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Measurement of level of natural gamma emitting radionuclides in charnockite rocks of Kalrayan Hills, India

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ABSTRACT

Determination of naturally occurring gamma emitting radionuclides concentration are of a great importance for the assessment of external and internal radiation dose received by human. The level of natural radioactivity of 65 rocks samples collected from different locations at Kalrayan Hills, Tamilnadu, India, was measured. Activity concentration of radionuclides in samples were determined by γ-ray spectrometer using NaI(Tl) crystal detector with specially designed shield. The average radioactivity concentration of ^{238}U, ^{232}Th and ^{40}K were determined and expressed in Bq/Kg. The result shows that these radionuclides were present in the range BDL to 22.90±5.81 Bqkg^{-1} for ^{238}U, BDL to 91.60±6.43 Bqkg^{-1} for ^{232}Th and BDL to 505.00±29.57 Bqkg^{-1} for ^{40}K. Also, to know about the radiological hazard, the absorbed dose rate was calculated from the measured activity concentrations.

Key words: *Natural radionuclides, dose rates, Kalrayan hills, rock samples*

INTRODUCTION

The knowledge of radionuclides distribution and radiation levels in the environment is important for assessing the effects of radiation exposure due to both terrestrial and extraterrestrial sources. Terrestrial radiation is due to radioactive nuclides present in different amounts in sediments, waters and rocks. Almost all the rocks contain naturally occurring radionuclides such as ^{238}U, ^{232}Th and ^{40}K. Some of these radionuclides from this source are transformed to man through food chain or inhalations [1]. However, above said effects are mainly depends on the level of these radionuclides present in the rocks and sediments.

The natural radionuclides at environmental levels is rising in order to contribute to the knowledge of radiation stochastic effects. According to UNSCEAR (2000) [2], more data on exposures from natural sources at low levels are needed. The hereditary effects of radiation on human population are still not properly quantified. The studies of the natural radioactivity may be quantitatively used for the environmental contamination studies. Therefore, the base line data of natural radiation is essential to determine the variation of radionuclide concentration in rocks so that man made contamination is contrasted from natural radioactivity.

India has a vast area and huge population with much diversified ways of life. Also, India is one of the countries in the world having the highest background radiation levels. These areas are the coastal plains of the south Indian peninsula. The background radiation levels are due to the presence of monazite sand. The monazite deposits in the coastal areas of Tamil Nadu and Kerala are due to the weathering of rocks in the Nilgiri hills and the Eastern Ghats [3]. Hence, the measurement of radiation level of this region is essential to assess the nature of radioactive nuclides and manmade radiation. In view of these, a detailed study has been undertaken to measure the activity level of various environmental samples in these areas for future assessment of the impact due to various industries. The present study involves preliminary quantitative analysis of natural radioactive elements present in rock samples of Kalrayan hills in Tamilnadu, India and also calculates the associated radiological hazards.

MATERIALS AND METHODS

Study area

The Kalrayan is one of the major hill ranges of Eastern Ghats situated to the north east of Tamilnadu. It lies between 11˚ 20' to 12˚ 05' N latitude and 78˚ 28' to 79˚ 05' E longitude (Figure 1). It spreads over an area of 1095 Sq.km. and is endowed with rich natural resources. The vegetation types of Kalrayans are scrub jungles of altitude 400m, deciduous forests between 800 to 1300m and shoals at the sheltered pockets on the plateau.

Sample collection and preparation

Sixty five rock samples were collected from different locations of the study region. The sample location were recorded in terms of degree - minute – decimals (Latitudinal and Longitudinal position) using Hand-held Global Positioning System (GPS) (Model: GARMIN GPS-12) unit. Each location is separated by a distance of 5-6 km approximately and is numbered as S_1 to S_{65}. The procedure adopted by Ramasamy et al. (2012)[4] was followed for the collection and preparation of the samples.

Experimental technique

Gamma-ray spectrometric technique has been used for the measurement of concentration of radionuclides. To estimate the activity levels of ^{40}K, ^{238}U and ^{232}Th in the collected samples, a gamma-ray spectrometer in the laboratory of Health and Safety Division, Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam was made use of in the present investigation. NaI(Tl) crystal detector of size $3^2 \times 3^2$ along with a 8 K multichannel analyser was used to record the gamma spectra. Standard sources: natural uranium (1997.56 Bq), natural thorium (1237.28 Bq) and KCl (5181.39 Bq), with a standard 250-ml container from International Atomic Energy Agency (IAEA) were used for calibrating the gamma-ray spectrometer. These standards were obtained from the Environmental Survey Laboratory, IGCAR, Kalpakkam with the counting time of 20,000 s for each samples.

RESULTS AND DISCUSSION

Activity concentration (Bq/kg) of ^{238}U, ^{232}Th and ^{40}K radio nuclides in rocks samples are presented in table 1. The below detectable limit (BDL) of the each radionuclide was determined from the background radiation spectrum for the same counting time as for rock samples and is estimated as 5.5 Bq/kg for ^{238}U and ^{232}Th and 21.5 Bq/kg for ^{40}K. The measured activity concentrations are ranged from BDL to 22.90±5.81 $Bqkg^{-1}$ for ^{238}U, BDL to 91.60±6.43 $Bqkg^{-1}$ for ^{232}Th and BDL to 505.00±29.57 $Bqkg^{-1}$ for ^{40}K. A wide variation in the activities of these radionuclides was observed. It may be due to mineralogy of the study area. The charnockite group of rocks such as basic, ultramafic, magnetite quartzite, pyroxene granulite and charnockite are major rock types in the study area [5].
In all sampling sites, mean activity concentration is of the order $^{238}U < ^{232}Th < ^{40}K$. Actually, concentration of ^{238}U is very lower than the ^{232}Th and ^{40}K, since ^{238}U is more soluble in rain water. ^{232}Th concentration is found to be higher than ^{238}U in all the sampling sites. This may be due to the low geochemical mobility and insoluble nature in water of thorium. The ^{40}K activity dominates over ^{238}U and ^{232}Th elemental activities which may be due to presence of feldspar minerals [6].

The maximum activity concentration of ^{238}U (22.90±5.81 $Bqkg^{-1}$) and ^{232}Th (91.60±6.43 $Bqkg^{-1}$) are observed in Ennadu (S_{20}) rock samples. These highest levels may be due to the presence of accessory minerals such as zircon, monazite, thorite and uranothorite. Uranium and thorium are generally enriched in the youngest and most potassic members of comagmatic suites of igneous rocks [4]. In the present study, higher values of ^{238}U and ^{232}Th could be due to the presence of higher amount of accessory minerals.

The highest activity concentration of ^{40}K (505.00±29.57 Bqkg^{-1}) is observed at site no.S_{12} (Vellimalai). According to Orgun et al. (2007)[7], ^{40}K occurs in major minerals such as feldspar and micas. Therefore in the present study, the highest activity concentration of ^{40}K may be due to presence of higher amount of feldspar.

Concentrations of natural radionuclides of some igneous and metamorphic rocks in Egypt were measured by Abbady et al., (2006) [8]. They reported that the metamorphic rocks are formed from igneous or sedimentary materials, the primary U, Th and K contents will be redistributed according to the degree of the metamorphic transformation. As a general rule, a decrease of the contents of U, Th and K is observed with an increasing degree of metamorphism. In the present study, the lower activity concentration of all the measured radio nuclides is found at Cheriyapattu (S_{54}) and Kurumbalur (S_{54}) villages. Rocks in the Cheriyapattu and Kurumbalur village may be formed due to increasing degree of metamorphism.

Statistical Analysis

The statistical values corresponding to the activities measured for ^{238}U, ^{232}Th and ^{40}K in the rock samples collected from different places are presented in table 2. Histograms of activity concentrations of ^{238}U, ^{232}Th and ^{40}K radionuclides are shown in figures 2.

The standard deviation higher than the mean value indicates the low degree of uniformity and vice versa [9]. In the present study, standard deviation values of activity concentrations of ^{238}U, ^{232}Th and ^{40}K radionuclides are lesser than the mean value (expect activity concentration of ^{232}Th), whereas the standard deviation of ^{232}Th is higher than mean value. It shows ^{238}U, ^{232}Th and ^{40}K are high degree of uniformity, except ^{232}Th.

Skewness refers to the asymmetry or lack of symmetry in the shape of a frequency distribution. When a distribution is not symmetrical (or is asymmetrical) it is called a skewed distribution. Skewed distribution could either be positively or negatively skewed [9]. In the present study, the skewness of activity concentrations of ^{238}U, ^{232}Th and ^{40}K radionuclides are positive, which shows that their distributions are asymmetric. The plotted graph has no bell shaped form and its positive values indicate the positive skewness.

Kurtosis is a measure of peakedness. It is also a function of internal sorting or distribution. Depending upon the peakedness, it is named as mesokurtic, leptokurtic and platy kurtic. If the value of kurtosis is zero, it is known as normal curve or mesokurtic. When the kurtosis value is positive, the curve is more peaked than the normal curve (i.e.,) leptokurtic whereas the negative value of kurtosis indicates less peaked than the normal curve (i.e.,) platy kurtic [9]. In the present study, the kurtosis values of activity concentrations of ^{238}U, ^{232}Th and ^{40}K are positive and it indicates that the curve is more peaked than the normal curve (i.e.,) leptokurtic whereas negative kurtosis value of activity concentration of ^{40}K indicates platy kurtic. This is due to uneven spatial distribution of radionuclides in the samples of the study area.

According to UNSCEAR (2000)[2] report, the world average data for ^{238}U, ^{232}Th and ^{40}K in rock is 33 Bqkg^{-1}, 45 Bqkg^{-1} and 420 Bqkg^{-1} respectively. If one compare these values with the present study, the mean activity concentrations of ^{238}U, ^{232}Th and ^{40}K are 0.2155, 0.2594 and 0.5334 times the world average values respectively. In the same way, present values of ^{238}U, ^{232}Th and ^{40}K are 0.2294, 0.1217 and 0.5686 times the Indian average values (31 Bqkg^{-1} for ^{238}U, 63 Bqkg^{-1} for ^{232}Th, 394 Bqkg^{-1} for ^{40}K) respectively[2].

Correlation between the activity concentrations

In order to determine any synergistic ratio among the activity concentrations of three natural radionuclides in rock samples, correlation between them were drawn using the SPSS 16.0 software. Table 3 represents correlation between the activity concentration of ^{238}U and ^{232}Th, $^{238}U$and ^{40}K, and ^{232}Th and ^{40}K respectively. In all the three cases, the correlation is found to be linear and positive. The correlation coefficient between ^{238}U and ^{232}Th is 0.94. Where as correlation between ^{238}U and ^{40}K and ^{232}Th and ^{40}K are low. It is expected, since ^{238}U and ^{232}Th came from natural decay series whereas ^{40}K, although a naturally occurring radionuclide, is not part of any such decay series. Lima et al. (2005) [6] have obtained the strong correlation (r = 0.9) between ^{238}U and ^{232}Th for rock samples. Also, they reported, this strong correlation indicates the presence of significant amount of radioactive accessory minerals such as zircon, monazite, thorite and garnet. In the present study, the strong correlation between ^{238}U and ^{232}Th indicates the presence of accessory minerals. However, a positive correlation may still be attributed to the property of the rock in retaining these radionuclides under varying weather conditions. The results shown in table (3) also indicated that the mean value of ^{40}K is highest and ^{238}U is the lowest. A poor correlations (r = 0.26) exists between

^{232}Th and ^{40}K and ^{238}U and ^{40}K with correlation coefficient of 0.30, indicates that ^{40}K concentrations may not be related with the presence of ^{232}Th and ^{238}U bearing mineral. The same type of poor correlation between these radionuclides was also observed by Mohanty et al. (2004)[10].

Activity ratios

The activity ratios (^{238}U/^{232}Th, ^{238}U/^{40}K, ^{232}Th/^{238}U, ^{232}Th/^{40}K, ^{40}K/^{238}U and ^{40}K/^{232}Th) are calculated and tabulated in table 4. ^{238}U/^{232}Th ratio varied from 0.25 (S_{20}) to 1.49 (S_{51}) with an average of ^{238}U/ ^{232}Th of 0.8. This average is equivalent to the upper crust value (0.8) [11]. This shows that the concentration of uranium and thorium in the present study area rock samples is more or less equal to the concentration of uranium and thorium in the upper crust value.

According to Orgun et al. (2007)[7], Th/U ratio is an indicative for the relative depletion or enrichment of radioisotopes. Th/U ratio of present study ranges from 0.67 to 4.00 for rock with an average of 1.45 (table 4). Th/U ratio for continental crust, varies from 3.84 to 4.2 [7]. The average value of Th/U ratio of present study is higher than the world average value 1.36 [7]. The concentration ratios are higher than unity for most of the sampling sites, which shows low geochemical mobility of thorium [12]. Thus, a preferential accumulation of thorium by sediments might explain the relatively higher ^{232}Th values than ^{238}U. The average values of Th/U, K/U and K/Th are also calculated and are equal to 1.45, 33.08 and 26.75 respectively. Ramasamy et al. (2004) have listed Th and U concentration in ppm for some rock-forming minerals and some igneous rocks. They found that either in rock-forming minerals such as quartz, feldspars, biotite, hornblende and olivine from dunite or in igneous rocks, thorium levels are always relatively higher than uranium levels. It was also shown that Th/U ratio is 3.5 for granite containing 70% SiO_2. In the present study, average thorium 11.67 Bq/kg is higher than the average of uranium (7.11 Bq/kg). It may be due the presence of granitic rocks in the study area. [13,14 and 15] Dheenathayalu et al. 2000 and Ramasamy et al. 2001 and 2004 were calculated, K/U and K/Th for crustal rocks and obtained K/U was larger than K/Th. In the present study, the same trend is observed.

Absorbed dose rate

It is of great importance to detect the ^{238}U, ^{232}Th and ^{40}K natural radionuclides to assess their hazards to the human. Exposures to radiation from the rocks were assessed by calculating absorbed dose rate. The measured activity concentration of ^{238}U, ^{232}Th and ^{40}K are converted into doses by applying the conversion factors 0.462, 0.604 and 0.0417 for uranium, thorium and potassium respectively [16]. These factors are used to calculate the total dose rate (D) (nGy h^{-1}) using the following equation

$$D= (0.462C_U + 0.604\ C_{Th} +0.0417\ C_K) \quad nGy\ h^{-1}$$

Where C_U, C_{Th} and C_K are the activity concentrations (Bq/kg) of ^{238}U, ^{232}Th and ^{40}K respectively. The calculated absorbed dose rates are presented in table 1. Maximum dose rate 81.59 $nGyh^{-1}$ was calculated for Ennadu samples (S_{20}) (table 1). This may be due to elevated level of ^{40}K. Minimum dose rate 6.76 nGy h^{-1} was calculated from Cheriyapattu and Kurumbalur (S_{54} and S_{55}) samples (table 1). This may be due to BDL of all the measured radionuclides and also due to lower amount of all the measured radionuclides. The average absorbed dose rate for rock samples is 19.67$nGyh^{-1}$ which is lower than the world average 51.5$nGyh^{-1}$[2].

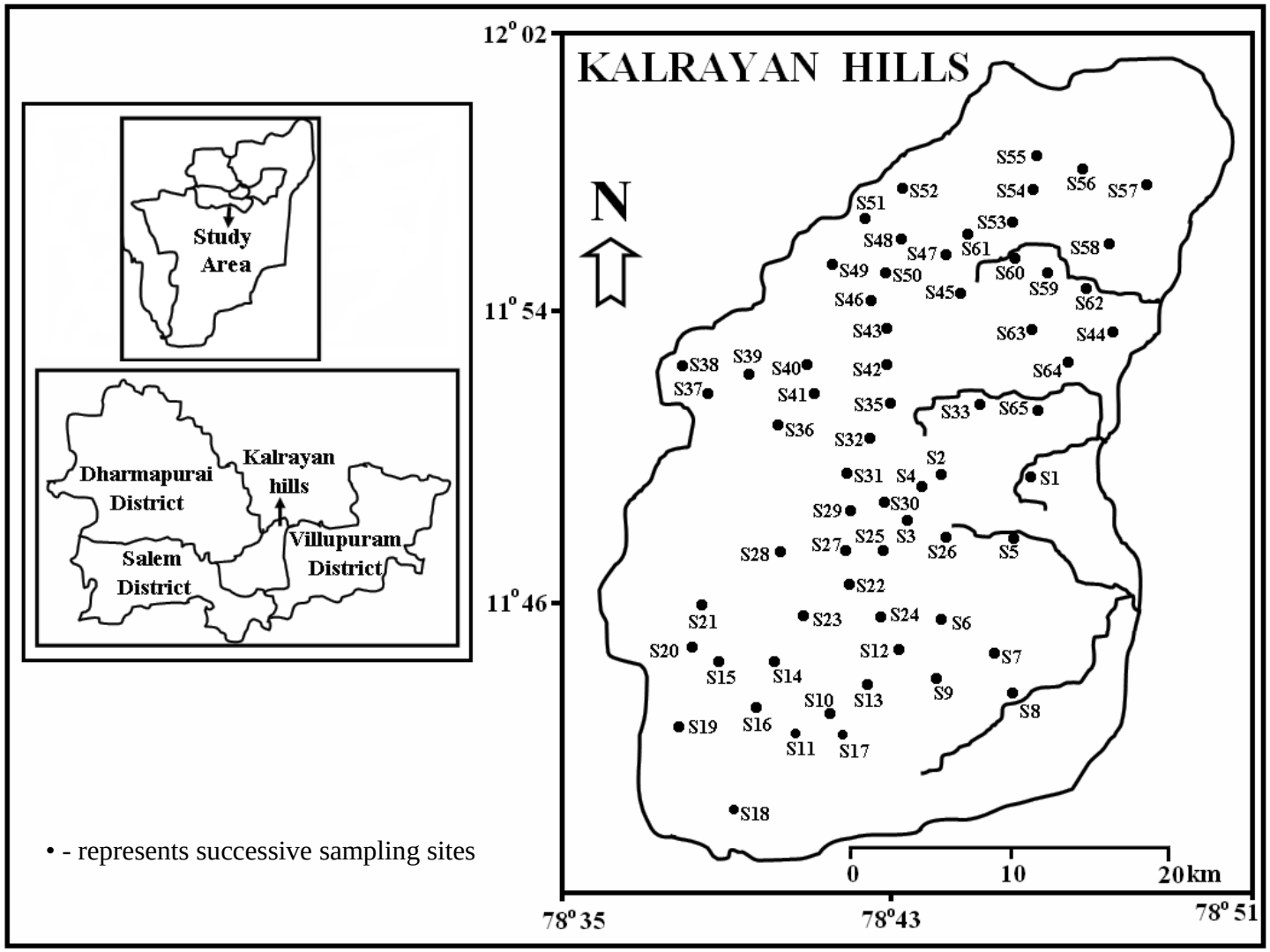

Figure 1 Location of Kalrayan hills with their experimental sites in Tamilnadu

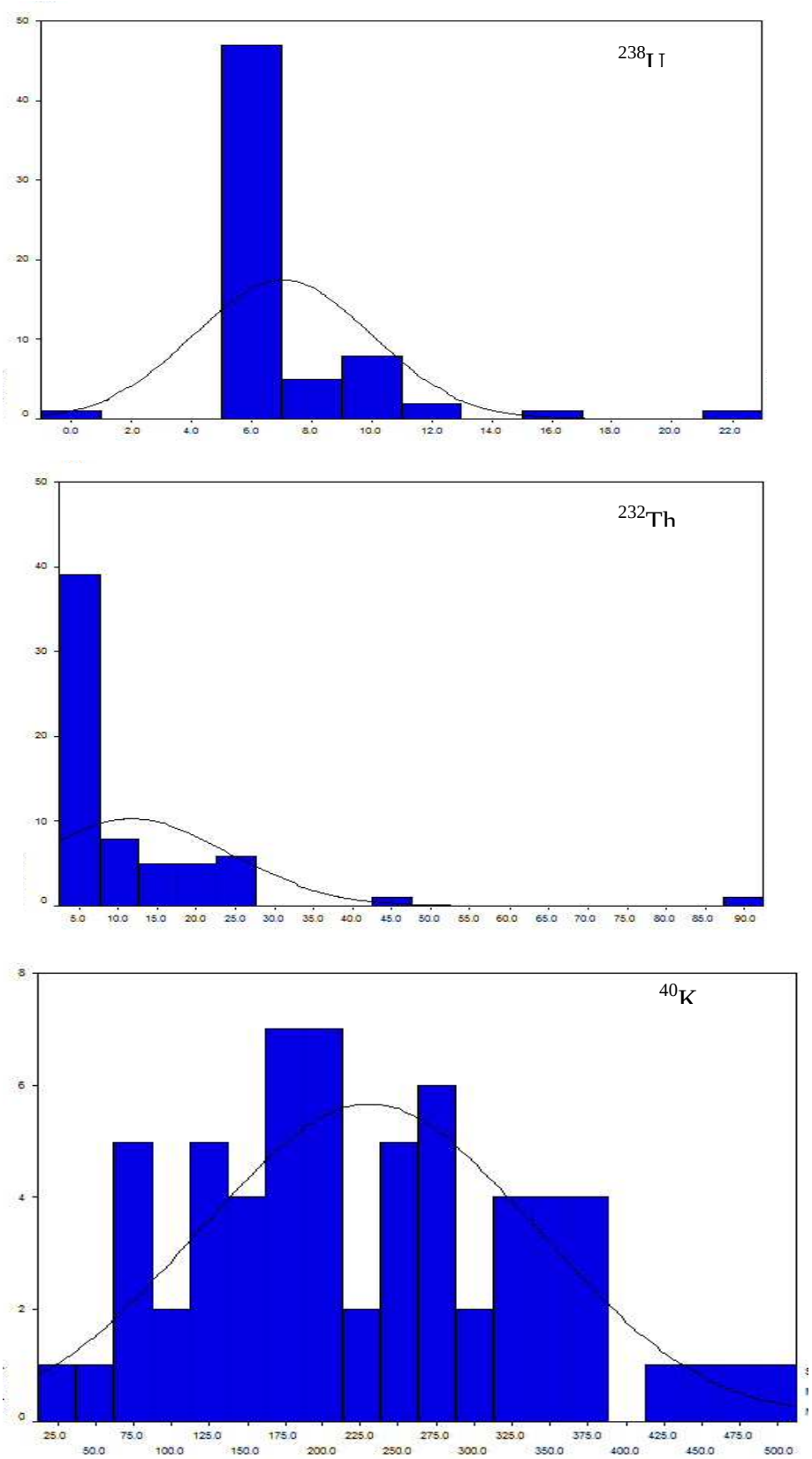

Figure 2 Distribution of ^{238}U, ^{232}Th and ^{40}K

Table 1 Activity concentrations of ^{238}U, ^{232}Th and ^{40}K with their uncertainties, Dose rates for Rock samples

Sl.No.	Location	Activity concentration (Bq/kg)			Dose rate (nGy/h)
		^{238}U	^{232}Th	^{40}K	
S_1	Vandagappadi	5.71±4.61	6.34±3.92	199.87±22.94	14.80±5.45
S_2	Torangur	5.83±4.63	5.82±3.17	98.61±19.37	10.32±4.86
S_3	Varam	5.79±4.59	5.71±3.87	132.11±20.15	11.63±5.30
S_4	Kattivalayu	5.93±4.59	6.17±4.84	212.36±22.27	15.32±5.97
S_5	Uppur	10.2±5.57	20.5±4.97	331±23.54	30.90±6.52
S_6	Arampundi	11.6±5.58	24.5±4.99	320±23.52	33.50±6.57
S_7	Vanniyur	5.61±4.47	6.01±4.38	330±23.54	19.98±5.69
S_8	Kottaputhur	BDL	7.88±4.63	238.64±23.54	17.25±3.78
S_9	Kandikkollai	6.73±4.81	8.47±4.58	344±23.62	22.57±5.97
S_{10}	Valappadi	6.47±4.75	9.13±4.99	436±24.43	26.68±6.23
S_{11}	Pudur	5.87±4.42	6.99±4.71	349±23.61	21.49±5.87
S_{12}	Vellimalai	5.87±4.41	5.71±3.88	505±29.57	27.22±5.61
S_{13}	Moypatti	5.61±4.32	5.89±3.97	480±24.35	26.17±5.41
S_{14}	Kariyalur	5.92±4.62	6.69±4.67	245±23.76	16.99±5.95
S_{15}	Allathi	5.63±4.49	5.99±3.13	124.62±20.18	11.42±4.81
S_{16}	Mavadippattu	11±5.49	23.5±4.98	365.99±23.67	34.54±6.53
S_{17}	Mattaiyanur	6.11±4.70	5.85±3.11	273±23.68	17.74±5.04
S_{18}	Velarikkadu	9.8±5.47	20.5±4.86	251±23.63	27.38±6.45
S_{19}	Erukkambatti	16.1±5.61	45.5±5.10	278±23.67	46.51±6.66
S_{20}	Ennadu	22.90±5.81	91.60±6.43	376±23.72	81.59±7.56
S_{21}	Vandagappadi	6.75±4.28	5.9±3.98	202.49±22.22	15.13±5.31
S_{22}	Torangur	9.8±5.46	20±4.81	121.71±20.97	21.68±6.30
S_{23}	Varam	9.1±5.53	23±4.96	371±23.70	33.57±6.54
S_{24}	Kattivalayu	5.73±4.39	5.72±3.42	50.77±19.97	8.22±4.93
S_{25}	Uppur	5.67±4.62	7.91±4.11	70.84±19.39	10.35±5.43
S_{26}	Arampundi	BDL	5.97±3.88	101.63±19.02	10.38±3.14
S_{27}	Vanniyur	5.71±4.63	6.71±4.12	182.18±22.6	14.29±5.57
S_{28}	Kottaputhur	5.59±4.83	5.83±3.07	284±23.58	17.95±5.07
S_{29}	Kandikkollai	7.4±4.92	26.5±5.01	11±22.25	28.22±6.23
S_{30}	Valappadi	BDL	BDL	27.83±18.99	7.02±0.79
S_{31}	Pudur	BDL	BDL	450±24.28	24.63±1.01
S_{32}	Vellimalai	8±4.97	15.5±4.80	255±23.57	23.69±6.18
S_{33}	Moypatti	5.93±4.51	6.43±4.29	242.37±23.78	16.73±5.67
S_{34}	Kariyalur	6.8±4.49	BDL	79.59±20.71	9.78±2.94
S_{35}	Allathi	BDL	BDL	128.19±19.05	11.21±0.79
S_{36}	Nakavalayu	6.13±4.10	13.62±4.88	158.76±20.86	17.68±5.71
S_{37}	Meladukuli	BDL	6.17±4.04	352±23.58	20.95±3.42
S_{38}	Aravangadu	5.81±4.58	5.69±3.92	72.83±19.39	9.16±5.29
S_{39}	Maniyarpalaiyam	5.78±4.39	BDL	67.37±19.04	8.80±2.82
S_{40}	Kiladukuli	7.2±4.87	7.83±4.32	233.96±23.68	17.81±5.85
S_{41}	Kulipuli	5.98±4.19	6.17±4.33	193.09±22.00	14.54±5.47
S_{42}	Melnilayur	BDL	14.52±4.01	76.42±19.07	14.5013.22
S_{43}	Kilnilayur	BDL	9.8±4.54	157.69±20.35	15.04±3.59
S_{44}	Vengadu	BDL	6.91±4.21	173.51±20.71	13.95±3.41
S_{45}	Vilvathi	5.81±4.47	11±4.71	380±23.59	25.17±5.89
S_{46}	Kannur	5.69±4.41	5.99±3.87	338±23.48	20.34±5.35
S_{47}	Perumalnattam	5.83±4.37	6.13±4.98	164±20.49	13.23±5.88
S_{48}	Kilakkadu	9.9±5.49	14.95±4.29	292±23.51	25.78±6.11
S_{49}	Kallippadi	5.73±4.40	5.73±3.06	163.64±20.49	12.93±4.47
S_{50}	Kattuvalayu	6.71±5.54	9.76±4.17	332.17±23.53	22.85±6.06
S_{51}	Gudaram	8.6±4.98	5.78±3.19	265±23.49	18.51±5.81
S_{52}	Alanur	5.63±4.10	6.19±4.71	171.15±20.49	13.48±5.76
S_{53}	Thakampattu	10.67±5.58	22.5±4.98	155.66±20.24	25.01±5.30
S_{54}	Cheriyapattu	BDL	BDL	BDL	6.76±0.00
S_{55}	Kurumbalur	BDL	BDL	BDL	6.76±0.00
S_{56}	Thaduthapalayam	6.91±4.49	6.87±4.29	137.65±20.61	13.08±5.52
S_{57}	Mulakkadu	BDL	13±4.84	175±20.51	17.69±3.78
S_{58}	Maankompu	5.64±4.83	7±4.19	185.48±20.63	14.65±5.62
S_{59}	Valakkuli	9.7±4.46	23±4.95	266.78±23.12	29.50±6.01
S_{60}	Vanjikkuli	10.8±5.57	21±4.13	310.89±23.67	30.64±6.05
S_{61}	Serkkalur	5.97±4.40	6.13±4.73	131.67±20.43	11.95±5.74
S_{62}	Perumbular	8.9±4.99	17.5±4.92	281.07±23.08	26.40±6.24
S_{63}	Pachcheri	5.61±4.39	5.81±3.32	226±23.53	15.53±5.62
S_{64}	Pudupalapattu	5.77±4.39	5.72±3.88	197.51±20.38	14.36±5.22
S_{65}	Kallippattu	5.91±4.81	6.91±4.99	189.48±20.13	14.81±6.08
Average		***7.11±4.76***	***11.67±4.37***	***224.01±22.14***	***19.67±5.04***
Maximum		***22.90±5.81***	***91.60±6.43***	***505.00±29.57***	***81.59±7.56***
Minimum		***BDL***	***BDL***	***BDL***	***6.76±0.00***

Table 2 Statistical data for activity concentrations of ^{238}U, ^{232}Th and ^{40}K for the Charnockite rocks of Kallrayan Hills

Statistics	Radionuclide activity concentration (Bq/kg)		
	Rock		
	^{238}U	^{232}Th	^{40}K
Mean	7.11±4.76	11.67±4. 37	224.01±22.14
Standard Deviation	2.86	12.58	115.09
Minimum	BDL	BDL	BDL
Maximum	22.90±5.81	91.60±6.43	505.00±29.57
Skewness	3.373	4.504	0.314
Kurtosis	14.762	25.857	-0.402
Frequency distribution	Log Normal	Log Normal	Log Normal

Table 3 Correlation of ^{238}U, ^{232}Th, ^{40}K and Absorbed dose rate

	^{238}U	^{232}Th	^{40}K	Dose
^{238}U	**1.00**			
^{232}Th	**0.94**	**1.00**		
^{40}K	**0.30**	**0.26**	**1.00**	
Dose	**0.30**	**0.91**	**0.65**	**1.00**

CONCLUSION

This study determined the average activity concentration of rocks samples from Kalrayan hills which are within the world and Indian average values although some extreme values have been determined. The average value of the absorbed dose rate for collected rock samples is lower than the world and Indian average values. On the basis of lower levels of natural radioactivity, charnockite rocks of Kalrayan hills, India can be considered as a less natural background radiation area. It is concluded that the activity of charnockite rocks has no harmful radiation effects that are pose to the local people and tourists visiting the Kalrayan hills and involving in activities in and around the area.

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Table 4 Radionuclides (^{238}U, ^{232}Th and ^{40}K) ratios of Charnockite rocks of Kallrayan Hills

Sl.No.	Activity ratios					
	$^{238}U/^{232}Th$	$^{238}U/^{40}K$	$^{232}Th/^{238}U$	$^{232}Th/^{40}K$	$^{40}K/^{238}U$	$^{40}K/^{232}Th$
S_1	0.90	0.03	1.11	0.03	35.00	31.53
S_2	1.00	0.06	1.00	0.06	16.91	16.94
S_3	1.01	0.04	0.99	0.04	22.82	23.14
S_4	0.96	0.03	1.04	0.03	35.81	34.42
S_5	0.50	0.03	2.01	0.06	32.45	16.15
S_6	0.47	0.04	2.11	0.08	27.59	13.06
S_7	0.93	0.02	1.07	0.02	58.82	54.91
S_8	0.70	0.02	1.43	0.03	43.39	30.28
S_9	0.79	0.02	1.26	0.02	51.11	40.61
S_{10}	0.71	0.01	1.41	0.02	67.39	47.75
S_{11}	0.84	0.02	1.19	0.02	59.45	49.93
S_{12}	1.03	0.01	0.97	0.01	86.03	88.44
S_{13}	0.95	0.01	1.05	0.01	85.56	81.49
S_{14}	0.88	0.02	1.13	0.03	41.39	36.62
S_{15}	0.94	0.05	1.06	0.05	22.13	20.80
S_{16}	0.47	0.03	2.14	0.06	33.27	15.57
S_{17}	1.04	0.02	0.96	0.02	44.68	46.67
S_{18}	0.48	0.04	2.09	0.08	25.61	12.24
S_{19}	0.35	0.06	2.83	0.16	17.27	6.11
S_{20}	0.25	0.06	4.00	0.24	16.42	4.10
S_{21}	1.14	0.03	0.87	0.03	30.00	34.32
S_{22}	0.49	0.08	2.04	0.16	12.42	6.09
S_{23}	0.40	0.02	2.53	0.06	40.77	16.13
S_{24}	1.00	0.11	1.00	0.11	8.86	8.88
S_{25}	0.72	0.08	1.40	0.11	12.49	8.96
S_{26}	0.92	0.05	1.09	0.06	18.48	17.02
S_{27}	0.85	0.03	1.18	0.04	31.91	27.15
S_{28}	0.96	0.02	1.04	0.02	50.81	48.71
S_{29}	0.28	0.04	3.58	0.13	28.51	7.96
S_{30}	1.00	0.20	1.00	0.20	5.06	5.06
S_{31}	1.00	0.01	1.00	0.01	81.82	81.82
S_{32}	0.52	0.03	1.94	0.06	31.88	16.45
S_{33}	0.92	0.02	1.08	0.03	40.87	37.69
S_{34}	1.24	0.09	0.81	0.07	11.70	14.47
S_{35}	1.00	0.04	1.00	0.04	23.31	23.31
S_{36}	0.45	0.04	2.22	0.09	25.90	11.66
S_{37}	0.89	0.02	1.12	0.02	64.00	57.05
S_{38}	1.02	0.08	0.98	0.08	12.54	12.80
S_{39}	1.05	0.09	0.95	0.08	11.66	12.25
S_{40}	0.92	0.03	1.09	0.03	32.49	29.88
S_{41}	0.97	0.03	1.03	0.03	32.29	31.29
S_{42}	0.38	0.07	2.64	0.19	13.89	5.26
S_{43}	0.56	0.03	1.78	0.06	28.67	16.09
S_{44}	0.80	0.03	1.26	0.04	31.55	25.11
S_{45}	0.53	0.02	1.89	0.03	65.40	34.55
S_{46}	0.95	0.02	1.05	0.02	59.40	56.43
S_{47}	0.95	0.04	1.05	0.04	28.13	26.75
S_{48}	0.66	0.03	1.51	0.05	29.49	19.53
S_{49}	1.00	0.04	1.00	0.04	28.56	28.56
S_{50}	0.69	0.02	1.45	0.03	49.50	34.03
S_{51}	1.49	0.03	0.67	0.02	30.81	45.85
S_{52}	0.91	0.03	1.10	0.04	30.40	27.65
S_{53}	0.47	0.07	2.11	0.14	14.59	6.92
S_{54}	1.00	0.26	1.00	0.26	3.91	3.91
S_{55}	1.00	0.26	1.00	0.26	3.91	3.91
S_{56}	1.01	0.05	0.99	0.05	19.92	20.04
S_{57}	0.42	0.03	2.36	0.07	31.82	13.46
S_{58}	0.79	0.03	1.26	0.04	32.89	26.01
S_{59}	0.42	0.04	2.37	0.09	27.50	11.60
S_{60}	0.51	0.03	1.94	0.07	28.79	14.80
S_{61}	0.97	0.05	1.03	0.05	22.06	21.48
S_{62}	0.51	0.03	1.97	0.06	31.58	16.06
S_{63}	0.97	0.02	1.04	0.03	40.29	38.90
S_{64}	1.01	0.03	0.99	0.03	34.23	34.53
S_{65}	0.86	0.03	1.17	0.04	32.06	27.42
Average	**0.80**	**0.05**	**1.45**	**0.07**	**33.08**	**26.75**
Maximum	**1.49**	**0.26**	**4.00**	**0.26**	**86.03**	**88.44**
Minimum	**0.25**	**0.01**	**0.67**	**0.01**	**3.91**	**3.91**