

Natural radionuclides in the South Indian foods and their annual dose

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Abstract

The study was carried out to evaluate the radioactivity concentration in the food crops grown in high-level natural radioactive area (HLNRA) in south west India. Food samples collected were analysed by means of a gamma spectroscopy and estimated annual dietary intakes of the radioisotopes ^{226}Ra , ^{228}Ra , ^{228}Th and ^{40}K . The annual intake of the food stuffs was estimated on the basis of their average annual consumption. Calculations were also made to determine the effective dose to an individual consuming such diets. The intakes of these radionuclides were calculated using the concentrations in south Indian foods and daily consumption rates of these foods. Daily intakes of these radionuclides were as follows: ^{226}Ra , 0.001–1.87; ^{228}Ra , 0.0023–1.26, ^{228}Th , 0.01–14.09 ^{40}K , 0.46–49.39 Bq/day. The daily internal dose resulting from ingestion of radionuclides in food was 4.92 $\mu\text{Sv/day}$ and the annual dose was 1.79 mSv/yr. The radionuclides with highest consumption is ^{40}K .

Keywords: South Indian foods; Daily intake; Ingestion dose; Dose coefficient

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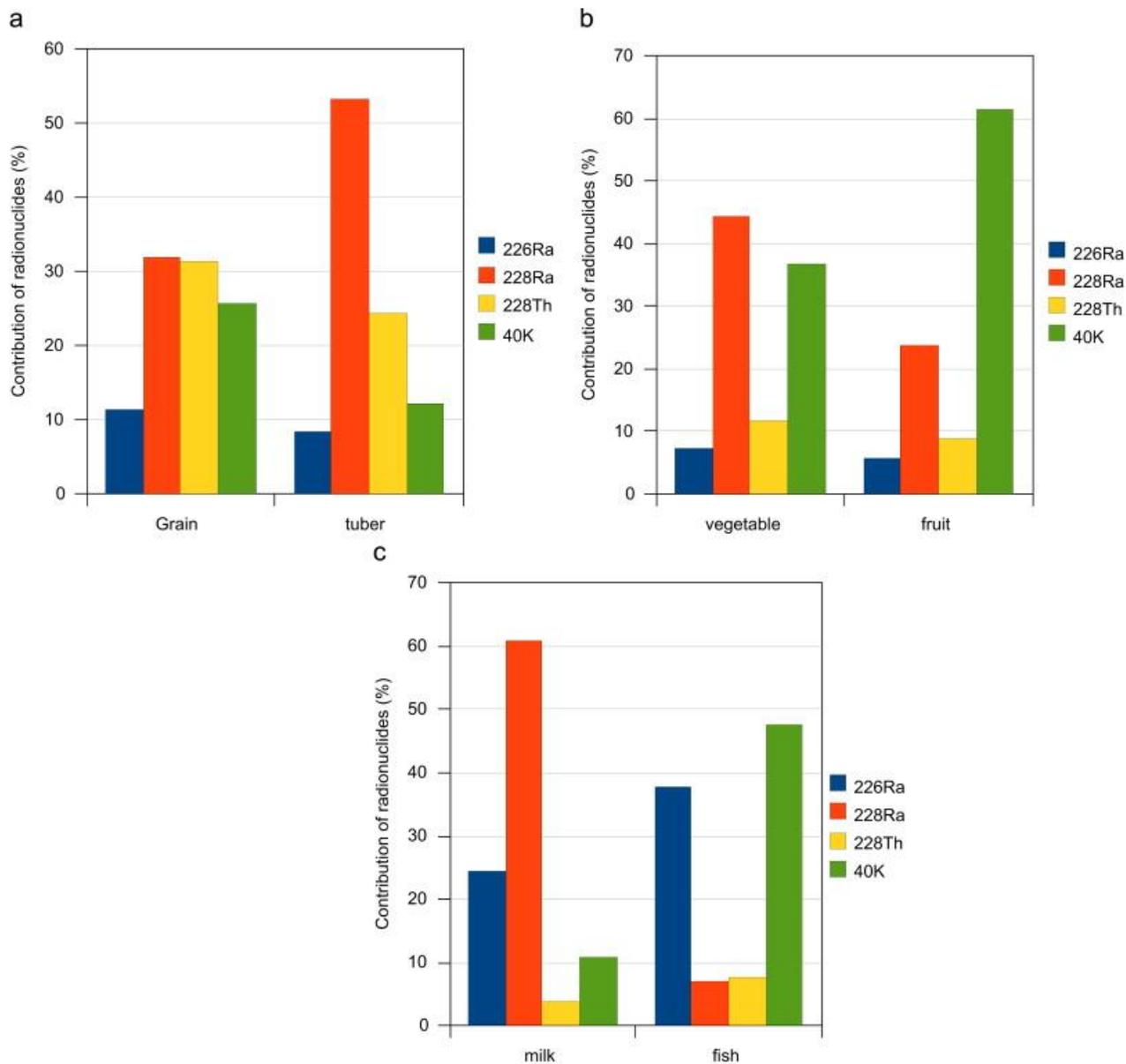
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1. Introduction

Naturally occurring radioisotopes are the main sources of both external and internal radiation exposure in humans. Of the terrestrial radioisotopes thorium, uranium and potassium enter the human body primarily by ingestion of foods, while inhalation of these isotopes are limited [1]. Study of natural radioactivity is usually done in order to gain information about the present levels of harmful pollutants discharged to the environment itself or in the living creatures [2]. It is also important to understand the behavior of natural radionuclides in the environment because such information can be used as the associated parameter values for radiological assessment [3]. The release of radionuclides into environment contaminates food according to the type of soil, its chemical characteristics, the physical and chemical forms of the radionuclides in the soil, radionuclide uptake by particular plant and finally the level of accumulation by particular foodstuffs [4].

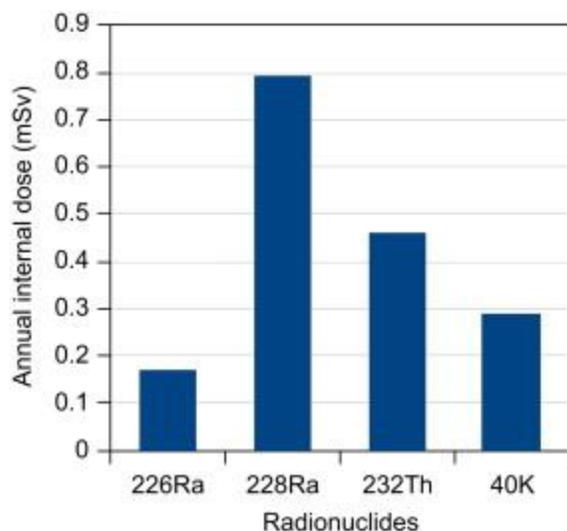
The southwest coast of Tamil Nadu is a high level natural radiation area is situated in the south India. Several studies have been undertaken during the past one or two decades to determine the effect of radiation on the Public. The present studies have been carried out at Midalam and its surrounding area, of Kanyakumari district. This is a naturally high background radiation area with the monazite content in the soil varying from 0.3% to 6% and the average annual effective dose is reported up to 60 mSv. The world average is 0.50 mSv yr⁻¹[10]. The monazite is the primary ore of several rare earth metals, thorium and uranium. The people of this area are involved in several varieties of farming. Public radiation exposure from natural radioactive decay series of uranium and thorium occurs mainly because they can get dissolved in water and migrate to surface water reservoirs, leading to the possibility of contaminating food stuffs, following soil to plant transfer as well as getting into the human body [5]. The aims of this study are to evaluate the annual

intake of natural radioisotopes (^{226}Ra , ^{228}Ra , ^{228}Th , ^{40}K) in typical South Indian foods such as milk, fish, rice, tapioca, banana, mango, guava, tomato etc., and estimate the annual internal dose from these natural isotopes for the south Indian adults (Fig. 1 and Fig. 2).



High-quality image (426K) Fig. 1.

Percentage contribution of some south Indian foods to the daily ingestion radionuclides doses.



High-quality image (107K) Fig. 2. Contribution of radionuclides to the annual ingestion dose.

2. Experimental methods

2.1. Sampling

Since the present study focuses on the ingestion of food crops grown and consumed by the general public in the investigated high background radiation area, the typical South Indian food crops were considered for preparation and analysis. Samples from six food categories were collected in south west India are presented in Table 1. The number samples analysed are given in the parenthesis along with the food product given in Table 1 (column2). The collected food samples were as follow: grains (rice, blackgrams), milk, fish, vegetables (Indian caper, drumstick, ladies finger, cucumber, Indian acalypha, tomato, leafy vegetables), fruits (mango, papaya, guava) and tuber (tapioca). The sampling site for this study are Midalam and the surrounding villages of Kanyakumari district which is the southern most district of India. The southern region of this district is surrounded by the Indian ocean. A radiation survey was carried out to get aid in selecting representative locations for samples. Here few places were identified as high background radiation areas which are very rich in monazite a prime ore of thorium that is being extracted by the Indian rare earth Ltd. Manavalakurichi in Kanyakumari. The coastal villages near to Manavalakurichi are naturally high background radiation areas. The surface area of the identified high background radiation area is nearly 12 sq km. The area of study is divided into approximately equal area (grid) in order to ensure the representative sampling. Samples of different food crops weighing 1–2 kg-fresh were collected from the farms and from vegetable gardens. The types of food samples were collected and their food group classification is presented in Table 1. Since the region is agricultural it was easy to collect

the samples. We made sure that at least four samples of each variety were collected across the entire grids. Nearly one to two kilogram of fresh samples were collected for the study. The selected food items are the major diet of the people of this area. The vegetables and fruits that are grown in the farms of this area are available in the local markets.

Table 1. Food categories and annual consumption of south Indian food product.

Food categories	Food product	Annual consumption	dried wt./fresh wt.
Grains/cereals	Rice (5)	150 kg	0.67
	Blackgram dhal (4)	5 kg	0.49
Milk	Milk (3)	40 it	0.13
Fish	Fish (pond) (4)	20 kg	0.23
Vegetables	Indian caper (5)	25 kg	0.06
	Drumstick (5)	10 kg	0.15
	Ladies finger (5)	25 kg	0.22
	Cucumber (3)	35 kg	0.04
	Indian acalypha (2)	9 kg	0.38
	Tomato (3)	20 kg	0.06
	leafy vegetable (4)	10 kg	0.28
	Coconut (4)	20 kg	0.48
Fruits	Mango (5)	10 kg	0.14
	Banana (5)	40 kg	0.14

Food categories	Food product	Annual consumption	dried wt./fresh wt.
	Papaya (5)	20 kg	0.05
	Guava (4)	5 kg	0.23
Tuber	Tapioca (5)	35 kg	0.31

Full-size table

2.2. Radioactivity measurements

All food samples were pre-treated according to the recommendations given by IAEA [16]. The collected samples were washed first with tap water and then with distilled water, peeled when necessary (banana, tapioca) and weighed. The samples were oven dried at approximately 100 °C until they reached a constant weight. The samples were then homogenized and ashed at 450 °C to remove organic matter. The ashed samples were sealed one month to allow the secular equilibrium of ²²²Rn and its progeny with ²²⁶Ra. Radioactivity measurements were carried out using a lead shielded 48×48 mm NaI(Tl) detector crystal coupled to a Multichannel Analyzer through a preamplifier. The detector had a resolution of about 7% at an energy of 662 KeV. This was enough to distinguish the ray energies of interest in the present study. The activity concentration of ²¹⁴Bi (determined from its 1760 keV ray peak) was chosen to provide an estimate of ²²⁶Ra in the food samples, while that of the daughter radionuclides ²⁰⁸Tl (determined from its 2615 keV ray peak) was chosen as an indicator of ²²⁸Th [7]. ⁴⁰K was determined by measuring the 1460 keV rays emitted during the decay of ⁴⁰K. ²²⁸Ra was determined through the ²²⁸Ac (911 keV) activity [6].

The food samples were placed on the detector and measured for a period of 5000 s. The net area under the corresponding peaks in the energy spectrum was computed by subtracting counts due to Compton Scattering of higher peaks and other background sources from the total area of the peaks [7]. From the net area of a certain peak, the activity concentrations in the samples were obtained using equations already used by few

authors [7], [8] and [9]. $C(\text{Bq kg}^{-1}) = \frac{C_n}{\xi P_\gamma M_s}$ Where, (Bq kg⁻¹) is the activity concentration of the radionuclide in the sample given in Bq kg⁻¹, C_n is the count rate under the corresponding peak, ξ is the detector efficiency at the specific γ-ray energy, P_γ is the absolute transition probability of the specific γ-ray and M_s is the mass of the sample.

2.3. Calculation of effective dose from the diet

In order to calculate the dose received by the public of South India, the rates of consumption are estimated by using the information from local residents. The consumption rates calculated for different types of food samples are shown in Table 1.

By using the following equation, effective dose from radionuclides in food and daily diet can be calculated [4] and [7].

$D = D_f \times U \times (C_d \times h)$, where, D is effective dose ($\mu\text{SV year}^{-1}$), D_f is the dose coefficient ($\mu\text{Sv Bq}^{-1}$) (second column of Table 5). U is the amount of food consumed in 1 yr (kg year^{-1}), C_d is the radionuclide content of dried food Bq kg^{-1} , h is the ratio of dried to fresh foods (fourth column of Table 1) and $(C_d \times h)$ is the radionuclide content in fresh food Bq kg^{-1} .

3. Result and discussion

3.1. Radioisotopes concentrations in major south Indian foods

Table 2 summarizes the activity concentration of the radionuclides measured on each of the foodstuffs. The activities are given in Bq/kg (fresh weight) and the measurement errors shown represent one sigma uncertainties. The concentration of ^{226}Ra ranged between 0.03 ± 0.02 (leafy vegetable) and 7.52 ± 0.5 (blackgram dhal) Bq/kg . For milk ^{226}Ra concentration was higher than vegetables and fruits, possibly because the cows which are fed mainly on the local grass which was grown in high background radiation area (Midalam in Kanyakumari district). ^{226}Ra activity concentration obtained in the present study are lower than those obtained by Banzi et al. [18] who reported ^{226}Ra concentration of 650 ± 11 and 393 ± 9 Bq/kg for wild leaf vegetations and edible leaf vegetations respectively in Tanzania. But the present work reports the activity concentrations are higher than the report by Ramachandran et al. [19] who estimated the activity concentrations in Indian foodstuffs varies from 0.01 to 1.16, 0.02 to 1.26 and 45.9 to 649 Bq/kg respectively for ^{226}Ra , ^{228}Th , ^{40}K . The activity concentration of ^{226}Ra in rice was estimated 4.56 ± 0.8 which is nearly ten times greater than the value reported from Iran [4]. The concentration of ^{228}Ra ranged from 0.082 ± 0.005 (leafy vegetable) to 5.42 ± 0.5 (tapioca) Bq/kg -Fresh. For tapioca samples the average radioisotope concentrations were much higher than those in the samples from other food samples, possibly because they are influenced by terrestrial radioisotopes.

Table 2. Activity concentration of radionuclides in the south Indian food product.

Food categories	Food Product	Activity concentration(Bq/kg-fresh)			
		226Ra	228Ra	228Th	40K
Grains/ Cereals	Rice	3.07±0.41	4.56±0.8	34.3±2.7	120.2±15.8
	Blackgram dhal	7.52±0.5	4.7±0.8	28.7±3.4	482.7±19.2
Milk	Milk	2.5±1.2	1.48±0.4	1.02±0.3	34.35±5.2
Fish	Fish	0.05±0.01	0.103±0.03	1.23±0.2	88.91±6.7
Vegetables	Indian caper	1.05±0.05	0.84±0.31	5.3±0.7	68.69±5.4
	Drumstick	1.23±0.24	0.27±0.1	1.7±0.4	78.7±9.3
	Ladies finger	0.38±0.04	0.594±0.08	0.42±0.18	72.8±8.2
	Cucumber	0.097±0.02	0.04±0.01	0.14±0.04	29.67±9.1
	indian acalypha	0.948±0.2	1.57±0.2	1.5±0.02	31.46±6.9
	Tomato	0.06±0.03	0.64±0.2	0.17±0.02	71.92±8.4
	Leafy vegetable	0.03±0.01	0.082±0.01	1.03±0.5	49.5±8.4
	Coconut	0.284±0.14	0.214±0.04	0.34±0.05	58.4±8.9
Fruits	Mango	1.21±0.06	1.29±0.008	4.5±1.2	50.44±4.4
	Banana	0.094±0.02	0.086±0.03	1.1±0.2	136.2±8.3
	Papaya	0.27±0.07	0.271±0.08	0.18±0.08	59.5±6.3
	Guava	0.25±0.03	0.17±0.06	0.71±0.3	33.4±4.5

Food categories	Food Product	Activity concentration(Bq/kg-fresh)			
		226Ra	228Ra	228Th	40K
Tuber	Tapioca	3.57±1.2	5.42±0.3	27.4±4.8	181.1±12.4

The concentrations of 228Th varies from 0.14±0.04 (cucumber) to 34.3±2.7 (rice) Bq/kg-fresh. The range of 228Th (0.14 to 34.3 Bq/kg) were higher than the ranges published in the UNSCEAR [1] report (0.003 to 2.3 Bq/kg-Fresh). The concentrations of 228Th were higher because 228Th is influenced by the in growth from 228Ra and 228Ac taken up by plants [13]. The activity concentration of radium and potassium in the fish (pond) sample of the present study is very low when comparing with the concentration of radionuclides in the fish of Korea but the 228Th concentration of fish is very much higher than result reported from in Korea [14]. The concentration of naturally occurring radioisotopes measured in typical south Indian foods were presented in Table 2. The range of 40K concentration was found to vary between 8.69±2.2 (Indian caper) to 482.7±19.2 Bq/kg-fresh. Among the natural radioisotopes in south Indian foods, the concentration of 40K was the highest, possibly due to the concentrations of 40K in the soil. The transfer factor of 40K is higher than some natural radioisotopes [11]. However, 40K is an essential biological element and its concentration in human tissue is under close metabolic control [12].

3.2. Daily radioisotopes intakes from south Indian foods

The radionuclide intakes were calculated by the consumption rate of foods of south Indians. The estimated daily radioisotopes intakes from the food consumed are presented in Table 3.

Table 3. Daily intake of radionuclides from the south Indian food product.

Food categories	Food Product	Daily Intake(Bq)			
		226Ra	228Ra	228Th	40K
Grain	Rice	1.87	1.26	14.09	49.39
	Blackgram dhal	0.11	0.064	0.393	6.612
Milk	Milk	0.27	0.16	0.11	3.76
Fish	Fish	0.13	0.0056	0.07	4.87
Vegetable	Indian caper	0.059	0.0719	0.36	0.595
	Drumstick	0.011	0.0074	0.046	2.16
	Ladies finger	0.04	0.025	0.028	4.98
	Cucumber	0.004	0.009	0.013	2.85
	Indian acalypha	0.04	0.023	0.036	0.78
	Tomato	0.0028	0.035	0.0093	3.94
	Leafy vegetable	0.0008	0.0022	0.028	1.36
	Coconut	0.016	0.012	0.018	3.2
Fruit	Mango	0.033	0.034	0.12	1.382
	Banana	0.012	0.01	0.09	14.92
	Papaya	0.015	0.014	0.01	3.26
	Guava	0.0035	0.0023	0.0097	0.457

Food categories	Food Product	Daily Intake(Bq)			
		226Ra	228Ra	228Th	40K
Tuber	Tapioca	0.35	0.519	2.62	17.36

The daily intakes of the radioisotopes measured in this study from typical south Indian foods were as follows. 226Ra, 3.05 Bq/day; 228Ra, 2.257 Bq/day; 228Th, 18.065 Bq/day; and 40K, 121.88 Bq/day. The highest radionuclides intake were from grains (73.79 Bq/day) and the lowest were from milk (4.302 Bq/day). The daily intake of radionuclides from south Indian food stuffs was compared with the intake in other countries. 40K intake from rice was higher than Korea [14]. The daily intake of 40K ranged from 108 to 244 Bq with an average of 148 Bq per person in Spain [17] which is consistent with this present work. In this work the radioisotopes with the highest daily intake was 40K and the food with the highest amount of 40K was rice. The daily intake of naturally occurring radionuclides from the ingestion of foods was 142.258 Bq/kg of which 119.15 Bq/kg (83.75%) came from 40K. The lowest intakes were of 228Ra and 226Ra. Daily radioisotopes intakes from rice, milk and tapioca were much higher than those from the other food samples. The daily intake of 228Th was higher than 226Ra and 228Ra in rice and tapioca but for all other food stuffs it keeps the same order. 228Th in rice is nearly 10 times greater than 226Ra and 228Ra. The results may be explained by the abundance of 228Th in soil. UNSCEAR [1] reports the 228Th in soil in India and in Europe are higher than other countries. The daily total effective doses calculated for the studied radionuclides varied from 0.023 μ Sv/day (fish) to 0.77 μ Sv/day (tubers) with a total value of 4.92 μ Sv/day, in this 40K contributes 1.261 μ Sv/day. 40K is usually of limited interest because as an isotope of an essential element it is homeostatically controlled in the human cells. As a result the body content 40K is determined largely by its physiological characteristics rather than by its intake [7].

3.3. Annual internal dose

The recommended dose conversion coefficient for 226Ra, 228Ra, 228Th, 40K are 0.23, 0.8, 0.072 and 0.0062 μ Sv/Bq, respectively [15] is given in Table 5. The total annual internal dose of 226Ra, 228Ra, 228Th, 40K in south Indian foods were estimated to be 0.201, 0.659, 0.475 and 0.460 mSv/year. The highest annual internal dose was for 228Ra. The Daily internal dose in the south Indian food category in μ Sv is presented in Table 4. The total annual internal dose from ingestion of food samples in this study was 1.798 mSv/year

(Table 5). There are no data available for the intake by the public from the natural high background radiation area in south west India. It can be seen that these doses are higher than annual dose limit of 1 mSv for general public [11].

Table 4. Daily internal dose in the south Indian food category in μSv .

Food category	226Ra	228Ra	228Th	40K	Total
grain/cereal	0.375	1.062	1.043	0.854	3.33
milk	0.052	0.129	0.00804	0.023	0.212
fish	0.024	0.0045	0.00484	0.0302	0.0635
vegetable	0.0244	0.1484	0.0389	0.1226	0.3343
fruit	0.0116	0.048	0.0178	0.124	0.2014
tuber	0.065	0.416	0.189	0.107	0.78
Total	0.55	1.807	1.3015	1.2608	4.9212

Table 5. Dose coefficients and annual internal radionuclides doses.

Radionuclide	Dose coefficients ($\mu\text{Sv/Bq}$)	Annual internal dose (mSv)
226Ra	0.19	0.201
28Ra	0.8	0.659
228Th	0.072	0.475
40K	0.006	0.460
Total		1.795

The total annual internal doses from ^{226}Ra , ^{228}Ra , ^{228}Th , ^{40}K in Korean foods [14] were estimated to be 1.81, 6.79, 0.35 and 101 $\mu\text{Sv year}^{-1}$, respectively and are very much lower than the result obtained in the present study. Jibiri et al. [7] worked in Jos plateau, Nigeria and calculated the annual effective dose to be 2.38 mSv/year.

4. Conclusion

The study estimated the activity concentration of radionuclides ^{226}Ra , ^{228}Ra , ^{228}Th , ^{40}K by means of gamma ray spectrometry in different food crops that are regularly consumed by the population of south India. Activity concentrations of these radionuclides in the soil samples from farms were high due to the natural abundance. ^{228}Th in foodstuffs were higher than ^{226}Ra , ^{228}Ra due to the high abundance in soil as reported by UNSCEAR [1]. The probability of another reason for the enhanced radionuclide concentration in the food crops are the application of fertilizers. The highest radionuclide concentration of those measured was that of ^{40}K . The daily intakes of these radionuclides were estimated using radionuclide concentration and the daily consumption rates of south Indian foods. The daily consumption of ^{40}K (2.84–56.0 Bq/day) was the highest intakes among the radionuclides measured. The daily consumption of ^{40}K by the Koreans ranges between 0.01 and 6.35 Bq/day but it was lower than intakes in other countries and than ICRP values. The food with the highest amount of ^{40}K was rice. The second concentration were those of ^{228}Th radionuclide which ranges from 0.04 to 4.48 Bq/kg. Radium in fish and fruits are very low when comparing with other radionuclides. For rice and tapioca the high radionuclide intake were not only due to high radioisotope concentration compared with other foods but they are the staple foods of south Indians.

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