HEALTH IMPLICATIONS OF RADIATION HAZARDS FROM SOIL IN RESIDENTIAL AREAS OF MAIGANGA MINING SITE IN GOMBE STATE OF NIGERIA

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ABSTRACT

Soil is a major source of natural radioactivity, radiation hazard for the population and it is the source of migration and transfer of radionuclide into the environment. This study used secondary data obtained by the collection of soil sample from Maiganga town using radon-impermeable cylindrical plastic containers. A total number of ten soil samples were collected at various location within the study area in Akko local government area of Gombe and radiation health hazard indices was evaluated by employing grammar-ray spectroscopy using a NaI (TI) detector. The obtained results showed that the mean values of 40-K concentrations in soil samples were lower than the range of the world average 370 Bq/kg. The activity concentrations of 226-Ra ranged from 139.94±6.4 to 65.87±3.2Bq/kg, with a mean value of 17.54±4.3Bq/kg the activity concentrations of 232-Th ranged from 95.42±4.3 to 24.10±1.4 Bq/kg with a mean value of17.00±2.8 Bq/kg. The activity concentration of Radium was found to be higher than the permitted limit of 30 Bq/kg. Also the average value of radium equivalent was found to be 197.74 Bq/kg while the average value of absorbed dose was 88.69 nGy/h. The average value of effective dose was also found to be 108.40 µSv/y. The results showed that the radionuclide activity found in the surveyed area was very higher and therefore pose a potential health hazard to the humans as well as plants in the study area

Keywords: Radiation hazard and Health implication, Mining Soil Maiganga.

INTRODUCTION

Human beings have always been exposed to natural radiation, which is mainly due to the activity concentration of primordial radionuclide ^{238}U, ^{226}Ra, ^{232}Th series and ^{40}K that present in the earths' crust (Xinweilu *et al*., 2011). The soil is a major source for natural radioactivity, and it is the source for the radiation-hazard for the population and a source for migration and transfer of radionuclide's into the environment. Therefore, soil's natural radioactivity is considered as a basic indicator for radiological contamination (Taqi *et al*.,2018). Natural radioactivity is widespread in the earth and is present in a different environment geological formation in the soil and rocks, plant sand water, food, air and building materials. So, the natural radioactivity of environmental studies, necessary not only for the impact of radiation, but have a great interest and importance in health physics.(Jassim *et al*., 2008). Humans are exposed to natural radioactivity at different levels depending on natural radioactive elements present in each area; as such, researchers investigated the natural environmental radiation and radioactivity in soils to conduct background checks and detect environmental radioactivity. The levels of radioactivity can be used to assess public dose rates and radioactive contamination and predict changes in environmental radioactivity caused by nuclear accidents, industrial activities and other human activities (Alzubaidi *et. al.*, 2016). The naturally occurring radionuclide present in soil, rocks, and water are not uniformly distributed all over the world, and depend primarily on geological and geographical conditions. Terrestrial gamma rays derive essentially from 40K and the radio nuclides belongs to^{238}U and ^{232}Th series that are present in the earth's crust. Apart from these natural sources, modern scientific and technological activities also contribute to radiation levels in the environment (Alshahri *et al*., 2018).

THE STUDY AREA

Kumo, in Gombe State of Nigeria, is situated at 10.040″ North latitude, 11.210″ East longitude and 521 meters elevation above the sea level. It is situated on the A345 highway, about 40 km south of Gombe. The people are predominantly farmers and traders with Population of 35,712, census 2006 (Wikipedia), as shown in Figure 1.

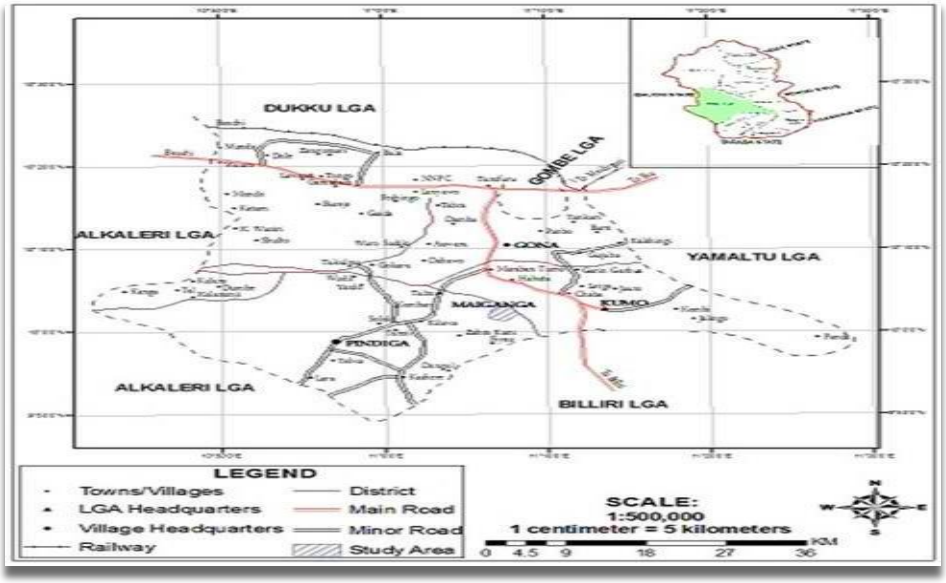

Figure 1: Map showing the sampled area in Maiganga Coal mine site of Kumo metropolitan (Rabiu& John, 2020)

MATERIALS AND METHODOLOGY

Materials

Soil samples, well calibrated Sodium Iodide gamma-ray spectrometry, paper, pen, and container. Other materials used for the various experimental stages of this work include: 2-litre plastic containers to collect the water samples; conductivity meter in order to measure the conductivity of the water samples; global positioning system (GPS) for obtaining correct geographical co-ordinates of the wells and boreholes; stainless steel planchettes; glass beakers; hot plate; weighing balance and hydraulic press. The following chemicals such as nitric acid, acetone, liquid binder and vinyl acetate were also used.

Methods

The International Standard Organization procedure (ISO9696 and ISO9697:1992E) for the measurement of gross alpha and beta activities in soil was employed in this analysis. This procedure provides a screening technique to determine the gross alpha and beta radioactivity in soil samples. The procedure is highlighted below.

Soil Sample Preparation

Each of the soil samples collected were sun dried and crushed to fine powder with the use of pulverized. The samples were being packed into radon-impermeable cylindrical plastic containers which were selected based on the space allocation of the detector vessel which measures 7.6cm by 7.6cm in dimension (geometry) was also carried out. 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.

Evaluation of Radioactivity Samples

The analysis was done using a 76x76mm NaI detector crystal coupled to a photomultiplier tube. The assembly has a preamplifier incorporated into it and a 1kilovolt external source. The detector is embedded in a 6cm lead shield comprises of cadmium and copper sheets. This arrangement is to minimizing the effects of background and scattered radiation. The acquisition of data software is being carried out by Maestro by Camberra Nuclear Products. For each sample, measurement were being carried for a period of 29000 seconds, The peak area of each energy in the spectrum was used to calculate the activity concentrations in each of the sample by using equation given by (Itodo*et al*., 2020).

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

where C is the sample activity concentration of the radionuclides measured in $Bq.Kg^{-1}$, Cn is the count rate which can be calculate as Total count divided life time while C_{fk} represent the system calibration factor.

Calibration and Data acquisition

Spectral energy calibration data used in the analysis shown in Table 1. The standards used for beta are Strontium-90 beta sources with diameter 38 mm and film of 12 mg/m^3 thick. The standards used for alpha are Plutonium-239 alpha sources of diameter 38 mm in an oxidable disc of 3 mm thick. Nitric acid of concentrated of 10mL was added to the water sample immediately after collection in order to reduce the pH, reduce the precipitation and prevent the absorption on the wall of the container. The following formulae by Itodo*et al*, (2020) was used to calculate the count rate and activity.

$$Count\ rate = \frac{Raw\ count}{Count\ time} \quad (2)$$

Quality control parameters for quantitative spectral analysis were shown in table 2 For energy and efficiency the calibration of the system were being carried out with two calibration point sources, Cs-137 and Co-60. The process was being carried out with the amplifier gain of 72%energy resolution for the 661.16KeV of Cs-137, and counted for 30 minutes. The standards followed to check for the calibration are the IAEA gamma Spectrometric reference materials RGU-1 for Ra-226 (Bi-214 peak) RGK-1 for K-40, and RGTh-1 for Th-232 (Ti-208).

Table 1: Spectral energy windows used in the Analysis

Isotope	Gamma Energy (Kev)	Energy Window (Kev)
R-226	1764.0	1620-1820
Th-232	2614.5	2480-2820
K- 40	1460.0	1380-1550

Table 2: Energy Calibration for quantitative Spectral Analysis

Isotope	Calibration Factors		Conversion Factors (Bq$^-$ Kg^{-1})	Detection Limits	
	10^{-3} (cps/ppm)	10^{-4}(cps/ppm)		Ppm	Bq/Kg
^{40}K	0.026	6.431	0.032	454.54	14.54
^{226}Ra	10.500	8.632	12.200	.32	3.84
^{232}Th	3.612	8.768	4.120	2.27	9.08

COUNTING

The counting procedure includes entering of present time, cycle's number as well as counting voltage. Characteristics of counter which includes efficiency and background count rate, volume of sample used and sampling efficiency were entered. The sampling efficiency was calculated as (Ibrahim *et al*, 2016):

$$Sampleefficiency = \frac{(W_{B+S} - W_B) \times 100\%}{W_{B-S} - W_B} \quad (3)$$

Where: W_{B+S} is weight of empty planchet plus sample after evaporation; W_B is weight of empty planchet; W_{B-S} is weight of empty planchet

$$Sample\ efficiency = \frac{Residure\ size\ obtained}{Required\ residure} \times 100\% \quad (4)$$

While the Channel efficiency is given as: (Ibrahim *et al*, 2016):

$$E_C = \frac{cpm\ (\alpha,\beta) \times 100\%}{A} \quad (5)$$

Where $cmp(\alpha, \beta)$ is the background count per minute and A is activity of the source used (Pu-239 for alpha and Sr-90 for beta) (Ibrahim *et al*., 2016).

(a) **Gross alpha counting:** Samples were counted for 30 minutes in alpha only mode while the high voltage for gross alpha counting was set at 1600V. Results were displayed as raw counts; (counts/minutes). The count rate and the activity were calculated using the formula: (Awosan *et al*., 2016).

$$\text{Activity } \alpha = \frac{\text{count rate(cpm)} - \text{Background count rate(cpm)}}{\text{D. E x sample volume x sample efficiency x 60}} \quad (6)$$

where, D.E is the detector efficiency. The reciprocal of 60 seconds is the conversion factor of activity to Bq/L from cpm.

(b) Gross Beta counting: samples were counted for 30 minutes in beta only mode while the high voltage for gross beta counting was set at 1,700V, and the count rate

and the activity were calculated using the formula: (Awosan*et al*., 2016).

$$Activity\ \beta = \frac{\text{count rate (cpm)} - \text{Background count rate (cpm)}}{\text{D. E x sample volume x sample efficiency x 60}} \quad (7)$$

where, D.E is the detector efficiency. The reciprocal of 60 seconds is the conversion factor of activity to Bq/L from cpm (Awosan *et al*., 2016).

Estimation of Radiation Hazard Indices

The radium equivalent activity index in Bq/kg indicates the specific activity levels of materials containing different concentrations of ^{236}Ra, ^{232}Th and ^{40}K, considering the hazard of radiation correlated with each component. This can be estimated based on the equation (UNSCEAR, 2000):

$$Ra_{eq} = C_{Ra} + 1.423C_{Th} + 0.077C_K \quad (8)$$

Where C_{Ra}, C_{Th} and C_K are concentrations of the activity for ^{236}Ra, ^{232}Th and ^{40}K respectively. The equation is based on the evaluate that 1 Bq/kg of ^{236}Ra, 0.7 Bq/kg of ^{232}Th and 13 Bq/kg of ^{40}K produce the same gamma ray dose rate.

Total absorbed dose at 1m above the ground level based on gamma radiation in air was estimated by assuming equal distribution of the natural radionuclides ^{236}Ra, ^{232}Th and ^{40}K using the following equation (UNSCEAR, 2000):

$$D(nGy/h) = 0.429C_{Ra} + 0.662C_{Th} + 0.0427C_K \quad (9)$$

To calculate the annual effective dose rate, the conversion coefficient from absorbed dose in air to effective dose was 0.7 Sv/Gy and outdoor occupancy factor (0.2) was used. The annual effective dose are estimated using the equation (UNSCEAR, 2000):

$$Deff(\mu Sv/y) = D(nGy/h) \times 8760(h/y) \times 0.2 \times 0.7(Sv/Gy) \times 10^{-3} \quad (10)$$

RESULTS AND DISCUSSION

Results

Gross potassium (K-40), Radon (Ra-226) and Thorium (Th-232) measurement were carried out on the soil samples collected to identify concentration of each radiation with a view of predicting possible hazards from ingestion of their sources**.** The gross concentration K-40, Ra-226 and Th-232 are presented in Tables 4.1 to 4.3.

Table 3: Gross potassium K-40 concentration in the soil sample

S/N	SAMPLE ID	Geographical Coordinate	K-40 (CPS)	Error ± (CPS)	K-40 (Bq/Kg)	Error ± (Bq/Kg)
1	BROWN 1	9.986264N 11.15259E	0.4518	0.0195	290.7550±8.44	1.2548±0.03
2	RED	9.986266N 11.15359E	0.6089	0.0178	391.8383±10.40	1.1476±0.01
3	WHITE	9.986274N 11.15269E	0.8010	0.0234	515.4440±14.55	1.5069±0.05
4	BLACK	9.986284N 11.15299E	0.5283	0.0191	339.9828±8.90	1.2280±0.03
5	BROWN 2	9.986264N 11.15259E	0.5393	0.0188	347.0613±9.94	1.2066±0.02
6	S 1	9.986264N 11.15359E	0.3771	0.0177	242.6534±8.22	1.1369±0.01
7	BROWN 3	9.986254N 11.15289E	0.4434	0.0203	285.3389±9.44	1.3085±0.04
8	BLACK 2	9.986564N 11.15459E	0.4901	0.0184	315.3689± 9.45	1.1851±0.01
9	S 2	9.986266N 11.15249E	0.4379	0.0180	281.7997±9.33	1.1583±0.02
10	BLACK3	9.986265N 11.15257E	0.3363	0.0169	216.4307±8.11	1.0886±0.01
Average values			0.09437	0.00127	60.7314±9.66	0.08194±0.02

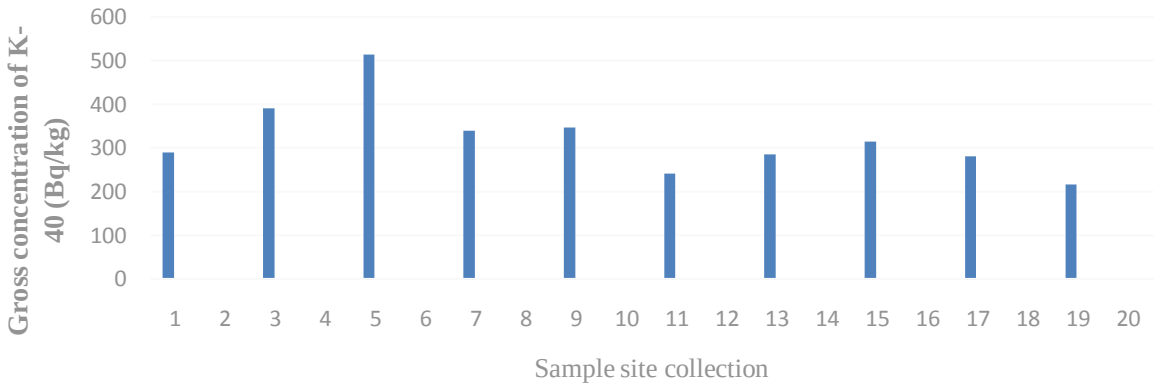

Figure 2: Gross potassium K-40 concentration in soil sample collected
CPS= Count per second. Bq/Kg = Becquerel per kilogram. Calibration factors: $x10^{-4}$
Conversion factor: cps/Bq-kg^{-1}. K-40 = 0.000643

Table 4: Gross Ra-226 concentration in the soil sample collected

S/N	Sample ID	Geographical Coordinate	Ra-226 (CPS)	Error ± (CPS)	Ra-226 (Bq/Kg)	Error ± (Bq/Kg)
1	BROWN 1	9.98635N 11.5346E	0.1597	0.0042	76.5420±4.2	1.9974±0.02
2	RED	9.98667N 11.1537E	0.1926	0.0037	92.3218±5.3	1.7578±0.03
3	WHITE	9.98663N 11.1536E	0.2919	0.0053	139.9409±6.4	2.5168±0.13
4	BLACK	9.86317N 11.1528E	0.2009	0.0046	96.3167±5.3	2.1972±0.10
5	BROWN 2	9.98635N 11.5366E	0.1448	0.0032	69.4311±3.5	1.5181±0.02
6	S 1	9.98635N 11.5346E	0.1358	0.0023	65.0767±3.2	1.1186±0.01
7	BROWN 3	9.98635N 11.5366E	0.2128	0.0036	102.0294±4.7	1.7178±0.03
8	BLACK 2	9.98645N 11.5376E	0.1674	0.0035	80.2573±3.9	1.6779±0.02
9	S 2	9.98655N 11.5346E	0.1449	0.0024	69.4711±3.3	1.1585±0.01
10	BLACK3	9.98635N 11.5346E	0.1374	0.0008	65.8757±3.2	0.3595±0.001
Average values			0.03658	0.00095	17.5407±4.3	0.45063±0.04

CPS = Count per second. Bq/Kg = Becquerel per kilogram.
Calibration factors: $x10^{-4}$
Conversion factor: cps/Bq-kg^{-1}.Ra-226= 0.000863

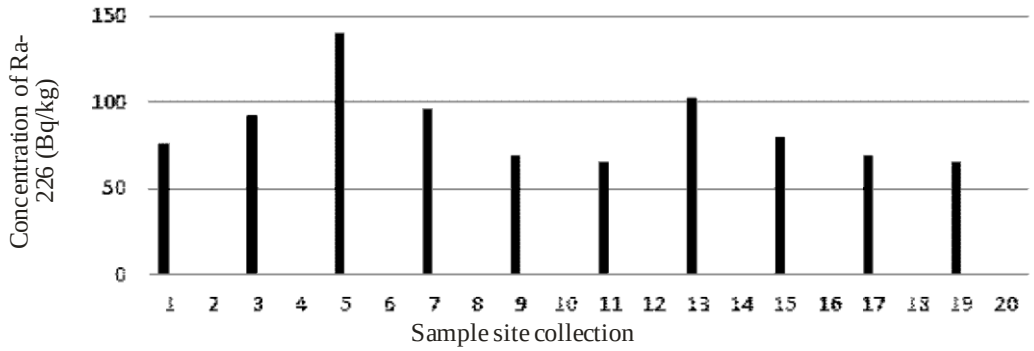

Figure 3: Gross Ra-226 concentration in the soil sample collected

Table 5: Gross Th-232concentration in the soil sample

S/N	Sample ID	Geographical Coordinate	Th-232 (CPS)	Error ± (CPS)	Th-232 (Bq/Kg)	Error ± (Bq/Kg)
1	BROWN 1	9.98635N 11.5346E	0.1442	0.0048	68.0218±3.3	2.2412±0.15
2	RED	9.98647N 11.1537E	0.2023	0.0044	95.4271±4.3	2.0839±0.11
3	WHITE	9.98663N 11.1536E	0.1713	0.0054	80.8397±3.9	2.5557±0.17
4	BLACK	9.86317N 11.1538E	0.0770	0.0046	36.3307±1.0	2.1625±0.12
5	BROWN 2	9.98665N 11.5376E	0.1400	0.0049	66.0558±3.3	2.3198±0.13
6	S 1	9.98685N 11.5346E	0.1222	0.0054	57.6416±3.1	2.5557±0.17
7	BROWN 3	9.98535N 11.5349E	0.0826	0.0056	38.9651±2.0	2.6344±0.80
8	BLACK 2	9.98665N 11.5356E	0.0511	0.0037	24.1025±0.4	1.7300±0.02
9	S 2	9.98635N 11.5376E	0.1585	0.0026	74.7846±3.7	1.2189±0.01
10	BLACK3	9.98665N 11.5376E	0.1334	0.0035	62.9496±3.2	1.6514±0.10
Average values			0.03603	0.00075	17.0015±2.82	0.3554±0.18

CPS = Count per second. Bq/Kg = Becquerel per kilogram. Calibration factors: $x10^{-4}$
Conversion factor: cps/Bq-kg^{-1} .Th-232 = 0.000877

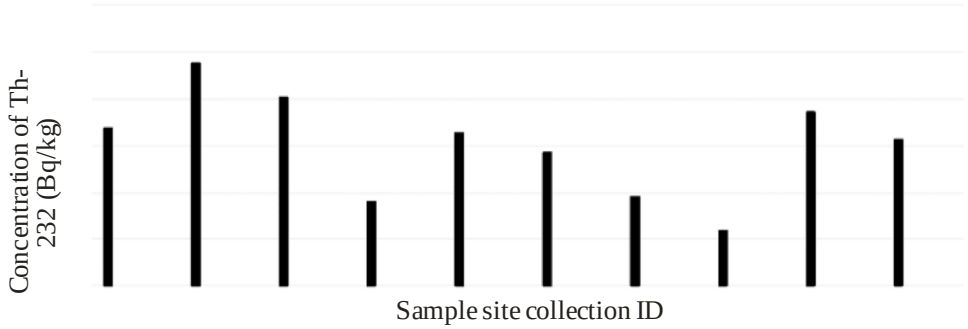

Figure 4: Gross Th-232 concentration in the soil sample collected

Table 6: Radium equivalent (Ra_{eq}), Total absorbed dose (D) and annual effective dose (D_{eff}) in the studied soil samples

S/N	Sample ID	Geographical Coordinate	Ra_{eq}(Bq/kg)	D (nGy/h)	D_{eff} (µSv/y)
1	BROWN 1	9.98635N 11.5346E	195.72	90.28	110.72
2	RED	9.98647N 11.1537E	258.29	97.28	119.30
3	WHITE	9.98663N 11.1536E	294.67	138.56	166.25
4	BLACK	9.86317N 11.1538E	174.19	79.89	97.97
5	BROWN 2	9.98665N 11.5376E	190.15	88.33	108.33
6	S 1	9.98685N 11.5346E	176.37	76.44	93.74
7	BROWN 3	9.98535N 11.5349E	179.45	81.75	100.26
8	BLACK 2	9.98665N 11.5356E	138.84	63.85	78.31
9	S 2	9.98635N 11.5376E	197.59	91.34	112.02
10	BLACK3	9.98665N 11.5376E	172.12	79.17	97.10
Average values			197.74	88.69	108.40

DISCUSSION

The activity concentrations of naturally occurring radionuclide (^{40}K, ^{226}Ra ^{232}Th) were determined in soil samples from Maiganga. The statistics of the activity concentration expressed in Bq/kg are presented in Tables 3 to 5.The obtained results show that the mean values of 40-K concentrations in soil samples were lower than the range of the world average370 Bq/kg. The mean values of activity concentrations of 226-Ra ranged from 139.94±6.4 to 65.87±3.2Bq/kg, which higher than the allowed limit of 30 Bq/kg with an average value of 17.54±4.3Bq/kg. From Table 6, the radium equivalent activity index (Ra_{eq}) in soil samples ranges from 138 to 294 Bq/kg which is less than the safe limit (370 Bq/kg) recommended by the Organization for Economic Cooperation and Development (OECD) (1979). The total absorbed dose (D) in the study area ranged between 63.85 and 138.56 nGy/h with average value 88.69 which is greater than the range of values given in UNSCEAR (2000) (57nGy/h). The annual effective in this study area ranged from 78.31 to 166.25 µSv/y. it is clear that the average value of annual effective dose (108.40 µSv/y) is greater than worldwide average value for outdoor effective dose of 70µSv/y, reported by UNSCEAR (2000).

CONCLUSION

In the present study, the activity concentrations for 40K, 226Ra, 232Th, were measured in 10 soil samples collected from Maiganga Akko local government area, Gombe state Nigeria, near an oil refinery and around a residential area using gamma-ray spectrometry, have clearly shown the existence of high level activity. The measurements of all samples under investigation showed that the mean values of radioactivity levels were lower than the world average for 40-K 226-Ra, 232-Th. The maximum value of 226-Ra in soil was 139.94±6.4Bq/kg, which is higher than the recommended value. The calculated average radium equivalent activity index (Ra_{eq}), the total absorbed dose rate and the annual effective dose in this study show that the radioactivity of radionuclides found in surveyed area is above the word activity values, and does constitute a radiological concern for people in the areas studied.

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