitoring programme for the Centre for Energy Research and Training (CERT) Nuclear research reactor site and environs*. Second technical report of the Centre for Energy Research and Training (CERT), Ahmadu Bello University, Zaria. CERT/MNSR/RMP/02.
- Jibiri N. N., Alausa S. K., Owofolaju A. E., Adeniran A. A. (2011): *Terrestrial gamma dose rates and physical-chemical properties of farm soils from ex-tin mining locations in Jos-Plateau, Nigeria*, African Journal of Environmental Science and Technology Vol. 5(12), pp. 1039-1049.

- Jonah, S.A., Okunade, I.O., Ibeanu, I.G.E., Jimba, B.W. (2002): *Natural radionuclides and elemental composition of chemical fertilizers used in Nigeria*, Journal of Nuclear Science, 4(1), 49-52.
- Muhammad A. M, Funtua I.I, Malam S.P., Abdullahi, A.S. (2010): *Distribution of gamma-emitting radionuclides in soils around the Centre for Energy Research and Training, Zaria, Nigeria*, Journal of American Science, 2010;6(12).
- Okeyode I.C., Akanni A.O. (2009): *Determination of some physical parameters of Olumo rock, Abeokuta Ogun-State, Nigeria*, Indian Journal of Science and Technology Vol.2 No 7, 0974-6846
- Olomo, J.B., (1990): *The natural radioactivity in some Nigerian foodstuffs*. Nucl. Instrum. Meth., 299:666-669
- Umar A.M., Onimisi M.Y., Jonah S.A. (2012): *Baseline measurement of natural radioactivity in soil, vegetation and water in the industrial district of the Federal Capital Territory (FCT) Abuja, Nigeria*, British Journal of Applied Science & Technology 2(3): 266-274.
- UNEP (2010): *Lead pollution and poisoning crisis*, United Nations Environment Programme, Report of environmental emergency response mission in Zamfara State, Nigeria.
- UNSCEAR (2000): *Radiological Protection Bulletin*, United Nations Scientific Committee on the Effects of Atomic Radiation No. 224, New York.