Assessment of Radiation Dose with Excess Life Cancer Risk of Mining Dumpsites Of Wase, Plateau State, Nigeria.

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Abstract

Mining dumps soils at Wase mine, Plateau State, Nigeria were assessed for their natural radionuclides (^{226}Ra, ^{232}Th and ^{40}K) contents using gamma-ray spectrometric technique. The radiological hazards were computed. The mean activity concentration of Base metal mining dumps (BMD) for ^{226}Ra, ^{232}Th and ^{40}K were obtained as 59.74±4.68, 123.00±4.12 and 309.46±7.74 Bqkg^{-1} respectively. Similarly, the mean activity ratios ^{226}Ra / ^{40}K and ^{232}Th/^{40}K were obtained as 0.47 and 0.75 respectively. The mean gamma absorbed dose rate was 109.77nGy/hr, Annual Effective Dose Equivalent, AEDE (indoor) was 0.13mSv/yr, the average AEDE (outdoor) calculated was 0.54mSv/yr and the Annual Gonadal Dose Equivalent (AGDE) obtained was 762.54mSv/yr. The Excess Lifetime Cancer Risk Index (ELCR) was4.65 x 10^{-3} as its mean value. All the radiation hazards and ELCR evaluated were greater than the world's permissive limits. These values imply that the study area is radiologically unsafe for agricultural activities and residential purposes. Further investigation was recommended using the High Purity Germanium (HPGe) detector for the locations.

Keywords: *Radionuclides, Activity concentration, Indices, Hazard, Cancer*

1. Introduction

Waste disposal is an integral part of the human life. Refuse dumpsites constitute environmental health hazards to the public in major cities of the world not only in terms of odour or the presence of disease causing micro-organisms, but the radiation emanating from such dumpsites [1]. Environmental pollution is one of the greatest problems the world is facing today. The indiscriminate waste dump causes soil pollution which can lead to unstable and wasteful utilization of resources, giving rise to dwindling wildlife, more land degradation and increasing generation and indiscriminate disposal of commercial, industrial and domestic wastes [2] . The air and water in area close to these dumpsites are contaminated, hence aerobic respiration becomes difficult for living creatures and clean water becomes scarce for drinking.

With increasing population and human activities, dumpsites experience diverse sources of waste with potential radiation hazards. Ionizing radiations have often been overlooked amongst researchers in third world countries and so information in this regard is lacking [3] . This is one of the reasons that ignited the interest of the researchers to check the effects of these wastes on the residents of Plateau state, Nigeria.

Hazardous waste can cause and has caused pollution, damage to health and even death [4].
Since radiation is all around and within us [5], this research work aims at studying the presence and level of radioactivity in the mining wastes in Wase, Plateau state, North central Nigeria, with the specific objectives of determining the radioactive activity concentrations of the mining dumpsites andassessing the health hazardsof the mining dumpsites .

2. Materials and Methods

2.1 Sample Area

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Wase is a town and a Local Government Area (LGA) of Plateau State, Nigeria. Situated some 216 km south east of Jos, the State capital, It is a traditional area founded in 1820; and became part of the British Royal Niger Company protectorate (later Northern Nigeria). It is situated in Plateau, with geographical coordinates as 9° 6' 0" North, 9° 58' 0" East.

Figure 1: Map of the Research Area (Wase)

2.2 Soil Sample Collection

To assess the presence and the level of the mining dumpsite, 12 soil samples were collected around the mining sites. The samples were carefully collected to satisfactorily represent the entire mine tailings dumped around the mine. Samples were randomly collected around each of the local government area where mining activities are carried out and were thoroughly mixed together to obtain a bulk sample that represents particular sampling point [6]. Each sample weighed about 1.00 kg, were neatly packed in well-labeled polyethylene bags, properly sealed and prepared for analysis.

2.3 Soil Sample Preparation

The soil samples collected were dried and crushed to fine powder with the use of pulverizer. They were packaged into radon-impermeable cylindrical plastic containers which were selected based on the space allocation of the detector vessel of 7.6cm by 7.6cm in dimension. To prevent radon-222 escaping, the packaging in each case was triple-sealed. The sealing process included smearing of the inner rim of each container lid with Vaseline jelly, filling the lid assembly gap with candle wax to block the gaps between lid and container, and tight-sealing lid-container with masking adhesive tape. Radon and its short-lived progenies were allowed to reach secular radioactive equilibrium by storing the samples for 30 days prior to gamma spectroscopy measurements [6].

2.4 Evaluation of radioactivity of samples

The analysis was carried out at the Energy Research Centre, Zaria, Kaduna State of Nigeria, using a 76x76mm **NaI (Tl)** detector crystal optically coupled to a photomultiplier tube (PMT). The assembly has a preamplifier incorporated into it and a 1kilovolt external source. The detector is enclosed in a 6cm lead shield with cadmium and copper sheets. The arrangement was to minimize the effects of background and scattered radiation.

The data acquisition software is of Maestroby Camberra Nuclear Products. The samples were measured for a period of 29000 seconds, for each sample. The peak area of each energy in the spectrum was used to compute the activity concentrations in each sample by the use of equation 1.

$$C\ (Bq.kg^{-1}) = \frac{C_n}{C_{fk}} \qquad (1)$$

where,

C = activity concentration of radionuclides in the sample given in $BqKg^{-1}$

C_n = count rate (counts per second)

Count per second (cps) = Net Count / Live Time

C_{fk} = Calibration factor of the detect ing system.

2.5 Calculation of Radiological Doses

The absorbed dose rate represents the dose received in an open air by the gamma radiation emitted from the radionuclides available in the environmental media. The conversion factors of 0.462, 0.604 and 0.0417 Bq kg^{-1} respectively for ^{226}Ra, ^{232}Th and ^{40}K were used to estimate the absorbed dose rate in air (DR) at 1m above ground level due to gamma-ray emissions from ^{226}Ra, ^{232}Th and ^{40}K in soils. The dose, D was calculated from equation 2 as given by Kolo et al [6].

$$D(nGyh^{-1}) = 0.416A_{Ra} + 0.623A_{Th} + 0.04144A_k \qquad (2)$$

where A_{Ra}, A_{Th} *and* A_k
are the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K respectively in Bq kg^{-1}.

Due to non-uniformity in the distribution of ^{226}Ra, ^{232}Th and ^{40}K in environmental sample, a common index of radiation, the radium equivalent activity (Ra_{eq}) was introduced to account cumulatively for the hazard associated with individual radionuclides. Ra_{eq} is expressed as a weighted sum of activities of ^{226}Ra, ^{232}Th and ^{40}K in Bq kg^{-1}, based on the assumption that 370 Bq kg^{-1} of ^{226}Ra, 259 Bq kg^{-1} of ^{232}Th and 4810 Bq kg^{-1} of ^{40}K. Ra_{eq} were estimated by equation 3.

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

where A_{Ra}, A_{Th} and A_k
are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K respectively in Bq kg^{-1}.

Exposure risk to any individual due to absorbed dose rate is estimated in terms of the Annual Effective Dose Equivalent (AEDE). AEDE was calculated by applying the conversion factors of 0.70 SvGy^{-1}, which converts absorbed dose rate in the air to effective dose and the outdoor occupancy factor of 0.2, assuming that an individual spends average of 80% of his time indoors (Equations 4a & 4b)

The AEDE (indoor) occurs within a house whereby the radiation risks due to building materials only are taken into consideration while AEDE (outdoor) involves a consideration of the absorbed dose emitted from radionuclides in the environment such as ^{226}Ra(^{238}U), ^{232}Th and ^{40}K.

AEDE in outdoor air, measured in mSv y^{-1} was evaluated using the equation.

$$AEDE_{outdoor} = D(nGyh^{-1}) x 8760\ (hy^{-1}) x\ 0.7(^{Sv}/_{Gy}) \times 0.2 \times 10^{-6} \quad (4a)$$

$$AEDE_{indoor} = D(nGyh^{-1}) \times 8760\ (hy^{-1}) x\ 0.7(^{Sv}/_{Gy}) \times 0.8 \times 10^{-6} \quad (4b)$$

The standard AEDE (Outdoor) value is 70μSvyr^{-1} and that for AEDE (Indoor) is 450μSvyr^{-1}. These indices measure the risk of stochastic and deterministic effects in the irradiated individuals[7].

Annual Gonadal Dose Equivalent (AGDE) represents the dose received by those organs which include the reproductive organs (gonads), bone marrows and bone cells. AGDE due to activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the tailing enriched soil samples was calculated from equation 5.

$$AGED(mSvy^{-1}) = 3.09A_{Ra} + 4.18A_{Th} + 0.314A_k \quad (5)$$

where A_{Ra}, A_{Th} and A_K
are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K respectively in Bq kg^{-1}.

3.09, 4.18 and 0.314 are the respective conversion factors that transform the specific activities of ^{226}Ra, ^{232}Th and ^{40}K into total dose received by the organs of interest.

Excess Lifetime Cancer Risk (ELCR)is associated with the probability of developing cancer over a lifetime at a given exposure level. It is a value depicting the number of cancers expected in a given number of people on exposure to a carcinogen at a given dose.

An increase in the ELCR causes a proportionate increase in the rate at which an individual can get cancer of the breast, prostate or even blood. Excess lifetime cancer risk (ELCR) is given according to Kolo et. Al [6].

$$ELCR = AEDE \times DL \times RF \quad (6)$$

where AEDE = Annual Effective Dose Equivalent
DL=average duration of life / life expectancy (estimated as 70 years), and
RF = Risk Factor (Sv^{-1}), i.e. fatal cancer risk per Sievert.

For stochastic effects, International Commission on Radiological Protection (ICRP) uses RF as 0.05 Sv^{-1} for public with the ELCR UNSCEAR standard being 0.29 X 10^{-3}.

3. Results

The results obtained for the activity concentrations, radiation hazards computed are presented in Table 1 to 4 and Figure 1 to 7.

Table 1: Activity Concentration of Base-Elements obtained

S/No.	Sample ID	Activity Concentration in ($BqKg^{-1}$)			Activity Concentration Ratios		
		^{226}Ra	^{232}Th	^{40}K	$^{232}Th/^{226}Ra$	$^{226}Ra/^{40}K$	$^{232}Th/^{40}K$
1	BMD 1	43.39±5.07	178.70±2.63	135.52±8.47	3.74	0.27	1.26
2	BMD 2	24.81±5.51	140.29±2.28	210.97±6.97	4.70	0.21	0.65
3	BMD 3	47.71±3.16	81.63±2.04	480.51±7.35	1.64	0.61	0.17
4	BMD 4	36.00±2.56	62.36±1.26	429.94±7.88	1.65	0.61	0.15
5	BMD 5	15.82±4.00	47.65±2.24	179.76±7.51	2.52	0.40	0.27
6	BMD 6	51.58±6.83	106.59±3.50	265.51±8.10	1.88	0.53	0.40
7	BMD 7	47.87±6.67	121.93±9.12	141.63±8.37	2.40	0.42	0.87
8	BMD 8	8.99±4.56	132.27±2.79	289.91±8.31	9.97	0.10	0.45
9	BMD 9	23.49±2.44	118.00±3.46	181.80±6.60	4.68	0.21	0.64
10	BMD 10	50.55±6.31	148.90±3.18	190.65±6.44	2.67	0.37	0.77
11	BMD 11	11.75±4.67	120.24±8.81	541.43±8.26	7.86	0.13	0.23
12	BMD 12	126.46±5.35	206.46±5.43	505.98±9.90	1.61	0.62	0.41
Minimum		8.99±4.56	47.65±2.24	135.52±8.47	1.61	0.10	0.15
Maximum		126.46±5.35	206.46±5.43	541.43±8.26	9.97	1.46	3.41
Mean Value		59.74±4.68	123.00±4.12	309.46±7.74	3.82	0.47	0.75
World Average		32	45	412	1.41	0.08	0.11

4. Discussion

The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the BMD ranged from 8.99±4.56Bqkg^{-1}, 47.65±2.24Bqkg^{-1} and 135.52±8.47 Bqkg^{-1} at BMD 8, BMD 5 and BMD 1 to 126.46±5.35Bqkg^{-1}, 206.46±5.43 Bqkg^{-1} and 541.43±8.26 Bqkg^{-1}for BMD 12, BMD 12 and BMD 11 with mean concentration values of 59.74±4.68 Bqkg^{-1}, 123.00±4.12Bqkg^{-1}and 309.46±7.74

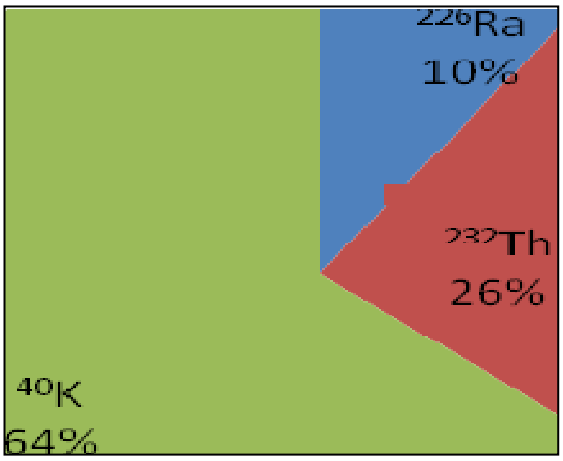

Figure 1: Percentage Activity Concentration of BMD

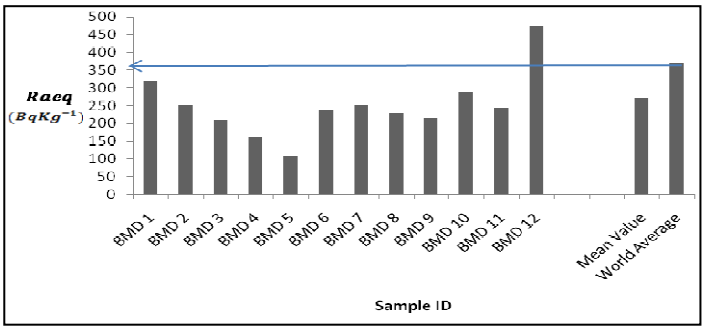

Figure 2: Radium Equivalent BMD

Table 2: Radium Equivalent BMD

S/No.	Sample ID	^{226}Ra ($BqKg^{-1}$)	^{232}Th ($BqKg^{-1}$)	^{40}K ($BqKg^{-1}$)	Ra_{eq} ($BqKg^{-1}$)
1	BMD 1	48.47	181.34	143.99	318.87
2	BMD 2	30.33	142.57	217.94	250.99
3	BMD 3	50.87	83.67	487.85	208.08
4	BMD 4	38.56	63.62	437.82	163.24
5	BMD 5	19.82	49.90	187.27	105.59
6	BMD 6	58.42	110.09	273.61	236.92
7	BMD 7	54.54	131.05	150.00	253.49
8	BMD 8	13.55	135.06	298.22	229.65
9	BMD 9	25.93	121.46	188.39	214.12
10	BMD 10	56.86	152.09	197.08	289.52
11	BMD 11	16.42	129.05	549.69	243.28
12	BMD 12	131.82	211.89	515.95	474.55
Minimum		13.55	49.90	143.99	105.59
Maximum		131.82	211.89	549.69	474.55
Mean Value		65.36	127.12	317.35	271.58
World Average		32	45	412	370

Bqkg^{-1}.The mean activities of ^{226}Ra and^{232}Th in the dumpsite enriched soils around the Wase mine were found to be higher than their respective world averages of 32 and 45Bq kg^{-1}. While the mean activities of and ^{40}K in the dumpsites was found to be lower than the world average of and 412Bq kg^{-1}. These results agree with the findings of Murugesan, et al for Cauvery River, India [8] and Masok et al,on the activities of mining dumpsites in Rayfield, Jos [9].The results are averagely lower than that of the processed

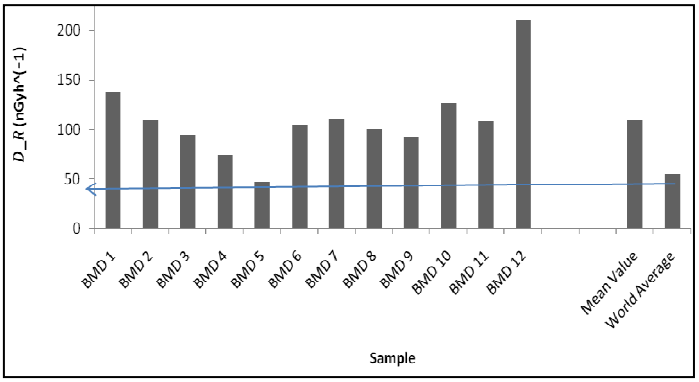

Figure 3: The Gamma Absorbed Dose Rates of BMD

Table 3: Radiation Dose of BMD

S/ No	*Sample ID*	*D_R ($nGyh^{-1}$)*	*AEDE ($mSvy^{-1}$) Outdoor*	*AEDE ($mSvy^{-1}$) Indoor*	*AGDE (μSvy^{-1})*
1	BMD 1	137.93	0.17	0.68	952.98
2	BMD 2	109.21	0.13	0.54	758.09
3	BMD 3	94.38	0.11	0.46	660.10
4	BMD 4	74.50	0.09	0.37	522.54
5	BMD 5	47.10	0.06	0.23	328.61
6	BMD 6	104.89	0.13	0.51	726.61
7	BMD 7	110.61	0.13	0.54	763.42
8	BMD 8	100.27	0.12	0.49	700.05
9	BMD 9	93.20	0.11	0.46	646.97
10	BMD 10	126.35	0.15	0.62	873.30
11	BMD 11	108.45	0.13	0.53	762.75
12	BMD 12	210.40	0.25	1.03	1455.03
Minimum		47.10	0.06	0.23	328.61
Maximum		210.40	0.25	1.03	1455.03
Mean Value		109.77	0.13	0.54	762.54
World Average		**55**	**0.07**	**0.45**	**300**

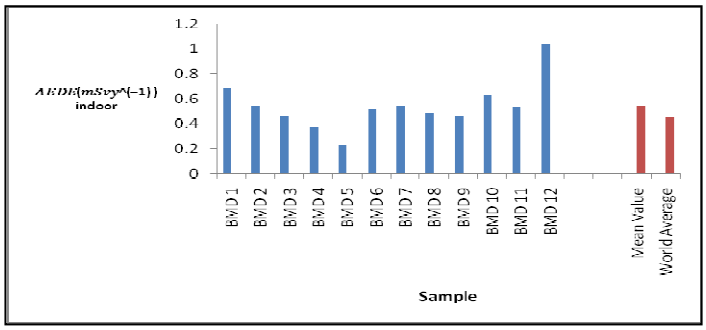

Fig 4: Annual Effective Dose Equivalent AEDE (indoor) of BMD

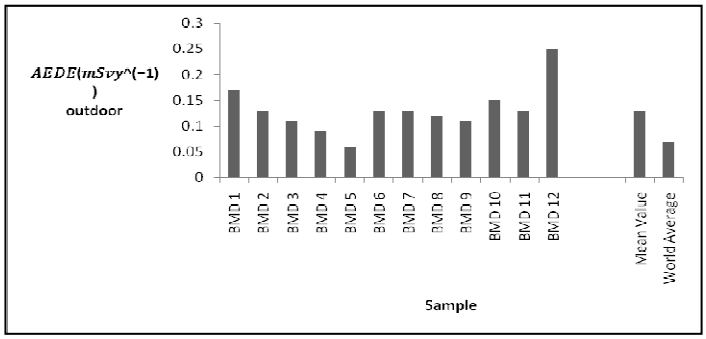

Fig 5: Annual Effective Dose Equivalent AEDE (outdoor)

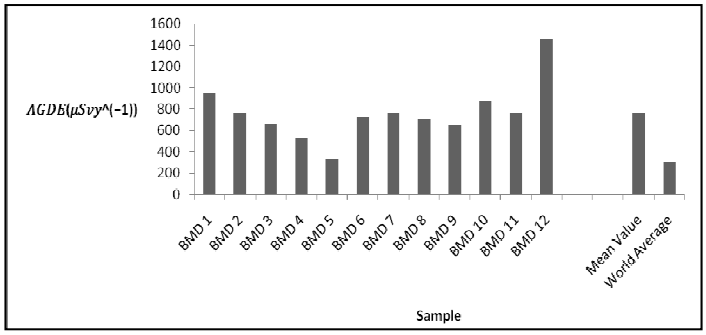

Fig 6: Annual Gonadal Dose Equivalent (AGDE) of BMD

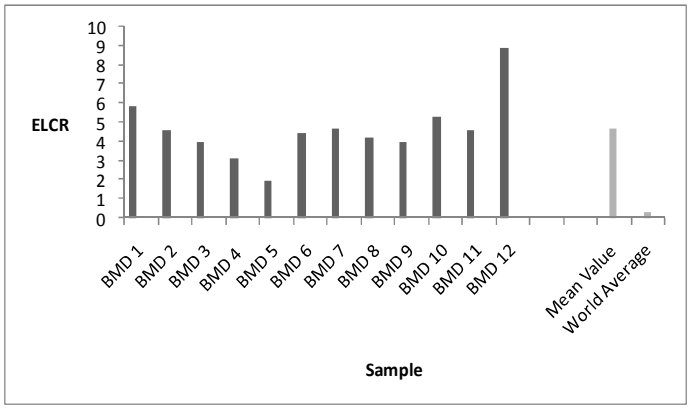

Fig 7: Excess Lifetime Cancer Risk Index (ELCR) of BMD

Table 4: Excess Lifetime Cancer Risk Index (ELCR) of BMD

S/No.	*Sample ID*	*ELCR x 10^{-3}*
1	BMD 1	5.84
2	BMD 2	4.63
3	BMD 3	4.00
4	BMD 4	3.15
5	BMD 5	1.99
6	BMD 6	4.44
7	BMD 7	4.68
8	BMD 8	4.25
9	BMD 9	3.95
10	BMD 10	5.35
11	BMD 11	4.59
12	BMD 12	8.91
Minimum		1.99
Maximum		8.91
Mean Value		4.65
World Average		**0.29**

mine tailings of Jos [10]. The results obtained were a bit higher than the concentrations in surface soils/ sediments of some mining areas in Central Nasarawa State Nigeria [11]. To measure the degree of soil contamination by radioactivity, the calculated mean $^{232}Th/^{226}Ra$ ratio was 3.82. This value was found to be three times the factor 1.2 reported for normal soils by Eisenbud [12] indicating that the enhancement of ^{232}Th above ^{226}Ra in the studied soil samples was tripled. Similarly, the mean values for activity ratios $^{226}Ra/^{40}K$ (0.47) and $^{232}Th/^{40}K$ (0.75) were less than unity but higher than the world average ratios of 0.08 and 0.11 respectively. These results were higher than the ratios obtain by Kolo et al., [6] showing that the specific activity of ^{40}K in the studied soil samples was higher than those for ^{226}Ra and ^{232}Th. The ratio of activity of Thorium to Radium is lesser in comparison to the result obtained by Usikalu, Anoka and Balogun [13] for Jos tin mining tailings.

On the average, ^{40}K accounts for 64%, ^{232}Th accounts for 26% and ^{226}Ra accounts for 10% of the total radionuclides as shown in Figure 1. These results are within the range of results obtained by Jibril, et al [14] in which activity concentrations of radionuclides in the soil samples around the mining sites in Benue State, North Central Nigeria ranged from 425±216.06, 40.34±12.58 and 33.69±4.73 Bq/ Kg for ^{40}K, ^{238}U and ^{232}Th respectively.

The radium equivalent (Ra_{eq}) in the BMD as calculated with equation 3, ranged from 105.59 $Bqkg^{-1}$(BMD 5) to 474.55 $Bqkg^{-1}$ (BMD 12) with a mean value of 271.58 $Bqkg^{-1}$ as clearly seen in Table 2. The mean value obtained was higher than that obtained by Kolo et al [6], and Murugesan, et al [8] but lower than the results of Masok et al [9]. obtained as 659.68Bq/Kg for Rayfield, Jos. The result was comparable with Avwiri et al [15]. All the radium equivalents obtained for BMD were less than the permissible limit of 370Bq/Kg except for sample BMD 12 as clearly seen in Figure 2.

The gamma absorbed dose rates calculated, ranged from 47.10nGy/hr to 210.40nGy/hr for BMD 5 and BMD 12 respectively. The average dose of 109.77nGy/hr was obtained. As clearly seen in Figure 3, the average value and all the samples analyzed with the exception of BMD 5 were above the world average of 55nGy/hr [16], higher than 38.17±12.45 nGy/hr for Eliozu dumpsite [17]. The result of the investigation revealed that the dumpsites recorded annual mean radiation dose that is similar to that of Jos metropolis obtained by Sombo Avaa Eweh Akohu Akine Shaibu and Iorungwa [18]. The result is relatively high and may be attributed to high average activity concentrations of ^{40}K, ^{238}U and ^{232}Th. Also, the results obtained are comparable to that obtained for Olusosun dumpsite in Lagos State [1] .

The AEDE (outdoor) calculated for BMD, ranged from 0.05mSv/yr for BMD 3 to 0.23mSv/yr for BMD 5 with an average of 0.54mSv/yr as presented in Table 3. All AEDE (0utdoor) calculated are higher compared with the world average value of $0.45mSvy^{-1}$[15]. Similarly, these AEDE (outdoor) values are higher than 71±6 μSv/yr obtained for soils around the mining site in Benue State [14] and 0.34mSv/y obtained for Rayfield of Plateau State [19] but but lower than the 81,3mSv obtained by Ademola, Bello & Adeniyi [19] with The variation can be attributed to the differences in the absorbed

dose rates.

The Annual Effective Dose Equivalent AEDE (indoor) was also calculated and shown in Table 3. The AEDE (indoor) calculated values ranged from 0.06 mSv/yr for BMD 5 to 0.25mSv/yr for BMD 12 with an average of 0.13 mSv/yr as presented in Table 3. All AEDE (indoor) calculated are higher compared with the world average value of $0.07mSvy^{-1}$ [20] with the exception of BMD 5. The results obtained, agrees with the findings of Jwanbot, Izam, Nyam and Dakon [21] for Jos environs.

The Annual Gonadal Dose Equivalent (AGDE) calculated, ranged from 328.61mSv/yr to 1455.03mSv/yr with BMD 5 having the least while BMD 12 has the highest as shown in Table 3 and figure 6 .The average value of AGDE for the location was 762.54mSv/yr which is above the threshold value of 300mSv/yr. The AGED values for all the locations of BMD are above the threshold limit. Figure 6 compares the AGDE values for the location with the standard. The high values of AGDE for all the locations indicate the possibilities of developing bone marrow problems, sterility or even leukemia in the long run. This is particularly so for location like TMD 3 with extremely high AGDE value.

The Excess Lifetime Cancer Risk Index (ELCR) obtained, ranged from 1.99×10^{-3} to 8.91×10^{-3} with an average value of 4.65×10^{-3} which exceeds the 0.29×10^{-3}[22]. All the locations have their ELCR values above the permissible threshold as seen in Figure 7. These values are higher than the soil profile for Udi and Ezeagu Local Government Area of Enugu State, Nigeria which was obtained as 0.065×10^{-3} and 0.057×10^{-3} respectively[22]. The average ELCR obtained is higher than the mean of 0.08×10^{-3} for Maiganga coal mine, Northeastern Nigeria [6]

5. Conclusion

The results show that the annual effective radiation dose from natural radioactivity has an average value higher than the natural world recommended value. The hazard indices indicate that the study area may be radiologically unsafe for agricultural and residential purposes. A further study on the mining dumpsite of Wase is therefore recommended to ascertain the safety of the residents. However, despite the significant difference in values between the measured radiological hazard indices compared to the world average values, no significant radiological impact have been observed on the surrounding environment and the living population of the study area.

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