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Distribution patterns of natural radioactivity and delineation of anomalous radioactive zones using in situ radiation observations in Southern Tamil Nadu, India

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Abstract

In situ radiation measurements in the beach sectors and adjacent hinterlands and along rivers in the interiors of southern peninsular India were carried out using a portable radiation survey meter. A very high intrinsic anomalous radioactivity >26 μGy/h has been observed in the hinterlands within a fresh quarry and weathered boulders in the syenite rock body around Puttetti in the western Kanyakumari district of southern Tamil Nadu. Over the weathered hillocks in the hinterlands adjacent to the coast around Inayam, Kurumpanai and Midalam, the in situ radiation measurements have also exhibited high radioactivity ranging from 4 to 22 μGy/h which is significantly higher than the radiation exposure rates (RER) observed along the beach sectors at various locations from Chavara to Tuticorin (1–14 μGy/h). The observed radiation levels are presumably the highest concentration in southern India and it is the first time that such a high intrinsic radiogenic source in the hinterlands is reported in southwest coast of India. It is also observed based on the laboratory analysis of samples and in situ radiation data that the rivers/channels in this region contain insignificant level of radioactivity concentration and hence they do not contribute much to the placer deposits on the beaches. The placer deposits associated with significant RER (both in situ observations as well as laboratory estimates from samples) in the beach sectors from Kadiapattanam to Inayam are inferred to be derived through the country rocks/weathered hillocks in the immediate hinterlands.

Keywords: Natural background radiation (NBR); Southern Peninsular India; Radioelements; Hinterlands; Petrologic microscope; Radiation exposure rates (RER)

1. Introduction

Many areas in the world such as Australia, Brazil, China, India, Iran, Japan, etc., possess high levels of natural radiation. In the recent years, studies on high natural background radiation areas in the world have been of prime importance for risk estimation due to long-term low-level whole body radiation exposures to the public. The high radiation levels are due to the presence of large quantities of naturally occurring radioactive minerals in the rocks, soils, water, etc., to some extent due to the cosmic ray latitude effect, and residual radioactivity from fallout of nuclear bomb explosions including nuclear reactor leaks. The most important places among the well documented high natural background radiation (NBR) areas of the world inhabited by large populations are: Guarapari in Brazil [1], Yangjiang in China [2], Chavara and Manavalakurichi in India [3], and Ramsar in Iran [4–6]. While the source of the high background radiation is monazite deposits in the first three cases, radium in soil/water and radon in air are the sources of high background radiation in Ramsar (Iran). The radiation levels in Ramsar (Iran), where the personal dose ranges up to 132 mGy/y, which is about four times higher than those reported from the above two countries [7]. With the increased public concern over radiation safety, the studies on natural background radiation areas provide a good scope for evaluating biological effects caused by low-level radiation exposures on a long-term basis [8]. It is an established fact that the radioactivity is harmful to the living beings, however small it may be. Natural background radiation comes from three

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primary sources: cosmic radiation, terrestrial sources, and radon. The worldwide average background dose for a human being is about 2.4 mGy/year. This exposure is mostly from cosmic radiation and natural isotopes in the Earth. The terrestrial radiation varies from place to place, which depends on geological environment, type of living accommodation and elevation above the sea level. Various scientific investigations have been conducted in those areas to collect information on radiation doses and their health effects, contributing greatly to advancing our knowledge [9].

Southwest coast of India is known since long as one of the high-level natural background radiation areas in the world [9–17]. Natural radiation levels in this region are higher than normal which are believed to be emitted from the rich deposits of the monazite bearing beach sands. The mineral monazite contains radioelements, which is the main cause for natural radiation in the southwest coastal belt. The important localities possessing high radioactivity levels along the southwest coastal belt are the Chavara–Neendakara in Kerala coast, and the Manavalakurichi–Kadiapattanam–Midalam in southern Tamil Nadu coast. The heavy minerals are abundant in the pegmatite veins within Precambrian rocks in the hinterlands as reported through the geological studies on samples [3,18]. In general, the weathered products of country rocks from the interior hinterlands containing radioactivity are transported by the rivers and deposited at the down stream and along the coastal region as placer deposits and this process is controlled largely by the geomorphologic (drainage patterns) and atmospheric (rainfall) set up in the region. It seems, these two parameters contribute a little to the transport process of weathered products in southern Tamil Nadu regions due to limited rainfall and low gradient river systems. The combined effect of weathering, rivers and streams, morphological features of the river basins and their interaction with the sea influenced the distribution of the heavy minerals in the beach sectors along the southwest coastal zone.

The study area is a southern part of Western Ghats in Southern Tamil Nadu and is bounded by coastal belt to the west and east side. The region is mostly confined in two districts namely Kanyakumari and Tirunelvelli districts. The southern part (Kanyakumari district) is thickly populated as compared to northern portion (Tirunelvelli district). According to 2001 Census of India, total population living in the region is 44 lacs with a population density 701/km^2 and 400–500/km^2 in Kanyakumari and Tirunelvelli districts, respectively. The male and female population living in Kanyakumari district is almost equal but number of females in Tirunelvelli district is more than males by about 55,000. Thick population lives in and around the area in Kanyakumari district where high natural radiations are observed in the present study.

Though significant concentration of natural radioactivity is present at certain locations in the southwest coastal belt but no systematic investigations employing geophysical survey techniques was carried out so far in this region to map its distribution and understand radiogenic sources in the hinterlands. With this background, a study has been initiated to understand general distribution pattern of natural radioactivity and to delineate anomalous radioactive zones in the hinterlands using portable radiation survey meter and Digi counter [17]. Measurements of radioactivity were made all along the beach sector; the connected inland regions over weathered/terai sand hillocks and exposed rocks and also along the rivers/channels/rivulets in the region. In addition, bulk samples of sand/soil/sediments and rocks were also collected from the important locations in three physiographic features, i.e. beach sector, river courses and hinterlands to correlate laboratory estimates of radioactivity with the in situ radioactivity measured at each sample point. The study yielded to trace a major anomalous radiation zone in the hinterlands, which is the highest ever noticed in the region and also in certain pockets along the southwest coastal belt of India. The details of the findings are discussed in this paper.

2. Geology of the study area

The present ground radiometric surveys were conducted in southern Tamil Nadu region enclosed by latitude 8.2–9.0°N and longitude 77.0–78.2°E (Fig. 1), which include largely of Kanyakumari and Tirunelvelli districts. It has a stretch of about 60 km of beach length in the west coast from Kanyakumari to Tangapattanam and about 110 km in the east coast from Kanyakumari to Tuticorin. The terrain comprises largely of Precambrian crystalline rocks of charnockites, khondalites and migmatitic gneisses. Beach deposits are derived from the adjacent hinterlands mainly from charnockites, khondalites, biotite-gneisses. The topography is mild with an elevation not exceeding 60 m at places in the coastal belt in which crystalline rocks are highly weathered to laterite. A syenite body, belonging to the group of alkaline rocks of Precambrian—Early Paleozoic taphrogenic magmatism, is present around Puttetti in the western part of the Kanyakumari district area, which is an important geological feature from the viewpoint of radioactivity concentration [18].

Other important geological features in the eastern and southern parts of this region are extensive dunes with terai sands. The study area can broadly be classified in to three basins viz.; Kumari basin, Nambiyar basin and Tambraparni basin and rivers draining these basins are mostly seasonal. The rivers draining the Kumari basin are; Tambraparni west (Kanyakumari district), Valliyar, Eraniel, Puthanar, Pazhayar, Paralayar, Kodayar and their tributaries. Nambiyar, Karamanaiyar, Hanuman, Uppar and their tributaries drain the Nambiyar basin. The Tambraparni basin is drained by Tambraparni east (Tirunelvelli district), Chittar, Pachayar and Uppadaiyar rivers. The major rivers draining this region are Tamraparni, Karamanaiyar and Nambiyar, which originate from the highlands of Western Ghats and flow towards east and west terminating in the Lakshadweep Sea and Gulf of Mannar. Coastal features like headlands; beach terraces and limestone cliffs are also present. The elevation in this region varies from mean sea level in the coastal regions to over 1600 m in the high ranges of Western Ghats. The region falls in the rain shadow zone and it receives less than 300 mm rainfall during both southwest and northeast monsoon periods. Due to this reason, long distance transport of weathered materials is limited to the coastal belt. Hence the placer deposits in the costal belt are

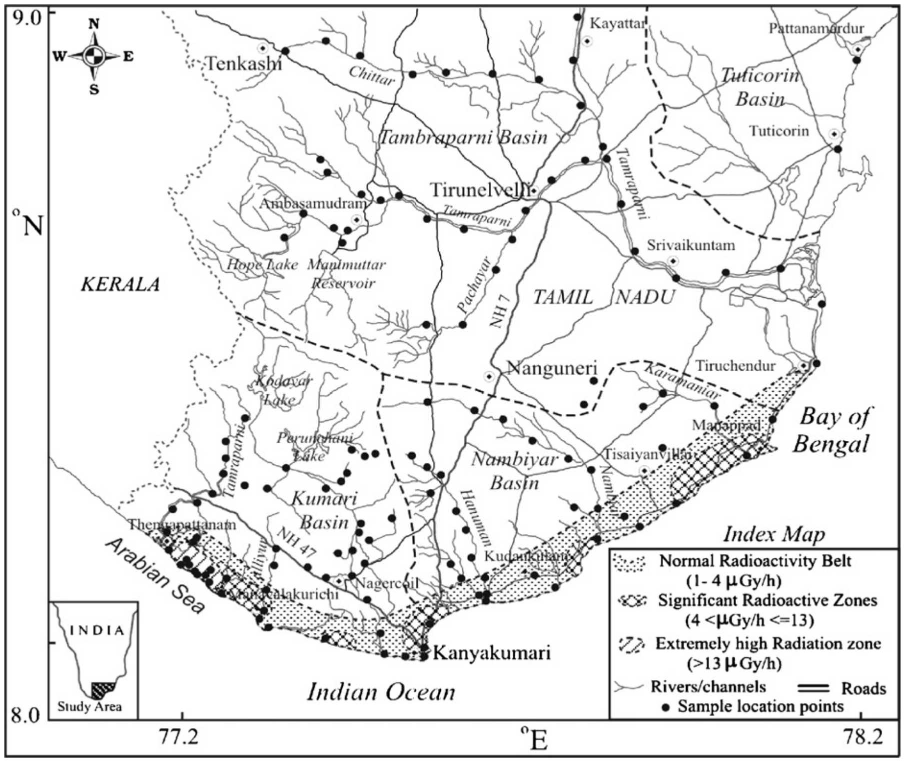

Fig. 1. Map of study area in southern Tamil Nadu showing drainage basins and rivers, and sample location points. Significant radioactivity belt, high and extremely high radiation background zones delineated based on in situ radiation surveys employing a portable radiation survey meter are mostly confined to certain patches in the hinterland regions adjacent to the beach sectors.

derived mostly from the adjacent hinterlands through the fluvial action, which are redistributed by ocean currents.

3. Methodology

In situ radioactivity surveys were conducted at appropriate intervals in southern Tamil Nadu region (Fig. 1) using a portable radiation survey meter in three physiographic features namely the rivers, beach sectors and hinterlands (connected to beach sectors and interior rock population). The surveys were conducted employing high precision portable radiation survey meter of Ludlum Measurements Inc., USA (model 44-2 and Digi Scalar rate meter No. 2241) and a Mini-monitor (Genitron make Digi-Counter model No. CX3) and measured ambient gamma radioactivity level (radiation exposure rate and low-level radioactivity count rate). Before initiating the actual field surveys, the radiation survey meter was calibrated by following the procedure furnished by the manufacturer in its manual. In the beginning, a reconnaissance survey was conducted to understand general distribution of radioactivity and delineated anomalous zones showing significant radioactivity. Subsequently, closely spaced observations were obtained from each anomalous zone and its surrounding areas to understand associated radioactivity concentration and its spatial extent. Extensive in situ radioactivity measurements in a space window of about 3 km wide parallel to the coast were carried out covering about 60 km in the southwest coastal belt from Tengapattanam to Kanyakumari and over 100 km stretch from Kanyakumari to Tuticorin in the east coastal belt. In situ observations were also obtained from each sample location point in the region. Likewise a total of 1656 in situ radioactivity observations were obtained along the rivers, beach sectors and in the hinterlands (Fig. 1). In addition, in situ radiation measurements in certain pockets along the Kerala coast from Chavara to Kovalam were also made. Survey of India toposheets on 1:50,000 scale was used as a base map for field measurements and estimations of location of each observation point. Locations of significant observed in situ radiation exposure levels are given in Table 1.

A large number of samples of rocks, sediment, soil/sand were collected from three prominent drainage basins of Kumari, Nambiyar and Tambraparni from important localities in their respective rivers, beach sectors and hinterlands but only 132 samples were considered after preliminary processing for identification of various heavy minerals and estimation of radiation exposure rates (RER) in laboratory (Fig. 1). Heavy minerals are separated using bromoform and acetone on mixing sieved samples of 170 and 230 mesh sizes. The heavy minerals are collected on a filter paper (as the lighter minerals are washed away with the bromoform), which was finally dried, and weight percent were calculated for all the samples. The samples of composite heavy minerals were used to prepare slides on a thin glass strip for mineral identification in each sample, which was done by examining these slides under a petrologic microscope, and thereby estimated concentration of each mineral (modal percent). The RER in each sample were measured using a total count gamma ray instrument. For this purpose, each sample is mixed thoroughly, cleaned, washed and sun dried. An amount of 500 g of each sample is stored in a plastic container for more

Table 1
Location of significant natural radioactivity observed in the field with the help of portable radiation survey meter in the beach sectors as well as adjacent hinterlands in southern peninsular India

Observation site numbers	Localities	Topographical regions	Location		In situ field radioactivity (μGy/h)
			°N	°E	
1	Thengapattanam	Hinterlands	8.25	77.17	1.87
2	Kizhkulam	Hinterlands	8.24	77.19	4.89
3	Puttetti	Hinterlands	8.22	77.19	44.81
4	Inayam Hillock	Hinterlands	8.21	77.21	21.56
5	Tenguvillai Hillock	Hinterlands	8.21	77.24	8.61
6	Melmidalam	Hinterlands	8.19	77.24	4.48
7	Kizhmidalam	Hinterlands	8.24	77.21	10.01
8	Kurumpanai	Hinterlands	8.17	77.29	9.14
9	Alanchi	Hinterlands	8.20	77.26	3.50
10	Manavalakurichi	Hinterlands	8.20	77.22	1.98
11	Koottapuli	Hinterlands	8.20	77.73	1.65
12	Chettikulam	Hinterlands	8.18	77.65	1.03
13	Idindakarai	Hinterlands	8.17	77.62	0.96
14	Kuttankuli	Hinterlands	8.23	77.77	3.50
15	Navaladi	Hinterlands	8.28	77.84	0.83
16	Kundal	Hinterlands	8.26	77.78	1.82
17	Tissianvillai	Hinterlands	8.33	77.75	0.57
18	Swamithoppu	Hinterlands	8.36	77.77	0.48
19	Kudu-talai	Hinterlands	8.33	77.94	0.91
20	Chavara	Beach sector	9.08	76.37	10.92
21	Varkala	Beach sector	8.76	76.67	7.01
22	Kovalam	Beach sector	8.38	76.97	6.46
23	Tengapattanam	Beach sector	8.24	77.16	0.64
24	Melmidalam	Beach sector	8.20	77.21	7.66
25	Midalam	Beach sector	8.18	77.22	6.40
26	Kurumpanai	Beach sector	8.16	77.27	13.53
27	Manavalakurichi	Beach sector	8.15	77.30	11.40
28	Kadiapattanam	Beach sector	8.12	77.31	8.35
29	Pillaithoppu	Beach sector	8.12	77.35	5.24
30	Pallom	Beach sector	8.10	77.40	2.26
31	Kovakulam	Beach sector	8.09	77.47	3.92
32	Kanyakumari	Beach sector	8.10	77.54	6.58
33	Chinnamuttum	Beach sector	8.12	77.55	2.83
34	Lipuram	Beach sector	8.13	77.56	2.31
35	Vattakottai	Beach sector	8.14	77.58	1.04
36	Idindakarai	Beach sector	8.17	77.71	0.18
37	Kuttankuli	Beach sector	8.19	77.77	0.67
38	Kundal	Beach sector	8.25	77.84	0.20
39	Ovari	Beach sector	8.29	77.90	0.26
40	Periya Talai	Beach sector	8.32	78.00	0.19
41	Manappad	Beach sector	8.36	78.05	0.15
42	Tiruchendur	Beach sector	8.48	78.12	0.13
43	Tuticorin	Beach sector	8.79	78.15	0.10
44	Pattanamardur	Beach sector	8.92	78.18	0.09

than 1 month to attain radioactive equilibrium. The radioactivity concentration in each sample was measured by placing them in a heavy lead chamber. The lead chamber is used in order to prevent the extraneous radiation while measuring the radioactivity [19]. The measured radioactivity was compared with the available standards of uranium, thorium and potassium obtained from Bendix Corporation, USA, BARC and AMD. All the in situ field measurements as well as the laboratory estimated data on samples along with their locations were compiled and a database was generated [17]. Spatial distribution of in situ field data on natural radioactivity in coastal sectors and adjacent hinterlands along with laboratory estimates from samples were studied and delineated significantly anomalous radioactivity zones.

4. Results and discussion

Spatial distribution of in situ radiation field data indicates the presence of prominent radioactivity zones in the western part of Kanyakumari district (Fig. 1) in which significant radiation exposure levels were recorded mostly on the west coast side from Tengapattanam to Kanyakumari. High to very high radiation levels were recorded in certain pockets along the beach as well as in the adjacent hinterlands. Significantly high exposure rates were observed in the immediate hinterlands connected to beach sector around Inayam, Midalam, Kurumpanai, Kizhmidalam, Manavalakurichi, and Alanchi as compared to the radioactivity in beach placers. High intrinsic radiation levels

Table 2
Frequency distribution of in situ radioactivity observations in southern Tamil Nadu

Range of radioactivity (μGy/h)	Number of observations
<0.87	1186
0.87–1.74	159
1.75–2.61	75
2.62–3.48	61
3.49–4.35	46
4.36–6.09	50
6.10–8.70	36
8.71–13.05	23
13.06–17.40	8
17.41–26.10	8
>26.1	4

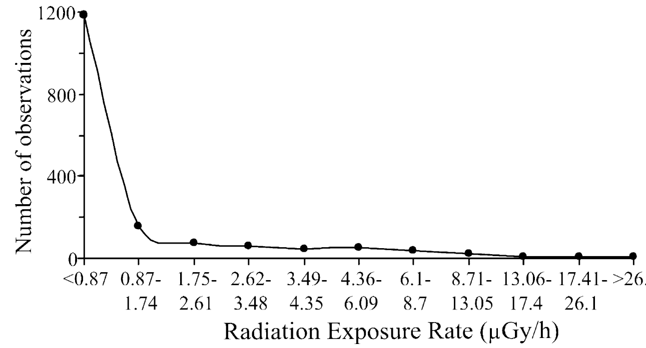

Fig. 2. Relation between observed in situ radiation exposure rates (μGy/h) in the field obtained from southern Tamil Nadu regions with the number of observations in each group. It is evident that a fraction of total observed sites have only exhibited significant radioactivity levels in the region, which are mostly confined to certain pockets in the beach sectors and its adjacent hinterlands especially in the western parts of Kanyakumari district.

were recorded in the hinterlands within the rock units of Puttetti syenite body. We had attempted to map the distribution of natural radioactivity along the rivers/channels and correlated the same with the geological and geomorphologic features of the area to delineate anomalous radioactive zones and pathways in the interiors of Western Ghats in southern Tamil Nadu. Detailed field observations at closely spaced intervals were obtained from the beach sectors and over the immediate hinterlands weathered hillocks around Thengapattanam, Inayam, Thenguvillai, Kizhmidalam, Kurumpanai and within the Puttetti syenite rock unit [17].

4.1. General distribution of observed in situ radioactivity

As indicated earlier, a total of 1656 in situ radiation observations were obtained from the study area and the values lie between 0 and 45 μGy/h (Tables 1 and 2). About 72% of these observations are below normal background levels (<1 μGy/h) and occupy major portion of the study area especially in the interior rock populations and east coastal belt (Figs. 1 and 2). All along the west and east coastal belt and connected hinterlands within 5 km range, normal radioactivity in the range of 1–4.5 μGy/h were observed and this contribution was made by only 21% of the total in situ observations. Significant radioactivity levels (4.5–13.1 μGy/h) are limited to ∼6% observations only and these are confined to only five anomalous zones in which lower levels (<5.2 μGy/h) are located in the hinterlands adjacent to the east coast belt; and higher levels (>5.2 μGy/h) in the west coastal belt and its adjacent hinterlands. Only about 1% observations have indicated extremely high radioactivity (>13.1 μGy/h), which are located in the hinterlands in the western Kanyakumari district around Inayam, Melmidalam, Kizhkulam, Kurumpanai and Puttetti (Figs. 1 and 2). High intrinsic radioactivity (>26 μGy/h) was observed at one location only in

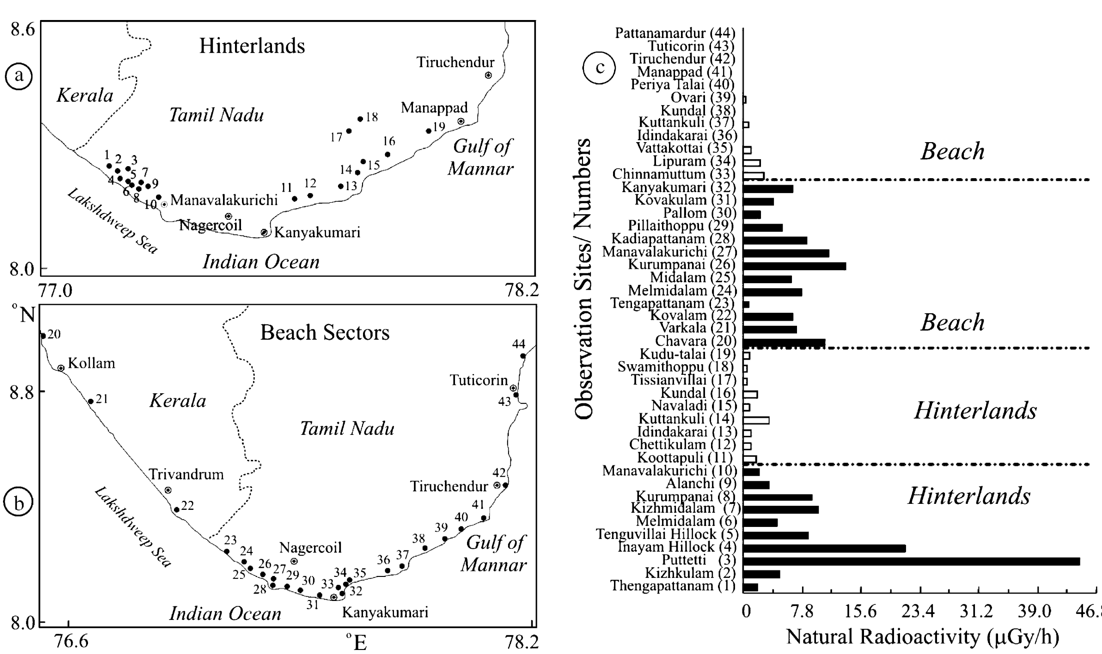

Fig. 3. Location of points with their numbers where in situ radiation observations were taken in (a) hinterlands; (b) along the beach sectors; (c) histograms of observed in situ radiation exposure rates at these location sites.

a fresh quarry within the Puttetti syenite body in the western Kanyakumari district (Figs. 1, 3 and 4).

4.2. West coast: beach sectors and connected hinterlands

In the west coast from Chavara to Kanyakumari (Fig. 3b), significant radiation levels ranging from 1.7 to 14.0 μGy/h were observed in certain pockets especially around Chavara, Varkala, Kovalam, Inayam, Midalam, Kurumpanai, Manavalakurichi, Kadiapattanam, Kovakulam beach sectors (observation nos. 20–32). This radioactivity is associated with beach placers only. Most of these sites in southern Tamil Nadu are located within 10 km beach stretch in the western part of the Kanyakumari district except Kovakulam, which is close to Kanyakumari (Fig. 1). The exposure rate around Kurumpanai (close to Manavalakurichi) is observed to be the highest (∼14 μGy/h) as compared to Chavara–Varkala beach sector (7.0–11.3 μGy/h) along Kerala coast (Fig. 3c).

Surprisingly, higher levels of radiation exposure rates (RER) ranging from 4.4 to 22 μGy/h were observed at several locations especially around Kizhkulam, Melmidalam, Kizhmidalam, Alanchi, Kurumpanai and Tenguvillai in the immediate hinterlands within 3 km to the beach in the western part of the Kanyakumari district (Fig. 3a and c; observation nos. 1–10). This high radiation exposure levels were observed over weathered rocks, terai sands and in red loams. These field observations suggest that the radioactivity in the famous placer deposits zones around Kadiapattanam, Manavalakurichi, Kurumpanai, Midalam, Chavara and Varkala have much lower concentration (∼14.0 μGy/h) than that of the connected hinterlands (4.5–22.0 μGy/h) in the west Kanyakumari district. In the same hinterland locality about 5 km away from Inayam to the east, high intrinsic radioactivity of >43 μGy/h was observed in a fresh quarry within the Puttetti syenite body close to a pegmatite vein in the form of deep bluish brown coloured crystals (Figs. 1, 3 and 4).

4.3. East coast: beach sectors and connected hinterlands

In situ radiation measurements in the east coastal belt, immediate hinterlands and in the interior rock population did not yield any significant radioactivity (Figs. 1 and 3). The radiation

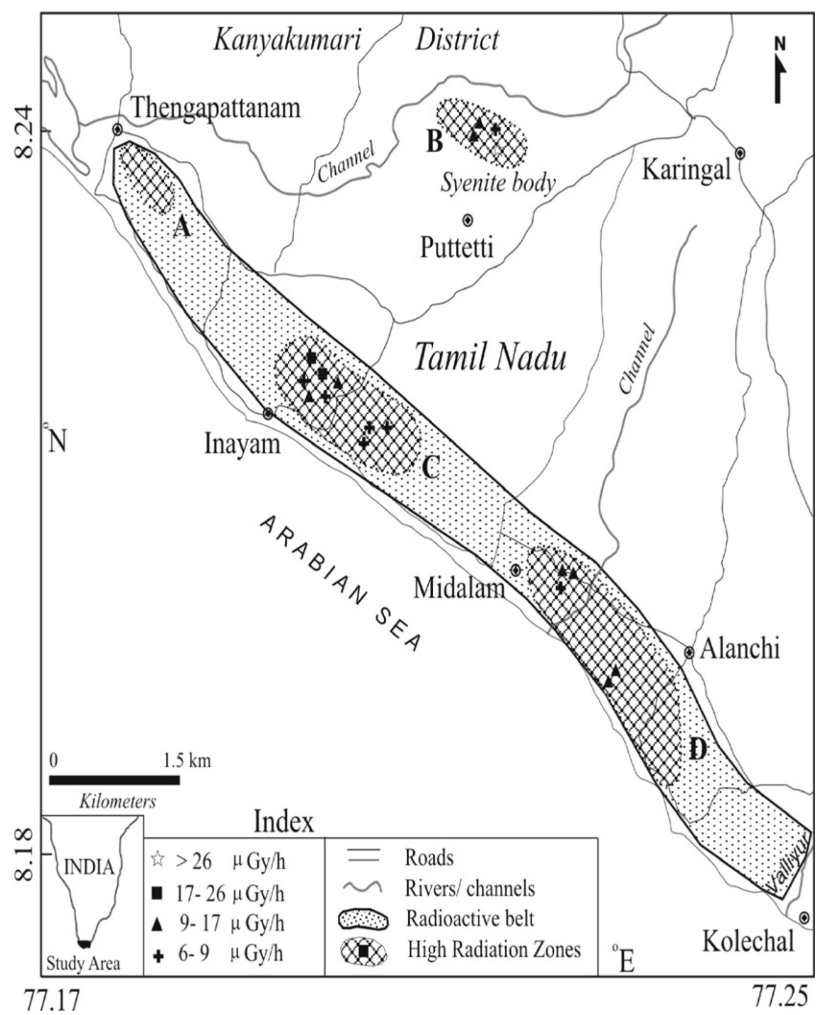

Fig. 4. Map showing high intrinsic radiation zones in the hinterlands delineated based on in situ radiation measurements in and around Puttetti in the western part of the Kanyakumari district. The anomalous radioactive zones A, C and D fall within the weathered country rocks, and zone B encloses exposed syenite rock body around Puttetti. These zones are delineated by conducting in situ radioactivity surveys using a portable radiation survey meter.

exposures observed in the eastern coastal segment (observation nos. 33–44) from Kanyakumari to Tuticorin is generally insignificant (<2.6 μGy/h) and it shows sharp decreasing trend towards north up to Pattanamardur (Fig. 3b and c). The radiation exposure rates in a short beach segment from Chinnamuttum to Vattakottai is observed to be the highest ∼2.6 μGy/h in the entire east coast beach sectors. Beyond Vattakottai to the north up to Tuticorin, radiation exposure rates (RER) did not exceed 1.0 μGy/h. Similar trend of radioactivity in the immediate hinterlands is also observed in the east coast (observation nos. 11–19 in Fig. 3 a and c). In this region, the ambient radiation exposure levels were observed to be ∼4.8 μGy/h and the higher levels of exposure rates are confined to a small segment from Kuttankuli to Kundal (Figs. 1 and 3a and c). The hinterland is mostly lateritic with patches of dunes at places. Garnet is a predominant mineral in the hinterlands and also all along the beaches of Kudankulam–Kuttankuli–Navaladi–Kundal.

4.4. Laboratory estimates of monazite and radioactivity concentration in field samples

Laboratory estimated average modal percent of monazite content and RER (μGy/h) of all the samples in each river, beach sector and hinterlands of the respective basin is shown in Fig. 5. The average modal percent of monazite content in the rivers of Kumari, Nambiyar and Tambraparni basins is estimated to be ≤16%-being maximum (∼16%) in Kumari basin and minimum (≤6%) in remaining two basins. Average monazite in individual rivers is estimated in the range 10–24% in Kumari basin, 3–7% in both Nambiyar and Tambraparni basins. The trend of variation of monazite concentration in beach sectors and hinterlands is observed to be more or less similar as in the riverine environment-being maximum in Kumari basin (∼15%) and <10% in other two basins. On the other hand, significant RER (avg.) in the beach sectors (∼0.5 μGy/h) and in the hinterlands (∼1.2 μGy/h) are observed in Kumari basin only and these samples are located in the western parts of Kanyakumari district where significantly high in situ radiation rates were already observed (Figs. 1, 3 and 4). Significantly high radiation exposure rates are observed in the individual samples in the hinterlands of Kumari basin around Puttetti syenite body (2.1–7.3 μGy/h), Alanchi (∼1 μGy/h) and Inayam and Kizhmidalam (∼2.4 μGy/h).

On the other hand, exposure rates in individual samples in the beach sectors of Kumari basin is observed to vary from 0.1 to 2.0 μGy/h being maximum ∼2.0 μGy/h around Manavalakurichi–Kurumpanai beach sector. The radiation exposure rates (RER) in rivers of all the basins are observed

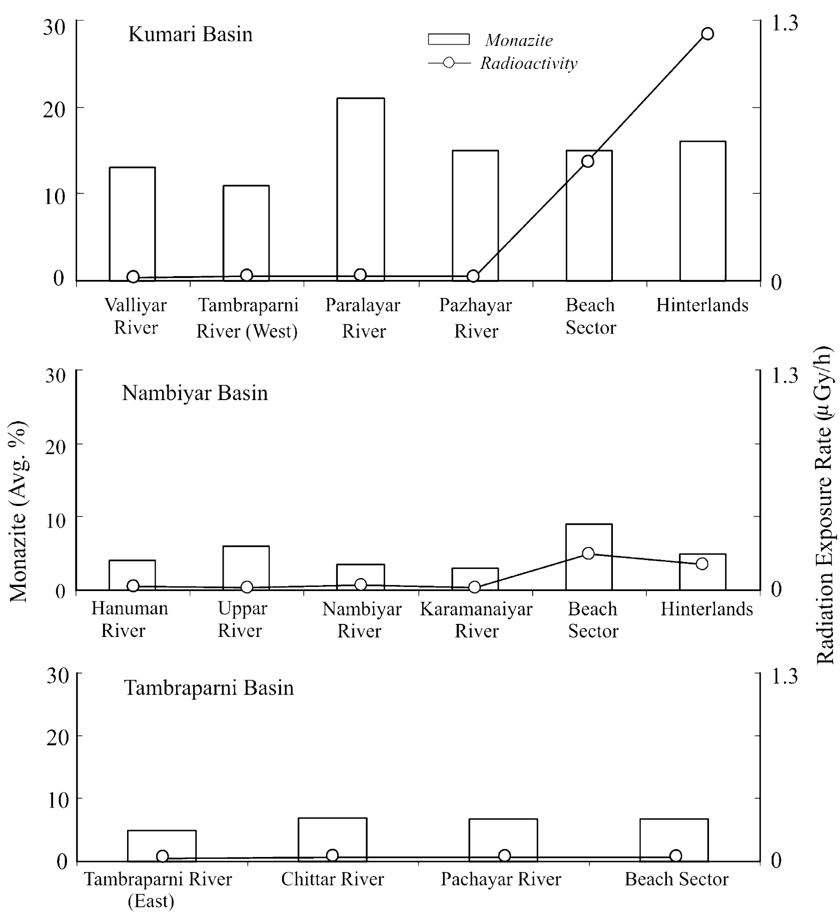

Fig. 5. Distribution patterns of laboratory estimated average monazite concentration (modal percent) and average radiation exposure rates through samples in three physiographic features (river systems, beach sectors and hinterlands) of Kumari, Nambiyar and Tambraparni basins. The data presented here are the average of monazite concentration and radiation exposure rates in individual samples pertaining to each river, beach sector and hinterlands.

to be insignificant which indicate that they generally do not transport radioactive minerals. More or less similar insignificant radiation rates are observed in the beach sectors and hinterlands of Nambiyar and Tambraparni basins. As far as exposure rates in individual samples in beach sectors of Nambiyar and Tambraparni basins are concerned, it is generally insignificant (<0.1 μGy/h) except in one sample around Perumanal beach in Nambiyar basin where it was observed to be ~1.0 μGy/h. Similar is the situations in the hinterlands of these two basins except in one sample around Kuttankuli in Nambiyar basin which had exhibited ~0.7 μGy/h.

The foregoing laboratory estimates of radiation exposure rates (RER) and monazite concentration in samples indicate that the rivers are not carriers of radioactive minerals from the interior rock population to the east and west beach sectors in southern Tamil Nadu. This data also suggest that the placer deposits having significant radioactivity in the beach sectors of western Kanyakumari district are derived through the adjacent hinterlands, which are observed to be associated about two-fold more radioactivity as compared to beach sectors in that region.

4.5. Delineation of high intrinsic radioactivity zones in western Kanyakumari district

Spatial distribution of in situ radioactivity observations indicated presence of significant radiation locales (>13.1 μGy/h) in the hinterlands of the western part of Kanyakumari district (Fig. 3). Such a high radioactivity was not found in other locations in the hinterlands as well as in the beach sectors in the entire study area. Encouraged with this result, closely spaced ground radiometric surveys were undertaken in the western part of the Kanyakumari district (Figs. 1 and 4) and collected over 300 in situ observations. The in situ radiation observations were contoured and delineated four potential zones A–D with significant high radioactivity as shown in Figs. 1 and 4. These high radioactivity locales are distributed in the hinterlands within 5 km comprising of weathered hillocks, red loams, terai sands and exposed rock bodies.

The weathered hillocks around Inayam–Melmidalam (zone C) and Kizhmidalam–Kurumpanai (zone D) are found to be significantly radioactive (Fig. 4). General radiation levels in zone C are observed to range 8.7–13.1 μGy/h at several locations in addition to the radiation levels as high as 21.8 μGy/h which was observed over red loamy soils near the foothill of a weathered hillock. Widespread significant radioactivity levels ranging from 4.4 to 11.3 μGy/h were also observed at several locations over weathered hillocks in zone D around Kizhmidalam and Kurumpanai. The zone A, which is not as much active as zones C and D, is situated around Tengapattanam–Kizhkulam sector in the hinterlands in which radiation levels ranging from 2.6 to 5.2 μGy/h were recorded. The geological formations in all these zones are observed to be the same. In addition exposure rates were observed to be ≤2.6 μGy/h in and around these zones and over certain exposed rock bodies.

High intrinsic radioactivity >43.5 μGy/h was observed in zone B that comprises of Puttetti syenite body. In general, the syenite body and its surrounding areas including boulders are found to possess high radioactivity. Rock exposures are quite common around this zone which have revealed higher radiation rates <2.6 μGy/h (Fig. 4) as compared to other areas away from this zone in all the directions. The main syenite body is elongated approximately in NW–SE direction where high intrinsic radiation exposure levels ranging from 8.7 to 44.8 μGy/h were recorded at many locations in the eastern portion of the delineated zone. The Puttetti syenite body consisting of several boulders is spread over an area of ~3 km^2 and most of these rocks are associated with high radiation levels. The highest radiation rate amounting to 44.8 μGy/h is observed at one location in a fresh quarry of Puttetti syenite body close to a pegmatite vein containing deep bluish brown coloured crystals. These crystals are suspected to be uraninite/pitchblende mineral. Further, comparatively lower levels of RER ranging from 8.7 to 17.4 μGy/h were confined to the nearby boulders on the western flank and over the exposed rocks on the northern side. The remaining hinterlands of Kanyakumari district did not exhibit any such significant radioactivity.

5. Conclusions

The present in situ radiometric surveys indicated that the beaches and immediate hinterlands in the west coast of southern Tamil Nadu possesses significant high radioactivity as compared to the east coast in which observed radioactivity is slightly above the normal background level. The in situ observations obtained from the interior rock population, along the rivers/channels and terai sands have resulted insignificant radioactivity (<1 μGy/h). In view of this, it is evident that the sources of placer deposits on the beaches are certainly the weathered hillocks/country rocks in the immediate hinterlands, which are eroded and transported collectively by seasonal rivers/channels and fluvial actions.

Puttetti syenite body located in the hinterlands in the western portion of Kanyakumari district is found to possess the highest radioactivity in southern India, and it is about four times more than the world famous beach placers at Chavara and Manavalakurichi. Such a high concentration of radioactivity in the rock units probably indicates presence of a strong radiogenic source in the Puttetti syenite body. The following conclusions are drawn:

- Anomalous high radioactivity zones are delineated in the hinterlands in the western part of Kayakumari district in which radioactivity as high as 21.8 μGy/h is observed over weathered hillocks close to the beach sectors. The Puttetti syenite body located in this region possesses high intrinsic radioactivity (~43.5 μGy/h) and it is observed to be the highest radiation exposure level ever recorded in southern India.
- Placer deposits in the west coastal regions contain high levels of radiation exposure rates (~13.9 μGy/h) as compared to similar regions in the east coast, which contains insignificant exposure rates (<2.6 μGy/h).
- The radioactivity observed in the immediate hinterlands in the western Kanyakumari district is much higher

(∼21.8 μGy/h) than the world famous high radiation belts of Chavara–Varkala of Kerala coast and Manavalakurichi–Midalam of Tamil Nadu coast (∼14.0 μGy/h).

- Insignificant concentration of monazite and radiation exposure rates observed in the samples of soil/sand/sediments collected from the rivers/rivulets in the region suggests that these features are not the sole carriers of radioactivity related materials to the coast.

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