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Research Article

Determination of Absorbed and Annual Effective Doses around Birnin Gwari Artisanal Goldmine, Kaduna State, Nigeria

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Abstract: This study presents result of outdoor absorbed dose rate and estimated annual effective dose rate from the naturally occurring radionuclides ^{238}U, ^{232}Th and ^{40}K around BirninGwari artisanal goldmine using Instrumental Neutron Activation Analysis (INAA). The results showed that the mean absorbed dose rate is 96.52 nGy/h with a standard deviation of 33.3 nGy/h and the standard error of 9.62 nGy/h the range falls between 26.67-123.85 nGy/h. The mean effective dose rate was estimated to be 0.675 mSv/year with a standard deviation of 0.234 mSv and standard error of 0.068 mSv and in range between 0.183-0.867 mSv. The mean annual effective dose rate from this work is lower than the 1mSv/year recommended by ICRP for public radiation exposure control.

Keywords: Absorbed dose rate, effective dose rate, 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 receipt 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-regenerative resources (Hayumbu and Mulenga, 2004). The second and third undesirable aspects arise when non-optimal management of mining operations results in environmental degradation and/or negative health impacts on miners and mining communities. Principal health problems among miners and mining 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 Standards (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 environment from ionizing radiation. These are based on the latest recommendations of the International Commission 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, there is general lack of awareness and knowledge of the radiological hazards and exposure levels by legislators, regulators and operators.

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The aim of this study is to determine the absorbed dose rate and annual effective dose level 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 of 2.5 m to 43.0 m 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 tiny bits of 38 µm (Kogo *et al*., 2009). The crushed samples were dried at about 100°C 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. Between 0.150g -0.180g of the powdered samples were wrapped in a polyethylene then placed in 7 cm^3. Rabbit capsules. The polyethylene and rabbit capsules containing the samples were cleaned by soaking in 1:1 HNO_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 concentration 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.

RESULTS

Absorbed dose rate: The gamma dose rates from the samples were calculated from the activity concentrations of the relevant radionuclides from Table 2 using Eq.(1) below:

$$D(nGy/h) = 0.0417A_k+0.462\ A_u+0.604/A_{th}^{-1} \qquad (1)$$

where, A_k, A_u and A_{Th} are the activity concentrations of ^{40}K, ^{238}U and ^{232}Th respectively and Table 3 shows the dose conversion factors of ^{40}K, ^{238}U and ^{232}th (UNSCEAR, 2000)

The result from Table 3 shows that the mean absorbed dose rate in the study area is 96.52 nGy/h witha standard deviation of 33.31 nGy/h and the standard error of the mean is 9.62 nGy/h, meaning that

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	BG9	24.00M	11° 01" 14'	06° 48" 20'	550M
KASTINA	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

Table 2: 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	62.99±6.2	66.18±0.8	1394.10±37.7
6	BG 6	29.64±2.5	75.52±1.2	996.59±37.9
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	37.37±5.45	62.69±6.33	997.57±119.97
	Standard deviation	18.9	21.94	415.59

Table 3: Percentage contribution to absorbed dose rate due to ^{238}U, ^{232}Th and ^{40}K

S/N	Sample code	Absorbed Dose in nGy/h	^{238}U%	^{232}Th%	^{40}K%
1	BG 1	26.67	21.39	65.29	13.31
2	BG 2	26.69	10.69	37.68	51.64
3	BG 3	114.03	21.52	21.29	57.22
4	BG 4	123.85	24.88	31.29	43.84
5	BG 5	114.98	13.40	36.04	50.56
6	BG 6	110.63	26.31	36.13	37.56
7	BG 7	100.04	13.69	45.60	40.69
8	BG 8	99.82	16.58	42.99	40.40
9	BG 9	108.57	12.09	42.69	45.23
10	BG 10	117.25	21.90	38.69	39.41
11	BG 11	109.44	13.55	48.18	38.27
12	BG 12	106.24	15.58	42.70	41.76
	Mean	96.52			
	Std. Dev.	33.33			
	Std. Err	9.62			

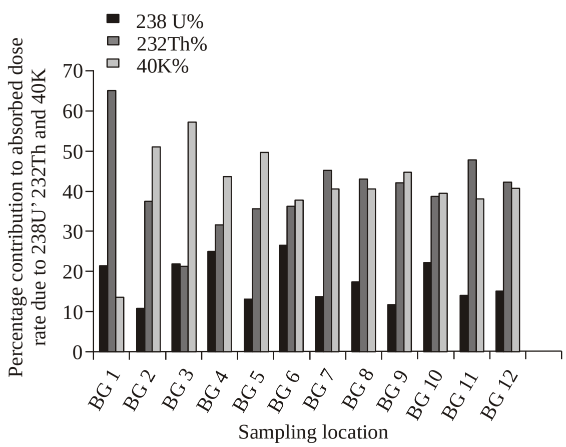

Fig. 1: Plot of % contribution due to ^{238}U, ^{232}Th and ^{40}K by location

the maximum sampling error in the results cannot exceed 9.62 nGy/h. The 95% Confidence interval for the mean dose rate in the study area lies between 26.67-123.85 nGy/h. In other words, there is 95% assurance that the mean dose rate in the study area lies between the limits (26.67-123.85) nGy/h as indicated in Table 3.

The percentage contributions to absorbed dose rate due to ^{238}U, ^{232}Th and ^{40}K are shown in Fig. 1

Annual effective dose rate: The annual effective dose rate measured in mS_v was calculated from the absorbed dose rate and is presented in Table 4.

The result from Table 4 showed that the mean effective dose rate is 0.685 mS_v with a standard deviation of 0.234 mS_v and the standard error of the mean is 0.068 mS_v meaning that the maximum sampling error in the result from the study area cannot exceed 0.068 msv. The 95% confidence interval for the mean annual effective dose rate in the study area falls between 0.1832-0.867 mS_v. This shows that there is 95% assurance that the mean annual effective dose in the study area lies between the limits (0.1832-0.867) mSv.

Table 4 Annual effective dose rate in (mS_v)

S/N	Sample code	Annual effective dose rate In (mS_V)
1	BG 1	0.183
2	BG 2	0.186
3	BG 3	0.798
4	BG 4	0.867
5	BG 5	0.805
6	BG 6	0.774
7	BG 7	0.700
8	BG 8	0.699
9	BG 9	0.759
10	BG 10	0.821
11	BG 11	0.766
12	BG 12	0.744
	Mean	0.675
	Std. Dev.	0.234
	Std. Err	0.068

The mean absorbed dose rate calculated from soil activity concentration was 96.52±9.62 nGy/h in a range of 26.67-123.85 nGy/h which is about $1\frac{1}{2}$ times the world wide average value of 60 nGy/h (UNSCEAR 2000), about 3 times the value of 29.9 obtained in Ghana (Faanu *et al.*, 2010) and about twice the value of 46.2 nGy/h obtained in Nigeria (Zaria) (Muhammad *et al.*, 2010). The difference could be attributed to the Fact that the samples collected in this study were from a mean depth of 17.35 m in the range between 2.5-43 m below the surface and also the geology and geochemical composition of the sampling site.

The mean percentage contribution of ^{238}U, ^{232}Th and $^{40}K$to the mean absorbed dose rate are 17.63% for ^{238}U, 40.71% for ^{232}Th and 41.66% for ^{40}K. The values show that ^{40}K contribution to the absorbed dose rate is more followed by ^{232}Th while the contribution of ^{238}U is lowest. Though the study area is K-Feldspar (MMDS, 2010) the % contributions of ^{232}Th compared favourably with that of ^{40}K.

The corresponding mean annual effective dose rate in this study is 0.675±0.068 mSv in the range of 0.183-0.867 mSv. In the determination of these values a dose conversion factor of 0.7 Sv/Gy an outdoor and indoor occupancy factor of 0.2 and 0.8 respectively were applied (UNSCEAR, 2000). The results from this study show that the annual effective dose rate is about $1\frac{1}{2}$ times the world average value of 0.41 mSv/year (UNSCEAR, 2000).

CONCLUSION

The ICRP philosophy of radiological protection aims at preventing the effect of radiation is achieved by a system of protection that requires justification of practice to ensure it produces a net benefit, optimization of protection to keep exposure as low as reasonable achievable (ALARA) and the protection of individuals by imposing either dose limits or control on the risk from potential exposure. In this study the potential exposure to the population in the study area was assessed by estimating the absorbed dose and annual effective dose in soil/rocks. The mean absorbed dose rate and the mean effective dose rate were estimated to be 96.52 nGy/h and 0.675 mS_v/year respectively. The mean annual effectively dose is lower than the 1 mS_v/year dose limit recommended by ICRP for public radiation exposure control.

Though the results in this work indicated higher levels of the absorbed and annual effective doses 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.

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