

RADIOACTIVITY AND ASSOCIATED RADIATION HAZARDS IN SOIL SAMPLES FROM SHANGUMUGAM, THIRUVANANTHAPURAM DISTRICT

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ABSTRACT

The concentration of natural radionuclides (^{226}Ra , ^{232}Th and ^{40}K) in the soil samples were determined along the coastal regions of Shangumugam, Thiruvananthapuram District by means of gamma spectroscopy with NaI (TI) detector. The mean activity concentrations for ^{226}Ra , ^{232}Th and ^{40}K are greater than the world average values reported by United Nations Scientific Committee on Effects of Atomic Radiation for areas of normal background radiation. Radiological indices were estimated for the radiation of the natural radioactivity of all soil samples. Estimated mean total absorbed dose from activity concentration of ^{226}Ra , ^{232}Th and ^{40}K are $115.2 \pm 8 \text{ nGy h}^{-1}$. Annual indoor and outdoor effective dose was also calculated. Also the representative level index, which resulted from the natural radionuclides in the soil samples were also estimated and given.

Keywords:

Introduction

The knowledge of radionuclide distribution and radiation levels in the environment is important for assessing the effects of radiation exposure due to both terrestrial and cosmogenic sources. Terrestrial radiation is due to radioactive nuclides present in varying amounts in soils, building materials, water, rocks and atmosphere. Some of the radionuclides from these sources are transferred to man through food chain or inhalations, while the cosmogenic radiation originates from outer space as primary cosmic rays. Everyone on the planet is exposed to some background level of ionizing radiation. External exposures occur as a result of irradiation, and internal exposures occur because of inhalation and ingestion [Joga Singh et al., 2009].

The natural radioactivity in soil comes from ^{238}U , ^{232}Th and from natural ^{40}K . Some other terrestrial radionuclides, including those of the ^{235}U series, ^{87}Rb , ^{138}La , ^{147}Sm and ^{176}Lu exist in nature but at such low levels that their contributions to the dose in the humans are small. Artificial radionuclides can also be present such as ^{137}Cs , resulting from fallout from weapons testing. The radiological implication of these radionuclides is due to the gamma-ray exposure of the body and irradiation of lung tissue from inhalation of radon and its daughters. Therefore, the assessment of gamma radiation dose from natural sources is of particular importance as natural radiation is the largest contributor to the external dose of the world population [UNSCEAR, 1988]. Natural environmental radioactivity and the associated external exposure due to gamma radiation depends primarily on the geological and geographical conditions, and appear at different levels in the soils of each region in the world [UNSCEAR, 2000].

The natural radioactivity of soil sample is usually determined from ^{226}Ra , ^{232}Th and ^{40}K contents [OECD, 1979]. Since 98.5% of the radiological effects of the uranium series are produced by radium and its daughter products, the contribution from the ^{238}U and the other ^{226}Ra , precursors are normally ignored [Zastawny et al., 1979]. Nationwide surveys have been carried out to determine the radium equivalent activity of soil samples in many countries [S. Singh et al., 2003; Al-Jundi et al., 2003; F. Mireles et al., 2003; N. M. Ibrahim et al., 1993]. Such investigations can be useful for both the assessment of public dose rates and the performance of epidemiological studies, as well as to keep reference-data records, to ascertain possible changes in the environmental radioactivity due to nuclear, industrial, and other human activities. The present work investigates the activity concentration of radioactive elements such as ^{226}Ra , ^{232}Th , ^{40}K and gamma ray absorbed dose in soil samples collected from the coastal regions of Shangumugam, Thiruvananthapuram district using gamma-ray spectrometry.

MATERIALS AND METHODS

1. Sampling and sample preparation

Thirty soil samples were collected along the coastal regions of Shangumugam, Thiruvananthapuram district. All collected soil samples were stored in the 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° 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 [X.Lu et al.,2006]. 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 [A.S.Alencar et al.,2005].

2. Gamma-spectrometric analysis

The concentrations of the natural radionuclides ^{226}Ra , ^{232}Th and ^{40}K in soil samples were determined using a 5X 5 cm NaI(Tl) gamma ray spectrometric system with 8 % energy resolution (^{137}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}K , 1.46 MeV gamma rays, ^{226}Ra , 1.76 MeV gamma rays (^{214}Bi) and ^{232}Th , 2.61 MeV gamma rays (^{208}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 [X.Lu et al.,2007]. All samples were counted for 10000 S.

3. Measurement of natural radioactivity

The concentrations of radionuclides were calculated using the following equation:

$$\text{Specific Activity} = \frac{\text{cps} \times 100 \times 100}{\text{BI} \times \text{Eff}}$$

where, CPS = Net count rate per second

B.I. = Branching Intensity, and

Eff = Efficiency of the detector

4. Radium equivalent activity

It was calculated through the following relation [K.N.Yu et al.,1992]: $Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.07C_K$

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

5. 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⁻¹/Bq kg⁻¹ for ^{40}K , 0.461 nGy h⁻¹/Bq kg⁻¹ for ^{226}Ra , and 0.623 nGy h⁻¹/Bq kg⁻¹ for ^{232}Th [UNSCEAR,1993], assuming that ^{137}Cs , ^{90}Sr and the ^{235}U decay series can be neglected as they contribute very little to the total dose from environmental background [D.C.Kocher et al.,1985;P.Jacob et al.,1986].

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

where, C_{Ra} , C_{Th} and C_K are the activity concentrations (Bq kg⁻¹) of radium, thorium and potassium in the samples.

6. 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⁻¹, 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].

$$\begin{aligned} \text{Indoor}(\text{nSv}) &= (\text{Absorbed Dose})\text{nGy h}^{-1} \times 8760\text{h} \times 0.8 \times 0.7\text{Sv Gy}^{-1} \\ \text{Outdoor}(\text{nSv}) &= (\text{Absorbed Dose})\text{nGy h}^{-1} \times 8760\text{h} \times 0.2 \times 0.7\text{Sv Gy}^{-1} \end{aligned}$$

7. External hazard index (H_{ex})

The external hazard index Hex can be calculated by the following equation [J.Beretka et al.,1985;B.Merdanoglu et al.,2006]:

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

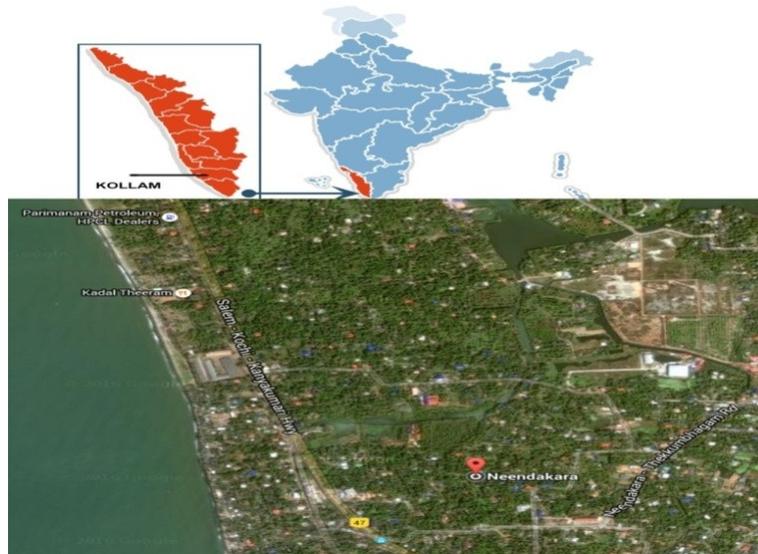


Fig:1 StudyArea

where C_{Ra} , C_{Th} and C_K are the activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K in Bq/kg, respectively. The value of this index must be less than 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 R_{eq} (370 Bq/kg).

8. 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.

9. Representative Level index

The representative level index I_{γ} 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:

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

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

Results and Discussion

The results of the gamma spectroscopy analysis for the soil samples collected along the coastal regions of Shangumugam are summarized in Table 1. The table shows the mean activity concentration of the studied radionuclides in the soil samples collected. The mean and standard deviation are also presented in the table 1. As it can be seen from the table, the activity concentrations of ^{226}Ra ranged from (30.4 to 44.2) Bq/kg with an average value of 36.2 ± 6 Bq/kg. The ^{232}Th activity concentrations varied from (39.2 to 58.6) Bq/kg with an average value 47.2 ± 3.2 Bq/kg, and that of ^{40}K varies from (290.2 to 410.2) Bq/kg with an average value of 392.2 ± 9 Bq/kg. The world average concentrations are 36, 37 and 420 Bq/kg for ^{226}Ra , ^{232}Th and ^{40}K in soil of these areas were higher than the world figures reported in UNSCEAR (2000). Table 2 summarizes the natural radioactivity of soils in some of the regions in the world and from this study.

Location	Sample code	²²⁶ Ra (Bq/kg)	²³² Th (Bq/kg)	⁴⁰ K (Bq/kg)	R _{eq} (Bq/kg)	Absorbed dose rate(nGy h ⁻¹)	Annual effective dose(mSv)	External Hazard index(H _{ex})	Internal Hazard index(H _{in})	I _γ (Bq/kg)
Shangumugam	SH1	50.5	110.5	410.2	237.2	108.9	0.13	0.64	0.78	1.41
	SH2	55.5	112.2	420.2	245.3	112.7	0.13	0.67	0.82	1.43
	SH3	69.2	115.5	399.8	262.3	120.2	0.14	0.71	0.91	1.46
	SH4	67.5	105.5	385.5	245.3	112.6	0.13	0.66	0.85	1.35
	SH5	49.5	107.8	390.2	230.9	105.9	0.12	0.63	0.76	1.37
	SH6	45.8	100.2	395.5	216.7	99.7	0.12	0.59	0.71	1.29
	SH7	44.2	120.2	412.2	244.9	112.1	0.13	0.66	0.78	1.51
	SH8	39.8	125.5	430.2	249.3	114.1	0.14	0.68	0.78	1.56
	SH9	41.2	100.5	435.2	215.3	99.4	0.12	0.58	0.71	1.32
	SH10	40.5	108.7	440.8	226.7	104.4	0.12	0.62	0.73	1.41
	SH11	42.3	125.9	389.7	249.6	113.9	0.13	0.68	0.79	1.54
	SH12	49.8	130.5	365.5	262.2	119.2	0.14	0.71	0.84	1.58
	SH13	47.8	122.2	342.2	246.4	68.5	0.084	0.41	0.53	1.53
	SH14	49.5	128.5	290.2	253.4	71.1	0.087	0.41	0.55	1.55
	SH15	41.3	118.5	351.2	232.01	65.4	0.077	0.41	0.53	1.53
Standard deviation	6.2	3.6	9.4	13.5	8.9	0.01	0.02	0.04	0.04	
Average	36.2	47.2	392.2	242.3	115.2	0.12	0.53	0.78	1.32	

Table 1: The activity concentrations of ²²⁶Ra, ²³²Th, ⁴⁰K, Radium equivalent, dose rate, external hazard index, internal hazard index and radioactivity level index of soil samples collected from the coastal regions of Shangumugam, Thiruvananthapuram district.

The radium equivalent activity of the soil samples ranges from (224.2 to 253.5) Bq/kg with an average value of 242.2±13 Bq/kg. This value is lower than the safe limit (370 Bq/kg) recommended by the Organization for Economic Cooperation and Development. Accordingly, any radium equivalent activity concentration that exceeds 370 Bq/kg may pose radiation hazards.

The determined absorbed dose rates as a result of gamma radiation of the detected natural radionuclides in soil samples for various sites are listed in Table 1. The results show that the dose rate varies from 60.2 to 141.2 nGy h⁻¹ with an overall average value of 115.2±8 nGy h⁻¹. The obtained values of dose rates are higher than the world average value of 55 nGy h⁻¹ [M. Chowhury et al., 2005]. The results of total average effective dose are 0.12±0.01 mSv y⁻¹ (Table 1). It can be seen that the above-mentioned values are higher than the corresponding worldwide values of 0.07 mSv y⁻¹ [UNSCEAR, 2000]. The level index I_γ is determined to estimate the gamma-radiation hazard associated with the natural radionuclide in the soil samples. The calculated values for most samples were higher than the international values (I_γ > 1).

Table 2. Comparison of mean activity concentration values (Bq/kg) of samples with other countries

Country	²²⁶ Ra	²³² Th	⁴⁰ K	Reference
Turkey	115	192	1207	B. Merdanoglu et al., 2006
China	112	71.2	672	Yanget al.,
Bangalore (India)	26.2	53.9	635	Shiva Prasad et al. 2008
Jordan	338± 54.3	21.4± 0.79	227.88 ± 112.8	Samer et al. 2008
Italy	57-71	73-87	580-760	Bellia et al., 1997
Spain	13-165	7-204	48-1570	Baeza et al., 1992
Nigeria	54.5 ± 38.7	91.1 ± 100.9	286.5 ± 308.5	Ajayi et al., 2009
Upper Siwaliks (India)	23.3-81	61.2-140.3	363.4-1002.3	Singh et al., 2009
Ropar District (India)	33.3- 41.7	65.6-81.4	422.9-634.4	Singh et al., 2009
HBRA (India)	44.07 ± 17.1	215 ± 2.7	1585 ± 64.4	Shanti et al., 2009
LBRA (India)	9.9 ± 1.1	21.59 ± 2.7	288.63 ± 32.34	Shanti et al., 2009

Shangumugam (Thiruvananthapuram)	36.6±6	47.1±3.6	392.4 ±9.4	Present Work
World Average	36	37	420	UNSCEAR,2000

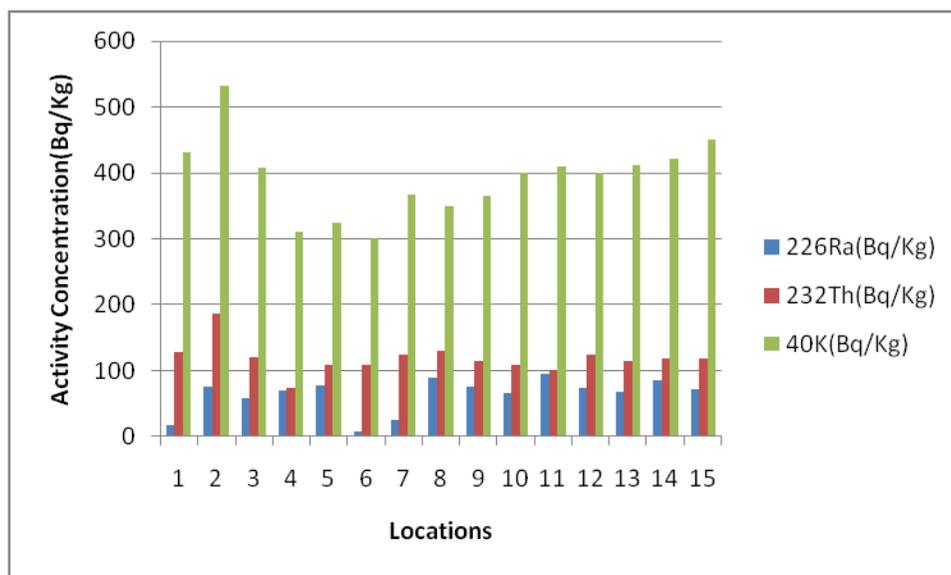


Fig 2: Activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K for investigated samples

Conclusion

- 1) These results indicate that the mean activities of the studied radionuclides are 36.6 ± 6 , 47.7 ± 3 and 392.2 ± 9 Bq/kg, respectively for ^{226}Ra , ^{232}Th and ^{40}K . The mean radium activity is higher than the world average.
- 2) The radiological characteristics and radiological indices were estimated from the measured activity concentration values of these radionuclides. The mean value of Ra_{eq} of the soil samples are 242.1 ± 11 Bq/kg
- 3) 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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