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**Research Article**

# ANALYSIS OF $^{226}$RA, $^{232}$TH AND $^{40}$K IN THE HOST ROCK AND THE SOIL SAMPLES AND ASSESSMENT OF RADIOLOGICAL RISKS FOR MANDYA REGION, INDIA

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## ABSTRACT

A study on concentrations of $^{40}$K, $^{226}$Ra and $^{232}$Th in host rock and the surrounding soil was carried out in the Mandya district, Karnataka, India. Samples were analyzed by HPGe gamma spectrometry. In rock samples the geometric mean activity concentrations of $^{40}$K, $^{226}$Ra and $^{232}$Th (Bqkg$^{-1}$) were 1143.8, 77.14 and 142.22, respectively and in soil the geometric mean values (Bqkg$^{-1}$) were 639.92, 40.57 and 72.76 respectively. The rock to soil ratio for these radionuclides, which would provide information about the weathering of these radionuclides from the host rock to the soil, were estimated. Correlation studies on the activity concentration of these radionuclides in host rock and the corresponding soil were carried out. A significant positive correlations were observed between these radionuclides in host rock, whereas, in soil the correlations were poor which, as reported in the literature, confirms the different migration rates for these radionuclides in soil medium. Radium-equivalent activities ($Ra_{eq}$), external hazard index ($H_{ex}$) and annual gonadal dose equivalent for $^{40}$K, $^{226}$Ra and $^{232}$Th were found to be within the permissible limits.

**KEYWORDS:** HPGe detector, $Ra_{eq}$ activities, Annual effective dose, External hazard index.

## INTRODUCTION

Gamma radiation emitted from naturally occurring radioisotopes, such as $^{40}$K and the radionuclides form the $^{232}$Th and $^{238}$U series which exists at trace levels in all ground formations represents the main external source of irradiation to the human body. Natural environmental radioactivity and the associated external exposure due to gamma radiation depend primarily on the geological and geographical conditions, and appear at different level in the soils of each region in the world (UNSCAR, 2000).The study of distribution of these radio nuclides in soil and rock samples is of great importance for radiation protection and measurements. The knowledge of radionuclides distribution and radiation levels in the environment is important for assess the effects of radiation exposure due to both terrestrial and extraterrestrial sources. Terrestrial radiation is due to radioactive nuclides present in varying amounts in soils, building materials, water, rocks and atmosphere (Akhtar et al., 2005). Some of these radionuclides from these sources are transferred to man through food chain or inhalations, while the extraterrestrial radiation originates from outer space as primary cosmic rays. Natural sources of radiation are the concentrations of radionuclides that represent ambient conditions present in the environment that are in no way influenced by human activity. There are many types of soil depending upon the physical and chemical composition. The soil is classified as saline, saline sodic and alkali etc. (Prasad et al., 2008; Ramola et al., 2008). The involvement of radionuclides in the biogeochemical cycles depends on the geographic, landscape, soil, and vegetation condition of the region.

Uranium and thorium in igneous and metamorphic rocks are usually found in a few accessory minerals such as apatite, sphene and zircon. Other highly radioactive minerals, like monazite, allanite, uraninite, thorite and pyrochlore, are widespread in nature, but they are very minor constituents of rocks (Beretka and Matthew, 1985). Thorium is much less soluble than uranium and potassium and does not move except by mechanical means such as wind and erosion processes. Both thorium and uranium contents tend to be high in felsic rocks and to increase with alkalinity or acidity, with their highest concentrations found in pegmatites.

The potassium content of rocks also increases with acidity. Potassium is usually found in potash feldspars, such as microcline and orthoclase, or in micas, like muscovite and biotite. Rocks that are free of these minerals have very low potassium activity (UNSCAR, 2000). Thorium, uranium and potassium concentrations of rocks are meticulously related to their mineral compositions and universal petrologic features. The petrologic features of rocks associated with effects of weathering and metamorphism produce expressive alterations in the relationship between the natural radionuclides (Akhtar et al., 2005; Anjos et al., 2005). The concentrations of $^{40}K$, $^{226}Ra$ and $^{232}Th$ in host rock and the surrounding soil was carried out in the Mandya district, Karnataka, India using HPGe gamma spectrometry.

**Study area**

The present study was carried out in Mandya district Karnataka, India. It lies between North latitude 12$^{o}$ 13'to 13$^{0}$ 04' and East longitudes 76$^{0}$ 19' to 77$^{0}$ 20'. The district is located in the southern meridian region of the state (Fig 1). Total geographical area of the district is 4961 sq.kms. The surface topography is in the form of undulating plain situated at an average elevation of 750- 900m amsl. In the present study area the soils range from red sandy loams to red clay loam very thin in ridges and higher elevations and comparatively thick in valley portions. The soils are highly leached and poor in bases. The water holding capacity is low. On the other hand the soil under the old channel areas of Malavalli, Pandavapura and Srirangapatna are high in clay

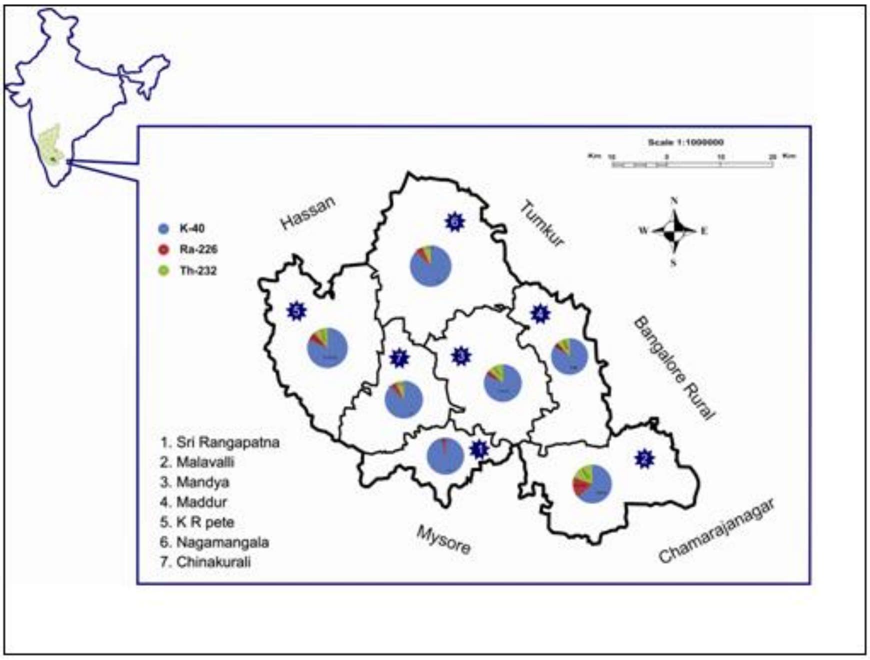


**Fig. 1: The Study area**

**METHODS AND MATERIAL**

Measurement of natural radioactivity consists of the collection of soil and rock samples and assessment of their activity. Soil and Rock samples were collected at different locations around Mandya city to determine the distribution of radionuclides in the soil and rock and compare the same with radiation exposure level. Gamma spectrometry uses semiconductor detector like Ge (Li) or Si (Li). In the current investigation, an HPGe spectrometer was used to measure the concentrations of gamma emitting radionuclides in soil and rock samples. The HPGe gamma ray detector essentially consists of a detector element and cryostat–Dewar and electronic components of the analysis system (IAEA/RCA, 1989).

The places, which were free from surface run–off during heavy rain, were carefully selected. An area of about 0.5 m$^2$ was marked and was cleared of vegetation and roots. The marked spot was dug up to a depth of 50 cm and about 2 kg of soil was collected at each spot. Finally the samples were mixed thoroughly and extraneous materials like plants, debris, big pieces of stones and pebbles were removed. Composite samples of about 2kg was taken and sealed in a polythene bag. The samples were transferred to a porcelain dish and oven dried overnight at 110$^0$C. The samples were powdered and sieved through 150 micron mesh sieves, weighed and sealed in a 500 ml plastic container, and kept for a month before counting by gamma spectrometry, in order to ensure that radioactive equilibrium was reached between $^{226}$Ra, $^{222}$Rn and its progeny (Sannappa et al., 2003).

Typical gamma ray spectra obtained for a rock and a soil sample are shown in Fig 2 and 3. The gamma photo peak of energy 609.31 keV (which is emitted by $^{214}$Bi, a decay product of $^{226}$Ra) with intensity of 43.30% was used for the quantitative determination of $^{226}$Ra, the photo peaks of 583.19 keV with intensity 85.97% and 911.05 keV with intensity 27.7% was used for the quantitative determination of $^{232}$Th and the characteristic photo peak of $^{40}$K is at 1460.8 keV with intensity 10.7% (IAEA/RCA, 1989).

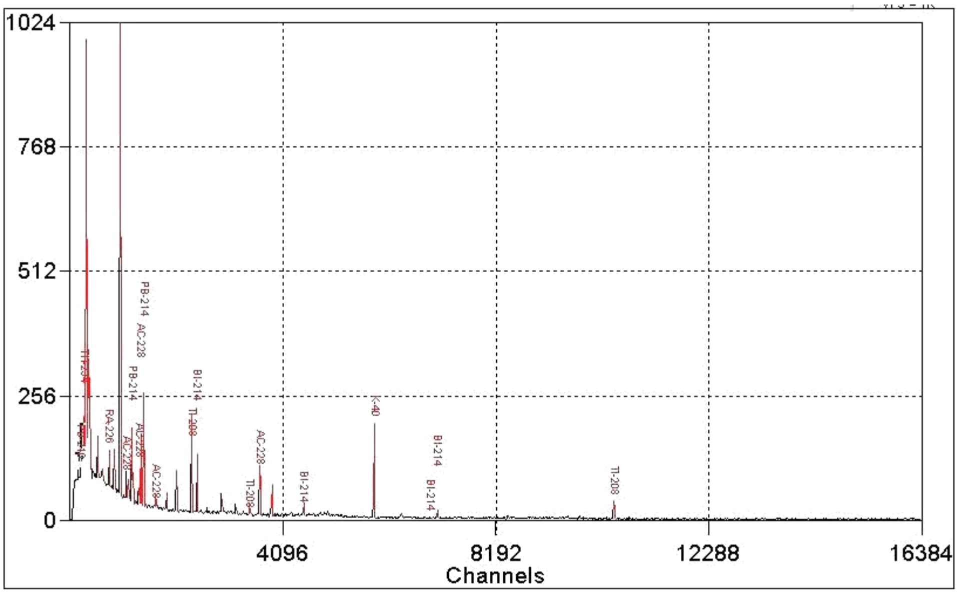


**Fig.2: The spectrum of the rock sample from Malavalli**

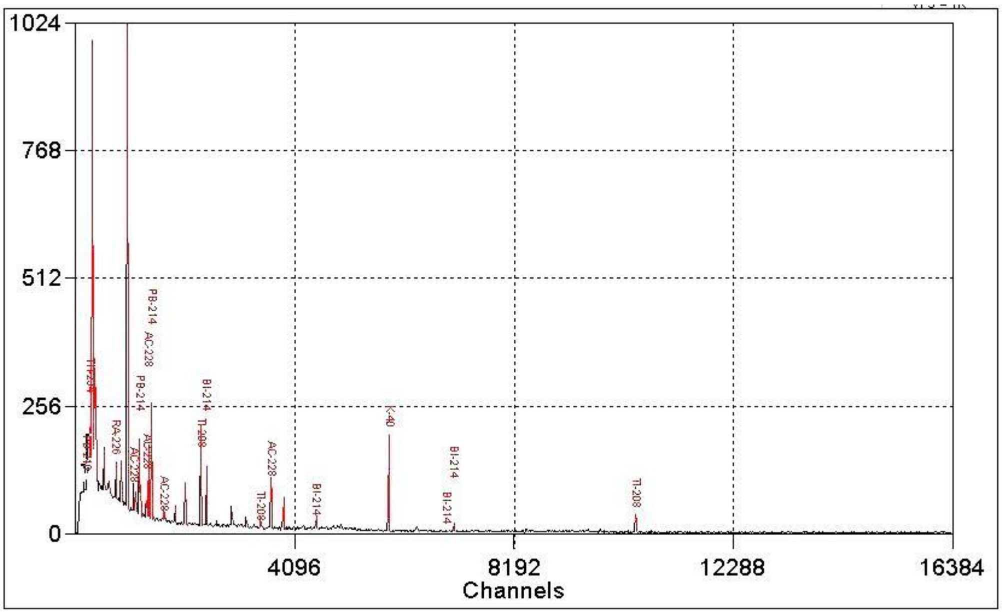


**Fig. 3: The spectral data plot of soil samples of Kunthi Mountain**

The activity of radionuclides was calculated using the
Equation

$$Activity\left(Bq.Kg^{-1}\right)=\frac{\left(S\pm\sigma\right)\times100\times1000\times100}{E\times W\times A}$$

where, S=Net counts/sec under the photo–peak of interest, σ=Standard deviation of S, E=Counting efficiency (%), A=Gamma abundance of the radionuclides (%), W=Mass of the sample (g).

In addition to the measurement of activity of radionuclides in soil and rock; we have also measured Radium Equivalent Activity ($Ra_{eq}$): To represent the activities due to $^{226}$Ra $^{232}$Th, and $^{40}$K by a Single quantity which takes into account the radiation hazard associated with them, a common index called the Radium Equivalent Activity ($Ra_{eq}$) ( Singh et al.,2009) has been introduced.

$$Ra_{eq}=A_{Ra}+\frac{10}{7}A_{Th}+\frac{10}{130}A_{K}$$

where, $A_{Ra}$, $A_{Th}$ and $A_K$ are the activities of $^{226}$Ra, $^{232}$Th and $^{40}$K in Bq kg$^{-1}$ (Singh et al.,2009; Kumar et al., 2003).

Representative Level Index ($I_{\gamma r}$): A radiation hazard index used to estimate the level of γ–radiation hazard associated with the natural radionuclides in the material, representative level index $I_{\gamma r}$, is given as (Singh et al.,2009; Kumar et al., 2003).

$$I_{\gamma r}=\left[\frac{A_{Ra}}{150}+\frac{A_{Th}}{100}+\frac{A_K}{1500}\right]$$

where, $A_{Ra}$, $A_{Th}$ and $A_K$ are the activities of $^{226}$Ra, $^{232}$Th and $^{40}$K in Bq kg$^{-1}$.

External Hazard Index ($H_{ex}$): The external hazard index is defined as (Beretka and Mathew 1985).

$$H_{ex}=\left[\frac{A_{Ra}}{370}+\frac{A_{Th}}{259}+\frac{A_K}{4810}\right]$$

where, $A_{Ra}$, $A_{Th}$ and $A_K$ are the activities of $^{226}$Ra, $^{232}$Th and $^{40}$K in Bq kg$^{-1}$ respectively.

Annual Gonadal Dose Equivalent (AGDE): The Gonadals, Active Bone Marrow and the bone surface cells are considered as the organs of interest. Therefore, the AGDE (μsvy$^{-1}$) owing to the specific activities of $^{226}$Ra, $^{232}$Th and $^{40}$KS was calculated using the following formula (Arafa et.al.,
2004)

$$AGDE = 3.09A_{Ra}+4.18A_{Th}+0.314A_K$$

where, $A_{Ra}$, $A_{Th}$ and $A_K$ are the activities of $^{226}$Ra, $^{232}$Th and $^{40}$K in Bq kg$^{-1}$ respectively.

## RESULTS AND DISCUSSION

The activity concentrations of $^{40}$K, $^{226}$Ra, and $^{232}$Th in host rock and soil samples collected form Mandya District, Karnataka state, India have been measured by gamma-ray spectrometry. The concentration of $^{40}$K, $^{226}$Ra, and $^{232}$Th in host rock and soil samples with their Radium equivalent activity ($Ra_{eq}$), Representative level index ($I_{\gamma r}$), External hazard index ($H_{ex}$), Annual Gonadal Dose Equivalent (AGDE) with the gamma absorbed dose were calculated and are shown in Table (1). The variation of $^{40}$K,$^{226}$Ra and $^{232}$Th in host rock and soil samples at different locations of Mandya district are shown in figure 2, 3 and 4 respectively. In rock samples the geometric mean activity concentrations of $^{40}$K, $^{226}$Ra and $^{232}$Th (Bqkg$^{-1}$) were 1143.8, 77.14 and 142.22, respectively and in soil the geometric mean values (Bqkg$^{-1}$) were 639.92, 40.57 and 72.76 respectively. The rock to soil ratio for these radionuclides, which would provide information about the weathering of these radionuclides from the host rock to the soil, is found to be 1.79, 1.90 and 1.95.

**Table 1: Activity concentration of $^{226}Ra$, $^{232}Th$ and $^{40}K$ Radionuclides in soil and rock samples and their Hazard index**

| Locations | Type | Specific activity ($Bq\,kg^{-1}$) | | | | $^{226}Ra$ / $^{232}Th$ | $I_{\gamma r}$ | $H_{ex}$ | AGDE ($mSv\,y^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|
| | | $^{226}Ra$ | $^{232}Th$ | $^{40}K$ | $Ra_{eq}$ | | | | |
| Chandagalu | Rock | 66.57 | 102.85 | 744.52 | 287.95 | 0.65 | 1.97 | 0.73 | 0.87 |
| | Soil | 59.98 | 178.13 | 621.81 | 376.63 | 0.34 | 2.60 | 0.98 | 1.13 |
| Chinakurali | Rock | 113.16 | 247.23 | 1945.67 | 660.91 | 0.46 | 4.52 | 1.66 | 1.99 |
| | Soil | 34.40 | 83.21 | 1064.33 | 259.70 | 0.41 | 1.77 | 0.64 | 0.79 |
| Besagarahalli | Rock | 55.82 | 90.58 | 701.65 | 255.39 | 0.62 | 1.75 | 0.65 | 0.77 |
| | Soil | 19.58 | 45.50 | 537.32 | 138.31 | 0.43 | 0.94 | 0.34 | 0.42 |
| Bindiganavele | Rock | 33.72 | 70.84 | 813.45 | 216.27 | 0.48 | 1.48 | 0.53 | 0.66 |
| | Soil | 62.52 | 81.29 | 264.35 | 205.08 | 0.77 | 1.41 | 0.54 | 0.62 |
| Bannangadi | Rock | 109.82 | 176.83 | 1250.52 | 487.49 | 0.62 | 3.33 | 1.24 | 1.47 |
| | Soil | 23.21 | 48.33 | 882.13 | 180.47 | 0.48 | 1.23 | 0.43 | 0.55 |
| Karigatta | Rock | 116.86 | 191.82 | 1249.17 | 515.81 | 0.61 | 3.53 | 1.32 | 1.56 |
| | Soil | 65.75 | 53.31 | 820.43 | 223.95 | 1.23 | 1.52 | 0.55 | 0.68 |
| Keragodu | Rock | 41.82 | 85.21 | 940.72 | 257.62 | 0.49 | 1.76 | 0.64 | 0.78 |
| | Soil | 18.97 | 58.37 | 364.99 | 138.85 | 0.32 | 0.95 | 0.35 | 0.42 |
| Kunthi Mountain | Rock | 129.70 | 273.56 | 2248.70 | 745.37 | 0.47 | 5.10 | 1.87 | 2.25 |
| | Soil | 49.71 | 98.72 | 723.01 | 263.04 | 0.50 | 1.80 | 0.67 | 0.79 |
| Kirugavalu | Rock | 118.61 | 232.81 | 1836.78 | 634.87 | 0.51 | 4.34 | 1.60 | 1.92 |
| | Soil | 57.27 | 69.08 | 866.43 | 242.60 | 0.83 | 1.65 | 0.60 | 0.74 |
| Maddur | Rock | 68.23 | 129.51 | 892.93 | 342.54 | 0.53 | 2.35 | 0.87 | 1.03 |
| | Soil | 24.00 | 65.52 | 482.52 | 165.85 | 0.37 | 1.14 | 0.42 | 0.50 |
| Malavalli | Rock | 89.27 | 181.44 | 1178.64 | 466.33 | 0.49 | 3.20 | 1.19 | 1.40 |
| | Soil | 63.99 | 70.90 | 926.49 | 257.92 | 0.90 | 1.75 | 0.64 | 0.79 |
| Palahalli | Rock | 62.23 | 97.03 | 949.39 | 295.78 | 0.64 | 2.02 | 0.74 | 0.90 |
| | Soil | 62.12 | 84.28 | 678.10 | 250.33 | 0.74 | 1.71 | 0.63 | 0.76 |
| Minimum | Rock | 33.72 | 70.84 | 701.65 | 216.27 | 0.46 | 1.48 | 0.53 | 0.66 |
| | Soil | 18.97 | 45.50 | 264.35 | 138.31 | 0.32 | 0.94 | 0.34 | 0.42 |
| Maximum | Rock | 129.70 | 273.56 | 2248.70 | 745.37 | 0.65 | 5.10 | 1.87 | 2.25 |
| | Soil | 65.75 | 178.13 | 1064.33 | 376.63 | 1.23 | 2.60 | 0.98 | 1.13 |
| Geometric Mean | Rock | 77.14 | 142.22 | 1143.80 | 396.77 | 0.54 | 2.71 | 1.00 | 1.20 |
| | Soil | 40.57 | 72.76 | 639.92 | 216.56 | 0.56 | 1.48 | 0.54 | 0.66 |

Where, $Ra_{eq}$ = Radium equivalent activity, $I_{\gamma r}$ = Representative Level Index, $H_{ex}$ = External Hazard Index, A G D E = Annual Gonadal Dose Equivalent.

In rock samples Radium equivalent activity ($Ra_{eq}$), varies from 216.27 to 745.37 with a geometric value of 396.77, Representative level index ($I_{\gamma r}$) varies from 1.48 to 5.10 with a geometric mean of 2.71, External hazard index ($H_{ex}$) varies from 0.53 to 1.87 with a geometric mean of 1.00 and Annual Gonadal Dose Equivalent (AGDE) varies from 0.66 to 2.25 mSv $y^{-1}$ with a geometric mean of 1.20 mSv $y^{-1}$. In soil samples Radium equivalent activity ($Ra_{eq}$), varies from 138.31 to 376.63 with a geometric value of 216.56, Representative level index ($I_{\gamma r}$) varies from 0.94 to 2.60 with a geometric mean of 1.48, External hazard index ($H_{ex}$) varies from 0.34 to 0.98 with a geometric mean of 0.54 and Annual Gonadal Dose Equivalent (AGDE) varies from 0.42 to 1.13 mSv $y^{-1}$ with a geometric mean of 0.66 mSv $y^{-1}$. The values found to be less than the permissible limits (Singh et al.,2009; Kumar et al., 2003; Beretka and Mathew 1985; Arafa et.al., 2004).

Correlation studies on the activity concentration of these radionuclides in host rock and the corresponding soil were carried out. The variation of $^{226}Ra$ and $^{232}Th$, $^{226}Ra$ and $^{40}K$, $^{232}Th$ and $^{40}K$ for rock and soil samples are shown in Fig 4. A detailed analysis of the result indicated a significant positive correlations were observed between these radionuclides in host rock, whereas, in soil the correlations were poor which, as reported in the literature, confirms the different migration rates for these radionuclides in soil medium (Yashodhara et al., 2011). The correlation coefficient between $^{226}Ra$ and $^{232}Th$, $^{226}Ra$ and $^{40}K$, $^{232}Th$ and $^{40}K$ for rock is found to be 0.95, 0.84 and 0.95 respectively (Singh et al., 2009). The heigher amount of $^{226}Ra$ and $^{232}Th$ in rocks depends to a large extent on the minaral composistion of the host rocks. The ratio of $^{226}Ra$ and $^{232}Th$ can be an indicater of the relative abundence of uranium and thorium (Chiozzi et al., 2002). In the present study the ratio of $^{226}Ra$ and $^{232}Th$ was found to vary from 0.46 to 0.65 with a geometric mean of 0.54 in rock samples and from 0.32 to 1.23 with a geometric mean of 0.56 in soil samples.

The average activity concentration of the radionuclieds for rock and soil Mandya district were found to be slightly higher than the adjoint areas of Mysore district but there in good agrement with those reported for soil of the gogi region of north Karanataka (Sannappa et al., 2003; Yashodhara et al., 2011; Shashikumar et.al.,2011). The heighest ratio $^{226}$Ra and $^{232}$Th was oberved at Karigatta for host rock and soil samples and is attributed to the presences of granites and gneisses interpreted with occasional patches of schist which might contain a small amount of uranium and its daughter products.

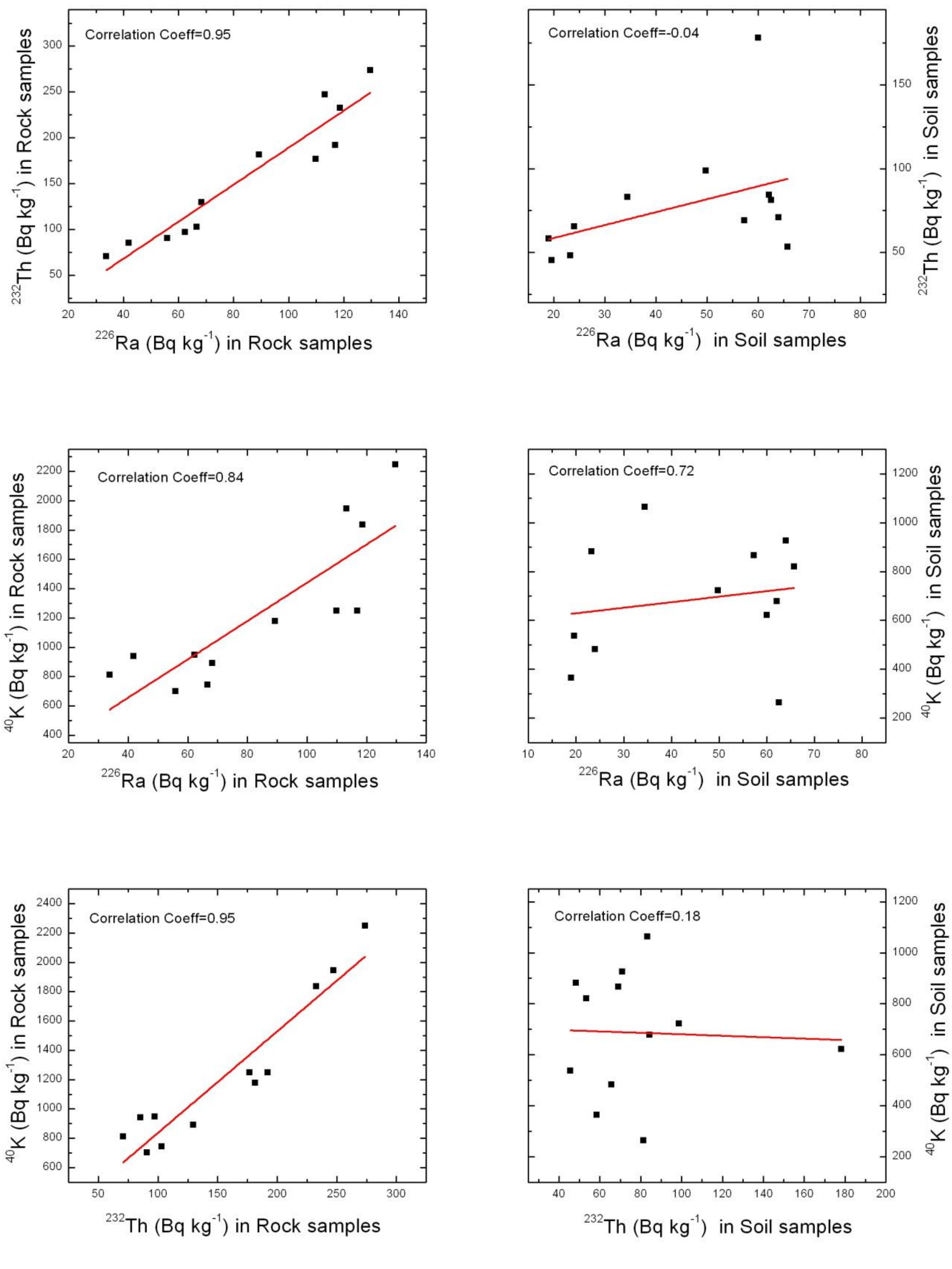


**Fig. 4: Correlation between different radionuclides in rock and soil samples of different locations.**

The average values of $^{40}$K, $^{226}$Ra, and $^{232}$Th concentration reported for normal background areas of Indian soil are 369.6, 15 and 18.36 Bq kg$^{-1}$, respectively, and the corresponding world average values are 420, 30 and 45 Bq kg$^{-1}$ respectively (UNSCEAR, 2000). The concentrations of radionuclides in rock and soil samples in the study area are slightly higher than Indian average and world average values. The study has established the base line data of on$^{40}$K $^{226}$Ra and $^{232}$Th in host rock and soil samples of Mandya district, it would help in assessing, in future the ecological impact of action.

## CONCLUSION

The concentrations of $^{40}$K, $^{226}$Ra and $^{232}$Th in host rock and the surrounding soil was carried out in the Mandya district, Karnataka, India using HPGe gamma spectrometry. In rock samples the geometric mean activity concentrations of $^{40}$K, $^{226}$Ra and $^{232}$Th (Bqkg$^{-1}$) were 1143.8, 77.14 and 142.22, respectively and in soil the geometric mean values (Bqkg$^{-1}$) were 639.92, 40.57 and 72.76 respectively. The rock to soil ratio for these radionuclides, which would provide information about the weathering of these radionuclides from the host rock to the soil, were estimated. The correlation coefficient between $^{226}$Ra and $^{232}$Th, $^{226}$Ra and $^{40}$K, $^{232}$Th and $^{40}$K for rock is found to be 0.95, 9.84 and 0.95 respectively. Radium-equivalent activities ($Ra_{eq}$), external hazard index ($H_{ex}$) and annual gonadal dose equivalent for $^{40}$K, $^{226}$Ra and $^{232}$Th were found to be within the permissible limits.

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