Journal of Natural Sciences Research
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.5, No.8, 2015
www.iiste.org

Gamma Radiation Hazard Associated with Tin Mining on Jos Plateau

Yakubu Hunira Ngadda[1] and Ndam Peter[2]
[1]Physics Department, Faculty of Science, University of Maiduguri, Nigeria.
[2]Physics Department, Faculty of Natural Sciences, University of Jos. Nigeria.
[1]Email of the corresponding author: yhngadda@yahoo.com

Abstract
Tin miners may be exposed to gamma radiation due to radio nuclide contaminants associated with the tin. In this work, 10 samples of soil were collected from different mining sites on the Jos Plateau of North central Nigeria and were analyzed by measuring the concentrations (Bq/kg) of the three radio nuclides ^{40}K, ^{238}U and ^{232}Th which are associated with the tin; and calculating the absorbed dose rates per year. The gamma ray measurements were achieved through the use of gamma ray spectrometer coupled to a NaI(Ti) scintillation detector. Estimation of the absorbed dose rates using the Beck and Decmopo formula showed the maximum absorbed dose rate in one of the ten locations as 4.704 mSv/y and an average of 2.718 mSv/y was obtainedfor the ten locations. These are within the range given by ICRP, the maximum permissible dose per year for a radiation worker, which is about 20 mSv/y. Thus the mining of tin on the Jos Plateau poses no serious danger to lives.

1. Introduction

The Jos plateau of Nigeria is located on a granite plateau about 1400 m above sea level in the north central part of the country. The main geological formation of this area lends itself to the mining and milling of tin. The Jos tin industry started around 1904, the primary purpose of which is to mine tin ore and mill the same for exportation. The lithological formation in this area is composed of basement complex biotite granite and new basalts (Ajayi, 1994). Tin and columbite ore are associated with biotite granites.

Thirteen major radioactive isotopes of tin exist of which only two, Tin-121 (half-life of 55 years) and Tin-126 (half-life is less than one year) have half-lives long enough to warrant concern at the Department of Energy (DOE) environmental management sites (Ajayi and Ajayi, 1999). Tin-126 has low specific activity which limits its radioactive hazard (Myrick, Berven and Haywood, 1983; Hart and Wall, 2002).).

Generally tin has very little or no radioactive characteristics but its associated minerals contain some trace of uranium and thorium which are radioactive (Henry, 1963).

Tin 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 (Oresegun and Babalola, 1993). The mining of tin 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 one (1) sievert may produce radiation sickness and more than 8 sieverts 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.

This work is aimed at sampling soil from different mining sites in Bukuru, on the Jos plateau, and investigating possible radioactivity associated with the samples and to compare the dose equivalent with recommended standard radiation levels.

2. Radiation dose and effective dose equivalent limit

The sievert (symbol: **Sv**) is a derived unit of ionizing radiation dose in the International System of Units (SI). It is a measure of the health effect of low levels of radiation on the human body. Quantities that are measured in sieverts are intended to represent the stochastic health risk, which for radiation dose assessment is defined, by the ICRP, as the probability of cancer induction and genetic damage.

The sievert is used for radiation dose quantities such as equivalent dose, effective dose, and committed dose. It is used both to represent the risk of the effect of external radiation from sources outside the body, and the effect of internal irradiation due to inhaled or ingested radioactive substances.

The SI definition given by the International Committee for Weights and Measures (CIPM) says: "The quantity dose equivalent H is the product of the absorbed dose D of ionizing radiation and the dimensionless factor of Q (quality factor) defined as a function of linear energy transfer by the ICRU"

$$H = Q \times D \quad (1)$$

In order to avoid any risk of confusion between the absorbed dose D and the dose equivalent H, the CIPM gave the special names for the respective units should be used, that is, the name gray should be used instead of joules per kilogram for the unit of absorbed dose D and the name sievert instead of joules per kilogram for the unit of dose equivalent H.

1 Sv = 1 joule/kilogram - a biological effect. 1 Sv represents the equivalent biological effect of the deposit of a joule of radiation energy in a kg of tissue. The equivalence to absorbed dose is denoted by Q.

As the sievert has a biological effects component which depends on the radiation type, a corrective experimentally derived Weighting factor, W_R, must be applied to convert the physical unit of the gray into the equivalent dose, see Table 1.

Table 1: Radiation weighting factors W_R used to represent relative biological effectivenessaccording to ICRP report 103 (2007)

Radiation	Energy, E (MeV)	$W_R(E)$
x-rays, gamma rays, beta particles, muons		1
neutrons	< 1 MeV 1 MeV - 50 MeV > 50 MeV	$2.5 + 18.2 \cdot e^{-[\ln(E)]^2/6}$ $5.0 + 17.0 \cdot e^{-[\ln(2 \cdot E)]^2/6}$ $2.5 + 3.25 \cdot e^{-[\ln(0.04 \cdot E)]^2/6}$
protons, charged pions		2
alpha particles, nuclear fission products, heavy nuclei		20

The equivalent dose is calculated by multiplying the absorbed energy, averaged by mass over an organ or tissue of interest, by a radiation weighting factor appropriate to the type and energy of radiation. To obtain the equivalent dose for a mix of radiation types and energies, a sum is taken over all types of radiation energy dose, ICRP report (2007)

$$H_T = \sum_R W_R . D_{T,R} \quad (2)$$

where H_T is the equivalent dose absorbed by tissue T, $D_{T,R}$ is the absorbed dose in tissue T by radiation type R and W_R is the radiation weighting factor defined by regulation.

Effective dose equivalent (EDE) limit is the largest amount of ionizing radiation a person may receive according to radiation protection guidelines. It combines both internal and external dose and has replaced the concept of maximum permissible dose for occupational exposures. The EDE limit is prescribed for various organs as well as whole body and for various working conditions. The current EDE limit for occupational exposures is 100 mrem/wk (or 1 mSv/wk). The annual EDE limit is 5000 mrem/yr or (50 mSv/yr). Also called maximum permissible dose. The current limit (averaged) for nuclear industry employees and uranium miners is 20 mSv/y.

3. Methodology

3.1 Sample collection and preparation

A total of 10 surface soil samples of natural origin were collected from selected locations. These were divided into grills at the same depth level of 0 to 6cm around 20 kilometer square surrounding the tin mining sites. The samples were collected on not less than every square kilometer. Samples were obtained by cleaning the surface vegetation and removing dead organic matter from the surface of the location and then taking a soil sample from it at a depth of 6 cm. Sample size varied from 1.0 to 1.5kg. At the collection point each soil sample was wrapped in black plastic bag and taken to the laboratory.

Each soil sample was allowed to dry for 72 hours under laboratory humidity of about 70%. Each dried soil sample was ground and served using a 2 mm mesh screen. The larger particles were disposed off and the meshed soil samples were stored in plastic containers for four weeks to allow time for secular equilibrium between ^{238}U and ^{232}Th. The plastic container of fixed geometry used was ensured to be airtight by using an epoxy glue to seal samples. About 100g of meshed soil sample was then transferred to a 100 cm^3 capacity aluminum container for analysis of gamma ray activities. This was repeated for all the soil samples.

3.2 Sample analysis

The gamma ray spectrometer includes a detector, multichannel analyzer and associated amplifiers and data readout devices. The detector is a sodium iodide (NaI) scintillation counter, (76 mm x 76 mm NaI(TI) scintillation detector), and has a resolution of about 74 % at 662 keV line for ^{137}Cs which is good enough for distinguishing gamma-ray energies of the radionuclide being measured. The detector was placed in a 5 cm thick lead shield to reduce the effect of natural background radiation.

The detector system was calibrated using a 10g soil standard radionuclide source sample obtained from the department of energy (DOE), environmental measurement laboratory, New York. This sample contains certified activities of the selected radio nuclides under study. It also has approximate density, dimension and known radionuclide contents as the soil samples.

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 energy of 1765 keV, due to ^{214}Bi, was used to determine the concentration of ^{238}U, while the gamma transition energy of 216.5 keV due to ^{208}Ti 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 and Decmopo, 1972, formula,

$$D = 0.042\ S_K + 0.429\ S_U + 0.666\ S_{Th} \quad (3)$$

Table 2: Activity concentrations and **a**bsorbed dose rates of the radio- nuclides of ^{40}K, ^{238}U and ^{232}Th at the ten locations on the Jos Plateau

Location Number	Activity Concentration (Bq/kg) ^{40}K	^{238}U	^{232}Th	Total Absorbed Dose Rate in Air (μGy/hr)	(mSv/y)
1	20.8	740	3.40	320.598	2.810
2	72.7	113	5.80	55.393	0.486
3	13.5	940	3.10	405.892	3.558
4	25.9	500	4.50	218.585	1.916
5	13.3	710	3.55	307.513	2.696
6	10.2	527	4.72	229.655	2.013
7	26.5	620	2.50	268.758	2.356
8	31.2	940	2.60	406.302	3.562
9	27.2	811	4.10	351.792	3.084
10	41.6	1240	4.40	536.638	4.704
Mean Value	28.29	714.10	3.87	310.113	2.718

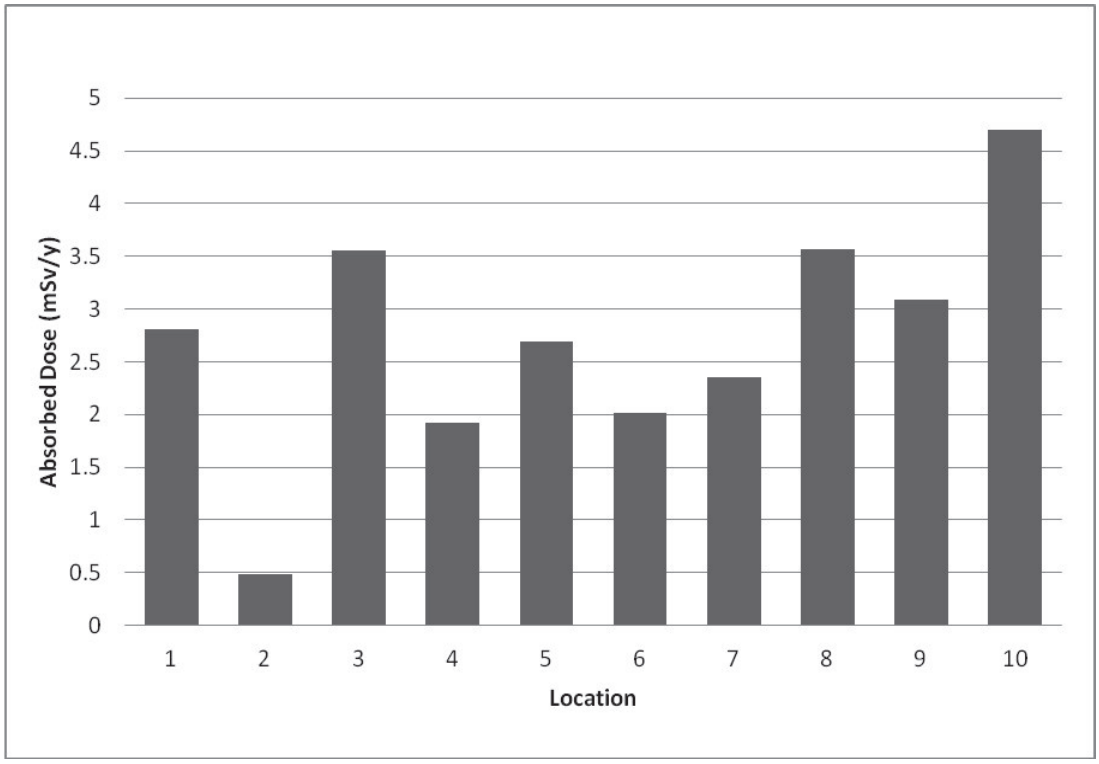

Figure 1: A**bsorbed dose rates of the radio- nuclides of ^{40}K, ^{238}U and ^{232}Th at the ten locations on the Jos Plateau**

where D is the absorbed dose rate in gray (Gy) due to the specific radio nuclide concentrations S_K, S_U and S_{TH} for ^{40}K, ^{238}U and ^{232}Th respectively, in Bq/kg at 1m above the ground.

4. Results and discussion

Table 2 shows the concentration values and the estimated absorbed dose rates and their mean values for the naturally occurring radio nuclides of ^{40}K, ^{238}U and ^{232}TH. As it can be seen from the Table 2, the concentration values differ with each location. There are maxima concentration values in locations 2, 10 and 2 for ^{40}K, ^{238}U and ^{232}Th respectively; and minima in locations 6, 2 and 7 for ^{40}K, ^{238}U and ^{232}Th respectively. The average concentration is maximum for uranium (714.10 Bq/kg) followed by potassium (28.29 Bq/kg) and minimum for thorium (3.87 Bq/kg), showing that for the three nuclides uranium is most abundant around the tin mining sites followed by potassium. Figure 1 shows that location 10 has the maximum concentration with a total absorbed dose rate of 4.704 mSv/y followed by locations 8 and 3 with a minimum absorbed dose rate in location 2.

A mean absorption rate of 2.718 mSv/y for the three radio-nuclides suggests that people living around the mining sites are subject to being irradiated by the radio nuclides of the three isotopes.

5. Conclusion

The Jos area of North central Nigeria is located on a granite plateau about 1400 m above sea level. The main geological formation of the area lends itself to the mining and milling of tin. However major contaminants which include ^{40}K, ^{238}U and ^{232}Th, which are gamma radioactive nuclides, are feared to pose danger to the miners and the closest communities.

In this work, 10 samples of soil were collected from different mining sites and were analyzed by measuring the concentrations of the three radio nuclides and calculating the absorbed dose rates per year. The gamma ray measurements were carried out through the use of gamma ray spectrometer coupled to a NaI(Ti) scintillation detector. The gamma ray energy 1460 keV (^{40}K), the gamma ray transition energy of 1765 keV (^{214}Bi) and the gamma ray transition energy of 216.5 keV (^{208}Ti) were used to determine the concentrations of ^{40}K, ^{238}U and ^{232}Th respectively in the soil samples.

Estimation of the absorbed dose rates using the Beck and Decmopo formula showed the maximum absorbed dose in one of the ten locations as 4.704 mSv/y and an average of 2.718 mSv/y was obtained. These are within the ICRP limit of maximum permissible dose per year for a radiation worker which is 20 mSv/y (Grajewski, Waters, Whelan and Bloom, 2002; ICRP report 2007). Thus the mining of tin on the Jos Plateau poses no serious danger to lives. However, location number ten should be thoroughly investigated to confirm the amount of uranium deposit in the area.

6. Acknowledgement

We sincerely acknowledge the Jos Metrological Centre for their services rendered for sample analysis, most especially the use of the gamma ray spectrometer, the scintillation detector and for the technical expertise.

7. References

Ajayi, I. R. (1994). Radionuclide analysis of soils and sedment. University of Ibadan.

Ajayi, I. R. and Ajayi, O. S. (1999).Estimation of absorbed dose rate and collective effective dose equivalent due to gamma radiation from selected radionuclide in soil in Ondo and Ekiti States, SW Nigeria. Radiation Prot. Dosim. 86:221.

Beck, H. I. and Decmopo, G. (1972). In-situ-Ge(Li) and NaI(Ti) gamma ray spectrometer. HASL-258.

Grajewski, B.; Waters, M. A.; Whelan, E. A. and Bloom, T. F. (2002). "Radiation dose estimation for epidemiologic studies of flight attendants". American Journal of Industrial Medicine **41** (1): 27–37

Hart, D. and Wall, B. F. (2002). Radiation Exposure of the UK Population from Medical and Dental X-ray Examinations. National Radiological Protection Board. p. 9.

Hendrick, R. E. (2010). "Radiation Doses and Cancer Risks from Breast Imaging Studies". Radiology **257** (1): 246–253.

Myrick T. E., Berven, A. A. and Haywood, F. F. (1983). Determination of concentrations of selected radionuclides in surface soils in the US. Health Phys. 45:631.

Oresegun, M. O. and Babalola, I. A. (1993). The environmental gamma radiation of Jos, Nigeria. Nigerian Journal of Science 27:263-268.

The 2007 Recommendations of the International Commission on Radiological Protection. *Annals of the ICRP*. ICRP publication 103 **37** (2–4). 2007. ISBN 978-0-7020-3048-2. Retrieved 17 May 2012.

The IISTE is a pioneer in the Open-Access hosting service and academic event management. The aim of the firm is Accelerating Global Knowledge Sharing.

More information about the firm can be found on the homepage:
http://www.iiste.org

CALL FOR JOURNAL PAPERS

There are more than 30 peer-reviewed academic journals hosted under the hosting platform.

Prospective authors of journals can find the submission instruction on the following page: http://www.iiste.org/journals/ All the journals articles are available online to the readers all over the world without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. Paper version of the journals is also available upon request of readers and authors.

MORE RESOURCES

Book publication information: http://www.iiste.org/book/

Academic conference: http://www.iiste.org/conference/upcoming-conferences-call-for-paper/

IISTE Knowledge Sharing Partners

EBSCO, Index Copernicus, Ulrich's Periodicals Directory, JournalTOCS, PKP Open Archives Harvester, Bielefeld Academic Search Engine, Elektronische Zeitschriftenbibliothek EZB, Open J-Gate, OCLC WorldCat, Universe Digtial Library , NewJour, Google Scholar