Bio-indicators in the tropical forest of Western Ghats environment

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Background: Investigation on the natural radionuclides ^{238}U, ^{232}Th, ^{40}K and natural fallout radionuclide ^{210}Po in the prominent plants species of Western Ghats tropical forest near Kotagiri have been carried out as a part of baseline background radiation studies in the forest environment. ***Materials and Methods:*** The prominent plants species of the region Evodia roxburghiana and Eleaocarpus oblangus were chosen and concentrations of ^{238}U, ^{232}Th, ^{40}K and ^{210}Po were measured by employing gamma ray spectrometer and alpha counter. ***Results:*** The radioactivity concentrations in plants and soils reflect the impact of the existence of igneous nature of rock in the area of study. Concentration ratios (CR) of these radionuclides, between plants and underlying soil, have been studied and results shows that the concentration ratios (CR) seem to be depend on radionuclides in soil. ***Conclusion:*** From careful analysis of the results, these plants could be used as an indicator to monitor these radonuclides. **Iran. J. Radiat. Res., 2008; 6 (2): 88-96**

Keywords: *Primordial radionuclides, Western Ghats, monazite, Igneous rock, CR –concentration ratio.*

INTRODUCTION

Environmental assessment use food chain models to determine the dose to man from radionuclides released to the biosphere. A traditional food chain model requires a plant/substrate transfer coefficient, referred as concentration ratio (CR). The concentration ratio concept is generally accepted and widely used in environmental transport models and describes the amount of nuclide expected to enter a plants from its substrate. Many of reviews have been published in which Sheppard and Sheppard (1985) [(1)] was observed a linear relation between the plant concentration and substrate concentration. Cannon (1952) [(2)] has stated that U may be a micronutrient for higher plants, which means that CR was not linearly related to the substrate concentration. Mordberg *et al.* (1976) [(3)] obtained CR value by fitting linear and hyperbolic functions to data obtained using different soil concentrations over their observed concentration. A hyperbolic relation for the CR for essential and non essential elements over a range of substrate concentrations was observed by Timperley *et al.* (1970) [(4)], Mengel and Kirkby (1979) [(5)] and concluded that plants readily take up elements essential for plant growth when concentrations are low, where as plant uptake of non-essential element is generally constant in this substrate concentration range. We have previously, shown that activity concentration of the ^{232}Th was high in the region of Western Ghats especially around the hill station Nilgiris due to the presence of monazite sand. Limited data's are available to evaluate the environmental radioactivity in these part of the region, therefore it was felt worthwhile to study radioactivity in some tropical forest plants so that indicators to be identified for monitoring soils and how they are been incorporated in the plants from its substrate concentration. Although these species are not directly involved in the human food chain, information on the concentration level and the transfer of radionuclides from contaminated soil will provide important data on the transfer mechanism in the case of those species more directly involved in the

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human diet.

MATERIAL AND METHODS

Sampling

Evodia roxburghiana and *Eleaocarpus oblangus* plants leaves samples of 2kg were collected from the different places within the forest of Long wood and the surface soil samples were also collected at four different places under the host trees, mixed thoroughly and about 2kg of composite sample was collected in polythene bag. Vegetation samples were dried in an oven at 110°C and about 30g samples were taken for the wet ashing and subsequent analysis of ^{210}Po. The remaining samples were charred over a low flame and converted into uniform white ash using a muffle furnace at 400°C and similarly soil samples were dried in an oven at 110°C and taken for the analysis.

Gamma ray spectrometer

The primordial radionuclides activities were estimated using NaI (Tl) spectrometer, which was coupled with TNI PCA II Ortec model 8K multichannel 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 energy 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 analysed (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, 8.4Bq/kgfor ^{238}U series and 13.2Bq/kg for ^{40}K at 3s confident levels. Details of the detector were presented in the previous paper [6-7]. To determine the concentration of ^{210}P, about 30g of dried samples were taken. To start with, the samples were digested with 4N HNO_3 then with 8N HNO_3 and with a mixture of concentrated HNO_3 and H_2O. The digested samples were brought to the chloride medium by adding 0.5N HCl solution. Then ^{210}Po was deposited on a background count brightly polished silver disc through electro chemical exchange method [8-12]. Then it was counted in ZnS[Ag] alpha counter of background 0.2cpm and efficiency 30%. Polonium-210 activity was estimated using the standard methods [12].

RESULTS AND DISCUSSION

The activity concentration of primordial radionuclides and the fallout radionuclides were presented in the tables 1 and 2 for the plants of *Evodia roxburghiana* and *Eleaocarpus oblangus* collected from the Long wood forest. Values of concentration ratio (CR), defined as the ratio between the concentration (dry mass) of radionuclide in the plants and the concentration (dry mass) of the same radionuclide in the substrate, are given in the same tables.

Eleaocarpus oblangus

In soil: The results of soil concentration reveal the secular equilibrium is attained between the ^{238}U and its daughter product. The graph shows the linear relation between ^{238}U and its daughter product with the regression of 0.93 (figure 1-a). Activity of daughter product is slightly higher [1.2 times] than the U. For different radionuclides graphs were drawn, all are linearly related with each other in the soil, 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.

Therefore hyperbolic function is formed between the activity ratios versus ^{238}U concentration and it is represented in figure-1b, figure 1c. From the graph it observed that the activity ratio remains constant only for high concentration of ^{238}U in the soil, for the activity concentration

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low, contamination of radionuclides from the ^{232}Th decay and K seems to be undistinguished. The same was observed by Mordberg *et al.* (1976) [3], Sheppard (1985) [1], Martinez-Aquirre and Garcia-leon 1997 [13].

The activity concentration of ^{232}Th is higher [1.9 times] than ^{238}U decay chain. Similarly, the concentration ^{40}K are also much higher [5.6 times that of ^{238}U and 3 times that of ^{232}Th] than the rest of the radionuclides.

In plants: The same radionuclides were analysed in samples of *Eleaocarpus oblangus* whose results are presented in tables 1 and 2. The activities range, in general from 10.46 to 13.80Bq/kg for ^{210}Po and 8.64 to 11.62Bq/kg for ^{238}U with the activity concentration of ^{210}Po being higher than the U in most of the samples. In general the highest radioactivity concentration in plants are found in those collected in area with the highest radioactive concentration in the soil substrate, and the lowest in those with lowest concentration in the substrate.

Concentration of ^{232}Th is clearly much higher than those of the ^{232}U decay chain [15.21 to 18.48Bq/kg for ^{232}Th]. Even though the mobility of ^{238}U decays chain is higher than the ^{232}Th, the higher concentration of ^{232}Th in the plants due to the impact of the igneous type rock presented in the study area [Monazite].

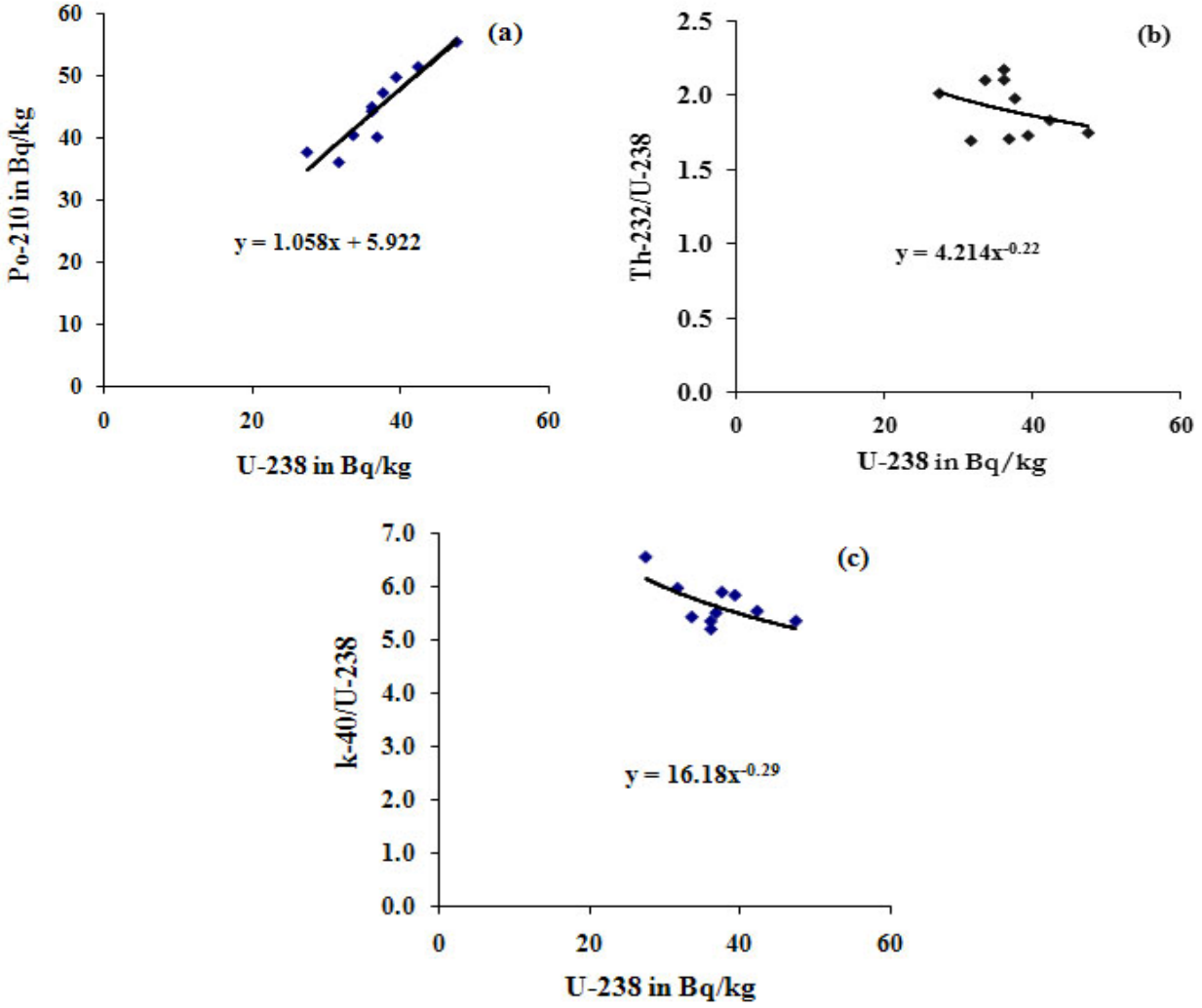


Figure 1. Relation between the activity concentrations of different radionuclides in soil.

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Table 1. Activity concentration of radionuclides in the Eleaocarpus oblangus.

Sample number	Activity concentration in Soil [Bq/kg]				Activity concentration in Plant [Bq/kg]				CR			
	Th-232	U-238	Po-210	K-40	Th –232	U-238	Po-210	K-40	Th-232	U-238	Po-210	K-40
1	78.46	36.09	45.13	193.19	16.69	9.47	10.60	181.32	0.213	0.262	0.210	0.939
2	62.57	36.77	40.22	202.76	15.21	9.70	10.92	176.98	0.243	0.264	0.241	0.873
3	82.66	47.41	55.63	254.01	18.12	11.62	13.80	198.01	0.219	0.245	0.209	0.780
4	75.95	36.10	44.40	187.8	17.08	9.93	12.18	170.45	0.225	0.275	0.224	0.908
5	70.52	33.56	40.53	182.37	16.04	9.83	11.54	167.01	0.227	0.293	0.243	0.916
6	53.47	31.66	36.15	189.54	15.83	8.64	10.79	173.64	0.296	0.273	0.239	0.916
7	55.15	27.42	37.79	180.54	18.48	8.79	10.46	160.23	0.335	0.321	0.233	0.888
8	74.28	37.57	47.39	222.04	17.87	9.64	11.27	196.57	0.241	0.256	0.203	0.885
9	77.26	42.26	51.61	234.42	17.82	10.30	12.61	188.23	0.231	0.244	0.199	0.803
10	67.82	39.31	49.92	230.1	16.2	9.90	11.99	183.43	0.239	0.252	0.198	0.797

Table 2. Activity concentration of radionuclides in the Evodia roxburghiana.

Sample number	Activity concentration in Soil [Bq/Kg]				Activity concentration in plant [Bq/Kg]				CR			
	Th-232	U-238	Po-210	K-40	Th-232	U-238	Po-210	K-40	Th-232	U-238	Po-210	K-40
1	64.96	34.47	36.11	203.90	12.61	8.60	9.19	190.00	0.194	0.250	0.254	0.932
2	49.07	28.00	32.21	202.76	12.41	8.92	9.40	188.20	0.253	0.319	0.292	0.928
3	77.66	44.58	51.15	253.81	16.33	11.59	12.64	206.79	0.210	0.260	0.247	0.815
4	62.45	32.18	35.11	186.89	14.30	9.25	10.38	180.30	0.229	0.287	0.296	0.965
5	57.02	35.05	37.77	192.27	13.28	9.11	9.98	183.92	0.233	0.260	0.264	0.957
6	53.47	28.93	32.40	156.74	13.97	9.01	9.49	150.20	0.261	0.311	0.293	0.958
7	44.65	23.72	31.04	170.54	11.99	8.51	9.34	160.26	0.269	0.359	0.301	0.940
8	74.28	37.72	42.58	202.40	16.23	9.99	11.24	190.71	0.219	0.265	0.264	0.942
9	67.12	36.18	41.88	213.72	15.95	10.63	11.04	199.12	0.238	0.294	0.264	0.932
10	64.53	33.87	36.45	210.01	15.18	10.21	10.93	198.15	0.235	0.301	0.300	0.944

It does seem interesting to study the relationship between these radionuclides. In figure 2a radioactive concentrations of U versus its daughter product ^{210}Po is plotted. The linear relationship can be found between the concentration of ^{210}P and ^{238}U in the plants [regression of 0.923]. Comparing the U concentration in the plants, Y intercept of this line [0.1089] is clearly different from zero. This Y intercept reflects the variation in the ^{210}Po/^{238}U activity ratio with the U concentration in the plant. Thus, for a low U concentration [background level], there is slight excess of ^{210}Po compare to U. This excess decreases to secular equilibrium for the high U concentrations. In fact, for plants with enhanced concentration, both radionuclides are practically in secular equilibrium Sheppard (1985) [1], Martinez-Aquirre and Garcia-leon (1997) [13]. More interesting seems to be the relationship of the ^{232}Th and ^{40}K concentration with ^{238}U concentrations figure - 2b and 2c. The concentration of ^{232}Th and ^{40}K in plants clearly increases as concentration of U increases, following linear relationships.

Evodia roxburghiana

The same study has been carried out in the plants of *Evodia roxburghiana*. The results are presented in table 2. From the table it's clear that the activity concentration of radionuclides in the soil and uptake

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of radionuclides by plant *Evodia roxburghiana* is following the similar trend of *Eleaocarpus oblangus*.

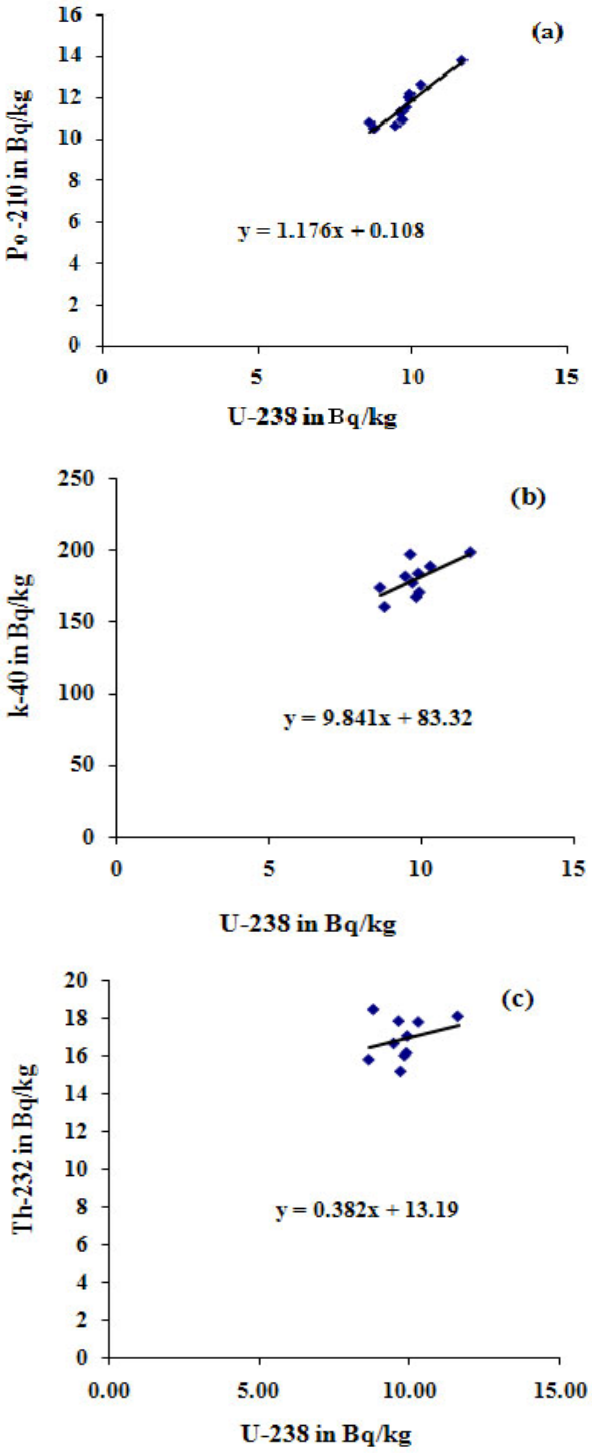


Figure 2. Relation between the activity concentrations of different radionuclides in *Eleaocarpus oblangus* samples.

In soil: The activity of U, Po, Th and K varies within the soil 23.72 to 44.58Bq/kg, 31.04 to 51.15 Bq/kg, 44.65 to 77.66Bq/kg and 156.74 to 253.81 Bq/kg respectively. The graph figure 3a, shows the linear relation between U and daughter product. For different radionuclides graphs were drawn, all are linearly related with each other in the soil. Since the y intercept is clearly different from zero, hyperbolic function is formed between the ratio of Th/U and K/U with activity concentration of U and it's shown in the graphs 3b and 3c. These activity ratios seems to be remains constant only for ^{238}U above some 30Bq/kg.

In plants: The same in the plants are in the range of 8.51 to 11.59 Bq/kg, 9.19 to 12.64 Bq/kg, 11.99 to 16.33 Bq/kg and 150.20 to 206.79 Bq/kg for U, Po, Th, and K respectively. The linear relationships are found between the radionuclides in the plant and are shown in the figure 4a. But their values are slightly higher than the former one [*Eleaocarpus oblangus*], this may lead to the conclusion that different plant species uptake the different amount of radionuclides depending on the substrate concentration, nature of the plants and ageing of the plant whereas the soil type and climate condition in which the plant growing are the same.

Concentration ratio

Tables 1 and 2, gives the CR values obtained for *Eleaocarpus oblangus*, for U, Po, Th and K and its range varies from 0.244 to 0.321, 0.198 to 0.241, 0.213 to 0.355 and 0.797 to 0.939 respectively and same for *Evodia roxburghiana* 0.250 to 0.359, 0.247 to 0.301, 0.194 to 0.269 and 0.815 to 0.958 respectively. The CR value is higher for K than rest of radionuclides, showing a greater transfer for K to plant than that of the rest.

Comparing the CR values for both plants species, there seems to be a tendency for a higher CR in the case of *Evodia*

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roxburghiana than the *Eleaocarpus oblangus* for all radionuclides expect ^{232}Th. It can be observed that CR depends on soil concentrations. In order to study the behavior of the concentration ratios for these radionuclides, concentration ratios versus the activity concentration at the radionuclide in the soil substrate (Cs) have been plotted in figure 3b and c, for ^{238}U, ^{232}Th and ^{40}K. The CR values clearly decrease when the activity concentration in the substrate soil increases. In fact, the data can be modeled by fitting of the form:

$$CR = a\ Cs^{b}$$

Where **a** and **b** are parameters to be determined. Thus, If b=0, this would mean that the concentration ratio is constant, regardless of the activity concentration in the soil substrate. Functions of this type have been fitted for ^{210}Po, ^{238}U, ^{232}Th and ^{40}K and the results are presented in figure 5 and table 3. Thus for all radionuclides from the ^{238}U, ^{210}Po, ^{232}Th and ^{40}K, the ***b*** value of hyperbolic function is clearly different from zero. Thus it seems that all these radionuclides follow the behavior of

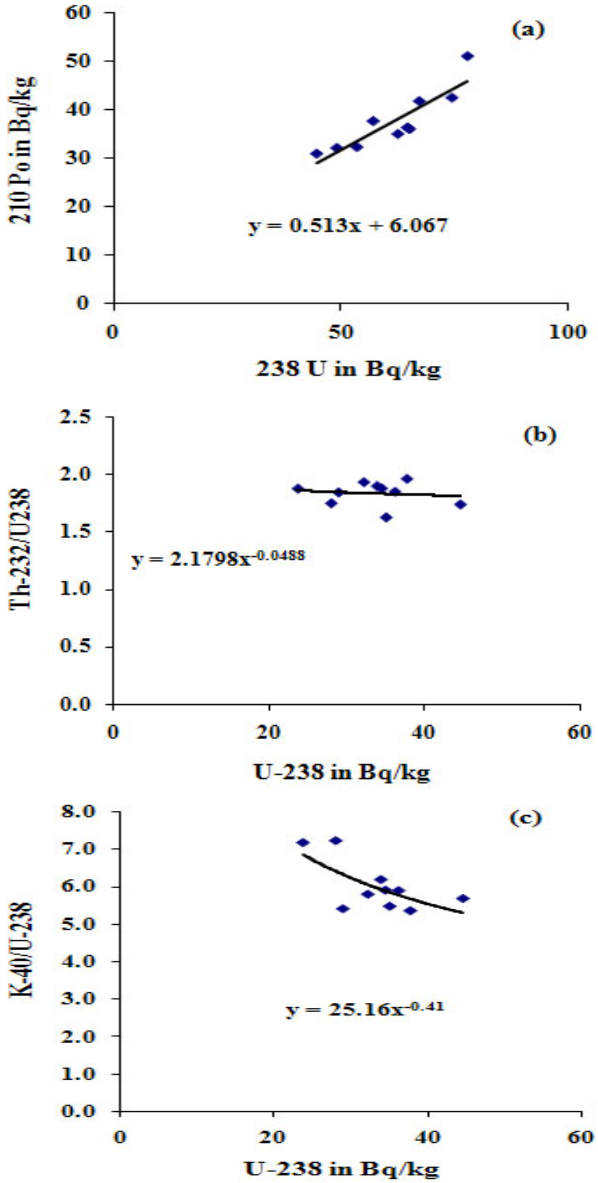


Figure 3. Relation between the activity concentrations of different radionuclides in soil samples.

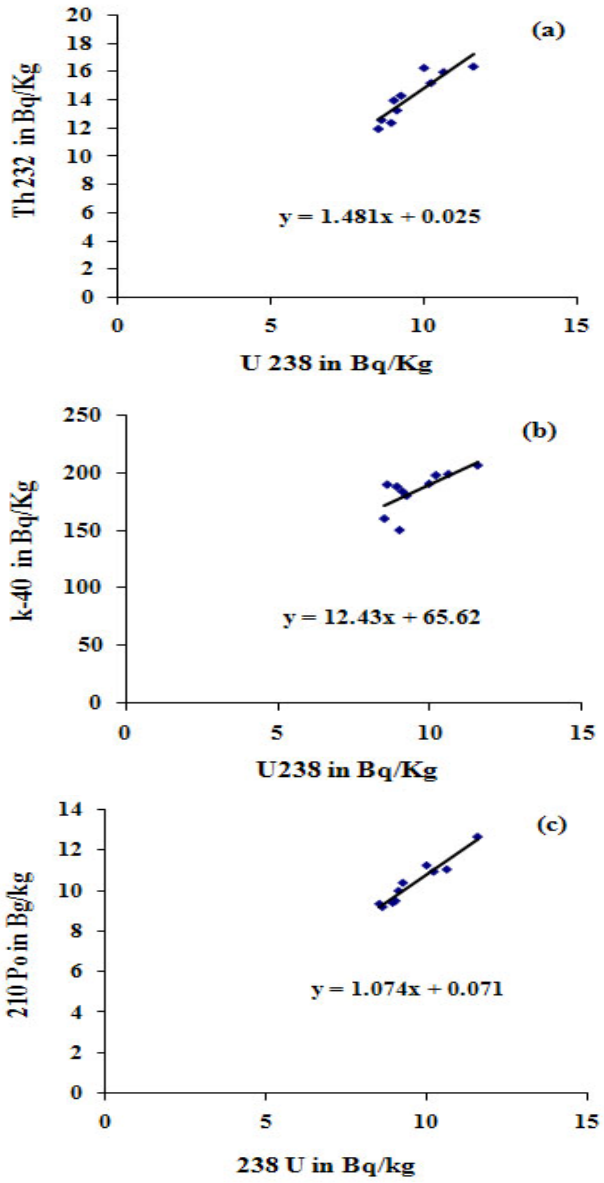


Figure 4. Relation between the activity concentrations of different radionuclides in *Evodia roxburghiana* samples.

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an essential for the plant growth. However, whether these elements are essential or are mimicking essential elements cannot be determined within this study. Moreover, activity concentration in the soil substrate very high, the CR value would be apparently constant. The same was observed by Sheppard (1985) [1], Timpereley

Table 3. Relation between concentration ratios of different radionuclides in soil and plants.

Radionuclide	Eleaocarpus oblangus		Evodia roxburghiana	
	$CR = aCs^b$	Regression	$CR = aCs^b$	Regression
^{232}Th	$CR=9.272Cs^{-0.8583}$	-0.869	$CR=1.434Cs^{-0.443}$	-0.775
^{232}U	$CR=1.674Cs^{-0.51}$	-0.873	$CR=1.939Cs^{-0.545}$	-0.819
^{210}Po	$CR=1.449Cs^{-0.4975}$	-0.849	$CR=1.136Cs^{-0.390}$	-0.7834
^{40}K	$CR=11.71Cs^{-0.4883}$	-0.890	$CR=4.082Cs^{-.2797}$	-0.812

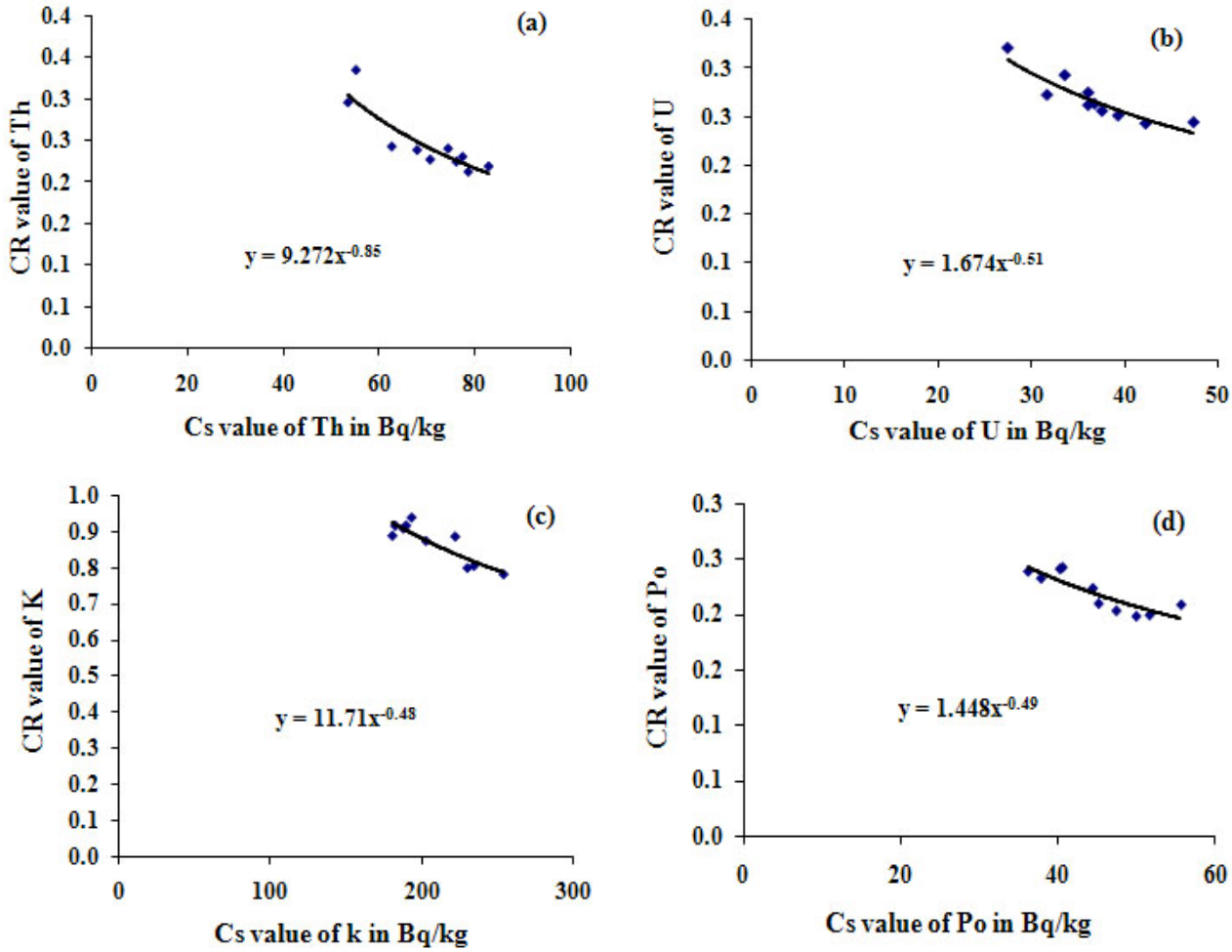


Figure 5. CR value vs. Cs of different radionuclides in soil for the plant of *Eleaocarpus oblangus*.

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et al. (1970) [4] and Martinez-Aquirre and Garcia-leon (1997) [13]. Using the given data's in the figure 6, we can predict the plant concentration from the substrate concentration only those place with high activity concentrations in the soil substrate, thus *Evodia roxburghiana* and *Eleaocarpus oblangus* could be used as bio indicators to monitor the primordial nuclides in plants species in the forest ecosystem in the Western Ghats.

CONCLUSION

Concentration ratios for all radionuclides in two Plants were determined. The concentration ratio of element seems to depend on the activity concentration of the same elements in its soil substrate. Thus, high CR appears in plant growing in soil with a low concentration. Moreover, the relation between the CR and the activity concentration of the soil substrate seems to be hyperbolic in all the cases. Thus we can predict activity concentration of these radionuclides in the plant from the substrate soil. CR values versus soil substrate graph for the different radionuclides, shows that all radionuclides behaves as an essential element at low Cs. In both plants, the CR value for all radionuclides seems to be constant in all the location with the higher substrate soil. Thus, it could be used as bio indicator to monitor both primordial and natural fall out nuclides in the plants at the Western Ghats region.

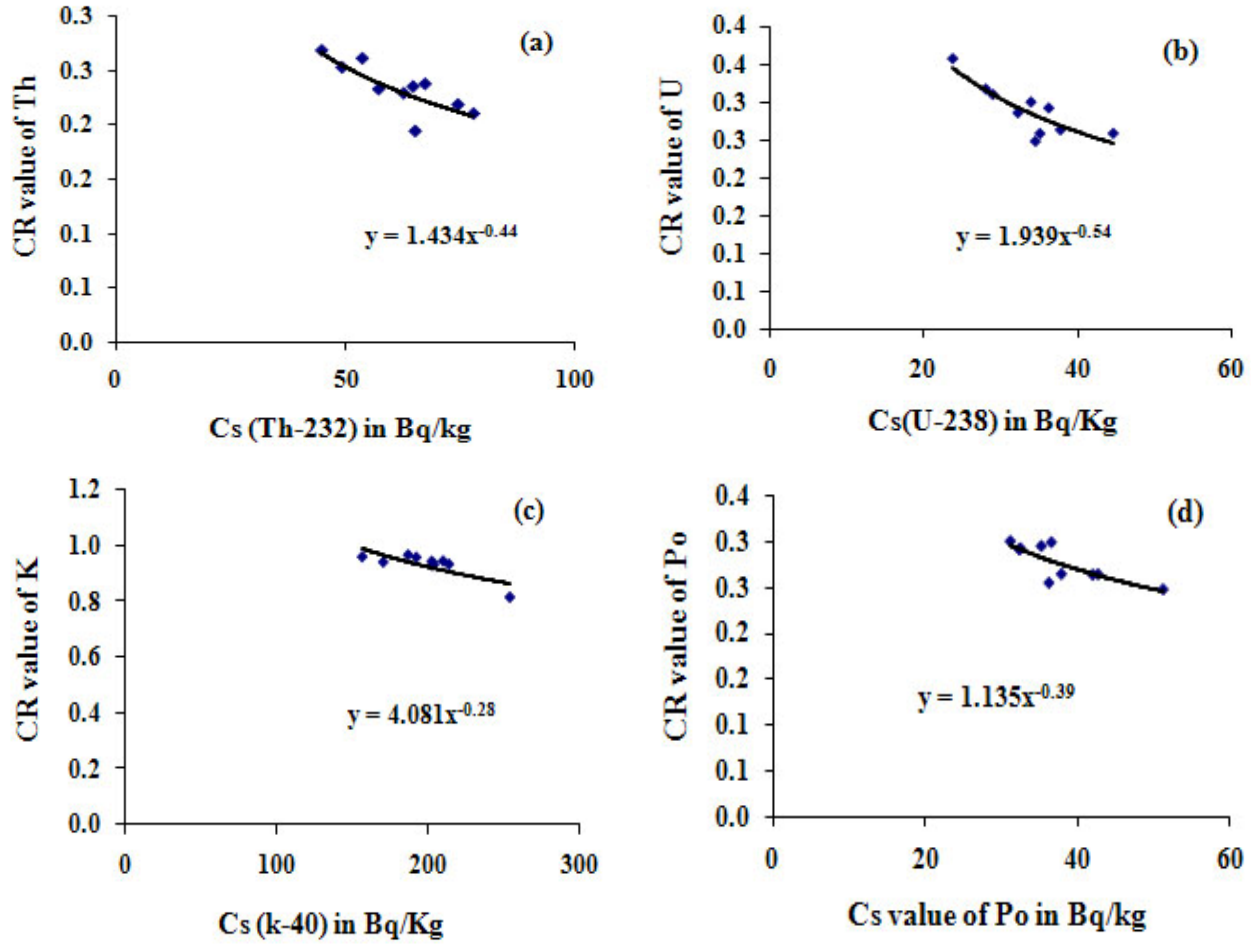


Figure 6. CR value vs. Cs of different radionuclides in soil for the plant of *Evodia Roxburghiana.*

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