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Population Study in the High Natural Background Radiation Area in Kerala, India

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A comprehensive survey of the population exposed to high-level natural radiation is presented. The population living in Karunagappally taluk in Kerala, India, presents a unique opportunity for studies on the health effects of chronic exposure to low-level radiation. The environmental radiation emanates largely from the thorium deposited mostly along coastal areas. In certain locations on the coast, it is as high as 70 mGy/year and on average is 7.5 times the level seen in interior areas. Using portable scintillometers, radiation levels in more than 66,306 houses were measured; outside levels were also measured in the same house compound. Of the total population of 400,000, 100,000 lived in areas with high natural radiation. Information on lifestyle, socio-demographic features, occupation, housing, residence history, and tobacco and alcohol use was obtained by house-to-house visits and enumeration of every resident individual. A population cancer registry system has been established to obtain cancer incidence rates. In this preliminary analysis, there is no evidence that cancer occurrence is consistently higher because of the levels of external γ-radiation exposure in the area. Further dosimetry-level studies are needed along with biological studies. Studies of soil, thoron-in-breath, and the radon-thoron levels in houses are ongoing, and further case–control analyses are continuing. © 1999 by Radiation Research Society

INTRODUCTION

Several laboratory studies and observations of humans have shown that ionizing radiation can cause cancer. All such observations have been made for high-dose and high-dose-rate radiations received either as therapy, during employment, or by accident. However, the effect of exposure to chronic low-level doses of radiation has been estimated only by extrapolating from the high-dose-rate effects. The radiation-emitting sands on the Kerala coast have attracted the attention of scientists the world over, particularly after the WHO expert committee's report in 1957 that the Chavara-Neendakara belt in Karunagappally taluk was best suited for epidemiological studies of high-level natural background radiation. The committee had noted that the aggregate mean dose to gonads and bones was around 830 mrem/year (*1*). Dr. Gopal-Ayengar, who pioneered studies in the area, had observed that the external radiation exposure in the region was caused by β-particle and γ radiation from natural uranium-thorium contained in the monazite sands and β-particle and γ radiation from radon, thoron and their decay products in the air (*2*). Due to the presence of the Rare Earth Factory, which conducts extensive mining operations and soil-mineral separation, the public awareness of the presence of radiation increased, and great concern was often expressed regarding health effects, particularly in relation to cancer induction. Several studies have measured the radiation sources and levels in the area (*3, 4*).

In 1990, the Regional Cancer Centre in Trivandrum initiated an epidemiological study of the relationship between cancer incidence and the natural background radiation in the Karunagappally taluk with support from the Atomic Energy Department of the Government of India. This is the first study of cancer in the area.

MATERIALS AND METHODS

The Study Area and Population Characteristics

The area covered in the study was the entire Karunagappally taluk of Kerala State (Fig. 1, left panel). This taluk is comprised of 12 panchayats, which are administrative divisions. The western boundary is the Lakshadweep Sea (Arabian Sea), and the seacoast of the taluk from south to north is almost 25 km long. The taluk tapers at the south end, and its average width is 5 km. At the southern end of the taluk is the Ashtamudi Lake, which joins the sea at this point (Fig. 1, right panel). Many rivers originating from the hills situated about 60 to 70 km east flow into this lake. It is believed that the sands are brought down by the flowing waters and that some sort of a panning action deposits the heavy metallic sand along the seacoast (*5*). The sand on the coast contains 1% monazite, of which 8–10% is thorium (*1*). The major source of γ radiation is this thorium.

The total population in the taluk according to the 1991 governmental

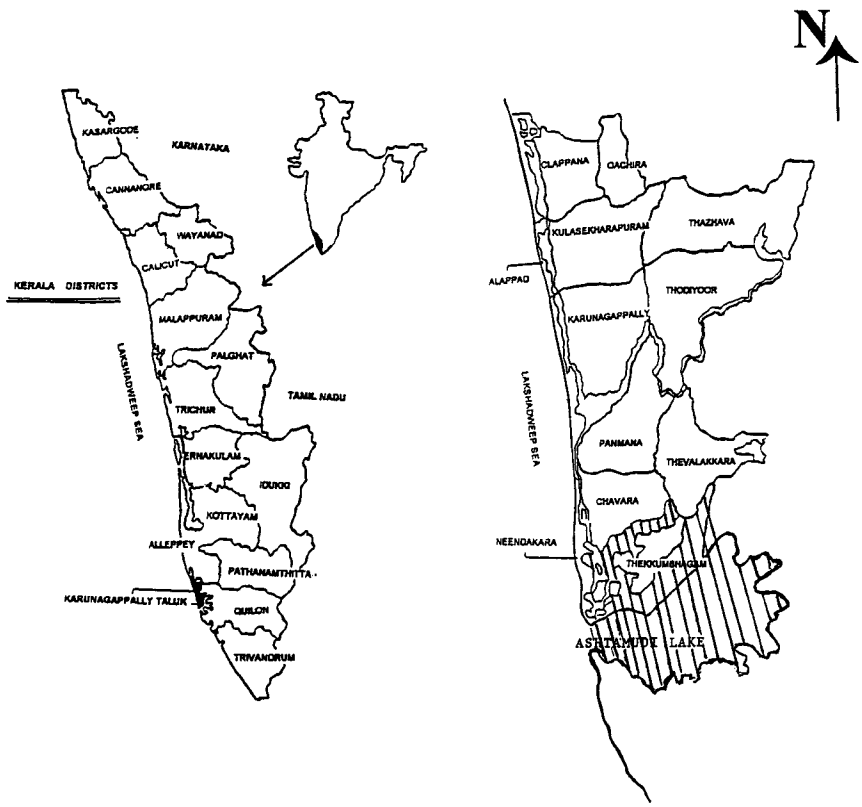

FIG. 1. Left panel: Map of Kerala state showing districts. Right panel: Map of Karunagappally taluk showing panchayats.

census was 385,103. There was about a 1.09% annual population growth rate in the taluk between 1981 and 1991. As in other parts of Kerala, females (193,942) outnumbered males (191,149). This is a rural area, and people are engaged in traditional jobs like agriculture, farm labor, fishing, coir making and fish processing. Some people work in cashew nut factories. There is a literacy rate of over 80%, and transportation and communication facilities are satisfactory. There is hardly any migration into or to outside the area, except that some of the youth have gone to gulf countries seeking jobs, but they come back regularly; otherwise, people have lived there for generations. The population density in the taluk in 1991 was around 2000 per square kilometer. Current information indicates that around 100,000 people live in the high background radiation areas.

Study Methods

There are three aspects of the study: (1) complete enumeration of the population; (2) radiation level measurements as advised by Bhabha Atomic Research Centre, Bombay; and (3) population-based cancer registration.

Complete enumeration of the resident population. By house visits, all resident individuals were interviewed and information was obtained using a precoded proforma. The information collected included details of identification, socio-demographic information, lifestyle, tobacco and alcohol use, occupation, marital and pregnancy status, residence history, type of house construction, and duration of stay.

Measurements of radiation level. In each house, the γ-radiation levels

TABLE 1
Tobacco Chewing and Smoking Habits in Different Age Groups in Karunagappally

	Age in years						
Tobacco habits	15–24	25–34	35–44	45–54	55–64	65–74	75+
Males							
Tobacco chewing only (%)	3.8	7.8	7.8	8.0	6.9	7.0	7.4
Chewing + smoking (%)	2.2	9.0	14.0	15.8	13.5	10.3	9.0
Smoking only (%)	6.4	24.0	34.3	35.7	37.1	30.1	25.0
No habit (%)	87.8	59.3	43.9	40.5	42.4	52.5	58.7
Total persons studied	27,485	13,099	8653	6172	5777	4202	1899
Females							
Tobacco chewing only (%)	0.2	3.0	13.7	28.5	36.1	39.0	40.7
Chewing + smoking (%)	0.0	0.0	0.1	0.7	1.6	2.6	3.7
Smoking only (%)	0.0	0.0	0.2	0.5	1.2	1.7	1.8
No habit (%)	99.7	97.0	86.0	70.3	61.0	56.7	53.7
Total persons studied	34,578	27,839	21,125	14,069	12,394	8489	3711

TABLE 2
Estimated Population by Panchayat on July 1, 1993, Median Level of Radiation and Maximum Level Measured, Average Age-Adjusted Annual Cancer Incidence Rate, All-Causes Death Rate/1000, and Cancer Death Rate/100,000 in Karunagappally Taluk, 1990–1996

	Population		Inrad (mGy/year)		Outrad (mGy/year)		Incidence rate[a]		All-causes death rate per 1000 population		Cancer death rate per 100,000 population	
Panchayat	Male	Female	Median	Maximum	Median	Maximum	Male	Female	Male	Female	Male	Female
Chavara	19,566	19,725	3.900	42.902	5.277	63.015	130.1	100.4	4.8	3.2	45.3	31.9
Neendakara	7925	7894	2.524	53.609	4.206	76.475	78.6	91.6	3.8	2.3	23.4	18.1
Panmana	23,505	23,388	2.294	21.413	3.212	30.590	85.3	65.3	5.4	3.5	39.5	26.3
Alappad	12,847	12,359	3.135	25.313	4.512	43.132	100.3	67.8	6.0	3.9	57.8	26.6
Thevalakkara	19,058	19,627	1.224	9.177	1.071	29.825	104.3	78.1	4.8	3.1	41.2	24.0
Thekkumbhagom	7988	8230	1.606	26.766	1.835	37.167	96.7	76.7	5.6	3.9	55.4	34.7
Karunagappally	22,470	22,341	1.912	7.647	2.600	13.765	98.8	70.2	5.3	3.7	37.5	22.4
Thodiyoor	20,861	20,772	1.377	3.977	1.147	5.736	88.9	75.5	4.7	3.1	40.4	23.4
Clappana	10,433	11,222	1.759	5.353	2.141	7.342	67.3	92.7	5.5	4.4	32.9	38.2
Thazhava	18,189	18,935	1.606	10.248	1.377	11.318	106.1	65.9	5.4	3.7	53.4	34.0
K.S. Puram	21,000	21,526	1.988	15.295	3.059	14.530	124.2	70.1	5.6	4.1	52.4	29.9
Oachira	12,119	12,829	1.071	9.559	0.918	12.083	118.6	89.4	6.3	4.1	56.6	30.1
Total taluk	195,962	198,848					102.6	79.8	5.8	3.8	45.5	28.2

[a] Age-adjusted incidence rate per 100,000, adjusted to world population recommended by WHO-IARC.

were measured using a portable scintillometer supplied by Bhabha Atomic Research Centre, Bombay. Measurements were done at a height of 1 m in the living room (inrad). A similar reading was taken in front of each house near the entrance (outrad). Some houses were unoccupied or locked, and in these only the outside radiation level was measured. Soil samples were taken from each 1-km^2 grid, and the levels of thorium, uranium and potassium were measured. A solid-state nuclear track detector technique was used to measure radon and thoron levels inside the house. Thoron levels in exhaled breath were measured in certain individuals. Only the γ-radiation measurement was taken in all the houses; the rest of the investigations were done for selected houses or persons. To verify the accuracy of the scintillometers for measurements of γ radiation, thermoluminescent dosimeters (TLDs) were used in 406 houses. The cumulated reading for the 12-month period from the TLD readings was then compared with the scintillometer reading estimated for the year from the spot scintillometer reading. A high correlation, $r > 0.98$, was obtained between the two readings. Subsequent to this, portable scintillometers were used only for external γ-radiation measurements.

Cancer registration. For our study, population-based cancer incidence rates were thought to be the most appropriate and feasible index, and hence a sustainable method of cancer registration was developed to cover the entire taluk. This population-based cancer registration followed an active registration process and was done according to standard procedures employed internationally. As the cancer incidence data were collected, data on cancer mortality were also obtained from the vital statistics department in each panchayat. The cancer registration was started on January 1, 1990, and is ongoing.

RESULTS AND DISCUSSION

Presented here are the results of the first large-scale population study of cancer occurrence in relation to the high-level background radiation occurring naturally in the coastal Karunagappally taluk in Kerala.

Data on the external γ-radiation levels for the entire taluk and soil samples analyzed from seven panchayats are presented; the rest of the investigations are ongoing. From the house-to-house survey and enumeration, baseline data on several socio-demographic and lifestyle variables were obtained. The population of each panchayat was available from census reports, and the vital statistics department of each panchayat maintains birth and death registration records. Hence the results of the house-to-house survey and the radiation level measurements are analyzed for each panchayat. The prevalence of tobacco use by the population is given in Table 1. Tobacco use is a powerful independent risk factor for cancer. The analysis by panchayat, the median levels of inrad and outrad radiation, the maximum levels measured in each panchayat, the age-adjusted cancer incidence, mortality from cancer, and the death rate from all causes are given in Table 2. The results of soil analysis are given in Table 3.

There are several competing risk factors such as tobacco use that are prevalent among the population. The radiation levels in the area indicated a nonhomogeneous distribution. There are areas with more than 10 times the normal levels of radiation. Areas with normal radiation levels are also present between areas with high radiation levels. Overall, the radiation levels are high in the coastal panchayats of Neendakara, Chavara, Alappad and Panmana in the taluk. Soil analysis indicated that thorium levels are higher than those of uranium and potassium. It appears that there is no uniformly elevated risk in total cancer rates in the panchayats. To pursue the dose–effect relationship further, investigations of dosimetry taking into account several associated factors such as house occupancy factor and mobility between areas are necessary and are ongoing. As there are only a small number of households exposed to annual doses of more than 20 mGy, the number of person

TABLE 3
Distribution of ^{232}Th, ^{238}U and ^{40}K in the Soil (Bq/kg), Karunagappally Taluk

	^{232}Th				^{238}U				^{40}K			
Panchayat	Minimum	Maximum	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum	Mean	SD
Chavara	96	5072	1029	1109	27	597	145	155	ND	206	51	49
Neendakara	112	9070	1759	2551	41	1453	304	389	ND	154	78	90
Panmana	168	3853	899	907	11	2550	182	474	ND	288	69	80
Alappad	136	3560	1213	837	86	603	332	147	ND	91	50	27
K.S. Puram	75	1660	533	362	ND	251	112	62	ND	168	75	40
Clappana	113	406	228	92	23	174	72	38	ND	175	57	45
Thazhava	44	922	131	131	ND	115	27	24	ND	74	24	24

Notes. Density of soil: 1.72 g/cm^2 (range: 1.29–3.00 g/cm^2). ND = not detected.

years of observation must be increased, for which continuation of the observations is essential. Further, these will give very useful and essential baseline information for biological studies of humans residing in the area.

The pattern of cancer incidence indicates that lung cancer in men and breast and cervix cancer in women were the leading cancers. To assess the excess cancer risk due to high background radiation, the feasibility of obtaining suitable control cases within the area is being studied, and information will be available when the radiation levels in different parts of the panchayat have been assessed completely. For this, subdivisions of panchayat areas by wards will be used. Each ward will have 2000 to 3000 people. There is some homogeneity in the radiation levels in the wards. While studying the dose–effect relationship, interaction between lifestyle habits and radiation level will also be assessed.

In this study, the cancer incidence rate is being assessed and not cancer mortality. The death-reporting system in the area is more or less complete, but certification of cause of death by medical doctors is not universally done. The death rates reported in Table 2 indicate that in Neendakara there is a low death rate, which we feel is due to under-reporting of deaths at young ages. The cancer incidence rate is also low in this panchayat. However, radiation levels are the highest here. These factors will be studied further. The overall death rate per 1000 in the taluk was 5.8 for males and 3.8 for females. The official vital statistics reports (*6*) indicate that the death rate for males and females combined in the rural area of Kollam district was 3.97 in 1992. This appears to be lower than the observed death rate in the study area. The reasons for this will be explored. The Neendakara panchayat has the highest radiation levels. However, the highest cancer incidence was in the Chavara area.

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