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# Use of Gamma-Ray Spectrometry for Assessment of Natural Radioactive Dose in Some Samples of Building Materials

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Samples of building materials (Granite, Bricks, Sand Stones) collected from Jalandhar area of Punjab have been analyzed for the primordial natural radionuclides viz. 226Ra, 232Th and 40K using HPGe detector based on high-resolution gamma spectrometry system. The calculated average values of the total absorbed dose are 253.91 nGyh-1, 74.86 nGyh-1 and 93.79 nGyh-1 for samples of granite, bricks and sandstones respectively. The average values of indoor and outdoor annual effective dose for the present study of samples of granite, bricks and sandstones are 1.25 mSv and 0.31 mSv, 0.37 mSv and 0.09 mSv and 0.46 mSv and 0.12 mSv respectively. The calculated average value of the radium equivalent activity (Raeq) for samples of bricks and sandstones are less and this value is higher for the granite samples than the safe limit (370Bq kg-1) recommended by Organization for Economic Cooperation and Development (OECD).

**Key Words: Building materials, Gamma-ray spectrometry, HPGe detector, Annual effective dose, External hazard index (Hex).**

## INTRODUCTION

Natural radioactivity is common in the rocks and soil that makes up our planet, in water and oceans, and in our building materials too. The radionuclides of the $^{238}U$ ($^{226}Ra$)-series, $^{232}Th$-series and $^{40}K$ isotope constitute the primordial sources of natural radioactivity which are mainly responsible for the natural radioactivity in building materials also. Ionizing radiations of radionuclides in building materials change background and use both internal (through food, water and air) and external (direct by gamma-radiations) exposures. The activity concentrations of radionuclides in the building materials and its components are important in the assessment of population exposures as most individuals spend

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80% of their time indoors. The aim of the present study is to determine the activity concentrations of natural radionuclides viz. $^{226}Ra$, $^{232}Th$ and $^{40}K$ in some building material samples and hence the dose rates in order to assess the health risks. The radium equivalent activity ($Ra_{eq}$) of samples is also calculated.

## EXPERIMENTAL PROCEDURE

**Sample Preparation:** The collected samples of bricks are crushed, sieved and then sealed in an airtight PVC container and kept for about four week's period to ensure the secular equilibrium between $^{226}Ra$ (of the $^{238}U$) and $^{232}Th$ and their respective radioactive progenies. An average of 0.25 kg per sample is used.

**Experimental Methods:** Radioactivity measurements are performed by using HPGe detector based on gamma-ray spectrometry. The secondary standard was calibrated with the primary standard (RGU-1) obtained from the International Atomic Energy Agency. Gamma transitions of 1461 keV for $^{40}K$, 186 keV and 609 keV of $^{214}Bi$ for $^{226}Ra$, 338, 463, 911, 968 keV for $^{228}Ac$, 727 keV for $^{212}Bi$, 238 keV for $^{212}Pb$ were used for the laboratory measurement of activity concentration potassium, radium and thorium by Mehra *et al.*[1]. The activity of the radionuclide was calculated using the following equation:

$$Activity\,(Bq) = \frac{CPS \times 100 \times 100}{B.I. \times Eff} \pm \frac{CPS_{error} \times 100 \times 100}{B.I. \times Eff} \quad (1)$$

where, *CPS* = Net count rate per second; *B.I.* = Branching Intensity, and *Eff* = Efficiency of the detector.

## RESULTS AND DISCUSSION

Table 1 shows that the range of activity concentrations of $^{226}Ra$, $^{232}Th$ and $^{40}K$ in the samples of granite, bricks and sandstones vary from (64.29 Bq $kg^{-1}$ to 68.10 Bq $kg^{-1}$, 313.11 Bq $kg^{-1}$ to 317.11 Bq $kg^{-1}$ and 651.20 Bq $kg^{-1}$ to 655.25 Bq $kg^{-1}$), (25.78 Bq $kg^{-1}$ to 29.26 Bq $kg^{-1}$, 79.56 Bq $kg^{-1}$ to 83.40 Bq $kg^{-1}$ and 276.31 Bq $kg^{-1}$ to 280.28 Bq $kg^{-1}$) and (40.52 Bq $kg^{-1}$ to 45.76 Bq $kg^{-1}$, 99.81 Bq $kg^{-1}$ to 104.35 Bq $kg^{-1}$ and 243.29 Bq $kg^{-1}$ to 248.29 Bq $kg^{-1}$) respectively. From table it is clear that, in general, the average and ranges of activity concentration of $^{232}Th$ in samples of granite, brick and sandstones in these areas are higher than the world figures reported in UNSCEAR[2]. However, the concentration for $^{226}Ra$ in brick samples is lower than the world average concentration value whereas the present concentration values of $^{226}Ra$ for samples of granite and sandstones are higher than the world average figures. The $^{40}K$ concentration in samples of bricks and sandstones is lower whereas for granite the activity concentration value for $^{40}K$ is higher than the world figures. The range of activity concentration values for $^{232}Th$ and $^{40}K$ for the present study is higher and the range of activity concentration value for $^{226}Ra$ for the present study is lower than those reported

Table1: The activity concentration values for 226Ra, 232Th and 40K using gamma ray spectrometry and Raeq activity values in samples of building materials

| Sr. No. | Radium Concentration $C_{Ra}$ ( Bq kg$^{-1}$) | Thorium Concentration $C_{Th}$ ( Bq kg$^{-1}$) | Potassium Concentration $C_K$ ( Bq kg$^{-1}$) | Radium equivalent (Bqkg$^{-1}$) |
|---|---|---|---|---|
| **Granite** | | | | |
| 1 | 66.84 | 315.13 | 653.56 | 563.23 |
| 2 | 64.43 | 313.11 | 651.65 | 557.79 |
| 3 | 67.51 | 316.12 | 654.45 | 565.38 |
| 4 | 68.10 | 317.11 | 655.25 | 567.43 |
| 5 | 65.32 | 314.14 | 652.30 | 560.20 |
| 6 | 64.29 | 315.01 | 651.20 | 560.34 |
| 7 | 65.00 | 317.00 | 653.02 | 564.03 |
| **Bricks** | | | | |
| 1 | 27.62 | 81.17 | 278.12 | 163.16 |
| 2 | 28.62 | 82.71 | 279.34 | 166.45 |
| 3 | 29.26 | 83.4 | 280.28 | 168.14 |
| 4 | 26.38 | 80.71 | 277.21 | 161.20 |
| 5 | 25.78 | 79.56 | 276.31 | 158.89 |
| 6 | 27.04 | 82.03 | 277.38 | 163.76 |
| 7 | 26.01 | 80.99 | 279.88 | 161.42 |
| **Sand Stones** | | | | |
| 1 | 42.33 | 101.18 | 245.01 | 204.17 |
| 2 | 43.25 | 102.35 | 246.23 | 206.85 |
| 3 | 44.67 | 103.53 | 247.32 | 210.03 |
| 4 | 45.76 | 104.35 | 248.29 | 212.36 |
| 5 | 40.52 | 99.81 | 243.29 | 200.28 |
| 6 | 44.99 | 100.04 | 245.55 | 205.24 |
| 7 | 43.09 | 102.78 | 246.01 | 207.29 |

for some Indian building materials by Kumar *et al.*[3]. The mean values of radium equivalent activity ($Ra_{eq}$) in these building materials are 562.63 Bq kg$^{-1}$, 163.29 Bq kg$^{-1}$ and 206.60 Bq kg$^{-1}$for the samples of granite, bricks and sandstones respectively. The radium equivalent activity value for samples of bricks and sandstones is lower whereas for granite samples this value is higher than the safe limit value (370Bq kg$^{-1}$) recommended by OECD[4]. A detailed analysis of the results indicates that there is a strong positive correlation between the activity concentrations of $^{232}$Th and $^{40}$K for the studied samples of building materials (Correlation coefficient, R=0.99).

Table 2: Air absorbed dose rates, External hazards and annual effective dose values for building materials samples

| Sr. No. | Absorbed dose ($nGyh^{-1}$) | | | | External Hazard Index $H_{ex}$ | Annual effective dose(mSv) | |
|---|---|---|---|---|---|---|---|
| | $^{226}$Ra | $^{232}$Th | $^{40}$K | Total | | Indoor | Outdoor |
| **Granite** | | | | | | | |
| 1 | 30.81 | 196.33 | 27.06 | 254.20 | 1.53 | 1.25 | 0.31 |
| 2 | 29.70 | 195.07 | 26.98 | 251.75 | 1.52 | 1.23 | 0.31 |
| 3 | 31.12 | 196.94 | 27.09 | 255.15 | 1.54 | 1.25 | 0.31 |
| 4 | 31.39 | 197.56 | 27.13 | 256.08 | 1.54 | 1.26 | 0.31 |
| 5 | 30.11 | 195.71 | 27.01 | 252.83 | 1.53 | 1.24 | 0.31 |
| 6 | 29.64 | 196.25 | 26.96 | 252.85 | 1.53 | 1.24 | 0.31 |
| 7 | 29.97 | 197.49 | 27.04 | 254.50 | 1.54 | 1.25 | 0.31 |
| **Bricks** | | | | | | | |
| 1 | 12.73 | 50.57 | 11.51 | 74.81 | 0.45 | 0.37 | 0.09 |
| 2 | 13.19 | 51.53 | 11.56 | 76.28 | 0.45 | 0.37 | 0.09 |
| 3 | 13.49 | 51.96 | 11.60 | 77.05 | 0.46 | 0.38 | 0.09 |
| 4 | 12.16 | 50.28 | 11.48 | 73.92 | 0.44 | 0.36 | 0.09 |
| 5 | 11.88 | 49.57 | 11.44 | 72.89 | 0.43 | 0.36 | 0.09 |
| 6 | 12.47 | 51.10 | 11.48 | 75.05 | 0.45 | 0.37 | 0.09 |
| 7 | 11.99 | 50.46 | 11.59 | 74.04 | 0.44 | 0.36 | 0.09 |
| **Sand Stones** | | | | | | | |
| 1 | 19.51 | 63.04 | 10.14 | 92.69 | 0.56 | 0.45 | 0.11 |
| 2 | 19.94 | 63.76 | 10.19 | 93.89 | 0.56 | 0.46 | 0.12 |
| 3 | 20.59 | 64.50 | 10.24 | 95.33 | 0.57 | 0.47 | 0.12 |
| 4 | 21.10 | 65.01 | 10.28 | 96.39 | 0.58 | 0.47 | 0.12 |
| 5 | 18.68 | 62.18 | 10.07 | 90.93 | 0.55 | 0.45 | 0.11 |
| 6 | 20.74 | 62.32 | 10.17 | 93.23 | 0.56 | 0.46 | 0.11 |
| 7 | 19.86 | 64.03 | 10.18 | 94.07 | 0.56 | 0.46 | 0.12 |

Table 2 shows that the total absorbed dose rate calculated from activity concentration of $^{226}$Ra, $^{232}$Th and $^{40}$K ranges from 251.75 $nGyh^{-1}$ to 256.08 $nGyh^{-1}$, 72.89 $nGyh^{-1}$ to 77.05 $nGyh^{-1}$ and 90.93 $nGyh^{-1}$ to 96.39 $nGyh^{-1}$ for the samples of granite, bricks and sandstones respectively. The average values of indoor and outdoor annual effective doses are 1.25 mSv and 0.31 mSv, 0.37 mSv and 0.09 mSv and 0.46 mSv and 0.12 mSv for samples of granite, bricks and sandstones respectively while the world wide average annual effective dose is approximately

0.5 mSv and the results for individual countries being generally within the 0.3-0.6 mSv range for indoors. Generally similar type of trend is observed in brick samples and sandstone samples but for granite samples the value of average indoor effective dose is more than the recommended safe limit value. The calculated values of $H_{ex}$ range from 1.52 to 1.54, 0.43 to 0.46 and 0.55 to 0.58 for the samples of granite, bricks and sandstones respectively.

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