Journal of Natural Sciences Research
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.4, No.24, 2014

Gamma Ray Spectrometric Analysis of Naturally Occurring Radioactive Materials (NORMS) in Gold Bearing Soil using NaI (Tl) Technique

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Abstract
In this work, the radioactivity in the gold bearing samples collected from the artisanal mining sites in Birnin Gwari Local Government Area, Kaduna State have been determined, experimental measurements of ^{226}Ra, ^{232}Th and ^{40}K activities concentration in the gold bearing samples have been carried out using a NaI(Ti) gamma ray spectrometer. The measured activity concentration for ^{226}Ra have been found to lie in the specific ranges from 1.0545±0.4983Bq/Kg to 3.8355± 0.3476Bq/Kg while the mean concentration is 2.383±0.4415Bq/Kg for ^{232}Th, the activity concentration ranges from 9.3501±1.0260Bq/Kg to 66.7047±0.5700Bq/Kg, while the mean activity concentration of ^{232}Th is 32.3644±9.3440Bq/Kg, for ^{40}K,the activity concentration ranges from 120.9953±6.5319Bq/Kg to 815.8631±10.504Bq/Kg, while the mean activity concentration is 383.7924±72.5436Bq/Kg. The mean absorbed dose rate in the study area is 35.7334nGy/hr; while the mean annual effective dose rate is 0.032mSv/year which is lower when compared with tolerable limits of 1mSv/year.
Keywords; Natural Radionuclides,Aactivity Concentrations, Absorbed Dose.

1.0 Introduction

Naturally Occurring Radioactive Materials (NORMS) are present in several types of materials, these are materials which may contain any of the primordial radionuclides or radioactive elements as they occur in nature, such as radium, uranium, thorium, potassium, and their radioactive decay products, that are disturbed as a result of human activities. However the concentration of NORM in most natural substances is so low that the risk is generally regarded as negligible. Higher concentrations may arise as a result of human activities. In most NORM, several or all of the radioactive isotopes of the three primordial decay series (235U, 238U and 232Th) are present in small concentrations in the natural matrix.(Darko and Faanu 2007, Faanu et al 2010)

Irradiation of the human body from external sources is mainly by gamma radiation from radionuclides of the 235U, 238U and 232Th decay series and from 40K. These radionuclides may be present in the body and irradiate various organs with alpha and beta particles as well as gamma rays [Cember, 1996; UNSCEAR, 2000; IAEA; 2005].

Mineral ores in the naturally undisturbed environments, the radionuclides in the decay series are more or less in radiological equilibrium. However, this equilibrium becomes disturbed through human activities such as mining and mineral processing, resulting in either an enrichment or depletion of some of the radionuclides concentrations compared to the original matrix. This disequilibrium is as a result of differences in the properties of the radionuclides in the series, due to geochemical migration processes and differences in their half-lives [Cember, 1996; UNSCEAR, 2000; Sato and Endo, 2001]

The International Basic Safety Standards (BSS) for protection against ionizing radiation and the safety of radiation sources [IAEA, 1996] specify the basic requirements for the protection of health and the environment from ionizing radiation. These are based on the latest recommendations of the International Commission on Radiological Protection [ICRP, 2007] on the regulation of Practices and Interventions. The BSS is applied to both natural and artificial sources of radiation in the environment and the consequences on living and non-living species. The mining activities is capable of enhancing the NORMS .NaI(Tl) gamma ray spectrometry was used to determined the activity concentration of natural occurring radionuclides (^{40}K ^{232}Th and ^{226}Ra) the absorbed and annual effective doses were also determined.

2.0. Materials and Methods

2.1. Sampling locations

Six samples were collected from 6 gold pits at different depth in the study area which comprised of the following artisanal gold mining sites: Kakini, Farinruwa and Tsohowar Gwari. Global Position System (GPS) was used to determine the location of each pit and a tape rule was used to determine the depth of each pit. Table 1 shows the location, depth and elevation of each pit where samples were collected.

2.2 Sample Preparation:
The samples collected were taken to the Laboratory of Mineral Resources Engineering Department of Kaduna Polytechnic where they were crushed and sieved to tiny bits of 38 µm (Kogo *et al*., 2009 and El-Taher *et al*., 2003). The crushed samples were dried at about 100°C to a constant weight. The samples were kept in a container for 30 days and then taken to Centre for Energy Research and Training Ahmadu Bello University Zaria, Nigeria for NaI(Tl)Gamma ray Spectrometry analysis.

3. Results and Discussion
The result of the activity concentration of ^{40}K ^{226}Ra and ^{232} Th is as indicated in the table 2 below:

The annual effective dose is calculated using

H_E = D (nGy/hr) TF

where,

H_E = Annual effective dose.

D = Absorbed dose rate (10^{-9} Gy/hr).

T= Coefficient factor (0.2)

F = Conversion coefficient (0.7 Sv/Gy)

For BG2

H_E = D (nGy/hr) TF.

$$H_E = \frac{15.6456\ X 10^{-9}\ X\ 0.2\ X\ 0.7\ X\ 36\ X\ 24}{10^{-3}}$$

= 0.019mSV

The annual effective dose of the other samples as calculated above are shown in the table 4. below:

3.1. Discussion

3.1.1Potassium:K-40

The mean activity concentration of ^{40}K is 383.79±72.54Bq/Kg with the highest value of 815.86±10.50Bq/Kg in BG4 and the lowest value of 120.99±6.53Bq/Kg at BG1 as shown in fig 1.

3.1.2 Radium Ra-226

The mean activity concentration of ^{226}Ra is 2.383±0.44Bq/Kg with highest concentration of 3.856±0.34 Bq/Kg at BG1 and the lowest at BG4 with value 1.054±0.498 Bq/Kg as shown in fig :2.

3.1.3 Thorium Th-232

The mean activity concentration of ^{232}Th is 32.36±9.34Bq/Kg with highest concentration of 66.70±0.57Bq/Kg at BG6 and lowest value of 13.45±1.25 Bq/Kg at BG.3 as shown in fig :3.

The result also indicated that in all location the activity concentration of ^{40}K is higher followed by ^{232}Th while ^{226}Ra has the lowest concentration in all location as shown in fig :4

3.1.4 Absorbed and Annual Effective Doses

The mean absorbed dose rate was calculated to be 3.73nGy/hr with the highest value of 65.17 nGy/hr at BG6 and lowest value of 12.46 nGy/hr at BG 1 as shown in table :3. The mean annual effective dose was calculated to be 0.032 mSv/year with the highest value of 0.079mSv/year at BG 6 and the lowest value of 0.015mSv/year at BG.6 as shown in table:4.

4 Conclusion

The mean activity concentration of ^{40}K,^{226}Ra and ^{232}Th in the samples analysed were 383.79±72.54Bq/Kg , 2.38±0.44 Bq/Kg and 32.36±9.34Bq/Kg respectively. The result obtained in this work show that the activity concentration of ^{40}K and ^{232}Th are slightly lower than the world average value of 420 Bq/Kg and 45Bq/Kg for ^{40}K and ^{232}Th while the activity concentration of ^{226}Ra obtained in this work is by far less than 33Bq/Kg world average value for ^{226}Ra . the mean absorbed dose rate of 35.73nGy/hr calculated in this study is less than the world average value of 59nGy/hr while the mean annual effective dose 0.032mSv/year calculated in this work is also lower than 1mSv/year tolerable limit recommended by ICRP. This therefore suggested that the level of exposure to radiation in the study area is within the tolerable limit .

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Table 1: Sampling Locations

	SAMPLE CODE	DEPTH	LOCATION N	LOCATION E	ELEVATION
KAKINI	BG1	2.70M	$11^{0}.10^{''}$ 25'	06^{0} $58^{''}$ 0'	663M
F/RUWA	BG2	7.00M	11^{0} $04^{''}$ 14'	06^{0} $47^{''}$ 34'	595M
TSBG KANO	BG3	19.00M	10^{0} $59^{''}$ 45'	06^{0} $48^{''}$ 27'	560M
TSBG JINEER	BG4	28.00M	11^{0} $00^{''}$ 43'	06^{0} $48^{''}$ 28'	547M
TS.BG KASTINA	BG5	24.00M	11^{0} $01^{''}$ 14'	06^{0} $48^{''}$ 20'	550M
TS.BG ABUJA	BG6	10.20M	10^{0} $59^{''}$ 19'	06^{0} $48^{''}$ 31'	558M

Table 2. Activity concentration of ^{40}K, ^{226} Ra and ^{232} Th (Bq/kg)

S/No	Sample Code	^{40}K (Bq/kg)	^{226}Ra	^{232}Th
1.	BG1	120.9953±6.5319	3.8355±0.3476	17.6739±1.0260
2.	BG2	226.283, ±3.7325	1.2167±0.1391	9.3501±1.3680
3.	BG3	376.9828±9.978	3.1286±0.3592	13.4549±1.2540
4.	BG4	815.8631±10.504	1.0545±0.4983	50.1710±1.02562
5.	BG5	492.8460±6.0653	2.6188±0.2202	36.0319±1.5960
6.	BG6	569.8289±8.3791	2.4218±0.2433	66.7047±0.5700
Mean		383.7924±72.5436	2.383±0.4415	32.3644±9.3440

Table 3. Absorbed dose rate (10^{-9}Gy/hr

S/NO	Sample Code	Absorbed dose rate (10^{-9}Gy/hr due to ^{40}K, ^{226}Ra, ^{232}Th).
1.	BG1	12.46
2.	BG2	15.64
3.	BG3	25.29
4.	BG4	52.30
5.	BG5	43.52
6.	BG6	65.17
	Mean	**35.7334**

Table 4. Annual Effective Dose in mSv/year

Location	Annual Effective Dose mSv/year (^{40}K, ^{226}Ra, ^{232}Th)
BG1	0.015
BG2	0.019
BG3	0.031
BG4	0.064
BG5	0.053
BG6	0.079
Mean	**0.032**

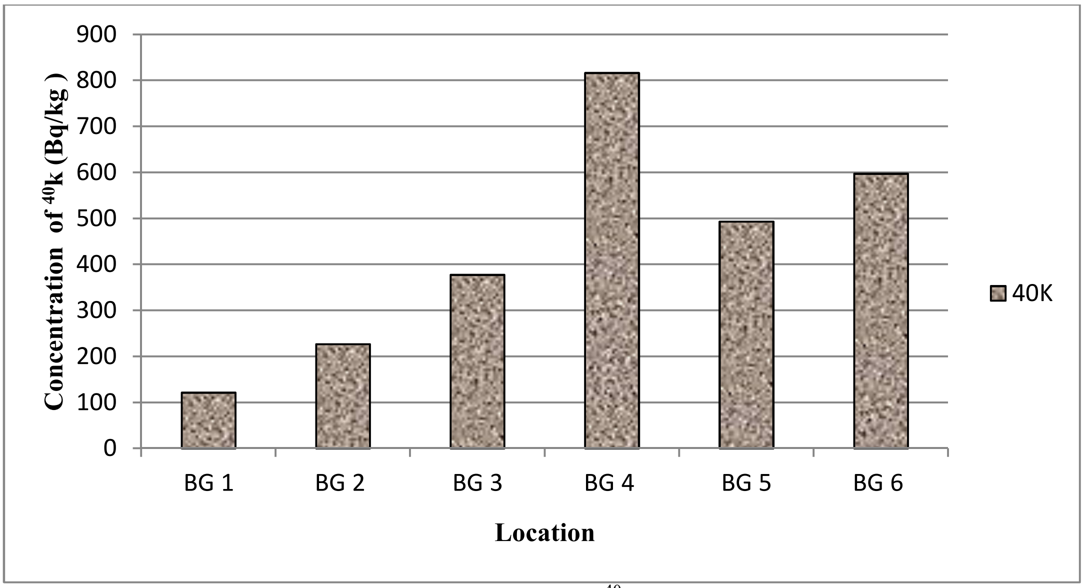

Fig. 1: Plot of concentration of ^{40}K against location.

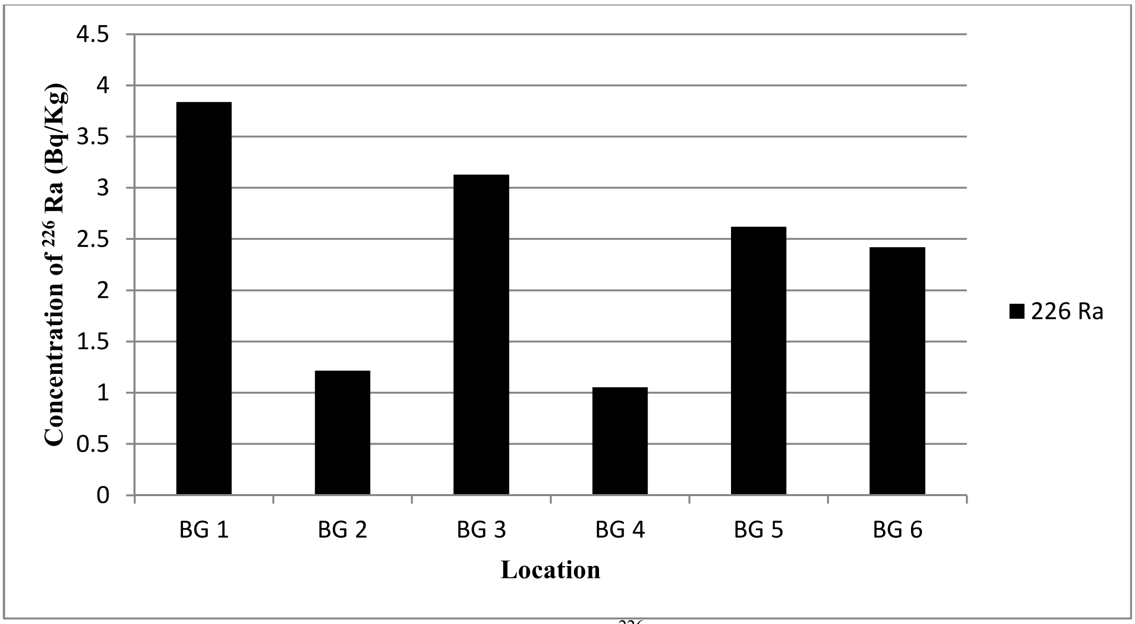

Fig.2: Plot of concentration of ^{226}Ra against location

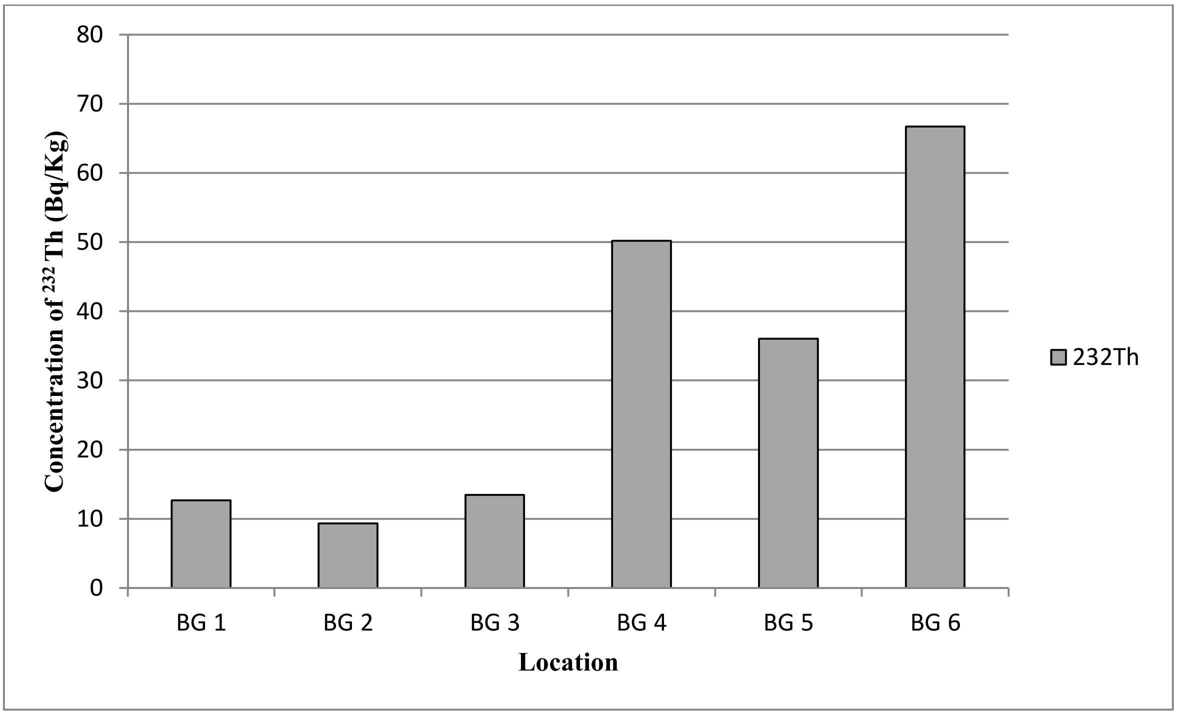

Fig. 3: Plot of Concentration of ^{232}Th against location

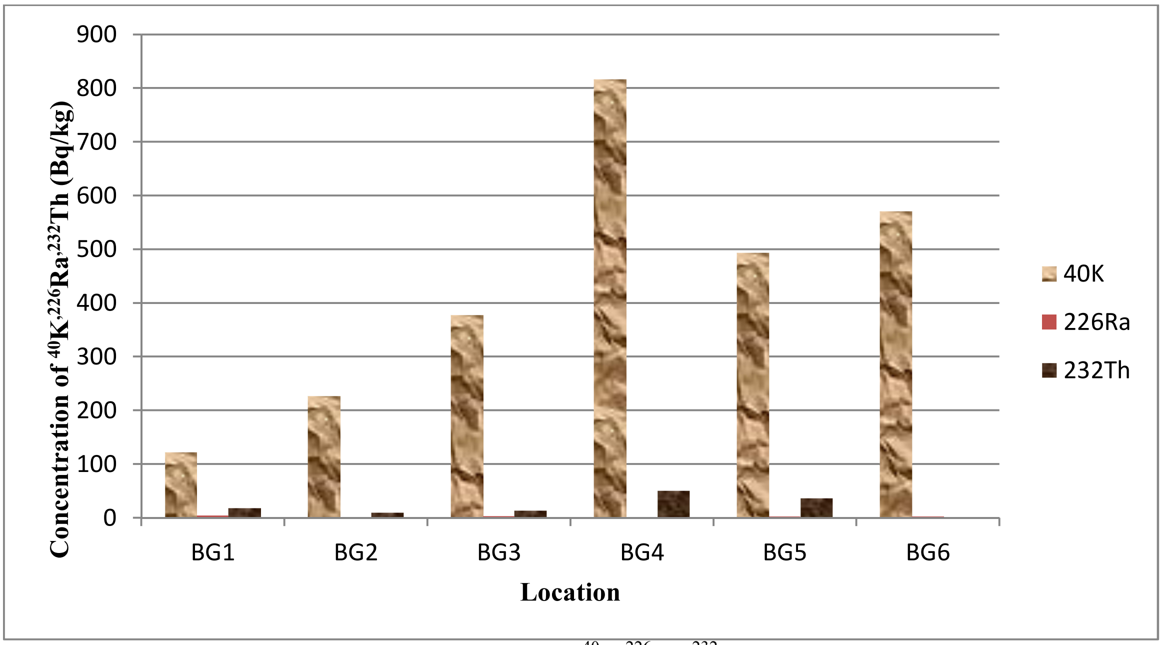

Fig: 4: Plot of Concentration of ^{40}K, ^{226}Ra, ^{232}Th against location