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Studies on Radon and Thorn Exhalation Rates in Beach Sand along East Coastal Region of Tamil Nadu, India

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Abstract: A study on radon and thoron exhalation rate measurements in beach sand samples collected along east coastal region of Tamil Nadu, India, at 45 locations are carried out. Activity concentration of ^{238}U and ^{232}Th are determined in the collected samples by subjecting it into gamma spectrometry. Radon/thoron exhalation rates are measured by employing, portable radon/thoron monitor, RAD 7. Thoron exhalation rate is found to be high in comparison with radon exhalation rate at many locations due to high ^{232}Th deposits along east coastal region. This work presents a comprehensive measured data on of ^{238}U and ^{232}Th radionuclides distribution and radon and thoron exhalation rate from sand samples collected in the study region.

Keywords: Radon, Thoron, Radon Exhalation rate, RAD 7, Natural radioactivity.

1 Introduction

Natural radioactive sources exist in environment due to distribution of primordial and cosmogenic radionuclides. ^{238}U, ^{232}Th and ^{40}K are the primordial radionuclides present in earth crust. The concentrations of U, Th and ^{40}K still exist in environment, as their half-lives are comparable to age of the Earth. The distribution of primordial radionuclides in environment, in particular, sand gives external exposure to human population because of gamma radiation emitted from the daughter products of ^{238}U and ^{232}Th. The study of the spatial distribution of primordial radionuclides in sand enables to estimate annual dose to members of public due to external exposure to outdoor environment [1-3].

In addition, Radon/thoron, a radioactive gases exist in ^{238}U and ^{232}Th decay series, would be emanated from building constructions and dwelling made from sands containing these radionuclides[4-5].This gives an exposure to human population via inhalation mode in indoor environment provided that the same sand is used for any mineral industries during separation of minerals [5-7].

According to UNSCEAR 2000 [8] report, about 55 % of world average annual dose to human population due to natural sources of radiation is contributed by indoor radon/thoron levels [8]. Epidemiological studies also indicated that radon as a major source to cause of lung related diseases [9]. The concentrations of radon/thoron depend on specific concentrations of parent radionuclides of radon and thoron namely, ^{238}U and ^{232}Th present in sand. Radon/Thoron exhalation rate, which represents activity release from sand per unit area (mass), is an essential parameter used to estimate indoor radon and thoron level in indoor environment. It also helps in dose assessment to human population those who are involving in handling beach sand in mineral industries.

In India, radioactivity assessment along east coast region of Tamil Nadu, India assumes importance due to distribution of thorium deposits and the region has been subject of research to many researchers. Many works have been reported on radioactivity measurements in beach sand from the east coast region by measuring the concentrations of primordial radionuclides. There was a wide variation in natural radionuclides and related dose rate along the south east coast region based on detailed survey on reported studies carried out during past four decades [10]. However, a detailed review on measurement of radon and thoron exhalation rate along east coast showed that data is available only at fewer locations and there is a lack of study focusing entire stretch of coastal line. Recent studies have indicated that a few regions the exposure due to thoron and its progeny are found be either equal or more than that of

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radon levels [11]. Prior to investigate the relation between radon and thoron level and associated health risk among human population, it is necessary to have extensive data on radon and thoron levels in the study region. Hence, the present study aims to obtain a comprehensive data on radon and thorn exhalation rate levels in the east coastal region of Tamil Nadu keeping in view to provide a baseline data for dose assessment due to occupational workers who are handling the beach sand in mineral industries.

2 Materials and methods

2.1 Study area

East coast region of Tamil Nadu, along Bay of Bengal, India is chosen as study area in the present work. It covers a total distance of ~ 300 km along coastal line starting from Panithittu and Veerapandiapattinam (Fig.1). Forty five sampling locations were chosen based on preliminary radiation survey. A calibrated ROTEM make gamma survey meter was used for radiation survey.

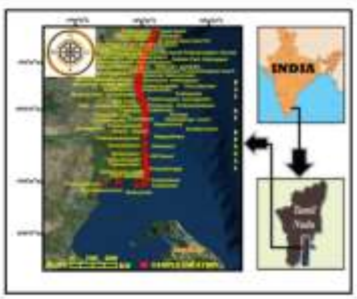

Fig.1: Study area – South East Coastal Region of Tamil Nadu.

2.2 Sampling and preparation

Beach sand samples collected by employing corer method as described in [8] in which a corer of 10.5 cm diameter and depth of 0-25 cm was employed. About ten samples collected, dried in oven at 110⁰ C and stored in a 250 ml sealed container for a period of one month to reach equilibrium among the daughter radionuclides.

2.3 Gamma spectrometric measurements

A calibrated 3”X3” NaI (Tl) detector, Model GSpec coupled with 1 K Multi Channel Analyzer (MCA) used for measurement of concentration of primordial radionuclides in sand. The detector is surrounded by 6 cm thick lead shielding around detector. Soil standards supplied by IAEA in 250 ml container were used for efficiency calibration. ^{232}Th and ^{238}U concentrations are determined from the decay of the daughter nuclides which emits relative high energy gamma rays. The gamma ray peaks that are typically utilized to extract the thorium and uranium concentrations are the 2614.5 keV peak of ^{208}Tl with an intensity of 99.2 % and the 1764.5 keV peak of ^{214}Bi with an intensity of 15.4 %, respectively. A detailed description on calibration and activity estimation of radionuclides are elaborated in [1].

2.4 Radon and thoron exhalation rate measurements

Radon and thoron exhalation from the beach sand samples were estimated using the RAD7 (Durridge Co.,USA) radon/thoron monitor. RAD7 is standard instrument which is widely used for the estimation of radon and thoron concentrations in different environmental matrices. The description of radon and thoron exhalations rates using RAD7 can be found in [12-14]. The minimum detectable values (MDA) of Radon exhalation rate is 2.34 mBq kg^{-1} h^{-1} and Thoron exhalation rate -162 Bqm^{-2} h^{-1}with present RAD 7 monitoring system.

3 Results and discussion

3.1 Radon and thorn exhalation rate measurements

Table 1 presents the results of mass exhalation rate of radon and surface exhalation rate of thoron in beach sand samples from the study regtion, obtained by using RAD7. Mean, minimum and maximum values of Radon and Thoron exhalation rates are given in Table 2. The mean value of thoron exhalation rates are found to be higher compared to radon exhalation rate. The standard deviation of Thoron exhalation rate is found to be greater than its mean which results in a high coefficient of variation (CV) between them. It shows that an abnormal distribution of a set of data and their deviation from the mean value. Two locations (S3 and S24) have recorded higher thoron exhalation rates compared to world average thoron exhalation rate reported by UNSCEAR which is 3600 Bq m^{-2} h^{-1}. Fig.2 and Fig.3 presents the frequency distribution of radon and thoron exhalation rate respectively.

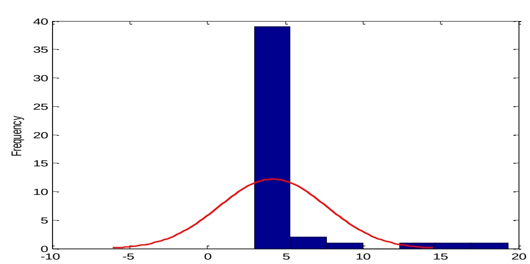

Fig.2: Frequency distribution of Radon exhalationrate.

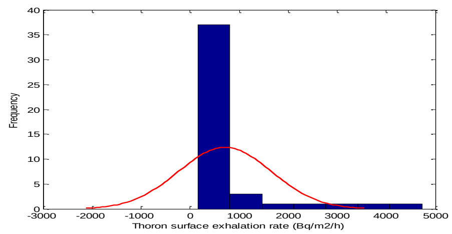

Fig.3 Frequency distribution of Thoron exhalation rate.

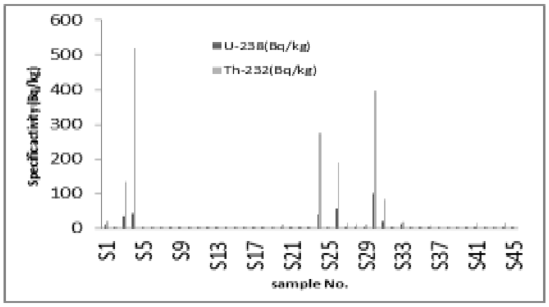

Fig.4. Specific concentrations of ^{238}U and ^{232}Th .

3.2 Uranium and thorium measurements

The measured concentrations of ^{238}U and ^{232}Th at 45 locations are tabulated in Table 3 and depicted in Fig.4. The frequency distribution of ^{238}U and ^{232}Th are shown in Fig.5 and Fig.6. ^{238}U concentration varies from 3 Bq/kg to 100.71 Bq/kg with a geometric mean of 4.55 Bq/kg and concentrations of ^{232}Th are found be in the range of 3 Bq/kg to 520.24 Bq/kg with a geometric mean of 7.07 Bq/kg. Out of 45 sampling points, 36 locations are recorded below detectable limit (BDL) i.e, 3 Bq/kg. Higher values of thoron concentrations are observed at S3 and S24

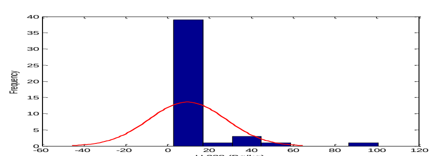

Fig.5:Frequency distribution of ^{238}U.

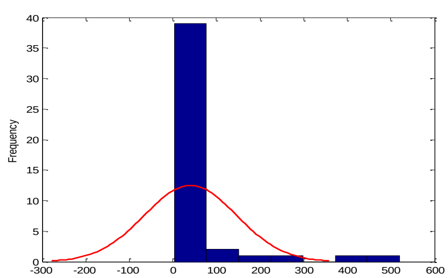

Fig. 6 :Frequency distribution of ^{232}Th.

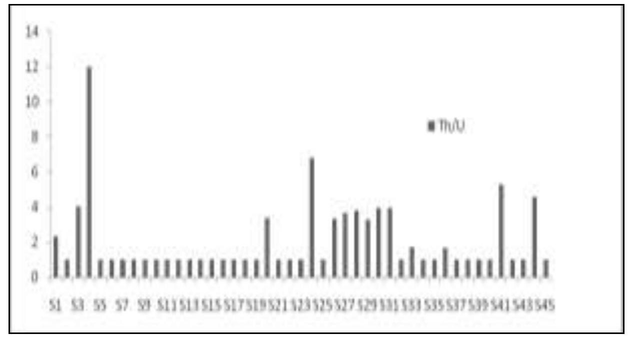

Fig.7: **Th/U activity ratio at sampling locations**

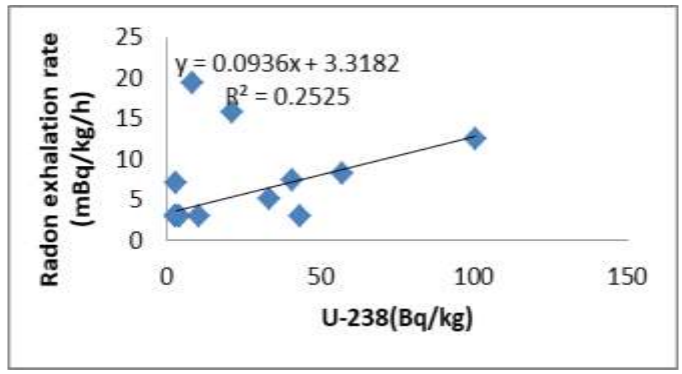

Fig.8: **Regression analysis between ^{238}U and Radon mass exhalation rate.**

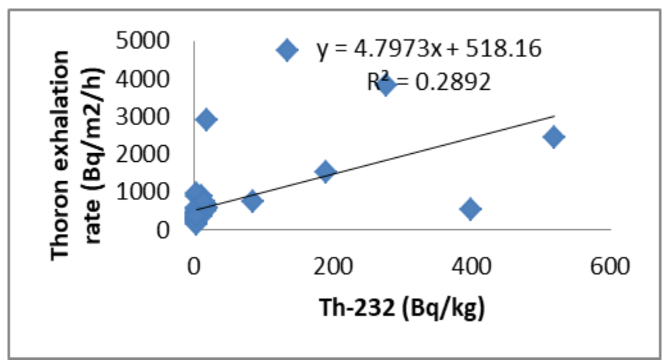

Fig.9: Regression analysis between ^{232}Th and Radon mass exhalation rate.

locations which contributed to higher thoron exhalation rates in the locations.

3.3 Activity ratio (^{232}Th/^{238}U)

The activity ratio of Th/U will be useful to investigate the enrichment/depletion processes as a result of the complexity involved in the process of rock formation, modification and/or weathering [15]. The activity ratio Th/U varies from 1-12.0 and indicates that the beach sand is higly enriched in Thorium in the study region (Fig.7).

Table 1 : Measurements of radon and thoron exhalation rate in the study area

Sample code. No.	GPS coordinates		Radon Exhalation rate (mBq/kg/h)	Thoron Exhalation rate (Bq /m2/h)
	Latitude	Longitude		
S1	11°49’29.4”	79°48’13.8”	19.34 ± 11	2898.36 ± 246
S2	11°48’20.4”	79°48’6.11”	BDL	BDL
S3	11°48’20.4”	79°47’51.6”	5.16 ±3	4725.49 ± 609
S4	11°47’20.5”	79°47’42.3”	BDL	2445.56 ± 108
S5	11°46’21.5”	79°47’30”	BDL	896.34 ± 96
S6	11°45’25.6”	79°47’25”	BDL	503.65 ± 142
S7	11°44’20.9”	79°47’12.6”	BDL	423.36 ± 64
S8	11°42’0.8”	79°46’39.9”	BDL	304.65 ± 64
S9	11°40’52.4”	79°46’17.6”	BDL	301.25 ± 84
S10	11°38’16.9”	79°45’46.1”	BDL	279.09 ± 49
S11	11°37’5.7”	79°45’26.9”	7.03 ± 4	211.53 ± 29
S12	11°36’21.2”	79°45’30.0”	BDL	268.09 ± 74
S13	11°35’6.8”	79°45’25.7”	BDL	303.66 ± 54
S14	11°34’22.0”	79°45’25.7”	BDL	269.61 ± 34
S15	11°33’42.3”	79°45’28.5”	BDL	334.27 ± 29
S16	11°31’35.8”	79°45’52.9”	BDL	268.19 ± 74
S17	11°30’37.0”	79°46’25.7”	BDL	290.25 ± 49
S18	11°30’4.3”	79°46’15.9”	BDL	249.96 ± 74
S19	11°29’9.5”	79°46’53.8”	BDL	411.66 ± 59
S20	11°25’56.0”	79°46’47.9”	BDL	899.88 ± 123
S21	11°24’0.38”	79°48’11.4”	BDL	967.99 ± 187
S22	11°22’27”	79°49’28.6”	BDL	247.25 ± 34
S23	11°21’0.44”	79°50’11.3”	BDL	246.76 ± 74
S24	11°17’31.3”	79°50’11.8”	7.44 ± 3	3825.75 ± 290
S25	11°14’47.1”	79°50’41.8”	BDL	265.93 ± 34
S26	11°8’55.5”	79°51’18.6”	8.24 ± 3	1518.90 ± 236
S27	11°3’35.0”	79°51’19.6”	BDL	511.75 ± 64
S28	11°1’43.1”	79°51’20.1”	BDL	350.83 ± 84
S29	10°59’10.8”	79°51’15.4”	BDL	446.40 ± 84
S30	10°55’5.0”	79°51’9.00”	12.43 ± 4	521.19 ± 172
S31	10°55’5.0”	79°51’7.49”	15.68 ± 4	746.87 ± 142
S32	10°48’49.1”	79°51’2.2”	BDL	263.42 ± 84
S33	10°47’0.2”	79°51’1.62”	BDL	569.98 ± 79
S34	10°40’29”	79°51’0.4”	BDL	245.29 ± 59
S35	10°38’42.3”	79°51’3.9”	BDL	255.36 ± 98
S36	10°33’47.1”	79°51’10.1”	BDL	272.36 ± 44
S37	10°30’47.2”	79°51’31.1”	BDL	157.6 ± 32.1
S38	10°29’5.1”	79°51’42.2”	BDL	576.86 ± 118
S39	10°17’9.13”	79°20’1.18”	BDL	377.37 ± 64
S40	10°22’16.7”	79°52’10.6”	BDL	424.24 ± 49
S41	10°20’3.6”	79°52’45.4”	BDL	673.17 ± 138
S42	10°16’29.6”	79°49’25.5”	BDL	412.50 ± 88
S43	10°16’19.2”	79°44’16.0”	BDL	562.61 ± 88
S44	10°19’35”	79°30’12.1”	BDL	750.16 ± 74
S45	10°17’9.13”	79°20’1.18”	BDL	365.41± 57

Table 2 : Basic statistics of radon and thoron exhalation rate.

Parameter	Minimum	Maximum	Mean	Standard deviation
Radon ER (mBq/kg/h)	2.34	19.34	10.76	4.39
Thoron ER ($Bq/m^2/h$)	157.6	4725.49	723.6545	949.49

Table 3: Measured activity values of ^{40}K ^{238}U and ^{232}Th in the study area.

Sample Code.	Name of the Location	Activity (Bq/kg) ± 2σ		
No		^{40}K	^{238}U	^{232}Th
S1	Panithittu	359.02±18.42	8.12±6.0	18.86±4.86
S2	Narambai	312.27±25.19	BDL	BDL
S3	Valluvarmedu	288.22±18.4	33.3±7.8	134.2±7.58
S4	Moorthikuppam	306.97±38.66	43.34±10.57	520.24±11.51
S5	Denammal Mariamman koil	305.32±21.34	BDL	BDL
S6	Devanampattinam	338.7±17.7	BDL	BDL
S7	Silver beach	391.77±26.84	BDL	BDL
S8	Sothikuppsm	356.5±18.4	BDL	BDL
S9	Raasapettai	318.6±17.6	BDL	BDL
S10	Reddiyar Pettai	333.66±26.29	BDL	BDL
S11	Thammanampettai	328.79±17.6	BDL	BDL
S12	Tiruchchepuram	306.8±17.2	BDL	BDL
S13	Ayyan Pettai	312.9±16.91	BDL	BDL
S14	Poochimedu	298.19±16.6	BDL	BDL
S15	Madavapallam	305.5±16.9	BDL	BDL
S16	Pudukkuppam	246.11±16.4	BDL	BDL
S17	Parangipettai	303.55±25.64	BDL	BDL
S18	Puthupettai	301.89±26.4	BDL	BDL
S19	MGR Thittu	346.71±28.39	BDL	BDL
S20	Vadaku Pitchavaram	339.31±28.11	BDL	10.17±5.35
S21	Pitchavaram	406.05±29.38	BDL	BDL
S22	Kodiyampalayam	409.8±17.8	BDL	BDL
S23	Pazhaiyar	360.0±17.6	BDL	BDL
S24	Kooliyar	330.20±21.19	40.64±9.55	276.17±10.24
S25	Thirumullaivasal	424.06±25.80	BDL	BDL
S26	Poompukar	1743.4±16.9	57.2±8.3	189.68±8.15
S27	Manikkapangu beach	285.32±16.45	4.3±1.2	15.7±4.4
S28	Tharangambadi	260.18±24.53	BDL	11.38±4.78
S29	Mandapathur	403.25±27.16	BDL	9.91±4.99
S30	Karaikal beach	204.76±19.55	100.71±10.22	398.42±10.67
S31	Vanjiur	319.5±18.6	21.3±7.2	84.2±6.7
S32	Nagore	412.13±19.44	BDL	BDL
S33	Nagapattinam	258.0±16.2	10.48±5.8	18.17±4.58
S34	Velankanni	275.9±15.7	BDL	BDL

S35	Prathamaramapuram	241.14±22.36	BDL	BDL
S36	Kameshwaram	611.09±36.33	BDL	39.42±6.99
S37	Vellapalayam	376.32±18.63	BDL	BDL
S38	Pushpavanam	442.46±27.65	BDL	BDL
S39	Periyakuthagai	538.98±30.44	BDL	BDL
S40	Vetharanyam beach	371.74±17.96	BDL	BDL
S41	Point Calimere	39.75±22.88	BDL	15.81±5.16
S42	Kodiyakarai	366.1±18.77	BDL	BDL
S43	Kodiyakadu	302.3±14.9	BDL	BDL
S44	Muthupettai	327.27±26.05	BDL	13.68±5.09
S45	Pudupattinam	47.62±11.3	BDL	BDL

[Minimum Detectable Activity : 11.0 Bq/kg for ^{40}K, 3 Bq/kg for ^{238}U and ^{232}Th]

3.3 Regression analysis

Linear regression analysis of the measured data is indicated that there exists a poor correlation (R^2=0.252) between ^{238}U with radon exhalation rate and ^{232}Th (R^2=0.289) (Fig.8 and Fig.9). This can be explained by the fact that radon/thoron exhalation in sand is mainly depend not only their concentration but largely on radon/thoron emanation factor, which is a function of grain size, porosity, etc [16].

Conclusion

In this work, comprehensive measured data on of ^{238}U and ^{232}Th radionuclides and radon/ thoron exhalation rate from sand samples at 45 sampling stations along the east coastal region of Tamil Nadu, India is presented. The results obtained in the present study would be baseline data useful to occupational workers those who are involved in metallurgical processes which involves removal of extraction of ore and elements from enriched monazite beach sand. Hence, radiation exposure due to inhalation of radon/thoron and associated risk to human population can be minimized by using adequate protection to avoid potential health risk.

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