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Distribution of radionuclide in the forest soils (Western Ghats-India)

P.K. Manigandan[1*], S. Selvasekarapandian[2], N. M. Manikandan[2]

[1] Dhafir Institute, Abu Dhabi, UAE
[2] Department of Physics, Bharathiar University, Coimbatore-641046, India

Background: The presence of radionuclides in the soil, measures need to be taken to minimize the radiation dose to humans. It is mostly gamma-emitting radionuclides that contribute to the radiation dose in long term behavior of these radionuclides in soil may determine the extent to which such countermeasures need to be applied. ***Materials and Methods:*** The activity concentration of these radionuclides in the soil samples that collected from the Longwood forest at western Ghats have been analyzed using Gamma spectrometry. ***Results:*** The mean activities of ^{238}U, ^{232}Th and ^{40}K were observed 26.261Bq/kg, 53.614 Bq/kg, 204.084 Bq/kg, dry weight, respectively. The average value of dose rate was calculated 55.48 nGy/h by applying the conversion factor where as the environmental dosimeter shows the absorbed dose rate at 1m high is 96.96 nGy/h. ***Conclusion:*** It was observed that the activity concentration of primordial radionuclides and the gamma dose rate measurements by ERD and from soil is relatively higher than world average. **Iran. J. Radiat. Res., 2007; 5 (1): 17-22**

Keywords: *^{238}U, ^{232}Th and ^{40}K, Western Ghats-South India, absorbed dose, ERD, monazite, Igneous rock.*

INTRODUCTION

The recent study in the Western Ghats region shows that the presence of high activity concentration of primordial radionuclides in soil [1, 2]. It was therefore felt worthwhile to study the radioactivity in some tropical forest in the region of Western Ghats; also to conform the monazite deposits on the coastal area of Kerala and Tamil nadu is formed due to the weathering of rocks in Nilgiris and Western Ghats [3], the similar observation was reported in the costal area of Brazil [4]. The study area, long wood forest is situated at the eastern part of Kotagiri and is shown in figure 1. Kotagiri, a Taluk in the eastern part of the Nilgiris district, is well known for its splendidly beautiful environment. The Nilgiris are well-defined massif that forms the southern limit of the main Western Ghats system that stretches unbroken from Mumbai in the north to the Nilgiris in the South. The altitude of the Kotagiri region varies from 1700 to 2400 m above mean sea level. This is one of the oldest and most important ecosystems in Indian peninsula. The annual average rainfall is 1590 mm. The annual temperature variation is from around 4°C to 24°C.

The present work aims to assess and try to understand the behavior of primordial radionuclides present in forest soils and to measure the radiation in the local

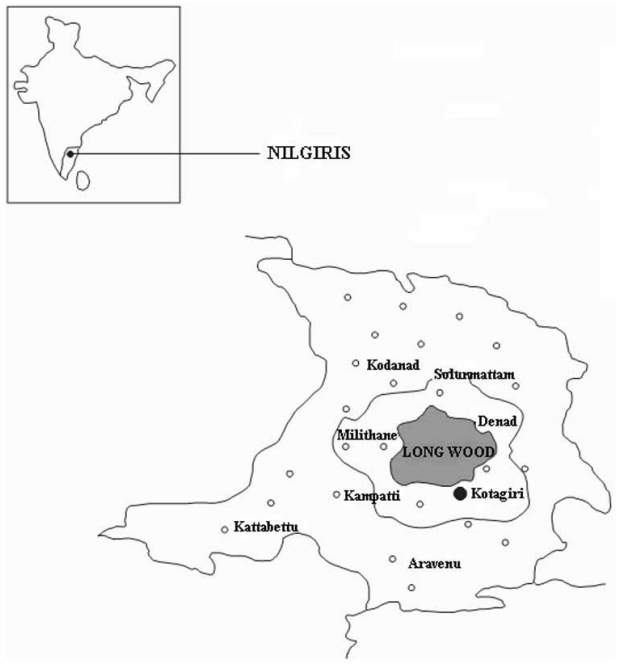


Figure 1. Study Area: Long wood Shola (Forest) in Kotagiri Taluk.

**Corresponding author:*
Dr. P.K. Manigandan, Dhafir Institute, Abu Dhabi, UAE.
Fax: *+971 2 6276678*
E-mail: *pkmgs@yahoo.com*

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environment of long wood forest of west Nilgiris system.

Gamma spectrometry analyses were performed on samples of soil from the surface collected homogeneously over the whole of forest in order to measure their activities in the isotopes of ^{238}U, ^{238}Th and ^{40}K. From these measurements the dose rate from external radiation at height of 1m was calculated using the conversion factor for dose rates published by UNSCEAR [5].

MATERIALS AND METHODS

Sampling

The sampling sites are selected to cover randomly the long wood forest. The soil samples have been collected in natural, uncultivated area in conformity with IAEA [6] recommendation. The about 2kg of composite sample were collected in a polythene bag. Collected soil was uniformly mixed and sieved. The sieved soils was then dried and transferred to a standard 250 ml plastic container, packed to its full volume and sealed with an adhesive tape. This sealing is to ensure that all the daughter products of uranium and thorium and in particular radon and thoron daughters that would be formed there after would not escape. These prepared samples were stored for one month before counting to ensure equilibrium between radium and its short-lived daughters. The net weight of the samples was determined before counting to get the activity concentration of radionuclide present in the soil. All the soil samples were subjected to detailed gamma ray spectrometry analysis.

Gamma Ray Spectrometer

To estimate the activity levels of ^{232}Th series, ^{238}U series and ^{40}K and evaluate the absorbed dose rate in air from these radionuclides in soil. The soil sample was analyzed by NaI (Tl) spectrometer which was coupled with TNI PCA II Ortec model 8K multi-channel analyzer. A 3"×3" NaI (Tl) detector was employed with adequate lead shielding which reduced the background by a factor of 95. The efficiency of various energies was arrived at using IAEA standard source and the required geometry. The system was calibrated both in terms of energy response and also for counting efficiency. The density of the sample used for the calibration was 1.3 gm/cm^3 which was same as average of soil sample analyzed (1.24 gm/cm^3) with the counting time of 20, 000 sec for each sample and a very good shielding to the detector the minimum detectable concentration was 7 Bq/kg for ^{232}Th series, 8.4 Bq/kg for ^{238}U series and 13.2 Bq/kg for ^{40}K at 3σ confident levels.

The concentrations of various radionuclides of interest were determined using the counting spectra of each sample. The peaks corresponding to 1.46 MeV (^{40}K), 1.76 MeV (^{214}Bi) and 2.614 MeV (^{208}Tl) were consider in evaluation the activity levels of ^{40}K, ^{238}U series and ^{232}Th, respectively. The resolution of the crystal detector was 6% for ^{40}K, 4.4% for ^{232}Th series and 5.5% for the ^{238}U series. The activity analysis of gamma spectra obtained for each soil samples was performed with dedicated software and the choice of reference was made so that they were sufficiently discriminated.

Measurement of gamma dose rate

The primordial radionuclides existing in the soil continuously emit gamma radiation. The gamma dose rate due to primordial radionuclides present in the soil samples at one m above ground level is also calculated. The conversion factor given in UNSCEAR (1998) [5] is used in this study and it is given below.

$$D=(0.662\ C_{Th} + 0.427\ C_U + 0.043\ C_K)\ nGy/h$$

Where; C_{Th}, C_U and C_K are the activity concentrations of primordial radionuclides, ^{232}Th, ^{238}U and ^{40}K existing in the soil in Bq/kg.

Ambient gamma exposure survey

In addition to the gamma ray spectrometric analysis, environmental radiation dosimeter was used to measure the ambient radiation level around Long Wood

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forest. In the present study the ambient gamma radiation level survey was conducted using an environmental radiation dosimeter. ERD type ER 705, supplied by Nucleonic System PVT Ltd., Hyderbad, India, a low-level survey meter. It consist of a halogen quenched G.M. Detector (Ind. lnc. USA) powered by a rechargeable battery. The Survey meter is designed to read exposure rate in two ranges of 0.1 iR/h and 1 iR/h. The survey meter is calibrated regularly using standard source, before starting survey work.

The measurements were done at 1m above the ground on open field. At each location, a total of 10 readings were noted. Geometric mean of value of the measured readings was calculated to reduce the small-scale variations of the level in a site. The ERD measure the radiation dose contributed from soil and from comic rays.

RESULTS AND DISCUSSION

Soil activity

In general, by considering the levels of ^{238}U activity in forest soil is less than the cultivated soil in Kotagiri hill station. The activity varies from 15.12 to 44.11 Bq/kg with geometric mean of 26.261 Bq/kg. This shows that, similar activity concentration found throughout the forestland with less variation. Since the soils are collected from the uncultivated hill areas covered with bushes and trees of various species where soil generally undisturbed expects weathering the activity may vary less.

On the other the activity concentration of ^{232}Th is much higher than the ^{238}U all the location. Its activity varies from 39.17 to 76.13 Bq/kg with mean of 53.614 Bq/kg. The spectral measurement clearly revealed the spectral photo peaks at 238.3, 373.3, 510.7, 727.3, 911.2, 916, 1587 and 2614 keV were due to the daughter products of ^{232}Th series viz, ^{212}Pb, ^{228}Ac, ^{208}TI, ^{208}Tl, ^{212}Bi, ^{228}Ac, ^{212}Bi and ^{208}Tl, respectively. This conform the abundance of ^{232}Th series radionuclides in soil there by concluding that the type of rock in Kotagiri is of igneous nature. The same was observed by Selvasekarapandian *et al.* [1, 2]. Its support the monazite deposit on the costal area of Kerala and Tamil nadu are formed due to the weathering of rocks in Nilgiris hills and Western Ghats [3].

Similarly, the activity concentrations of ^{40}K in forest soils are higher in magnitude due contamination of ^{40}K in uncultivated soil. Activity of ^{40}K varies from 127.54 to 248.12 Bq/kg with mean of 204.084 Bq/kg was found in forest soil. Figure 2 shows the activity concentration of primordial radionuclides in soil substrate collected in Longwood forest at Kotagiri.

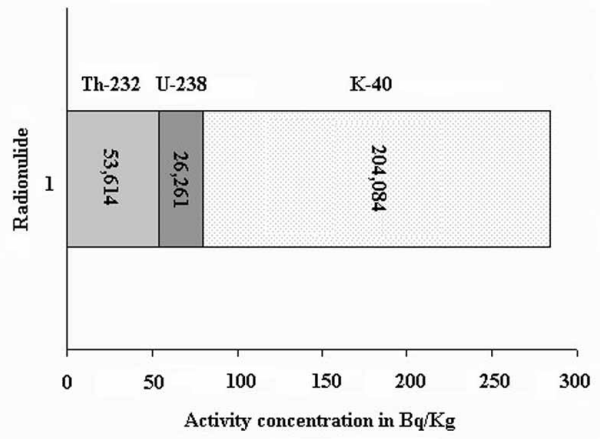


Figure 2. Activity concentrations of primordial radionuclides in soil substrate collected in Longwood forest at Kotagiri.

Comparing radionuclides from different decay chain (^{232}Th, ^{238}U and ^{40}K), it can be observed that they are also linearly related, ^{232}Th and ^{40}K concentration increases when ^{238}U concentration increase, but Y- intercept is clearly different from zero. This fact reflects that the $^{232}Th/^{238}U$ and $^{40}K/^{238}U$ activity ratio are not constant across the forest soil at Kotagiri.

In figures 3 and 4, the activity ratios versus the ^{238}U concentration are plotted. The curves reflect the variation of activity ratio and can be expressed mathematically as hyperbolic function:

$R = {}_aC_s{}^b$.

Where R is the activity ratio, Cs is concentration of radionuclide ^{238}U in the soil and a and b parameters to determined. Using above equation in the case of figure3 and figure 4, the following function is obtained:

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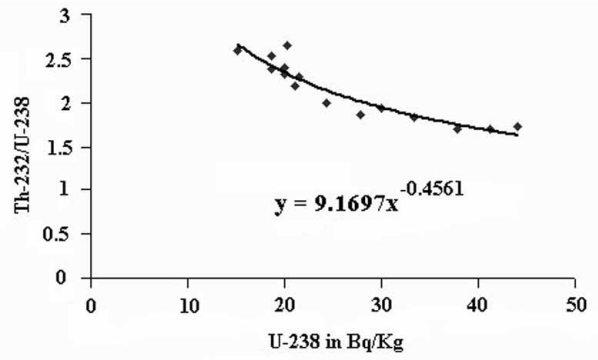


Figure 3. $^{232}Th/^{238}U$ activity ratio versus concentration of ^{238}U in soil.

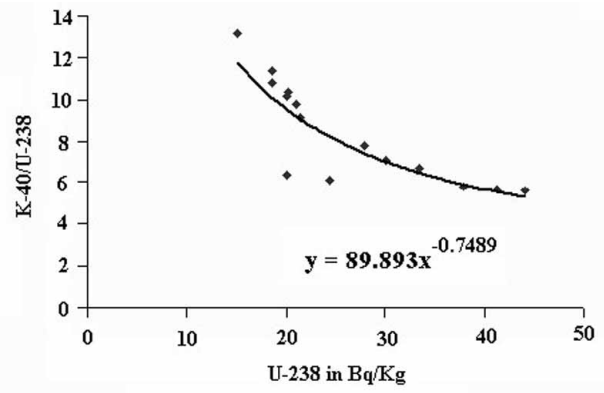


Figure 4. $^{40}K/^{238}U$ activity ratio versus concentration of ^{238}U in soil.

$^{232}Th/^{238}U=9.1697\ (^{238}U)^{-0.4561}$, (With regression coefficients of -0.9058)

$^{40}K/^{238}U= 89.89\ (^{238}U)^{-0.7439}$, (With regression coefficients of -0.8058)

This relationship may reflect that the activity ratio remains constant only for high concentration of ^{238}U in the soil. For the activity concentration low, contamination of radionuclides from the ^{232}Th decay chain and ^{40}K seems to be undistinguished.

Gamma-ray dose

The gamma radiation dose at a height 1 meter above the ground calculated from the radioactivity concentration of the primordial radionuclides, using the dose rate activity conversion factor published by UNSCEAR[5] along with the dose rate measured by environmental radiation dosimeter are also presented in table. The value of dose rate calculated from the soil activity lies in the range of 40.93 -79.90 nGy/h, with a mean dose of 55.48 nGy/h

Table 1. Activity concentrations (Bq/kg) of some natural radionuclides ^{238}U, ^{232}Th, and ^{40}K in soil samples from Longwood forest at Kotagiri Hill station.

Location	Activity Concentration in Bq/kg			Soil Dose nGy/h	ERD nGy/h
	Th-232	U-238	K-40		
S-1	39.17	15.12	198.79	40.93	93.98
S-2	45.89	21.03	205.37	48.19	96.59
S-3	47.76	19.99	202.77	48.87	86.36
S-4	48.91	21.42	195.39	49.93	94.32
S-5	53.55	20.19	209.67	53.09	78.41
S-6	51.86	27.9	218.06	55.62	82.95
S-7	46.96	18.57	201.14	47.67	89.77
S-8	48.67	24.38	148.89	49.03	93.18
S-9	44.14	18.56	211.19	46.23	90.91
S-10	58.46	30.12	214.56	60.79	98.90
S-11	61.32	33.42	224.56	64.52	115.72
S-12	70.28	41.21	233.71	74.17	118.23
S-13	76.13	44.11	248.12	79.90	123.81
S-14	64.61	37.91	221.5	68.48	100.82
S-15	46.5	19.99	127.54	44.80	90.45

However, the mean ambient gamma dose rate at 1M above the ground level measured using the environmental dosimetry is 96.961 nGy/h, which is approximately 50% higher than the dose calculated from the soil sample analysis. The excess dose measured by the environmental dosimeter is due to the significant contribution from the cosmic radiation. Since the present study area is located at 1700m to 2400m above from the sea level, the contribution of cosmic ray much higher than the normal.

Taking the dosimeter to a location vary far from the shore, dose rate is measure at the point where the depth of water level is very high. At this point, gamma dose contribution from the soil is found to be negligible and the dose rate measured is wholly due to the

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cosmic rays and measured cosmic dose is found to be 41.2 nGy/h. This dose is comparable with that measurement done by Nimbi (1986) [7]. Hence the gamma dose from the soil sample is about 55.761 nGy/hr. The geometric mean dose calculated from the soil activity measurement for the forest area is 55.48 nGy/hr, which is equal to the ambient measurement.

Comparative analysis

Comparison of statistical data of the present study area Longwood forest and the data available for Kotagiri Taluk [1, 2] is given in table 2. It has been observed that the mean activity concentration of ^{232}Th, ^{238}U and ^{40}K and as well as dose in the forest area are found to be lower than that of Kotagiri taluk since the soil samples collected from the uncultivated area, the contamination of soil from extraterrestrial material and the fertilizer become less.

The gamma dose rate from the soil samples is found to be much higher than the world average value. Table 2, provides a comparison of the mean activity concentration of primordial radionuclide concentration in soil and the dose rate calculated at 1m above the ground with the world average value reported by UNSCEAR 1982 [5]. The mean dose rate measure at Kotagiri (95.2 nGy/h) was higher than that reported for the world average (42.7nGy/h) and the same was observed in the forest area in Kotagiri (55.48 nGy/h). It was observed that the major contribution to the soil rate comes from the ^{232}Th series radionuclides in the soil samples of forest. The percentage of contribution to the external dose rate from these radionuclides is 64% (35.49nGy/h) from ^{232}Th series, 20.2% (11.21 nGy/h) from ^{238}U and 15.8% (8.77 nGy/h) from ^{40}K. From table 2, it can be concluded that the activity concentration of ^{232}Th series is 2.17 times than the world average value, the activity concentration of ^{40}K is 55% lesser than that of world average as reported by UNSCEAR. Also if you compare these results with the other parts of the world and India, it's clear that the activity of ^{232}Th series in soils is higher than the value reported but ^{238}U series is more or less equal to the reported value in table 3. The ^{232}Th series activity is also higher than that of reported for Taiwan [8], Cacers in Spain [9], China [10], California in USA [11], and Greece [12]. However the activity of ^{232}Th series and ^{238}U series are less than that reported for Japan [13] and Hong Kong [14]. The concentration of ^{40}K in soil samples of

Table 2. Comparison of statistical data from Longwood forest and Kotagiri Taluk.

Radionuclides	^{232}Th	^{238}U	^{40}K
World Average			
Concentration (Bq/kg)	24.60	23.80	370.2
Dose rate (nGy/h)	16.55	10.68	15.54
Kotagiri Taluk			
Concentration (Bq/kg)	102.0	41.0	229.0
Dose rate (nGy/h)	67.62	17.8	9.8
Kotagiri (Longwood Forest)			
Concentration (Bq/kg)	53.61	26.26	204.1
Dose rate (nGy/h)	35.49	11.21	8.77
Contribution %	64	20.2	15.8

Table 3. Concentration of radionuclides ^{232}Th, ^{238}U and ^{40}K in Kotagiri soil samples (longwood forest) that at different parts of the world.

Location	Mean Activity concentration Bq/kg			Dose Rate nGy/h
	^{232}Th	^{238}U	^{40}K	
Kotagiri (forest soil)	53.6	26.3	204.1	55.8
Kotagiri (Taluk)	102	41	229	100.1
All India	18.3	14.8	-	-
Cacers	41	38.3	653	56.6
Taiwan	44	30	431	54
California	45.6	39.4	420	23
China	52	41	681	-
Japan	54	32.4	794	83
Hong Kong	146	119	352	87
Greece	24	49	760	42

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Kotagiri is lower than that of other environs [15-18], which may be attributed to the leaching of the radionuclides due to heavy rainfall in the study area.

CONCLUSION

The measurement of the radioactivity concentration of radionuclides in forest soil in Western Ghats region and subsequent calculation of the dose from external radiation due to these gamma emitter present in the soil leads to the conclusions that the activity concentration of these radionuclides in the uncultivated soil are 1.90, 1.576, and 1.12 times lower than that of the cultivated soil but higher than the world average, in particular the activity concentration of ^{232}Th series. The activity concentration of ^{232}Th is 2.17 times higher than the world average; ^{238}U is comparable to the reported values where as ^{40}K activity shows 55% lesser than the world average. This may due to the existence of igneous nature of rock in the area of study. The investigation also indicates a good correlation exists between ^{232}Th series vs. ^{238}U and ^{40}K only for high concentration in soil.

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