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EVALUATION OF NATURALLY OCCURRING RADIONUCLIDE IN SOIL SAMPLES FROM SARKIN PAWA MINING SITES IN NIGER STATE, NIGERIA.

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ABSTRACT

Abstract

This study presents results of Activity Concentrations, Absorbed dose rate and the Annual Effective dose rates of naturally occurring radionuclides (^{40}K, ^{232}Th and ^{226}Ra) absorbed in 8 soil samples collected from different areas within the Sarkin Pawa mining sites in Niger State, North Central Nigeria. A laboratory γ-ray spectrometry NaI (Tl) at the Centre for Energy Research and Training (CERT), Ahmadu Bello University Zaria, was used to carry out the analysis of the soil samples. The values of Activity Concentration for ^{40}K ranged from 27.9938 ± 1.3997 to 986.4697 ± 10.5754; for ^{226}Ra it ranged from 22.7115 ± 2.2016 to 128.6210 ± 4.9826 $BqKg^{-1}$ and for ^{232}Th the ranged is from 16.3056 ± 1.7104 to 74.4583 ± 3.8769 $Bq.Kg^{-1}$. While the Absorbed Dose for ^{40}K ranged from 1.1673±0.0647 to 41.1358 ± 0.4410 $ŋGy.h^{-1}$, for ^{226}Ra the range is from 10.4927 ± 1.0171 to 59.4229 ± 2.3020 $ŋGy.h^{-1}$ and for ^{232}Th range from 9.8486 ± 1.0331 to 44.9728 ± 2.3416 ŋ $Gy.h^{-1}$. The total average Absorbed Dose rate of the 7 soil samples collected is 96.6375 $ŋGy.h^{-1}$ and the estimated Annual Effective Dose for the sampled areas range from 0.0264- 0.1425 $mSvy^{-1}$ (i.e. 26 – 143 $\mu Sv.y^{-1}$), with an average Annual Effective Dose of 0.1185 $mSv.y^{-1}$ (i.e. 118.5$\mu Sv.y^{-1}$). These results show's that the radiation exposure level reaching members of the public in the study areas is lower than the recommended limit value of 1 $mSv.y^{-1}$ (UNSCEAR, 2000). Also the mean Radium Equivalents obtained ranged from 48.1840 $BqKg^{-1}$ (SP1) to 247.5553 $BqKg^{-1}$ (SP3). These results show that the recommended Radium Equivalent Concentration is $\leq$ 370 $BqKg^{-1}$ which is the requirement ^{for} soil materials to be used for dwellings, this implies that the soil from this site is suitable use for residential buildings. The mean External Hazard Index (H_{ext}) ranged from 0.1302 $Bqkg^{-1}$ (SP1) to 0.6686 $Bqkg^{-1}$ (SP3). While 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 materials to 1.5mGy y^{-1}. That is, this index should be equal to or less than unity (H_{ext}) ranged from 0.1916 $Bqkg^{-1}$ (SP1) to 0.9766 $Bqkg^{-1}$ (SP2) .Finally, the mean value of the Excess Alpha Radiation (I_α) ranged from 0.1136 $Bq.Kg^{-1}$ (SP1) to 0.6431 $Bq.Kg^{-1}$ (PA1). 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 of the study areas and the miners working on those sites area.

1. 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 Sarkin Pawa mining sites with a view of assessing the activity concentration and effective dose rate of naturally occurring radionuclides materials in these sites. 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 Sarkin Pawa 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. Finally, giving the results obtained, we made some recommendations.

2. MATERIALS AND METHODS

2.1 SAMPLE COLLECTIONS AND PREPARATION

The study area is located in the Sarkin Pawa mining site in Rafi 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 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 Sarkin Pawa are labeled as SP1- Pa8

2.2 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

Figure 1: Sarkin Pawa Mining Site Area.

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.

3. RESULTS AND DISCUSSION

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

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

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.

3.1 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.

3.2 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 in 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).

$$N_c = G_c - B_c \qquad (2)$$

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).

3.3 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)

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

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 present 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 presents the 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) and Figure (2).

3.4 ABSORBED DOSE RATES (D)

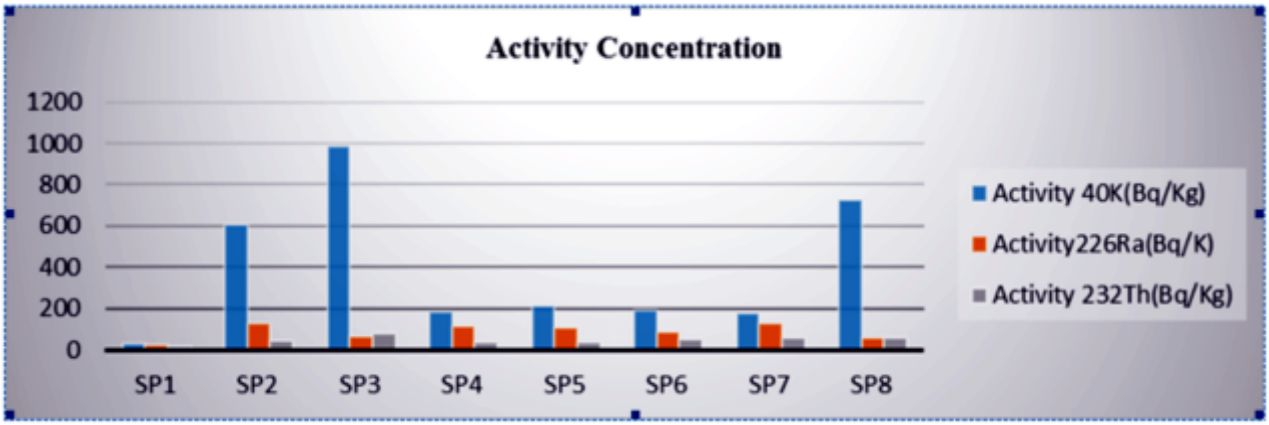
The Absorbed Dose is the energy imparted by radiation per unit mass of irradiated material. The gray **(Gy),** which has units of (j/ kg), is the SI unit of absorbed dose, and is the amount of radiation required to deposit 1 joule of energy in a kilogram of any kind of matter. The external absorbed dose 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.

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

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

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

Sample ID	Activity ^{40}K (Bq/Kg)	Activity^{226}Ra (Bq/K)	Activity ^{232}Th (Bq/Kg)	Total Activity (Bq/Kg)
SP1	27.9938 ±1.3997	22.7115 ± 2.2016	16.3056± 1.7104	67.0109 ± 5.3117
SP2	605.9098± 7.1540	128.6210 ±4.9826	40.2509 ± 2.6226	774.7817 ± 14.7592
SP3	986.4697 ±10.5754	65.1217 ±2.2016	74.4583± 3.8769	1126.0497 ±16.6539
SP4	185.2255 ±12.9082	111.4716±4.4032	38.8825 ±2.9647	335.5796 ± 20.2761
SP5	208.5537 ±6.6874	106.6049±4.9826	34.7777 ±2.2805	349.9363± 13.9505
SP6	191.4463 ±6.9984	88.0649 ±3.2445	49.7149 ± 2.1665	329.2261± 12.4094
SP7	175.1167 ± 6.5319	125.2607 ± 4.4036	54.9601± 1.7104	355.3375 ±12.6459
SP8	727.6827± 9.0203	58.1692± 2.7810	55.9863± 1.9384	841.8382 ± 13.7397



KEY: Series 1= 40K ; Series 2 = 226Ra and Series = 232Th

Figure 2: Activity Concentration of 40K, 226Ra and 232Th in Pandogari Mining Site Are

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, ^{226}R and ^{232}Th for the 7 soil samples investigated.

3.5. 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 (msv.y^{-1})

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

E_d = D (ŋGy.h^{-1}) x 8760 (hr.y^{-1}) x 0.2 x (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.

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

Table 4: Absorbed dose rate D (ŋGy.h^{-1}) of the investigated Soil Samples in air at 1m above the ground level due to activity concentrations of ^{40}K, ^{226}R and ^{232}Th for the 8 sample.

Sample ID	^{40}K (ŋGy.h^{-1})	^{226}Ra (ŋGy.h^{-1})	^{232}Th (ŋGy.h^{-1})	Total D (ŋGy.h^{-1})
SP1	1.1673 ±0.0647	10.4927 ± 1.0171	9.8486± 1.0331	21.5086± 2.1149
SP2	25.2664± 0.2983	59.4229 ± 2.3020	24.3115 ± 1.5841	109.0008± 4.1844
SP3	41.1358±0.4410	30.0862 ±1.0171	44.9728± 2.3416	116.1948 ±3.7997
SP4	7.7239 ±0.5383	51.4999±2.0342	23.4850 ±1.7907	82.7043 ± 4.3632
SP5	8.6967 ±0.2789	49.2515±2.3020	21.0057 ±1.3774	78.9537±3.9583
SP6	7.9833 ±0.2918	40.6860 ±1.4990	30.0278 ± 1.3086	78.6971± 3.0994
SP7	7.3024 ±0.2724	57.8704 ± 2.0345	33.1959± 1.0331	98.3687 ±3.3400
SP8	30.3443± 0.3761	26.8742± 1.2848	33.8157± 1.1708	91.0342 ± 2.8317

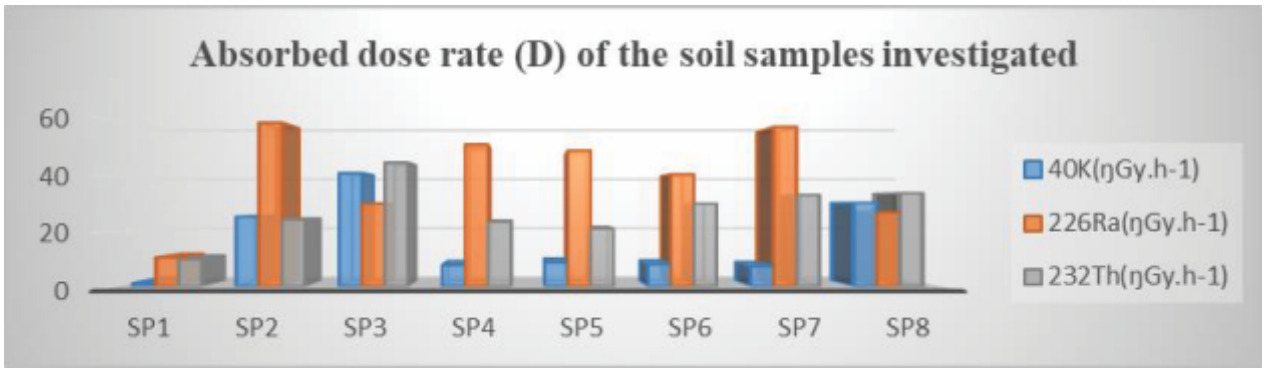


Fig.3: Absorbed dose rate D (ηGy.h^{-1}) of ^{40}K, ^{226}R and ^{232}Th for the 8 soil samples investigated.

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.

3.6. 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 Raeq 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):

$Raeq = CRa + (Cth \times 1.43) + (Ck \times 0.077) \leq 370$ 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 Raeq 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 $\leq$ 370 BqKg-1 for soil materials to be used or dwellings by OECD (Organization for Economic Cooperation and Development) and cited by Ahmad Hussein, (1998) is met by the soils collected around the mine sites. This behavour 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-

Table 5: Annual Effective Dose Rates (E_d) in (mSv.y^{-1}) the 8 Soil Samples

Sample ID	^{40}K ($mSv.y^{-1}$)	^{226}R ($mSv.y^{-1}$)	^{232}Th ($mSv.y^{-1}$)	Total ($mSv.y^{-1}$)
SP1	0.0014	0.0129	0.0121	0.0264
SP2	0.0310	0.0729	0.0298	0.1337
SP3	0.0504	0.0369	0.0552	0.1425
SP4	0.0095	0.0632	0.0288	0.1014
SP5	0.0107	0.0604	0.0258	0.0968
SP6	0.0098	0.0499	0.0368	0.0965
SP7	0.0090	0.0710	0.0407	0.1206
SP8	0.0372	0.0330	0.0415	0.1116

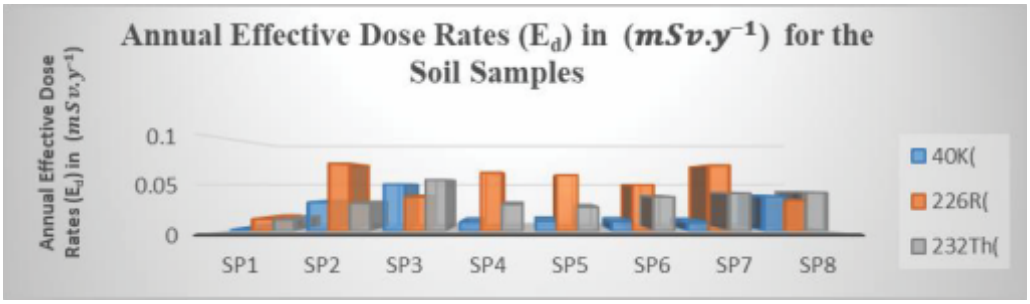


Fig.4: Annual Effective Dose Rates (Ed) in **(mSv.y^{-1})** for the Soil Samples investigated.

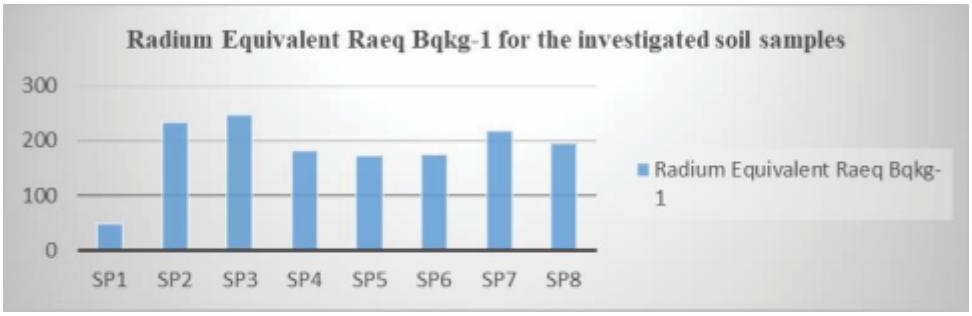


Figure 5. Radium Equivalent Raeq Bqkg-1 for the investigated soil samples.

versa.

Table 6: Radium Equivalent in the investigated Soil Samples.

Soil Sample ID	Radium Equivalent Ra_{eq} of the Soil Samples Bqkg-1
SP1	48.1840
SP2	232.8349
SP3	247.5553
SP4	181.3360
SP5	172.3956
SP6	173.8986
SP7	217.3376
SP8	194.2612

3.7. 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 by (UNSCEAR 2000).

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

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 of the Soil Samples

Soil Sample ID	External Hazard index of the Soil Samples
SP1	0.1302
SP2	0.6290
SP3	0.6686
SP4	0.4899
SP5	0.4658
SP6	0.4697
SP7	0.5871
SP8	0.5246

Table 8: External Hazard Index of the Soil Samples

Soil Sample ID	External Hazard Index of the Soil Samples
SP1	0.1916
SP2	0.9766
SP3	0.8446
SP4	1.0951
SP5	0.7539
SP6	0.7077
SP7	0.9256
SP8	0.6818

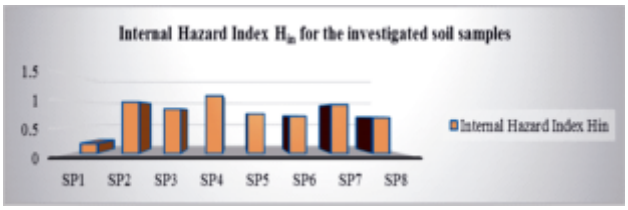


Fig 7: Internal Hazard Index H_{in} for the investigated soil samples.

3.8. 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) :

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

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.

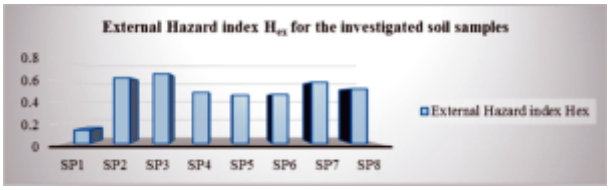


Figure 6: External Hazard index H_{ex} for the investigated soil samples.

3.9. 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):

$$I_\alpha = C_{Ra}/200 \qquad (10)$$

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 study areas.

Table 9 : Excess Alpha Radiation of the soil samples

Soil Sample ID	Excess Alpha Radiation of the Soil Samples
SP1	0.1136
SP2	0.6431
SP3	0.3256
SP4	0.5573
SP5	0.5330
SP6	0.4403
SP7	0.6263
SP8	0.2908

Figure 8: Excess Alpha Radiation I_α for the investigated soil samples.

4.0 RECOMMENDED DOSE LIMIT EXPOSURE TO NATURAL RADIATION SOURCES

Table 10 below gives an average worldwide exposure to natural radiation sources for occupational persons and members 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**.**

5.0 DISCUSSION

The method of gamma spectrometry was used to measure the radioactivity concentration of soil samples collected from the mining sites of Sarkin Pawa in Rafi 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 SP3 with 986.4697 $BqKg^{-1}$ 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 SP8 with 727.6827 $Bqkg^{-1}$. The least radioactivity concentration of ^{40}K was found in soil samples SP1 with 27.9938 $Bqkg^{-1}$ .The highest radioactive concentration of ^{226}Ra was found in soil sample SP2 with 128.6210 $Bqkg^{-1}$(Table 3, Fig.2). 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 SP7 and SP4 with 127.2607 and 111.4716 $Bqkg^{-1}$ respectively. Soil sample SP1 had the lowest radioactivity concentration of 22.7115 $Bqkg^{-1}$.Also, the highest radioactive concentration of ^{232}Th was found in soil sample SP3 with 74.4583 $Bqkg^{-1}$(Table 3 and Fig.2).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 SP1 with 16.3056 $Bqkg^{-1}$.The result also shows that the total concentration of ^{266}Ra is 706.0255 $BqKg^{-1}$ which is higher than that of ^{232}Th which has a total concentration of 365.3363 $BqKg^{-1}$, while ^{40}K leads the table of radioactivity concentrations with total value of 3108.3982 $BqKg^{-1}$.

From Table 4, and Fig 3, it shows that the absorbed dose rate due to the three radionuclides is highest for soil sample SP3 with absorbed dose rate of 116.1948 $ŋGy.h^{-1}$, this might be due to accumulation of mineral sands from different mining sites. The average absorbed dose rate of the soil samples is 96.6375 $ŋGy.h^{-1}$.According to Table 4, ^{226}Ra had the highest value of total absorbed dose rate of 326.1838 $ŋGy.h^{-1}$ among the three radionuclides detected in the soil samples collected, thus it had the highest dose level in the study areas followed by ^{232}Th which has the total absorbed dose rate of 1220.6620 ŋ $Gy.h^{-1}$, while ^{40}K had the least total absorbed dose rate of 129.6201 $ŋGy.h^{-1}$.

From Table 5 and figure 4, the annual effective dose rate in air at the study area ranged from 0.0264 - 0.1425 $mSv.y^{-1}$ and the average annual effective dose rate in air at the study area was 0.1185 $mSv.y^{-1}$ 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 48.1840 $BqKg^{-1}$ (SP1) to 247.5553 $BqKg^{-1}$ (SP3). 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 and Development) Ahmad Hussein, 1998) is applicable to the soils collected around the mine sites. These behavour 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 ($H_{ext} \leq = 1$). 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 and figure 6, which show that the, mean external hazard index (H_{ext}) ranged from 0.1302 $Bqkg^{-1}$ (SP1) to 0.6686 $Bqkg^{-1}$ (SP3).

The 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 0.1916 $Bqkg^{-1}$ (SP1) to 1.0951$Bqkg^{-1}$ (SP4) as shown in Table 8 and figure 7.

The mean value of Excess Alpha Radiation (I_α) ranged from 0.1136 $Bq.Kg^{-1}$ (SP1) to 0.6431 $Bq.Kg^{-1}$ (PA1) 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 Sarkin Pawa study areas and the miners working on these sites.

6.0 CONCLUSION

This study presents results of Activity Concentrations, Absorbed dose rate and the Annual Effective dose rates of naturally occurring radionuclides (^{40}K, ^{232}Th and ^{226}Ra) absorbed in 8 soil samples collected from different areas within the Sarkin Pawa mining sites in Niger State, North Central Nigeria.

A laboratory γ-ray spectrometry NaI (Tl) at the Centre for Energy Research and Training (CERT), Ahmadu Bello University Zaria, was used to carry out the analysis of the soil samples.

The values of Activity Concentration for ^{40}K ranged from 27.9938 ± 1.3997 to 986.4697 ± 10.5754; for ^{226}Ra it ranged from 22.7115 ± 2.2016 to 128.6210 ± 4.9826 $BqKg^{-1}$ and for ^{232}Th the ranged is from 16.3056 ± 1.7104 to 74.4583 ± 3.8769 $Bq.Kg^{-1}$.

While the Absorbed Dose for ^{40}K ranged from 1.1673±0.0647 to 41.1358 ± 0.4410 ŋ$Gy.h^{-1}$, for ^{226}Ra the range is from 10.4927 ± 1.0171 to 59.4229 ± 2.3020 ŋ$Gy.h^{-1}$ and for ^{232}Th range from 9.8486 ± 1.0331 to 44.9728 ± 2.3416 ŋ $Gy.h^{-1}$, the total average Absorbed Dose rate of the 7 soil samples collected is 96.6375 ŋ$Gy.h^{-1}$ and the estimated Annual Effective Dose for the sampled areas range from 0.0264- 0.1425 $mSvy^{-1}$ (i.e. 26 – 143 μ$Sv.y^{-1}$), with an average Annual Effective Dose of 0.1185 $mSv.y^{-1}$ (i.e. 118.5μ$Sv.y^{-1}$).

These results shows that the radiation exposure level reaching members of the public in the study areas is lower than the recommended limit value of 1 $mSv.y^{-1}$ (UNSCEAR, 2000).

Also the mean Radium Equivalents obtained ranged from 48.1840 $BqKg^{-1}$ (SP1) to 247.5553 $BqKg^{-1}$ (SP3). These results show that the recommended Radium Equivalent Concentration is $\leq$ 370 $BqKg^{-1}$ which is the

requirement for soil materials to be used for dwellings, this implies that the soil from this site is suitable for use for residential buildings.

The mean External Hazard Index (H_{ext}) ranged from 0.1302 $Bqkg^{-1}$ (SP1) to 0.6686 $Bqkg^{-1}$ (SP3). While 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 materials to 1.5mGy y^{-1}. That is, this index should be equal to or less than unity ($H_{ext} \leq = 1$).

Furthermore, the mean Internal Hazard Index (H_{ext}) ranged from 0.1916 $Bqkg^{-1}$ (SP1) to 0.9766 $Bqkg^{-1}$ (SP2) .Finally, the mean value of the Excess Alpha Radiation (I_{α}) ranged from 0.1136 $Bq.Kg^{-1}$ (SP1) to 0.6431 $Bq.Kg^{-1}$ (PA1). 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 of the study areas and the miners working on those sites area.

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8. COMPETING INTEREST

There is no competing interest whatsoever that could have influenced the results of this study in any manner.

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