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Radiological Dose Assessment to the Public from Mining Activities in Adamawa State, Nigeria

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Abstract: Mining activities in Adamawa is exposing the public residing around the mining environs to high radiation dose due to exposure to radioactivity. This study assessed the external and internal radiation dose received by the public as a result of mining activities in Adamawa State using sodium Iodide (NaI) detector. The activity concentration of 226Ra, 232Th and 40K in soil from four selected mining locations were determined, Microshield computer code was used in estimating external dose and Integrated Module for Bioassay Analysis (IMBA) code was used in estimating internal dose from inhalation. Result shows that, the total mean activity concentration of 226Ra, 232Th, and 40K from all mining sites are all above the UNSCEAR standard limits of 35Bq/kg 30Bq/kg and 400Bq/kg. The mean external dose rates were 1.15E-05mSv/yr, 5.36E-06mSv/yr, 3.79E-06mSv/yr, and 4.43E-06mSv/yr for mining sites S-A, S-B, S-C, and S-D. While the mean total inhalation doses were 3.68E-04mSv/yr, 3.84E-04mSv/yr, 3.64E-04mSv/yr, and 2.90E-04mSv/yr for mining sites S-A, S-B, S-C, and S-D respectively. Although the doses are lower than the ICRP recommended public dose boundary of 1mSv/yr, accumulation of low exposure dose has the possibility of resulting to stochastic effects over a long period. Attention should be given to mining location S-A and S-B due to high activity concentration, external dose and inhalation dose.

Keywords: Radiation Dose, Mining Activities, External Dose Rate, Inhalation Dose Rate, Activity Concentration, Microshield Code.

1 Introduction

Mining activities have had a negative influence on individuals and the environment even at low concentrations by facilitating the release of radioactive materials from the host material and creating an unreasonable radiation risk to human health due to the nature of the daughter radioactive products formed via gaseous decay of ^{238}U, ^{232}Th and Gamma decay of ^{40}K resulting to internal dose through inhalation and external irradiation via contribution from [1-3]. Naturally occurring radionuclides resulting from mining or any human activities constitutes both external and internal sources of radiation exposure to the members of the public, and can be found in the air we inhale, the food and water we consume via ingestion and have resulting to public health concerns [4-6]. Individuals get exposed to radiation from mining or any human activities via inhalation, Ingestion and external sources among others [7-9].

The largest contributor to radiation exposure are Radon and Thoron (^{222}Rn and ^{220}Th) which are Alpha emitters and are the daughter yields of ^{238}U and ^{232}Th commonly found in rocks and soils. These decay products releases might contaminate the air thereby delivering public radiation dose to the dwellers around the mining sites and the environs though inhalation pathway resulting to internal exposure. Also, the contribution of gamma from decay of ^{40}K constitutes external exposure [10]. Alpha (α) when breathed, ^{238}U and ^{232}Th decay, while ^{40}K decays by producing 89 percent Beta (β) and 11 percent Gamma (γ). The contribution of gamma decay of ^{40}K, on the other hand, accounts for the majority of external exposure during mining activities [11]. An exposure route is the way through which a pollutant reaches a receptor after interaction [12].

The International Commission on Radiation Protection (ICRP) has suggested a public dosage limit of 1 micro Sievert per year. new ICRP commendations are founded on the considerate foundation that there no such thing as a safe

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or harmless equal of radiation contact, since the tiniest quantity of radiation exposure has the potential to cause stochastic effects like cancer. However, in addition to maintaining below the dose limits, the basic standard of protection all exposure intensities "as low as reasonably achievable" (ALARA) was encouraged [13].

This paper focuses on performing radiological dose assessment to the public resulting from mining activities in some selected mining locations in Adamawa State. External dose evaluation to the public was performed from the measured activity concentration (AC) of ^{226}Ra, ^{232}Th and ^{40}K in soil obtained around four selected mining sites in Adamawa State using Microshield computer code. The external dose encompasses doses emanating from through external radiation or exposure to radiation sources. Several criteria are examined while evaluating external dose, including the time of exposure, distance from the source, source activity, potential shielding, and isotope, among others.

Also, internal dose to the public from inhalation of gaseous decay products of such radionuclides was assessed using Integrated Module for Bioassay Analysis (IMBA) computer code from the determined activity concentration values of ^{226}Ra, ^{232}Th and ^{40}K in soil samples obtained around four selected mining sites. Such mining activities could be potential source of radiation and radioactivity which contaminate the environment, resulting to radiation exposure. The radiation protection principles are meant to minimize radiation exposure to worker and the general public. External dose from external irradiation was evaluated using Micro shield computer code and internal dose from inhalation of gaseous decay products was assessed using Integrated Module for Bioassay Analysis (IMBA) computer code. Both assessment were performed using the measured activity concentration values of ^{226}Ra, ^{232}Th and ^{40}K in soil obtained around four selected mining locations.

2 Materials and Methods

2.1 Materials

The Sodium Iodide (NaI) detector, Global Positioning System (GPS), Ziplock Polyethylene, Shovel and Cutlasses, Disposable Gloves, Face Mask, a computer, an internet connection, Integrated Module for Bioassay Analysis (IMBA) code, and Microshield computer code.

2.2 Methods

2.2.1 Study Area

Adamawa State is situated in the Nigerian north-eastern region, having a total land mass of 39,742.12 square kilometers, occupying approximately 4.4% total land mass of Nigeria. It is situated between latitudes 80 and 110 north, and longitudes 11.50 and 13.50 east. Figure 1 presents the map of Adamawa State showing the study locations.

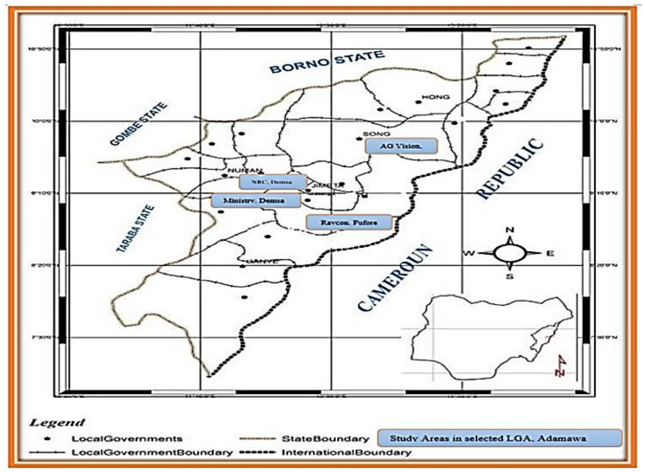

Fig. 1: Map of Adamawa State showing Boundaries point and study Areas [14].

2.2.2 Sample and Sampling Technique

Using systematic sampling techniques, fifteen (15) soil samples were collected from four quarry mining sites located 500 meters apart. To avoid cross contamination during transit, composite samples were collected using a shovel at a depth of about 10cm and placed in a sealed labeled polythene bag. To eliminate moisture, open air drying at room temperature for seven days was used, and stone samples were ground into powdery form with a mortar and pestle and sieved with a wire mesh with holes of thickness 0.5mm to achieve uniformity of sample size. About 400g of mass were held in polythene bags for 28 days to achieve secular equilibrium between ^{226}Ra, ^{232}Th, and ^{40}K and their progeny before sending to CERT Zaria for analysis. Table 1 shows the sample points for each quarry mining location, as well as their coordinates and sample identification numbers.

Table 1: Soil sample codes and coordinates.

Mining Locations	Sample Code	Sampling Coordinates	
		Northing	**Easting**
Raycon Fufore	S - A1	09^0 08' 36"	12^0 19' 09"
Raycon Fufore	S - A2	09^0 08' 29"	12^0 19' 19"
Raycon Fufore	S - A3	09^0 08' 23"	12^0 19' 04"
Raycon Fufore	S - A4	09^0 08' 39"	12^0 19' 14"
NRC Demsa	S - B1	09^0 21' 48"	12^0 11' 32"
NRC Demsa	S - B2	09^0 21' 42"	12^0 11' 28"
NRC Demsa	S - B3	09^0 21' 36"	12^0 11' 22"
NRC Demsa	S - B4	09^0 21' 53"	12^0 11' 19"
Ministry Demsa	S - C1	09^0 21' 55"	12^0 11' 23"
Ministry Demsa	S - C2	09^0 21' 51"	12^0 11' 20"
Ministry Demsa	S - C3	09^0 21' 45"	12^0 11' 17"
Ministry Demsa	S - C4	09^0 21' 59"	12^0 11' 13"

AG Vision Song	S - D1	09^0 56' 15"	12^0 37' 46"
AG Vision Song	S - D2	09^0 56' 19"	12^0 37' 39"
AG Vision Song	S - D3	09^0 56' 11"	12^0 37' 44"

2.2.3 Dose Assessment Scenario Description

The structural diagram for external and inhalation dose assessment scenarios considered in this study using the mean activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in soil from selected mining sites in Adamawa State as well as appropriate computer codes are shown in Figure 2 and Figure 3.

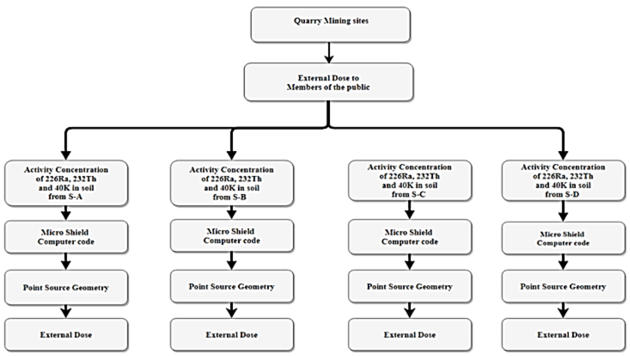

Fig.2: Summary of External Dose Assessment Scenario.

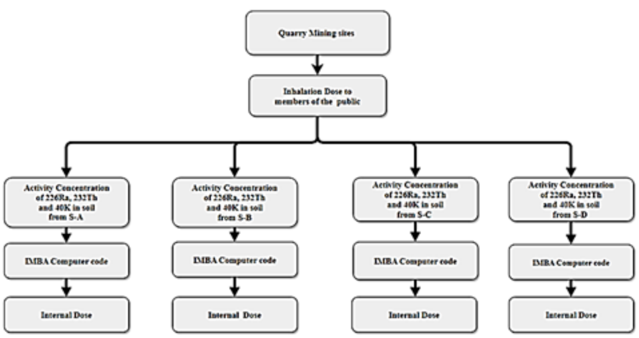

Fig. 3: Summary of internal Dose Assessment Scenario.

2.2.4 Micro Shield Computer Code

MicroShield is a photon/gamma-ray shielding and dose estimate computer code manufactured by grove software. Protection design, predicting radiation source strength, reducing human contact, and education protective ideas are all popular applications. Dose conversion factors established from AN-SI/ANS-6.1.1-1977 standards are used in the MicroShield program. The customary has been applied to assess whole-body radiation contact rates for classified workers and public. In terms of radiation safety, the computer code has become more crucial for engineers and health specialists. The programme uses the point-kernel approach to estimate gamma-ray shielding, in which the source region is partitioned into patches of smaller volume and the doses are integrated in terms of space and energy in the analysis [15]. Figure 4 shows the external dose calculation window in MicroShield code.

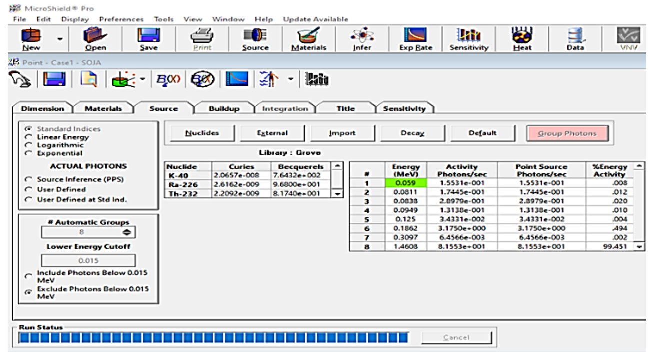

Fig.4: External dose calculation window of Microshield code [9].

2.2.5 Integrated Module for Bioassay Analysis (IMBA) Code

Integrated Module for Bioassay Analysis (IMBA) was established by Public Health England to estimate the internal radiation dosage following ingestions of radionuclides through inhalation, ingestion or absorption or bioassay quantity data. The code has two models namely Biokinetic model for bioassay sample calculations and Dosimetric models for dose calculation using activity concentration. The code was based on various ICRP Publications and Code of Federal Regulation (CFR) 835 titled Occupational Radiation Protection for reference workers and applies the wound model for dose calculations.

IMBA uses several routes of intake to estimate types of intake and maximum to estimate optimal intake from multiple measurements samples. The code allows the user to select and defined various input parameters for analysis including the indicator and associate radionuclides from the radionuclides library, measured activity concentration from intake or bioassay samples using some parameters including the particle characteristics (such as particle diameter, density, shape factor), the particle absorption type (fast, moderate and slow), absorption fraction and bioassay function among others [16]. IMBA offers defaulting standards endorsed by ICRP for convenience incase the user lacks basic knowledge or requires information about input parameters. Figure 5 shows the dose calculation window of IMBA code.

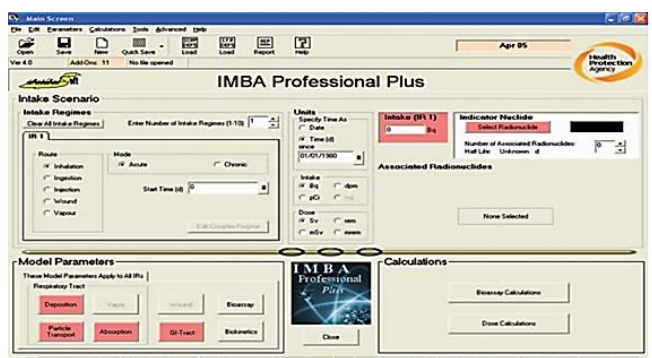

Fig. 5: IMBA Dose calculation window [10].

2.2.6 Governing Equation for External Dose Calculation using MicroShield Code

The mathematical equation that governs the estimation of the external gamma dose using MicroShield computer code based on the point-kernel isotropic point source method which was used in estimating external dose using the measured of ^{226}Ra, ^{232}Th and ^{40}K in soil is presented as [15]:

$$F = \int dE \times \frac{e^{-\mu r}}{4\pi r^2} \times C(E) \times S(E) \times B(\mu r, E) \qquad (1)$$

Where F is the total external dose rate, E is the energy of the photon, S is the intensity of the source (specific activity), C is the density of Gamma flux, r is the distance between the source and detector, μ is the attenuation coefficient, and B is the buildup factor.

2.2.7 Governing Equation for Inhalation Dose Calculation using IMBA Code

The amount of radiation absorbed by the body through inhalation or ingestion and accrues in certain tissues or organs, resulting a radiation dose is termed as internal dose. The Inhalation dose resulting from inhalation of gaseous decay products of ^{226}Ra, ^{232}Th and ^{40}K in soil were estimated using Integrated Module for Bioassay Analysis (IMBA) computer code using the measured activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in soil obtained from the four mining sites. IMBA calculates the Inhalation dose according to the following equation [16].

$$D_{int(inh)}(mSv/yr) = Co._{R} \times Inh._{R} \times Ex._{T} \times DCF._{inh} \qquad (2)$$

Where $Co._R$ is the measured activity concentration of inhaled radionuclide R (Bq/kg), $Inh._R$ is the inhalation rate by an individual decay products (1m^3/h or 1225g/hr), $Ex._T$ is the exposure time of contaminated air in (hr/y), and $DCF._{inh}$ is the dose coefficient for inhalation in (Sv/Bq).

3 Results and Discussion

3.1 Results

3.1.1 Activity Concentration in Soil

The activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in soil samples as obtained from the four selected mining sites in Adamawa State are presented in Table 2, while the mean activity concentrations for the four mining sites is shown in Figure 6.

Table 2: Activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in soil samples.

Soil Sample Code	Ra-226 (Bq/Kg)	Th-232 (Bq/Kg)	K-40 (Bq/Kg)
S - A1	88.29	78.72	1080.28
S - A2	120.29	92.67	1074.70
S - A3	104.59	92.79	941.28
S - A4	121.72	76.67	342.61
Mean (S-A)	**108.72**	**85.21**	**859.72**
S - B1	99.83	73.02	368.83
S - B2	114.29	157.24	251.34
S - B3	95.92	76.59	441.98
S - B4	144.97	81.31	527.35
Mean (S-B)	**113.75**	**97.04**	**397.38**
S - C1	104.91	110.64	295.05
S - C2	124.40	92.40	352.96
S - C3	110.38	52.92	261.69
S - C4	122.64	60.00	208.01
Mean (S-C)	**115.58**	**78.99**	**279.43**
S - D1	89.37	82.49	174.07
S - D2	75.54	64.09	45.67
S - D3	96.80	81.74	764.32
Mean (S-D)	**87.24**	**76.11**	**328.02**
Grand Mean	**107.60**	**84.89**	**475.34**

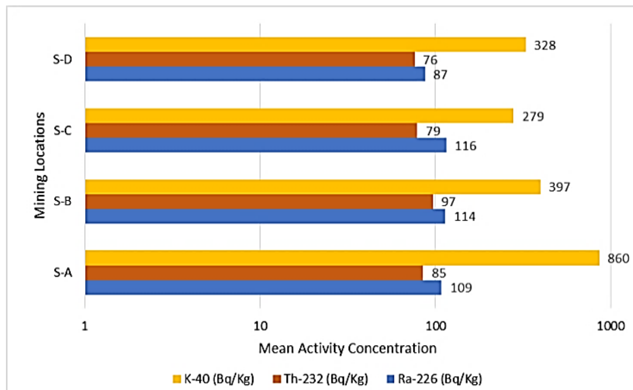

Fig.6: Mean Activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in soil samples.

From Table 2, the maximum average activity concentration (AC) value for ^{226}Ra, the occurred at S-C having mean AC value of 115.58Bq/kg followed by S-B having mean AC value of 113.75Bq/kg, while the minimum average AC occurred at S-D with mean 87.27Bq/kg. The mean values from individual mining sites are all above the UNSCEAR standard value of 35Bq/kg.

For ^{232}Th, the maximum average activity concentration (AC) value occurred at S-B and AC with values of 97.04Bq/kg, followed by S-A with AC value of 85.21Bq/kg, while the lowest value occurred at S-D with AC value of 76.11Bq/kg. The mean values from the individual mining sites are all above the UNSCEAR standard value of 30Bq/kg.

For ^{40}K, the maximum mean AC value occurred at S-A and AC value of 859.72Bq/kg, then S-B and AC value of 397.38Bq/kg, while the minimum occurred at S-C and AC value of 279.43Bq/kg. The mean AC value of ^{40}K from S-A is above the UNSCEAR recommended value of 400Bq/kg, while that of remaining three locations (S-B, S-C and S-D) are below the UNSCEAR value of 400Bq/kg.

The activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K varies across each mining sites varies with mean values of ^{226}Ra and ^{232}Th all above the UNSCEAR standard limits of 35Bq/kg and 30Bq/kg, while ^{40}K in S-A is above the world average of 400Bq/kg while those of site S-B, S-C and S-D are below the UNSCEAR values. This implies that the host community are more open to ^{226}Ra and ^{232}Th as against ^{40}K.

The total mean activity concentration of ^{226}Ra, ^{232}Th, and ^{40}K from all mining sites are all above the UNSCEAR standard limits of 35Bq/kg 30Bq/kg and 400Bq/kg.

3.1.2 External Dose Evaluation

Table 3 shows the evaluation of external dose using Microshield computer code from the measured activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in soil samples obtained from four selected mining sites in Adamawa State while Figure 7 shows the corresponding mean external doses from each mining site.

Table 3: External dose calculated from Mining sites.

Mining Sites	Soil Sample ID	External Dose rate (mSv/yr)	Mean Dose rate (mSv/yr)
S-A	S - A1	1.45E-05	1.15E-05
	S - A2	1.45E-05	
	S - A3	1.26E-05	
	S - A4	4.63E-06	
S-B	S - B1	4.97E-06	5.36E-06
	S - B2	3.42E-06	
	S - B3	5.94E-06	
	S - B4	7.10E-06	
S-C	S - C1	3.99E-06	3.79E-06
	S - C2	4.77E-06	
	S - C3	3.55E-06	
	S - C4	2.84E-06	
S-D	S - D1	2.37E-06	4.43E-06
	S - D2	6.53E-07	
	S - D3	1.02E-05	

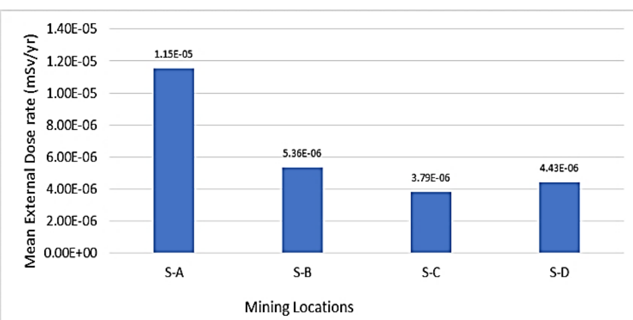

Fig.7: Mean External Dose rate from mining sites.

Table 3 shows the distribution of external dose from each sampling point of the four selected mining sites under investigation. Highest external dose of 1.45E-05mSv/yr occurred at the first two sampling points of Raycon mining site at S-A1 and S-A2. While the lowest external dose of 6.53E-07mSv/yr occurred at the second sampling points in AG Vision at S-D2. The distribution of external dose from each sampling points are mainly attributed due to the contribution from the activity concentration of ^{40}K resulting from mining activities since ^{40}K decays by discharging 89% beta and 11% Gamma, hence bulk of the external exposure are mainly from 11% Gamma decay of ^{40}K.

Figure 7 shows the distribution of mean external dose per mining site from four-selected mining location in Adamawa state. Mining site S-A has the highest external dose rate with mean value of 1.15E-05mSv/yr followed by mining location S-B with mean value of 5.36E-06mSv/yr while the lowest mean value of external dose occurred at S-C with mean value of 3.79E-06mSv/yr. The external dose rate is mainly attributed from the contribution of Gamma decay of ^{40}K resulting from mining activities, the result implies that high activity concentration is more dominant in mining site S-A and less dominant in mining site S-C. Although mean contribution of external dose are all below the recommended public dose limit of 1mSv/yr, attention should be given to mining location S-A and S-B which exhibits high chance of resulting to external dose to the public.

3.1.3 Internal Dose Evaluation

Table 4 shows the evaluation of internal dose from inhalation using Microshield computer code from the measured activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in soil samples obtained from four selected mining sites in Adamawa State while Figure 8 shows the corresponding average internal dose from each mining location.

Table 4: Internal dose due to inhalation of Radionuclides from Mining sites.

Soil Sample ID	Inhalation Dose Ra-226 (mSv/yr)	Inhalation Dose Th-232 (mSv/yr)	Inhalation Dose K-40 (mSv/yr)	Total Inhalation Dose (mSv/yr)
S - A1	1.89E-04	1.25E-04	9.67E-06	3.24E-04
S - A2	2.53E-04	1.44E-04	9.58E-06	4.07E-04
S - A3	2.10E-04	1.44E-04	8.42E-06	3.62E-04
S - A4	2.53E-04	1.22E-04	3.04E-06	3.78E-04
Mean	**2.26E-04**	**1.34E-04**	**7.68E-06**	**3.68E-04**
S - B1	1.89E-04	1.17E-04	3.22E-06	3.09E-04
S - B2	2.32E-04	2.40E-04	2.24E-06	4.74E-04
S - B3	2.00E-04	1.22E-04	3.96E-06	3.26E-04
S - B4	2.95E-04	1.26E-04	4.66E-06	4.26E-04
Mean	**2.29E-04**	**1.51E-04**	**3.52E-06**	**3.84E-04**
S - C1	2.10E-04	1.76E-04	2.60E-06	3.89E-04
S - C2	2.53E-04	1.44E-04	3.13E-06	4.00E-04
S - C3	2.32E-04	8.33E-05	2.33E-06	3.18E-04
S - C4	2.53E-04	9.61E-05	1.76E-06	3.51E-04
Mean	**2.37E-04**	**1.25E-04**	**2.46E-06**	**3.64E-04**
S - D1	1.64E-04	1.27E-04	1.52E-06	2.93E-04
S - D2	1.58E-04	8.33E-05	3.58E-07	2.42E-04
S - D3	2.02E-04	1.26E-04	6.80E-06	3.35E-04
Mean	**1.75E-04**	**1.12E-04**	**2.89E-06**	**2.90E-04**

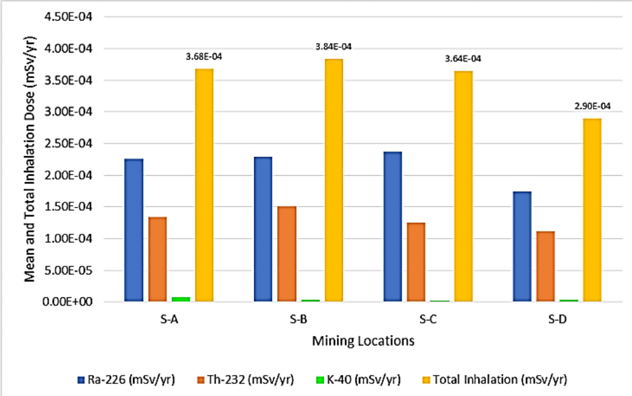

Fig. 8: Mean and total internal dose rate due to inhalation from mining locations.

From Table 4, For ^{226}Ra, the highest mean value of inhalation dose occurred at mining location S-C with value of 2.37E-04mSv/yr followed by mining locations S-B and S-A with values of 2.29E-04mSv/yr and 2.26E-04mSv/yr respectively, while the lowest mean inhalation dose occurred at S-D with value of 1.75E-04mSv/yr.

For ^{232}Th, the highest mean value of inhalation dose occurred at mining location S-B with value of 1.51E-04mSv/yr followed by mining locations S-A and S-B with values of 1.34E-04mSv/yr and 1.25E-04mSv/yr respectively, while the lowest mean inhalation dose occurred at S-D with value of 1.12E-04mSv/yr.

For ^{40}K, the highest mean value of inhalation dose occurred at mining location S-A with value of 7.68E-06mSv/yr followed by mining locations S-B and S-D with values of 3.52E-06mSv/yr and 2.89E-06mSv/yr respectively, while the lowest mean inhalation dose occurred at S-C with value of 2.46E-06mSv/yr.

Higher values of inhalation dose are attributed to ^{226}Ra and ^{232}Th than ^{40}K due to Alpha gaseous decay of ^{226}Ra and ^{232}Th which are harmful when inhaled, with negligible contribution from ^{40}K due to its nature of Beta and Gamma decay which are mainly contribution to external dose.

From Figure 8, the highest total inhalation dose occurred at S-B with inhalation dose values of 3.84E-04mSv/yr followed by S-A and S-B with inhalation dose values of 3.68E-04mSv/yr and 3.64E-04mSv/yr respectively, while the lowest total inhalation dose value of 2.90E-04mSv/yr occurred at S-D.

3.2 Discussion

Estimating radioactivity levels is very critical for protecting the population from inappropriate radiation exposure, which can fluctuate depending on human and natural activities. The amount of radioactivity measurement all over the world must assure adherence to radiation safety procedures Agbalagba *et al.* [11]. Findings from this study have shown that the activity concentration varies across each mining site and the total mean concentration of ^{226}Ra, ^{232}Th, and ^{40}K from all mining sites (107.60Bq/kg, 84.89Bq/kg, and 475.34Bq/kg) are all above the UNSCEAR standard limits of 35Bq/kg 30Bq/kg and 400Bq/kg respectively. This finding is in line with that of Orosun *et al.* [18] who also obtained higher activity concentration while using a super spec gamma spectrometer to determine activity concentration of ^{238}U, ^{232}Th, and ^{40}K in soil samples from Gold mining sites in Kwara State, Nigeria. Also, similar to that of Ademola *et al.* [19] who also obtained higher values for ^{238}U and ^{40}K and lower value for ^{232}Th in soil samples surrounding gold mining locations in Itagunmodi, Ogun State Nigeria. The results are also comparable to that of Nwankwo *et al.* [20] who also obtained higher activity concentration of ^{238}U, ^{232}Th, and ^{40}K in soil samples near Komu mining location, but lower values at Olode mining location in Oyo State.

Findings from this study have also revealed mean external dose rate values of 1.15E-05mSv/yr, 5.36E-06mSv/yr, 3.79E-06mSv/yr, and 4.43E-06mSv/yr for mining sites S-A, S-B, S-C, and S-D respectively. The external dose rate is mainly attributed from the contribution of gamma decay of 40K which implies that high activity concentration of 40K is more dominant in mining site S-A and less dominant in mining site S-C. Although, the mean contribution of the external doses are all below the standard value public dose limit of 1mSv/yr suggested by ICRP, attention should be given to mining location S-A and S-B which exhibits high chance of resulting to external dose to the public since accumulation of low dose over a long period has high tendency of resulting to stochastic effects to the host community. The findings in this study is in line with the external dose reported by Joseph and Kim [11] from their radiological dose assessment to members of the public using consumer products containing naturally occurring radioactive materials in Korea.

Inhalation of dusts containing long-lived alpha-emitting radionuclides and short-lived decay yields is one major source of radiation exposures from mining activities which has resulted to inhalation dose to the workers and the public UNSCEAR [6]. However, findings from this study have shown that the mean total inhalation doses are 3.68E-04mSv/yr, 3.84E-04mSv/yr, 3.64E-04mSv/yr, and 2.90E-04mSv/yr for mining sites S-A, S-B, S-C, and S-D respectively. The mean inhalation dose received from each mining site are below the standard value public dose limit of 1mSv/yr suggested by ICRP. The result obtained from this present study is higher than the inhalation doses reported by Joseph and Kim [11] from their radiological dose assessment to members of the public using consumer products containing naturally occurring radioactive materials in Korea. However, higher values of inhalation dose are attributed to ^{226}Ra and ^{232}Th than ^{40}K due to alpha gaseous decay of ^{226}Ra and ^{232}Th which are harmful when inhaled. The results from this study implies that the activity concentration of ^{226}Ra and ^{232}Th are higher in S-B, than S-

A and S-C and lower in S-D. Thus people living within the environs of mining location S-B, S-A and S-C tends to receive higher inhalation dose than those within the environment of S-D. Although the inhalation dose received from each mining sites are below the ICRP suggested public dosage boundary of 1mSv/yr, ICRP recommends that no amount of radiation exposure is safe, since the lowest exposure has a tendency of resulting stochastic effects. The underlying standard is to keep all exposure levels as low as reasonably achievable while maintaining the dose limits.

4 Conclusions

The ICRP dose limits function as a shield between deterministic and stochastic effects by preventing deterministic significances whereas reducing the possible likelihood of stochastic consequences. Public protection measures must be applied if the dose is greater than 1mSv/yr. This study performs the Radiological dose assessment to the public from mining activities in Adamawa State. Evaluation of external and internal dose from inhalation were performed using Microshield and IMBA computer codes. The results of external and internal dose incurred by the members of the public as a result of mining activities obtained from each sampling points and mining sites are all less than ICRP recommended unrestricted dosage boundary of 1mSv/yr. Although S-B mining location shows higher inhalation dose than all other mining locations while S-D AG Vision shows lower inhalation dose, the results are all lower than the ICRP recommend public dose limit.

The contribution of external dosage are attributed due to 11% Gamma decay of ^{40}K since while that in inhalation dose is due to Alpha decay of ^{226}Ra and ^{232}Th which are harmful when inhaled in gaseous form. Since the grand mean activity concentration value of ^{40}K obtained from the four-selected mining site under study is higher than the UNSCEAR's value of 400Bq/kg, evaluation of external dose is key in assessing the extent of external exposure dose incurred by the members of the public. Although the ICRP maintains that, no safe radiation exposure due to its tendency to results to stochastic effects in the end. It is advisable that all exposure be kept as low as reasonably achievable while maintaining the dose limits. The radiation protection standards are designed to keep workers and the general public safe from undue radiation exposure.

Footnotes

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