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Original Research Article

Site-Specific Analysis of Cancer Incidence and Related Sociological Parameters in a 'Radiation Hot Spot', along the West Coast of Tamil Nadu, India

Aneesh D[1], Kanagappan, M[2], Godwin Wesley S[3]

[1]Research Scholar, [2]Associate Professor, [3]Professor Emeritus,
Department of Zoology and Research Centre, Scott Christian College (Autonomous), Nagercoil - 629 003, Kanniyakumari District, Tamil Nadu

Corresponding Author: Aneesh D

ABSTRACT

Background: Manavalakurichi, along the west coast of Tamil Nadu, India is well known for its natural radioactivity due to deposition of monazite sand and considered as high background natural radiation area (HBNRA). The incidence of cancer in relation to background radiation and parameters such as occupation, habits (tobacco chewing, smoking, drinking) and gender was preliminarily assessed. Although residing in a HBNRA has been reported to lead to an increase in the frequency of chromosomal aberrations in lymphocytes, the carcinogenic effect has not yet been established. The present study aims to evaluate the impact of background radiation in residents of HBNRA.
Materials and Methods: A cross-sectional study was conducted considering 938 and 778 residents from HBNRA and low background natural radiation area (LBNRA), respectively using as health assessment survey questionnaire.
Result: The incidence of cancer was 1.49% in HBNRA and 1.43% in LBNRA. Regression analysis of the total population of both areas revealed that radiation dose is not significantly related to incidence of cancer (R^2 = 0.010, p=0.411). Pearson chi-square analysis of data showed that a higher proportion (age >18 years) has relationship between cancer and tobacco usage [HBNRA: χ^2 (1, N=364) = 7.098, p = 0.009, LBNRA: χ^2 (1, N=322) = 5.544, p = 0.024]. The rate of infertility, incidences of miscarriages and still births and gestation period were also found to have no relation to radiation.
Conclusion: The impact of background radiation in cancer incidence is not well established. The statistical power of the study might not be adequate due to the low dose to estimate the cancer risk. The detailed study should be needed in wider population to find out the exact effect of background radiation in cancer incidence.

Keywords: Cancer incidence, Background radiation, Radionuclide, HBNRA, Manavalakurichi

INTRODUCTION

Many radionuclides occur naturally in terrestrial soils and rocks and in building materials derived from them. Upon decay, these radionuclide's produce an external radiation field to which human beings are exposed. [1] Long-term monitoring of radioactivity provides useful information about environmental radiation and helps to evaluate its impact on man. [2,3] Surveys have been done among populations inhabiting high-background natural radiation areas (HBRNA). [1,4–7] In the coastal region of Kerala, several epidemiological and biological studies have been conducted, including the analysis of the distribution and enrichment pattern of radionuclides, [8] assessment of individual

exposure dose and estimation of cancer risk [9] and heritable effects on newborns. [10] Many studies have also been carried out to find out radon levels in dwellings in different parts of the world. [11-16] Singh et al. (2007) have already extensively studied the region, including the Manavalakurichi HBNRA belt, with regard to outdoor and indoor radiation doses. [17] However, the analysis of cancer incidence in high-background natural radiation area (HBNRA) of Tamil Nadu has not been carried out. The present study involved the site-specific analysis of cancer incidence and related parameters such as occupation, habits (tobacco chewing, smoking, drinking), and background radiation dose in the west coast of Tamil Nadu.

MATERIALS AND METHODS

Description of the study area

The study has been carried out in 4 villages. The two villages of Manavalakurichi - Chinnavilai (08° 08′ 216″ N, 77° 18′ 268″ E) and Kadiapattanam (08° 08′ 217″ N, 77° 18′ 270″ E) was taken as the high background natural radiation area (HBNRA) and two control villages - Manakudy (08° 05′ 170″ N, 77° 29′ 146″ E) and Rajakkamangalam Thurai (08° 06′ 522″ N, 77° 22′ 366″ E), as low background radiation area (LBNRA) Fig. 1. Manavalakurichi, situated along the west coast of Tamil Nadu, is known for its high radiation levels due to the presence of monazite, which is rich in thorium. The deposit extends to a length of about 6 km, from the north of Muttom promontory to Colachel, with an average width of 45 m. The radioactive elements such as Uranium and Thorium present in soil and water will account for significant component of the background radiation exposure in the population. The low background natural radiation area (Manakudy and Rajakkamangalam Thurai), are situated between coastal regions of Pillaithoppu and Kanyakumari with the average width of 40m. The absence of monozite in soil makes these areas less to background radiation.

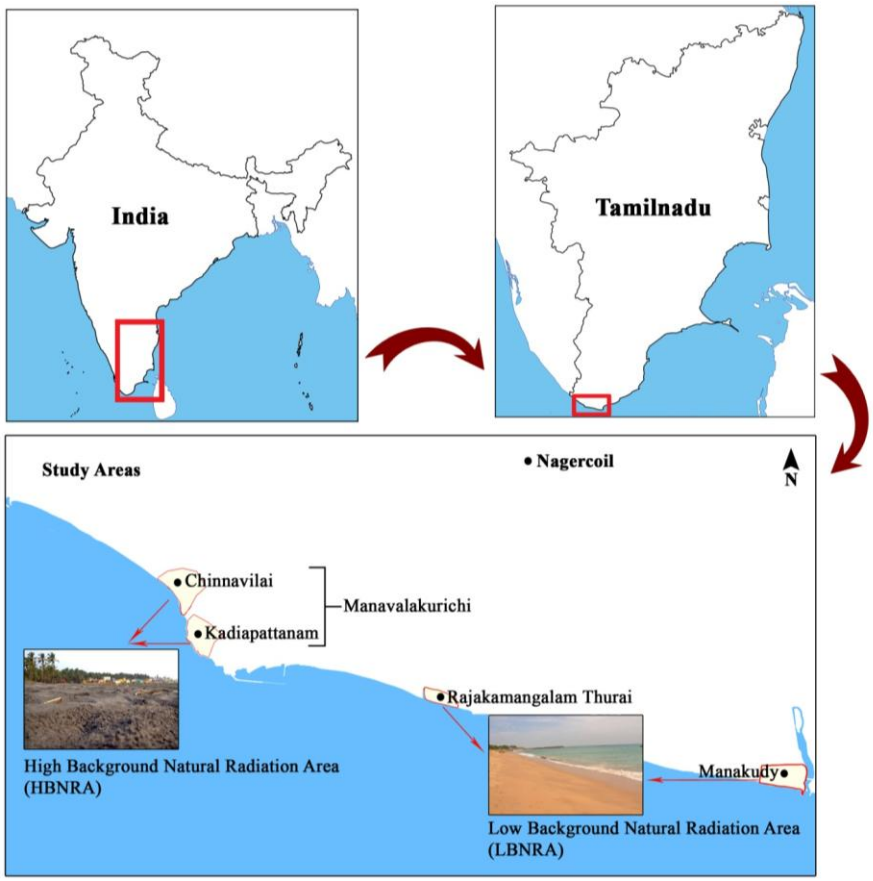

Fig 1. Map showing study areas

Baseline survey

Baseline survey of the population was conducted during the year 2012 – 2013 using a health assessment survey questionnaire. The survey was performed in both HBNRA and Low Background Natural Radiation Area (LBNRA). The HBNRA includes the villages of Manavalakurichi - Chinnaviali and Kadiapattanam and LBNRA includes Manakudy and Rajakkamangalam Thurai. In these four villages the questionnaire so designed to access socio-demographic factors, dietary habits, tobacco and alcohol use, major diseases (including cancer), disabilities, abnormalities, infertility, miscarriages & still births and gestation period. The survey included 938 and 778 residents of HBNRA and LBNRA, respectively.

Outdoor and indoor dosimetry

In order to examine the effect of exposure to high-level natural radiation on cancer risk, age-specific radiation dose is necessary. Since it is difficult to directly measure cumulative dose due to terrestrial gamma radiation, cumulative radiation dose at each age was estimated for each individual, on the basis of the measurements of indoor and outdoor doses at the house of the individual and sex- and age-specific house occupancy factors. Dosimetry was conducted using a hand-held survey meter (micro-R Survey meter, Nucleonix). For indoor measurement the reading was taken in the centre of room with maximum occupancy factor at a height of 1m above the ground for 5 minutes. The measurement of background radiation in random spots of along radionuclide's deposits were also recorded (Table 1)

Table1. Outdoor radiation levels in random spots of HBNRA

Sl.No.	Location	Altitude (metre)	Radiation Dose (μR h^{-1})	Radiation Dose (mGy y^{-1})
1	08°08′125″N, 77°18′264″E	13	1134	99.4
2	08°08′303″N, 77°18′225″E	19	1573	137.9
3	08°08′272″N, 77°18′243″E	20	1243	109.0
4	08°08′217″N, 77°18′270″E	21	1615	141.6
5	08°08′216″N, 77°18′268″E	21	1627	142.6
6	08°08′765″N, 77°18′221″E	23	1089	95.5
7	08°08′886″N, 77°18′121″E	23	1329	116.5
8	08°08′767″N, 77°18′119″E	26	1462	128.2

Individual dose estimation

$$Annual\ Dose(mGy) = \{[Indoor\ dose\ y^{-1} - 0.227] \times OF_{indoor} + [Outdoor\ dose\ y^{-1}\ (mean\ of\ village) - 0.252] \times OF_{outdoor}\} \times CF$$

0.227 and **0.252** are the assumed air kerma values for the cosmic ray component of the measured radiation level [18-21]

OF = Occupancy Factor

CF = Conversion factor for air kerma for organ-specific absorbed dose [22]

CF of ^{232}Th = 0.782 (colon) and 0.791 (red bone marrow). The CFs of children aged 1-14 y and infants aged less than 1 y were increased by 10% and 30% respectively [23]

Statistical analysis:

Statistical analysis was based on survey questionnaire considering sex, occupation, duration of stay, tobacco use, alcohol intake, incidence of cancer, infertility and miscarriages & still births. The annual effective dose was calculated using the indoor and outdoor dosimetry for each individual and dose was statistically analyzed in relation to cancer. Regression analysis of total population of both areas was performed for cancer incidence and radiation dose. Chi-square analysis was performed to find the relationship between consuming habits (tobacco and alcohol) and cancer in residents above the age 18y. Similarly the relationships between radiation dose and infertility and miscarriages were also analyzed.

RESULTS

In the present study, 938 (500 males, 438 females) residents of HNBRA and 778 residents (420 males, 358 females) of LNBRA were surveyed. The mean annual effective dose (AED) to humans residing in the Chinnavilai and Kadiapattanam has

found to be 12.98±8.96 mGy y^{-1} and 7.71±5.50 mGy y^{-1} respectively (Table 2).

Table 2. Background radiation dose received by resident of study areas

	HBNRA		NBRA	
	Chinnavilai	**Kadiapattanam**	**Manakudy**	**Rajakkamangalam Thurai**
Indoor dose (mGy y^{-1})				
Median	5.19	3.24	0.96	0.99
Maximum	31.47	23.93	3.16	4.91
Outdoor dose (mGy y^{-1})				
Median	5.22	2.70	0.83	0.88
Maximum	36.03	21.48	4.56	4.38
Annual Effective Dose (mGy y^{-1})				
Mean	12.98	7.71	2.07	2.23
SD	8.96	5.50	0.98	1.21

The socio-demographic features and habits in the study population is studied and enumerated in Table 3. The gender was more or less equally distributed in all villages. In chinnavilai village the female rate was higher compared to male and in the remaining villages male rate was higher. Most men were engaged in fishing and in Chinnavilai, the same was found to be less. In this village most of the men's occupation is sand mining. The Indian Rare Earth Limited located in this village provides the job preference for the same villagers. The remaining occupations, House wife and number of students are more or less equally distributed among the villages. The consuming habits such as Smoking, Tobacco chewing and Alcohol drinking does not show significant differences among the villages. The most people of the villages use cigarette compared to bidi and surutte. In case of tobacco chewing, the most villagers use betel leaves along with areca nut and chewing tobacco. Very few villagers are using pan masala and oral snuff. The alcohol drinking is also more or less equally distributed among the villages. More than 80% of villagers are non-smokers, non-chewers and non-alcoholic, which includes women and students.

Table 3. Socio-demographic features and habits of study population

	HBNRA			NBRA		
	Chinnavilai	Kadiapattanam	**Total (%)**	Manakudy	Rajakkaman-galam thurai	**Total (%)**
	N=423	**N=515**		**N=408**	**N=370**	
Gender						
Male	222 (48.5%)	278 (54.0%)	**53.2**	211 (51.7%)	209 (56.5%)	**54.1**
Female	201 (52.5%)	237 (46.0%)	**46.8**	197 (48.3%)	161 (43.5%)	**45.9**
Occupation						
Fishing	50 (11.8%)	170 (33.0%)	**22.4**	140 (34.3%)	115 (31.1%)	**32.7**
Mining	80 (18.9%)	0 (0.0%)	**9.5**	1 (0.2%)	0 (0.0%)	**0.1**
Housewife	114 (27.0%)	134 (26.0%)	**26.5**	96 (23.5%)	102 (27.6%)	**25.5**
Govt. Employee	0 (0.0%)	2 (0.4%)	**0.2**	2 (0.5%)	2 (0.5%)	**0.5**
Private Sector	7 (1.7%)	22 (4.3%)	**3.0**	8 (2.0%)	14 (3.8%)	**2.9**
Student	127 (30.0%)	144 (28.0%)	**29.0**	105 (25.7%)	86 (23.2%)	**24.5**
Others	45 (10.6%)	43 (8.3%)	**9.5**	56 (13.7%)	51 (13.8%)	**13.8**
Smoking						
Non-Smokers	377 (89.1%)	472 (91.7%)	**90.4**	370 (90.7%)	338 (91.4%)	**91.0**
Cigarette	22 (5.2%)	25 (4.9%)	**5.0**	24 (5.9%)	21 (5.7%)	**5.8**
Bidi	13 (3.1%)	4 (0.8%)	**1.9**	2 (0.5%)	2 (0.5%)	**0.5**
Surette	11 (2.6%)	14 (2.7%)	**2.7**	12 (2.9%)	9 (2.4%)	**2.7**
Tobacco Chewing						
Non-Chewers	363 (85.8%)	438 (85.0%)	**85.4**	346 (84.8%)	308 (83.2%)	**84.0**
Betel leaves	55 (13.0%)	70 (13.6%)	**13.3**	60 (14.7%)	59 (15.9%)	**15.3**
Pan masala	5 (1.2%)	3 (0.6%)	**0.9**	1 (0.2%)	1 (0.3%)	**0.3**
Oral snuff	0 (0.0%)	4 (0.8%)	**0.4**	1 (0.2%)	2 (0.5%)	**0.4**
Alcohol Drinking						
Never	354 (83.7%)	446 (86.6%)	**85.1**	340 (83.3%)	299 (80.8%)	**82.1**
Occasional	34 (8.0%)	37 (7.2%)	**7.6**	41 (10.0%)	43 (11.6%)	**10.8**
Regular	35 (8.3%)	32 (6.2%)	**7.2**	27 (6.6%)	28 (7.6%)	**7.1**

The cancer rate and disabilities were studied in the residents of 4 villages and detailed in Table 4. There is no difference in cancer rate between the HBNRA (1.4%) and NBRA (1.4%) villages. But within HBNRA villages, the cancer rate is found to be significantly different. The Kadiapattanam village has the cancer rate of 2.3% compared to Chinnavilai, which has the cancer rate of 0.5%. The two villages of LBNRA shows nearly equal pattern of cancer rate distribution i.e., 1.2% and 1.6% for Manakudy and Rajakkamangalam thurai respectively. The disabilities such as Mobility/Orthopedic impairments, Deaf/Hearing impairments, Mental illness/Mental retardation, Blindness/Visual impairments, Dumb/Speech impairments were recorded in the study population. The total disability percentage in HBNRA and LBNRA is 2.9% and 1.9% respectively. No significant difference is seen in percentage wise for other disabilities in the HBNRA and LBNRA villages. The syndromes such as Down syndrome, Turner syndrome, and Klinefelter syndrome were surveyed in the study population. The HBNRA villages found to be significant number of syndrome cases compared to the LBNRA villages. The total percentage of syndrome in HBNRA is found to be 1.5%, which is high compared to LBNRA (0.4%).

Table 4. Health features of study population

	HBNRA			**LBNRA**		
	Chinnavilai	Kadiapattanam	**Total (%)**	Manakudy	Rajakkaman-galam thurai	**Total (%)**
	N=423	**N=515**		**N=408**	**N=370**	
Cancer						
Absent	421 (99.5%)	503 (97.7%)	**98.6**	403 (98.8%)	364 (98.4%)	**98.6**
Present	2 (0.5)	12 (2.3%)	**1.4**	5 (1.2%)	6 (1.6%)	**1.4**
Disabilities						
Absent	414 (97.0%)	511 (97.1%)	**97.1**	403 (98.3%)	363 (98.1)	**98.1**
Mobility/Orthopaedic impairments	6 (1.4%)	3 (0.6%)	**1.0**	3 (0.7%)	4 (1.1%)	**0.9**
Deaf/Hearing impairments	2 (0.5%)	0 (0.0%)	**0.2**	0 (0.0%)	0 (0.0%)	**0.0**
Mental illness/ Mental retardation	4 (0.9%)	11 (2.1%)	**1.5**	2 (0.5%)	1 (0.3%)	**0.4**
Blindness/Visual impairments	0 (0.0%)	1 (0.2%)	**0.1**	1 (0.2%)	3 (0.8%)	**0.5**
Dumb/Speech impairments	1 (0.2%)	0 (0.0%)	**0.1**	1 (0.2%)	0 (0.0%)	**0.1**
Syndromes						
Absent	419 (99.1%)	504 (97.9%)	**98.5**	406 (99.5%)	369 (99.7%)	**99.6**
Down Syndrome	3 (0.7%)	7 (1.4%)	**1.0**	2 (0.5%)	1 (0.3%)	**0.4**
Turner Syndrome	1 (0.2%)	3 (0.6%)	**0.4**	0 (0.0%)	0 (0.0%)	**0.0**
Klinefelter Syndrome	0 (0.0%)	1 (0.2%)	**0.1**	0 (0.0%)	0 (0.0%)	**0.0**

The fertility and reproductive parameters were surveyed in the study population and results were tabulated in Table 5. The infertility cases in HBNRA are 0.7% and LBNRA is 1.2%. LBNRA reported slightly higher value compare to HBNRA, but does not have a major difference. The 99.2% of HBNRA and 98.9% of LBNRA residents are fertile.

Miscarriages and still births are recorded based on women who had the miscarriages or still births at any point of her pregnancies. The miscarriages and still births percentage in HBNRA and LBNRA is found to be 20.5% and 24.6% respectively. The gestation period of women residing in HBNRA and LBNRA is recorded based on the number of pregnancy. The 97.5% and 96.7% of gestation period in pregnancy were full term (37 to 42 weeks), 2.3% and 3.1% were pre-term (<37 weeks) for HBNRA and LBNRA respectively. The post-term gestation period (>42 weeks) remain same (0.2%) for both HBNRA and LBNRA.

Table 5. Fertility and reproductive parameters of study population

	HBNRA			LBNRA		
	Chinnavilai	Kadiapattanam	**Total (%)**	Manakudy	Rajakkaman-galam thurai	**Total (%)**
Infertility						
Absent	232 (99.2%)	296 (99.3%)	**99.2**	210 (99.5%)	221 (98.2%)	**98.9**
Male	1 (0.4%)	0 (0.0%)	**0.2**	0 (0.0%)	3 (1.3%)	**0.7**
Female	1 (0.4%)	2 (0.7%)	**0.5**	1 (0.5%)	1 (0.4%)	**0.5**
Miscarriages & Still births						
Absent	78 (74.3%)	89 (84.8%)	**79.5**	76 (76.8%)	74 (74.0%)	**75.4**
Present	27 (25.7%)	16 (15.2%)	**20.5**	23 (23.2%)	26 (26.0%)	**24.6**
Gestation Period						
Full term	297 (97.4%)	208 (97.7%)	**97.5**	199 (95.7%)	166 (97.6%)	**96.7**
Pre term	7 (2.3%)	5 (2.3%)	**2.3**	8 (3.8%)	4 (2.4%)	**3.1**
Post term	1 (0.3%)	0 (0.0%)	**0.2**	1 (0.5%)	0 (0.0%)	**0.2**

Regression analysis of the relationship between radiation dose (mGy) and cancer in the study population (HBNRA: N=938; LBNRA: N=778) of both areas were revealed that they be insignificant (R^2 = 0.010, p=0.411). The relative risk (RR) was analyzed in the residents of HBNRA (Table 6). The RR was analysed in the residents of HBNRA at different radiation dose 0 – 2.99 mGy y^{-1} , 3 – 5.99 mGy y^{-1} and ≥6 mGy y^{-1} for the age ranges from 18 to 80 years. The radiation dose of 0 – 2.99 mGy y^{-1} is a reference group. The radiation dose ranges from 3 – 5.99 mGy y^{-1}, the RR is found to be 1.024 (95% CI=0.354, 2.930) and for radiation ≥6 mGy y^{-1}, the RR is found to be 1.061 (95% CI=0.431, 2.614), p=0.992. There is no relative risk of cancer at different radiation levels. The RR for age group of 18–39 and 40–80 years at same radiation dose level was analyzed. The age group of 18–39 years has the relative risk of 1.202 (95% CI=0.219,6.606) and 0.7984 (95% CI=0.143,4.304) at background radiation dose of 3 – 5.99 mGy y^{-1} and ≥6 mGy y^{-1} respectively. The age group of 40–39 years has the relative risk of 0.968 (95% CI=0.252,3.718) and 1.232 (95% CI=0.420,3.612) at background radiation dose of 3 – 5.99 mGy y^{-1} and ≥6 mGy y^{-1} respectively. The both age groups does not have significant RR on cancer due to background radiation. The P value was found to be 0.904 and 0.946 for 18–39 and 40–39 years ages groups respectively.

Table 6. Relative risk assessment of cancer on background radiation dose

		Radiation dose (mGy y^{-1})			
		0–2.99	**3 – 5.99**	**≥6**	
Mean dose (mGy)		4.81			
SD		4.78			**P-value**
Age (years)					
	Total Cases	843	343	530	
	Cancer cases	12	5	8	
	RR	1	1.024	1.061	**0.992**
	95% CI	Reference	(0.354, 2.930)	(0.431, 2.614)	
18–39		564	235	357	
	Cancer cases	4	2	2	
	RR	1	1.202	0.784	**0.904**
	95% CI	Reference	(0.219, 6.606)	(0.143, 4.304)	
40–80		279	108	171	
	Cancer cases	8	3	6	
	RR	1	0.968	1.232	**0.946**
	95% CI	Reference	(0.252, 3.718)	(0.420, 3.612)	

As tobacco use is related to the risk of cancer excluding leukemia, this factor was also taken into account in the analysis examining the risk associated with radiation dose. Chi-square analysis of tobacco use and cancer revealed significant correlation in both area residents >18 y of age [HBNRA: χ^2 (1, N=364) = 7.098, p = 0.009, LBNRA: χ^2 (1, N=322) = 5.544, p = 0.024. But, Chi-square analysis of alcohol intake and cancer does not show significant relationship in both the area residents >18 y

of age. The infertility of residents in both areas (HBNRA: N=532; LBNRA: N= 438) using t-test were found have no relation to background radiation. Similarly, the miscarriages & still births and gestation period in female residents of both areas (HBNRA: N=209; LBNRA: N= 199) was also found to have no relation to background radiation in the study population.

DISCUSSION

The primordial radionuclides of the uranium (U) and thorium (Th) decay series are ubiquitous in the environment. The west coast of Tamil Nadu, India is well known for the monazite placer deposits and consider as HBNRA. The HBNRA extends to a length of about 6 km, from the north of Muttom promontory to Colachel, with an average width of 45m. The radioactive elements such as Uranium and Thorium present in soil and water will account for significant component of the background radiation that result in an annual effective dose to the public above a defined level.

In the present study the socio-demographic as well as consuming habits of the study population does not show the significant difference, as all four villages are coastal areas. The parameters such as occupation, income level, education and life style was more or less equal in all villages. The one noted difference was, the villagers in the Chinnavilai, a HBNRA area, where the people are involved in sand mining as their occupation. The Indian Rare Earths Limited located at Manavalkurichi provides the job for mining monazite deposited sand.

The health features of the study population was studied and found the cancer rate is equally distributed among the HBNRA and LBNRA. Within the HBNRA villages, Kadiapattanam shows higher percentage compared to Chinnavilai. Although the most people in Chinnavilai is involved in monazite sand mining and risk being exposed is in higher percentage, the rate of cancer is low. The occupation specific survey is needed in this population to know the exact effect of background radiation in occupational workers. It is noted that the syndromes is found to high in HBNRA compared to the LBNRA. The differences may be due radiation-induced genetic abnormalities or due to consanguinity marriages. Kochupillai et al., 1976 conducted study at high background radiation in coastal Kerala and reported the positive correlation between background radiation and Down syndrome. [24] Rezayat et al., 2013 studied Down syndrome and consanguinity in Iran population and reported no significant difference in Down syndrome cases due to consanguinity. [25] The present study did not analyze the statistical significance of background radiation and syndrome.

The infertility parameters in the study population were low compared to report of WHO (2004) which estimates the overall prevalence of primary infertility in India to be between 3.9 and 16.8 percent. [26] This low infertility in study population may due to existence of differences in environmental conditions associated with reproductive behaviors, such as age at marriage, environmental pollution, absence of smoking and alcohol intake in women, and regulated diet. And in the case of miscarriages there is no real agreement throughout the literatures on just how frequently miscarriage and stillbirth occurs, with suggested rates of 8–20%, [27] 31% [28] and up to 50%. [29] The present study has the same finding in study population with compare to previous reported values in literatures. Beck et al., 2010 reported preterm delivery occurs in approximately 9.6% of all births globally and is the leading cause of neonatal death. [30] The present study has significantly low level of pre-term delivery compare to global average. This is because of difference in nutritional status, hygiene, smoking, and physical activity of women among the countries.

Nair et al., 2009 studied cancer mortality relationship to background radiation in 69,958 residents of Karunagapally, Kerala and find out

incidence of cancer has no statistically significant association with high background radiation. [9] Similarly, another important study by Tao et al., 2000 examining the cancer risk by cancer mortality study among HBRA residents in the HBRA area of Yangjiang, China, where 78,614 and 27,903 in the HBNRA and control area respectively were followed for 16 years and the finding, high background radiation was not related to cancer mortality overall. [31] In the present study also it was observed no statistical relationship between radiation dose and cancer.

In conclusion, the cancer incidence study in west coast of Tamil Nadu, India, showed no background radiation related excess of cancer rate. The statistical power of the study might not be adequate due to the low dose to estimate the cancer risk and detailed study should be needed in wider population to find out the exact effect of background radiation in cancer incidence.

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