International Journal of Advance Research in Science and Engineering
Volume No 06, Special Issue No. 03, September 2017, AFM-2017
www.ijarse.com
IJARSE
ISSN: 2319-8354

A MULTIPRONGED APPROACH TO THE INDOOR DOSE ASSESSMENT IN A HIGHLY HETEROGENEOUS BACKGROUND RADIATION AREA

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Abstract

Heterogeneity of the Natural background radiation owestothe geological and geographical texture of the region. There are regions on earth with unusually high deposits of radionuclides. The southwest coastal region of Kerala is one of such high background Areas (HBRA) in India due to the presence of thorium rich monazite sand patches and the radiation dose received by the population in the region is higher and heterogeneous as compared with the neighboring regions and the world average. The present study reports an assessment of the external gamma dose to the population in the coastal parts of HBRA through passive, active and theoretical methods. About 220locations in southern state of Kerala extending from Thiruvananthapuram to Alappuzha District were chosen for the study. The region was divided into seven zones. The analysis of results shows highly varying levels of indoor and outdoor external gamma dose to the population is in theregion. Measurements of external dose were carried out with two simultaneous independent methods using TLDs and gamma dosimeter. A good correlation was found between the assessments of indoor gamma dose using gamma dosimeter and TLDs. Among the seven zones, Chavara was found to have high and heterogeneous doses owing to the varying distribution of radionuclides. A few locations in Chavara has effective dose equivalent levels above 5 mSv y^{-1}.

Keywords: High background radiation, indoor external gamma dose, Thermo luminescent dosimeter, gamma dosimeter, Gamma ray spectroscopy.

1 INTRODUCTION

Natural radiation environment activated and catalyzed some of the important stages in the very evolution of life.The natural radiation sources include external sources of extra-terrestrial origin (cosmic rays), radiation of terrestrial origin (radionuclides in the earth's crust, in building materials and in air) and internal sources of radiation (natural radionuclides inhaled and ingested into the human body) (Chongaonkar*et.al.*,2004).Extensive studies on external gamma dose have been done world over using TLDs

(Sivakumar*et.al.*.,2002,IdrishMiah*et.al.*.,2001, Ben Byju *et. al*.,2012) and by analysis of radionuclides concentrations in soil samples by Gamma ray spectroscopy (Abusins*et.al*.,2007, Shetty *et.al*.,2005, Mohanty*et.al*.,2003) in many parts of the world. Studies in HBRA are important in the wake of reports of higher frequency of chromosome aberrations in the circulating lymphocytes of exposed persons.The objective of the present study was to determine the annual indoorexternal gamma dose to the population in the HBRA and the neighboring locations along with the assessment of the levels of primordial radionuclidesviz. radium (^{226}Ra), thorium (^{232}Th) and potassium (^{40}K) in soilfor the determination of radiological risk parameters.In southwest coastal region of Kerala extended from Thiruvananthapuram to Alappuzha Districts, 220 locations were chosen for the study. The studies were carried out using TLDs and GM tube based gamma dosimeterinthe thickly populated locations in the coastal region namely Varkala, Paravoor, Eravipuram, Chavara, Karunagappally, Kayamkulam. The sites for the investigation were chosen in a grid manner at almost equal distances spreading from the coast towards the inland.The average distance between the sites was about 100m. For comparison of results obtained from costal region a normal background area of Punalur was also selected for investigations.

The coastal plain of Kerala constitutes a special ecological variety with the low land fringing the sea extending over 590 km about 15 % of the state's total area. The coast is well known for several places of historical importance, heritage areas and places of captivating natural scenic beauty. Most of the dynamic processes which have been occurred within the coastal zones produce diverse and productive ecosystems. Fisher folk form an important segment of the population of the region. Out of the two types of fishermen, the marine and the inland, the concentration of marine fishermen is more in Trivandrum, Alapuzha, and Kollam districts in Kerala. The fishing villages have a distinctively different appearance as compared to other villages in the state. They are characterized by a very high density of population along the coast and are made up of a large number of houses clustered together and occupying the coastal fringes of the state. Over the last few decades, most of the old hutments or semi permanent structures made with mud having thatched roofs or tiles are replaced with concrete structures indicating the overall betterment of the living standards (CMFRI,2012).The present study is important in the changed dwelling conditions in the region as well as its multipronged approach to investigate the dose and its radiological allusions.

2 MATERIALS AND METHODOLOGY

2.1 LOCALE

Kerala, the tropical paradise of India is located on the southernmost tip of India and holds the coast of Arabian Sea on the west and is bounded by the Western Ghats in the east. The state islying between north latitudes 8°18' and 12°48' and east longitudes 74°52' and 77°22'. Kerala has a coast of 590 km and width of the state varies between 15 and 120 km. Kerala can be divided into three regions, eastern highlands, Central mid –land and coastal low lands. On the Southwest coast of India, the monazite deposits are larger than those in Brazil(Ramesh Tripathi D*et.al.*, 2010). Kerala possess one of the major deposits of mineral sand containing Ilmenite, Rutile, Leucoxene and Monazite.The region also has high rate of

International Journal of Advance Research in Science and Engineering
Volume No 06, Special Issue No. 03, September 2017, AFM-2017
www.ijarse.com
IJARSE
ISSN: 2319-8354

background radiation levels ranges about 70% to 30% above the global average at some locations. For several thousand years inhabitants in the coastal region have been bathed with the elevated levels of radiation.

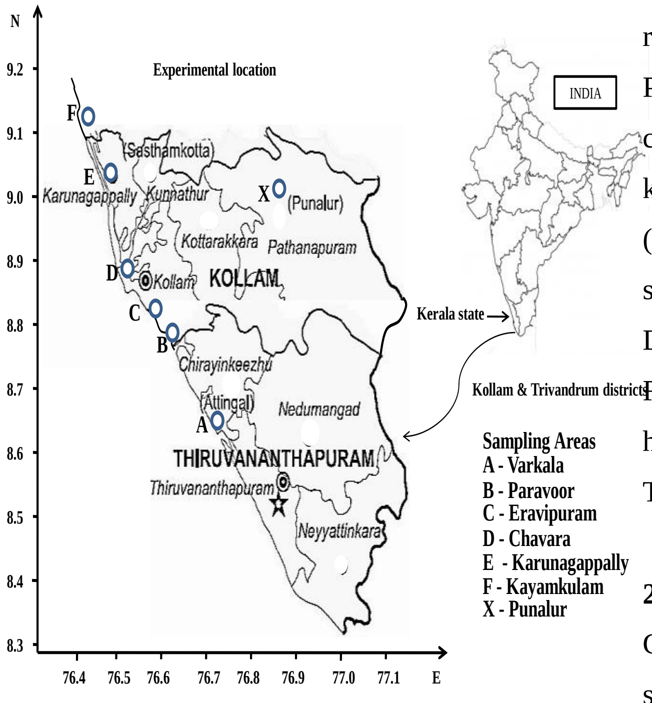

Figure 1 Experimental location chosen for the study

The area selected for the study includes 220 locations from seven zones in the coastal region of Kerala. Seven zones selected for the study are Varkala (8.73°N76.71°E), Paravoor(8.51°N 76.66°E) Eravipuram(8.82°N 76.37°E),Chavara(8.99°N76.53°E),Karunagappally(9.01°N76.32°E),Kayamkulam(9.17°N76.50°E)and Punalur (9.02^{o} N 76.92^{o}E). The last zone, Punalur, is in the Normal Background Radiation Area (NBRA) away from the coast. All the coastal locations are spread over the districts of Thiruvananthapuram, Kollam and Alappuzha from south to north. For the convenience of representation the zones are demarcated as A for Varkala, B for Paravoor, C for Eravipuram, D for Chavara, E for Karunagappally and F for Kayamkulam representing the coastal HBRA and X for Punalur as representing the NBRA. The coastal belt of Karunagappally and Chavara, is known for its high background radiation (HBRA) from thorium-containing monazite sand (Nair R R*et.al.*, 2009, Mary Thomas Derin*et.al.*, 2012). The Normal Background Radiation Area was selected from the eastern highlands in the Kollam and Thiruvananthapuramdistricts.

2.2 EXTERNAL DOSIMETRY

Gamma dose rates were measured at the sampling locations using a portable gamma dosimeter as well as TLDs. Spot surveys for the indoor external gamma ray doses were carried out using Gamma Dosimeter (Nucleonix, India, UR705) consisting of a GM tube and microprocessor based digital display.While fixing and retrieving the TLDs in houses, dosimeter readings were taken inside and outside the dwellings at the ground level and 1 meter height from the ground. The dosimeter readings were noted while fixing and retrieving TLDs and the averages were determined.TLD Badges used in the study were based on $CaSO_4$: Dy and are highly sensitive thermo-luminescent(TL) phosphor with a TL glow peak at about 240^{o}C. The response and chemical form are highly stable to climatic variations and therefore, are being used in wide-spread applications of radiation dosimetry.

Freshly prepared and annealed TLDs were deployed in the 220 houses at the sampling locations. The TLD badges were fixed in the bedroom ofthe dwellings selected for the study at a height of six feet from the floor. After the exposure for about 3 months, the TLDs were retrieved and were analyzed for the counts they recorded during the exposure period using a PC-based TL analyzer in presence of a continuous flow of nitrogen gas maintained at constant flow rate. The counts obtained from the TLDs were used to determine the absorbed dose rate using the predetermined calibration factor.

3 RESULTS AND DISCUSSION

For the indoor atmosphere we have the average of two dosimeter readings and the estimate of time averaged dose determined using the TLDs.

3.1 INDOOR EXTERNAL DOSE

The dose rates for the seven zones showing the values of maximum, minimum, arithmetic mean, geometric mean and standard deviation of the measured doses for indoor and outdoor atmospheres are shown in the table 1.Indoor dose valuesmeasured using gamma dosimeter ranged from 577 µGy y^{-1} to12112 µGy $y^{-1}$and the doses determined using TLDs were between 663 µGy y^{-1} and 11419 µGy y^{-1}. In general the Chavara zone was found to have high and heterogeneous dose values.

Table 1 Indoor gamma absorbed dose using TLDs and gamma dosimeters

Sl No	Name of zone (No of Locations)	Annual Indoor Gamma Dose (mSv/y)					
				< 0.3 mSv/y	**0.3-0.7 mSv/y**	**0.7-1.5 mSv/y**	**1.5< mSv/y**
				% of houses	**% of houses**	**% of houses**	**% of houses**
1	**Varkala (24)**	(Max)	1.21	--	95.83	4.16	--
		(Min)	0.37				
		(Mean)	0.46				
		(SD)	0.12				
2	**Paravoor (20)**	(Max)	0.64	--	100	--	--
		(Min)	0.36				
		(Mean)	0.48				
		(SD)	0.09				
3	**Eravipuram (24)**	(Max)	1.06	--	91.6	8.3	--
		(Min)	0.39				
		(Mean)	0.44				
		(SD)	0.03				
4	**Chavara (22)**	(Max)	5.99	--	9.09	50	40.9
		(Min)	0.35				
		(Mean)	1.84				
		(SD)	0.25				
5	**Karunagappally (22)**	(Max)	1.35	9.09	72.72	9.09	9.09
		(Min)	0.26				
		(Mean)	0.54				
		(SD)	0.16				
6	**Kayamkula**	(Max)	0.61	9.09	90.9	--	--
		(Min)	0.28				
		(Mean)	0.42				

	m (22)	(SD)	0.08				
7	NB RA (10)	(Max)	0.71	--	100	--	--
		(Min)	0.35				
		(Mean)	0.31				
		(SD)	0.14				
	Tota l			3	78	11	8

If we classify the annual effective dose rates into four levels as 'low' for less than 0.3mSvy^{-1} 'medium' 0.3-0.7 mSvy^{-1}, 'high' for 0.7-1.5 mSvy^{-1} and 'very high' for >1.5 mSvy^{-1} (Jolyon*et.al.,* 2009) the measured values in the present study shows that there is no zone which can be identified to have even medium level of indoor gamma. But a few locations in the Chavara (zone D) fall in the category of 'medium' level with above 0.3 -0.7mSvy^{-1}.Here, it should be remembered that the dose estimated here is only the external dose which is much less than inhalation dose that could exist in the region.

It can be seen that the dosimeter readings are generally high as compared with the estimation of dose from radionuclides. This is natural because of the ambient radioactivity that would be present in the air. Figure 2 shows the correlation between the measurements and the y-intercept of the graph could be due to the ambient terrestrial and cosmic ray components of exposure. Worldwide average of radiation dose level due to cosmic ray is 31nGyh^{-1} and a reported value in India is 32nGyh^{-1}(N. Karunakara et.al, 2014)

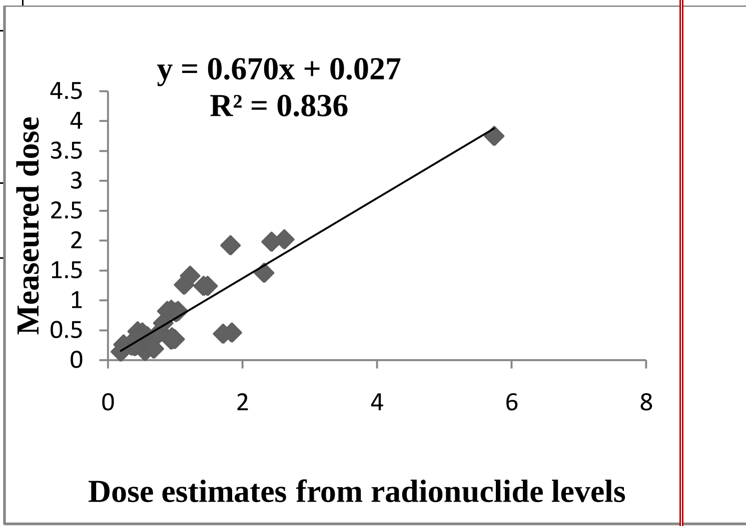

Figure 2. Comparison of dose estimates and measured doses

Figure 3 shows the frequency of indoor gamma dose levels at all the 220 locations. It can be seen that for more than 50% cases the measured indoor doses imparting external exposure are between 100 and 300 nGyh^{-1} corresponding to the effective dose of 0.49 mSvy^{-1} and 1.47mSvy^{-1} respectively. As measured by gamma dosimeter, it is observed thatthe geometric mean of indoor to outdoor dose ratio to be 0.88 with a range from 0.58 to 1.48. This is in agreement with another study carried out by Cougaonkar et.al.(Chougankar*et. al.*, 2004) . According to another study in India, the reported value of the ratio is 1.2 for the houses have tiled flooring and concrete walls(N. Karunakara *et.al.*, 2014).

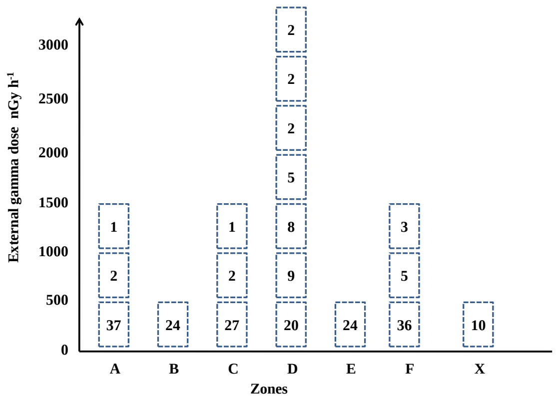

Figure 3 Occurrence of gamma dose levels at different zones in all 220 locations.

4 CONCLUSIONS:

Among the seven zones, Chavara was found to have high and heterogeneous doses owing to the varying distribution of radionuclides. A few locations in the Chavara (zone D) has effective dose equivalent levels above 5 $mSvy^{-1}$.The dose estimated here is only the external dose which is much less than inhalation dose that could exist in the region. In the zones Varkala (A) and Karunagappally (E), there are locations with higher activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K. For more than 50% of all the locations the measured indoor doses imparting external exposure were between 100 and 300 $nGyh^{-1}$ corresponding to the effective dose of 0.49 $mSvy^{-1}$ and 1.47$mSvy^{-1}$ respectively. The maximum value of estimated excess cancer risk is only 1.3%.

ACKNOWLEDGMENT:

The present research work is carried out in Centre for Advanced Research in Physical Sciences, Research Department of Physics, Fatima Mata National College, Kollam. The authors are thankful to the residents living in the study area for their cooperation during the field work and the research scholars in the department who provide the nesscery support.

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