



RADIOACTIVE POCKETS IN THE SOUTHERN SEASHORE OF KERALA, INDIA

Physics

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ABSTRACT

There are quite a few identified monazite sand-bearing placer deposits causing environmental high radiation area along its long coastline of Kerala and Tamil Nadu in India. The extent and effects of the radioactivity in the regions like Chavara and Neendakara in Kollam, Kerala is well known. Following a pilot study along the southern west coast of Kerala state, India we found certain regions with higher levels of natural radioactivity and hence made a detailed investigations of ambient gamma levels in those locations namely Perumathura, Kovalam and Varkala. Estimation of external gamma dose levels based on soil spectrometry was carried out. The results show that more than 90% of samples have higher specific activities for ^{238}U and ^{232}Th in the soil collected from the region with a mean absorbed dose rate of $176 \pm 73 \text{ nGyh}^{-1}$ in Perumathura, $161 \pm 29 \text{ nGyh}^{-1}$ in Kovalam and $197 \pm 162 \text{ nGyh}^{-1}$ in Varkala.

KEYWORDS:

Radionuclides, Natural radioactivity, gamma ray spectrometer, Radiological hazard parameters

Introduction

Weathering and erosion of rocks are the main cause for the formation of mineral deposits in beach sand and soil. These deposits found at different levels within the sand contain natural radionuclides that contribute to ionizing radiation exposure on earth. The UNSCEAR 2000 reports that about 87% of the radiation dose received by mankind is due to natural radiation sources while the rest is contributed by anthropogenic radiation. Most of natural radioactive elements present in soil are primordial radionuclides originating from the uranium series, thorium series, and ^{40}K . The gamma ray exposure of the body and irradiation of lung tissue from inhalation of radon and its daughters are implied by these radionuclides. Therefore, the study of gamma radiation dose from natural sources is vital as it becomes the major contributor of external radiation dose to the world population. (UNSCEAR, 2000).

Known high background radiation areas (HBRA) in the world are at Ramsar (Iran), Yangjiang (China), Guarapari (Brazil), the northern Flinders ranges in Australia and the coastal belt of Kerala and Tamilnadu (India). The central parts of France have granitic and schistous rocks and sands in an area in the southwest of that country is one of many associated with uranium minerals in soil (Radhakrishna et al., 1993; Herb, 2008, UNSCEAR, 2000, Ben Byju et al., 2012).

Findings of very high thorium and uranium in the monazite rich sand in the Chavara, Neendakara, Karunagappally in the state of Kerala and Manvalakurichi in Tamilnadu state are available in literature. (Narayana Y et al., 2005, Kannan V et al. 2002.). We have conducted a pilot study of environmental gamma levels along the coastline between Neendakara and Manavalakurichi, the two regions where the HBRA's exist. Three intervening locations namely Perumathura, Kovalam and Varkala along this stretch of coast were found to have elevated levels of ambient gamma. Incidentally these three locations are famous tourist destinations with thick population. These shallow beaches attract tourists from India and abroad. Perumathura is a small hamlet located 26 km towards North from District head quarters Thiruvananthapuram. Kovalam has three beaches separated by rocky outcroppings in its 17 km coastline and the three together form the crescent of the Kovalam beach. Varkala is a coastal town located 50 km north-west of Thiruvananthapuram (Trivandrum).

After identifying these locations, we conducted an intensive study on the radiation levels and its cause. The objective was to estimate the

additional radiation burden on the inhabitants of the region and the probable radiological consequences. In addition to the floating population (tourists) average population in these regions are about 60,000 each.

Materials and Method

Sampling and sample preparation

Kerala state is situated on the southwest coast of India and has nearly 600 km of Arabian Sea shoreline. Perumathura, Kovalam and Varkala belong to the district of Thiruvananthapuram, the state capital. For assessing the ambient radiation levels an extensive direct dose measurements were carried out in 630 locations along the coast between Neendakara and Manavalakurichi using a scintillator based dosimeter. Several locations were found to have elevated levels of gamma radiation and most of them were highly localised. We have chosen three regions where a large area has higher natural radioactivity levels. Assessments of gamma dose in the dwellings and spectrometric studies of soil in these three regions were carried out..

Each sample was taken maintaining a distance of about 200 m from each other. About 0.75 - 1.00 kg of sample was collected from each location. These samples were first weighed, and then dried at 110°C in a dry air oven for 24 hours. The homogenized and sieved samples were transferred to cylindrical plastic container of 7 cm height and 5.5 cm in diameter. All the sample containers were sealed hermetically and were stored for eight weeks to ensure the secular equilibrium between ^{226}Ra (of the ^{238}U) and ^{232}Th and with their radioactive progenies.



Fig.1 The experimental regions along the southern coast of Kerala

Gamma spectrometric analysis

Analyses of soil samples collected from the three regions as well as neighbouring locations were carried out using gamma ray

spectrometry using 5" x 4" NaI (TI) detector coupled with a 1K multichannel analyzer. Detector was mounted in 3" thick lead well with movable lid having the same thickness and the system is connected with a dedicated PC for data storage and analysis. The counting period for samples and background was set for 60000 s. The activity of 40K was evaluated from the 1460KeV photo peak of its own gamma, the activity of 226Ra from 1764KeV gamma of 214Bi and that of 232Th from 2614KeV gamma of 208Tl in its series. The Minimum Detectable Levels (MDL) of the isotopes were determined as 4.7 Bqkg⁻¹ for uranium, 14.3 Bqkg⁻¹ for thorium and 27.18 Bqkg⁻¹ for potassium. The shielding for the detector housed in the first floor of the lab with 3" thick high grade lead well reduced the background radiation. The gamma spectra of the samples were recorded using a PC based multichannel analyzer and were processed using a software WinTMCA32 of ScintiSPEc

Radiation Dose estimation

Absorbed gamma dose rate (D_r)

By neglecting the other radionuclides, such as ¹³⁷Cs, ⁹⁰Sr and ²³⁵U decay series as they contribute very little to the total dose from environmental background. The outdoor air-absorbed dose rate was estimated from ²³⁸U, ²³²Th and ⁴⁰K concentrations in soil. The dose conversion factors used for ²³⁸U, ²³²Th and ⁴⁰K were 0.462, 0.604 and 0.042 respectively (UNSCEAR2000)

$$D_r(\text{nGy h}^{-1}) = 0.462C_u + 0.604C_{th} + 0.042C_k$$

C_u - concentration of U (Bqkg⁻¹)

C_{th} - concentration of Th (Bqkg⁻¹)

C_k - concentration of K (Bqkg⁻¹)

Annual effective dose equivalent (AEDE)

To determine the annual effective dose rates, one has to consider the conversion coefficient from the absorbed dose in air to the effective dose received by adults (0.7 SvGy⁻¹) and the outdoor occupancy factor (0.2) which implies that 20% of the time people spend outdoors, on the average, around the world proposed by UNSCEAR (2000) were used

$$AEDE = D_r(\text{nGy/h}) \times 8760\text{h} \times 0.2 \times 0.7\text{SvGy}^{-1} \times 10^{-6}$$

$$AEDE (\text{mSv y}^{-1}) = D_r \times 0.00123$$

Radium equivalent activity

Owing to uneven distribution of radionuclides in soil in this region, a common radiological index known as radium equivalent activity, Ra_{eq} has been determined. It provides the safety standard in radiation protection for a human population (UNSCEAR 1993). It can be calculated by the following formula:

$$Ra_{eq} = C_u + 1.43 C_{th} + 0.077 C_k$$

The assumption is that 370Bqkg⁻¹ of ²³⁸U, 259 Bqkg⁻¹ of ²³²Th, 4810 Bqkg⁻¹ of ⁴⁰K produces the same gamma dose rate. Ra_{eq} is related to external gamma dose received by the population (Ravisankar et al; 2014b;NEO-0ECD,1979).

Annual gonadal dose equivalent (AGDE)

Somatic mutation is a consequence of elevated level of natural radiation along with the possibility of modifications in the genetic cells. AGDE estimates the genetic significance of annual dose equivalent received by population's reproductive organs. This is due to the specific activities of ²³⁸U, ²³²Th and ⁴⁰K was calculated using the following formula. (Ravisankar et al;2015).

$$AGDE(\text{mSv y}^{-1}) = 3.09C_u + 4.18C_{th} + 0.314C_k$$

Radiation hazard indices

External hazard index (H_{ex})

H_{ex} is used to find out the radiological suitability of a material. The main intention of this index is to limit the radiation dose to the permissible dose equivalent limit of 1mSv/y (ICRP60) and was evaluated using the equation,

$$H_{ex} = \frac{C_u}{370 \text{ Bq/kg}} + \frac{C_{Th}}{259 \text{ Bq/kg}} + \frac{C_K}{4810 \text{ Bq/kg}}$$

The value of external hazard index must be lower than unity for insignificant radiation hazard.

Excess lifetime cancer risk (ELCR)

The additional or extra risk of developing cancer is due to exposure to a toxic substance incurred over the lifetime of an individual (Ravisankar et al;2014b). The excess lifetime cancer risk (ELCR) was estimated using the equation:

$$ELCR = AEDE \times DL \times RF$$

AEDE - Total annual effective dose equivalent

DL - Duration of life (Taken as 70y)

RF- risk factor (Sv⁻¹). For stochastic effects, ICRP 60 uses 0.05 for the public (Taskin et al.,2009).

Results and Discussion

The representative values of specific activity of radionuclides, radium equivalent activity, absorbed dose rate and annual effective dose rate of primeval radionuclides ²³⁸U, ²³²Th and ⁴⁰K in soil samples collected from Perumathura, Kovalam, Varkala and other 20 locations along the coast are given in Table-1. Since the measured values were found to vary widely from location to location, we have presented Arithmetic mean (± Standard deviation) as well as Geometric mean (Geometric standard deviation) so that the extent dispersion from the representative values is well understood.

Table 1

Representative values of specific activity of radionuclides, radium equivalent activity, absorbed dose rate and annual effective dose rate

Region		Specific Activity (Bqkg ⁻¹)			Raeq (Bqkg ⁻¹)	Absorbed Dose Rate (nGyh ⁻¹)	Annual effective dose rate (mSvy ⁻¹)
		C _k	C _u	C _{th}			
Perumathura (N = 20)	Ari. Mean ± SD	287±187	180±78	134±92	394±168	176±73	0.22±0.09
	Geo. Mean (G. Std. Dev)	180(3.7)	156(1.9)	102(2.3)	342(1.8)	153(1.8)	0.19 (1.8)
Kovalam (N = 20)	Ari. Mean ± SD	46±21	54±21	219±52	375±69	161±29	0.20±0.04
	Geo. Mean (G. Std. Dev)	23(2.9)	39(1.4)	214(1.2)	370(1.1)	159(1.2)	0.19(1.1)
Varkala (N = 20)	Ari. Mean ± SD	227±109	173±74	128±55	445±381	197±162	0.24±0.2
	Geo. Mean (G. Std. Dev)	196(1.8)	151(1.8)	107(1.7)	348(2.1)	155(2.1)	0.19(2.1)
Other locations (N = 20)	Ari. Mean ± SD	354±68	56±12	46±10	149±28	68±18	0.08±0.02
	Geo. Mean (G. S.Dev)	352(1.1)	55(1.1)	44(1.1)	147(1.1)	67(1.1)	0.08(1.1)

In Perumathura the range and mean values (in brackets) of the activities for ⁴⁰K, ²³⁸U and ²³²Th were 27–663(287), 20–312(180) and 12–392(134) Bqkg⁻¹ respectively. But in Kovalam the range of activities for ⁴⁰K, ²³⁸U and ²³²Th were 27–250 (46)Bqkg⁻¹, 34–98 (57)Bqkg⁻¹ and 156–358(219) Bqkg⁻¹ respectively. In Varkala the distribution of activity concentration of ⁴⁰K, ²³⁸U and ²³²Th were 42–446 (227), 20–311(173) and 12–1198(128)Bqkg⁻¹ respectively. The average

and geometric mean of specific activity of ⁴⁰K, ²³⁸U and ²³²Th are also displayed in the table. It can be seen that except for ⁴⁰K, the specific activities of the isotopes are higher as compared with the neighbouring locations and consequently the dose rates are also higher for the three study regions as compared with the other locations along the coast. The global average of ⁴⁰K, ²³⁸U and ²³²Th in soil is 420, 35 and 45 Bq kg⁻¹, respectively. These values for the Indian subcontinent are 394, 31 and 63 Bq kg⁻¹, respectively (UNSCEAR 2000).

The uneven distribution of radioactivity in soil has been observed for all the three regions under study. The variation among radionuclides in beach soil may be due to the continuous wave action, results in the deposition of heavy minerals along the sea shore (Herb et al., 2008; Ravisankar et al; 2015). The heterogeneity is seen quite less in the other locations, where normal background radiation prevails, as understood from the arithmetic and geometric mean values.

The range of absorbed dose rate in air due to terrestrial radionuclides in Perumathura ranges from 18 to 324 nGyh⁻¹ with a mean of 176nGyh⁻¹. In Kovalam the range of absorbed dose rate due to natural radionuclides was from 133 to 251nGyh⁻¹ with a mean of 161nGyh⁻¹ and in Varkala, the absorbed dose rates were found to vary from 18 to 820 with an average value of 197nGyh⁻¹. All these values are higher than the world average of 60nGyh⁻¹ given by UNSCEAR(2000). Other 20 locations out of the experimental regions show comparable dose rates with the world average.

The annual effective dose equivalent obtained from the investigation are higher than the world average of 0.07mSv⁻¹. The average value of annual gonadal dose equivalent (Table-2) in Perumathura, Kovalam and Varkala are 1.21mSv⁻¹, 1.11mSv⁻¹ and 1.35 mSv⁻¹ respectively. These values are higher than threshold limits recommended by ICRP (1.0 mSv/y⁻¹) as permissible recommended limit. (Mary Thomas Derin et al., 2012).

Table 2

Radiological parameters in soil samples of study area.

Location		Hex	ELCR x 10 ⁻³	Annual Gonadal Dose (mSv ⁻¹)
Perumathura	Maximum	2.01	1.40	2.24
	Minimum	0.11	0.08	0.13
	Mean	1.07	0.76	1.21
	Standard Dev.	0.46	0.32	0.50
	Geometric Mean	0.93	0.66	1.06
	Geo. Standard Dev	1.9	1.9	1.9
Kovalam	Maximum	1.59	1.08	1.73
	Minimum	0.84	0.57	0.92
	Mean	1.01	0.69	1.1
	Standard Dev.	0.19	0.12	0.20
	Geometric Mean	1.00	0.69	1.1
	Geo. Standard Dev	1.1	1.1	1.1
Varkala	Maximum	5.19	3.53	5.67
	Minimum	0.11	0.08	0.13
	Mean	1.20	0.85	1.35
	Standard Dev.	1.03	0.70	1.12
	Geometric Mean	0.94	0.67	1.07
	Geo. Standard Dev	2.1	2.1	2.1

Radiological consequence of the elevated levels estimated in terms of external hazard index (Hex) and excess lifetime cancer risk (ELCR) for the three study regions are given in Table 2. The calculated average values of external hazard index and ELCR are slightly higher than the acceptable limits of 1 (ICRP60) and 0.29 x10⁻³ (UNSCEAR 2000) respectively

Conclusion

The three regions under investigation Perumathura, Kovalam and Varkala have higher specific activities for ²³⁸U and ²³²Th. The mean values of absorbed dose rates in the study regions are about three times higher than the world average of 60nGyh⁻¹. The annual effective dose rate of normal back ground radiation area is 0.46mSv/y. The obtained mean annual effective dose values are within the permissible limit. The annual gonadal dose rate from the study areas are slightly higher than the permissible limit. The value of Ra_{eq} in Kovalam and Perumathura are slightly high compared to the criteria limit(370Bq/kg). But Varkala showed very high Radium equivalent activity. Higher ELCR values are noticed in the study area. This may be due to the higher value of activity of radionuclides in this location. The

external hazard indices are also slightly high, compared to the criteria limit. However, the results of radiation Risk indices reflect that the investigated area of East coast of Kerala pose some significant radiological health risk to human beings living in that area.

Competing financial interest declaration

The authors declare that no competing financial interests exist.

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