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Evaluation of Natural Radoiactivity of Soil Samples in Some Selected Areas of Adamawa State, Nigeria

AndrewFambia, * Yakubu I. Java, ** Sunday I. Adigwe, ***Saidu A.Dawa, ****

**(Department of physics, Umar Ibrahim El-kanemi college of education, science and technology, Bama, Borno state, Nigeria*
(Email:andrewfambia@gmail.com)

*** (Department of physics, Umar Ibrahim El-kanemi college of education, science and technology, Bama, Borno state, Nigeria*
Email:yacks76yji@gmail.com)

**** (Departmentof Integrated science, Umar Ibrahim El-kanemi college of education, science and technology, Bama, Borno state, Nigeria)*
(Email:increaseadigwe@gmail.com)

***** (Department of physics, Umar Ibrahim El-kanemi college of education, science and technology, Bama, Borno state, Nigeria)*
(Email:saidualidawa@gmail.com)

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Abstract:

Evaluation of naturally, occurring radionuclides,^{238}U,^{232}Th and^{40}K. in the five locations of Adamawa state were carried out using gamma-ray spectrometry with well-type NaI detector to determine the natural radionuclides in the living environment and farmland soil samples to evaluate the hazards they might pose on the public. The calculated average activity concentrationsare 17.60 BqKg^{-1}, 5.16 BqKg^{-1} and 847.24 BqKg^{-1} respectively. The mean activity concentration of the radionuclides ^{238}U, and ^{232}Th in the present study are much lower than the worldwide average permissible values of 33 BqKg^{-1} and 45 BqKg^{-1} respectively. That of ^{40}K is higher than the world average value of 420 BqKg^{-1}. For those of the farmland soil samples, the average activity concentrations of the radionuclides: ^{238}U, ^{232}Th and ^{40}K were 17.95 BqKg^{-1}, 5.61BqKg^{-1} and 891.34 BqKg^{-1} respectively. It was also seenthat, the average activity concentration of ^{238}U and ^{232}Th are much lower, compared to the world allowed average of 33 BqKg^{-1} and 45 BqKg^{-1}. In addition, that of ^{40}K is much higher than the world average of 420 BqKg-1. The study also revealed that the calculated of Ra_{eq}, absorbed dose rate and annual effective dose rate of the living environment, soil samples were found to be 90.20 BqKg^{-1}, 47.36 nGyh^{-1} and 0.29mSvy^{-1} respectively. Those of the farmland soil samples were also found to be 92.41 BqKg^{-1}, 49.69 nGyh^{-1} and 0.3 mSvy^{-1} respectively. The mean values of all the parameters are within the world average recommended safety limits. The internal commission on Radiological Protection (ICRP) has recommended the annual effective dose equivalent limit of 1mSvy^{-1} for the individual members of the public and 20mSvy-1 for the radiation workers.Therefore, it can be concluded that the present study areas are safe from radiation hazards with no harmful effects posed to the living population in the environments**.**

Keywords **—Natural radioactivity, soil, farmland, living environment, radiological hazard parameters.**

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I. INTRODUCTION

Natural radioactivity is the activity existing in nature.it is the radioactive decay of naturally occurring elements.

Natural radioactivity can be classified into two basic types viz: ionizing and non-ionizing radiation. Ionizing radiation is a radiation with enough energy so that during interaction with an atom, it can remove tightly bound electrons from the orbit of an atom, causing the atom to become ionized.

Some atoms are naturally stable while others are unstable. Atoms with unstable nuclei, which spontaneously transforms, releasing energy in the form of radiation, is referred to as radionuclides. Radionuclides in the soil are responsible for the background radiation exposure to the population [1].

The primordial radionuclides U-238, Th-232, K-40 and their decay products are present at different concentrations in all environments over the globe and produce significant exposure to the population [1, 4, and 5]. These radionuclides find their ways into the soil, surface water and ground water through different earth's processes [2, 6]. Their concentrations increase above normal levels in combination anthropogenic activities, such as testing of nuclear weapons [2], mining and the use of phosphate and sulfate fertilizers [9, 10, and 11]. The phosphate ore, the raw materials used in the manufacture of phosphate fertilizers, contain naturally, occurring radionuclides such as 238U, 232Th and 40K in increased concentrations [3, 7].

The application of phosphate fertilizers can thus be major sources of radionuclides and heavy metals applied to agricultural farmlands [7, 8].

Over the years, there has been increased application of phosphate fertilizers to agricultural farmlands of the region in order to meet the demands of high yields of farm produce, because of continuous cultivation of same farmlands leading to the depletion of nutrients in the soil.

Based on the available literatures, there has not been sufficient work in assessing the radionuclides in the study areas.

Therefore, the work is aimed at evaluating the natural radioactivity of the soil in the region to ascertain whether the levels of radionuclides conform to the world mean dose via the following objectives: determining the activity concentration, radium equivalent activity, absorbed dose rate, and annual effective dose rate.

II. STUDY LOCATION

Adamawa is a state in the North –East Nigeria with its capital at Yola. It has a total area of 36, 917 Km2, with an estimated population of 3,373,223 as at 2005. The state is geographically located at latitude 8°N and 11°N and longitude 11.5°E and 13.75°E: international Journal of Science and Technology, 2012. The major occupation of the people is farming as reflected in their two notable vegetation zone – Sub-Sudan Northern Guinea Savannah zones. The areas selected for this research work are: Mubi-North, Mubi-South, Michika, Hong and Gombi local government areas.

The map of the study location is shown below.

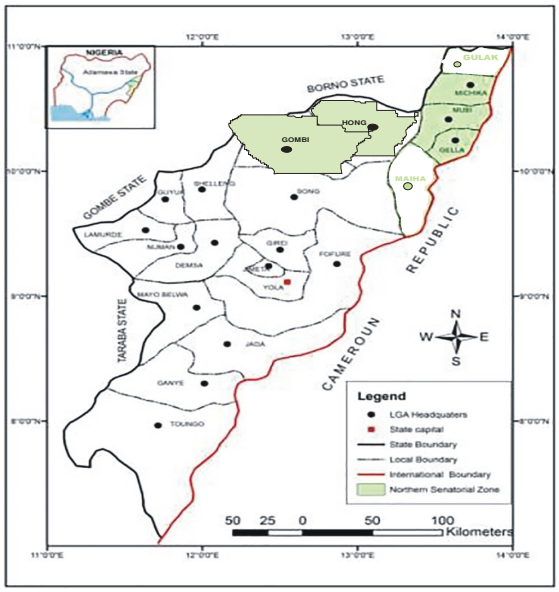

Figure 1: : Map of Adamawa State Showing the Study Area (Source: GISlaboratorydepartmentofgeography,MAUTECH,Yola2024

III. MATERIALSAND METHOD

A. *Four soil samples, two each from the agricultural farmland and living environment were collected from different locations of the study areas at a depth of 30 cm using matchet and hand trowel. The samples were separated from each other, packed in black polythene bags and given a label to avoid mix-up after collection, spread in a pan and dried under the sun for 72 hours to a constant weight. This was to remove the water content. After wards, the samples were crushed into fine particles and sieved through a 0.2 mm sieve. The sieved samples were weighed and a mass of 500g of each samples was tightly sealed in a black polythene bags to avoid random escape of ^{226}Rn (12]. These stored samples were taken to the Nigerian institute of radiation protection and research, university of Ibadan.200 g of each soil sample were placed in a cylindrical beaker of dimension 7 by 7cm, and kept for 30 days, for secular equilibrium to take place [13].*

B. Instrumentation and Calibration

The instrument used in this research is the gamma ray spectrometer of Well type Nal Detector of dimension 7.6cm by 7.6cm housed in a 6cm thick lead shield to minimize background radiation. The Choice of the detector was due to its modest resolution. The detector was coupled to a Multichannel Analyzer (MCA) through a photomultiplier tube, which converts the visible light photons produced in the crystal into amplified electrical pulse. The gamma spectrometry detector was calibrated before it was used for analysis. This was done to ensure that the radiation parameters in the samples could be expressed in physical radiometric units. This energy calibration was performed with point sources: Am-241, Cs-137 and Co-60 with their channel numbers and energies given as 29.22 and 59.54, 212.77 and 661.65, 365.87 and 11173.22 respectively. The energy calibration converts channel numbers to y-ray energy in MeV. This was done by placing different gamma sources of known energy on the detector at a distance of 7cm from it. After a preset counting time of 18,000s, the channels of the various photo peaks corresponding to the gamma energies were identified through the personal computer, which is connected to a Multichannel Analyzer (MCA) through a photomultiplier tube.Since some radioactivity is present everywhere (i.e., background radiation), the spectrum was analyzed when no source was present.

The background radiation was then subtracted from the actual measurement. Lead absorbers were placed around the measurement apparatus to reduce background radiation.

B. ACTIVITY CONCENTRATION.

The activity concentration of the soil samples was calculated directly by the computer software connected to the instrument (NaI detector) using the formula [14], practical gamma ray spectroscopy).

$$Ai = \frac{Ao \times M}{Ro \times m,}. \qquad Eq.(1).$$

Where Ai =Activity of nuclide;

Ri = Net count rate of sample;

Ao =Activity of standard;

Ro =Net count rate of standard;

M = Mass of Standard;

m = mass of Sample.

VI. ASSESSMENT OF RADIOLOGICAL HAZARD PARAMETERS

A. *RADIUM EQUIVALENT ACTIVITY*

The radium equivalent activity, Ra_{eq} measured in Bqkg-^{1}, was introduced to identify the uniformity to radiation exposure. The calculated values of$Ra_{eq}$are generally used to compare the specific activity of materials containing different amounts of ^{238}U, ^{232}Th, and ^{40}K. Besides, Ra_{eq}data can be used to assess the health hazard effects produced from the activity concentrations of ^{238}U.^{232}Th, and^{40}K radionuclides in soil.The measured values of Ra_{eq}were obtained by making use of the following equation [15, 16].

$Ra_{eq} = A_u + 1.43A_{Th} + 0.077A_{k}$ Eq. (2)

B. *ABSORBED DOSE RATE*

If the activity concentration of radionuclides in soil is known, assuming that radionuclides are uniformly, distributed in the soil, the exposure dose rate in air causing these radionuclides can be calculated using the formula [17].

$D = 0.462A_u \pm 0606A_{Th} \pm 0.0417A_K$ [18].

where D denotes the dose rate (nGyh^{-1}) in the air at 1m above the ground surface; A_u, A_{Th}, and $A_k$are the activity concentration of ^{238}U, ^{232}Th and ^{40}K respectively in the soil sample; while 0.462, 0.604 and 0.0417 are the dose conversion factors for ^{238}U, ^{232}Th, and ^{40}K respectively.

C. *ANNUAL EFFECTIVE DOSE RATE.*

To assess the radiation hazard associated on the health effect of the absorbed dose, annual effective dose is obtained. The conversion coefficient from the absorbed dose in air to the effective dose is (0.7SvGy"') and the outdoor occupancy factor (0.2) in reference [18]. The annual effective dose was calculated based on the equation:

AED (mSv^{-1}) = D(nGy^{-1})x 24 x 365(hy^{-1})0.2 x 0.7(SvGy^{-1})x 10^{-6}Eq. (3)

V. RESULTS AND DISCUSSION

The results of activity concentration of radionuclides obtained from gamma ray analysis of soil samples of the living environment and the farmland collected from the five locations of Adamawa state are presented in table **1** and **2** respectively. The radium equivalent activity (BqKg-^{1}), the gamma absorbed dose rate (nGyh^{-1}) at 1 m above the ground due to ^{238}U, ^{232}Th and ^{40}K and the annual effective dose rate (mSvy-^{1}), of the soil samples of living environment and farmland are presented in table **3** and **4** respectively.

Figure **1** and **2** also show the column charts of living environment and farmland soil samples respectively.

TABLE 1: ACTIVITY CONCENTRATIONS OF RADIONUCLIDES; K-40, U-238 AND TH-232 OF THE LIVING ENVIRONMENT SOIL SAMPLES OF THE FIVE LOCATIONS.

S/N	Zone	Location	Soil type	Sample name	K-40($BqKg^{-1}$)	U-238($BqKg^{-1}$)	Th-232($BqKg^{-1}$)
1	Mubi-North	Barama	Sandy Soil	Sample 6	683.36±48.51	1.22±0.32	2.20±0.22
2	Mubi-North	Viratim	Sandy Soil	Sample 5	1065.92±74.65	26.9U4.89	8.24±0.82
3	Mubi-South	Madanya	Sandy-Loam	Sample 2	673.35±47.44	18.84±3.56	4.80±0.48
4	Mubi-South	Gipalma	Clay Soil	Sample 15	800.30±40.41	22.90±2.45	6.66±0.39
5	Hong	Fachi	Sandy-Loam	Sample 9	635.18±4470	20.40±3.80	4.92±0.49
6	Hong	Kala'a	Sandy Soil	Sample 16	341.36±24.38	2.81±0.72	1.84±0.19
7	Gombi	A/Nepa	Sandy Soil	Sample 3	989.07±69.35	14.94i2.94	5.43±0.54
8	Gombi	Jama"are	Sandy Soil	Sample 14	1302.28±64.99	23.27±2.43	5.27±0.31
9	Michika	Michika-Town	Sandy Soil	Sample 7	1179.61±82.47	24.08±4.42	6.77±0.67
10	Michika	Bazza	Sandy Soil	Sample 19	802.01±56.35	20.55±3.83	5.46±0.54
Maximum					1302.28	26.91	8.24
Minimum					341.36	1.22	1.84
Average					847.24	17.60	5.16
World average					420	33	45

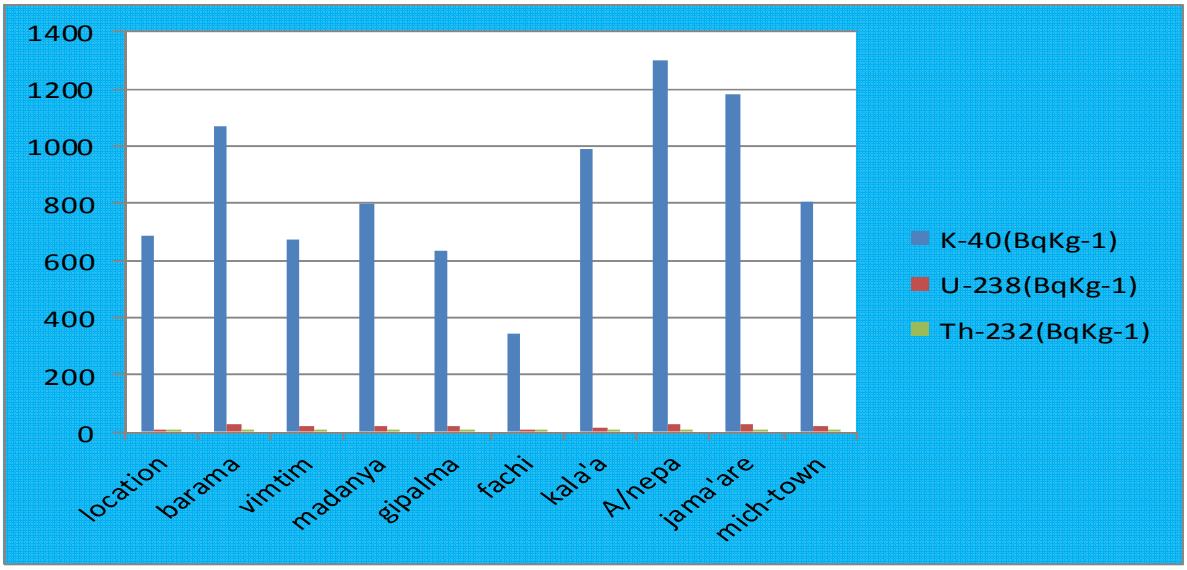

Figure 1: shows column chart of the activity concentrations of radionuclides soil samples of living environment

TABLE 2: ACTIVITY CONCENTRATIONS OF RADIONUCLIDES: K-40, U-238 AND TH-232 OF THE FARMLAND SOIL SAMPLES IN THE FIVE LOCATIONS.

S/N	Zone	Location	Soil type	Sample name	K-40($BqKg^{-1}$)	U-238($BqKg^{-1}$)	Th-232($BqKg^{-1}$)
1	Mubi-North	Barama	Sandy-Loam	Sample 12	1145.72±57.56	19.47±2.32	6.79±0.40
2	Mubi-North	Vimtim	Clay Soil	Sample 1	823.57±41.53	27.7±2.79	7.75±0.46
5	Mubi-South	Madanya	Sandy-Loam	Sample 18	687.89±48.4	22.26±4.07	6.31 ±0.63
4	Mubi-South	Gipalma	Clay soil	Sample 20	890.41±62.52	18.54±3.49	6.22±0.62
5	Hong	Fachi	Sandy-Loam	Sample 11	867.86±43.74	18.34±2.1	4.67±0.28
6	Hong	Kala'a	Clay soil	Sample 10	905.77±45.69	5.41±1.04	5.47±0.33
7	Gombi	A/Nepa	Sandy-Loam	Sample 8	1156.46±80.88	22.71±4.92	6.26±0.62
8	Gombi	Jama"are	Sandy soil	Sample 13	990.96±50.34	3.13±0.61	1.31 ±0.09
9	Michika	Michika-Town	Sandy soil	Sample 4	590.59±41.71	16.90±3.29	5.35±0.54
10	Michika	Bazza	Clay Soil	Sample 17	854.12±60.06	25±4.76	5.78±0.58
Maximum					1156.46	27.7	7.75
Minimum					590.59	3.13	1.31
Average					891.34	17.95	5.61
World average					420	33	45

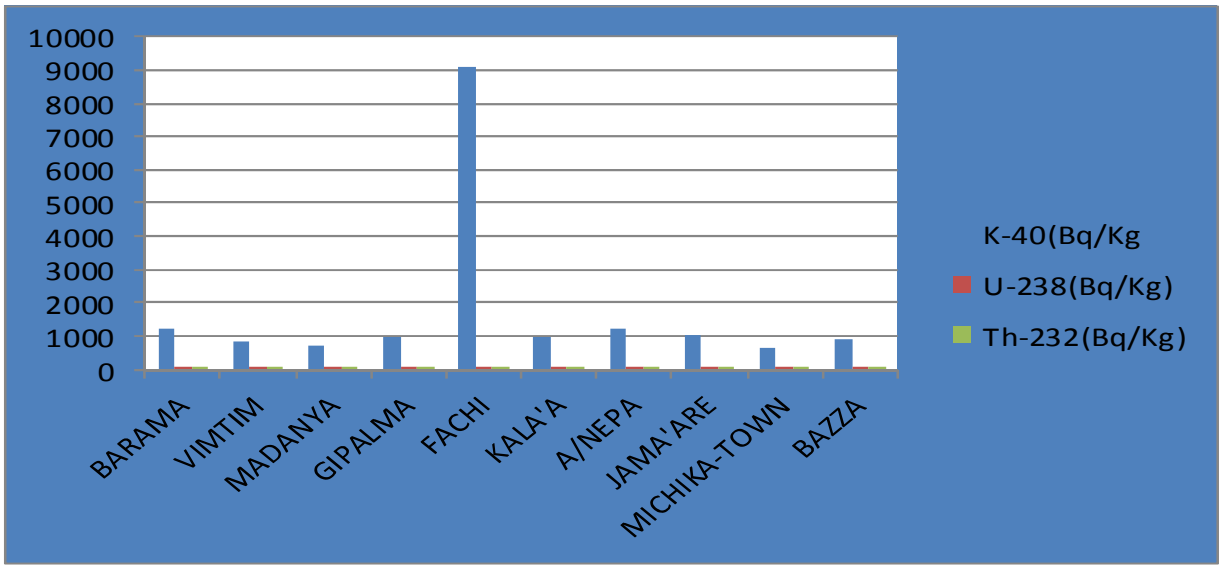

Figure 2: shows the column chart of the activity concentration of radionuclides; K-40, U-238 and Th-232 of the farmland soil Samples.

TABLE 3: SHOWS CALCULATED VALUES OF RADIUM EQUIVALENT ACTIVITY, ABSORBED DOSE RATE AND ANNUAL EFFECTIVE DOSE RATE OF THE LLIVING ENVIRONMENTSOIL SAMPLES.

S/N	Zone	Location	$Ra_{eq}(Bqkg^{-1})$	$D(nGyh^{-1})$	$AED(mSvy^{-1})$
1	Mubi-North	Barama	56.98 ±4.37	31.36±12.37	0.19±0.01
2	Mubi-North	Vimtim	120.77±11.81	62.78 ±5.81	0.38±0.04
3	Mubi-South	Madanya	77.55 ±7.90	40.18±3.85	0.25±0.02
4	Mubi-South	Gipalma	94.05 ±6.12	48.60±3.02	0.30±0.02
5	Hong	Fachi	76.34 ± 7.94	39.28±3.84	0.23±0.02
6	Hong	Kala'a	31.73±12.87	17.10±1.48	0.10±0.01
7	Gombi	Jama'are	98.86±9.05	52.50 ±4.57	0.32±0.03
8	Gombi	A/Nepa	131.08+ 7.88	69.42 ±4.02	0.43±0.02
9	Michika	Mich-town	124.60 ± 11.73	65.48±5.85	0.40±0.04
10	Michika	Bazza	90.11 ±8.94	46.88±14.39	0.29±0.03
Minimum			31.73	17.10	0.10
Maximum			131.08	69.42	0.43
Average			90.20	47.36	0.29
World average			370	59	0.5

TABLE 4: SHOWS CALCULATED VALUES OF RADIUM EQUIVALENT ACTIVITY, ABSORBED DOSE RATE AND ANNUAL EFFECTIVE DOSE RATE OF THE FARMLAND SOIL SAMPLES.

S/N	Zone	Location	$Ra_{eq}(Bqkg^{-1})$	$D(nGyh^{-1})$	$AED(mSvy^{-1})$
1	Mubi-North	Barama	56.98 ±4.37	31.36±12.37	0.19±0.01
2	Mubi-North	Vimtim	120.77±11.81	62.78 ±5.81	0.38±0.04
3	Mubi-South	Madanya	77.55 ±7.90	40.18±3.85	0.25±0.02
4	Mubi-South	Gipalma	94.05 ±6.12	48.60±3.02	0.30±0.02
5	Hong	Fachi	76.34 ± 7.94	39.28±3.84	0.23±0.02
6	Hong	Kala'a	31.73±12.87	17.10±1.48	0.10±0.01
7	Gombi	Jama'are	98.86±9.05	52.50 ±4.57	0.32±0.03
8	Gombi	A/Nepa	131.08+ 7.88	69.42 ±4.02	0.43±0.02
9	Michika	Mich-town	124.60 ± 11.73	65.48±5.85	0.40±0.04
10	Michika	Bazza	90.11 ±8.94	46.88±14.39	0.29±0.03
Minimum			31.73	17.10	0.10
Maximum			131.08	69.42	0.43
Average			90.20	47.36	0.29
World average			370	59	0.5

DISCUSSION OF RESULTS.

The activity concentration due to contribution from the three radionuclides, ^{40}K, ^{238}U and ^{232}Th of the living environment soil samples ranged from: (341.36 to 1302:28) $BqKg^{-1}$ with average value of 847.24 $BqKg^{-1}$, (1.22 to 26.91) $BqKg^{-1}$ with average value of 17.60 $BqKg^{-1}$ and (1.84 to 8.24) $BqKg^{-1}$ with average value of 5.16 $BqKg^{-1}$ respectively. The highest activity concentration of ^{40}K was recorded at sample 14 (Jama'are) with 1302.28 $BqKg^{-1}$ and the lowest value was recorded at sample 16 (Kala'a) 341.36 $BqKg^{-1}$. While that of the farmland soil sample, the activity concentration ranged from: (590.59 to 1156.46) $BqKg^{-1}$, with average value of 891.34 $BqKg^{-1}$, (3.13 to 27.7) $BqKg^{-1}$ with average value of 17.95 $BqKg^{-1}$ and from (1.31 to 7.75) $BqKg^{-1}$ with average value of 5.61 $BqKg^{-1}$ respectively. The highest activity concentration was recorded at sample 8 (Anguwan Nepa) with value of 1156.46 $BqKg^{-1}$ while the lowest value was recorded at sample 4 (Michika-town) with value of 590.59 $BqKg^{-1}$. The activity concentration values of ^{40}K in each of the living environment and the farmland soil samples were higher than the world average of 400 $BqKg^{-1}$. The activity concentration values of U-238 and Th-232 in both cases are insignificant compared to the world average values of 35 and 30 $BqKg^{-1}$ respectively. From table 3 and 4, the calculated average values of radium equivalent activity, the absorbed dose rate, andthe annual effective dose rate; are, 90.20 $BqKg^{-1}$, 47.36 $nGyh^{-1}$. 0.29$mSvy^{-1}$,respectively, for the living environment soil samples.While for the farmland soil samples, the values are92.41$BqKg^{-1}$, 49.69 $nGyh^{-1}$, 0.3$mSvy^{-1}$ respectively. In both cases, the values obtained were lower than world average values of 370 $BqKg^{-1}$, 59$nGyh^{-1}$, and 0.5 $mSvy^{-1}$, respectively.

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