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An evaluation of the equivalent dose due to natural radioactivity in the soil around the consolidated Tin mine in Baukuru-Jos, plateau state of Nigeria

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Background: The equivalent dose in the human body due to the natural gamma-emitting radionucides (^{238}U, ^{232}Th and ^{40}K) in the surface soil surrounding the Consolidated Tin mine site in Bukuru-Jos, Nigeria has been determined in this study. ***Materials and Methods:*** Measurements of the soil natural radioactivity were made using a multi-channel pulse-height analyzer (Canberra Series 10 plus) coupled to a 76 mm×76 mm NaI (Tl) scintillation detector. ***Results:*** The mean concentrations obtained for each of the radionuclides is 35.4±17.6 Bq/kg for ^{40}K; 776.0± 158.0 Bq/kg for ^{238}U and 2.72±0.58 kBq/kg for ^{232}Th. The mean absorbed dose rate due to natural radioactivity calculated at a height of 1.0 m above the ground is 2.16 µGy/hr which converts to an equivalent dose of 3.0 mSv/y. ***Conclusion:*** The results obtained in this study are far above the world average equivalent dose of 0.41 mSv/y but lower than the annual limit of 20 mSv/y for radiation workers but still represents a health risk to workers on the site. **Iran. J. Radiat. Res., 2008; 5 (4): 203-206**

Keywords: *Equivalent dose, natural radioactivity, gamma-ray, scintillation detector, soil, absorbed dose.*

INTRODUCTION

Natural radioactivity occurs when a nucleus decays spontaneously without external interference. The greatest contribution to the average public radiation exposure comes from radioactive elements in the earth's crust and from cosmic radiation originating in deep space. Natural sources contribute on average more than 98% of the human radiation dose excluding medical exposures [1]. The global average dose from natural sources is estimated to be a bout 2.4 mSv/y [2]. Exposure is both external, from direct cosmic and terrestrial radiation and internal from inhalation and ingestion of terrestrial and cosmogenic radionuclides found in air water food and soil.

Terrestrial radiations results from radionuclide sources found in the earth's crust occurring in the different types of rocks and soils. The commonest of these primordial radionuclides are ^{40}K, ^{238}U and ^{232}Th and their progenies [3]. The concentrations and hence the activities of these radionuclides in any given environment depend on such factors as the geological features of the area, weather conditions, human economic and technological activities etc [4]. Several of the elements in the decay of uranium and thorium emit beta and gamma rays, the radiation of which also form a significant portion of the external radiation field on the earth's surface [5].

The interaction of ionizing radiation with the human body leads to various biological effects which may later show up as clinical symptoms [6]. The nature and severity of the symptoms depend on the absorbed dose as well as the dose rate and many sicknesses and diseases which should have been effectively managed if information about the radiation level of an environment is available are being attributed to other sources. The knowledge of the natural radioactivity concentration of our environment is essential

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in the assessment of the dose accruing to the populace and also in forming the basis for the assessment of the degree of radioactive contamination or pollution in the environment in the future.

The Jos area of Nigeria is located on a granite plateau about 1400 m above sea level in the North Central part of the country (figure 1). The main geological formation of this area lends itself to the mining and milling of Tin. The lithological formations in the area are composed of basement complex, biotite granite and new basalts [7]. Tin and Columbite ore are associated with greisenized, Biotite granites. The Jos Tin industry started around 1904, the primary purpose of the industry is to mine Tin ore and mill the same for Tin and some by-products (especially Columbite) for exportation.

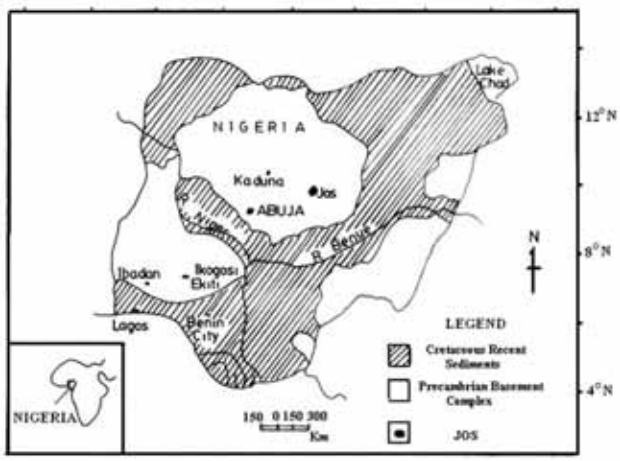

Figure 1. Map of Nigeria showing the study area, Jos.

The objective of this study was to determine the gamma activities due to the presence of the natural radionuclide (^{40}K, ^{232}Th and ^{238}U) in the soil in the vicinity of the Consolidated Tin Mine. This is in order to determine the possible dose impact of the mining operations on the miners and other members of the public in the area. For the purpose of the study, 20 locations were selected randomly around the mining site from where the soil samples were collected. Gamma-ray spectroscopy was used to determine the gamma-ray activities of the natural radionuclides [4].

MATERIALS AND METHODS

A total of 20 surface soil samples of natural origin were collected from the 20 different locations at the same depth level of 0 to 6 cm around the 20 km^2 Tin Mine site. The samples were collected on every square kilometer. Samples were obtained by clearing the surface vegetation and removing dead organic matter from the surface of the location, and then taking a core sample from it from a depth of 6 cm [8]. Sample size varied from 1.0 to 1.5 kg.

At a collection point the soil sample was wrapped in black plastic bag and then taken to the laboratory. All soil samples were individually allowed to dry for 72 hours under laboratory temperature of about 27°C and relative humidity of about 70% [8]. Each dried soil samples was ground and sieved using a 2 mm mesh screen. The larger particles were disposed of and the meshed soil sample were stored in plastic containers for four weeks to allow time for secular equilibrium between ^{238}U and ^{232}Th and their corresponding progenies [5]. The plastic container of fixed geometry used was ensured air-tight by using an epoxiglue to seal samples. About 100g each of meshed soil sample was then transferred to a 100-cm^3 capacity aluminum container and analyzed for gamma activity immediately.

The gamma-ray analysis was done on a very sensitive gamma spectroscopic system which consists of a 76 mm×76 mm NaI (Tl) scintillation detector coupled to a Canberra Series 10 plus multichannel analyzer (MCA). The detector has a resolution of about 7.4% at the 662 keV line for ^{137}Cs which is good enough for distinguishing gamma-ray energies of the radionuclide being measured [9]. The detector was placed in a 5 cm thick lead shield [5, 10] to reduce the effects of natural background radiation.

The detector system was calibrated using a 100 g soil standard radionuclide source sample obtained from the Department of Energy (DOE), Environmental Measurement Laboratory, New York, USA. This sample contains certified activities of the selected

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radionuclide. The radionuclides were calculated on the basis of comparison with same-day counts of background and the standard sample which has the same approximate density and dimensions as the soil samples and known radionuclide contents.

The 1460 keV gamma-ray energy of ^{40}K was used to determine the concentration of ^{40}K in the different samples. The gamma transition of energy of 1765 keV (due to ^{214}Bi) was used to determine the concentrations of ^{238}U while the gamma transition of energy 261.5 keV (due to ^{208}Tl) was used to determine the concentration of ^{232}Th in the soil samples.

Estimation of absorbed dose rate for each location was done using the Beck *et al.* [11] formula in equation 1 as follows:

$$D=0.042S_k+0.429S_u+0.666S_{Th} \quad (1)$$

Where D is the absorbed dose rate in μGy/h due to the specific radionuclide concentration S_k, S_u and S_{Th} for ^{40}K, ^{238}U and ^{232}Th respectively in kBq/kg at 1m above the ground.

RESULTS

The table 1 shows the results of the gamma-ray analysis for the natural radionuclides ^{40}K, ^{238}U and ^{232}Th concentration values, their averages in the 20 soil samples and the estimated absorbed dose rate and its mean value. The location value of ^{40}K concentration in the soil was found to vary from 10 Bq/kg in location 15 to 75 Bq/kg in location 1. For ^{238}U, the location value ranged from 80 Bq/kg in location 5 to 1240 Bq/kg in location 20. The location values for ^{232}Th concentration in the soil vary from 0.5 kBq/kg in location 16 to 5.8 kBq/kg in location 10.

The mean concentration S_k, S_u and S_{Th} for ^{40}K, ^{238}U and ^{232}Th in the site were 35±13 Bq/kg, 780 ± 160 Bq/kg and 2.7±0.6 kBq/kg respectively. Substitution of these values into equation 1 gives the mean absorbed dose rate due to the three primordial radionuclide as 2.16 μGy/h for the site. A conversion factor of 0.8 Sv/Gy was used to convert the absorbed dose rate to human effective dose equivalent with an outdoor occupancy of 20% for the absorbed dose rate to arrive at 3 mSv/y for workers on the mining site. This value is well above the 0.41 mSv/y reported as the world average by UNSCEAR [2].

DISCUSSION

This study has shown that the equivalent dose of 3 mSv/y obtained due to the gamma radiation from the natural radionuclides ^{40}K, ^{238}U and ^{232}Th in the soil samples of the surroundings of the Tin Mine in Jos is low and within the ICRP limit of 20 mSv/y for radiation workers [6] for which access should be severely restricted. However the value is far above the world average of 0.41 mSv/y reported by the UNSCEAR [16].

Table 1. Result of natural radio activities in sample locations; average gamma activity at soil depth 0-5 cm in Bq/kg.

Location number	^{40}K	^{238}U	$^{232}Th \times 10^3$	Absorbed dose rate in air (μGy/hr)
1	75.1 ± 4.0	680.0 ± 40.0	1.50 ± 0.40	1.29
2	42.1 ± 2.3	830.0 ± 30.0	1.20 ±0.48	1.36
3	20.8 ± 1.9	740. ± 33.0	3.40 ± 0.47	2.58
4	22.7± 2.0	927.0 ± 15.0	2.20 ± 0.60	1.86
5	31.7± 1.4	80.0 ± 6.0	1.70 ± 0.62	1.17
6	42.7 ± 1.0	1110.0 ± 100.0	2.00 ± 0.70	1.80
7	53.2 ± 6.0	800.0 ± 83.0	1.50 ± 0.50	1.34
8	63.0 ± 6.0	820.0 ± 19.0	1.70 ± 0.16	1.49
9	62.0 ± 8.0	700.0 ± 28.0	1.40 ± 0.25	1.24
10	72.7± 15.0	1130 ± 15.0	5.80 ± 0.15	4.35
11	20.9 ± 6.9	670.0 ± 20.0	2.05 ± 0.70	1.65
12	13.5 ± 2.6	940.0 ± 25.0	3.10 ± 0.69	2.47
13	25.9 ± 7.4	500.0 ± 19.0	4.50 ± 0.52	3.21
14	13.3 ± 2.9	710.0 ± 28.0	3.55 ± 0.62	2.67
15	10.2 ± 4.0	527.0 ± 90.0	4.72 ± 0.81	3.37
16	12.7 ± 5.1	750.0 ± 15.0	0.50 ± 1.50	0.65
17	26.5 ±1.2	620.0 ± 12.0	2.50 ± 0.50	1.93
18	31.2 ± 9.5	940.0 ± 25.0	2.60 ± 0.50	2.14
19	27.2 ± 6.5	811.0 ± 24.0	4.10 ± 0.90	3.08
20	41.6±1.3	1240.0 ± 40.0	4.40 ± 0.60	3.46
Range	10.2 → 75.1	80.0 → 1240.0	0.50 → 5.80	0.65 → 4.35
Mean Value	35.4 ± 8.1	780.0 ± 53.0	2.72 ± 0.83	2.16

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The result has clearly shown that the mining operation in the site has got a significant effect on the natural radioactivity in the area. This annual dose definitely does not pose a serious radioactive health hazard to the miners and the populace living in the environment. However, exposure to the dose level over a long period can constitute serious health hazard especially to the miners on the site and also the intake from inhaled and ingested radioactivity could present further risks to workers and adjacent populations. The result agrees with similar works done for the city of Jos and some other areas in Nigeria [12, 13]. The data obtained in this work can therefore reliably serve as reference values for the current assessment of the equivalent dose due to natural radioactivity in the mining site.

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