Assessment of environmental radioactivity levels and associated radiogenic heat production in rock samples at locations spread along Thrissur-Palakkad highway region, Kerala, India.

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Introduction

Naturally occurring radionuclides (^{238}U, ^{232}Th and ^{40}K) have been in existence since the formation of the Earth. They are the primary sources of terrestrial ionizing radiation. The human beings are continuously exposed to these radiations while at home and the places of work outside. Radionuclides are present in rocks in varying amounts, and they are easily mobilized into the environment. The concentrations of these naturally occurring radionuclides depend on the distribution of rocks from which they originate and the processes that are responsible for the removal of these radionuclides from the parent rocks to soil and surrounding air [1].

Radiogenic heat production (RHP) rate is a physical property defining the amount of heat liberated in unit time per unit volume of rock by the decay of unstable radioactive isotopes; in unit of μWm^{-3}. In crustal rocks, it is dominated by contributions from the above-mentioned radioactive elements (^{238}U, ^{232}Th and ^{40}K).

The objective and significance of the present study is to assess the radioecological safety of the population in the study area and the consequent radiological implications.

The potential radiological hazard parameters include the absorbed dose rates in the air (D_{out}), annual effective dose equivalent (AEDE), internal hazard index (H_{in}), the external hazard index (H_{ex}) and gamma radiation index (I_γ). The results are compared with corresponding values reported from other places in India and outside.

Sample Collection and Analysis

In order to obtain a representative coverage of geological formations, 45 rock samples were collected from 15 locations, distributed over a distance of 48 km which are part of the Western Ghats in Kerala. So far, no similar studies have been carried out in this area.

The collected samples were subjected to standard procedures before starting the data collection. The activity concentration of ^{226}Ra, ^{232}Th, and ^{40}K in the samples were determined by employing the gamma spectrometry technique. For this we used a 42% relative efficiency p type low background high-purity germanium (HPGe) detector having an energy resolution 2.1 keV at 1.33 MeV together with the associated electronics.

Evaluation of Parameters

Activity concentration in the samples were evaluated using the equation,

$$\mathbf{A = \frac{C_t}{P_\gamma\, \eta\, m}\ (Bq\ kg^{-1})}$$

where C_t is the counts per second above background, P_γ is the absolute gamma ray transition probability, η is the photo peak efficiency (%) of the detector and m is the mass in kg.

Radium equivalent activity (Ra_{eq}) gives a single index which expresses the gamma yield from diverse mixture of these radionuclides in a sample

$$\mathbf{Ra_{eq}\ (Bq\ kg^{-1}) = A_{Ra} + 1.43A_{Th} + 0.077A_K}$$

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

Gamma absorbed dose rate (nGyh^{-1}) in air is evaluated as,

$$\mathbf{D_{out} = 0.462A_{Ra} + 0.621A_{Th} + 0.0417A_K}$$

The outdoor annual effective doses ($AEDE_{out}$) were calculated using the following equations

$$\mathbf{AEDE = D_{out} \times 8760 \times 0.2 \times 0.7 \times 10^{-3}}$$

where 0.7× 10^{-3} SvGy^{-1} is a conversion factor, 8760 and 0.2 correspond to the number hours per year and the outdoor occupancy factor, respectively.

The radioactive heat production of rocks was deduced using the relation [2]

$$\mathbf{RHP = \rho\,(9.52\,C_U + 2.56\,C_{Th} + 3.48\,C_K) \times 10^{-5}}$$

where ρ is the dry density of rocks (kg/m^3). Here C_U and C_{Th} are the concentrations of U and Th in ppm, respectively and C_K concentrations of K and K in %.

Results and Discussion

Natural radioactivity concentrations of ^{226}Ra and ^{232}Th and ^{40}K are estimated in the various rock outcrops of the study area are shown in figure 1. For ^{226}Ra, it ranged 16.44 to 88.33 Bq kg^{-1} with a mean of 59.28 Bq kg^{-1}. for ^{232}Th ranged between 67.42 to 174.3 Bq kg^{-1} with a mean of 120.09 Bq kg^{-1}. for ^{40}K it ranged from 739 to 1250 Bq kg^{-1} with a mean of 952 Bq kg^{-1}.

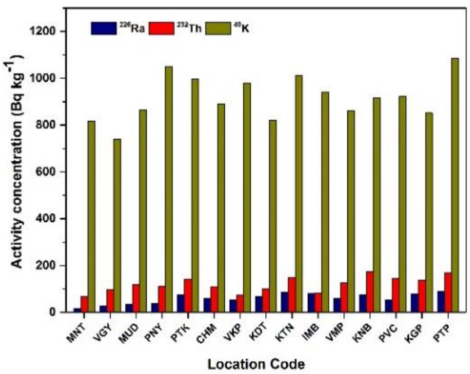

Fig. 1 Activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K.

The values of Ra_{eq} in rock samples are found to vary from 175.68 to 412.75 Bq kg^{-1}, with a mean value of 301.57 Bq kg^{-1}. Hence the mean value is below the permissible limit of 370 Bq kg^{-1}.

The outdoor absorbed dose rate (D_{out}) values of rock samples vary from 86.51 to 186.95 nGyh^{-1} with a mean value of 139.63 nGyh^{-1}. This value is higher than the 60 nGy h^{-1}, world average value of as per UNSCEAR report [3].

A positive correlation coefficient (R^2) value of 0.87 between D_{out} and ^{232}Th concentration was observed and it is shown Figure 2. For ^{226}Ra and ^{40}K the correlation is not so significant. Mean values of radiological parameters-hazard index, gamma activity and activity utilization index, are all below the permissible limit of 1 mSvy^{-1}. Regarding the consequences of radiological exposures, results emphasis that the natural radionuclides in studied rock samples does not pause any risk to the populations in areas being investigated.

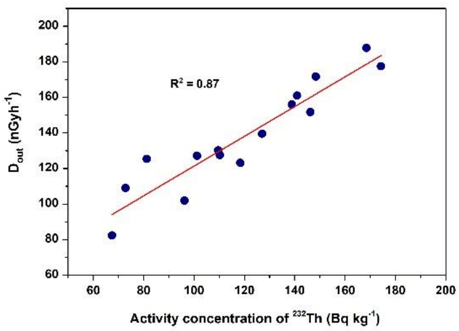

Fig. 2: Correlation between absorbed dose rate and the activity concentration of ^{232}Th.

The RHP values range from 1.73 to 5.03 μWm^{-3} with an average value of 3.52 μWm^{-3}, which is below the permitted value of 4 μWm^{-3} of heat to be considered for economic importance.

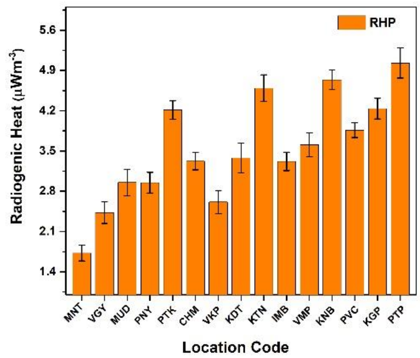

Fig. 3: The distribution of radiogenic heat in rock samples study.

In conclusion, the present study reveals that, the rock samples in the study area release radioactive elements Radium, Thorium and Potassium in different proportions, with ^{232}Th having relatively higher effect on the effective dose. However, the mean values are well below the stipulated upper limit. The evaluated RHP rate is also under the safe limit.

References

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