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Original Article

Thorium and uranium in vegetables and fruits from a high background radiation region – along the south west coast of India

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ABSTRACT

The concentration of natural radionuclide (^{238}U, ^{232}Th and ^{40}K) in the soil samples and vegetables were determined in the High background radiation areas – along the South West Coast of India by gamma spectroscopy with NaI (Tl) detector. The absorbed dose rate ranged from 86.46 to 163.12nGyh^{-1}. The annual effective dose (0.15mSvy^{-1}) exceeded world average dose of 0.07mSvy^{-1}. The vegetable to soil concentration ratio (CR) was high in tubers and leafy vegetables.

Keywords: radionuclide, vegetables, effective dose, spectroscopy, kanyakumari, cucumber

INTRODUCTION

The South West Coast of the Indian peninsula is a radioactive hotspot with its high activity due to thorium and uranium nuclei as reported from earlier studies [1,2] along the Manavalakurichi, and Midalam coasts in Kanyakumari extended to the Chavara region, in Kerala. The presence of primordial radionuclides such as ^{238}U and ^{232}Th in the biotic systems has been widely acknowledged [3].There is a definite link between the plant and the substrate soil, where the radionuclide if present may appear in the plant organs along the roots. The distribution of these radionuclides in different parts of the plant depends on the biogeochemical characteristics of the soil. The elevated levels of radionuclide in the soil often results in the proportionate uptake by the plants [4] which in turn will result in increased radiation dosage to the herbivorous, through their food chain [5]. Studies on radioactivity of consumable items assume importance in view of its necessity to estimate the ingestion dose passed on to the consumer. A host of studies in the high background radiation areas have revealed interesting information. Lalit and Shukla (1982) who studied radiation uptake by vegetables, fruits and cereals have estimated the ^{228} Th and ^{228} Ra content in the foodstuffs using gamma ray spectrometric analysis [6,7]. Jha et al., (2005), have estimated ^{226}Ra and ^{238}U in fruits grown in Allahabad region and reported that ^{226}Ra intake in fruits is of a higher order compared to that of ^{238}U from the substrate soil. Also the effective per capita ^{226}Ra dosage in fruits has been reported to be 0.113µSv/y. Maniyan et al., (2007) have also estimated the committed effective dose due to the consumption of certain vegetables and fruits to be 0.279 µSv/y and 0.218 µSv/y respectively along the south-west coast [8]. The present study undertakes at least in part, to unravel the link between the activity of the plant and the soil and an evaluation of the possible biological hazard in the consumption of vegetables, in terms of effective dose and transfer factor.

MATERIALS AND METHODS

Soil samples from a depth of about 150cm were collected from the coastal villages near Manavalakurichi (Fig .1) along the South West coast of India already identified as a high background radiation area (HBRA) [9]. Three to four samples from each area were collected and crushed into fine powder by using agate motor. Before measurement the samples were dried in an air- oven at a temperature of 110ºC for 24 hours. Each sample was packed and sealed into a polythene bag that was kept in air – tight container. The sealed samples were stored for about 4 weeks before gamma analysis was performed to allow ^{226} Ra and its short- lived progenies to attain equilibrium. Fresh vegetables and fruits grown in this area collected in fresh polythene bags and brought to the Lab , were first washed in tap water,

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and then in distilled water, to remove all attached sand and dust particles. The initial wet weight of the samples was noted. They were first dried in an electric oven at temperature of 150ºC for about 48 hours and then ashed in a silica crucible using Muffle furnace at 700ºC, for 8 hours.

Radioactivity measurements: The concentration of gamma ray emitting radio isotopes in the samples were measured by employing high efficiency 48mm × 48mm NaI (Tl) detector.The detector had a resolution of about 7 % and an energy of 662 KeV. The ^{238}U and ^{228}Th activities were calculated through 1764 KeV of ^{214}Bi and 2614.5 KeV of ^{208}Tl respectively and ^{40}K activity was calculated through 1460 KeV from the net area under each photo peak after deducting the background activity. The gamma spectrum was recorded using a PC based multi-channel analyzer and processed using the NETSWIN software [10]. From the net area within peak, the activity concentrations in the samples were obtained using equation

$$Ac = C/mP\gamma\varepsilon \ .$$

where Ac is the activity concentration (Bq/Kg) of the radionuclide in the sample, C is the count rate obtained under the corresponding peak (s^{-1}), m the sample mass (Kg), $P\gamma$ the emission probability and ε is the detection efficiency at a specific energy.
The gamma radiation absorbed dose rate in air D_R (nGy h^{-1}) was calculated as

$$D_R = 0.623C_{Th} + 0.427C_U + 0.043C_K$$

where C_{Th}, C_U and C_K are the activity concentrations (Bq/Kg) of thorium, uranium and potassium in the soil samples.
The annual effective dose (H_R) was calculated using the following equation that converts the absorbed dose rate ($nGyh^{-1}$) in air to effective dose (mSv)

$$H_R = D_R \text{ x } 8760h \text{ x } 0.2 \text{ x } 0.7 \text{ Sv Gy}^{-1}$$

Activity concentration in soil and vegetables: The radiation among the activity levels in soils of different places may be attributed to the wide variations on geological formation of different types of soils. The activity concentration of soils of ten different sampling stations and the total effective dose are as recorded in Table-1. All the soil samples exhibit appreciable levels of thorium and potassium activity compared to the global average of 35.0Bq/Kg and 410.0 Bq/Kg respectively (UNSCEAR, 2000). The highest values (23.5 ±0.9Bq/Kg,229.6±0.3Bq/Kg and 1021±0.1Bq/Kg) for 238U, ^{232}Th and ^{40}K respectively are recorded in station-1 (Fig.2.a) whereas the mean values in this area are 17.8Bq/Kg, 142.3Bq/Kg and 815.41Bq/Kg respectively. The absorbed dose rate (D_R) at the ten different sampling stations in the study area, ranges between 86.46nGyh^{-1} and 163.12 nGyh$^{-1.}$ The ariel dose rates (Hand survey) also follow a similar order (63nGyy^{-1} to 258nGyy^{-1}) obviously under the impact of the soil radionuclides. The annual effective dose (outdoor) values vary from 0.07 to 0.25 with the mean value of 0.15 mSvy^{-1} . This is too high compared to the world average of 0.07 mSvy^{-1}. The annual effective dose (indoor) also varies from 0.29 to 0.96 mSvy^{-1} with the mean value of 0.64mSvy^{-1}. The vegetable samples too exhibit proportionately high thorium activity especially in tubers and leafy vegetables. Tapioca, papaya and red spinach have recorded the maximum values (17.35, 21.04, and 16.20) with correspondingly higher values for uranium (Fig.2.b)

Concentration Factors: Radionuclide in the soil can reach human body through food, air and water. Vegetables and crops grown in active area can absorb a small fraction of the soil activity along with other minerals through the root system. [11]. The ability of various plant species to absorb radionuclides from soil or other substrates expressed in terms of concentration factor (CR) is determined [12, 13, 14]. Concentration Factors in Vegetables are a simple ratio between the concentrations of an element in individual species to the concentration in the medium in which it grows. These factors can be of immense help for quick environmental impact assessment and implementation of counter measures. It is also used for assessing the consequences of radiation exposure to non-human biota (ICRP 2007). Table-3 shows the concentration factor for the respective nuclides in vegetables due to root uptake through food and water. The intake of ^{238}U and ^{232}Th through dietary item is very small as indicated by the generally lower values. Not surprisingly the uptake factor for potassium is found to be uniformly high in all the vegetables, as it is one of the major nutrients for plants. Whereas tapioca, papaya, ladies finger and cucumber have a high intake of ^{232}Th from the soil, drumstick, red spinach, coconut and tomato exhibit a higher tendency to absorb ^{238}U. But , the activity concentration of ^{232}Th in vegetables is one order higher in all samples compared to that of ^{238}U(Table.2).Thus thorium contributes more to the effective dose in vegetables than that of uranium. The ^{40}K absorption by the plant though one order higher compared to even that of thorium ,the dose rate depends mainly on the ^{232}Th concentration in vegetables due to its large conversion factor(0.623). Moreover, the proportional intake of thorium and uranium in plants ($^{238}U/^{232}Th$) follows the same order as that in the soil (8.01). There is also a definite link between the dose rate due to soil and that due to vegetables. The two parameters are in direct correlation as observed (Fig.3) from the correlation coefficient (r =0.35).

Conclusion

Papaya and tubers in general, tapioca in particular have recorded the highest gamma activity. The high transfer factor reported here for tapioca and papaya reveals the high intake of radionuclide through their root system with multiplied thin hair roots spread all over the surface soil; hence tapioca and papaya grown in this area are not safer enough for consumption in view of their high activity. A succulent fruit like papaya has the highest transfer factor indicating the vulnerability of the consumer. Cucumber and ladies finger consumption could be safer as noticed from their relatively low activity and transfer factor.

Table 1. Activity concentration (Bq Kg^{-1}) of radionuclide and total effective dose rates in the soil

Sampling Stations	Activity concentration (Bq Kg^{-1})			D_R(nGy/h)	$H_{Routdoor}$ (mSv/y)	$H_{Rindoor}$ (mSv/y)	$^{232}Th/^{238}U$
	^{238}U	^{232}Th	^{40}K				
1	23.5	229.6	1021.0	196.97	0.24	0.96	9.77
2	21.5	129.6	921.1	129.52	0.15	0.63	6.02
3	18.1	175.6	872.2	156.15	0.19	0.76	9.70
4	22.1	184.1	841.0	160.28	0.19	0.78	8.31
5	21.8	180.4	809.1	156.47	0.19	0.76	8.27
6	13.4	98.3	965.1	108.49	0.13	0.53	7.33
7	12.4	107.5	715.2	.103.01	0.12	0.51	8.66
8	19.4	129.7	921.5	128.68	0.15	0.63	6.68
9	20.5	121.1	721.1	115.21	0.14	0.56	5.90
10	5.3	68.4	367.5	60.67	0.07	0.29	12.91
Mean	17.8	142.4	815.4	131.54	0.15	0.64	8.01

Table 2. Activity concentration of radionuclides in the vegetables in ($Bqkg^{-1}$)

S.No	Vegetables	^{238}U	^{232}Th	^{40}K	Dose	$^{232}Th/^{238}U$
1	Drum stick	0.81	1.43	82.10	15.26	1.76
2	Drumstick leaves	0.88	8.90	58.50	2.80	10.10
3	Gooseberry	0.39	2.17	179.10	6.21	5.56
4	Tapioca	1.13	17.35	65.30	33.01	15.35
5	Red spinnach	1.63	21.04	77.50	17.41	12.91
6	Coconut	0.72	1.98	33.81	7.41	2.76
7	Tomato	0.31	1.45	21.61	2.42	1.43
8	Cucumber	0.21	1.51	140.10	14.52	7.12
9	Ladies finger	0.24	3.21	76.11	8.29	13.11

10	Papaya	0.63	16.21	39.50	20.96	1.90
Mean		0.69	5.42	77.31	12.82	7.19

Table 3. Concentration Ratio of radionuclides in fruits and vegetables

Vegetables	$^{238}U \times 10^{-2}$	$^{232}Th \times 10^{-2}$	$^{40}K \times 10^{-2}$	$^{238}U/^{232}Th$
Drum stick	3.71	1.12	8.01	3.31
Drumstick leaves	4.12	6.81	15.02	0.60
Gooseberry	2.11	1.20	46.02	1.75
Tapioca	5.10	9.41	7.01	0.54
Red spinach	7.41	1.11	9.01	6.72
Coconut	5.32	1.72	3.02	3.11
Tomato	2.51	1.41	3.01	1.70
Cucumber	1.12	1.42	15.02	0.78
Ladies finger	1.21	2.61	11.01	0.46
Papaya	4.10	9.61	4.01	0.42

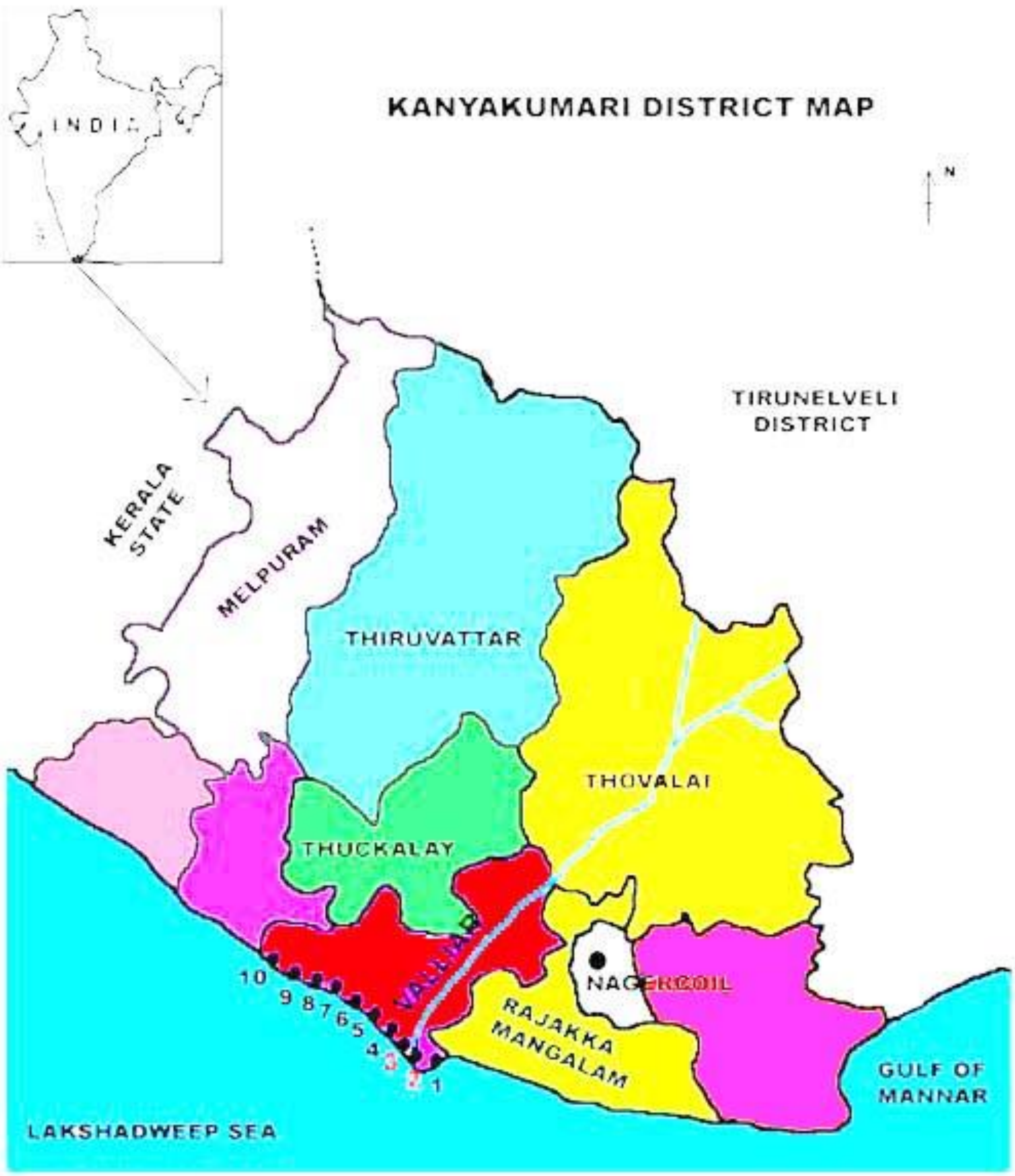

Fig 1. The Sampling Stations

1. Muttom	4. Periavilai	7. Kootumangalam	9. Mondaikadu
2. Kadiapattinam	5. Manavalakurichi	8. Pudur	10. Colachel
3. Chinnavilai	6. Parapattu		

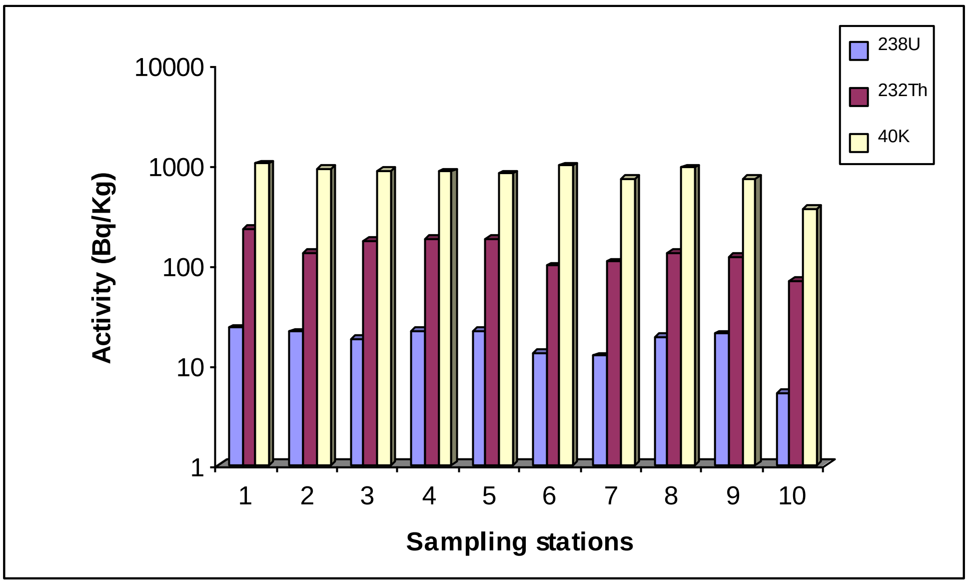

Figure 2.a. Activity concentration of radionuclides in soil

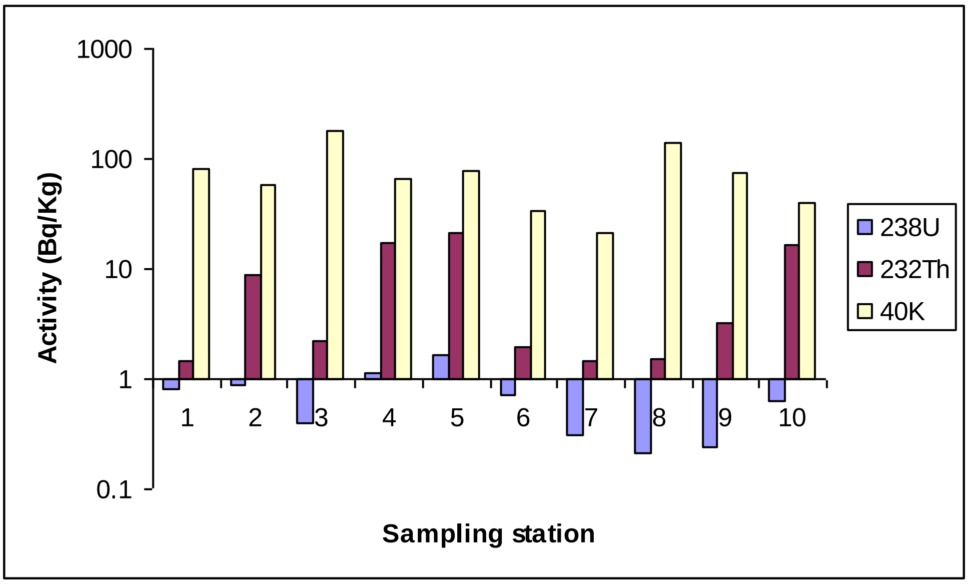

Figure 2.b. Activity concentration of radionuclides in vegetables

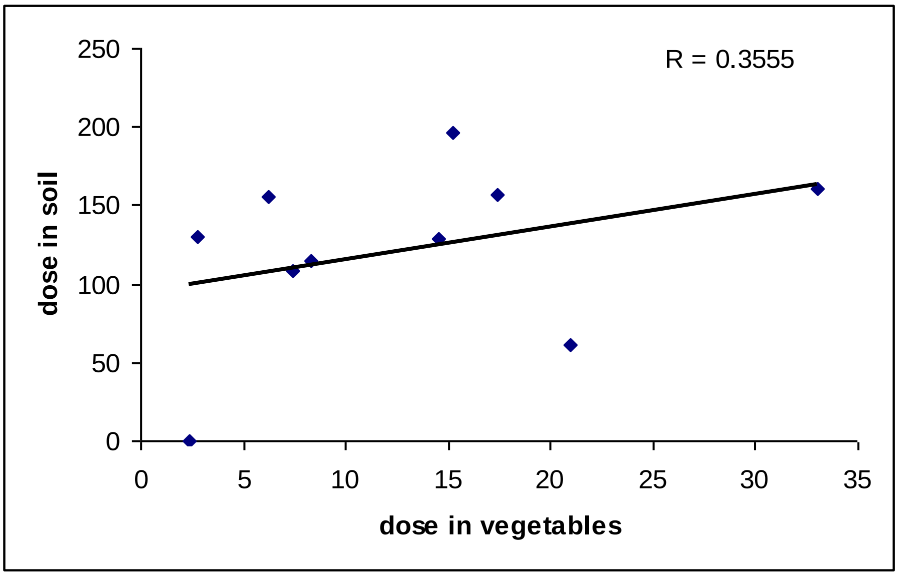

Figure 3.Correlation of doses in soil and vegetables

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