



Assessment of ingestion dose through staple food to the populace in the placer deposits region of west coast India

Physics

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ABSTRACT

High natural background radiation due to the presence of radiogenic heavy minerals in the beach placer deposits along the south-west coast of India is well known. The present study reports the results of radiometric analysis of most common and habitual food items consumed by the populace in the region. Cereals, pulses, grains, tubers, vegetables, tea powder, coffee powder, marine food samples and full meals of 156 samples, collected from the high background radiation areas of Kerala were studied. ^{238}U was found to be below detectable level (4.7 Bqkg⁻¹) in all food stuff while ^{232}Th showed a narrow band of 15 Bqkg⁻¹ and 35 Bqkg⁻¹. The levels of ^{40}K in the samples were found to vary in a wide range from 60Bqkg⁻¹ to 859Bqkg⁻¹. The ingestion dose estimates show that whole meal twice daily would ingest 1.08 ± 0.2 mSv/y. The estimate from various major food items amounts to 1.34 ± 0.37 mSv/y

KEYWORDS:

primordial radionuclides, ingestion dose, gamma ray spectrometer

INTRODUCTION

The environment contains varying amounts of radioactive elements that are derived from primordial and secondary cosmogenic sources (Kessaratikoon, P., and Awaekuchi, S., 2008). According to the data available in literature, the concentrations of primordial radionuclides in soil in various states of India are ^{238}U varies from BDL (Below detectable level) to 32 Bqkg⁻¹, ^{232}Th varies from BDL to 5 Bqkg⁻¹ and ^{40}K varies from BDL to 957 Bqkg⁻¹ (Pathra et al., 2013). Radionuclides in air, soil, water and rocks that make up earth's geosphere and atmosphere can be transferred into the biosphere by many organisms and can also cause bioaccumulation in the food chain (Pöschl, M., and Nolle, M.L., 2007). There is a continuous competition for uptake between nutrient cations at the root surface (Shanthi et al., 2012). Plant uptake of radionuclides is one of many factors for introduction into the human food chain (Morton et al., 2002). The presence of higher levels of long-lived radionuclides such as naturally occurring ^{238}U , ^{232}Th , ^{40}K and their daughter products in soil is of potential health concern as they may stay for a longer time in the rooting zone (Chibowski, S., 2000) and may be taken up along with the nutrients into the plants (Asefi, M et al., 2005).

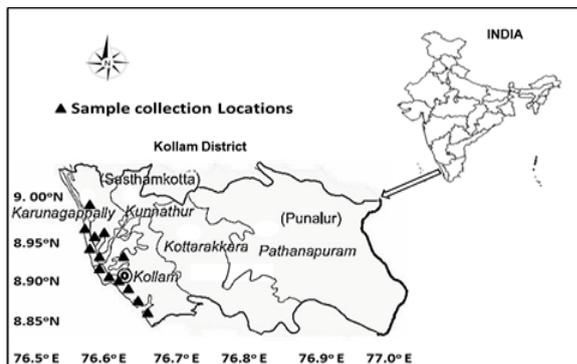
The radioactivity content of the food products from high background radiation areas can be higher when compared to similar samples collected from normal background radiation area. The south west coastal region of Kerala on the coast of Arabian Sea is known as a High Background Radiation Area (HBRA) owing to the presence of thorium-rich monazite sand available in abundance in the region (Chougaonkar, M.P et al., 2003). The studies on internal radiation exposure through airborne dust inhalation and ground water ingestion has concluded that the dose rates are lower than the limiting standards, the reason being that monazite cannot disperse in air and is insoluble in water (Pillai, P.N.B., and Khan, A.H., 2003). The radioactivity elemental composition in soil was a subject of several studies. But the radiometric analysis of agricultural and other edible products from the region are scarce even from the normal background regions. In the present study, we have made radiometric analysis of 156 samples of common edible items namely cereals, pulses, grains, tubers, vegetables, tea powder, coffee powder, marine food samples and full meals. We have also estimated the ingestion dose due to the primordial radionuclides based on the results of gamma ray spectrometry of food samples and the dietary data.

MATERIALS AND METHODS

For a precise assessment of annual ingestion dose, a dietary habit study was conducted among the inhabitants of the study area using a

detailed questionnaire. Based on the inputs, the most commonly used food stuff in the usual diet of the population was determined and selected for the study. Collection of locally grown / produced food samples were made in consultation with the local people, agriculture officers and anganwadi teachers in the region. The 156 samples of 53 varieties of food items were collected from the southern coastal belt of Kerala (Figure-1). While collecting the samples gross gamma dose rates in the locations were recorded with a gamma dosimeter.

Figure-1. Locations of sample collection in the HBRA



For collection, preparation and analysis of the samples we followed IAEA Guidelines (IAEA, 1989). Fresh agricultural samples were collected from the farms in the study area. Samples were washed and the edible parts were separated. Wet weight of each sample was noted. Samples were dried under an IR lamp for 24 hours and further in a hot air oven at 110°C for 24 hours. The weights of the dried samples were noted. Dried samples were powdered using a grinder and sieved to get homogenized sample. These samples were further fired at about 300-320°C in a muffle furnace to ash the samples. Ashed samples were then transferred to clean empty cylindrical plastic containers of specific size and were hermetically sealed. The samples were shelved for six weeks before gamma spectrometry analysis.

Gamma spectrometry was used for the analysis of gamma emitting radionuclides in environmental samples (Yang, D., and Guo, Y., 1994). Convenient and non-destructive analysis of the sample for determining the levels of ^{238}U , ^{232}Th and ^{40}K were done using a 5"×4" NaI(Tl) detector based on Gamma ray spectrometry. The detector was housed in a 3" thick graded lead shield and PC coupled 8 K MCA.

The measurement was carried out in three main steps: energy calibration, sensitivity calibration and gamma-ray analysis. The activity of ⁶⁰K was evaluated from the 1460 keV photo peak of its own gamma, the activity of ²³⁸U from 1764 keV gamma ray of ²¹⁴Pb and that of ²³²Th from 2614 keV gamma ray of ²⁰⁸Tl. The counting times of sample were 60000s for obtaining the net activity. Selecting the respective peaks for the isotopes, the regions of interest (ROI) were selected and the corresponding gross counts were noted. The contribution of background was deducted from the gross counts and the net activity was determined. The specific activity of the samples was determined using the wet weight of the samples and the ingestion dose was calculated. Minimum Detectable Level (MDL) of the spectrometer for ⁴⁰K, ²²⁶Ra and ²³²Th were 27.2Bqkg⁻¹, 4.7Bqkg⁻¹ and 14.3 Bqkg⁻¹ respectively.

The ingestion dose to the population has been calculated using the equation(UNSCEAR, 2008).

Ingestion dose, D (Sv y⁻¹) = (C_U DCF_U + C_{Th} DCF_{Th} + C_K DCF_K) I
 Where C_U – concentration of ²³⁸U (Bqkg⁻¹),
 DCF_U – dose conversion factor for U (²²⁶Ra) = 0.28 SvBq⁻¹,
 C_{Th} – concentration of ²³²Th (Bqkg⁻¹),
 DCF_{Th} – dose conversion factor for Th (²³²Th) = 0.072SvBq⁻¹,
 C_K – concentration of K (Bqkg⁻¹),
 DCF_K – dose conversion factor for ⁴⁰K = 0.0062 SvBq⁻¹,
 I – annual intake of the food item as obtained from the dietary habit study(kg y⁻¹).

RESULTS AND DISCUSSION

Results of the gamma spectrometry analysis of the agricultural and food items collected from the experimental area showed that in all samples, ²³⁸U level was below detectable level of the gamma ray spectrometer, 4.7 Bqkg⁻¹. This is in concurrence with findings that plants grown in radionuclide – rich soil, there is significant increase in concentrations of ²³²Th and ²³⁸U in roots, while concentrations of the radionuclides in upper plant parts were rather low(Shtangeeva, I., 2010). Among the samples we studied, except tubers, all were non-root samples. Moreover, the vegetable farms are a few kilometers away from the beach region where high levels of radioactivity in soil prevail. The range of ²³²Th was in a close range of 15Bqkg⁻¹ (in Nanakizhangu – Dioscoreaesculenta) and 35Bqkg⁻¹ (Red gram - Cajanus cajan) and the levels of ⁴⁰K was found to vary from 60Bqkg⁻¹ (in carrot and rice) to 859Bqkg⁻¹ (in Plantain). In marine food samples the range of ²³²Th was between 15Bqkg⁻¹ and 18Bqkg⁻¹, and ⁴⁰K was found to vary from 34Bqkg⁻¹ to 110 Bqkg⁻¹. In whole meal samples comprising of cooked rice, vegetables and fish, ²³²Th levels were between BDL (14.3 Bqkg⁻¹) and 18 Bqkg⁻¹ while ⁴⁰K was found within the range of 228Bqkg⁻¹ and 340 Bqkg⁻¹. Variation of levels of ²³²Th and ⁴⁰K in tubers and vegetables are graphically depicted in the figures 2 and 3. From the analysis of spectrometry results, it can be inferred that translocation of heavy radioactive elements, namely ²³⁸U and ²³²Th, are quite small while ⁴⁰K is found at a higher level.

Figure 2.Levels of Thorium and Potassium in Tubers

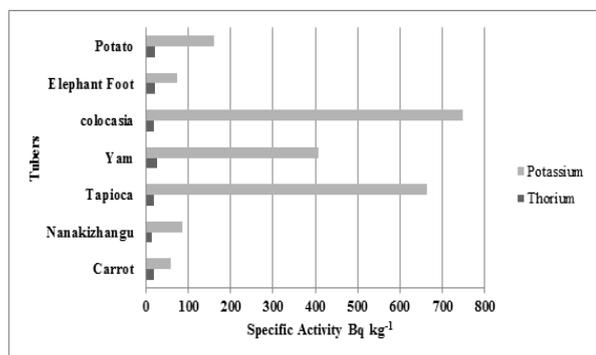
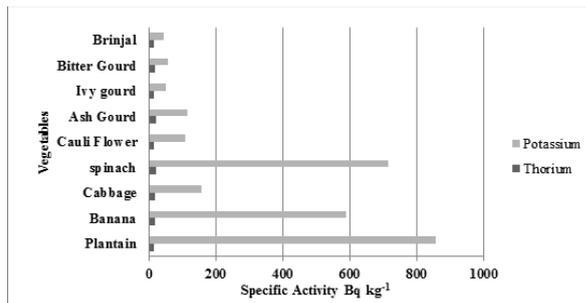


Figure 3.Levels of Thorium and Potassium in Vegetables



Average levels of ²³²Th and ⁴⁰K in each item of food sample is shown in the table -1. Based on the inputs of the dietary habits study, the average amount of the components of the diet was determined (Table-2) for the assessment of ingestion dose. It has been seen that the annual intake estimates we arrived at are in par with the dietary habit data given by UNSCEAR, 2013 Report.

Table 1.Average levels of Thorium and Potassium in each class of food item

No	Sample	Thorium (Th-232) (Bqkg-1)	Potassium (K-40) (Bqkg-1)
1	Rice	19±4	64±14
2	Wheat	18±4	187±17
3	Leafy vegetables	20±4	436±84
4	Non- leafy vegetables	17±4	75±28
5	Fruits	17±3	724±24
6	Grains	23±4	320±88
7	Tubers	20±4	314±77
8	Fish	17±4	102±18
9	Coffee	35±7	483±23
10	Tea	31±9	386±19
11	Cooked whole meal	18±4	272±14

Table 2.Average per capita annual intake of diet of adults in the region.

Type of diet	Range (kg)	MeanSD(kg)
Rice	62 - 204	98±26
Wheat	38 - 98	60±24
Leafy vegetables	06 - 17	12±6
Non leafy vegetables	14 - 58	48±28
Fruits	12- 28	19±9
Grains	14 - 64	28±18
Tubers	24 - 37	34±14
Fish	44 - 102	68±26
Coffee	6 - 18	10±6
Tea	15- 30	18±4
*Meals	376-530	447±74

* Wet weight

Estimate of ingestion dose assuming half of the minimum detectable level of uranium (taken as 2.4 Bqkg-1) of the counting system is presented in the table-3. It is worth mentioning that the estimates are only from the primordial radionuclides present in the individual and mixed food stuffs and other radionuclides, especially the TENORM are not taken into account.

Table 3.Estimation of annual Ingestion dose

Sample	Average level (Bqkg-1)			Intake rate I (kg y-1)	Ingestion Dose D (mSvy-1)	Total Ingestion Dose (mSvy-1)
	Cu	CTh	C _K			
Rice	2.4±0.3	19±4	64±8	98±26	0.24±0.06	1.34±0.37
Wheat	2.4±0.3	18±4	187±13	60±24	0.19±0.04	
Leafy veg.	2.4±0.3	20±4	436±20	12±6	0.06±0.03	
Non leafy veg.	2.4±0.3	17±4	75±8	48±28	0.11±0.04	

Fruits	2.4±0.3	16±4	724±27	19±9	0.12±0.04	
Grains	2.4±0.3	23±5	320±18	28±18	0.16±0.06	
Tubers	2.4±0.3	20±4	314±18	34±14	0.14±0.03	
Fish	2.4±0.3	17±4	102±10	68±26	0.17±0.03	
Coffee	2.4±0.3	34±6	482±22	10±6	0.06±0.02	
Tea	2.4±0.3	31±6	386±19	18±4	0.1±0.02	
*Meals	2.4±0.3	17±4	272±16	447±74	1.08±0.2	1.08±0.2

*Wet weight

Whole meal, the mixed food, comprising of cooked rice and curries twice daily would ingest 1.08 ± 0.2 mSv annually. Instead, if we estimate the total ingestion dose from various individual sources, it amounts to 1.34 ± 0.37 mSv per annum.

Conclusion

Assessment of primordial radionuclides in agricultural and other food products in the southern coastal region of Kerala has been done. We restricted ourselves analyzing samples only for primordial radionuclides, namely ^{238}U , ^{232}Th and ^{40}K since the radiation dose imparted by the other radionuclides like Iodine, Cesium, Cerium etc are quite meager as compared with the selected radionuclides (UNSCEAR, 2013). ^{238}U was found to be below detectable level (4.7 Bqkg^{-1}) in all vegetable and other food stuffs while ^{232}Th showed a narrow band of 15 Bqkg^{-1} and 35 Bqkg^{-1} . The levels of ^{40}K in the samples were found to vary in a wide range from 60 Bqkg^{-1} to 859 Bqkg^{-1} . From the analysis of ingestion dose for the population in the region, it may be concluded that the average ingestion dose through staple food, would be 1.34 ± 0.37 mSv per annum as estimated from the locally available components of food based on the dietary habit study. Ingestion dose due to whole meal consuming twice daily accounts to 1.08 ± 0.2 mSv per annum. Both the estimates have been made with the assumption that the food items contain ^{238}U at a rate equal to half of the minimum detectable level of 4.7 Bqkg^{-1} of the detecting system.

Though these values commensurate with the acceptable limits, they are slightly higher as compared to other areas in the world having thorium rich monazite sand (Khandaker, M.U et al., 2015). Present study concludes that radionuclide intake from consumption of locally available food items poses no significant health hazard to public health.

Competing financial interest declaration

The authors declare that no competing financial interests exist.

Acknowledgment

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