BACKGROUND RADIATION AND INDIVIDUAL DOSIMETRY IN THE COSTAL AREA OF TAMIL NADU, INDIA

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South coast of India is known as the high-level background radiation area (HBRA) mainly due to beach sands that contain natural radionuclides as components of the mineral monazite. The rich deposit of monazite is unevenly distributed along the coastal belt of Tamil Nadu and Kerala. An HBRA site that laid in 2m x 7m along the sea was found in the beach of Chinnavillai, Tamil Nadu, where the maxumum ambient dose equivalent reached as high as 162.7 mSv/y. From the sands collected at the HBRA spot, the HPGe semi-conductor detector identified six nuclides of thorium series, four nuclides of uranium series, and two nuclides belonging to actinium series. The highest radioactivity observed was 43.7 Bq/g of Th-228. The individual dose of five inhabitants in Chinnavillai, as measured by radiophoto-luminescence (RPL) glass dosimetry system, demonstrated the average dose of 7.17 mSv/y ranging from 2.79 mSv/y to 14.17 mSv/y.

INTRODUCTION

The costal belt of southern Indian peninsula, belonging to the states of Tamil Nadu and Kerala, is known as one of the high background radiation area (HBRA) in the world(1). The radionuclides-containing monazite sands are deposited along the coast, which are supposed to come from the sea and, in some cases, from the rocks of the interior hinderlands via transportation by rivers. In the costal region of Kerala, several physical, epidemiological, and biological studies have been conducted, including the analysis of the distribution and enrichment pattern of radionuclides(2), assessment of individual exposure dose(3), estimation of cancer risk(3), and heritable effects on the newborns(4). In Tamil Nadu, outdoor or indoor radiation doses in a part of costal area(5) as well as around the nuclear power plant site(6-9) have been already reported; however, the analysis of radionuclides and individual dose assessment in HBRA have not been carried out. As the rich deposit of monazite is unevenly distributed in a stretched area longer than 100km along the coastal belt of Tamil Nadu and Kerala, the composition of beach sands and radiation dose from them widely differ depending on the site. This study presents the analytical data of radionuclide in beach sands in Tamil Nadu from the site where high radiation dose was observed by in-situ measurement. In addition, individual dose to inhabitants around the site was measured by using a radiophoto-luminescence (RPL) glass dosemeter.

MATERIALS AND METHODS

Background Radiation

Background radiation was measured in-situ by a survey meter equipped with a CsI(Tl) scintillation detector (Field Radiation Meter PDR-201, Aloka, Tokyo, Japan). Sand samples at 0 to 10cm depth were collected from three different spots of HBRA site on February 6, 2009 and from two normal background sites in Nagasaki. Sands were then packed in U-8 type plastic containers and subject to the gamma-ray spectrometric analysis by using an HPGe semi-conductor detector (GMX-25190, ORTEC, TN). Standard radionuclide source mixture of 9 nuclides for calibration was obtained from the Japan Radioisotope Association (MX033U8PP, Tokyo, Japan). Data from the multi-channel analyzer was acquired and processed by the 'Gamma-Studio' software (SEIKO EG&G, Tokyo, Japan).

Individual and indoor dosimetry

Measurement of individual and indoor ambient dose was conducted for 87 local inhabitants (67 in HBRA and 20 in control area, Figure 1) and in their dwellings in southern Tamil Nadu, by an RPL glass dosemeter (Chiyoda Technol, Tokyo, Japan) during the period from August 3 to 23, 2009. Subjects were asked to wear a dosemeter as a necklace all day long except the sleeping period. Another dosimeter was hung from the ceiling of the dwelling at 2m high from the floor. For both individual and ambient dose assessment, a cumulative dose in a measuring period (around 14days) was converted to an annual dose (mSv/y).

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Figure 1. Sampling locations in Tamil Nadu.

RESULTS

In the beach of Chinnavillai of Kanyakumari district, approximately 30km far from the south tip of the Indian peninsula to northwest, an HBRA spot was found in 2m (width) x 7m (long) along the seashore. By in-situ radiation measurements using a field meter, the highest dose rate in this spot reached as high as 18.6 μSv/h, corresponding to 162.7 mSv/y.

In the sand samples from three different HBRA spots at Chinnavillai beach, the HPGe detector identified 6 nuclides of thorium series, 4 nuclides of uranium series, and 2 nuclides belonging to actinium series. Most of those nuclides found in Chinnavillai were hardly detectable in normal background beach area in Nagasaki except for Ra-226 showing approximately 1% of radioactivity found in Chinnavillai. The highest radioactivity observed was 43.7 Bq/g of Th-228 in sands from spot-3 (Table 1).

The lower detection limit of an RPL glass dosemeter for individual dose assessment was set at 50 μSv. Doses lower than this limit were then taken as zero. The average readings of glass badge dosimeters per exposed period in Ibaraki, Japan and in Nagercoil, Tamil Nadu were 0.12 mSv and 0.27 mSv, respectively. As Nagercoil is in normal background area, the exposure by cosmic or artificial radiation during the air transportation of the dosemeters from Japan to India may account for the difference. Therefore, the doses for all test subjects were subtracted by the average reading in Nagercoil.

A linear correlation was observed between ambient and individual personal doses for all 87 inhabitants as shown in Figure 2. In control areas, no detectable individual dose was found although the average indoor dose was 0.31 mSv/y ranging from 0 to 1.83 mSv/y. In contrast, the average individual and ambient dose for 67 subjects from 24 villages of HBRA were 2.09mSv/y and 2.90 mSv/y, respectively. Among them, subjects in Chinnavillai were exposed to the average dose of 7.17mSv/y ranging from 2.79 to 14.17 mSv/y. The average ambient dose in their dwellings was 7.59mSv/y ranging from 3.65 to 14.17 mSv/y. The person who received 14.17 mSv/y, the highest dose among all subjects, was a housewife and her lifetime cumulative dose was estimated as 921.05 mSv based on the update life expectancy data for female Indian in recent statistics by WHO[10].

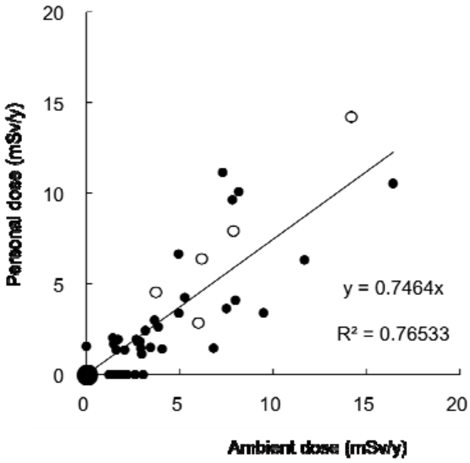

Figure 2. Correlation between ambient and personal doses for all 87 subjects. Opened circles represent the results in Chinnavillai.

DISCUSSION

According to the results reported by Singh et al., who measured background radiation in 25 beach sectors in south Tamil-Nadu, exceptionally high external radiation dose rates of 13.53 μGy/h, 11.40 μGy/h, and 8.35 μGy/h were observed at HBRA spots in villages of Kurumpanai, Manavalakurichi and Kadiapattanam[5]. Since all of these sites locate nearby Chinnavillai where we found 18.6 μSv/h in this study, the northeast costal area from the tip of Indian peninsula appears to be a typical HBRA in Tamil Nadu. The dose rates ranging from 8.35 to 18.8 μGy/h in this area are comparable or even higher than the dose rate ranges in other well-known HBRA in the world such as 0.09 to 90 μGy/h at Guarapari in Brazil, 0.2 to 4 μGy/h at Kerala in India, and 0.07 to 17 μGy/h at Ramsar in Iran[1]. Furthermore, the estimated annual external dose of 162.7 mSv/y in Chinnavillai is far beyond the regulatory level of 1 mSv/y for the general public recommended by the ICRP.

Gamma-ray spectrometric analysis of sand samples clearly confirmed that naturally occurring radionuclides belonging to thorium series and uranium series largely contribute to the high background radiation. The maximum radioactivity was 43.70 Bq/g by Th-228 collected from the spot-3, which was comparable to the result in Kerala by Shetty et al. who reported that the radioactivity of Th-232 and Ra-226, as evaluated from the 2614 keV gamma line of Tl-208 for Th-232 and 1764 keV of Bi-214 for Ra-226, was within the range of 0.01 to 136.81 Bq/g and 0.03 to 10.31 Bq/g, respectively[2].

This study was the first to apply the RPL technology to indoor and individual dose assessment in HBRA. The personal doses for 87 subjects exhibited a good correlation to indoor radiation doses inside their dwellings with a correlation cofactor of 0.7653 and a slope of 0.7464 for a linear regression line, suggesting that roughly 75% of the indoor ambient dose corresponds to the personal dose of each inhabitant. This is in good consistency with the study conducted in Kerala that obtained a slope of 0.7169 in a regression line of comparison between personal doses measured by the optically stimulated luminescent dosimeters (OSLD) and estimated external doses by scintillometers for 135 subjects(3). The range of indoor doses of 3.65 to 14.17 mSv/y found in Chinnavillai was reasonably higher than dose rates observed not only in control areas of this study but also in other areas of Tamil Nadu (0.05 to 0.97 my/y)(8,11). The average individual dose of all HBRA (2.09 mSv/y) and Chinnavillai subjects (7.17mSv/y) is within 56% and 18% of total subjects in order of dose rates in Kerala study(3). Therefore, the inhabitants in the south Tamil Nadu HBRA are likely exposed to a similar level, at least, of background radiation to HBRA in Kerala.

Assessment of radiation dose and health status in HBRA is deeply involved in the establishment of public health system in the area, as well as gives a clue to understand the biological effect of low dose radiation. In this sense, our previous study screened urinary iodine concentrations, which in part relate to the function of radiation-sensitive thyroid glands, in southern Tamil Nadu villages including Chinnavillai, and detected no severe iodine deficiency among the subjects(11). Neither excess cancer risk in inhabitants(3) nor increased frequency of micronuclei in newborns(4) was detected in Kerala studies. Taken together, the health effect of terrestrial radiation in HBRA in India has not been scientifically evidenced. However, the need for estimation of radiation health risk in India seems more important than ever because the nation-wide use of medical radiation is in progress and the number of nuclear power plant is planned to increase to meet the energy demand by the recent population explosion. In line with this, the thorough and continuous dose assessments of inhabitants, including HBRA, combined with medical, epidemiological, and biological examinations may facilitate better understanding of radiation and its health effect.

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Table 1. Radioactivity in beach sands from 3 different HBRA spots at Chinnavilai beach.

Nuclide	Radioactivity (Bq/g)				
	Chinnavilai			Nagasaki[1]	
	spot-1	spot-2	spot-3	spot-1	spot-2
Thorium series					
Ac-228	35.40	26.90	40.80	0.006	0.004
Th-228	38.60	33.70	43.70	N.D.	N.D.
Ra-224	33.90	22.70	37.40	N.D.	N.D.
Pb-212	35.10	23.70	38.70	0.006	0.004
Bi-212	40.30	25.90	40.20	0.013	N.D.
Tl-208	11.00	7.17	11.50	0.001	0.001
Uranium series					
Pa-234m	12.20	12.50	15.90	N.D.	N.D.
Ra-226	5.69	3.92	9.34	0.079	0.046
Pb-214	4.81	2.85	4.66	0.005	0.004
Bi-214	4.34	2.90	4.53	0.005	0.004
Actinium series					
U-235	0.19	0.15	N.D.	N.D.	N.D.
Th-231	7.19	6.28	8.12	N.D.	N.D.

[1]Normal background area at Nagasaki beach