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Estimation Of Activity Concentration Of Uranium, Thorium And Potassium, By Using HPGe Detector

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Abstract
The measurements of activity concentration of uranium, thorim and potassium were carried out in radiation shielding bricks, granites, soil, hematite, bricks, and sand by using a high resolution high purity Germanium (HPGe) gamma-ray spectrometer system. The activity concentrations of uranium, thorium and potassium contents are 80 ± 5 Bq/kg, 103±10 Bq/kg and 1014±15 Bq/kg, respectively in radiation shielding bricks, 61 ±2.0 Bq kg, 23.27±1.8 Bq/kg and 270±14 Bq/kg, respectively in hematite aggregate, 50±4.0 Bq/kg, 41±3.7 Bq/kg and 370±I5 Bq/kg, respectively in cement. 57±3.5 Bq/kg, 64.56±2.0 Bq/kg and 990±7.3 Bq/kg, respectively in ordinary aggregate, 35±2.0 Bq/kg, 50±2.8 Bq/kg and 490±11 Bq/kg, respectively in sand, 31±1.75 Bq/kg, 42±2.5 Bq/kg and 280±10 Bq/kg, respectively in bricks and 27±2.0 Bq/kg, 18±2 Bq/kg, 190±7 Bq/kg, respectively in soil. The result shows that the measured activity concentrations in all samples are less than the average international recommended value. The calculated indoor and outdoor effective dose due to natural radioactivity of radiation shielding bricks, hematite aggregate, ordinary aggregate, cement, bricks, sand, and soil samples are also lower than the average national and international recommended value of 1.0 mSv.Y^{-1}.

Keywords: *Natural radioactivity, HPGe detector, Gamma radiation, Elemental concentration*

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I. Introduction

The natural radioactivity present in the environment is the main source of radiation exposure for humans and constitutes the background radiation level. The main natural contributors to external exposure from gamma rays are ^{226}Ra, ^{232}Th, and ^{40}K. Since these radionuclides are not uniformly distributed, the knowledge of their distribution in soil and rocks play an important role in radiation protection and measurement. It is important to determine the sources and their individual contributions to the total radiation dose. In a typical environment, respective contribution to radiation exposure is about 13.8% for ^{40}K, 55.5% for ^{226}Ra, and 14% for ^{232}Th. Naturally occurring isotopes of uranium and thorium are unstable elements and go through several steps of radioactive decay, before ultimately becoming the stable element. They eject alpha and beta particles. Gamma radiation usually accompanies each of these particles ejection. Uranium occurs in minerals such as pitchblende, uraninite, etc. It is also found in phosphate rock, lignite and monazite sands. Radon is formed from the decay of radium, which in turn is formed from uranium. Uranium is present to some extent in all rocks but is most common in those of granitic composition and its concentration varies with specific sites and geological materials. There are two principal radiological effects derived from radioactivity in soils, Rocks, granites etc., that justifies the interest of their measurement. First is the internal irradiation of lung by alpha emitting short-lived decay products of Rn-222 and Rn-220. Second is the external irradiation of the body given by gamma rays emitted from in-situ radionuclides. The soil concentration evaluation for the presence of radionuclides with respect to the natural background levels and regulatory control actions, estimating the potential environmental transport to man, and studying the magnitude and extent of deposition, specially for long term releases, are very good reasons to carry out a radiological characterization of soils, rocks and granites (Beck, 1980, Leung et al., 1990, Fong and Alvarez, 1997). The level of background radiation varies from 1.4 mSv to 2.4 mSv per bear depending on the concentration of primordial radionuclides in soil and altitude, latitude and longitude of the place. Even though the natural radionuclides are almost uniformly distributed in the narrow range on earth surface, but in certain regions due to mineralization of uranium and close to earth surface, the natural radiation levels can be much higher thorium than 2.4 mSv per year. Radon ^{222}Rn, an alpha radioactive inert gas is associated with the presence of radium and its ultimate precursor uranium in the ground. The main source of radionuclides in the atmosphere are (i) radon, the decay products of the uranium, which is produced from mineralized regions and along the walls of tunnels and the associated working area and (ii) daughter products of radon subsequent to its formation, diffusion and containment in the mine atmosphere. Regular monitoring of the radon gas is a good indicator of air quality in mine and also helps in quantification of the environment in mines and quarries, which are required to be carefully monitored as compared to those which do not require the same (Bernahrd et al., 1983). This paper deals with the preliminary analysis of the radiation shielding materials, hematite, granites and common building materials

II. Material And Methods

Sample Collection And Preparation

About 300 grams of samples are collected from radiation shielding bricks, granites, soil, hematite, bricks, sand, etc., for the measurements. After collection, samples are crushed into fine powder by using Mortar and Pestle. Fine quality of the sample is obtained using scientific sieve of 150 micron-mesh size. Before measurement samples are dried in an oven at about 110 °C for 24 hours. Each sample is packed and sealed in an airtight PVC container and kept for about 4 week period to allow radioactive equilibrium among the radon ^{222} Rn), thoron (^{220}Rn), and their short lived decay products. An average 300- 350 grams of soil was taken for each sample. For calibration of the low background counting system a secondary standard was obtained, which has calibrated with the primary standard obtained from the International Atomic Energy Agency. Gamma transitions of 1461 KeV for ^{40}K, 186 KeV for ^{226}Ra, 295 and 352 KeV for ^{214}Pb, 609, 1120 and 1764 KeV for ^{214}Bi, 338, 463, 911 and 968 KeV for ^{228}Ac, 727 KeV for ^{212}Bi.

Sample Counting

Using HPGe detector of high-resolution gamma spectrometry system, the activity of samples is counted. The detector is a co-axial n-type high purity germanium detector (Make EG&G, ORTEC, Oak Ridge, USA). The detector has a resolution of 2.0 KeV at 1332 KeV and relative efficiency of 20%. The output of the detector is analyzed using a 4K ADC system connected to PC, the spectrum is analyzed using the locally developed software "CANDLE (Collection and Analysis-of Nuclear Data using Linux network)". The detector is shielded using 4" lead on all sides to reduce the background level of the system (Kumar et al., 2001). The efficiency calibration for the system is carried out using secondary standard source of uranium ore in geometry available for the sample counting. Efficiency values are plotted against energy for particular geometry and are fitted by least squares method to an empirical- relation that takes care of the nature of efficiency curve for the HPGe detector. The samples were counted for a period of 72000 seconds and the spectra are analyzed of the photo peak of uranium, thorium daughter products and K-40. The net count rate under the most prominent photo peaks of radium and thorium daughter peaks are calculated by subtracting the respective count rate from the background spectrum obtained for the same counting time. Then the activity of the radionuclide is calculated from the background subtracted area prominent gamma ray energies.

III. Results And Discussion

The concentration of uranium, thorium and potassium are calculated using the following equation

Activity (Bq) = $\{(CPS\times100\times100)/B.I.\times E\} \pm \{(CPS_{error}\times100\times100)/B.I.\times E\}$

Where CPS is the net count rate per second, BI is the Branching Intensity and E is the Efficiency of the detector

Table 1: Activity concentration of U-238, Th-232 and K-40

S.No.	Sample	Activity Concentration (Bq/Kg)		
		U-238	Th-232	K-40
1	Radiation Shielding Bricks	80 ± 5	103±10	1014±15
2	Hematite aggregate	61 ± 2.0	23.27±1.8	270±14
3	Cement	50 ± 4.0	41±3.7	370±15
4	Ordinary Aggregate	57 ± 3.5	64.56±2.0	990±7.3
5	Sand	35 ± 2.0	50±2.8	490±11
6	Bricks	31 ± 1.75	42±2.5	280±10
7	Soil	27 ± 2.0	18±2	190±6

Table 1 shows the average concentration of the radionuclides measures, as well as the corresponding standard deviation. The activity concentrations of uranium, thorium and potassium contents are 80 ± 5 Bq/kg, 103±10 Bq/kg and 1014±15 Bq/kg, respectively in radiation shielding bricks, 61 ±2.0 Bq kg, 23.27±1.8 Bq/kg and 270±14 Bq/kg, respectively in hematite aggregate, 50±4.0 Bq/kg, 41±3.7 Bq/kg and 370±I5 Bq/kg, respectively in cement. 57±3.5 Bq/kg, 64.56±2.0 Bq/kg and 990±7.3 Bq/kg, respectively in ordinary aggregate, 35±2.0 Bq/kg, 50±2.8 Bq/kg and 490±11 Bq/kg, respectively in sand, 31±1.75 Bq/kg, 42±2.5 Bq/kg and 280±10 Bq/kg, respectively in bricks and 27±2.0 Bq/kg, 18±2 Bq/kg, 190±7 Bq/kg, respectively in soil. The correlation coefficient between radon concentration and the Uranium activity is shown in Figure 1. A positive correlation (Coefficient, R= 0.853) was observed between uranium and radon concentration, which is due to the porosity of the samples (Folkerts et al., 1984). The measured activity concentrations of ^{238}U, ^{232}Th and ^{40}K are converted into doses ($nGy.h^{-1}$ per $Bq.kg^{-1}$) by applying the factors 0.427, 0.662 and 0.043 for uranium, thorium and potassium, respectively (UNSCEAR, 1988). These factors are used to calculate the total absorbed gamma dose rate in air at one meter above the ground level using the following equation:

$$(nGy.h^{-1} \text{ per } Bq.kg^{-1}) = (0.427C_U + 0.662C_{Th} + 0.043C_K)$$

Where C_U, C_{Th} and C_K arc the activity concentrations ($Bq.kg^{-1}$) of uranium, thorium and potassium in the samples. The indoor and outdoor annual effective dose equivalent are determined by the following formula
Indoor (mSv) = (Absorbed Dose) $nGyh^{-1}$x 8760h x 0.8x0.7$SvGy^{-1}$
Outdoor (mSv) = (Absorbed Dose) $nGyh^{-1}$x 8760h x 0.2x0.7SvG y^{-1}

The annual estimated average effective dose equivalent received by a member is calculated using a conversion factor of 0.7 $SvGy^{-1}$, which is used to convert the absorbed rate to human effective dose equivalent with an outdoor occupancy of 20% and 80% for indoors (UNSCEAR, 1993).

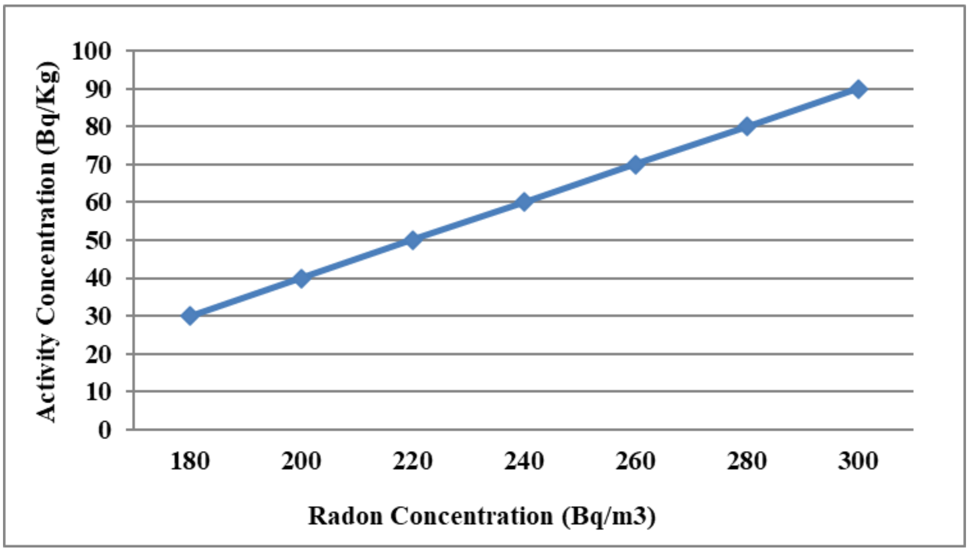

Fig.1: Variation of Uranium and radon concentration

Table 2: Radiation absorbed dose and dose equivalents for all the samples

S.No.	**Sample**	**Absorb Dose ($nGy.h^{-1}$)**	**Effective Dose Equivalent($mSvy^{-1}$)**	
			Indoor	**Outdoor**
1	Radiation Shielding Bricks	145.94	0.71	0.17
2	Hematite aggregate	53.06	0.26	0.06
3	Cement	64.40	0.31	0.07
4	Ordinary Aggregate	131.85	0.64	0.16
5	Sand	69.11	0.33	0.08
6	Bricks	53.08	0.26	0.06
7	Soil	31.61	0.15	0.03

The calculated absorbed and annual effective dose rates of samples are shown in the Table 2. It is clear that radiation dose equivalent observed for the radiation shielding material, hematite and common building materials are lower than the recommended value. The International Commission on Radiological Protection (ICRP) has recommended the annual effective dose equivalent limit of 1 $mSvY^{-1}$ for the individual members of the public and 20 $mSvY^{-1}$ for the radiation workers (ICRP, 1993).

IV. Conclusion

The results shows that the indoor and outdoor effective dose due to natural radioactivity of radiation shielding bricks, hematite aggregate, ordinary aggregate, cement, bricks, sand, and soil samples are lower than the average national and international recommended value of 1.0 $mSv.Y^{-1}$. It was found that the radiation dose equivalent received by the radiation workers in the nuclear facility from the most common radiation shielding bricks, and the radiation doses received by general public from the common building materials are within the safe limit. As such there is no need for radiation precaution and public awareness for the associated industrial activities (Sonkawade, et al., 2005). However, a positive correlation between radon concentration and uranium contents in soil indicates that a detail study of the samples distributed over the area is required, to reach at more conclusions.

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