

## AMBIENT GAMMA LEVELS IN THE IN SEASIDE REGIONS OF ALAPUZHA DISTRICT, KERALA

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### Abstract

Even though the south coastline of Kerala is well studied owing to the high background radiation prevailing in the Kollam district, the neighboring areas are not well studied. Towards the southern end of the state intermittent high background pockets are observed. Here we present the report of an in depth investigation in the shoreline of Alappuzha district situated north to the Kollam district where the well known high background radiation area exists. Indoor and outdoor gamma dose rates were evaluated along the coastal regions of Porakad, Alappuzha district, Kerala through direct measurements using a GM based gamma dose survey meter, time integrated measurement using  $\text{CaSO}_4:\text{Dy}$  based thermo luminescent dosimeters (TLDs) and gamma spectrometry of soil samples. The mean values of indoor and outdoor Annual Effective dose rates observed were  $2.17 \pm 0.47 \text{ mSv/Yr}$  and  $0.67 \pm 0.12 \text{ mSv/Yr}$ , respectively with an indoor to outdoor dose ratio of 0.82. The radioactivity content in the soil samples, the absorbed dose rate, annual effective dose equivalent, radium equivalent activity, internal and external hazard indices, the representative gamma index and alpha index ( $I_{\text{gamma}}$  and  $I_{\text{alpha}}$ ), the annual gonad dose equivalent (AGDE) and the excess lifetime cancer risk (ELCR) were determined and compared with recommended values. Correlation study showed that the dose estimated from the TLDs is better correlated with that measured directly using the portable survey meter. The results of natural radioactivity levels in the soil samples has been compared with the levels reported in other Indian cities as well as other parts of the world.

**Keywords:** Gamma dose, Thermoluminescence, Effective dose

### Introduction

The knowledge of distribution of radionuclides and radiation levels in the environment is important for assessing the effects of radiation exposure due to both terrestrial and extraterrestrial sources. Human beings are constantly exposed to natural sources of ionizing radiations in nature. The natural background radiations have both terrestrial and extra-terrestrial origins. The extra-terrestrial radiation is largely due to cosmic rays. The worldwide average radiation dose at sea level due to cosmic rays is  $31 \text{ nGy h}^{-1}$  [1] and that for India is  $32 \text{ nGy h}^{-1}$  [2], the dose increases with the altitude. The terrestrial gamma rays are essentially derived from  $^{40}\text{K}$  and radionuclides belonging to  $^{238}\text{U}$  and  $^{232}\text{Th}$  series that are present in the earth's crust. The worldwide average value for outdoor gamma absorbed dose rate in air due to terrestrial sources is  $54 \text{ nGy h}^{-1}$  and the relative contributions of  $^{40}\text{K}$ ,  $^{238}\text{U}$ , and  $^{232}\text{Th}$  to this dose are about 35%, 25%, and 40%, respectively [3].

The variation of terrestrial radiation is typically larger than that of cosmic rays. There are regions in the world where the outdoor terrestrial radiation exceeds substantially the average value due to the enrichment of certain radioactive minerals leading to the formation of what are known as high background areas. The presence of high background areas has been reported in several countries like China, Iran, Germany, USA, Brazil, and India [1].

The main objective of this study was to measure the indoor and outdoor radiation dose rates and calculate annual effective dose (AED) received by the people along the coastal regions of Porakad, Alappuzha district, Kerala. The activity concentration of radioactive elements such as  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$  and gamma ray absorbed dose in soil samples was also determined using gamma-ray spectrometry. The values obtained were compared with that of the world average as well as

with the other values reported in literature. A brief review of radiological survey in some areas as carried out within and outside the country by some researchers with result obtained is shown in Table 1. A comparative study of in situ measurements of gamma dose rates using

portable dosimeters and integrated measurements over a period of 90 days using TLDs, and the correlation study showed that the dose estimated from the TLDs is better correlated with that measured directly using the portable survey meter.

Table 1: A review of radiological survey in some areas as carried out within and outside the country.

Region	Annual effective dose	Reference
India	2.3 mSv/yr	Ramachandran et al., 2011
Iran	1.73 mSv	Sadegh et al., 2012
Jos, Nigeria	2.063 mSv/yr	Jwanbot et al., 2012
Adeokuta, Nigeria	(0.19-1.64) mSv/yr	Farai and Vincent, 2006
Yazd Province	1.03 mSv/yr	Bouzarjomehri et al., 2005
Abeokuta, Nigeria	68.74 $\mu$ Sv/yr	Okeyode et al., 2010

## 2. Materials and methods

### 2.1 Selection of the measurement sites

The gamma background radiation measurements were performed both indoor and outdoor along the coastal region of Porakad, Alapuzha district, Kerala.

### 2.2 Gamma absorbed dose measurements using portable dose surveymeter

The ambient gamma absorbed dose rates were measured in the sampling locations using GM tube-based gamma dosimeter (POLIMASTER PM 1405). This device can detect gamma rays in the energy range of 0.05–3 MeV and the dose rate measurement range is 0.1  $\mu$ Sv/h to 100 mSv/h. The gamma radiation levels were measured both inside and outside the dwellings at 1 m above the ground. About 20 readings were taken at different points in each location.

### 2.3. Gamma absorbed dose measurements using Thermo luminescentdosimeter (TLD)

TLD is a passive device for the measurement of gamma dose and in this the dose is acquired and stored for a long period of time until the system is stimulated by heat. The advantage of this system is that since it acquires the dose continuously the variation of dose during different periods of time is averaged out. Therefore, the long-term integrated measurements of gamma dose rates are carried out using thermo luminescent dosimeters based on CaSO<sub>4</sub>:Dy phosphor. The dosimeters were specially designed to measure the environmental gamma radiation by the Bhabha Atomic

Research Centre (BARC), Mumbai Chougankar et al. [4]. The details of the preparation of the TLD dosimeters and calibration are published elsewhere by Chougankar et al. [4]. The TLDs were deployed inside 20 dwellings and 20 outdoor locations for a time period of 90 days. Inside the dwellings, they were installed at least 1 m away from the walls and about 3 m above the floor. In the outdoors they were installed just outside the dwelling at a similar height. The retrieved dosimeters were analyzed using the automatic TLD reader (LLRRL,Kollam) and the absorbed dose was arrived at using standardized methodology [4]. An appropriate number of TLDs were kept as control TLDs at both laboratory and field location to determine the control dose at both these locations and transit TLDs were used to determine the transit dose. At the time of installing and retrieving the TLDs, the gamma dose rates were measured using the survey meter, as detailed in the earlier section.

### 2.4. Soil sample collection and measurement of radionuclide activity Concentrations

Twenty soil samples were collected along the coastal regions of Porakad, Alapuzha district. All collected soil samples were stored in sealed polyethylene bags, labelled and then transported to the laboratory. In the laboratory, after removing the stones and organic materials, the samples were dried in an oven at 110<sup>0</sup> C for 24 h to remove the moisture content and then crushed to pass through a 150-mesh sieve to homogenise it. Finally, weighed samples were sealed in gas-tight, radon-impermeable, trap-shaped polyethylene

containers. These samples were stored in a dry room at room temperature for 30 days before counting radium and thorium daughter products to attain radioactive equilibrium.

The concentrations of the natural radionuclides  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in soil samples were determined using a 5X 5 cm NaI(Tl) gamma ray spectrometric system with 8 % energy resolution ( $^{137}\text{Cs}$  661 keV). The detector is maintained in a vertical position in a lead cylindrical shield. The detector was coupled to a 256 multichannel pulse-height analyser, and the system was calibrated for the gamma energy range 80 keV–3.2 MeV. The energy region for  $^{40}\text{K}$ , 1.46 MeV gamma rays,  $^{226}\text{Ra}$ , 1.76 MeV gamma rays ( $^{214}\text{Bi}$ ) and  $^{232}\text{Th}$ , 2.61 MeV gamma rays ( $^{208}\text{Tl}$ ) were chosen as 1.30–1.60, 1.62–2.00 and 2.45–2.90 MeV, respectively. Detector calibration and content calculations have been described in detail previously. All samples were counted for 10000 S.

## 2.5. Estimation of Radium Equivalent, absorbed dose, Effective doses, Annual Gonadal dose, cancer risk and representative level indices from soil radioactivity measurements

### 2.5.1 Radium equivalent activity

It was calculated through the following relation [5]:  
 $Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.07C_K$

where  $C_{Ra}$ ,  $C_{Th}$  and  $C_K$  are the activity concentrations of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in Bq/kg, respectively. While defining  $Ra_{eq}$  activity, it has been assumed that 370 Bq/kg  $^{226}\text{Ra}$  or 259 Bq/kg  $^{232}\text{Th}$  or 4810 Bq/kg  $^{40}\text{K}$  produce the same gamma dose rate.

### 2.5.2 Calculation of air-absorbed dose rate

The external terrestrial gamma radiation absorbed dose rate in air at a height of about 1 m above the ground was calculated by using the conversion factor of 0.0414 nGy h<sup>-1</sup>/Bq kg<sup>-1</sup> for  $^{40}\text{K}$ , 0.461 nGy h<sup>-1</sup>/ Bq kg<sup>-1</sup> for  $^{226}\text{Ra}$ , and 0.623 nGy h<sup>-1</sup>/Bq kg<sup>-1</sup>for  $^{232}\text{Th}$ [UNSCEAR,1993], assuming that  $^{137}\text{Cs}$ ,  $^{90}\text{Sr}$  and the  $^{235}\text{U}$  decay series can be neglected as they contribute very little to the total dose from environmental background.

$$D(\text{nGyh}^{-1}) = 0.461C_{Ra} + 0.623C_{Th} + 0.041C_K$$

where,  $C_{Ra}$ ,  $C_{Th}$  and  $C_K$  are the activity concentrations (Bq kg<sup>-1</sup>) of radium, thorium and potassium in the samples.

### 2.5.3 Calculation of annual effective dose

Annual estimated average effective dose equivalent received by a member was calculated using a conversion factor of 0.7 Sv Gy<sup>-1</sup>, which was used to convert the absorbed rate to human effective dose equivalent with an outdoor occupancy of 20% and 80% for indoors [UNSCEAR,1993].

$$\text{Indoor}(nSv) = (\text{Absorbed Dose})nGyh^{-1} \times 8760h \times 0.8 \times 0.7SvGy^{-1}$$

$$\text{Outdoor}(nSv) = (\text{Absorbed Dose})nGyh^{-1} \times 8760h \times 0.2 \times 0.7SvGy^{-1}$$

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The concentrations of the natural radionuclides  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in soil samples were determined using a 5X 5 cm NaI(Tl) gamma ray spectrometric system with 8 % energy resolution ( $^{137}\text{Cs}$  661 keV). The detector is maintained in a vertical position in a lead cylindrical shield. The detector was coupled to a 256 multichannel pulse-height analyser, and the system was calibrated for the gamma energy range 80 keV–3.2 MeV. The

energy region for  $^{40}\text{K}$ , 1.46 MeV gamma rays,  $^{226}\text{Ra}$ , 1.76 MeV gamma rays ( $^{214}\text{Bi}$ ) and  $^{232}\text{Th}$ , 2.61 MeV gamma rays ( $^{208}\text{Tl}$ ) were chosen as 1.30–1.60, 1.62–2.00 and 2.45–2.90 MeV, respectively. Detector calibration and content calculations have been described in detail previously[5]. All samples were counted for 10000 S.

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$$D(\text{nGyh}^{-1}) = 0.461C_{Ra} + 0.623C_{Th} + 0.041C_k$$

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$$\text{Indoor}(nSv) = (\text{Absorbed Dose})nGyh^{-1} \times 8760h \times 0.8 \times 0.7SvGy^{-1}$$

$$\text{Outdoor}(nSv) = (\text{Absorbed Dose})nGyh^{-1} \times 8760h \times 0.2 \times 0.7SvGy^{-1}$$

### 2.5.4.External hazard index (Hex)

The external hazard index Hex can be calculated by the following equation:

$$H_{ext} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \leq 1$$

where  $C_{Ra}$ ,  $C_{Th}$  and  $C_K$  are the activity concentrations of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in Bq/kg, respectively. The value of this index must be less than the unity in order to keep the radiation hazard to be insignificant. The maximum value of Hex equal to unity corresponds to the upper limit of  $Ra_{eq}$  (370 Bq/kg).

### 2.5.5.Internal Hazard Index

The internal hazard index  $H_{in}$  can be calculated by the following Equation:

$$H_{in} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810}$$

$H_{in}$  must be less than unity to have negligible hazardous effects of carcinogenic radon and its short lived progeny to the respiratory.

### 2.5.6. Representative Level index

The representative level index  $I_{rv}$  of the soil is used to estimate the level of gamma radiation hazard associated with natural emitters in the soil. It was calculated using the relation:

$$I_{rv} = \frac{C_{Ra}}{1500BqKg^{-1}} + \frac{C_{Th}}{100BqKg^{-1}} + \frac{C_K}{1500BqKg^{-1}}$$

The representative level index must be lower than unity in order to keep the radiation hazard insignificant.

### 2.5.7 Excess lifetime cancer risk

Excess lifetime cancer risk (ELCR) was calculated using the following equation and presented in Table 4.

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

where AEDE, DL and RF are the annual effective dose equivalent, duration of life (70 y) and risk factor ( $Sv^{-1}$ ), fatal cancer risk per sievert. For stochastic effects, ICRP 60 uses values of 0.05 for the public(12).

### 2.5.8 Annual gonadal dose equivalent

The annual gonadal dose equivalent (AGDE,  $mSv y^{-1}$ ) due to the specific activities of  $^{226}Ra$ ,  $^{232}Th$  and  $^{40}K$  was calculated using the following formula(13):

$$AGDE = 3.09C_{Ra} + 4.19C_{Th} + 0.314C_K$$

The average values of AGDE are presented in Table 4 .

## 3. Results and Discussion

### 3.1. Gamma absorbed dose rates

The indoor and outdoor gamma absorbed dose rates along the coastal region of porakad, Alapuzha district measured using portable dose surveymeter, are presented in Table 1, and the doses measured using the TLDs are presented in Table 2. The indoor gamma dose, measured using the survey meter, varied in the range of (371.12–735.1)  $nGy h^{-1}$  with the mean value of  $468.57 \pm 96.01224 nGy h^{-1}$ , and outdoor gamma dose varied in the range of ( 442.85–742.11)  $nGy h^{-1}$  with the mean value of  $582.85 \pm 104.86 nGy h^{-1}$  . Similarly, the

mean values of the doses measured using TLDs were  $459.89 \pm 95.23 nGy h^{-1}$  and  $579.022 \pm 106.32 nGy h^{-1}$ , respectively, for indoor and outdoor. These results show that the indoor and outdoor dose rates were comparable to each other and the difference between them is <10%. Also, the mean value of the dose for the entire region was higher when compared to the values (mean of 59  $nGy h^{-1}$  in the range of 18–93  $nGy h^{-1}$ ) given in UNSECAR [9] for different countries and with the all India mean value (89  $nGy h^{-1}$  in the range of 27–3051  $nGy h^{-1}$ ) reported by Nambi et al. [2].

### 3.2. Indoor and outdoor annual effective dose

From the hourly dose rate, the annual effective dose was computed using the indoor occupancy factor of 0.8 and the outdoor occupancy factor of 0.2 [1] and these are also presented in Tables

1 and 2. The annual effective dose thus calculated from the survey meter data had mean values of  $2.18 \pm 0.47 mSv y^{-1}$  and  $0.67 \pm 0.12 mSv y^{-1}$ , respectively, for indoor and outdoor (Table 1) and the corresponding dose values computed from TLD data had mean values of  $2.25 \pm 0.46 mSv y^{-1}$  and  $0.71 \pm 0.12 mSv y^{-1}$ , respectively (Table 2). The total annual effective dose (indoor + outdoor) ranged from (0.499–4.52)  $mSv y^{-1}$  with a mean value of  $2.86 \pm 0.77 mSv y^{-1}$  (Table 1, Column 6). This value was approximately equal to the mean of annual effective dose ( $2.96 \pm 0.48 mSv y^{-1}$ ) computed from the TLD measurements (Table 2, column 6). Nambi et al. [2] found the dose levels in India, except HBRAs in the states of Kerala and

Tamil Nadu, to be  $0.44 \pm 0.13 mSv a^{-1}$ . Thus, the total gamma ray dose is higher than the average value for normal background regions of India

**Table 1:** Indoor and outdoor gamma absorbed dose rates (measured using portable survey meter).

Sample code	Gamma absorbed dose rate( $nGy/hr$ )		Annual effective dose( $mSv/Yr$ )		Total annual effective dose(indoor+outdoor) $mSv/Yr$
	Indoor	Outdoor	Indoor	Outdoor	
POR 1	471.43	585.7143	2.31264	0.71832	3.03096
POR 2	371.43	457.1429	1.82208	0.56064	2.38272
POR 3	414.29	557.1429	2.03232	0.68328	2.7156
POR 4	514.29	728.5714	2.52288	0.89352	3.4164
POR 5	414.29	442.8571	2.03232	0.54312	2.57544
POR 6	428.57	628.5714	2.1024	0.77088	2.87328
POR 7	457.14	471.4286	2.24256	0.57816	2.82072

<b>POR 8</b>	485.71	785.7143	2.38272	0.9636	3.34632
<b>POR 9</b>	485.71	742.8571	2.38272	0.91104	3.29376
<b>POR 10</b>	457.14	557.1429	2.24256	0.68328	2.92584
<b>POR 11</b>	785.71	542.8571	3.8544	0.66576	4.52016
<b>POR 12</b>	485.71	542.8571	2.38272	0.66576	3.04848
<b>POR 13</b>	442.86	485.7143	2.17248	0.59568	2.76816
<b>POR 14</b>	400	628.5714	1.96224	0.77088	2.73312
<b>POR 15</b>	414.29	585.7143	2.03232	0.71832	2.75064
<b>Mean</b>	468.5713	582.8571	2.184398	0.678178	2.862576
<b>Stan.Dev</b>	96.01224	104.86	0.47	0.1286	0.776167

**Table 2:** Indoor and outdoor gamma absorbed dose rates (measured using TLDs)

Sample code	Gamma absorbed dose rate(nGy/hr)		Annual effective dose(mSv/Yr)		Total annual effective dose(indoor+outdoor) (mSv/Yr)
	Indoor	Outdoor	Indoor	Outdoor	
<b>POR 1</b>	460	580.12	2.256576	0.711459	2.968035
<b>POR 2</b>	360	456.12	1.766016	0.559386	2.325402
<b>POR 3</b>	300.5	558.23	1.474133	0.684613	2.158746
<b>POR 4</b>	490	720.22	2.403744	0.883278	3.287022
<b>POR 5</b>	450	445.5	2.20752	0.546361	2.753881
<b>POR 6</b>	430	624.2	2.109408	0.765519	2.874927
<b>POR 7</b>	440	469.23	2.158464	0.575464	2.733928
<b>POR 8</b>	490	780.22	2.403744	0.956862	3.360606
<b>POR 9</b>	480	735.2	2.354688	0.901649	3.256337
<b>POR 10</b>	450	550.2	2.20752	0.674765	2.882285
<b>POR 11</b>	752	535.22	3.639955	0.656394	4.296349
<b>POR 12</b>	480	535.2	2.354688	0.656369	3.011057
<b>POR 13</b>	430	490.2	2.109408	0.601181	2.710589
<b>POR 14</b>	390	625.25	1.913184	0.766807	2.679991
<b>POR 15</b>	505.87	580.22	2.4815	0.711582	3.193178
<b>Mean</b>	459.8913	579.022	2.256043	0.710113	2.966156
<b>Stan. Dev</b>	95.2321	106.3257	0.467171	0.125655	0.482338

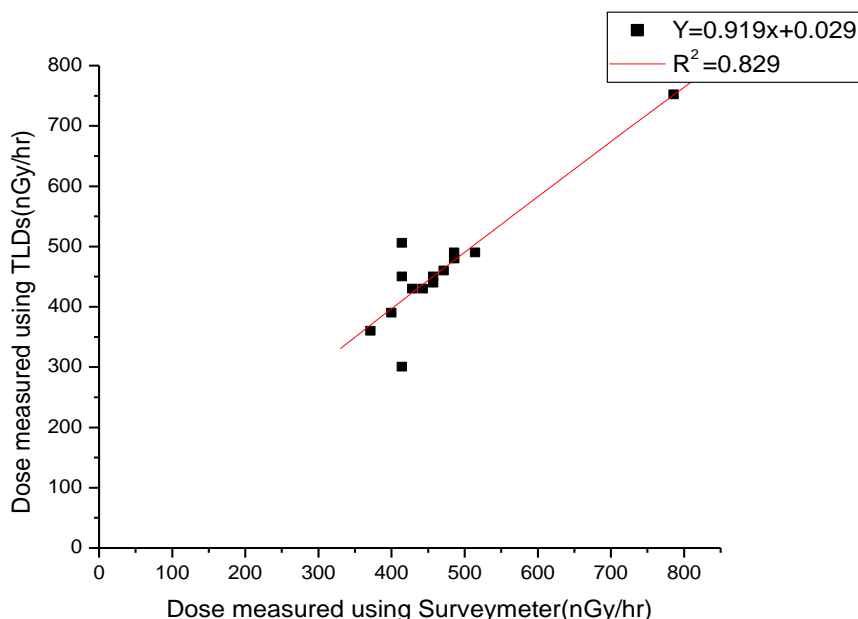


Fig: Correlation between gamma absorbed dose rates measured using surveymeter and TLDs.

### 3.3. Indoor to outdoor gamma dose ratio

In this study, we obtained a geometric mean value of 0.82 for the indoor to outdoor dose ratio. The data obtained from the surveymeter reading were used to estimate the dose ratio. The ratio of indoor to outdoor gamma ray doses, in normal radiation background areas in India, is found to be approximately 1.2, particularly in houses which have tiled/cemented floors and concrete walls and ceilings [13] In another study, Chougankar et al. [8] have reported that the mean value of ratio was 0.8 for those dwellings which used construction materials such as bricks, cement, and masonry tiles, which were procured from a different region and these

construction materials, had less radioactivity content than the surrounding soil.

### 3.4. Comparison of dose measured by survey meter and TLDs

The correlation between the dose rate values measured using TLD and portable survey meter is plotted in Fig. 1, which indicates a significant positive correlation ( $R^2=0.822$ ) between the results of the two different methods. However, as indicated in the correlation plot, the agreement between the two techniques is good for low dose values and the deviation increases at higher dose values.

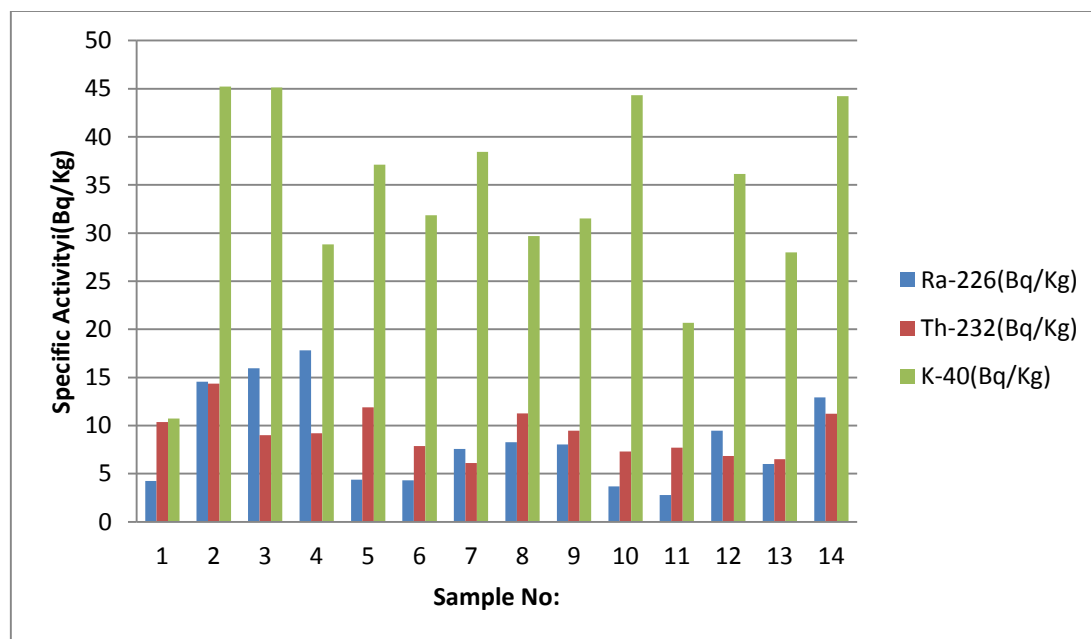
Table 3: Activity concentrations (Bq/ kg) of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$ , Radium equivalent(Bq/Kg),Dose rate(nGy/hr) and total annual effective dose(mSv/Yr).

Sample code	Ra-226(Bq/Kg)	Th-232 (Bq/Kg)	K-40 (Bq/Kg)	$Ra_{eq}(\frac{Bq}{Kg})$	Dose rate(nGy/hr)	Tota annual effective dose(indoor+outdoor) (mSv/Yr)
POR 1	4.23	10.37	10.73	19.8102	8.85047	0.054271
POR 2	14.55	14.35	45.23	38.2366	17.50203	0.107322
POR 3	15.94	9.011	45.12	31.98413	14.81211	0.090828
POR 4	17.811	9.203	28.825	32.98904	15.12617	0.092754
POR 5	4.37	11.88	37.1	23.9554	10.93691	0.067065
POR 6	4.302	7.88	31.84	17.7992	8.197902	0.05027
POR 7	7.56	6.096	38.45	18.96878	8.859418	0.054326
POR 8	8.27	11.27	29.703	26.46531	12.0515	0.0739
POR 9	8.04	9.45	31.53	23.7606	10.88652	0.066756

<b>POR10</b>	3.69	7.29	44.33	17.2178	8.06029	0.049426
<b>POR11</b>	2.79	7.701	20.66	15.24863	6.930973	0.042501
<b>POR12</b>	9.48	6.83	36.128	21.77586	10.10662	0.061974
<b>POR13</b>	5.99	6.514	27.98	17.26362	7.966792	0.048852
<b>POR14</b>	12.94	11.22	44.21	32.0793	14.76801	0.090557
<b>Mean</b>	8.568786	9.218929	33.70257	24.11103	11.07541	0.067914
<b>Sta.Dev</b>	4.925288	2.379983	10.01968	7.193466	3.297159	0.020218

**Table 4:** Hazard indices ( $H_{ex}$  and  $H_{in}$ ), excess lifetime cancer risk (ELCR) and annual gonadal dose equivalent (AGDE) ( $\frac{\mu Sv}{Yr}$ ).

Sample Code	$H_{exte}$	$H_{inte}$	Alphaindex	Gamma index	Representative level index	AGDE( $\frac{\mu Sv}{Yr}$ )	ELCR
POR 1	0.053702	0.065134	0.02115	0.069527	0.113673	59.78652	0.000217
POR 2	0.104133	0.143457	0.07275	0.135327	0.183353	119.1447	0.000428
POR 3	0.087253	0.130334	0.0797	0.113228	0.130817	101.0883	0.000362
POR 4	0.089663	0.137801	0.089055	0.114993	0.123121	102.5556	0.00037
POR 5	0.065393	0.077203	0.02185	0.086333	0.146447	74.8111	0.000268
POR 6	0.048671	0.060298	0.02151	0.064353	0.102895	56.22934	0.000201
POR 7	0.051963	0.072395	0.0378	0.068497	0.091633	60.91498	0.000217
POR 8	0.07204	0.094391	0.04135	0.093818	0.138015	81.98964	0.000295
POR 9	0.064771	0.086501	0.0402	0.08456	0.12088	74.24502	0.000266
POR 10	0.047336	0.057309	0.01845	0.063527	0.104913	55.79392	0.000197
POR 11	0.041569	0.04911	0.01395	0.054692	0.092643	47.29852	0.00017
POR 12	0.059503	0.085125	0.0474	0.077793	0.098705	69.18679	0.000247
POR 13	0.047157	0.063346	0.02995	0.061863	0.087787	54.52334	0.000195
POR 14	0.087485	0.122458	0.0647	0.11397	0.1503	100.7661	0.000361



**Fig 2:** Activity concentrations of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  for investigated samples

## Conclusion

The mean value of the gamma dose observed along the coastal region of porakad was higher when compared to the worldwide average value as well as all India average value. The mean values of annual effective dose were  $2.18 \pm 0.47$  mSv  $y^{-1}$  and  $0.67 \pm 0.12$  mSv  $y^{-1}$  for indoor and outdoor, respectively. The indoor to outdoor dose ratio had a mean value of 0.82. A significant positive correlation was observed between the indoor and outdoor dose rates. A good correlation was observed between the gamma dose rate values measured using TLD and portable survey meter. The agreement between the two techniques is good for low dose values and the deviation increased at higher dose values. The mean activity concentrations of the soil samples are  $8.56 \pm 4.92$ ,  $9.21 \pm 2.37$  and  $33.702 \pm 10.019$  Bq/kg, respectively for  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$ . The mean radium activity is higher than the world average. The radiological characteristics and radiological indices were estimated from the measured activity concentration values of these radionuclides. The mean value of  $R_{\text{eq}}$  of the soil samples are  $24.11 \pm 7.19$  Bq /Kg. For each sample, in this study, the representative level index has been determined to assess the radiological hazard of exposure of the public. The absorbed dose rate in air and the mean value of the representative level index are greater than the recommended level.

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