Research Journal of Applied Sciences, Engineering and Technology 6(17): 3255-3258, 2013
DOI:10.19026/rjaset.6.3631
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: January 16, 2013 Accepted: February 18, 2013 Published: September 20, 2013

Research Article

Distribution of Gamma Emitting Radionuclides in Gold Ore Mine From Birnin Gwari Artisanal Goldmine Kaduna State Nigeria

[1]R. Nasiru, [1]I.Y. Zakari and [2]M.A. Abdullahi
[1]Department of Physics Ahmadu Bello University, Zaria, Nigeria
[2]Department of Applied Science, College of Science and Technology, Kaduna Polytechnic, Kaduna, Nigeria

Abstract: The activity concentrations of naturally occurring radionuclides (^{238}U, ^{232}Th and ^{40}K) were investigated in gold ore mined from Birnin Gwari Artisanal Goldmine in Kaduna state Nigeria using Instrumental Neutron Activation Analysis (INAA) technique. Twelve samples were collected from pits at different depths and the locations of pits were marked out using Global Positioning System (GPS). The measured activity concentration due to ^{238}U range from 6.18±3.7 to 66.69±4.9 Bq/Kg with mean value 37.36±5.45, Bq/Kg ^{232}Th range from 16.65±0.8 to 87.29±1.2 Bq/Kg with mean value of 62.69±6.33 and ^{40}K range from 85.13±4.5 to 1564.69±57.9Bq/Kg with a mean value of 997.52±11 9.97 Bq/Kg. The value compared well with published data from other countries and all values from this study are higher than the world average values and other countries with the exception of ^{232}Th concentration from India and Malaysia that are slightly higher than the mean value of ^{232}Th obtained in this study.

Keywords: Activity concentrations, neutron activation analysis, radionuclides

INTRODUCTION

Mining is a global industry known for its economic benefits of wealth creation and employment. In Africa, commercial scale mining provides important benefits in term of exports/foreign exchange earnings and tax receipts to nineteen African countries (Hayumbu and Mulenga, 2004).

The above mentioned socio- economic benefits of the mining industry not withstanding in developing countries, the industry is likely to be associated with three potential negative effects. The first one is the socio-economic dislocation an ill-prepared mining community goes through at mine closure, which arise from exploitation of a non-generative resource ((Hayumbu and Mulenga, 2004). The second and third undesirable aspects arise when non-optimal management of mining operation results in environmental degradation and/or negative health impacts on miners and mining commities. Principal health problems among miners and communities from various countries that have been cited by the literature include respiratory disease, neoplasm/cancer, chronic hypertension, mental health and genetic impact (WHO, 1999). The major cause of these diseases can be attributed to the heavy metal contamination and naturally occurring radioactive materials (ICRP, 1994).

The International Basic Safety Standard (BSS) for protection against ionizing radiation and the safety of radiation sources (IAEA, 1996) specify the basic requirement for the protection of health and the environmental from ionizing radiation. These are based on the latest recommendation of the International Commision on Radiological Protection on the regulation of Practices and interventions (ICRP, 2007). The BSS is applied to both natural and artificial sources of radiation in the environment and the consequences on living and non-living species.

Irradiation of the human body from external sources is mainly by gamma radiation from radionuclides of the ^{235}U and ^{232}Th decay series and from ^{40}K. 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 and 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 has been identified as one of the potential sources of exposure to NORM (UNSCEAR, 2000).

In many developing countries including Nigeria, mining activities have not been subjected to radiological regulatory control. Data on radionuclide concentrations in raw materials, residues and waste streams and data on public exposure are scanty (Darko *et al.*, 2005; Darko and Faanu, 2007). Consequently,

Corresponding Author: M.A. Abdullahi, Department of Applied Science, College of Science and Technology, Kaduna Polytechnic, Kaduna, Nigeria

Table 1: Sample locations

PLACE	Sample code	Depth	Location N	Location E	Elevation
KAKINI	BG1	2.70M	11°10" 25'	06°58" 0'	663M
	BG2	4.30M	11°10" 23'	06°59" 15'	685M
F/RUWA	BG3	7.00M	11°04" 14'	06°47" 34'	595M
	BG4	7.50M	11°04" 16'	06°47" 33	594M
TSBG KANO	BG5	19.00M	10°59" 45'	06°48" 27'	560M
	BG6	43.00M	10°59" 37'	06°48" 25'	562M
TSBG JINEER	BG7	28.00M	11°00" 43'	06°48" 28'	547M
	BG8	26.00M	11°00" 37	06°48" 23'	542M
TS.BG KASTINA	BG9	24.00M	11°01" 14'	06°48" 20'	550M
	BG10	28.00M	11°01" 10'	06°48" 21'	546M
TS.BG ABUJA	BG11	10.20M	10°59" 19'	06°48" 31'	558M
	BG12	8.50M	10°59" 17'	06°48" 32'	559M

there is general lack of awareness and knowledge of the radiological hazards and exposure levels by legislators, regulators and operators.

The aim of this study is to determine the activity concentrations of Naturally Occurring Radioactive Materials (NORM) at the mining locations in Birnin Gwari Local Government Area of Kaduna State, Nigeria.

MATERIALS AND METHODS

Twelve samples were collected from 12 gold pits at different depth between (2.5m -43.0m) 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.

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 a tiny bits of 38 µm (Kogo *et al*., 2009). The crushed samples were then dried at about 100ºC to a constant weight. The samples were then taken to Centre for Energy Research and Training Ahmadu Bello University Zaria Nigeria for Neutron Activation Analysis. 0.1 50 g-0.1 80 g of the powdered samples were wrapped in a polyethylene then placed in 7cm^3. Rabbit capsules. The polyethylene and rabbit capsules containing the samples are cleaned by soaking in 1:1 $HN0_3$ (Nitric acid) and then washed with de-ionised water in order to eliminate every contamination prior to sample irradiation (El-Taher *et al*., 2003).

Sample analysis: The concentrations of elements of interest from the collected and prepared samples were investigated using Neutron Activation Analysis technique (NAA) with the Nigeria Research Reactor 1 (NRR1) No NRR1/DS/JC/09/16. At the Centre for Energy Research and Training, Ahmadu Bello University Zaria Nigeria.

Table 2: Concentration of U and Th in PPm and K in %

S/N	Sample code	U (ppm)	Th (ppm)	K%
1	BG 1	1.0 ±0.3	7.1±0.2	0.272±0.0144
2	BG 2	0.5±0.3	4.1±0.2	1.056±0898
3	BG 3	4.3±0.5	9.9±0.2	4.999±0.1849
4	BG 4	5.4±0.4	15.8±0.2	4.162±0.2081
5	BG 5	2.7±0.5	16. 9±0.2	4.454±0.1204
6	BG 6	5.1±0.5	16.3±0.2	3.184±0.1204
7.	BG 7	2.4±0.2	18.6±0.3	3.128±0.0313
8	BG 8	2.9±0.3	17.5±0.3	3.092±0.0340
9	BG 9	2.3±0.3	18.9±0.2	3.762±0.0564
10	BG 10	4.5±0.3	18.5±0.2	3.540±0.0566
11	BG 11	2.6±0.3	21.5±0.3	3.209±0.0546
12	BG 12	2.9±0.3	18.5±0.3	3.399±0.0646

Table 3: Specific activity of ^{238}U, ^{232}Th and ^{40}K in Bq/kg

S/N	Sample code	^{238}U (Bq/kg)	^{232}Th (Bq/kg)	^{40}K(Bq/kg)
1	BG 1	12.35±3.7	28.83±0.8	85.13±4.5
2	BG 2	6.18±3.7	16.65±0.8	330.53±28.1
3	BG 3	53.11±6.2	40.19±0.8	1564.69±57.9
4	BG 4	66.69±4.9	64.15±0.8	1302.71±65.1
5	BG 5	33.35±6.2	68.61±0.8	1394.10±37.7
6	BG 6	62.99±2.5	67.52±1.2	996±13.79
7.	BG 7	29.64±2.5	75.52±1.2	976.06±9.8
8	BG 8	35. 82±3.7	71.05 ±0.8	967.80±10.6
9	BG 9	28.41±3.7	76.73±0.8	1177.51±17.7
10	BG 10	55.58±3.7	75.11±0.8	1108.02±17.7
11	BG 11	32.11±3.7	87.29±1.2	1004.42±17.1
12	BG 12	35.82±3.7	75.11±1.2	1063.89±20.2
	Mean	37.36±5.45	62.69±6.33	997.57±199.97
	Standard daviation	18.9	21.94	415.59

RESULTS

The results of the neutron activation analysis showing the concentrations of elements of interest U, Th and K present in each sample are shown in Table 2.

Concentration of U, Tb and % k: The mean concentrations of U in the samples is 3.05±0.35 ppm mean values of range between 0.5-5.1 ppm, for Th the mean concentration is 15.30±0.23 ppm in range between 4.1-21.5 ppm while the mean % of K is 3.19±0.09% in range between 0.27 to 4.99%. the average crustal abundances of these elements quoted in the literature are in the range 2- 3 ppm U, 8-l2 ppm Th and 2-2.5% K (IAEA, 2003). This shows that the mean values obtained in this study are slightly higher than the crustal average quoted above.

Table 4: Comparison of activity concentration of $^{238:}$U; $^{232:}$ Thand; $^{40:}$ K in soils in the study area and published data (UNSCEAR, 2000; Muhammad *et al*., 2010; Faanu *et al*., 2010; Darko *et al*., 2005)

	Concentration in Soil Bq/Kg					
	^{238}U		^{232}Th		^{40}K	
	Range	Mean	Range	Mean	Range	Mean
This work	6.18-66.69	37.36	16.65-87.29	62.69	85-87	997.57
Nigeria (zaria)*	4-12	8	15-47	34	317-985	641
Ghana (1)+	8-26	15	9-67	27	60-249	157
Ghana (2)++		29		25		582
Ghana (3)++		35		21		682
Algeria-	2-10	30	2-140	25	66-1150	370
Egypt-	6-120	37	2-96	18	29-650	320
U.S.A-	4-140	35	4-130	35	100-700	370
India-	7-81	29	14-160	64	38-760	400
Malaysia-	49-86	66	63-110	82	170-430	310
Lithaunia-	3-30	20	9-46	25	350-850	600
UK-	2-330		1-180		0-3200	
Hungary-	12-66	29	12-45	28	79-570	370
Spain-			2-210	33	25-1650	470
Word Average		33		45		420

Legend-UNSCEAR 2000 Report, ++ Darko *et al*., 2010; +Faanu *et al*., 2010; *: Muhammad *et al*., 2010

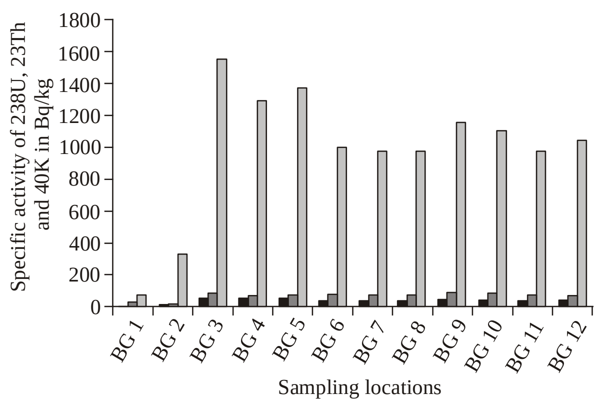

Fig. 1: Mean plot for specific activity of 238U, 232Th and 40K per location

Specific activity: The results obtained from the neutron activation analysis were the concentrations of elements present in each sample and were given in Part Per Million (PPM). Conversion factor of radioelement concentration to specific activity (IAEA, 2003) was used to convert the concentration in ppm of U and Th to activity in Bq/Kg of ^{238}U, ^{232}Th and K% to ^{40}K as shown in Table 3.

Descriptive statistics and one-way analysis of variance (ANOVA) at the 5% level significance was employed and the result is presented in Table 1. the Result have shown that ^{238}U has a mean concentration of 37.36 Bq/Kg with a standard deviation of 18.89 Bq/Kg across the mining sites. The standard error of the mean is 5.45

Bq/Kg; which implies that the maximum sampling error in the results cannot exceed 5.45 Bq/Kg. The 95% confidence interval for the mean concentration of ^{238}U lies between 6.18±3.7 and 66.69±4.9 Bq/Kg. In other words, there is 95% assurance that the mean concentration of ^{238}U in any mining site within the study area will lie between (0.18±3.7 and 66.69±4.9 Bq/Kg).

Similarly, ^{232}Th has a mean concentration of 62. 69 Bq/Kg with a standard deviation of 21 .94 Bq/Kg across the mining sites. The standard error of the mean is 6.33 Bq/Kg; which implies that the maximum sampling error in the results for Thorium cannot exceed 6.33 Bq!Kg. The 95% confidence interval for the mean concentration of ^{232}Th lies between the limits (16.65±0.8 and 87.69±1.2) Bq/Kg.

Furthermore, ^{40}K has a mean concentration of 997.57 Bq/Kg with a standard deviation of 415.59 BqJKg; and standard error I 19.97 Bq/Kg. Meaning that the maximum sampling error in the results for ^{40}K cannot exceed 11 9.97 Bq/Kg. Moreover, the 95% confidence interval for the mean concentration of ^{40}K lies between 85.13 and I 564.69 Bq/Kg. In other words, there is 95% assurance that the mean concentration of 40K in any mining site within the study area will lie between the limits (85.13 and 1564.69)Bq/Kg.

The average concentrations of ^{238}U, ^{232}Th and ^{40}K in the mining sites within the study area are not equal. Further results reveal that ^{238}U is the least available radionuclide in the mining sites followed by ^{232}Th which is more prevalent than ^{238}U. While ^{40}K is by far the most abundant radionuclide in the study area as shown in Fig. 1.

Activity concentrations: The mean value of the activity concentrations of ^{238}U is 37.36±5.45 Bq/Kg in range of 6J8-66.69 Bq/Kg, for ^{232}Th the mean activity concentration is 62.69±6.33 Bq/Kg in range of 16.65-87.29 Bq/Kg and that of 40K is 997.57±119.97 Bq/Kg in a range of 85.13- 156469 Bq/Kg. The highest value (66.69 Bq/Kg) for 238u was measured in soil sample taken from Tsohon Gwari, Kano (BG, 4), that of ^{232}Th (87.29 Bg!Kg) was taken from Tsohon Gwari Abuja (BG. 11) while that of ^{40}K (1564 Bq/Kg) was taken from farin ruwa (BG.3).

The mean values of activity concentrations of ^{238}U, ^{232}Th and ^{40}K are all more than the world average values on normal areas (UNSCEAR, 2000). The world wide average activity concentrations of ^{238}U, ^{232}Th and ^{40}K in soil samples have values of 33.45 and 420 Bq/Kg respectively (UNSCEAR, 2000).

Table 4 is a comparison of the mean activity concentration of ^{238}U, ^{232}Th and ^{40}K in soil in the study area with similar studies done in Nigeria (Zaria) and with published reports from other countries (Muhammad *et al*., 2010; UNSCEAR, 2000; Darko *et al*., 2005; Faanu *et al*., 2010). The values compared well with published data from other countries and all values from this study were higher than the world average values and other countries with the exception of the activity concentration of ^{232}Th in India and Malaysia that are slightly higher than the mean value of ^{232}Th obtained in this study.

CONCLUSION

In this study, data on the activity concentrations of ^{238}U, ^{232}Th and ^{40}K in soil/rocks samples in the study area have been established. The activity concentration of ^{238}U, ^{232}Th and ^{40}K in soils/rocks is one of the potential pathways where members of the public, animal and farm produce could be exposed were quantified using instrumental neutron activation analysis.

The mean activity concentrations of ^{238}U, ^{232}Th and ^{40}K in the soil/rock samples were estimated to be 37.36, 62.69 and 997.57Bq/Kg, respectively. The result in this study is slightly higher when compared with other studies carried out in other countries and the world wide average activity concentrations (UNSCEAR, 2000).

Though the results in this study indicate higher levels of the natural radionuclide than worldwide average and the results from other countries, the mining activities in the study area do not pose significant radiological hazard to the communities in the area.

REFERENCES

Cember, H., 1996. Introduction to Health Physics. 3rd Edn., McGraw Hill, New York.

Darko, E.O. and A. Faanu, 2007. Baseline radioactivity measurement in the vicinity of a gold treatment plants. J. Appl. Sci. Tech., 10(1, 2): 45-51.

Darko, E.O., G.K. Tettea and E.H.K. Akaho, 2005. Occupational radiation exposure to NORMS in gold mine. J. Radiat. Prot. Dosimetry, 114(4): 538-45.

Darko, E.O., A. Faanu, A. Razak, G. Emi-Reynolds, J. Yeboah, O.C. Oppon and E.H.K. Akaho, 2010. Public exposure hazards associated with natural radioactivity in open-pit mining in Ghana. Rad. Prot. Dosim., Vol. 138.

El-Taher, A., K.L. Kratz, A. Nossair and A.H. Azam, 2003. Determination of gold in two Egyptian gold ores using instrumental neutron activation analysis. Radiat. Phys. Chem., 68: 751-755.

Faanu, A., E.O. Darko and J.H. Ephraim, 2010. Assessment of public exposure to naturally occurring radioactive materials from mining and processing activities of Tarkwa gold mine in Ghana. J. Environ. Monit. Assess, 180: 15-29.

Hayumbu, P. and S. Mulenga, 2004. Status of radon dosemetry in Zambia underground mine. Proceedings of the IAEA International Conference (NORM iv) S2OZyrk, Poland.

IAEA, 1996. International Basic Safety Standard for protection against lonising radiation and for the safety of radiation sources. Safety Series No. 115, IAEA, Vienna.

IAEA, 2003. Guidelines for radioelement mapping using gamma-ray spectrometry data. IAEA-TECDOC-1363, IAEA, Vienna, Austria.

IAEA, 2005. Naturally occurring radioactive materials (IV). Proceedings of the International Conference held in Szczyrk, IAEA-TECDOC-1472, Poland.

ICRP, 1994. Protection against Radon-222 at Home and at Work Publication 65. Ann. ICRP23, 2 Pergamon Press, Oxford and New York.

ICRP, 2007. The 2006 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103, Pergamon Press, Oxford.

Kogo, B.E., E.N. Gajere, J.K. Ogunmola and J.O. Ogbole, 2009. Neutron activation analysis of soil samples from different parts of Abuja metropolis. Middle-East J. Sci. Res., 4(4): 254-262.

Muhammad, A.M., I.F. Isa, S.P. Mallam and S.A. Arabi, 2010. Distribution of gamma emitting radionuclides in soils around the Centre for Energy Research and Training (CERT) Ahmadu Bello University Zaria, Nigeria. J. Am. Sci., 10(12).

UNSCEAR, 2000. Exposures from natural sources. Report to General Assembly, Annex B, New York.

WHO, 1999. Hazard prevention and control in the work environment. Air borne dust WHO/SDE/OEHJ1 99.14, Geneva.