effect of the crystalline phase on the complex dielectric constant is further evidence that the relaxation is likely related mainly to the cooperative orientation movement of the existing dipoles. The magnitude of the peak increases with temperature. This is expected due to increase in K^+ conducting ion available. Figure 6 shows two relaxation processes near 0.1 MHz and 3 MHz. This is attributed to crystalline and residual glass phases in GC. As the temperature increases, the relaxation at low frequency becomes indistinguishable.

Two distinct relaxation peaks were observed in the frequency dependence of dielectric loss. The absorption appears to be related to dipole motion in the crystalline and residual glass phases of GC.

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Gamma-ray spectroscopic analysis of biotite granites

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Samples collected at various altitudes of the Rajapalayam hills, Western Ghats, Tamil Nadu (lat. 9°19′ and long. 77°32′) were subjected to radioactive analysis using gamma-ray spectrometric technique. The activities of naturally occurring radioactive elements ^{232}Th, ^{238}U and ^{40}K have been determined and compared with *in situ* measurements using an environmental radiation dosimeter. The linear correlation coefficient has been obtained. The high values found in the activities for ^{232}Th, ^{238}U and ^{40}K are attributed to upward motion of uranium due to metamorphism. The ratio of Th to U exhibits a close agreement with universal value for crustal rock.

INDIA is one of the countries in the world having the highest background radiation levels[1]. These areas are the coastal plains of the south Indian peninsula. The background radiation levels are due to the presence of monazite sand[2]. 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 Western Ghats[3]. Rajapalayam hills (Muthulingapuram) occupy a portion of the Western Ghats (lat. 9°19′ and long. 77°32′). We measured the background radiation levels at different altitudes (sites) in biotite-granites of Rajapalayam hills and identified naturally occurring radionuclides. Calcium carbonate deposits are largely found in the adjoining areas of Rajapalayam. There are a number of cement factories in and around this place, which make use of these deposits[3] for the cement manufacture. As the River Arjuna migrates, minerals containing radionuclides from the Rajapalayam hills can get mixed with the calcium deposits and thereby occur in the calcium products such as white limestone used for wall painting and cement manufacture. Hence the study of minerals with special reference to radionuclides gain importance.

The site, Muthulingapuram hills, is situated about 6 miles southeast of Rajapalayam and about 15 miles south of Srivilliputhur, Tamil Nadu, India. According to the Survey of India toposheet No. 58 G/11/1, it lies between latitudes 9°19′ and 9°25′ and longitudes 77°32′ and 77°45′ (Figure 1). The samples analysed in the present investigation were collected both on the southern and northern side of the hills.

Determination of radioactivity involves measurements of either alpha, beta or gamma radiations from the sam-

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ples. Due to the inherent properties of gamma rays like high penetrating power and interaction process with matter, the measurement of gamma radiation offers more useful information than those of α and β radiations. Gamma-ray spectrometric technique has been used for the measurement of concentration of radionuclides in various minerals and other samples. To estimate the activity levels of ^{40}K, ^{238}U and ^{232}Th in the biotite-granitic 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″ × 3″ 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 and the spectra of these standard samples are shown in Figure 2 *a–c*. These standards were obtained from the Environmental Survey Laboratory, IGCAR, Kalpakkam. With the counting time of 20,000 s for each sample, the minimum detectable activity (MDA) limits were 13.25 Bq/kg for ^{40}K, 8.5 Bq/kg for ^{238}U and 1 Bq/kg for ^{232}Th. *In situ* dose measurements were done by using digital environmental radiation dosimeter (ERDM). The ERDM was placed at a height of 1 m from the sampling spot[4].

The biotite-granite samples collected at different sites were powdered to obtain more or less the same grain size of 120 μm. The dried powder samples were packed fully in a 250-ml plastic container and the net weight was determined before counting. These containers with the powdered rock samples were sealed hermetically to ensure that all daughter products of ^{238}U and ^{232}Th, in particular, gaseous radon isotopes formed, did not escape. A time of 30 days was allowed after packing to attain secular equilibrium between ^{226}Ra and its short-lived daughter products[5].

The investigations were carried out to determine the naturally occurring radionuclides, viz. ^{232}Th, ^{238}U and ^{40}K in the samples. Four to five samples from each of 14 sites at different altitudes were analysed by γ-ray spectrometric technique. Some representative γ-ray spectra are given in Figure 3 *a* and 3 *b*. The photo peaks at 2.614 MeV corresponding to ^{208}Tl at 1.764 MeV corresponding to ^{214}Bi and at 1.46 MeV corresponding to ^{40}K were used to calculate the activity concentration of ^{232}Th, ^{238}U and ^{40}K respectively using a computer program, after correcting for background and Compton scatter contributions and using efficiency factors obtained from standard

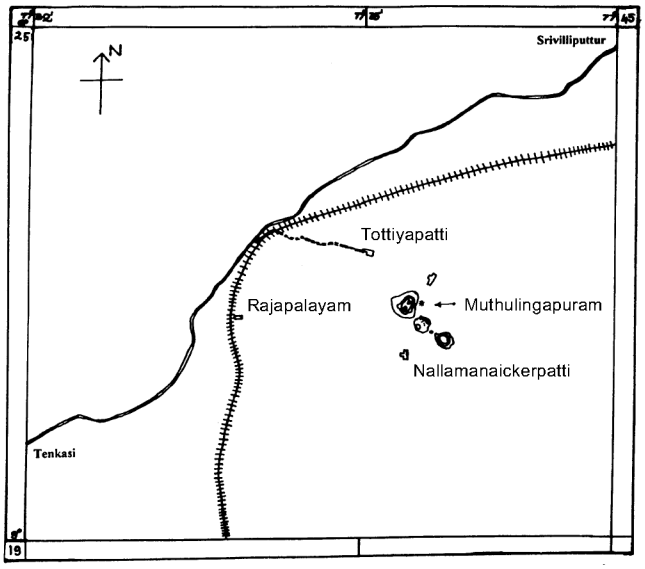

Figure 1. Location of the sample collection area (hill). (The asterisk shows the specific hill from which samples were obtained.)

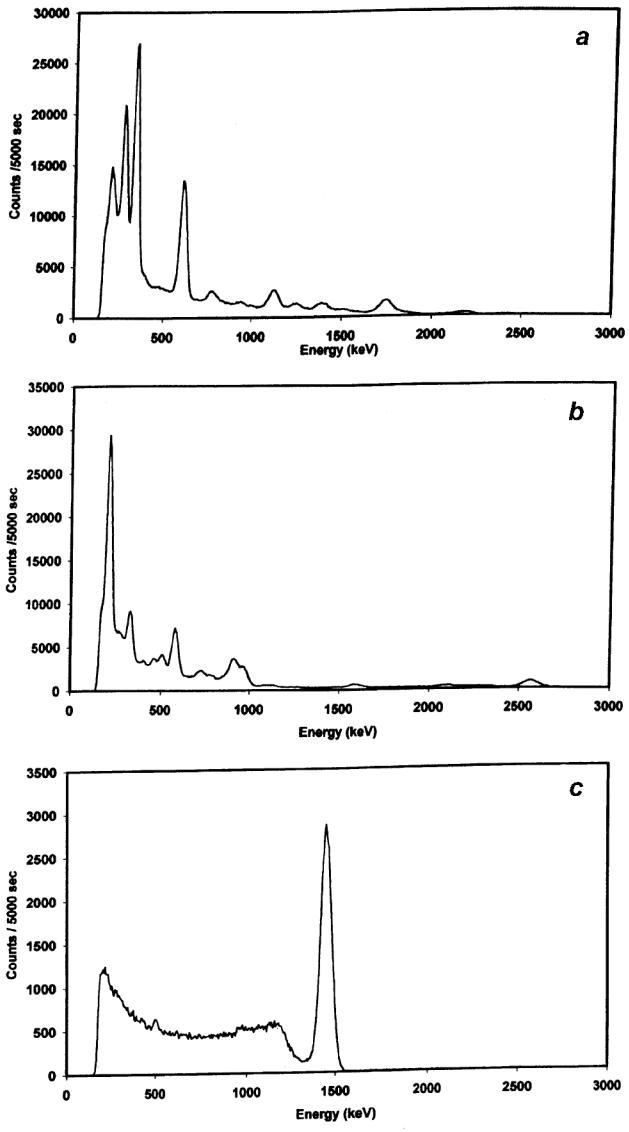

Figure 2. Gamma spectra of IAEA standard natural. *a*, ^{238}U; *b*, ^{232}Th; and *c*, ^{40}K.

samples for ^{232}Th, ^{238}U and ^{40}K. The activities of ^{232}Th, ^{238}U and ^{40}K are calculated by the following method.

$$\frac{\text{Net counts per second}}{\text{Efficiency}} \times 100 = \text{Dose per second or Becquerel (Bq).}$$

$$\frac{\text{Bq}}{\text{Mass of the sample in kg}} \times 1\ \text{kg} = \text{Bq/kg}.$$

The expression adequate for determining the efficiency of desired gamma energies[6] is given by

$$\ln(\text{efficiency}) = a_1 + a_2 \ln(\text{energy}),$$

where a_1 and a_2 are the fit parameters and ln is the natural logarithm. The efficiency of ^{232}Th, ^{238}U and ^{40}K is programmed in the computer associated with the gamma-ray spectrometer. The calculated average activity of radionuclides for the samples from each site is given in Table 1.

The assumption that the radionuclides ^{232}Th, ^{238}U and ^{40}K were in radioactive equilibrium with their daughter products, has been used in calculating dose equivalent of activity (Gy/h per Bq/kg). The calculated dose rates (D) as deduced from the activity values obtained from the count spectra using conversion factors given by Beck[4] are given below.

$$D = (0.623\ C_{Th} + 0.427\ C_U + 0.043\ C_K)\ \text{nGy/h},$$

where C_{Th}, C_U and C_K are the activity concentrations of primordial radionuclides ^{232}Th, ^{238}U and ^{40}K respectively. For *in situ* dose measurements using ERDM, at each sampling site, five readings were taken in air at 1 m above the sites successively, the average values were recorded are reported in Table 1. An attempt has been made to compare the dose rate as measured by ERDM and the calculated dose rate deduced from the activity values (obtained from the counts spectra). Figure 4 shows the graphical relation between observed and calculated radiation dose rate. The linear correlation coefficient was found to be 0.9188. The observed and calculated dose rates are not always the same. The difference in the rates may be due to several reasons: (i) the ERDM may not be maintained at the same levels at all sites, (ii) the contribution from radon to the external exposures is not taken into account, and (iii) the secondary cosmic rays enhance the reading in the ERDM (since a GM counter is used in the ERDM).

From Table 1, it may be seen that in the rock samples, the ^{40}K activity varies from 533 Bq/kg to 1484 Bq/kg, and the arithmetic mean is 995 Bq/kg. The activity of ^{232}Th varies from below detectable limit (BDL) given elsewhere, to 542 Bq/kg and the arithmetic mean is

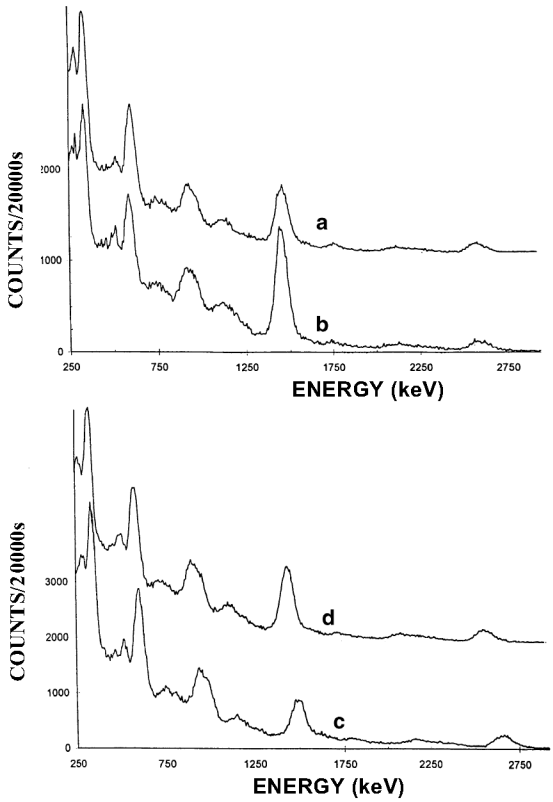

Figure 3. Gamma spectra of samples: (a) site no. 2; (b) site no. 3; (c) site no. 4; and (d) site no. 5.

Table 1. Activity and exposure dose rate of naturally occurring radionuclides in biotite-granitic samples of Rajapalayam hills, Western Ghats

Site number	Height from ground level (m)	Activity (Bq/kg)			Exposure dose rate (μR/h)	
		^{232}Th	^{238}U	^{40}K	Calculated	Observed
1	109	542.33	649.82	1484.39	68.40	71.30
2	110*	174.13	273.72	1204.12	26.00	31.20
3	100*	115.73	22.71	1302.31	21.30	24.90
4	100	421.76	53.86	1026.12	34.50	39.10
5	90*	404.32	52.55	1199.19	32.90	36.30
6	90	378.56	59.42	1247.61	31.80	34.70
7	76	365.45	63.41	1181.34	30.08	35.20
8	74	333.43	40.99	1090.56	29.64	33.90
9	60*	12.41	26.21	903.82	6.70	10.10
10	60	6.41	BDL	692.42	7.40	10.90
11	45	4.9	16.76	641.20	4.00	9.20
12	35	BDL	15.82	786.40	4.10	9.40
13	20	BDL	9.53	639.02	4.50	9.60
14	Ground level	BDL	102.13	533.76	6.70	10.20

*, Height of the hill on the northern side; BDL, below detection limit.

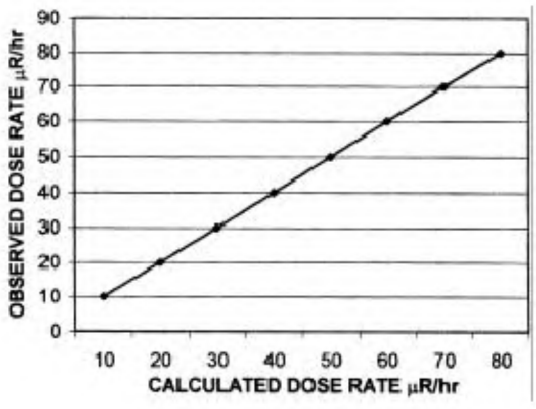

Figure 4. Correlation between calculated dose rate and observed dose rate.

197 Bq/kg. The activity of ^{238}U varies from BDL to 649 Bq/kg and the arithmetic mean is 99 Bq/kg. The world average activity concentrations of ^{40}K, ^{232}Th and ^{238}U are 370 Bq/kg, 26 Bq/kg and 26 Bq/kg respectively[7]. In the present study, if the activity of ^{40}K is compared with the world average value, the ^{40}K activity is much higher, almost by a factor of three. ^{232}Th activity values in the samples is eight times higher than the world average value. Similarly, the activity of ^{238}U is four times higher than the world average value.

At the ground level, ^{232}Th activity is less than that of the world average value. At the same time, ^{40}K and ^{238}U activities are much higher, i.e. one and a half and four times higher than the world average values. At the top of the hill, i.e. about 109 m from the ground level, the samples show the maximum level of activity for ^{40}K, ^{232}Th and ^{238}U, which is much higher than the world average value by factors of 4, 20 and 25 respectively.

The distribution of α-activity is uniform in mafic rocks indicating that uranium and thorium are evenly distributed among the principal rock-forming minerals such as plagioclase and pyroxene. Silicic rocks contain more uranium than the ultra-mafic rocks[8]. Crustal rocks[8] generally have the following ratios: Th/U = 3.5, K/U = 1×10^4 and K/Th = 3×10^3. As was discussed, the average value of K, U and Th is 995, 99 and 197 Bq/kg respectively.

The average values of Th/U, K/U and K/Th are also calculated and are equal to 1.9, 10.07 and 5.07 respectively. Rogers and Adams[8] 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, the granitic rock samples containing quartz and feldspar show that thorium levels (197 Bq/kg average) are higher than uranium levels (99 Bq/kg average). These granitic rock samples studied by Dheenathayalu *et al.*[9] and Ramasamy and Dheenathayalu[10] were found to contain 21.2% SiO_2 on an average, with Th/U ratio of 1.9. Th/U ratio calculated from our results is slightly lower than that of crustal rocks[8]. For crustal rocks, K/U is larger than K/Th. A similar trend is also observed in the present investigation.

The IR spectroscopic studies undertaken by the authors have shown the presence of orthoclase in the samples of sites 1 to 8 and microcline in the samples of sites 9 to 13, with the exception of the site 14 containing orthoclase. The present study shows that sites 1 to 8 contain higher values of ^{232}Th, ^{238}U and ^{40}K and high Th/U average, while the sites 9 to 14 show lower values of Th, U and K and low Th/U average.

The high value of ^{40}K obtained for sites at intermediate heights to higher sites, as seen from the Table 1, may be due to the large proportion of K-feldspar in the biotite-granites. In the case of felsic minerals (feldspar and quartz), a significant part of uranium may be present in the intergranular boundaries and as a loosely-bound paint on mineral surfaces. When mobilization takes place during metamorphism, the uranium associated with the felsic minerals gets more readily mobilized than that associated with mafic minerals (biotite, garnet, magnetite, hypersthene and hornblende) and could move upwards[8,11]. All the samples at the sites of interest show the maximum percentage of felsic minerals than mafic minerals[9,10]. The study shows that uranium is found in larger quantities in the sites 1 to 8, compared to other sites.

The previous studies[9,10] have shown that at sites 10 to 14, mafic minerals are either absent or form a small proportion compared to the felsic minerals. This explains the concentration of thorium occurring either BDL or with low values. At the same time, uranium content is found to decrease from 102.13 Bq/kg to a minimum value in going from site 14 to 10, and is found to increase on going to the top of the hill. Since the density does not vary much from sample to sample (ranging from 2.20 and 2.25 gm/cm^3), the correlation between activity and density has not been attempted.

We had earlier investigated several sites of Rajapalayam hills for the presence of minerals through IR, XRD and thin section analysis[9,10]. The samples of the same sites are subjected to gamma-ray spectrometry for studying the existence of naturally occurring radionuclides, namely ^{238}U, ^{232}Th and ^{40}K. The samples show different levels of these nuclides. It is found that the concentration of ^{40}K is normally higher than that of ^{238}U or ^{232}Th. Concentration of ^{238}U and ^{232}Th is found to be higher in the samples of sites 1 to 8 compared to those from the sites 9 to 14. Similar is the case observed for ^{40}K. As felsic minerals form the maximum percentage of our samples[9,10] and uranium is largely associated with the felsic minerals than the mafic minerals, where uranium is concentrated in lattices (the percentage of mafic minerals in our samples is low), the larger quantity of the uranium found in the upper sites than that in the lower sites suggests upward drift of uranium caused due to metamorphism. The average value of the Th/U ratio calculated from our data is about 1.9, which is also observed in the case of granites with low percentage of quartz.

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Pharmacokinetics of chloroquine in Indian tribal and non-tribal healthy volunteers and patients with *Plasmodium falciparum* malaria

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The pharmacokinetics of chloroquine was studied in Indian tribal and non-tribal healthy volunteers and patients infected with *Plasmodium falciparum* malaria, after a single dose of 600 mg chloroquine. Mean area under the curve (AUC), half-life ($T_{1/2}$) and peak concentration (C_{max}) in tribal *P. falciparum* patients were 18.79 ± 5.82 μg h ml^{-1}, 115.94 ± 57.71 h and 435 ± 135.17 ng ml^{-1} respectively, while in non-tribal *P. falciparum* patients they were 17.00 ± 5.60 μg h ml^{-1}, 76.15 ± 8.00 h and 454 ± 193 ng ml^{-1} respectively. Pharmacokinetic parameters did not appreciably differ between tribal and non-tribal groups of subjects in healthy volunteers or in *P. falciparum* patients. However, the time to reach maximum concentration (T_{max}) was 8 h in tribal subjects and 4 h in non-tribal subjects. Mean ratio of AUC of chloroquine to desethylchloroquine in tribal *P. falciparum* patients was higher (4.26 ± 1.34) than non-tribal subjects (3.41 ± 0.66), suggesting reduced chloroquine metabolism in tribal subjects. However, the difference was statistically insignificant ($t = 1.35$, $P < 0.5$). Delayed T_{max} and impaired chloroquine metabolism may be associated with general health problems such as malnutrition, anaemia and parasitic infestations of the tribal population in India.

CHLOROQUINE has long been the drug of choice for the treatment and prevention of malaria in India. The pharmacokinetics of chloroquine has been studied in different ethnic groups and conditions, e.g. Caucasians[1], Swedish[2] and Thais[3]. However, the pharmacokinetics does not differ substantially among various ethnic groups. Walker and coworkers[4] have compared disposition of chloroquine between kwashiorkor and normal children, and found decreased chloroquine absorption in patients with kwashiorkor. Little is known about the pharmacokinetics of chloroquine in malnourished patients. Tulpule and Krishnaswamy[5] found faster clearance of chloroquine in undernourished subjects. Tribals contribute 7.95% of the total population in India and 23.73% of them live in Madhya Pradesh (MP)[6,7]. High prevalence of malnutrition (60%), anaemia (40%; Hb < 7 g%) and parasitic infestations (75%)[7] was observed in the tribal population from MP. We now report plasma chloroquine pharmacokinetics in tribal and non-tribal healthy volunteers and patients with *Plasmodium falciparum* malaria, after a single oral dose of 600 mg chloroquine.

Studies on tribal subjects were carried out at the Bijadandi Primary Health Centre (PHC), District Mandla, MP, India under the supervision of PHC doctors, while the studies on non-tribal subjects were performed at the main hospital of the Indian Oil Corporation (IOC), Mathura, India.

A total of 12 subjects were selected from the tribal forest area. Six of these (4 males and 2 females) were healthy volunteers, while another six (4 males and 2 females) were patients with *P. falciparum* infection with a mean parasite density of 1720 mm^3 (range 1200–2320). Five *P. falciparum*-infected non-tribal patients (4 males and 1 female) with mean parasite density of 2688 mm^3 (range 800–7680) and five male healthy volunteers were also selected for comparison. Patients and volunteers were adults and selected randomly depending on their willingness to participate in the study, and their numbers were based on earlier reports[2,4] along with the feasibility of blood sampling in tribal areas.

All tribal subjects were malnourished, having an anthropometric index[5] below 0.18 and their mean haemoglobin levels were 8.5 g%. Mean anthropometric index and haemoglobin levels of non-tribal population were > 0.20 and > 11.0 g% respectively. No investigation for parasitic infestation was performed on any tribal subject.

The study was confined to those subjects who did not have any other disease or abnormality along with

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