International Journal of Engineering, Science and Mathematics
Vol7.Issue 2, Febeuary 2018,
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijmra.us, Email: editorijmie@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

Measurement of Radiation from Naturally Occurring Radioactive Materials in a Mineral Called "Ewoa", Gurage zone, Ethiopia.

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Abstract

Using an experimental technique (NaI(Tl)-gamma spectroscopy) the natural radioactivity emanating from a mineral soil which is in use in far-flung areas of Ethiopia was determined. The results of the experiment were converted in to radiation dose units and it is compared with internationally set standards for a public. The calculated average absorbed dose rate in air due to gamma ray from the mineral soil activity, likewise the average hazard indexes obtained for both external and internal exposure do not exceeded the limits set by United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Therefore the mineral soil does not pose a threat to the public.

Keywords:

Gamma spectroscopy;
Naturally Occurying radioactive Materials;
Mineral Soil;
Radiation dose.

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1. Introduction:

Natural radioactivity is the major contributor to ionizing radiation in environment that comes from both natural background and man-made sources [1]. Most of thes radio nuclides are long half-lives which will remain in the environment even after millions of years. Some of these radionuclide and their progenies are emitting gamma rays, which become one of the major sources for external and internal exposure that can cause soft tissue cancers, like lung cancer [2]. Naturally abundant radionuclide (^{226}Ra; ^{232}Th and ^{40}K) in the environment and releases from fertilizers, agrochemicals, research and medical facilities forms the bulk of radionuclide in ground and surface water, [3]. Therefore presence of radioactivity in contaminated environment can be attributed to naturally occurring and or artificially induced sources. Naturally occurring radioactivity is due to bedrock formations which are weathered, resulting in mineral leaching that leads to contamination [4].

Artificial radioactivity is due to human activities. Contaminations are mainly as a result of agriculture, medicine, research as well as other activities like mining and milling of mineral ore which exposes the earth surface. All this contamination may have health effect [5]; that poses great danger to human and other living organisms. Early investigations in soil and rock (i.e., components of earth's crust) showed that there are measurable amounts of radionuclide such as Uranium and Thorium. Some of radioactive gaseous isotopes are released to the atmosphere. Radium-226 produces Radon-222 via alpha decay which diffuses from the earth into the atmosphere producing a number of short lived radio nuclide; inhalation of the radiation in larger doses can produce lung cancer [2]

In south-western rural region of Ethiopia people are using a mineral soil; locally called "EWOA", as an additive for cabbage cooking, as a soap to wash cloths and as a mineral additive for livestock. The mineral soil can not be found by digging the ground everywhere in the region, but only in some areas of the region during winter, for this reason the people living in this region purchases the soil from local markets in the winter season and store larger amount of the soil inside their home to be used in the other seasons of the year. Most people in the surrounding commonly are affected by cough; they locally call it "Gheri" to mean cold air. Sometimes domestic animals are seen to be affected by cough. In this research we want to experimentally determine the amount and the hazardous level of naturally occurring radiation in the mineral soil EWOA in order to check if the cough, Gheri, which is common in animals and people in the surrounding has some connection with the radioactive dose emanating from the soil.

2. Research Method:

To determine the radiation emanating from the mineral soil due to NORM, an experimental technique NaI(Tl) gamma spectroscopy was used.
Materials: During the experiment the following devices and chemicals were used. NaI(Tl) gamma spectroscopy, (MCA) multi channel Analyzer, High power supply, pre-amplifier, Post amplifier, Signal Acquisition software (MAESTRO), Desktop computer, IAEA-RGKUTh energy and efficiency calibration standard, quality assuring standards (IAEA-RGU-1, IAEA RGK-1 and IAEA-RGTh-1), four sample holders which exactly fit the space left for a sample inside NaI(Tl) detector container, wax, plastic sheet, masking tape and data log sheet.
Method: The major technique employed in to the analysis of the samples for concentration Naturally Occurring Radioactive Materials the Gamma Spectroscopy using NaI(Tl) detector because the resolution of the detector is not very important as the spectrum contains well separated peaks. Three samples of the mineral soil were collected from three known mining areas in the region ("Agena, Shamene, and Bojebar"). The samples were kept opened to dry at ambient temperature at laboratory in a clean environment, which were later carefully packed into polyethylene bags and transported to the Center for Energy Research and Training, Zaria, Nigeria for further preparation, Gamma spectroscopy count and analysis in accordance with IAEA method.

Experiment: The three soil samples were dried at ambient temperature, powdered and packed fully inside three different sample holders, of height 7cm by diameter 6cm to fit with the sample putting space left inside the lead shielding of the NaI(Tl) detector, as shown in the fig.1 below. The samples were weighed 300g each. The three samples were carefully sealed to prevent radon escape using wax, plastic sheet and masking tape. The sealed samples were (coded as SS001 for Agena mining, SS003 for Shamene mining, and SS005 for Bojebar Mining) kept for more than twenty days before the counting was started in order to attain secular equilibrium between

progenies and the parent. Before the gamma spectroscopy is used to detect gamma radiation from the samples, energy and efficiency calibration of the detector was performed using a calibrator standard, IAEA-RGKUTh which was sealed inside a container equivalent to sample holders.

After having the energy and efficiency calibration data, IAEA NORM standards (IAEA-RGK-1, IAEA-RGU-1 and IAEA-RGTh-1) containing known amount of the radioactive elements were counted for the purpose of quality assurance or checking the correctness of the measurement system. Analyzing the standards' activity counted with the present setup and compared with the known values given in the certificates of the standards [6]. This helps to check the system is working effectively. Having checked the counting system is correct in the 95% level of confidence, the three samples were counted one by one for 29,000 seconds each with exactly the same condition of counting of the standards. In order to get lab background concentration an empty sample holder was put in to the sample space and counted for twelve hours in a similar procedure as the samples.

Figure 1. Sealed samples of the mineral soil inside a sample holder.

3. Results and Analysis.

From the experimental data; Geometry dependent peak efficiency of the detector, the concentration of radioactive materials in the standards, the concentration of radioactive materials in the soil samples, counting laboratory background concentration of radioactive materials, doses of radiation due to the soil, internal and external hazard effects due to the radiations, were analyzed. The analyzed data were given in tables.

Energy calibration: The graph shown in fig 2 shows the energy calibration for the NaI(Tl) gamma spectroscopy during the measurement. Using the linear fit equation of the curve it was easy to find the channel at which the energy peaks were arrived.

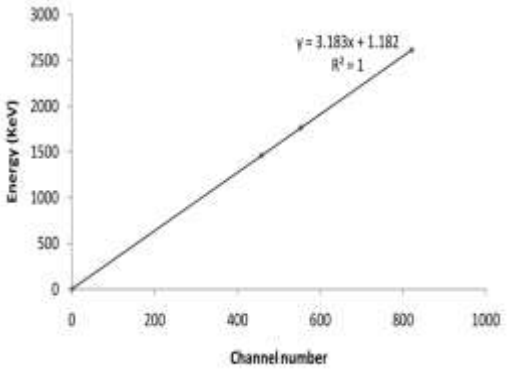

Figure 2. Energy calibration curve of NaI(Tl) gamma detector using the energy calibration mixed standard IAEA-RGKUTh.

Efficiency calibration: The peak efficiencies of the detector for the three peaks were determined using a mixed standard calibrator at the same geometry as the geometry used for the counting of the samples. The value of the efficiencies for each peack was used in the calculation of activity concentrations of NORM in the samples.

Lab Background: The measured activity from the lab background at a specified energies, counted for 12Hrs have been subtracted from the activity of the soil samples. The spectrum obtained during the counting of lab background was as shown in the fig 3. Since NORM occurs everywhere on the crust, the spectrum shows the expected activities from the norm of the background materials in the room, (roof, wall, ceiling, etc.) but with small concentration.

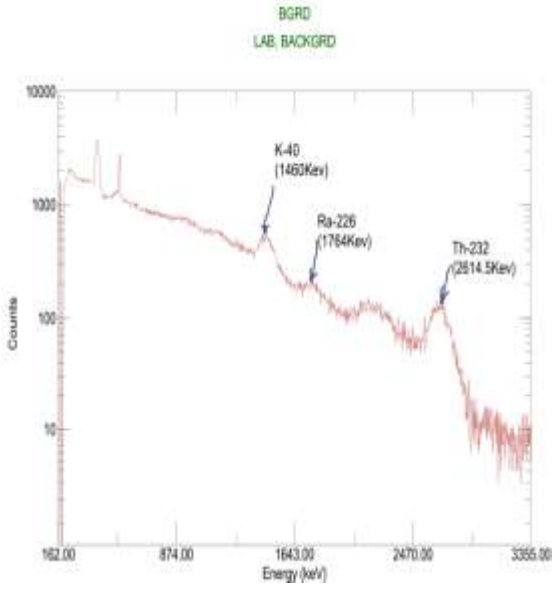

Figure 3: Activity spectrum from NORM in the room background.

Concentration of radioactive materials in the reference: For the purpose of checking the quality of the experimental detection of activities by the experimental set up and analysis in this work, three IAEA standards were measured and analyzed before the measurement of the mineral samples. The spectrums of the counting of the reference materials using the experimental set uop were as shown in the figures Fig. 4, Fig 5 and Fig.6.

The results obtained by the analysis of the reference materials were compared with the values in the certificates which are given with 95% confidence of interval (95%C.I) [6], as shown in the table 1.

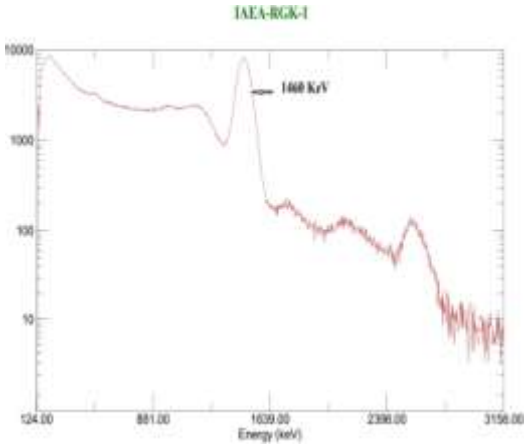

Figure 4: The spectrum obtained by the IAEA standard (IAEA/RGK-1) showing the potassium energy peak.

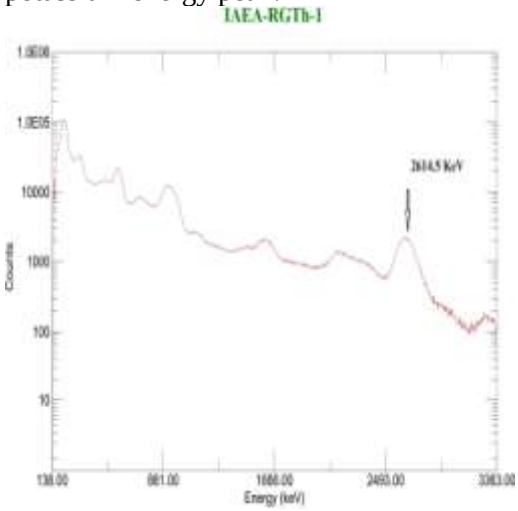

Figure 5: The spectrum obtained by the IAEA standard (IAEA-RGTh-1), showing the gamma peak of Thorium-232.

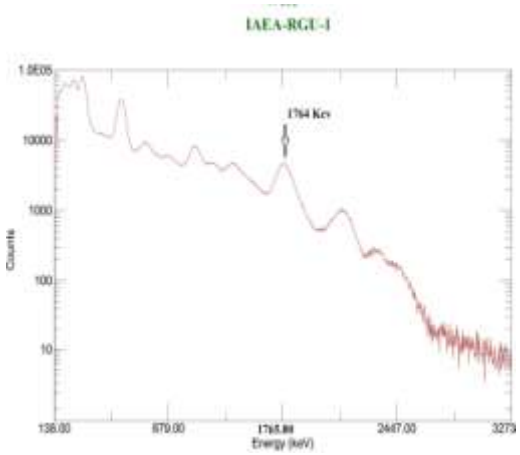

Figure 6: Spectrum of the Uranium standard IAEA-RGU-1, showing the energy peak of Radium-226.

Analyte	IAEA Stand	Concentration (Bq/Kg)	
		Certificate 95% C.I.	This work
^{40}K	RGK-1	13600 to 14400	13950 ±30.48
^{226}Ra	RGU-1	4910 to 4970	4942±4.90
^{232}Th	RGTh-1	3160 to 3340	3279±28.20

Table 1: Activity concentration of radioactive nuclides in IAEA reference materials obtained during the experimental work compared with the values in the certificate.

As could be seen from Table 1 the experimental set up was acceptable because the results of analysis of the concentration of NORM in the reference materials were in a good agreement with the certified values in the certificates with 95% interval of confidence. Thus the same procedure was carried out on the mineral soil samples with the same geometry of detector to sample position and set up.

Concentration of radioactive materials in the soil samples: Three samples of the mineral soil each were taken from three different mining places were coded SS01, SS03 and SS05, as shown in fig. 1, had been measured. The spectra that were generated from samples during spectrometric analysis, one of such spectrum was shown in the Fig. 8, was used in identification of the radionuclide and analysis of the concentration of each radionuclide in the samples. The result of the analysis was shown in the Table 2. The concentration after the laboratory background is subtracted from the activity of the soils was as shown in Table 2.

Sample ID	C (Bq/Kg)		
	K-40	Ra-226	Th-232
SS01	437.01±3.11	24.33±0.46	72.90±0.11
SS03	438.57±2.80	22.02±0.35	31.93±0.11
SS05	433.90±3.26	27.80±0.46	76.39±0.23

Table 2: Concentration in (Bq/kg) of ^{40}K, ^{226}Ra, and ^{232}Th for the mineral soils collected at three mining locations.

The activity (C) is reported in Bq/kg (Becquerel per kilogram) on the basis of the soils dry weight, calculated using the conversion factors as was used in different litratures [7, 5].

As can be seen from table 2, the concentration of K-40 activity ranges from 433.9±3.26 to 438.57±2.8 in Bq/kg in the mineral soil samples collected from different mining areas. This shows that there is no significant difference between the K-40 activity concentrations of the three mineral soil samples. These obtained activity concentration of ^{40}K is slightly higher when compared to the world average values for sediments, 420 Bq/kg, [2]. But there is a slight difference between the radium concentrations in the three soil samples which lies between 22.02±0.35 and 27.80±0.46 in Bq/kg. If we compare the concentration of radium in the soil samples with the world average concentration values of radium in sediments (32Bq/kg) [2], the mineral soil samples contain less concentration of radium. The reported concentrations in Table 2 indicated that there was concentration difference between SS03 and SS05 in the activity concentration of ^{232}Th, i.e. the mineral soil coded with SS05 obtained from "Bojebar" mining site has activity concentration higher than the activity concentration of ^{232}Th in the soil coded SS03 obtained in the "Shamene" mining site by a factor of about 2.4. The obtained activity concentration of ^{232}Th in Shamene mineral soil is smaller than the world average values for sediments, (45Bq/kg) [6], while the result of the concentration in "Agena" and "Bojebar" mineral soil samples show higher concentrations of ^{10}Th compared to the world average of sediments (45Bq/kg) [6].

Absorbed Dose Rate, Annual Effective dose equivalent, External Hazard and Internal Hazard Indexes of the Soil: The absorbed dose rates due to the emitted gamma rays at 1m above the ground for the activity concentration from ^{226}Ra, ^{232}Th and ^{40}K in the samples of the mineral soil were determined as shown in Table 3.

The reported values of, Table 3, absorbed dose values ranges from 50.34±0.358 nGy/h to 82.29±0.509 nGy/h with a rough average of 70.4 nGy/h.

Quantities with units	SS01	SS03	SS05
Absorbed dose rate (nGy/ h)	78.49±0.42	50.34±0.35	82.29±0.51
Effective dose rate (10^{-3} mSv/y)	96±0.52	62±0.44	101±0.62
External Hazard index (Hex) (10^{-3} mSv/y)	400±2.31	274±1.95	460±2.81
Internal Hazard index (Hin) (10^{-3} mSv/y)	466±3.5	317±3.07	496±3.93

* nGy/h = nano gray per hour, *mSv/y = mili seviert per year

Table 3: Experimentally determined dose rates and hazard indexes due to Ewoa samples.

This is within the worldwide value range which is from 18 nGy/h to 93 nGy/h of sediments. The effective annual dose rate due to these radionuclides in the mineral soil was also obtained from Eq.32 and the values ranges from 0.062_0.0004 mSv/y to 0.101_0.0006 mSv/y with an average value of 0.082 mSv/y. This is also less than the average annual dose limit set for radiological assessment which is 1 mSv/y [7]. The external (Hex) and internal (Hin) hazard indexes, which represent the risk associated from exposure to a radiation, for the radionuclide in the samples of the mineral soil was found, the results were as presented in the table 3. From the table 3, it had been shown that the minimum value of (Hex) was 0.274±0.00195 mSv/y and the maximum value 0.460±0.0028 mSv/y with over all rough average of 0.378 mSv/y which is far less than the limit for radiological exposure protection to the public (1 mSv/y) set by International Commission on Radiological Protection [1]. The analysis of the samples SS01, SS03, and SS05 for their internal hazard index (Hin) gives the minimum value 0.317±0.003 mSv/y from the analysis of the sample SS03 and a Maximum value of 0.496±0.0039 mSv/y from the analysis of SS05. The sample SS01 analysis resulted in a value of 0.466±0.0035 mSv/y which lies between the two mineral soil samples and less than the limiting value of radiological exposure protection 1 mSv/y. If the overall average value of the indexes (Hex) and (Hin) of the mineral samples were considered, (0:378 ±0:00236 mSv/y and 0:426±0:0035 mSv/y respectively), they have a value less than 1 mSv/y. This indicated that the risk associated with the mineral soil samples is quite below the limit for radiological exposure protection to the public [1, 8]. The activity concentration value obtained for the mineral soils

in this study were found to be within the acceptable limits. Most of the activities obtained were lower than the worlds average values. The calculated effective absorbed dose rate, the average hazard indexes obtained for both external and internal exposure do not exceeded the limits set by ICRP, UNSCEAR [1, 8]

4. Conclusion

Based on the analysis of the results, the mineral soil does not pose much threat to the public since the average hazard indexes obtained for both external and internal exposure do not exceeded the limits set by ICRP, UNSCEAR. However, the calculated values were based on exposure at one meter distance from the soil. But in our case, animals and human swallow the mineral soil mixed with food as a spice so that the radiation damage that may be caused may be more intense. Recent studies show that exposure to Ionizing radiation can cause cancer. Washington, DC July 30, 2005 The National Academies of Science released an over 700-page report on the "Health Risks from Exposure to Low Levels of Ionizing Radiation". The report confirmed that there is no safe level of exposure to radiation that even very low doses can cause cancer [9]. Even exposure to background radiation can cause some cancers. Low dose of radiation causes other health effects such as heart disease and stroke as reported in [10], and further study is needed to predict the doses that result in these non-cancer health effects.

In this regard the mineral soil since it is taken by animals and human together with food, the existing (the measured amount of radiation dose) in the mineral soil might cause radiation effects. Therefore care should be taken at least in the frequency and amount of taking the mineral soil together with food since larger doses of the mineral could give higher internal radiation dose.

References(12pt)

The main references are international journals and proceedings. All references should be to the most pertinent and up-to-date sources. References are written in APA style of Roman scripts. Please use a consistent format for references – see examples below (9 pt):

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