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Assessment of Naturally Occurring Radionuclide in Soil Samples from Kutayi Mining Sites in Muya Local Government Area, Niger State, Nigeria

Suleiman, I. K.

Department of Physics, Ibrahim Badamasi Babangida University Lapai, Nigeria.

*Corresponding author's email: ibsguto@gmail.com

ABSTRACT

This work examines the Kutayi mining sites with a view of assessing the activity concentration and effective dose rate of NORM (i.e. ^{40}K, ^{232}Th and ^{226}Ra) in these site absorbed in 8 soil samples collected from different areas within the Kutayi mining sites, A γ-ray spectrometry NaI (Tl) at CERT. ABU Zaria, was used to carry out the analysis of the soil samples. The result shows that, activity concentration for ^{40}K ranged from 428.9269 to 93.6236 $BqKg^{-1}$; for ^{226}Ra it ranged from 50.1738 to 13.7891 $BqKg^{-1}$ and for ^{232}Th the ranged is from 52.1095 to 18.7457 $Bq.Kg^{-1}$, the absorbed dose for ^{40}K ranged from 17.8863 to 3.9041 $ŋGy.h^{-1}$, for ^{226}Ra the range is from 23.1803 to 3.1614 $ŋGy.h^{-1}$ and for ^{232}Th range from 31.47419 to 11.3224 $ŋGy.h^{-1}$. The total mean absorbed dose rate is 42.5341 $ŋGy.h^{-1}$ and the annual effective dose range from 0.0355 $mSvy^{-1}$ (i.e. 36 – 76 $μSv.y^{-1}$), with an mean annual effective dose of 0.0522 $mSv.y^{-1}$ (i.e. 52.2 $μSv.y^{-1}$, Also the mean Radium Equivalents (Ra_{eq}) obtained ranged from 64.0280 $BqKg^{-1}$ (KT6) to 135.3245 $BqKg^{-1}$ (KT8). This results show that, the Raeq is ≤ 370 $BqKg^{-1}$ which is the requirement for soil to be used for dwellings; hence the soil from this site is suitable use for buildings. The mean H_{ext} ranged from 0.1730 $Bqkg^{-1}$ (KT6) to 0.3438 $Bqkg^{-1}$ (KT8). The maximum allowed value of (H_{ext} = 1) corresponds to the upper limit of Ra_{eq} (370 $BqKg^{-1}$) in order to limit the external gamma radiation dose from the soil to 1.5 mGy y^{-1}, i.e. index should $H_{ext} \leq = 1$. All these values for $I_α$ are below the maximum permissible value of $I_α$= 1 which corresponds to 200 $Bq.Kg^{-1}$. Hence no radiological hazard is envisaged to dwellers of the study areas and the miners working on those sites.

Keywords:
Radionuclides,
Soil mining,
Activity concentration,
Absorbed dose,
Niger state.

INTRODUCTION

Radionuclide of natural origin is present in both working and public environments, although their activity concentrations vary considerably. Exposures to natural sources are in most cases not a matter for regulatory concern. However, there are situations where exposures to natural sources may warrant consideration as to whether controls should be applied. One such situation is where the conditions are conducive to the buildup of elevated concentrations of radon in air. Another situation is the mining and/or processing of material where the activity concentrations of radionuclide's of natural origin in the material itself, or in any material arising from the process, are significantly elevated — such material, has come to be referred to as Naturally Occurring Radioactive Material (NORM). (IAEA-TECDOC-1472 – (2004)). In the past, regulatory attention has been focused mostly on exposures arising from the mining and processing of uranium ores because such activities are part of the nuclear fuel cycle. More recently, attention has been broadened to include exposures from other industrial activities involving NORM, in recognition of the potential for such activities to also give rise to significant exposures of workers and members of the public if not adequately controlled. More and more countries are now including provisions in their national legislation and regulations for the control of exposures to natural sources, and the body of radiological data on such exposures is growing rapidly. In recent times, there has been increase in the solid minerals mining in Niger State and some of the miners operate with operating license, while other operate without operating license, The areas, where the miners have been operating in recent time are in the exploitation of solid minerals such as copper, gold, quartz, limestone, diamond, tale,

gypsum, calcite topaz apatite and a host of other minerals. This work examines the Kutayi mining sites with a view of assessing the activity concentration and effective dose rate of naturally occurring radionuclides materials in these site. The exploration activities are also associated with a number of environmental degradations. One of such degradation is increase in radiation levels as a result of drilling the earth's crust in search of minerals, thereby stimulating major naturally occurring radioactive nuclei to release more radiations into the environment. Minerals are naturally occurring, solid chemical substances found in –situ in the earth's crust. A rock for example is an aggregate of several minerals. Therefore, it is of significance that the total amount of radioactivity in an environment is accurately known and kept to a level as low as reasonably achievable (ALARA) in order to safeguard the lives of the people, and ensure radiation- pollution free environment. Hence this work is an efforts geared towards protecting people and the environment from accumulation of higher doses of radiation. In the work, measurement of gamma radiation level in the mining sites of the selected areas was performed in the environmental laboratory using gamma spectroscopy system at the Centre for Energy Research and Training (CERT) Ahmadu Bello University (ABU), Zaria, Nigeria. This was used to assess the concentrations of NORM i.e. three most prominent primordial radionuclides, potassium, thorium and radium by determining the base line radioactivity associated with their occurrences in 8 soil samples collected from the Kutayi mining sites of in Muya Local Government area in Niger State, North Central Nigeria. We also analyzed their possible effects on human lives due to occupational and settlement exposures from the mining sites, with aim of to determine the presence and the concentration of NORM (i.e potassium, radium and thorium), by determining the base line radioactivity associated with their occurrences in the soil samples at the Kutayi mining. Finally, giving the results obtained, we made some recommendations.

MATERIALS AND METHODS

Sample Collections and Preparation

The study area is located in the Kutayi mining site in Muya Local Government area in Niger State, North Central Nigeria. A framework for the protection of the environment against the hazards of radiations from the minerals mining requires a logical methodology for proper assessment of the dose rate arising from the naturally occurring radionuclide. The methodology that was employed in carrying out this work includes careful collection of soil samples (of about 1 kg each) from the mining site as shown in Figure 1, initially filled into polyethylene bags separately from respective points in equal measures sealed and labeled for easy of identification and transported to CERT ABU Zaria, Nigeria, for laboratory analysis. In the laboratory, the soil samples were put in an oven at a temperature of 105°C to allow for drying overnight in order to remove any available moisture. After drying, the samples were crushed and sieved with a mesh having holes each of diameter of 2mm in order to remove organic materials, stones and lumps. Thereafter, the homogenized samples were packed to fill cylindrical plastic beakers of 7cm by 6cm diameter which is the same as geometry of the counting detector. This satisfies the selected optimal sample container height.(Ibeanu IGE et al (2000)). The samples were carefully sealed using vaseline, candle wax and masking tape in order to prevent trapped radon gas from escaping.They were then weighed on a digital weighing balance with a precision of ±0.01g . Each plastic beaker accomodates approximately 300g of the soil sample. The sealed samples were kept for a minimum period of 30 days so as to allow for ^{226}Ra and its short-lived progenies to reach secular radioactive equilibrium before gamma counting(Okeyode IC, Akanni AO (2009;2(7)). The samples taken from Kutayi are labeled as KT1- KT8.

Figure 1a: Kutayi Mining Site

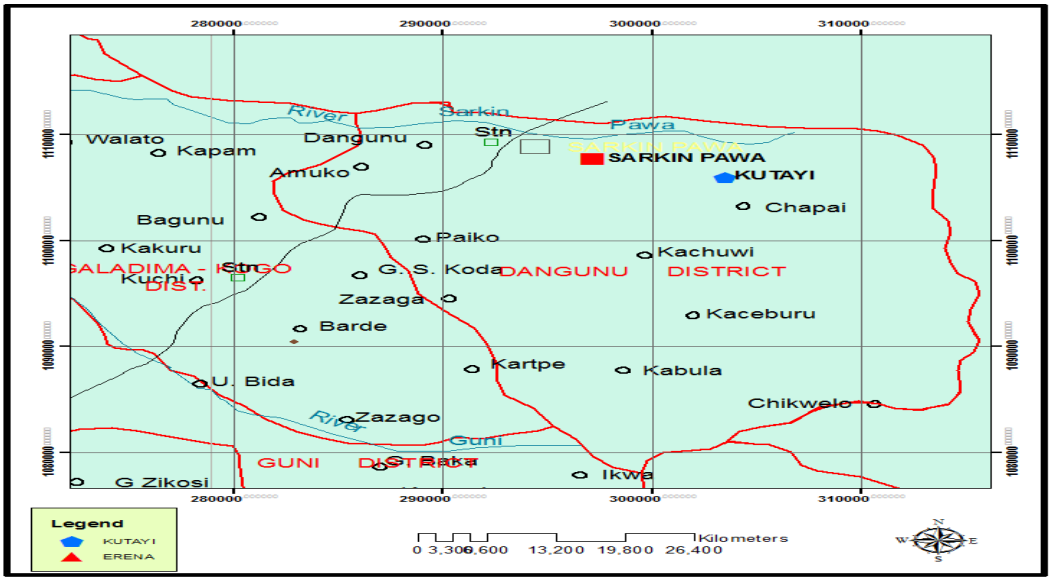

Figure 1b: Map of Kutayi Mining Site

The Experimental Set-up and Procedures for Sodium Iodine Thallium (NaI (Ti)) Detector Gamma Spectroscopy System

The gamma-ray spectrometry operation of the NaI(TI) system was done in four procedures; i.e Initial Procedure, Startup Procedures, Spectrum Acquisition Procedure and Shut Down Procedure.

The initial procedure was to ensure equipment settings were adhered to in terms of voltage supply to the equipment regulation as specified, however the initial high voltage supply was switch off.

The startup procedure was to ensure that the operator was consciously starting the experiment by turning on the set up from the power button to booting of the computer according to laid down regulations. The

operating voltage for this equipment which was given as 900 volts was attained by turning the control knob in steps of 100, until one attains the desired level of 900 Volts was attained.

The spectrum acquisition procedure which puts the set up in the spectra acquisition mode was carefully executed. After the computer booting process, the acquisition command was preset by setting the live time limits (which was about 29000 seconds i.e 8 hours 3 minutes 20 seconds), then the analog –to- digital converter (ADC) set up and the manual control to adjust the amplifier gain was setup according to specification and finally the startup command was given to commence counting for the background of the sample, for a specified time limit. The acquired spectrum and values of the live time were duly recorded in the already created save medium.

After the completion of the experiment, the shutdown command or procedure allows for proper demobilization of the equipment, in accordance with the specified protocol, most especially the stepwise reduction of the voltage level from the highest operating point of 900 volts down to the 0 level. Then the computer was shut down.

NaI (TI) gamma spectroscopy detection is one of the most preferred ways, to characterize dispersed radionuclides in or on the soil to ascertain possible changes in the environmental radioactivity. Most radiation measurement systems in nuclear science and technology use pulse height analysis to sort out different radiation energies striking the detector. This is called pulse height or energy spectrometry. It is used to identify the emission of unknown radionuclides and discriminate against background radiation sources, scattered radiation, etc. Pulse height spectrometry is used to examine the amplitudes of the signal (i.e. electrical current or light) from a radiation detector in order to determine the energies or for counting those detectors that provide output signals with amplitudes proportional to radiation energy detected.

RESULTS AND DISCUSSION

The peak area of each energy in the spectrum was used to compute the activity concentrations in each of the soil sample by the use of the equation (1):

$$C(Bq.kg^{-2})=Cn/C_{fk} \quad (1)$$

where C = activity concentration of the radionuclides in the sample given in $BqKg^{-1}$ Cn = Count rate (count per second) = count per second (cps) = Net/Live time. C_{fk} = calibration factor of the detecting system.

Calibration and Efficiency Determinations

Calibration of the system for the energy and efficiency were done with two calibration point source, Cs-137 and Co-60. These were done with the amplifier gain that gives 72% energy resolution for the 66.16 Kev of Cs-137 and counted for 30 minutes.

Standards to check for the calibration

The standards used to check for the calibration are the IAEA Gamma Spectrometric reference materials RGK-1 for K-40, RGU -1 for the Ra-226 (Bi – 214 peak) and RTG -1 For Th-232 (Ti -208). Background area count corresponding to the three radionuclides (i.e. ^{40}K, ^{226}R &^{232}Th) were measured and the evaluation of the results evaluated. The background count rate was done for 29000 seconds and the results obtained are given Table (1):-

Table 1: Background count rate used in the evaluations of the samples.

Serial	Isotope	Background Count (CPS)	Background Count (Bq/kg)
1.	^{40}K	0.2219± 0.017	345.1011±25.5940
2.	^{226}R	0.0229± 0.0109	26.5353± 12.6304
3.	^{232}Th	0.01202± 0.0078	137.0582± 8.8940

The gross area count $G_c$is related to the area count by through the expression (Okeyode IC and Akanni AO -2009).

$$N_c = G_c – B_c \quad (2)$$

where B_c is the background area count, (area count recorded by the detector in the absence of the samples). Using equation (2), the net area counts N_c was calculated from the gross area counts G_c generated by the gamma spectroscopy system. Consequently, the net count per second (cps) was also calculated for the three radionuclides (^{40}K, ^{226}R & ^{232}Th).

Activity Concentrations

The activity concentrations for the natural radionuclides in the measured samples were computed using the following relation (Okeyode IC and Akanni AO (2009).

$$A_c=\frac{Nc}{Lt}\sigma - 1 \quad (3)$$

where L_t is the lifetime of the counting, and σ is the conversion factor. It is constant for each radionuclide at a constant geometry and it is the characteristics of the efficiency of NaI (TI) detector assembly used in the analysis of the sample.

In Table 2, we presents the values of the conversion factor (σ) for the ^{40}K, ^{226}R and ^{232}Th (Umar AM, Onimisi MY, Jonah SA 2012).

Table 2: Values of the conversion factor (σ) for the ^{40}K, ^{226}R and ^{232}Th

Serial	Nuclides	CPS/Bq-kg^{-1}	Gamma ray line (KeV)
1.	^{40}K	0.000643	1460
2.	^{226}R	0.000863	1764
3.	^{232}Th	0.000877	2614.5

All the raw data obtained from the detector were converted to conventional units using calibration factors to determine the activity concentrations of ^{40}K, ^{226}R and ^{232}Th respectively. Using equation (3), the activity concentrations were calculated and the results obtained are presented in Table (3) .

Table 3: Activity Concentration of ^{40}K, ^{226}Ra and ^{232}Th in Kutayi Mining Site Area

Serial	Soil Sample ID	Activity Concentration of ^{40}K in Bqkg^{-1}	Activity Concentration of ^{226}Ra in Bqkg^{-1}	Activity Concentration of ^{232}Th in Bqkg^{-1}	Total Activity Concentration in Bqkg^{-1}
1.	KT1	293.0016	20.0464	34.8917	347.9397
2.	KT2	341.2131	19.6987	40.8210	401.7328
3.	KT3	277.7605	13.7891	46.5222	338.0718
4.	KT4	93.6236	15.0637	33.9795	142.6668
5.	KT5	146.9673	18.0765	34.3216	199.3654
6.	KT6	126.4386	19.2352	24.5154	170.1892
7.	KT7	428.9269	50.1738	18.7457	497.8464
8.	KT8	342.7683	34.4148	52.1095	429.2926
9.	Total	2045.6999	190.4982	285.9066	2527.1047
10.	Mean	255.7125	23.8123	35.7383	315.8881

Absorbed Dose Rates (D)

The Absorbed Dose is the energy imparted by radiation per unit mass of irradiated material. The gray **(Gy),** which has units of (j/ kg), is the SI unit of absorbed dose, and is the amount of radiation required to deposit 1 joule of energy in a kilogram of any kind of matter. The external absorbed dose rate D (ŋGy.h^{-1}) due to gamma radiation in air at 1 meter height above the ground level due to activity concentrations of ^{40}K, ^{226}R and ^{232}Th for the 7 soil samples were evaluated based on international standard guide lines using equation (4) (UNSCEAR . No.224, NY 2000) below.

$$D\ (\text{ŋGy.h}^{-1}) = 0.0417A^{40}{}_{K} + 0.462A^{226}{}_{Ra} + 0.604A^{232}{}_{Th} \quad (4)$$

where A^{40}K, A^{226}R and A^{232}Th; are the activity concentrations of ^{40}K, ^{226}R and ^{232}Th respectively in Bq.kg^{-1}. The conversion factors 0.0417, 0.462 and 0.604 are expressed in ŋGy.h^{-1}/ Bq.kg^{-1}**.** The absorbed dose rates in air are usually related to human absorbed dose in order to assess radiological implications. Hence, Table (4) and figure (3) presents the results of the external Absorbed Dose rate D (ŋGy.h^{-1}) in air at 1m above the ground level due to activity concentrations of ^{40}K.

Table 4: Absorbed dose rate D (ŋGy.h^{-1}) of ^{40}K, ^{226}R and ^{232}Th in Kutayi mining Site Area

Serial	Sample ID	^{40}K(ŋGy.h^{-1})	^{226}Ra(ŋGy.h^{-1})	^{232}Th(ŋGy.h^{-1})	Total D (ŋGy.h^{-1})
1.	KT1	12.2182	9.2614	21.0746	42.5542
2,	KT2	14.2286	3.1614	24.6559	42.0459
3.	KT3	11.5826	6.3706	28.0994	46.0526
4.	KT4	3.9041	6.9594	20.5236	31.3871
5.	KT5	6.1285	8.3513	20.7302	35.2100
6.	KT6	5.2725	8.8867	14.8073	28.9665
7.	KT7	17.8863	23.1803	11.3224	52.3890
8.	KT8	14.2934	15.8996	31.4741	61.6671
9.	Total	85..5142	82.0707	172.6875	340.2724
10	Mean	10.6893	10.2588	21.5859	42.5341

Annual Effective Dose Rates (E_d)

To estimate the annual effective dose rates, the conversion coefficient from absorbed dose in air to effective dose ($0.7Sv.Gy^{-1}$) and outdoor occupancy factor (0.2) proposed by (UNSCEAR 2000; Harb et al., 2010 and (Agbalagba et al, 2011)) were used. In this work therefore, we calculated the annual effective dose rates ($mSv.yr^{-1}$) using their formula:

Annual effective dose rate (mSv/yr) (E_d) =

E_d = D (ŋGy.h^{-1})× 8760 (hr.y^{-1}) ×0.2 × (0.7 x 10^3 mSv) x (10^9ŋGy)$^{-1}$ (5)

where 8760 (i.e. 365 x 24 hours of the day) is the numbers of hours in one year.

Equation (5.5) simplifies into such that,

$E_d = D \times 1.21 \times 10^{-3}$ (mSv/yr) (6)

where E_d is the annual effective dose rate in $(mSv.y^{-1})$and D is the value of absorbed dose rate earlier calculated from equation (4). Table (5) and figure (4) present the calculated Annual Effective Dose Rates (E_d) $(mSv.y^{-1})$ for the investigated soil samples.

Table 5: Annual Effective Dose Rates $E_d(mSv.y^{-1})$ for Kutayi Area

Serial	Sample ID	$^{40}K(mSv.y^{-1})$	$^{226}R(mSv.y^{-1})$	$^{232}Th(mSv.y^{-1})$	Total D $(mSv.y^{-1})$
1.	KT1	0.0150	0.0114	0.0258	0.0522
2.	KT2	0.0174	0.0039	0.0302	0.0516
3.	KT3	0.0143	0.0078	0.0345	0.0565
4.	KT4	0.0048	0.0085	0.0252	0.0385
5.	KT5	0.0075	0.0102	0.0254	0.0432
6.	KT6	0.0065	0.0109	0.0182	0.0355
7	KT7	0.0219	0.0284	0.0139	0.0642
8.	KT8	0.0175	0.0195	0.0386	0.0756
9	Total	0.1049	0.1006	0.2118	0.4173
10	Mean	0.0131	0.0126	0.0265	0.0522

Radium Equivalent

The Magnitude of radiation exposure from natural soil materials is strictly connected with the radium, thorium and potassium contents in the soil material and also on ventilation conditions; hence the Ra-equivalent concentration Ra_{eq} is a useful and instructive quantity which is internationally accepted parameters that is applied to describe the suitability or otherwise of a soil material for construction or farming purposes. The radium equivalent in the samples was estimated using equation (7):

$Ra_{eq} = C_{Ra} + (C_{Th} \times 1.43) + (C_k \times 0.077) \leq 370$ Bqkg $^{-1}$ (7)

The value of this parameter should be less than 370 $Bqkg^{-1}$ so as to keep the annual radiation dose below 1.5 mGy y^{-1} (UNSCEAR 2000). The results obtained for Ra_{eq} are presented in Table (6) and figure (5). The results obtained shows that, the mean radium equivalents ranged from 82.7770 $BqKg^{-1}$ (ER4) to 171.9653 $BqKg^{-1}$(ER2).The results show that the recommended radium equivalent concentration of ≤ 370 $BqKg^{-1}$ for soil materials to be used or dwellings by as by OECD (Organization for Economic Cooperation Development) and cited by Ahmad Hussein, (1998) is met by the soils collected around the mine sites. This behaviour of radium equivalent activity is similar to that of radiation dose rate i.e. if the value of absorbed dose rate is high, the value of radium equivalent activity is also high and vice-versa.

Table 6: Radium Equivalent in the Kutayi Mining Site.

Soil Sample ID	Radium Equivalent Ra_{eq} of the Soil Samples Bqkg-1
KT1	92.5026
KT2	104.3461
KT3	101.7035
KT4	70.8634
KT5	78.4728
KT6	64.0280
KT7	110.0076
KT8	135.3245

External Hazard Index

The external hazard index (H_{ext}) is a criterion used for evaluation of external exposure to gamma radiation in the air. This has served as safety criterion in many countries of the world. It was proposed by Krisiuk et al (1971) and supported by Stranden (1976) and was used by Berektka and Mathew in 1985. In order to limit the external gamma radiation dose from the soil materials to 1.5 mGy y^{-1} this index should be equal to or less than unity ($H_{ext} \leq = 1$). The maximum allowed value (H_{ext} = 1) corresponds to upper limit of Ra_{eq} (370 $BqKg^{-1}$). (Beretka and Matthew), A widely used hazard index (reflecting external exposure) called the external hazard index Hex is defined as follows (UNSCEAR 2000).

$H_{ex} = C_{Ra}/370 + C_{Th} / 259 + C_k/4810$ … .(8)

The results obtained are shown in Table 7 and figure 6**.** The mean external hazard index ranged from 0.2236 $Bqkg^{-1}$ (ER4) to 0.5003 $Bqkg^{-1}$ (ER6).

Table 7: External Hazard index in Kutayi Mining Site of the Soil Samples

Soil Sample ID	External Hazard index of the Soil Samples
KT1	0.2498
KT2	0.2817
KT3	0.2746
KT4	0.1914
KT5	0.2120
KT6	0.1730
KT7	0.2972
KT8	0.3438

Internal Hazard Index

Radon and its short lived progeny are also hazardous to the respiratory organs. Thus in addition to the external hazard index, internal exposure to radon and its daughter progenies is quantified by the internal hazard index H_{in} which is given by the equation (UNSCEAR 2000) :

$H_{in} = C_{Ra}/185 + C_{Th}/259 + C_k/4810$ …… (9)

The values of the indices (H_{ex}, H_{in}) must be less than unity for the hazard to be negligible (Agbalagba et al 2011). Hence results obtained are shown in Table 8 and figure 7.

Table 8: Internal Hazard Index of the Soil Samples

Soil Sample ID	Internal Hazard Index of the Soil Samples
KT1	0.3040
KT2	0.5425
KT3	0.3118
KT4	0.2321
KT5	0.2608
KT6	0.2250
KT7	0.4328
KT8	0.4585

Excess Alpha Radiation

The use of soils from and around these mining sites may pose external radiation and internal hazard to the dwellers and miners as a result of inhalation of radon and its decay products, which are predominantly alpha emitters. The excess alpha radiation due to radon inhalation originating from soil materials is estimated using the relation below (Isinkaye and Shitta, 2009):

$I_\alpha = C_{Ra}/ 200$ … (10)

The mean value of excess alpha radiation (I_α)calculated in this work ranged from 0.1165 $Bq.Kg^{-1}$ to 0.3766 $Bq.Kg^{-1}$, These results obtained are shown in Table 9 and figure 8**.** All these values for I_α are below the maximum permissible value of I_α=1 which corresponds to 200 $Bq.Kg^{-1}$. It can therefore be said that no radiological hazard is envisaged to dwellers and miners in the of study areas.

Table 9: Excess Alpha Radiation of the soil samples in Kutayi Mining Site

Soil Sample ID	Excess Alpha Radiation of the Soil Samples
KT1	0.1002
KT2	0.0985
KT3	0.0690
KT4	0.0753
KT5	0.0904
KT6	0.0962
KT7	0.2509
KT8	0.1721

Recommended Dose Limit Exposure to Natural Radiation Sources

The Table 10 below gives an average worldwide exposure to natural radiation sources for occupational persons and member of the public.

Table 10: Recommended Dose Limit Exposure to Natural Radiation Sources.

Application	Dose Limit	
	Occupational Exposed Person	Member of the Public
Effective Dose	20 mSv per year average over 5 consecutive calendar years	1 mSv in a year
Equivalent dose to :		
1. Lens of the eye	150 mSv in a year	15 mSv in a year
2. Skin	500 mSv in a year	50 mSv in a year
3. Hands and Feet	500 mSv in a year	No limit specified

Source: HRD-WHS-GUI-144.6 Appendix C (2012 October).

Note 1: With the further provision that the effective dose must not exceed 50mSv in any single year (provided the 100 mSv (max) dose averaged over 5 years is maintained). Recommended tissue weighting factors are listed in the Radiation Safety guidelines to determine whole body dose and tissue relationship.

Discussion

The method of gamma spectrometry was used to measure the radioactivity concentration of soil samples collected from the mining sites of Kutayi in Muya Local Government area of Niger State, North Central Nigeria. The result shows that, the highest radioactivity concentration of ^{40}K was found in soil sample KT7 with 428.9269 BqKg^{-1} this high value could be due to the presence of abundant radioactive minerals such as kaolinite, feldspars and so on in the sample. The radioactivity concentration order was followed by soil sample KT8 with 342.7683 Bqkg^{-1}. The least radioactivity concentration of ^{40}K was found in soil samples KT4 with 93.6236 Bqkg^{-1} .The highest radioactive concentration of ^{226}Ra was found in soil sample KT7 with 50.1738 Bqkg^{-1}. This high value of ^{226}Ra concentration could be due to high presence of uranium minerals such as uraninite, zircon, and monazite and so on. The radioactivity concentrations orders of ^{226}Ra were followed by soil samples KT8 and KT1 with 34.4148 and 20.0464 Bqkg^{-1} respectively. Soil sample KT34 had the lowest radioactivity concentration of 13.7891 Bqkg^{-1}.Also, the highest radioactive concentration of ^{232}Th was found in soil sample KT8 with 52.1095 Bqkg^{-1}. This could be due to presence of abundant radioactive thorium minerals such as monazite, zircon and thorianite (Okeyode et al., 2009).The least radioactivity concentration of ^{232}Th was also found in soil sample KT7 with 18.7457 Bqkg^{-1}.The result also shows that the total concentration of ^{266}Ra is 190.4982 BqKg^{-1} which is less than that of ^{232}Th which has a total concentration of 285.9066 BqKg^{-1}, while ^{40}K leads the table of radioactivity concentrations with total value of 2045.6999 BqKg^{-1}.

From Table 4, it shows that the absorbed dose rate due to the three radionuclides is highest for soil sample KT8 with absorbed dose rate of 61.6671 ŋGy.h^{-1}, this might be due to accumulation of mineral sands from different mining sites. The average absorbed dose rate of the soil samples is 42.5341 ŋGy.h^{-1}.According to Table 4, ^{232}Th had the highest value of total absorbed dose rate of 172.6875 ŋGy.h^{-1} among the three radionuclides detected in the soil samples collected, thus it had the highest dose level in the study areas follow by ^{40}K which has the total absorbed dose rate of 85.5142 ŋGy.h^{-1}, while ^{226}R had the least total absorbed dose rate of 82.0707 ŋGy.h^{-1}.

From Table 5, the annual effective dose rate in air at the study area ranged from from 0.0355- 0.0756 mSvy^{-1} (i.e. 36 – 76 µSv.y^{-1}) and the average annual effective dose rate in air at the study area was 0.0522 mSv.y^{-1} which is slightly less than the maximum recommended world average outdoors exposure to external terrestrial radiation. (UNSCEAR, 2000). Thus, the exposure level

for the members of general public is still within the recommended value of 1 $mSv.y^{-1}$ (IAEA, 1999) &UNSCEAR (2000; No.224 NY):).

Therefore, this is an indication that the mining activities in the study areas do not appear to have any impact on the radiation burden of the environment.

The Ra-equivalent concentration (Ra_{eq}) is a useful and instructive quantity which is an internationally accepted parameters that is applied to describe the suitability or otherwise of any soil material for construction or farming purposes, Hence the value of this parameter should be less than 370 $Bqkg^{-1}$ so as to keep the annual radiation dose below 1.5 mGy y^{-1}(UNSCEAR, 2000). The results obtained for Ra_{eq} as presented in Table 6, shows that, the mean radium equivalents obtained ranged from 64.0280 $BqKg^{-1}$ (KT6) to 135.3245 $BqKg^{-1}$ (KT8) . This results show that the recommended radium equivalent concentration of ≤ 370 $BqKg^{-1}$for soil materials to be used for dwellings by OECD (Organization for Economic Cooperation Development) Ahmad Hussein, 1998) is applicable to the soils collected around the mine sites. These behavior of radium equivalent activity is similar to that of radiation dose rate i.e. if the value of absorbed dose rate is high, the value of radium equivalent activity is also high and vice-versa.

The external hazard index (H_{ext}) is also a criterion used for evaluation of external exposure to gamma radiation in the air, this has served as a safety criterion in many countries of the world. It was proposed by Krisiuk et al (1971) and supported by Stranden (1976) and was used by Berektka and Mathew in 1985.In order to limit the external gamma radiation dose from the soil materials to 1.5 mGy y^{-1} this index should be equal to or less than unity (H_{ext}≤ = 1). The maximum allowed value (H_{ext}= 1) corresponds to upper limit of Ra_{eq} (370$BqKg^{-1}$). (Beretka and Matthew) .These results as obtained are shown in Table 7, which show that the, mean external hazard index (H_{ext}) ranged from 0.2250 $Bqkg^{-1}$ (KT6) to 0.5425 $Bqkg^{-1}$ (KT2).

T he use of soils from and around these mining sites may pose external radiation and internal hazard as a result of inhalation of radon and its decay products, which are predominantly alpha emitters to dwellers and miners. The mean internal hazard index (H_{ext}) ranged from 0.2250 $Bqkg^{-1}$ (KT6) to 0.5425 $Bqkg^{-1}$ (KT2) as shown in Table 8 and figure 7.

The mean value of Excess Alpha Radiation (I_α) ranged from 0.0690 $Bq.Kg^{-1}$ (KT3) to 0.2509 $Bq.Kg^{-1}$ (KT7) and this is presented in table 9 and figure 8. All these values for I_α are below the maximum permissible value which is I_α=1 which corresponds to 200 $Bq.Kg^{-1}$.

It can therefore be said that no radiological hazard is envisaged to dwellers of this Kutayi study areas and the miners working on these sites.

CONCLUSION

These results show's that the radiation exposure level reaching members of the public in the Kutayi Mining Sites is lower than the recommended limit value of 1 $mSv.y^{-1}$ (UNSCEAR, 2000). It can therefore be said that no radiological hazard is envisaged to dwellers of the study areas and the miners working on those sites.

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