PHYSICS MEMOIR
Available online @ https://journals.fulafia.edu.ng/index.php/pmjtap

Phys. Memoir 1 (2019) 161–170

Journal of Theoretical & Applied Physics

Original

Radiometric Evaluation of Naturally Occurring Radionuclides in Mining Sites across Mararraba-Udege of Nasarawa State, Nigeria

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Abstract

This study evaluates the existence of radionuclides in some mining sites in Mararaba-Udege using a hand held interceptor TM–Thermo scientific radio nuclear identiFINDER designed for in situ operation. The device is placed in contact with the soil and the radionuclides in the soil are detected as well as the contribution of those radionuclides to the background radiation. Gamma Activity (mRem/yr), possible radionuclide present and their trust levels, Exposure Dose Rate (μSv/hr), Absorbed Dose Rate (nGy/hr), Effective Dose Rates (mSv/yr) and Excess Lifetime Cancer Risk, were determined. Results obtained shows that the gamma activity level ranged from 0.955 to 1.260 mrem/hr with the mean of 1.1245 mrem/hr. Exposure dose rate of the study area ranged from 9.55 to 12.6 μSv/hr with the mean of 11.245 μSv/hr. The local miners in the study area are subjected to absorb dose rate ranging from 9553 to 12600 nGy/hr with the mean value of 11245 nGy/hr. Effective dose rate of the area under investigation were ranged from 1.605 to 2.117 mSv/yr with a mean of 1.889 mSv/yr. The excess lifetime cancer risk of the area ranged from 5.618×10^{-3} to 7.408×10^{-3} with the mean of 6.629×10^{-3}. The result also shows that there is Palladium (^{103}Pd), Americium (^{241}Am), Iodine (^{125}I), Uranium (^{235}U), Cadmium (^{106}Cd), Selenium (^{75}Se) and Cobalt (^{57}Co) in significant percentage. From the findings presented, it can be concluded that natural radionuclides pollution in the mining area is an issue of health concern.

Keywords: Soil, Borehole, Health, Radionuclide, Absorbed Dose, Effective Dose, IdentiFINDER.

Article History:
Received: 27 August 2019
Received in revised form: 21 October 2019
Accepted for publication: 18 November 2019
Published: 31 December 2019

1. Introduction

The great interest expressed worldwide for the study of naturally occurring radionuclides and environmental radioactivity has led to interest in extensive survey in many countries [1]. Natural sources still contribute almost 80%

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of the collective radiation exposure of the world population [2]. There are many sources of radiation and radioactivity in the environment [3]. Gamma radiation emitted from naturally occurring radionuclides also called terrestrial background radiation, represents the main external source of irradiation of human body [3]. Human beings are exposed to radiation from sources outside their bodies, mainly, cosmic rays and gamma rays emitted in soil [4].

Studying the levels of radionuclide distribution in the environments provides essential radiological information. It is important to monitor the terrestrial background radiation mainly due to natural radionuclides in soil. Soil from mining sites may contain naturally occurring radionuclides in significant amounts and the resulting external radiation exposure pathway to the population has been the subject for study [3-4]. Even though, there had been series of researches to checkmate the radiation level of the study area, but yet there had never been any evidence of research on the holistic radionuclide survey in the area of study. Some of these radionuclides can be used for medical purposes and some for industrial purposes; hence there is need for this research in order to unveil those radionuclides that can be used for medical purposes and those that can be used for industrial purposes as well as their effects on human health.

2. Materials and Methods

2.1. Materials

The materials that were used in the field radiometric evaluation of naturally occurring radionuclides in mining sites across Mararraba-Udege Development Area can be shown below:

- Thermo Scientific Interceptor is a spectroscopic Personal Radiation Detector Design for in situ operation combining the qualities of personal radiation detection with radioisotope identiFINDER capabilities which was used to detect the radionuclides and their trust level as well as their contribution to the background radiation of the area.
- Map of Mararraba-Udege was ued to provide names and directions of all the localities in the area.
- Measuring Tape was used for measuring grid size and depth of the pit. Geographical Positioning System (GPS) was used in finding the coordinates at each sample point.

2.2. The Study Area

Four villages were chosen in Mararraba-Udege Development Area. The villages are Eyenu, Opanda, Okereku and Udegen-Mbeki abbreviated as EY (ABC), OP (ABC), OK (ABC) and UM (ABC) respectively. The villages are located at 08°24'38.2"N and 07°52'59.2"E, 08°24'33.1"N and 07°52'54.1"E, 08°24'28.0"N and 07°52'49.0"E, 08°21'24.9"N and 07°54'29.6"E, 08°21'19.8"N and 07°54'24.5"E, 08°21'15.5"N and 07°54'20.2"E, 08°24'04.1"N and 07°52'10.6"E, 08°24'01.2"N and 07°52'07.7"E, 08°23'99.8"N and 07°52'04.8"E, 08°25'56.3"N and 07°53'49.3"E, 08°25'51.2"N and 07°53'44.2"E, and 08°25'46.9"N and 07°53'39.9"E respectively. Columbite is mined in all the four villages as represented in Figure 1.

2.3. Data Collection

The data were collected manually from the spectrometer and recorded in a book for further analysis. After the drilling of the soil, the radiation measurement was done with the device touching the soil surface. The procedure was done in sequence, covering all the data points in the study area.

2.4. Sampling Method

To assess a radiometric evaluation of the study area, the stratified random sampling technique was adapted where a grid sampling (data) was defined for the region. The grid of the study area was defined in a range of 50×25 meters grid. Since the net was defined, in each data point, the gamma radiation rate (mrem), the dose rate (μ Sv per hour), the trust level and the type of radionuclides are obtained. The procedure was made following the recommendations in technical documents of some Regulatory Agencies such as IAEA and NNRA which cover all aspects of the uranium mining industry, from exploration to exploitation, decommissioning and the application of techniques in other non-uranium resource areas. The measurements was done using a portable gamma spectrometer (i.e. thermo scientific interceptor), which carries out qualitative and quantitative analysis of gamma radiation using a Cadmium Zinc Telluride (CZT) detector. The initial calibration and furthermore, the permanent and continuous stabilization running in the background in paralleled to any performed measurement are based on an automatic internal stabilization source [5].

2.5. Population Sample

When the grid of the study area was defined, four villages were chosen base on the minerals deposited there and in each area. In these mining sites, three (3) locations were chosen, which are, the mining spot, 200 metres away from the mining spot and the water way around the mining spot. Four data were taken randomly in each location making 48 and the coordinate of each location is taken for further analysis.

2.6. Data Analysis

In order to compute the experimental result for exposure dose rate (μ Svhr^{-1}), absorbed dose rate (nGyhr^{-1}), the effective dose rate (mSvhr^{1}) and excess lifetime cancer risk, the following methods and formulas were used:

$$GammaActivityLevel(GAL)(mremhr^{-1}) = \frac{\Sigma N}{N} \tag{1}$$

$$ExposureDoseRate(\mu Svhr^{-1}) isgottenfromtherelation 1 mremhr^{-1} = 10\mu Svhr^{-1} \tag{2}$$

$$AbsorbedDoseRate, D(nGyhr^{-1}) isgottenfromtherelation 1\mu Svhr^{-1} = 10^{3} nGyhr^{-1} \tag{3}$$

$$EffectiveDoseRate(mSvhr^{-1}), ED = D \times T \times OF \times CCF \times 10^{-6} \tag{4}$$

$$ExcessLife - TimeCancerRisk(ELCR) = EDR \times DL \times RF \tag{5}$$

$$CCF = ConversionCoefficientfactor = 0.7SvGy^{-1} \tag{6}$$

From Table 1, it is possible to see that ^{103}Pd and ^{125}I were found in 66.7% of the points where the values were measured the trust level of the device reaches 50-65% indicating that the radionuclides are likely found in the area. It is also possible to see that ^{109}Cd was found in 16.7% of the points where the values were measured. The trust level of the device for ^{109}Cd reaches 50% indicating that the radionuclides is likely found in the area. It is also possible to see that ^{241}Am, ^{235}U, ^{75}Se and ^{57}Co were found in 8.3% of the points where the values were measured. The trust level of the device for ^{241}Am, ^{235}U, ^{75}Se and ^{57}Co reaches 81%, 57%, 57% and 54% respectively, indicating that the radionuclide is likely found in the area. However, the trust level of the device indicate that the radionuclides used for both medical and industrial purposes found in the study area with the exception of five (5), are most likely present. Also from Table 1, it is possible to see that the mean gamma activity level for EY A, OP A, OP B, OP C, OK A, OK C, UM B and UM C is found to be above the Basic Safety Standard (BSS) of $1mremhr^{-1}$. Except for EY B, EY C, OK B and UM A, this is found to be lower than the Basic Safety Standard (BSS) of $1mremhr^{-1}$. This high values may be because of radiation emitted from the radionuclides being excavated by the local miners. If we consider the villages, from Table 1, it is possible to see that all villages have average values above the Basic Safety Standard (BSS). Except EY which has lower average value.

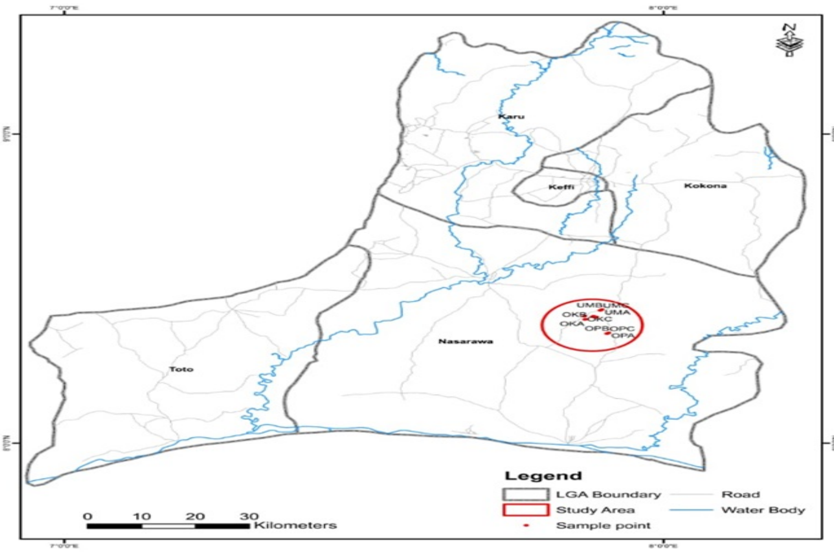

Figure 1. Map showing sample location in Nasarawa west, Nasarawa State

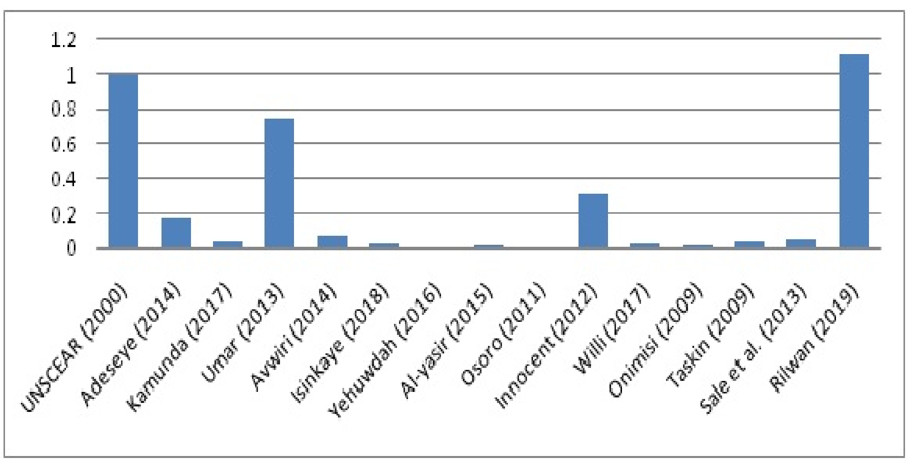

Figure 2. Comparison of gamma activity (mren/hr) with other authors

From Table 2, it is possible to see that the exposure dose rate for EY A, OP A, OP B, OP C, OK A, OK C, UM B and UM C is found to be above the Basic Safety Standard (BSS) of $1 mremhr^{-1}$. Except for EY B, EY C, OK B and UM A, this is found to be lower than the Basic Safety Standard (BSS) of 10 $\mu Sv/hr$. This high values maybe because of radiation emitted from the radionuclides being excavated by the local miners. If we consider the villages, from Table 2, it is possible to see that all villages have average values above the Basic Safety Standard (BSS). Except EY which has lower average value. Also from Table 2, it is possible to see that the gamma absorbed dose rate for EY A, OP A, OP B, OP C, OK A, OK C, UM B and UM C is found to be above the Basic Safety Standard (BSS) of $1 mremhr^{-1}$. Except for EY B, EY C, OK B and UM A, this is found to be lower than the Basic Safety Standard (BSS) of 10000 nGy/hr. This high values may be because of radiation emitted from the radionuclides being excavated by the local miners. If we consider the villages, from Table 2, it is possible to see that all villages have average values above the Basic Safety Standard (BSS). Except EY which has lower average value. Similarly, from Table 2, it is possible to see that the effective dose rate for all the areas under investigation is found to be below the Basic Safety Standard

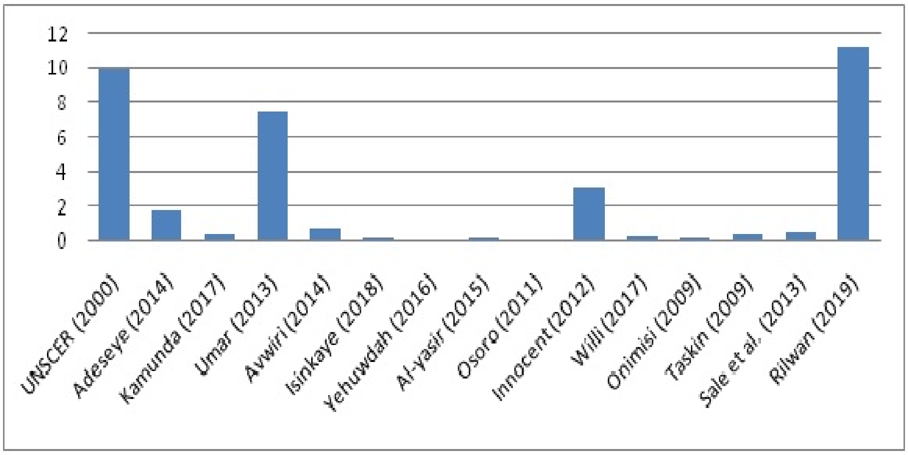

Figure 3. Comparison of exposure dose rate ($\mu Sv/hr$) with other authors

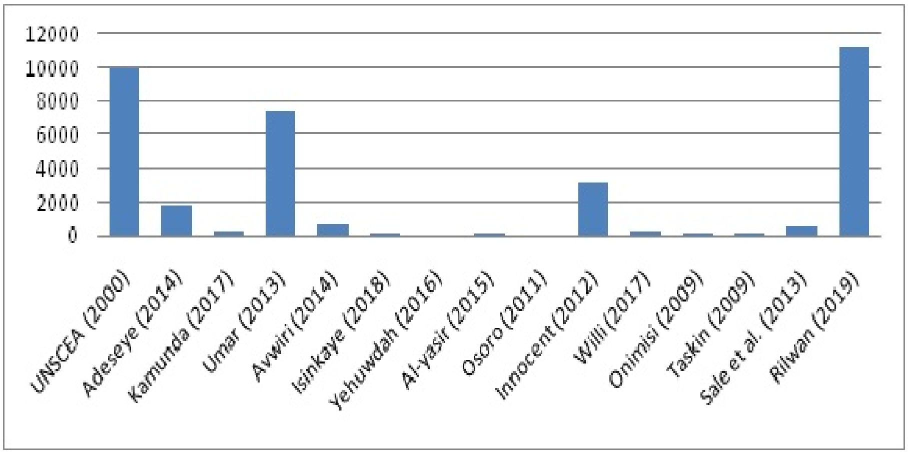

Figure 4. Comparison of absorbed dose rate (nGy/hr) with other authors

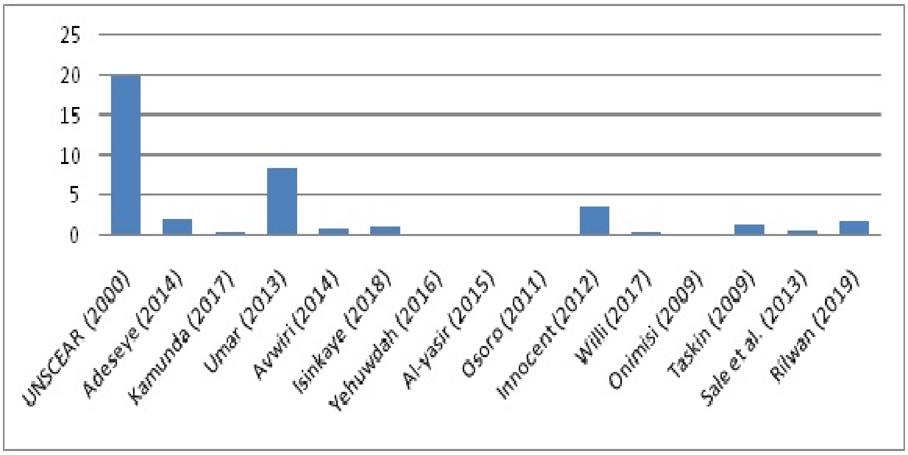

Figure 5. Comparison of effective dose rate (mSv/yr) with other authors

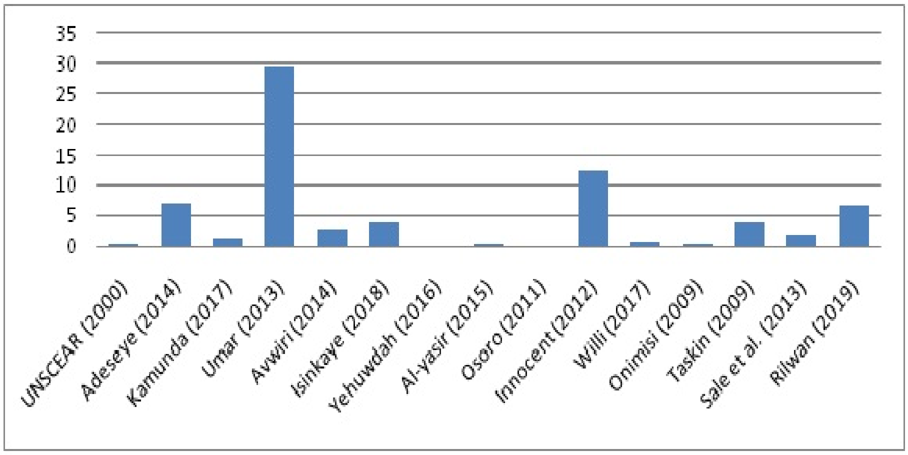

Figure 6. Comparison of excess lifetime cancer risk with other authors

Table 1. Table 1: Radionuclides, Trust Level and Gamma Activity Level

Point Code	Gamma Activity Level (mrem/hr)	Radionuclide I	Trust Level (%)	Radionuclide II	Trust Level (%)
EY A	1.050	Med-Pd-103	63	-	-
EY B	0.927	Ind-Am-241	81	-	-
EY C	0.889	Med-I-125	62	Med-Pd-103	50
EYav	0.955				
OP A	1.500	Med-I-125	61	Med-Pd-103	54
OP B	1.250	Med-Pd-103	53	Ind-Cd-109	50
OP C	1.030	Med-U-235	57	Med-I-125	52
OPav	1.260				
OK A	1.100	Med-I-125	49	Med-Pd-103	46
OK B	0.983	Med-Se-75	57	Ind-Co-57	54
OK C	1.120	Med-I-125	49	Ind-Cd-109	42
OKav	1.068				
UM A	0.965	Med-I-125	53	Med-Pd-103	45
UM B	1.400	Med-I-125	64	Med-Pd-103	51
UM C	1.280	Med-I-125	56	Med-Pd-103	52
UMav	1.215				
Overall Mean	1.1245				

(BSS) of 20 $mSvyr^{-1}$ for workers. This high values maybe because of radiation emitted from the radionuclides being excavated by the local miners. Finally, from Table 2, it is possible to see that the excess lifetime cancer risk for all the areas under investigation is found to be above the Basic Safety Standard (BSS) of 0.29×10^{-3}. This high values may be because of radiation emitted from the radionuclides being excavated by the local miners.

3. Results

The data collected from different mining sites such as radionuclides with their respective trust level and gamma activity level (mrem/yr), the evaluations made for the radiological hazard parameters such as exposure dose rates ($\mu Sv/hr$), absorbed dose rate (nGy/hr), effective dose rate (mSv/yr) and excess lifetime cancer risk are presented in Table 1 and Table 2.

Table 2. Table 2: Exposure Dose Rates, Absorbed Dose Rates, Effective Dose Rate and Excess Lifetime Cancer Risk

Point Code	Exposure Dose Rates ($\mu Sv/hr$)	Absorbed Dose Rates (nGy/hr)	Effective Dose Rate (mSv/yr)	Excess Lifetime Cancer Risk ($\times 10^{-3}$)
EY A	10.50	10500	1.764	6.174
EY B	09.27	09270	1.557	5.450
EY C	08.89	08890	1.494	5.229
EYav	**09.55**	**9553**	**1.605**	**5.618**
OP A	15.00	15000	2.520	8.820
OP B	12.50	12500	2.100	7.350
OP C	10.30	10300	1.730	6.055
OPav	**12.60**	**12600**	**2.117**	**7.408**
OK A	11.00	11000	1.848	6.468
OK B	09.83	09830	1.651	5.779
OK C	11.20	11200	1.882	6.587
OKav	**10.68**	**10676**	**1.794**	**6.278**
UM A	09.65	09650	1.621	5.874
UM B	14.00	14000	2.352	8.232
UM C	12.80	12800	2.150	7.525
UMav	**12.15**	**12150**	**2.041**	**7.210**
Overall Mean	**11.245**	**11245**	**1.889**	**6.629**

3.1. Radionuclides, Trust Level and Gamma Activity Level

The radionuclides with their respective trust levels as well as the gamma activity level obtained from the field using radiation identiFINDER are presented in Table 1.

3.2. Analysis of Results

In this study, the results were obtained by the use of mathematical formulae (see Equation 1 to 5). The average values highlighted in table 1 and 2 are used to plot charts presented in Figure 2 to 6 in order to compare the results with those previous works.

4. Discussion

The results of the radiometric evaluation of naturally occurring radionuclides in mining sites across Mararraba-Udege, Nasarawa, Nasarawa State, Nigeria using thermo scientific radiation identiFINDER device have been presented. The trust level of the various radionuclide found in the mining sites are presented in Table 1 and 2. Seven radionuclides (^{103}Pd, ^{125}I, ^{109}Cd, ^{241}Am, ^{235}U, ^{75}Se and ^{57}Co) were found in the soil from mining site. It is possible to see from these tables that, ^{103}Pd and ^{125}I were found in 66.7% of the points where the values were measured; the trust level of the device reaches 50-65% indicating that the radionuclides are likely found in the area. It is also possible to see that $1^{109}Cd$ was found in 16.7% of the points where the values were measured. The trust level of the device for ^{109}Cd reaches 50% indicating that the radionuclides are likely found in the area. It is also possible to see that ^{241}Am, ^{235}U, ^{75}Se and ^{57}Co were found in 8.3% of the points where the values were measured. The trust level of the device for ^{241}Am, ^{235}U, ^{75}Se and ^{57}Co reaches 81%, 57%, 57% and 54% respectively, indicating that the radionuclide is likely found in the area.However, the trust level of the device indicate that the radionuclides used for both medical and industrial purpose found in the study area with the exception of five (5), are most likely present.

Charts were plotted (Fig. 2 to 6) in order to compare the results with those in previous literatures. Findings of this study have revealed that the mean Gamma Activity Level for Udege mining area is 1.1245 mrem/hr, which implies that the level of radiation in those areas is significantly higher than 1mrem/hr as agreed by regulatory bodies and may cause radiological hazard to the workers. This finding is in line with the finding of [7] whose case study was North central, but not in line with the finding of [8] whose work was carried out in Riyom, Plateau State, Nigeria and whose mean gamma activity level was 0.18 mrem/hr, [9] whose work was carried out in South Africa and whose mean gamma activity level was 0.03 mrem/hr, [10] whose work was carried out in Port Harcourt, Rivers State, Nigeria and whose mean gamma activity level was 0.07 mrem/hr, [11] whose work was carried out in Southwest Nigeria and whose mean gamma activity level was 0.02 mrem/hr, [12] whose work was carried out in Abak Local Government of Akwa Ibom, Nigeria and whose mean gamma activity level was 0.002 mrem/hr, [13] whose work was carried out in Amman Aqaba Highway, Jordan and who's mean gamma activity level was 0.01 mrem/hr, [14] whose work was carried out in Kenya and whose mean gamma activity level was 0.003 mrem/hr, [15] whose work was carried out in Kauran-Namoda, Zamfara State, Nigeria and whose mean gamma activity level was 0.315 mrem/hr, [16] whose work was carried out in selected beaches on coastline of Kenya and whose mean gamma activity level was 0.02 mrem/hr, [17] whose work was carried out in Some Mining Sites in Zamfara State, Nigeria and whose mean gamma activity level was 0.009 mrem/hr, [18] whose work was carried out in in Kirklareli and whose mean gamma activity level was 0.032 mrem/hr and [19] whose work was carried out in Pantian District, Johor, Malaysia and whose mean gamma activity level was 0.05 mrem/hr.

On Exposure Dose Rate, Finding of this study has revealed that the mean Exposure Dose Rate for Udege mining area is 11.245 $\mu Sv/hr$, which implies that the level of radiation in those areas is significantly higher than 10 $\mu Sv/hr$ as agreed by regulatory bodies and may cause radiological hazard to the workers. This finding is in line with the finding of [7], but not in line with the finding of [8] whose mean Exposure Dose Rate was 1.8 $\mu Sv/hr$, [9] whose mean Exposure Dose Rate was 0.312 $\mu Sv/hr$, [10] whose mean Exposure Dose Rate was 0.664 $\mu Sv/hr$, [11] whose mean Exposure Dose Rate was 0.2 $\mu Sv/hr$, [12] whose mean Exposure Dose Rate was 0.02 $\mu Sv/hr$, [13] whose mean Exposure Dose Rate was 0.1 $\mu Sv/hr$, [14] whose mean Exposure Dose Rate was 0.03 $\mu Sv/hr$, [15] whose mean Exposure Dose Rate was 3.15 $\mu Sv/hr$, [16] whose mean Exposure Dose Rate was 0.2 $\mu Sv/hr$, [17] whose mean Exposure Dose Rate was 0.09 $\mu Sv/hr$, [18] whose mean Exposure Dose Rate was 0.32 $\mu Sv/hr$ and [19] whose mean Exposure Dose Rate was 0.5 $\mu Sv/hr$.

On Absorbed Dose Rate, Finding of this study has revealed that the mean Absorbed Dose Rate for Udege mining area is 11245 nGy/hr, which implies that the level of radiation in those areas is significantly higher than 10000 nGy/hr as agreed by regulatory bodies and may cause radiological hazard to the workers. This finding is in line with the findings of [7] but not in line with that of [8] whose mean Absorbed Dose Rate was 1771 nGy/hr, [9] whose mean Absorbed Dose Rate was 312 nGy/hr, [10] whose mean Absorbed Dose Rate was 664 nGy/hr, [11] whose mean Absorbed Dose Rate was 163.28 nGy/hr, [12] whose mean Absorbed Dose Rate was 20 nGy/hr, [13] whose mean Absorbed Dose Rate was 98 nGy/hr, [14] whose mean Absorbed Dose Rate was 25.2 nGy/hr, [15] whose mean Absorbed Dose Rate was 3150 nGy/hr, [16] whose mean Absorbed Dose Rate was 204 nGy/hr, [17] whose mean Absorbed Dose Rate was 89 nGy/hr, [18] whose mean Absorbed Dose Rate was 164.53 nGy/hr and [19] whose mean Absorbed Dose Rate was 469 nGy/hr.

On Effective Dose Rate, Finding of this study has revealed that the mean Effective Dose Rate for Udege mining area is 1.889 mSv/yr, which implies that the level of radiation in those areas is significantly higher than 20 mSv/yr as agreed by regulatory bodies and may cause radiological hazard to the workers. This finding is in line with the finding of [8], [11] and [18], but not in line with the finding of [9] whose mean Effective Dose Rate was 0.38 mSv/yr, [10] whose mean Effective Dose Rate was 0.75 mSv/yr, [12] whose mean Effective Dose Rate was 0.023 mSv/yr, [13] whose mean Effective Dose Rate was 0.111 mSv/yr, [14] whose mean Effective Dose Rate was 0.062 mSv/yr, [15] whose mean Effective Dose Rate was 3.56 mSv/yr, [16] whose mean Effective Dose Rate was 0.23 mSv/yr, [17] whose mean Effective Dose Rate was 0.073 mSv/yr, [7] whose mean Effective Dose Rate was 8.45 mSv/yr and [19] whose mean Effective Dose Rate was 0.53 mSv/yr.

On Excess Lifetime Cancer Risk, finding of this study has revealed that the mean Excess Lifetime Cancer Risk for Udege mining area is 6.629×10^{-3}, which implies that the level of radiation in those areas is significantly higher than 0.29×10^{-3} as agreed by regulatory bodies and may cause cancer to the workers when they work their ages of 70. This finding is in line with the finding of [8], but not in line with the finding of [9] whose Mean Excess Lifetime Cancer Risk was 1.33×10^{-3}, [10] whose mean Excess Lifetime Cancer Risk was 2.77×10^{-3}, [11] whose mean Excess Lifetime Cancer Risk was 3.99×10^{-3}. [12] whose mean Excess Lifetime Cancer Risk was 0.081×10^{-3}, [13] whose mean Excess Lifetime Cancer Risk was 0.39×10^{-3}, [14] whose mean Excess Lifetime Cancer Risk was 0.22×10^{-3}, [15] whose mean Excess Lifetime Cancer Risk was 12.46×10^{-3}, [16] whose mean Excess Lifetime Cancer Risk was 0.81×10^{-3}, [17] whose mean Excess Lifetime Cancer Risk was 0.26×10^{-3}, [18] whose mean Excess Lifetime Cancer Risk was 29.58×10^{-3}, [19] whose mean Excess Lifetime Cancer Risk was 1.86×10^{-3} and [7] whose mean Excess Lifetime Cancer Risk was 3.89×10^{-3}.

5. Conclusion

To quantify and evaluate the damages done by the mining activity is not a simple problem. This work shows the preliminary net that is chosen to analyze the Mararraba-Udege area, and it is possible to verify that there is ^{103}Pd and ^{125}I found in 66.7% of the total points. Indicating that the radionuclide is likely found in the area. It is also possible to verify that there is ^{109}Cd found in 16.7% of the total points. It is also possible to verify that there is ^{241}Am, ^{235}U, ^{75}Se and ^{57}Co found in 8.3% of the total points. However, the trust level of the device indicate that the radionuclides used for both medical and industrial purpose found in the study area with the exception of five (5) are most likely present. From the findings presented, it can be concluded that natural radionuclides pollution in the mining area are issues of health concern because the radiation levels found shows that the study site cannot be considered as a free area. Therefore, this is an indication that the mining activities may appear to have much impact on the radiation burden of the environment but also, gross alpha and gross beta assessment of water in the area will also compliment this work. It is therefore recommended that proper radiation monitoring exercise should be conducted on the processing sites from time to time in order to safeguard the workers from high radiation exposure due to direct inhalation of the above mentioned radionuclides excavated from the soil in the process of mining.

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