ABSTRACT

In HBRA, the monazite presence is high compared to other areas located in India. Monazite is a rich source of natural radionuclides like Thorium ($^{232}\text{Th}$), Uranium ($^{238}\text{U}$), Radium ($^{226}\text{Ra}$ & $^{228}\text{Ra}$) and Potassium ($^{40}\text{K}$). The plants and animals uptake these radionuclides from the soil and accumulated in different parts of their tissues and organs. Residents of HBRA’s region are expected to receive significant amount of radionuclides through ingestion of food material, which are grown from HBRA. The bioaccumulation of the radionuclides in the humans would lead to deposit in various organ and tissues, which may lead to health problems. There is a need in assessing the natural radionuclides levels in the dietary sources for the health concern to the public residing in High Background Radiation Areas (HBRA’s).

Primarily, the study was carried using ground radiometric survey to identify the background radiation area in season wise. 137 survey spots were located from the south west – east coast of Tamil Nadu and categorized into 5 blocks based on the background radiation areas. The dose rate for 5 blocks ranges from 167-1,394 nGy/h. The spatial mapping showed no seasonal variation during winter, pre-monsoon, monsoon and post-monsoon. The highest dose rate was observed in block 3 (1,394 nGy/h) and the lowest dose rate was observed in block 5 (167 nGy/h). Similar patterns were observed in hot spot analysis. The annual outdoor effective dose from terrestrial radiation in block 3 is 1.66 mSv/y and in block 5 was 0.27 mSv/y.

Based on the ground radiometric survey, the villages were identified from 5 blocks for recruiting the volunteer participants for duplicate diet sample (DDS) collection. The voluntary participation showed from 3 out of 10 villages. The recruited subjects identified was 161 which corresponds to 33 families. The various age groups such as children (1-11 y), adolescent (12-17 y), adult (18-45 y) & elderly (46+ y) was included in the DDS collection and 24 h food intake was recorded. The 24 h food record intake data showed high food intake in Tengapattinam village rather than Manavalakurichi and Puttetti in all age groups. The average food consumption rate from
3 village is high in adults (738 kg/y) than children (486 kg/y), adolescent (681 kg/y) and elderly (728 kg/y) age groups. The record intake also showed the predominant consumption of the food is cereals contributing 60% in the diet (cooked food) from the study region. The collected diet samples will be analyzed for the natural radionuclide activity.

Based on the food components present in the DDS (uncooked) samples were collected by MBS method. The samples were collected from the HBRA region of block 1, 2 & 3 and from the agricultural field, local markets (vegetable/fish) and animal farm house, where the food samples are grown in this region and available in the market for public consumption. The MBS food samples were classified into 12 categories such as Leafy Vegetables, Other Vegetables, Roots & Tubers, Spices & Condiments, Nuts, Fruits, Fish, Dry Fish, Meat Products, Milk, Cereals and Pulses based on the National Nutrition Monitoring Board (NNMB) and processed for analysis the natural radionuclides activity analysis.

The collected DDS and MBS were processed for the natural radionuclide activity by radiometric instruments. The average concentration of natural radionuclides in DDS were 7 mBq/kg for $^{238}$U & $^{234}$U, 315 mBq/kg for $^{226}$Ra, 334 mBq/kg for $^{210}$Po, ≤710 mBq/kg for $^{228}$Ra and 26 Bq/kg for $^{40}$K (activity represented are in fresh weight). Based on the radionuclide concentration, the total annual intake of natural radionuclides from the food intake was 12,755 Bq/y for children, 17,872 Bq/y for adolescent, 19,352 for adult and 19,091 Bq/y for elderly. Among the natural radionuclides, the highest contribution was from $^{40}$K in the cooked food. The ingestion dose of DDS was high for children 1,071 µSv/y compared to adolescent 819 µSv/y, adults 478 µSv/y and elderly 472 µSv/y.

In MBS, the highest concentration of natural radionuclides was observed in dry fish except $^{228}$Ra which was higher in leafy vegetables. The order of magnitude of natural radionuclides were as follows. $^{238}$U – Dry fish (419 mBq/kg-dry weight) > Milk (122 mBq/L) > Fish (104 mBq/kg-fresh weight) > Meat Products (84 mBq/kg-fresh weight) > Leafy Vegetables (81 mBq/kg-fresh weight) > Spices & Condiments (31 mBq/kg-fresh weight) > Roots & Tubers and Other Vegetables (13 mBq/kg-fresh weight).
weight) > Fruits (5 mBq/kg-fresh weight) > Nuts (≤3.6 mBq/kg-fresh weight), Cereals and Pulses (≤3.6 mBq/kg-dry weight).

\(^{234}\text{U} \) – Dry Fish (365 mBq/kg-dry weight) > Fish (106 mBq/kg-fresh weight) > Meat Products (98 mBq/kg-fresh weight) > Leafy Vegetables (74 mBq/kg-fresh weight) > Milk (69 mBq/L) > Spices & Condiments (27 mBq/kg-fresh weight) > Roots & Tubers and Other Vegetables (12 mBq/kg-fresh weight) > Fruits (5 mBq/kg-fresh weight) > Nuts (≤3.6 mBq/kg-fresh weight), Cereals and Pulses (≤3.6 mBq/kg-dry weight).

\(^{226}\text{Ra} \) – Cereals (3,250 mBq/kg-dry weight) > Dry Fish (1,889 mBq/kg-fresh weight) > Meat Products (1,459 mBq/kg-fresh weight) > Leafy Vegetables (1453 mBq/kg-fresh weight) > Pulses (1,142 mBq/kg-dry weight) > Spices & Condiments (1,013 mBq/kg-fresh weight) > Milk (331 mBq/L) > Fruits (322 mBq/kg-fresh weight) > Fish (284 mBq/kg-fresh weight) > Roots & Tubers (200 mBq/kg-fresh weight) > Other Vegetables (149 mBq/kg-fresh weight) > Nuts (≤130 mBq/kg-fresh weight).

\(^{210}\text{Po} \) – Dry fish (140.8 Bq/kg-dry weight) > Fish (31.6 Bq/kg-fresh weight) > Spices & Condiments (1.8 Bq/kg-fresh weight) > Meat products (1.2 Bq/kg-fresh weight) > Leafy Vegetables (1.03 Bq/kg-fresh weight) > Cereals (0.3 Bq/kg-dry weight) > Roots & Tubers (0.3 Bq/kg-fresh weight) > Fruits (0.06 Bq/kg-fresh weight) > Other Vegetables (0.07 Bq/kg-fresh weight) > Milk (0.03 Bq/kg-fresh weight) > Nuts (≤ 0.03 Bq/kg-fresh weight) and Pulses (≤0.03 Bq/kg-dry weight).

\(^{232}\text{Th} \) – Dry Fish (11.35 mBq/kg-dry weight) > Roots & Tubers (6 mBq/kg-fresh weight) > Meat Products (3.12 mBq/kg-fresh weight) > Leafy Vegetables (2.83 mBq/kg-fresh weight) > Spices & Condiments (1.17 mBq/kg-fresh weight) > Nuts (1 mBq/kg-fresh weight) > Pulses (0.68 mBq/kg-fresh weight) > Other Vegetables (0.65 mBq/kg-fresh weight) > Fruits (0.6 mBq/kg-fresh weight) > Fish (0.37 mBq/kg-fresh weight) > Cereals (0.31 mBq/kg-dry weight) > Milk (0.05 mBq/L).

\(^{228}\text{Ra} \) – Leafy vegetables (5,543 mBq/kg-fresh weight) > Dry fish (4,078 mBq/kg-dry weight) > Meat Products (3,313 mBq/kg-fresh weight) > Cereals (3,194 mBq/kg-dry weight) > Pulses (1,573 mBq/kg-dry weight) > Spices & Condiments (1,466 mBq/kg-fresh weight) > Roots & Tubers (856 mBq/kg-fresh weight) > Fruits
(676 mBq/kg-fresh weight) > Milk (≤360 mBq/L), Fish and Nuts (≤360 mBq/kg-fresh weight).

$^{40}$K – Dry Fish (471 Bq/kg-dry weight) > Pulses (299 Bq/kg-dry weight) > Leafy Vegetables (246 Bq/kg-fresh weight) > Spices & Condiments (214 Bq/kg-fresh weight) > Roots & Tubers (137 Bq/kg-fresh weight) > Cereals (119 Bq/kg-dry weight) > Nuts (108 Bq/kg-fresh weight) > Other Vegetables (95 Bq/kg-fresh weight) > Fruits (81 Bq/kg-fresh weight) > Fish (61 Bq/kg-fresh weight) > Meat Products (26 Bq/kg-fresh weight) and Milk (26 Bq/L).

The total annual intake of natural radionuclides from all food categories showed 19140, 28664, 35528 and 35528 Bq/y and similarly the total ingestion dose was 3072, 4392, 1646 & 1646 µSv/y for children, adolescent, adults and elderly. It was observed that compared to DDS (cooked Food), the MBS (uncooked food) showed higher annual intake, ingestion dose of radionuclides, the calculated life time cancer risk assessment was high, but within the recommended EPA risk limit of $10^{-4}$ population.

The total cancer risk calculated from the DDS was 2.27 $\times 10^{-6}$ for children, 2.78 $\times 10^{-6}$ for adolescent, 2.23 $\times 10^{-6}$ for adults and 9.23$\times 10^{-7}$ for elderly. But from MBS, the risk was observed as 5.11 $\times 10^{-6}$ for children, 7.22 $\times 10^{-6}$ for adolescent 6.44$\times 10^{-6}$ for adult and 2.78$\times 10^{-6}$ for elderly (is it from MBS). It was observed that compared to the EPA recommended cancer risk values our values were lower indicating that there is no threat to the residents of HBRA because of consuming the dietary sources grown in HBRA.

From the hospital based cancer registry, the cancer reported cases were collected from Regional Cancer Center, Trivandrum for the period of the period of 2001-2011, to estimate the prevalence of cancer cases in the study region. The percentage prevalence of cancer cases were 0.42% from 10,969 population for 10 years. In which 13% from Leukemia. The mouth & thyroid cancer was 11%, Lymphoma & Breast cancer was 9%, Lung cancer was 6% and kidney, tongue, stomach, corpus uteri, penis, urinary bladder, and nasopharynx was 4%, pancreas, colon, liver, brain, heart and bone of limbs showed was (2%). The observed cancer cases may be due to other environmental factors like smoking, drugs and other chemicals. Thus the present study clearly showed that there is no significant radiological risk to the public in this region.