Heterogeneity of Radiation Dose to The Population in The West Coast of India

Rani K Pillai	Center for Advanced Research in Physical Sciences, Department of Physics, Fatima Mata National College, Kollam
P J Jojo	Center for Advanced Research in Physical Sciences, Department of Physics, Fatima Mata National College, Kollam
K.Madhukumar	Department of Physics, Mahatma Gandhi College, Thiruvananthapuram

ABSTRACT

External radiation exposures, the second largest source of total dose to human beings originates from terrestrial radionuclides in soil, primarily. Highly diverse distribution of primordial radionuclides in soil could be the cause the of highly varied radiation dose as reported by many. The region under study is known to have high deposits of monazite sand containing several minerals and radionuclides. There are several reports of radionuclide levels in different parts of the beach sand having a wide range of activity levels. The present investigation aims at the study of extend of radionuclides distribution in soil hence to assess the dose levels and other major radiation parameters. Activities of soil borne primordial nuclides namely 238U, 232Th and 40K were assessed using Gamma ray spectrometry. The specific activities were found to vary two to three orders of magnitude. Radium equivalent activity, external hazard index and internal hazard index were estimated for different zones in the coastal region of Kerala.

INTRODUCTION

The ubiquitous radiation has its origin from primordial, cosmogenic and manmade radionuclides. Primordial radionuclides are present in earth right from its creation. They are usually long lived, with half lives of the order of millions of years. There are more than 250 stable and about 30 primordial radionuclides on earth major of which are ^{40}K, ^{238}U, and ^{232}Th. Cosmogenic radionuclides are produced as the consequence of cosmic ray interactions with atmosphere and do not add significantly to external gamma radiation doses. ^{10}Be, ^{26}Al, ^{36}Cl etc are the examples of cosmogenic radio nuclides. Tritium (^3H), ^{131}I, ^{137}Ce are the examples of manmade radionuclides. The contribution of primordial and cosmogenic radiation towards the background radiation is almost constant and the globally it is 3.1 mSv per annum (NCRP-160, 2006). High background radiation levels are found in many parts of the world including south west coastal region of Kerala. The high background radiation in this region is due to the thorium rich monazite sand. Monazite, is a highly insoluble rare-earth mineral that occurs in beach sand together with Ilminite. The most abundant radionuclides in monazite originate from ^{232}Th decay series, Uranium and its progeny ^{226}Ra. With an intention to study the diverse distribution of these radionuclides in soil, we conducted an investigation in the coastal region of Thiruvanathapuram to Alappuzha Districts of Kerala. The study area was divided into seven zones with six of them in the high background radiation area and the remaining one in the normal area. The sites for the study were preferred in a grid manner at almost equal distances from the coast towards the National Highway (NH47). The average distance between the sites was about 100m. About ten locations were chosen in Normal background radiation (NBRA) region in eastern side of Highway in Kollam and Thiruvanthapuram districts. The coastal plain of Kerala comprises a special ecological variety. The Coastal region of Kerala is the low land fringing the sea extending over 560 krn about 15 % of the state's total area. The coast is well known for several places of historical importance, heritage areas and areas of outstanding natural scenic beauty. Most of the dynamic processes which have been occurred within the coastal zones produce diverse and productive ecosystems.
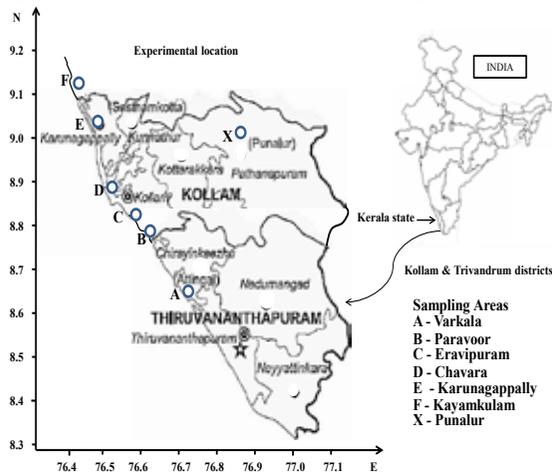
EXPERIMENTAL

Location of Study area

Altogether hundred and fifty locations were selected along the coastline from Thiruvanandhapuram to Alappuzha District for the investigations. Two or more soil samples were collected from each location. The selected zones were centered at Varkala, Paravoor, Eravipuram, Chavara, Karunagappally, Kayakulam which are represented as A,B,C,D,E and F respectively . The Normal background zone, Punalur was demarcated as X. Figure 1 shows the locations chosen for the study.

Sampling and Sample Preparation

Samples were collected following the ASTM protocol from the locations in the specified zones in the costal districts of Kerala. Collected soil samples were dried at 110^0 C for 24 h to remove moisture. All the samples were turned into fine homogeneous powder and were stored in the polyethylene cans of specific size (70 mm diameter and 80mm height) for the analysis using 3" x 5" Na I Gamma Ray Spectrometer. Sealed airtight containers were kept for about six week's period to ensure the secular equilibrium between ^{226}Ra (of the ^{238}U) and ^{232}Th and their radioactive progenies. The measurements were carried out in three main steps: energy calibration, sensitivity calibration and gamma-ray analysis. The energy calibration was carried out by two radioactive calibration sources, ^{137}Cs and ^{57}Co. The sensitivity calibration was achieved by using three artificial standard sources of Ra, Th and K. The activity of ^{40}K was evaluated from the 1460 keV photo peak of its own gamma, the activity of ^{238}U from 1764 keV gamma ray of ^{214}Bi and that of ^{232}Th from 2614 keV gamma ray of ^{208}Tl. The counting times of sample were 10000s and that of background is 60000s for obtaining the net activity. Minimum Detectable Level (MDL) of this spectrometer for the ^{40}K, ^{226}Ra and ^{232}Th were 27 Bqkg⁻¹, 5 Bqkg⁻¹ and 14 Bqkg⁻¹ respectively.

Figure 1 The zones selected for the investigations

$^{-1}$).

Internal Hazard Index is defined as (NCRP-160, 2006; Belaf-rites & Ahmed Tedjani 2012)

$$H_{In} = \frac{AR_a}{185} + \frac{ATh}{259} + \frac{Ak}{4810} \qquad (4)$$

Where A_{Ra}, A_{Th} and A_K are the activity concentrations in Bq kg^{-1} for ^{226}Ra, ^{232}Th and ^{40}K, respectively. H_{In} should be less than unity for the radiation hazard to be negligible.

RESULT AND DISCUSSIONS
The maximum, minimum and mean values of specific activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th in soil samples from the different sampling zones are shown in the table 1. Activity concentrations of ^{40}K was observed from 29±14 to 5761±82 Bqkg^{-1}, that for ^{226}Ra was found to vary from 15±2 to 1646±209 Bqkg^{-1} and for ^{232}Th the range was from 35±1 to 3387±321 Bqkg^{-1}. In the Normal Background Region the average values of ^{40}K, ^{226}Ra and ^{232}Th were 144±36 Bqkg^{-1}, 60±43 Bqkg^{-1} and 49±34 Bqkg^{-1} respectively. The world average value of activity concentrations for ^{40}K, ^{226}Ra and ^{232}Th are 110±66 Bqkg^{-1}, 60±63 Bqkg^{-1}, 45 Bqkg^{-1} respectively (UNSCEAR 2000). It can be seen that the maximum values are many fold of their respective minimum concentrations, reiterating the heterogeneous distribution of the radionuclides in the area.

Radium Equivalent Activity
The radium equivalent (Ra$_{eq}$) activity represents a weighted sum of activities of ^{226}Ra, ^{232}Th and ^{40}K. For assessing the hazardous effect of all the three radionuclides, a common index has been used to represent the collective activities of ^{226}Ra, ^{232}Th and ^{40}K due to the non uniformity of radioactivity in the soil samples, termed as radium equivalent activity (Ra$_{eq}$) (Belafrites & Ahmed Tedjani 2012).

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.07C_K \qquad (1)$$

Where C_{Ra}, C_{Th} and C_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K, respectively. This formula is based on the estimation that 1 (Bqkg^{-1})of ^{238}U, 0.7 Bq /kg of ^{232}Th and 13 Bq/ kg of ^{40}K produce the same γ-ray dose rates.

External gamma dose

UNSCEAR (1988) has given the dose conversion factors for estimating external gamma ray dose due to the primordial radionuclides ^{226}Ra, ^{232}Th and ^{40}K as 0.427, 0.662 and 0.043, (nGy.h^{-1} per Bq.kg^{-1}) respectively. The external doses to the population living in the area due to gamma ray radiation originating from the primordial radionuclides in soil were estimated from the equation:

$$D = 0.427\ A_{Ra} + 0.662\ A_{Th} + 0.043\ A_K \qquad (2)$$

Where D is the dose rate in nGy.h^{-1} and A_{Ra}, A_{Th}, A_K are the concentrations of Radium, Thorium and Potassium, respectively (NCRP-160, 2006; Belafrites & Ahmed Tedjani 2012)

Radiation Hazard Indices
Radiation hazard indices are used to evaluate the effects of radiation on the health condition of people exposed to radiation and the environment. The important parameters to evaluate health hazard due to natural gamma radiation are External hazard index H_{Ex}, Internal hazard index H_{In} and Gamma index I_γ.

External Hazard index is defined as:

$$H_{Ex} = \frac{AR_a}{370} + \frac{ATh}{259} + \frac{AK}{4810} \qquad (3)$$

Where A_{Ra}, A_{Th} and A_K are the activity concentrations in Bq kg^{-1} for $_{226}$Ra, $_{232}$Th and $_{40}$K, respectively. The value of this index must be less than unity in order to keep the radiation hazard to be insignificant. The maximum value of H_{ex} equal to unity corresponds to the upper limit of Ra$_{eq}$ (370 Bq kg

Zone		Specific Activity of ^{40}K (Bqkg^{-1})	Specific Activity of ^{238}U (Bqkg^{-1})	Specific Activity of ^{232}Th (Bqkg^{-1})
Varkala (A)	Max	1214± 148	244.15±12	1505±89
	Min	121 ± 28	16±1	35±1
	Mean	**479±261**	**105±62**	**309±302**
Paravoor (B)	Max	790± 80	201±51	409±20
	Min	93± 18	15±2	69±7
	Mean	**441±225**	**241±114**	**73±50**
Eravi-puram (C)	Max	2335±22	1399±401	730±12
	Min	29±14	18±5	36±51
	Mean	**465±46**	**143±159**	**191±161**
Chavara (D)	Max	5761±82	1646±209	3387±321
	Min	215±31	132±41	112±7
	Mean	**1446±133**	**610±540**	**766±775**
Karuna-gappally (E)	Max	3496±368	1411±101	1433±112
	Min	165±48	96±18	44±16
	Mean	**775±594**	**269±222**	**312±304**
Kayam-kulam (F)	Max	648±72	288±15	362±24
	Min	80±5	46±35	39±65
	Mean	**308±230**	**85±76**	**133±73**
NBRA (X)	Max	165±24	76±12	124±26
	Min	129±8	39±32	20±18
	Mean	**144±36**	**60±43**	**49±34**

Table 1 Activity concentrations of the soil samples

The calculated radium equivalent activity (R$_{eq}$) was found to vary from 334 Bqkg^{-1} to 6661 Bqkg^{-1} with an average of 1812 Bqkg^{-1}. This value is much higher than the world average of 370 Bqkg^{-1} reported by Organization of Economic and Control Department (OECD-1979; S. Harb et al.2008; G. Viruthagiri, B. Rajamannan & K. Suresh Jawahar, 2013). Figure 3 represents the comparison of radium equivalent activity in different zones. In the Normal Background Region the value of radium equivalent activity (R$_{eq}$) was found to vary from 53 Bqkg^{-1} to 257 Bqkg^{-1} with an average of 138 Bqkg^{-1} which is lower than world average (UNSCEAR, 2000; M. Idrish Miah, 2001). Among the seven

Research Paper

zones we studied, Chavara zone was found to show the highest value of mean R_{eq} and that too with a wide range varying from 334 ± 36 Bqkg^{-1} to 6661 ± 1736 Bqkg^{-1}. For the other six zones the value of R_{eq} was almost same with a very minute variation.

Figure-3 Comparison of Radium equivalent activity of different locations
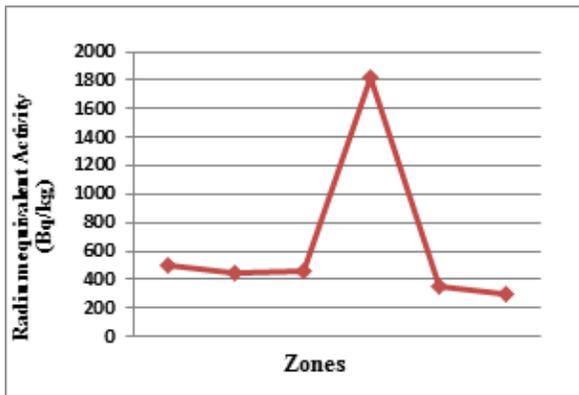

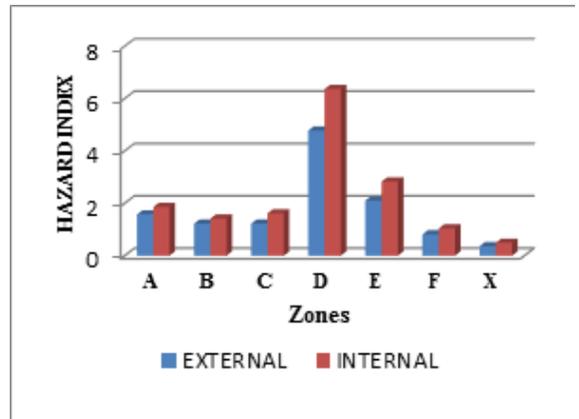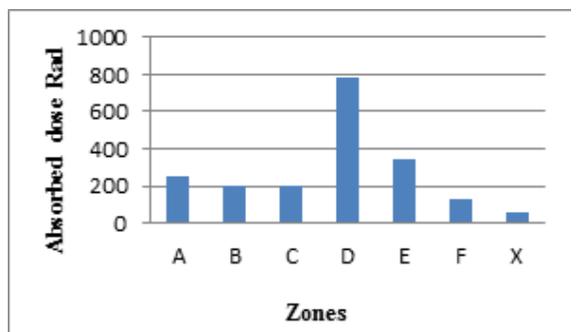**Figure 4: Comparison of hazard indexes in different locations**

Figure 5: variation of absorbed dose in different location

Conclusions:

The indoor gamma ray dose rate in the HBRA areas (Chavara and Karunagappally) surveyed is similar to those reported in the earlier studies in the region (Mary Thomas et al, 2012). The heterogeneity of the distribution of radionuclides in the HBRA regions are very evident from the range of standard deviations expressed as the uncertainties in the results. Among the seven zones we studied, Chavara zone was found to show the highest value of mean R_{eq} and that too with a wide range and heterogeneity. For the other six zones the R_{eq} was within a narrow range. Having such a high heterogeneity for the concentrations of primor-

dial radionuclides, indicates the insignificance of figuring out an average dose estimate representative for the region. Same is the case with risk assessments for the population.

References

1. NCRP 160, (2006) National Council on Radiation Protection and Measurements

2. D Abdelfettah Belafrites and Ahmed Tedjani (2012) .Natural radioactivity in Algerian building materials Journal of Physical Science and Application 2 (6) (2012) 171-174

3. Organization for Economic Cooperation and Development (OECD) (1979) Exposure to radiation from the natural radioactivity in building materials. Report by a group of experts of the OECD Nuclear Energy Agency (Paris, France: OECD),

4. S. Harb, A. H. El-Kamel, A. I. Abd El-Mageed, A. Abbady, and Wafaa Rashed (2008), Concentration Of U-238, U-235, Ra-226, Th-232 And K- 40 For Some Granite Samples In Eastern Desert Of Egypt. , Proceedings of the 3 rd Environmental Physics Conference, Aswan, Egypt

5. G. Viruthagiri, B. Rajamannan And K. Suresh Jawahar (2013) Radioactivity and associated Radiation Hazards In Ceramic Raw materials And End Products Radiation Protection Dosimetry Advance Access published June 13, 2013

6. UNSCEAR (2000) United Nations Scientific Committee on the Effects of Atomic Radiation Sources and effects of ionizing radiation. Report to General Assembly, with Scientific Annexes (New York: UN) (2000).

7. M. Idrish Miah(2001) .Study on the variation of indoor gamma radiation in the Dhaka district . Radiation Protection Dosimetry Vol. 95(4), 365–370.

8. Mary Thomas Derin, Perumal Vijayagopal, Balasubramaniam Venkatraman, Ramesh Chandra Chaubey, Anilkumar Gopinathan (2012) Radionuclides and Radiation Indices of High Background Radiation Area in Chavara-Neendakara Placer Deposits (Kerala, India) PLoS One. 2012; 7(11): e50468. http://dx.doi.org/10.1371/journal.pone.0050468