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Gamma Radiation Associated with Gold Mining in Erinmo, Osun State, Nigeria

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Abstract: Gold miners may be exposed to gamma radiation due to radionuclide contaminants associated with the gold. Twenty samples of soil were collected from different illegal mining locations in Erinmo in Osun State of Nigeria and were counted using the high purity germanium detector. The radionuclides identified in all the samples with reliable regularity are ^{238}U, ^{232}Th and ^{40}K. The ^{238}U concentrations in soil range from 9.01±1.7-35.4±3.7 Bq kg^{-1} with an average of 21.9±2.1 Bq kg^{-1}. The mean specific activities for ^{232}Th range from 10.9±2.8-37.5±4.6 Bq kg^{-1} with an average of 23.4±2.9 Bq kg^{-1} and the mean specific activities for ^{40}K in soil ranged from 99.0±12.3-182.8±18.5 Bq kg^{-1} with a mean of 136.5±18.2 Bq kg^{-1}. The uranium and thorium specific activities fall within the earth crustal mean for normal environmental, hence, no uranium or thorium deposit could be said to be in Erinmo. The total absorbed dose rate in air for Erinmo in Osun State ranged between 15.4 and 47.2 nGyh^{-1} with an average of 30.7 nGyh^{-1}. The average value of the absorbed dose rate obtained in this work represents 55.8% of the world average of value of 55.0 nGyh^{-1}. These are within the ICRP limit of maximum permissible dose per hour for a radiation worker. Thus, the illegal mining of goldin Erinmo Osun state poses no serious danger to the populace.

INTRODUCTION

It is a known fact that South-West area of Nigeria, especially, Osun State is home to some of the most important minerals which include bitumen, gold, kaolin, salt limestone, tantalite, coal and phosphate. As a result of the mineral occurrence, some parts of Osun state have become associated with significant levels of natural radioactivity. Erinmo is a village in Ilesha East local government area of Osun state where some commercial quantity of gold has been discovered. Erinmolies on latitude 07^{0}36N and longitude 004^{0}52E and is underlain by crystalline rocks of Precambrian Basement Complex of Southwestern Nigeria. The major rock units within the belt are amphibolites complex, the schists and the quartzitie sequence. The rocks have varying textures from equigranular, medium grained to coarse grained (Ayodele, 2011).

Illegal mining of gold has been going on in this area without the government approval. The exploration and exploitation of this mineralis known to have enormous consequences on the environment. Gold mining and processing constitute a source of environmental pollution due to its associated minerals which pose harmful threats

even in low concentrations in humans and animals. The mining of gold facilitates the release of radioactive minerals from the host rock into the environment (Hendrick, 2010).

Humans can absorb radiation dose of 0.25 sievert without immediate ill effects while 1.0 sievert may produce radiation sickness and >8.0 sievert causes death. The International Commission on Radiological Protection Unit (ICRU) standard stands at 20 mSv per year for a radiation worker, for which access should be restricted. An average of 0.41 mSv per year has been reported by the UNSCEAR (1988).

This research was to measure the baseline radioactivity levels in Erinmo gold mining areas and hence predict the potential radiological health effects.

MATERIALS AND METHODS

Sample collection and preparation: With the help of Global Positioning System (GPS) device, each sampling location was marked and at each sampling location, two sets of samples were collected but at different points. In order to collect the soil samples, the surface vegetation from a chosen location was cleared, then a 3.00 m transect established with four equally spaced sampling points. Core samples at a depth of 50 mm were manually taken from the sampling points with an auger. These samples were bulked separated in labeled plastic bags. A total of twenty soil samples were collected.

Individual soil sample was thoroughly dried at room temperature to constant weight and later crushed and sieved with a 2 mm mesh sieve. The 250 g each of the sieved soil samples was then transferred to 1 L Marinelli beakers and sealed. The soil samples remained in the sealed 1 L Marinelli beakers for 28 days which is a sufficient time required to attain a state of secular radioactive equilibrium prior to gamma-spectrometry (Hinshaw and Trenholm, 2002).

Sample analysis: With the detector having been calibrated for both energy and efficiency in order to aid the identification and quantification of the radionuclides, current decay data for nuclides were obtained from the literature. The gamma counting using the high purity germanium (HPGe) detector was done in the Pollution Laboratory, Department of Physics, Obafemi Awolowo University, Ile-Ife. The prepared sealed samples were placed over the HPGe detector, respectively for counting. The HPGe detector, Canberra model GR2520-7500SL, serial number b93565 used is of coaxial geometry with one end open and a closed end-facing window. The mean counting time for each sample was 36000s. Also, an empty 1-L Marinelli beaker was counted under identical geometry as the samples in other to determine the background spectrum distribution. The photo peak of gamma transmission at 1460 keV was used for the measurement of ^{40}K while the peak at 1760 keV from ^{214}Bi and 2614 keV from ^{208}Tl were used for the measurement of ^{226}Ra (^{238}U) and ^{228}Ra (^{232}Th) respectively. Estimation of absorbed dose rate for each location was done using the Beck *et al*. (1972), formula:

$$D = 0.429\ S_U + 0.666\ S_{Th} + 0.042\ S_K$$

where, D is the absorbed dose rate in gray (Gy) due to the specific radionuclide concentrations S_K, S_U and S_{Th} for K, U and Th respectively, in Bq kg^{-1} at 1m above the ground.

RESULTS AND DISCUSSION

The distribution of the average activity concentrations of the radionuclides in the soil samples and the total absorbed dose rate in air are shown in Table 1. It is observed that locations 6, 10 and 16 recorded the highest mean activity values for ^{238}U and ^{232}Th while the minimum values were obtained in locations 13 and 20. However, location 5 has the highest mean specific activity for ^{40}K with a value of 182.8±18.5 Bq kg^{-1}. This high value of ^{40}K could be attributed to the use of potassium based fertilizers by the local farmers.

The ^{238}U concentrations in soil range from 9.01±1.7-35.4±3.7 Bq kg^{-1} with an average of 21.9±2.1 Bq kg^{-1}. These values fall within the wide range of values reported for soil in the United States (4.4-140 Bq kg^{-1} with a geometric mean of 36 Bq kg^{-1}), for Yangjiang, PR China (21.1-119.2 Bq kg^{-1}), for the southern Saskatchewan, Canada (31.4-34.1 Bq kg^{-1}) and also for worldwide data (arithmetic mean of 24 Bq kg^{-1}) (Daling *et al*., 1990; Kiss *et al*., 1999).

Table 1: Activity concentration and absorbed dose rates of the radionuclides

Location number	Activity concentration (Bq kg^{-1}) (^{238}U)	(^{232}Th)	^{40}K	Total absorbed dose rate (nGy h^{-1})
1	21.5±2.6	23.2±2.8	123.1±9.2	29.9
2	20.0±2.5	23.3±3.1	129.4±15.6	29.5
3	27.6±3.0	26.3±3.6	132.2±25.4	34.9
4	18.7±4.4	22.9±6.5	124.5±20.1	28.5
5	17.8±2.6	21.1±3.0	182.8±18.5	29.4
6	32.7±3.6	35.3±4.8	134.5±37.3	43.2
7	11.7±1.9	13.6±2.1	118.8±21.9	19.1
8	12.5±2.3	12.7±2.8	122.9±19.0	19.1
9	29.7±3.2	33.7±5.6	141.1±31.8	41.0
10	31.0±3.7	34.6±4.1	141.5±36.5	42.2
11	26.9±3.2	25.8±3.5	134.8±30.4	34.4
12	28.9±4.1	28.2±3.0	153.1±28.7	37.6
13	9.0±1.7	10.9±2.8	99.0±12.3	15.4
14	17.4±3.3	20.4±4.1	123.9±17.1	26.3
15	24.4±3.9	22.7±3.2	138.1±31.3	31.3
16	35.4±3.7	37.5±4.6	167.1±33.6	47.2
17	12.6±3.9	17.9±1.0	146.0±22.3	23.4
18	22.0±2.9	22.2±2.6	142.9±27.3	30.2
19	26.6±2.6	23.6±2.5	146.0±27.9	33.2
20	10.5±3.1	11.6±2.9	129.6±30.6	17.6
Mean value	21.9±2.1	23.4±2.9	136.5±18.2	30.7

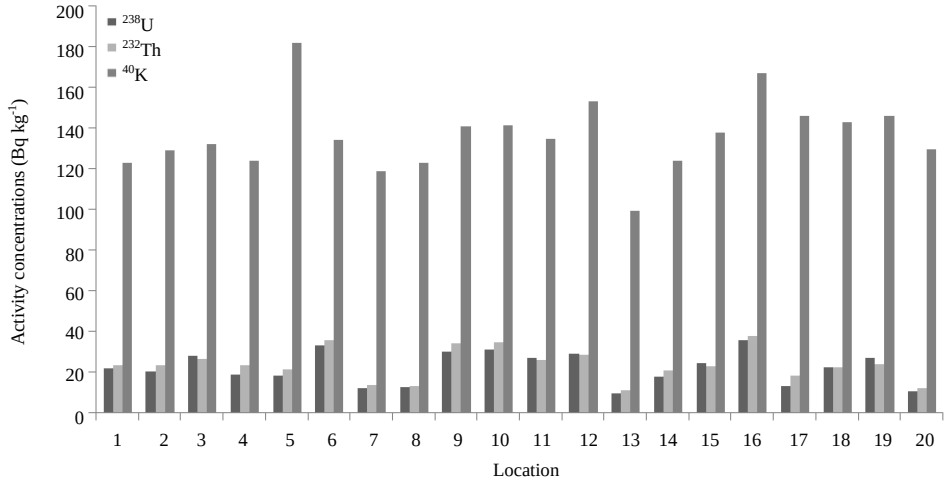

Fig. 1: Activity concentrations of the radionuclides ^{238}U, ^{232}Th and ^{40}K at various locations

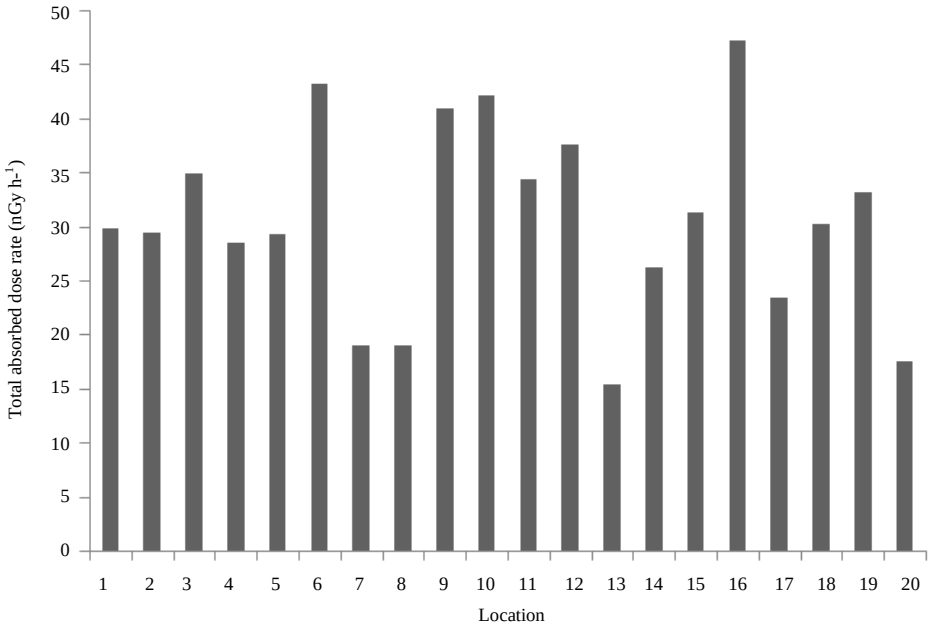

Fig. 2: Total absorbed dose rates of ^{238}U, ^{232}Th and ^{40}K at various locations

The mean specific activities for ^{232}Th in soil range from 10.9±2.8-37.5±4.6 Bq kg^{-1} with an average of 23.4±2.9 Bq kg^{-1}. The ^{232}Th concentrations recorded for this work fall within the wide range of values quoted for the USA (4.0-130 Bq kg^{-1} with a geometric mean of 32 Bq kg^{-1}). The current ^{232}Th values are similar to the worldwide arithmetical mean of 21 Bq kg^{-1} (NCRP., 1987) (Fig. 1). The mean activity concentration values of ^{238}U and ^{232}Th in Erinmo were found to be lower than the Earth's crustal mean of between 37.8 and 49 Bq kg^{-1} for ^{238}U and about 60 Bq kg^{-1} for ^{232}Th (Ayodele, 2011).

The mean specific activities for ^{40}K in soil ranged from 99.0±12.3-182.8±18.5 Bq kg^{-1} with a mean of 136.5±18.2 Bq kg^{-1}. The results for ^{40}K lie within the range obtained elsewhere for surface soil primarily characterized as sand, gravy loams and sandy clays (Kirchner *et al*., 2002).

In fact, ^{40}K, a naturally occurring radionuclide is present abundantly in the Earth crust and in human body, hence is expected to contribute significantly to man's committed effective dose through ingestion (Fig. 2).

CONCLUSION

The total absorbed dose rate in air for Erinmo in Osun State ranged between 15.4 and 47.2 $nGyh^{-1}$ with an average of 30.7 $nGyh^{-1}$. The average value of the absorbed dose rate obtained in this work represents 55.8% of the world average of value of 55.0 nGy h^{-1} (UNSCEAR., 1988), 39.9% of the value (77.0 $nGyh^{-1}$) obtained for the Nigerian cities (Jibiri and Farai, 1998).

The highest total absorbed dose rate of 47.2 $nGyh^{-1}$ was recorded at location 16 representing 85.8% of the world average. The least value of 15.4 $nGyh^{-1}$ was recorded at location 13 representing 28% of the world average value of 55.0 $nGyh^{-1}$. These are within the ICRP limit of maximum permissible dose per year for a radiation worker (ICRP., 2007). Thus, the illegal mining of goldin Erinmo, Osun State poses no serious danger to the populace.

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