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RESEARCH PAPER

Radiometric Evaluation of Radionuclides in Some Selected Mining Sites across Azara Development Area of Nasarawa State, Nigeria

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Abstract

The data for this research contains the in-situ measured activity concentration of radionuclides and gamma-radiation dose rate obtained from the radiometric survey in Azara development area of Awe Local Government, Nasarawa State, Nigeria. The data were manually collected in eight (8) locations with 20 data taken from each point using a portable hand held Thermo Scientific Interceptor and a radionuclide IdentiFINDER. The descriptive statistical analysis of the data was equally explored for possible statistical relationships. The result obtained is made available publicly for further extended analyses that can provide insights into the safety status of the study area from radiological health concerns. The data could also serve as a significant baseline radiometric data for future researches and monitoring initiative in Azara and its environs. The data for this research contains the in-situ measured activity concentration of radionuclides and gamma-radiation dose rate obtained from the radiometric survey in Azara development area of Awe Local Government, Nasarawa State, Nigeria. The data were manually collected in eight (8) locations with 20 data taken from each point using a portable hand held Thermo Scientific Interceptor and a radionuclide IdentiFINDER. The descriptive statistical analysis of the data was equally explored for possible statistical relationships. The result obtained is made available publicly for further extended analyses that can provide insights into the safety status of the study area from radiological health concerns. The data could also serve as a significant baseline radiometric data for future researches and monitoring initiative in Azara and its environs.

Keywords: In-situ; Radionuclide; IdentiFINDER

INTRODUCTION

The great concern expressed all over the world for the study of naturally occurring radionuclides and environmental radioactivity has led to interest in extensive research and survey in many countries. Natural sources still contribute almost 80 % of the collective radiation exposure of the world. Naturally occurring radioactivity originates from extra-terrestrial sources as well as from radioactive sources from earth crust. About 340 nuclides have been found in nature, and more than 60 of these are radioactive. All elements with atomic number greater than 80 possess radioactive isotopes, and all isotopes of elements heavier than number 83 are radioactive (Tailor, 2006; Kragh, 2018; Stacey, 2018). Radiometric evaluation in some selected mining sites is important for the protection of public health especially if the released radionuclides enter the food chain or result in the unnecessary radiation exposure to population (Osimobi et al., 2018). It is globally well accepted that direct ingestion of contaminated soil, inhalation of fugitive dusts, external radiation dose exposure and ingestion of home produce in a residential setting may result in serious health hazard (Abuelhia, 2019).

The country is to be stigmatized in the international scene as the result of the degree of involvement of its citizen in illegal mining across the nation. People living in the area who are the primary target of the research will benefit because the study will unveil the existence radionuclides in the area where they live. The second beneficiaries of this research are the regulatory bodies and research institutes in the country. In situ measurements offers a rapid, low-cost and spatially representative radiometric method for rapid assessment of radiation exposure and environmental radioactivity in contrast to laboratory based techniques (Adagunodo et al., 2018). Portable detectors were deployed for the measurement and typically 10–15 mins were spent per measuring point.

The research is aimed at identifying and evaluating the radionuclides in some selected mining sites from Azara Development Area in order to assess the contribution of mining activities in the area to environmental radiation level.

STUDY AREA

Currently, there are hundreds of mines in the southern part of Nasarawa State which are now active with a few abandoned ones. Mining being the second source of income after farming to the people of the settlements that are closer to the mines. The inhabitants may be exposed to a technically enhanced level of background radiation due to the presence of naturally occurring radioactive materials (NORM) in the earth, mining by-products and wastes (Ferreira et al., 2012; Najib et al., 2016)).

The study area is located in Awe LGA in the south-eastern part of Nasarawa State. It forms part of the Benue Basin in North-central Nigeria (Figure 1). It lies between latitude 8° 21′ 43″N and 8° 19′ 22″N, and longitudes 9° 14′ 48″E and 9° 18′ 25″E and it covers the area of approximately 2529 km^2. The town is located at 224 meters above sea level and its population is 71,657 (Abba et al., 2017). The main commercial activities of the town are farming and mining (Aliyu et al., 2015).

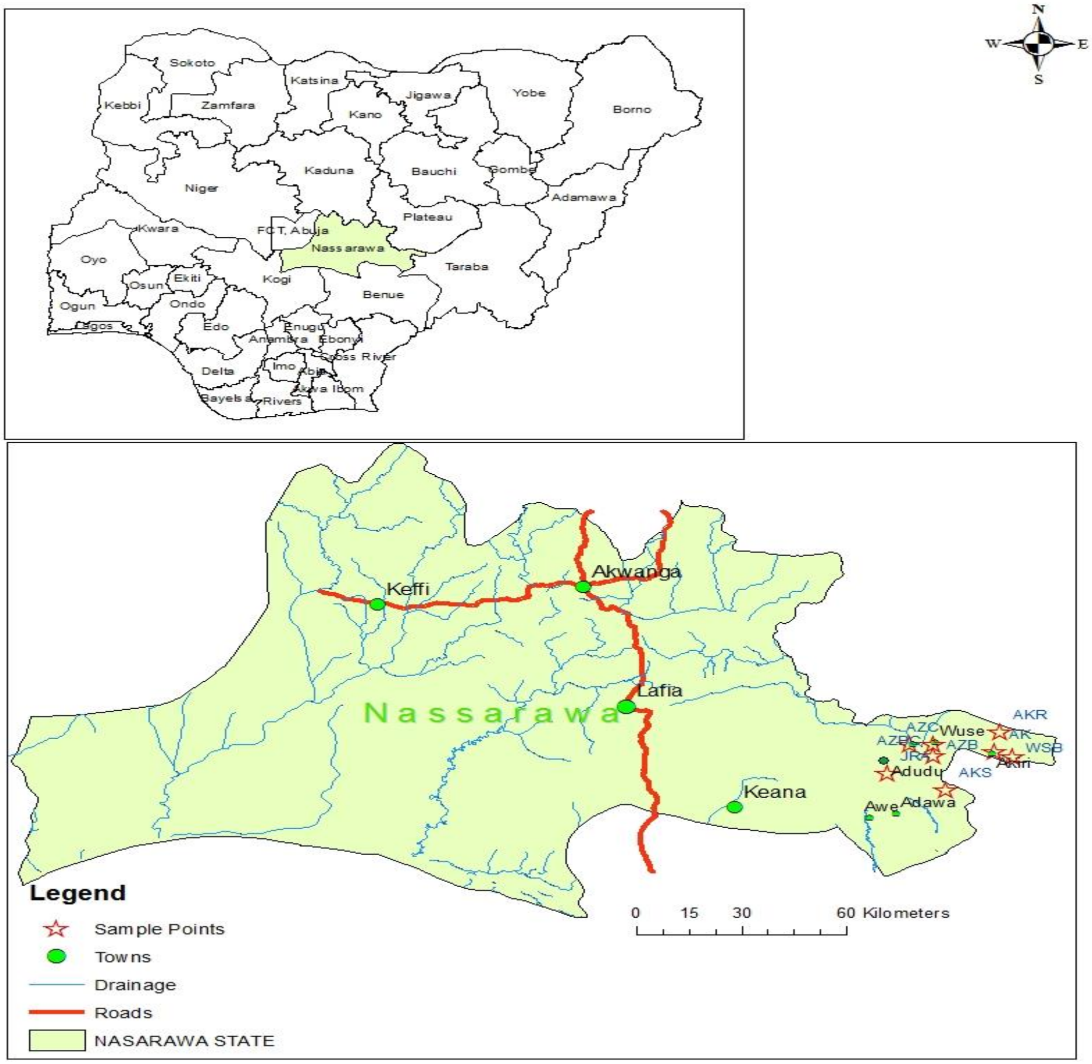

Figure 1. (a) Map of Nigeria, (b) Extracted map of Nasarawa State from the map of Nigeria showing the sample locations

MATERIALS AND METHODS

The instruments used in this research include; Thermo Scientific Interceptor which is a spectroscopic personal radiation detector designed for in situ operation combining the qualities of personal radiation detection with radioisotope identification capabilities.

The measurements were done using a portable Thermo Scientific Interceptor (Thermo Fisher Scientific, Inc., 81 MA 02454), that effectuates quantitative and qualitative study of gamma radiation with a high-efficiency Cadmium Zinc Telluride (CZT) finder as its main detector. A high dose rates with high performance, 1024-channel DSP-based MCA with energy compensation dose rate algorithm on finder detectors. The operating Temperature range of the device is 20 $^{\circ}$C to +50 $^{\circ}$C (-4 $^{\circ}$F to +122 $^{\circ}$F) at up to 95 %RH @

95 $^{\circ}$F with energy ranging from 25 KeV to 3 MeV and sensitivity, 1.5 cps/µR/h, 1.2 cps/nv. The device has a resolution of 7 mm x 7 mm x 3.5 mm CZT identification detector; ^{3}He Neutron Detection; 8 atm., 13 mm diameter x 66 m at 1.2 cps/nv. A specific automatic energy calibration and stabilization that is essential for any nuclide's identification presence in the field.

The soil is firstly drilled so as to collect gasses as part of the studying the environment (Najib et al., 2016), the measurement of the radiation was carried out with the device in contact with the surface of the soil. The process was done in sequence, which covers all the sample points in the area under study. The temperature of the soil was also taken (for gas analyses). The procedure was carried out with the device pointing the radiation source. The algorithm for the radionuclides identification does not start when the acquisition time is very short or the level of the radiation is too low. The device is programmed to detect one or two radionuclides, so as to improve its performance. The instrument is designed with inbuild trust level ranging from zero (what means unlikely) to 100 % (very likely). A weak sign is displayed as "-". The capacity of this device to correctly identify the radionuclides spectrum is represented by the trust level (Ferreira et al., 2012).

In situ γ-ray spectrometry was used in this study which offers a low-cost, rapid and spatially representative radiometric method for rapid assessment of radiation exposure and environmental radioactivity in contrast to laboratory based techniques (Mallo, 2010).

RESULTS AND DISCUSSION

The results of the evaluation conducted in the study area is given in Table 1 for different sample points. From Table 1, it is observed that the point with code Azara II (AZB) shows the highest trust level of 61 % which indicates the high tendency of the device to identify correctly the radionuclides spectrum. However, the trust level show that there is no likely the presence of all the identified radionuclides.

Table 2 shows the classification of natural radiation based on Gamma dose rate. According to UNSCEAR (2000), the radioactive areas are classified based on the average effective dose of the natural radiation in µSv/h (Aliyu et al., 2015; Abba et al., 2017).

Table 1. Coordinates, radionuclides and trust level.

Point code	Coordinates	Radionuclide I	Trust Level	Radionuclide II	Trust Level
Akiri I (AK)	8° 20’15’’N	Ind-Te-132,	55.4 %	-	42.3 %
	9° 27’58’’E	Ind-Co-58	58.0 %	-	51.0 %
Akiri II (AKR)	8° 32’18’’N 9° 37’52’’E	Ind-Te-132	58.4 %	-	48.0 %
Akiri III (AKS)	8° 12’23’’N	Ind-Co-58	45.5 %	-	59.6 %
	9° 20’16’’E	Ind-Te-132	58.8 %	-	52.0 %
Azara I (AZC)	8° 21′ 43′N	Ind-Ag-110	44.6 %	-	54.4 %
	9° 14’ 48‘’E	Ind-Cs-137	48.5 %	-	38.0 %
Wuse I (WSB)	8° 19’15’’N	Ind-Co-58	56.2 %	-	51.5 %
	9° 30’42’’E	Ind-Co-59	57.5 %	-	34.0 %
Azara II (AZB)	8° 19′ 22′N	Ind-Cs-137	53.6 %	-	61.0 %
	9°18′ 25′E	Ind-Te-132	55.3 %	-	54.3 %
Azara III (AZBC)	8° 21’52’’N	Ind-Te-132	59.0 %	Ind-Co-59	54.2 %
	9° 18’23’’E			-	32.0 %
				-	35.0 %
				-	41.0 %
				Ind-Co-58	52.9 %
Jara (JRA)	8°15’46’’N	Ind-Cr-51	55.6 %	-	57.0 %
	9° 11’20’’E	Med-Pb-103	45.6 %	-	43.9 %

Table 2. The classification of natural radiation based on gamma dose rate.

Gamma Dose Rate	Classification of Natural Radiation
Less than 12 µSV/h	Normal values
Between 12 µSV/h and 50 µSV/h	Medium values
Between 50 and 125 µSV/h	High values
Higher than 125 µSv/h	Very high values.

From the classification as shown in Table 2, the dose rate in μSv/h are within the normal values for all the sample points (UNCEAR, 2000). Therefore, the levels of the radiation are within the safety limits since the values obtained are less than 12 μSv/h (Ibrahim et al., 2014). The limit dose established for workers is 20 mSv/year as stated by CNEN rules (CNEN, 2005) (Abba et al., 2017), that corresponds to 2.28 μSv/h. In the current study, 8 points were studied, and none had a measured dose rate value higher than the permissible dose.

The absorbed gamma dose-rates in air measured approximately 1 m above a plane assuming an infinite homogeneous soil medium were given by the interceptor. The annual effective dose rate (AEDR) given by Eq. (1) is a factor of dose-rate, the quotient of annual effective dose received by adults to dose-rate (0.7 $SvGy^{-1}$), the outdoor occupancy factor in this case, 0.4 and the number of hours in a year (8,760) (UNCEAR 1993; Ibrahim et al., 2019).

$$AEDR\ (mSvyr^{-1}) = D \times 0.7 \times 0.4 \times 8760 \tag{1}$$

where D is the absorbed gamma dose rate.

The detailed statistical descriptions which provide basic statistical information about the measured activity concentrations of the radionuclides and the radiation dose rate are presented in Table 3. The histogram and box plots showing the statistical distribution of each measured radionuclide parameter are shown in Figures 2-5. Table 3 shows the values of the evaluations that were carried out in the study area.

Table 3. Gamma activity, (CPS), exposure dose rate ($\mu Svhr^{-1}$), Absorbed Dose Rate ($nGyhr^{-1}$) and Effective Dose Rate ($mSvyr^{-1}$).

S/No	Sample points	Gamma activity (cps)	Exposure dose rate (μSvh^{-1})	Absorbed dose rate ($nGyhr^{-1}$)	Effective dose rate ($mSvyr^{-1}$)
1	Akiri I (AK)	60	0.38	176	0.43
2	Akiri II (AKR)	137	0.99	204	0.50
3	Akiri III (AKS)	76	0.48	183	0.45
4	Azara I (AZC)	28.5	0.18	135	0.33
5	Azara II (AZB)	55.8	0.24	170	0.42
6	Azara III (AZBC)	36.7	0.20	166	0.41
7	Wuse I (WSB)	32.0	0.37	184	0.45
8	Jara (JRA)	23.8	0.16	160	0.39

A statistical analysis was conducted for all the measurements given in Table 3, using a MINITAB 16 software. The dose rate as shown in Table 3 and gamma radiation distribution curves (Figure 2) show similar feature as expected; this may have arisen as a result of different minerals deposits in the study area. Figures 2 and 3 display a frequency versus gamma activity distribution and frequency against dose rate for all the sample points respectively. It is possible to observe that both the gamma activity and dose rates are relatively small in some areas, this could probably be due to the presence, in a significant amount, of metallic deposits that may likely act as a barrier to the radiation (McLaughlin et al., 2002; Bello et al., 2012; Musa et al., 2015).

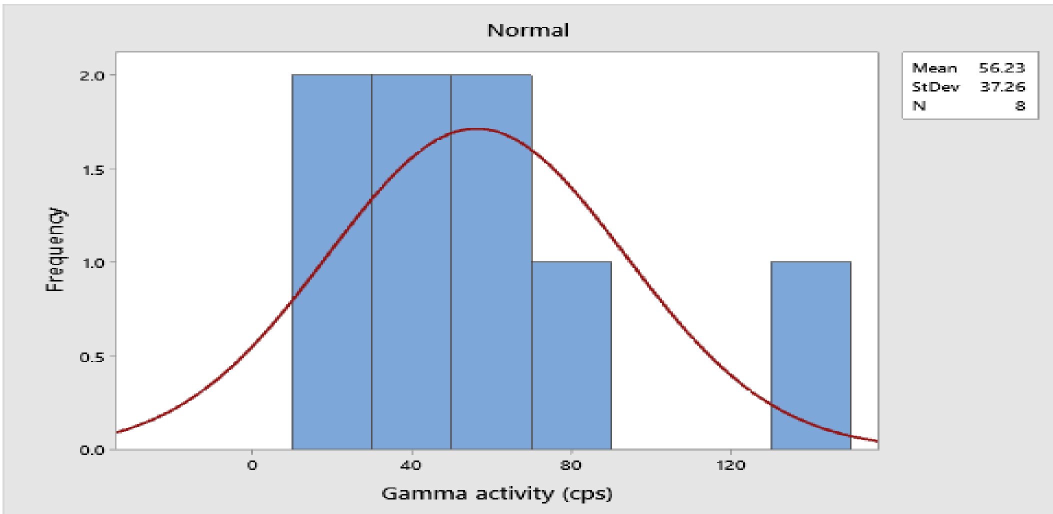

Figure 2. Gamma activity distribution curve.

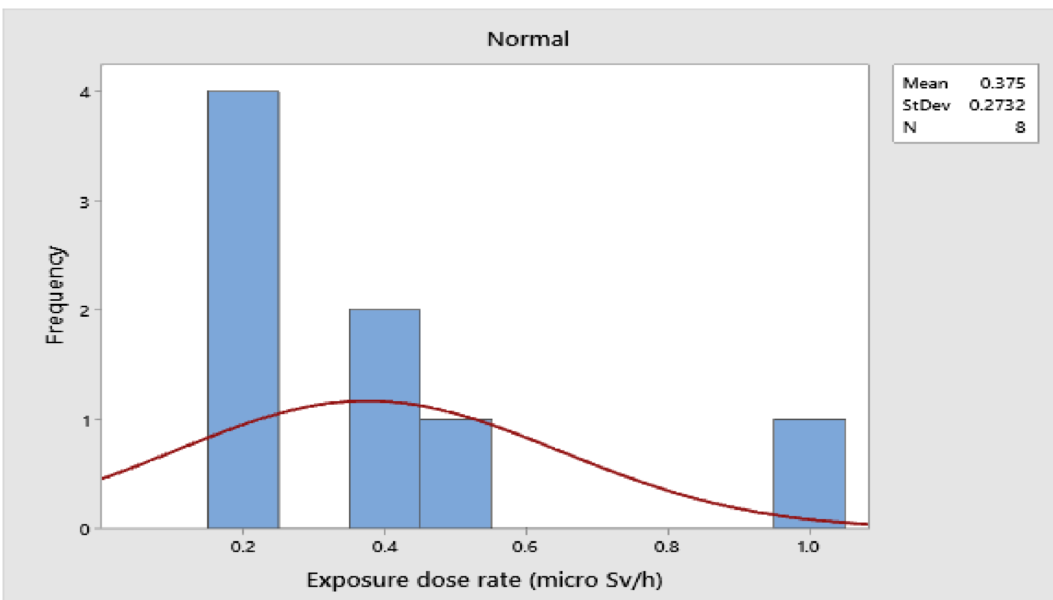

Figure 3. Dose rate distribution curve.

The box plot for count per second (cps) and dose rate are illustrated in Figures 4 and 5. The results show that only one point is considered as outlier which is located around Akiri II sample point (Oyeyemi et al., 2017).

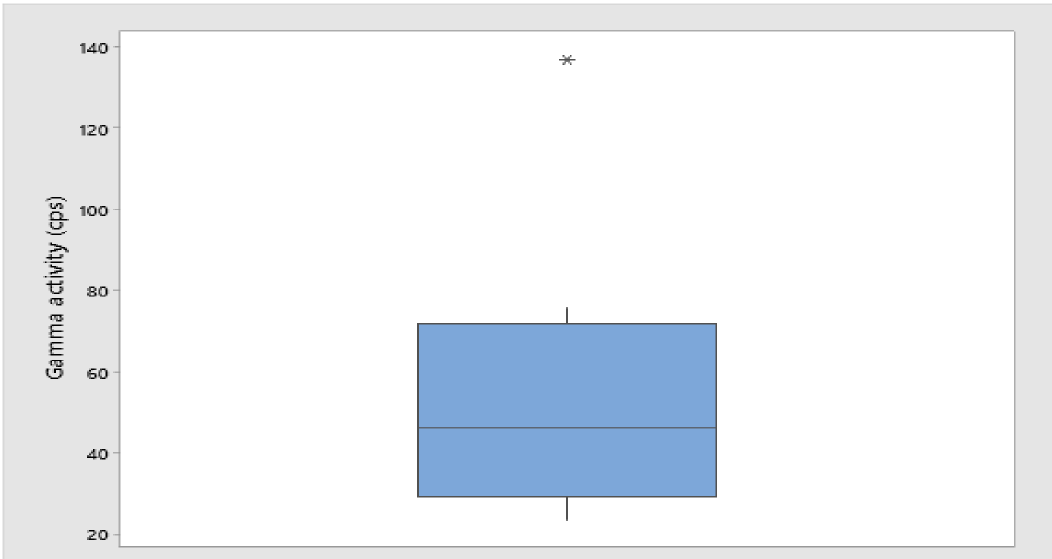

Figure 4. Box plot for gamma activity.

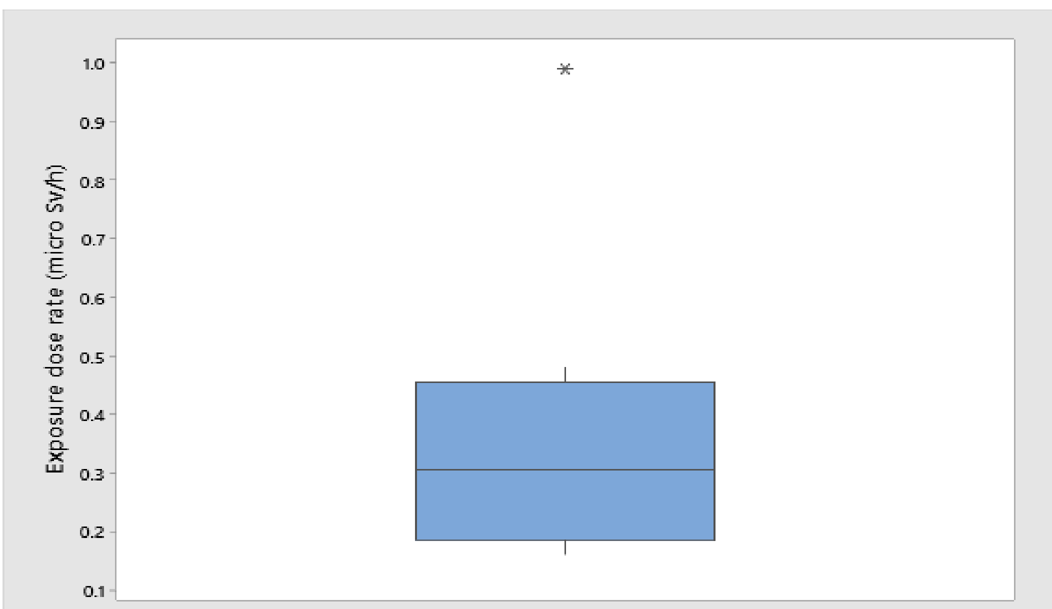

Figure 5. Box plot for dose rate.

CONCLUSIONS

In this study, the initial net that was selected to investigate the selected mining sites across Azara is shown. To evaluate and quantify damages caused by the mining activity is very complicated, however, efforts are made to in order to assess such reparations. Nevertheless, based on the trust level, the results in this work should not be considered as reliable. The levels of the radiation obtained indicate that the sites under study are considered as safe. The existing environmental obligations in the area under study should be evaluated carefully and quantified, since the mining activities is continuously seen as a segment with no transparency in its procedures and actions. The local inhabitants should be conversant with all the tasks that are being performed. Public acceptance and participation are significant for the success of all the related questions on mining activities.

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