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Natural Radioactivity Concentration And Effective Dose Rate From Jos Tin Mining Dumpsites In Rayfield, Nigeria

Felix B. Masok [1,2] Paulus L Masiteng [1] Jwanbot I Daniel.[3]
1, Department of Applied Physics and Engineering Mathematics University of Johannesburg, South Africa.
2, Department of Physics, Plateau State University Bokkos, Jos, Nigeria.
3, Department of Physics University of Jos, Nigeria.

Abstract
The International Commission on Radiological Protection (ICRP) has recommended the annual effective dose equivalent limit of 1mSvy^{-1}for the individual members of the public and 20mSvy^{-1} for the radiation workers. The assessment of naturally occurring radio nuclides ^{226}Ra, ^{232}Th and ^{40}K in nine major tin mine dumpsites in and closely around Rayfield area of Jos Plateau were carried out using gamma-ray spectrometry with NaI(Tl) detector to determine the natural radio nuclide in the dumpsites and to evaluate the hazards these might have on the public. The calculated average activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in the samples were 132.6±21.4, 351.4±20.9 and 319.6±37.7 Bqkg^{-1} respectively. The mean activity concentration of ^{226}Ra and ^{232}Th in the present study is much higher than the world-wide average values of 33 Bqkg^{-1} and 45 Bqkg^{-1} respectively but the mean concentration of ^{40}K is lower compared to the world average of 420 Bqkg^{-1}.
The present study revealed that the calculated average absorbed dose rate, radium equivalent dose, indoor annual effective dose rate and outdoor annual effective dose were found as 293.27nGyh^{-1}, 569.68mSvy^{-1}, 1.44mSvy^{-1} and 0.34mSvy^{-1} respectively. The mean values of the absorbed dose rate, radium equivalent dose and the indoor annual effective dose rate are much higher than the world average recommended safety limits. Therefore it can be concluded that the present study area is radiologically unsafe from radiological hazards and will pose harmful effects to the environmental and the living population. However, no significant radiological impact have been observed on the surrounding environment and the living population, this might be attributed to the higher value of the Nigeria annual effective dose of 0.098 mSvy^{-1} compared to the world annual effective dose of 0.07mSvy^{-1}.
Keywords: Radioactivity, Effective dose, Tin mining, Dumpsites.

1. Introduction

Radioactivity concentration of radio nuclides above the permissible level is very harmful for human health. Natural radioactivity is wide spread in the earth environment and it exists in various geological formations such as earth crust, rock, soils, plant and air (UNSCEAR, 2000). Human beings are exposure to radiation arising from sources including cosmic rays, natural radio nuclides in water, air soil, rocks plants; and artificial radioactivity from fall out in nuclear processes and medical applications. IAEA, 1996. Estimated that 80% of doses contribution in the environment are derived from the natural radio nuclides while the remaining 20% is from cosmic rays and nuclear processes.

Soil provides a direct source of radioactivity in food chain due to its uptake by agricultural plants. The radioactivity caused by radio nuclides can be transfer from soil, water, air to plants, tress and other biological elements and finally to human body. The natural radioactivity of soil samples is usually determined from its ^{238}U, ^{232}Th and ^{40}K contents. It is widely spread in the earth's environment and depends primarily on the geological and geographical conditions, and appears at different levels in the soil of each region in the world (UNSCEAR, 2000). Rayfield, in Jos plateau host the administrative government house of the state, thus inhabiting a large number of people both for residential ans business purposes. The lithological formation of Jos are basement complex, new basalt and biotite granite. Biotite granite is associated with tin and columbine. Information was first received in 1884 about the presence of tin on the Jos Plateau, then known as the Bauchi Plateau; but it was not until the mineral survey of northern Nigeria (1904-1909) that the occurrence of tin over wide area of the Plateau was proved. As far back as 1909, the Niger Company was producing 458 tons of tin on the plateau. Different types of environmental damage and hazards inevitably accompany the harnessing of this mineral (UNSCEAR 2000). By products from mining and processing of tin such as monazite, thorite, zircor which contain some heavy metals that are highly radioactive are often dump in the mining site indiscriminately due to lack of market. De wet, 1996. Found that a wide range of agricultural products including milk meat and vegetable from farms near mining areas and polluted rivers contain radium. Exposure to these radio nuclides constitute a health hazard. IARC monographs have concluded that there is a sufficient evidence that exposure to radium-226 cause bone sarcomas and mastoid process while radon-222 is a cause of lung cancer(IARC, 2012). Although review of literature revealed that studies have been done on the activity concentration in Jos (Jwanbot *et al*.,2010; Usikalu *et al*., 2011, Ike *at al*., 2002, and Umar and Rabiu, 1999) there are generally little or no awareness and knowledge of the radiological hazards and exposure levels to NORMs in mining areas as people

still use the dumps either for building or the mining sites farmland for dry season farming. Numerous types of human activities and non-nuclear industries contribute to further concentrate some of the natural radio nuclides that can be found in the earth crust affecting the human and the environment. Gamma radiation from the natural radio nuclides and cosmic rays constitute the external exposure to humans while those from inhalation and ingestion through foods and drinking water constitutes internal exposure to humans. The present study is aimed at determining the level of radioactive elements (radium, thorium and potassium) and corresponding health risk due to exposure to these radio nuclides from tin mined soil dumped in Rayfield, Jos Plateau.

Study Area.

Jos Plateau has dimension of almost 105km North to south and 80km east to West, It is located at latitude 9^0 55'N and longitude 8^0 53'E (Masok *et al*., 2014). Jos Plateau is a geological Island of volcanic formation and its varied land forms are closely associated with the various phases of volcanic activities in the area. The specific area of study is located within the Jos-Bukuru complex. The people are mostly farmers, miners, traders and civil servants. The major part of the land is used for the cultivation of agricultural products and the rest is used for building residential houses and business.

2.0 MATERIALS AND METHODS.

2.1 Sample Collection.

Soil samples were collected from different tin mine dumps of the study area using digger and spade. The samples were air dried for seven days to attain a constant weight. The samples were then crush and sieved with a fine mesh having holes each of diameter 500µm in order to remove organic materials, piece of stones, gravels and lumps. Afterwards, the homogenized samples were packed to fill a cylindrical plastic container of diameter 7.2cm and 6.0cm height to satisfy the selected optimal sample container used for detector calibration. The samples were properly sealed to avoid random escape of ^{222}Rn and stored for 720 hrs to allowed for 238U and its short-lived progenies to reach secular radioactive equilibrium (Veige *et al*. 2006) before gamma counting.

2.2 Gamma Counting And Activity Determination.

The gamma-ray spectrometry setup used for the measurement of activity concentration consist of a highly shielded and well calibrated 7.62cm by 7.62cm NaI(Tl) detector enclosed in a 6cm thick lead shield line with cadium and copper sheets to assist in reducing background radiation. In addition, the set up was coupled with a computer based multichannel analyzer (MCA) which was used for the data acquisition and analysis of gamma spectra. The soil samples were mounted on the surface of the detector and each counted for 2100s in reproducible sample-detector geometry. The large counting time was to minimize statistical uncertainty. The 1764KeV ɣ-line of Bi was used in the assessment of activity concentration of ^{226}Ra while 2614KeV ɣ-line of ^{208}Tl was used to determine the concentration of 234Th. The single 1460KeV ɣ-line of ^{40}K was used to determine the concentration of ^{40}K in the samples.

The activity of each of the radionuclide in the sample was determine using the net area under the photo peaks using the relation;

$$A_c = \frac{C_n}{\varepsilon_\gamma M_s \, I_\gamma} \qquad (1)$$

Where; A_c is the activity concentration of radio nuclide in the sample given in Bqkg^{-1}, C_n is the net count per second of the sample under the corresponding peak, $\mathcal{E}_\gamma$ is the efficiency of the detector at the specific ɣ-ray energy of interest. M_s is the mass of the sample (kg) I_γ is the intensity of gamma ray at the particular energy being counted

2.3 Absorbed Dose Rate.

The gamma absorbed dose rate was calculated by using the equation given by (UNSCEAR, 1993). The conversion factors of 0.461 nGyh^{-1}/Bqkg^{-1} for ^{226}Ra, 0.623nGyh^{-1}/Bqkg^{-1} for ^{232}Th and 0.0414nGyh^{-1}/Bqkg^{-1} for ^{40}K. Assuming that ^{137}Cs, ^{90}Sr and ^{235}U decay series can be neglected, they contribute very little to the total dose from the environmental background (Kocher and Sjoreen, 1985; Jocob *et al*.,1989; Leung et al.,1990).

$$D(nGyh^{-1}) = 0.416A_{Ra}+0.623A_{Th} + 0.0414A_K \qquad (2)$$

Where: D is the absorbed dose rate in air 1m above the ground due to ^{226}Ra,^{232}Th and ^{40}K in the soil samples. $A_{Ra,}$ A_{Th} and A_k are the activity concentration in Bqkg^{-1} of ^{226}Ra, ^{232}Th and ^{40}K.

2.4 Radium Equivalent Dose.

The distribution of ^{226}Ra, ^{232}Th and ^{40}K in soil is not uniform. Uniformity with respect to exposure to radiation has been define in terms of radium equivalent activity (Ra_{eq})in Bqkg^{-1} to compare the specific activity of materials containing different amount of ^{226}Ra, ^{232}Th and ^{40}K. The radium equivalent activity (Ra_{eq}) which is a single index used to describe the gamma output from different mixture of radium thorium and potassium in the

material was calculated from equation described by Beretke and Mathew, 1985; UNSCEAR, 1982)

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_K \quad (3)$$

Where: A_{Ra}, A_{Th} and A_K are the activity concentration in $Bqkg^{-1}$ of ^{226}Ra, ^{232}Th and ^{40}K respectively.

2.5 Annual Effective Dose Rate

To estimate the annual effective dose rate ($mSvy^{-1}$) due to the natural radio nuclides in the soil samples, the following factors were considered (i) the conversion factor of 0.7 $SvGy^{-1}$ (UNSCEAR, 2000) which converts the absorbed dose in air to effective dose. (ii) The indoor and outdoor occupancy factors of 0.8 and 0.2 were used respectively (Masok *et al* 2015; UNSCEAR 1988), these occupancy factors are the proportion of the total time during which an individual is exposed to a radiation field. (iii) Eight thousand seven hundred and sixty hours per year (iv) the factor converting nano to milli (10^{-6}).

The effective dose rate was calculated using the equation given by (Kessaratikoon *et al*. 2008; Masok *et al.* 2015).

$$IAEDR(mSvy^{-1}) = D(nGyh^{-1})\times 8760(hy^{-1})\times 0.8\times 10^{-6} \quad (4)$$

$$OAEDR(mSvy^{-1}) = D(nGyh^{-1})\times 8760(hy^{-1})\times 0.2\times 10^{-6} \quad (5)$$

Where (IAEDR) is the indoor annual effective dose rate and (OAEDR) is the outdoor annual effective dose rate.

3.0 RESULTS

The results of activity concentration of radio nuclides obtained from gamma ray analysis of soil samples collected from nine tin mined dumpsite Jos Rayfield area are presented in Table 1. From the results obtained in table 1, the gamma absorbed dose rate ($nGyh^{-1}$) at 1m above the ground due to ^{238}U, ^{232}Th and ^{40}K in the soil samples was calculated from equation (2) and presented in column 2 of table 2. The radium equivalent dose which gives a single index used to describe the gamma output from different mixtures of radium, thorium and potassium in the material was calculated from equation (3) and presented in column 3 of table 2. The indoor annual effective dose rate ($mSvy^{-1}$) was calculated from equation (4) while the outdoor annual effective dose rate was calculated from equation (5) and presented in columns 4 and columns 5 respectively in Table 1

Table1. Activity Concentration Of Radionuclide In The Soil Sample.

Sample I.D	Activity concentration ($Bq.kg^{-1}$)		
	^{222}Ra	^{232}Th	^{40}K
S-01	115.8±23.1	159.7±22.7	295.4±46.6
S-02	104.2±23.1	262.3±22.7	730.8±46.6
S-03	57.9±11.6	182.5±11.4	108.8±15.2
S-04	115.8±19.8	330.7±21.3	108.8±13.6
S-05	92.7±10.9	239.5±19.0	108.8±14.9
S-06	46.3±11.3	136.8±11.4	186.6±31.2
S-07	104.2±23.1	307.9±11.1	171.0±30.9
S-08	393.9±46.3	866.8±22.8	730.8±93.2
S-09	162.2±23.6	676.5±45.6	435.4-46.6
Min	46.3±11.3	136.8±11.4	108.8±13.6
Max	393.9±46.3	866.8±22.8	730.8±46.6
World average	33	45	420

Table 2. Calculated Values of Absorbed Dose Rate, Radium equivalent, Indoor and Outdoor Annual Effective Dose Rate respectively.

Sample I.D	Absorbed dose rate ($nGyh^{-1}$)	Ra_{eq} ($Bqkg^{-1}$)	Annual Effective absorbed dose rate. ($mSvy^{-1}$)	
			Indoor	Out door
S-01	165.12	366.92	0.81	0.20
S-02	241.70	535.56	1.12	0.29
S-03	144.89	327.25	0.71	0.18
S-04	263.91	597.08	1.29	0.32
S-05	196.45	443.56	0.96	0.24
S-06	114.24	256.29	0.56	0.14
S-07	246.94	557.67	1.21	0.30
S-08	751.86	1689.69	3.69	0.92
S-09	514.26	1163.12	2.52	0.63
Min	114.29	256.29	0.56	0.14
Max	751.86	1689.69	3.69	0.92
Average	293.27	659.68	1.44	0.34
World Average	59	370	0.50	0.07

4.0 DISCUSION OF RESULTS.

4.1 Activity Concentration of Radionuclide.

Table1 summarizes the results of measurement of natural radio nuclides (^{226}Ra, ^{232}Th and ^{40}K) concentration in the collected soil samples. World average concentrations are 33Bqkq^{-1} , 45Bqkg^{-1} and 420Bqkg^{-1} for ^{226}Ra, ^{232}Th and ^{40}K respectively (UNSCEAR 2000). From table 1, the activity concentration of ^{226}Ra ranges from 46.3±11.3 Bqkg^{-1} to 393.9±46.3 Bqkg^{-1} with an average of 132.6±21.4 Bqkg^{-1} while that of ^{232}Th ranges from 136.8±11.4 Bqkg^{-1} to 866.8±22.8 Bqkg^{-1} with an average of 351.4±20.9 Bqkg^{-1} and that of ^{40}K ranges from 108.8 ±13.6 Bqkg^{-1} to 730.8±46.6 Bqkg^{-1} with an average of 319.6±37.7 Bqkg^{-1}. The ranges and averages of activity concentration of ^{226}Ra and ^{232}Th in the study area are higher than the world figures of 33 Bqkg^{-1} and 45Bqkg^{-1} respectively. However, the concentration of ^{40}k is lower compared with the world average of 420 Bqkg^{-1}.

4.2 Radiological Hazard Assessment.

Radiation dose depend on the intensity and energy of radiation, type of radiation, exposure time, the area exposed and the depth of the energy deposition. In order to assess the health effects of people living in the study area, the 'Absorbed Dose Rate' (D), 'Radium Equivalent Dose' (Ra_{eq}) 'Indoor Annual Effective Dose Rate' (IAEDR) and the 'Outdoor Annual Effective Dose Rate' (OAEDR) have been calculated from the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K using equations (2), (3) (4) and (5) respectively and the values are presented in Table 2.

Table 2 shows that, the absorbed dose rates due to the terrestrial gamma rays at 1m above the ground in the study area are in the range of 114.29 nGyh^{-1} to 751.86 nGyh^{-1} with an average of 293.27 nGyh^{-1} which is higher than the world average value of 59 nGyh^{-1} given by (UNSCEAR, 2000). The indoor annual effective doses are in the range of 0.56mSvy^{-1} to 3.69mSvy^{-1} with an average of 1.44mSvy^{-1} while the outdoor annual effective doses are in the range of 0.14mSvy^{-1} to 0.92mSvy^{-1}with an average value of 0.34mSvy^{-1} both of which are higher compared with the world average value of 0.5 mSvy^{-1} and 0.07mSvy^{-1} respectively (UNSCEAR, 2000). The radium equivalent (Ra_{eq}) in these soil samples ranges from 256.29 Bqkg^{-1} to 1689.69 Bqkg^{-1} with a mean value of 659.68 Bqkg^{-1} which is higher than the permissible value (370 Bqkg^{-1}) that is acceptable as safe limit. (OECD, 1979).

5. Conclusion

The international commission on radiological protection has recommended the annual effective dose equivalent limit of 1mSvy^{-1} for the individual members of the public and 20mSvy^{-1} for the radiation workers (ICRP, 1993).The average activity concentration of ^{226}Ra and ^{232}Th in the study area were 132.6±21.4 Bqkg^{-1} and 351.4±20.9 Bqkg^{-1} respectively which are much higher compared to the world average values of 33 Bqkg^{-1} and 45 Bqkg^{-1} reported by (UNSCEAR, 2000). However, the concentration for ^{40}K was lower than the world figure. The Slight variation observed in the activity concentration of the soil samples may be attributed to the soil type, formation, geological location and transport process involve in the study area. The Average value of the absorbed dose rate (293.27nGykg^{-1}) and radium equivalent dose (659.68nGykg^{-1}) were much higher than the world average values 59 nGykg^{-1} and 370 nGykg^{-1} respectively (OECD, 1979). The results shows that the indoor annual effective dose from natural radioactivity has an average value higher than the natural world recommended value.

The values of hazards indices confirm that the study area is radiologically unsafe for agricultural activities and residentially purposes. However, despite the significant different in values between the measured radiological hazards indices compared to the world average values, no significant radiological impact have been observed on the surrounding environment and the living population of the present study area. This could be attributed to the higher value of Nigerian annual effective dose value of 0.098mSvy^{-1} reported by (Farai and Jibiri 2000) compared to the world average annual effective dose of 0.07mSvy^{-1} given by (UNSCEAR, 200)

References

Berekta, J., and Mathew, P.J (1985). Natural Radioactivity in Australian building materials, industrial waste and by- product. *Health Physics,* 48, 87-95.

De Wet, P.D. (1996).The occurrence and bio-accumulation of selected metals and radionuclides in aquatic and terrestrial ecosystem on the Witwatersrand. Unpublished PhD. Thesis , rand Afrikaans University Johannesburg.

Farai, I.P., and Jibiri, N.N (2000). Baseline studies of terrestrial outdoor gamma dose rate levels in Nigeria. Radiation Protection Dosimetry, 88(3), 247-254

International Agency for Research on Cancer (IARC, 2012). A review of human carcinogens; radiation. IARC monographs on the evaluation of carcinogenic risks to human, Vol. 100 D.

International Commission on Radiological Protection. ICRP, (1991).1990 recommendation of the international commission on radiological protection, Oxford: pergamon press. ICRP publication 60, Annal of the

ICRP 210-3.

Jacob, P., Paretzke, H. G., Rosenbaum, H. And Zanki, M. (1986). Effective dose equivalents for photon exposure from plane sources on the ground. *Radiat. Prot. Dosim*. 14,299-310

Kessaratikoon, P. and Awaekechi, S. (2008) Natural radioactivity measurement in soil samples collected from municipal area of Hat Yai District in Songkhla Province, King Mongkut's Institute of technology Ladkrabang Science Journal, 8(2) 52-58.

Kocher, D.C and Sjoreen,A.L (1985). Dose-rate conversion factors for external exposure to photon emitters in soil. *Health Phys.* 48,193-205.

Leung,K.C., Lau, S.Y and Poon, C.B (1990) Gamma radiation dose from radionuclides in Hong Kong soil. *J.Environmental Radioactivity.* 11,279-290.

Masok F.B, Songden D. S and Ike E.E..(2014) Prevalence and Variation of Refractive Anomalies among Patients in the Bingham University Teaching (ECWA Evangel) Hospital, Jos, Nigeria. *Journal of Biology, Agriculture and Healthcare* 4(22) 54-57

Masok F.B., Dawam R.R. and Mangset W.E (2015).Assessment of Indoor and Outdoor Background Radiation Levels in Plateau State University Bokkos Jos, Nigeria *Journal of Environment and Earth Science* 5(8):1-4.

Organization for Economic cooperation and Development (1979). Exposure to radiation from the natural radioactivity in building materials. Report by a group of experts of the OECD Nuclear Energy Agency (Paris, France: OECD).

Usikalu M.R., Anoka O.C. and Balogun F.A (2011). Radioactivity measurement of the jos tin mine tailings in Norther Nigeria. *Achives of physics research,* 2(2)80-86.

United Nation Scientific committee on the effects of Atomic Effects of Atomic Radiation (UNSCEAR)(2000). Radiation sources and effects of ionizing radiation. New York, USA: United Nations. Report of the United Nation Scientific Committee on the effect of Atomic Radiation to General Assembly.

UNSCEAR (1993). Sources and Effects of Ionizing Radiation. *Report of United Nations Scientific Committee on the Effect of Atomic Radiation*. New York: United Nations, 2,Ref 12-15.

UNSCEAR (1982). *Ionizing radiation effects.* New York: United Nations. E.82.IX.8.

Veiga, R., Sanche, N., Anjos, R.M., Macario, K., Bastos, J., Iquateny, M., et al. (2006). Measurement of natural radioactivity in Brazillian Beach sands. Radiation Measurements, 41(2), 189-196.

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