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Assessment of Natural Radioactivity and radiation hazards in beach sand samples from Kanyakumari District, TamilNadu

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ABSTRACT

Natural radionuclides of terrestrial origin have very long half – lives or driven from very long – lived parent radionuclides, which have been created in stellar processes before the earth formation. The study of natural radioactivity in marine and coastal environments is of significant importance for better understanding of oceanographic and sedimentological processes. The sampling sites are selected to cover randomly to cover the southern part. The soil samples have been collected in beach sides. In situ gamma measurements were conducted using a high-purity germanium (HPGe) detector (coaxial cylinder of 50.1 mm in diameter and 44 mm in length) with a relative efficiency of 50% and an energy resolution (FWHM) of 1.8 keV at the 1.33 MeV reference transition of ^{60}*Co. The measurements shows that the values of the absorbed dose rates in air in the investigated area are lower than the recommended limit by the United Nations Scientific Committee on the Effect of Atomic Radiation.*

INTRODUCTION

One inescapable feature of life in the earth is exposure to ionizing radiation. Ionizing radiation of the environment is the most ubiquitous form of exposure therefore determination of health risk of background gamma radiation is of great importance in health physics [1]. Natural ionizing radiation is emitted as a result of spontaneous nuclear transformation of unstable radionuclide's naturally occurring in the earth's crust (i.e. terrestrial origin) as well as those coming from outer space into the atmosphere (i.e. extraterrestrial origin) . Natural radionuclides of terrestrial origin have very long half – lives or driven from very long – lived parent radionuclides, which have been created in stellar processes before the earth formation. Naturally occurring primordial radionuclide's mainly include ^{238}U, ^{235}U and ^{232}Th series and ^{40}K [2]. All living organisms of the planet are exposed to natural radiation, which is mainly due to the activity concentration of primordial radionuclides ^{232}Th, ^{238}U and their product of decay, in addition to the other natural radionuclide 40K present in the earth' crust .

Naturally occurring radionuclides in building materials are the additional sources of radiation exposure in dwellings [3].Natural environment radioactivity and associated external exposure due to gamma radiation depend primarily on the geological conditions of soil and sediment formation of each region in the world [4]. The study of natural radioactivity in marine and coastal environments is of significant importance for better understanding of oceanographic and sedimentological processes. The distribution of natural radionuclides in the seabed can be used as a tracer for both sediments and dredged soil dispersal and accumulation mechanisms[5]. They also provide an estimation of the sedimentological composition of the seabed. Usually, the activity concentration of radionuclides increases inversely with the grain size and in proportion, with the density of the sediment [6]. The ^{232}U – ^{238}Th radionuclides are associated with heavy minerals; whereas ^{40}k is concenterated with clay minerals [7]. In addition, other parameters such as mineralogy, organic content, and geochemical composition could play an important role in the absorption of radioactive elements in the sediments.

It is a well-known fact that the west coast of the southern part of the Indian peninsular has one of the richest deposits of monazite, a thorium-bearing mineral. Some of the regions of the east coast also have sparse distribution of monazite [8]. Awareness of the dose received from natural sources is very important not only for its effects on health but also for the incidence of other radiation from man-made sources [9].

Such investigations can be useful for both the assessment of public dose rates, as well as to keep reference data records, in order to ascertain possible changes in environmental radioactivity due to nuclear, industrial and other human activities.

Materials and methods

Sample Collection and Preparation

The sampling sites are selected to cover randomly to cover the southern part. The soil samples have been collected in beach sides. The about 2 kg samples of composite sample were collected in a polythene bag. Collected samples were uniformly mixed and sieved. The sieved sand was then dried and transferred to a standard 250 ml plastic container, packed to its full volume and sealed with adhesive tape. This sealing is to ensure that all the daughter products of uranium and thorium and in particular radon and thoron daughters that would be formed thereafter would not be escape. These prepared samples were stored for one month before counting to ensure equilibrium between radium and its short lived daughters. The net weight of the samples was determined before counting to get the activity concentration of radionuclide present in the soil. All the soil samples were subjected to detailed gamma ray spectrometry analysis.

Radiometric Analysis

In situ gamma measurements were conducted using a high-purity germanium (HPGe) detector (coaxial cylinder of 50.1 mm in diameter and 44 mm in length) with a relative efficiency of 50% and an energy resolution (FWHM) of 1.8 keV at the 1.33 MeV reference transition of ^{60}Co. The detector is coupled to a cryostat, dipped into a small dewar (capacity 30 litre) filled with liquid nitrogen, that features in all-attitude capability. The whole system was mounted at a fixed position, with the (detector) Ge crystal facing the ground at a height of 1 m. For this survey, the "ORTEC Spectroscopy System" was used, which incorporates a high-voltage power supply, a spectroscopy amplifier and a multi-channel analyzer (MCA) consisting of a 16k ADC in a compact unit supply and amplifier as well as control of the data acquisition, storage, display and analysis of the acquired spectra.

Result and Discussion

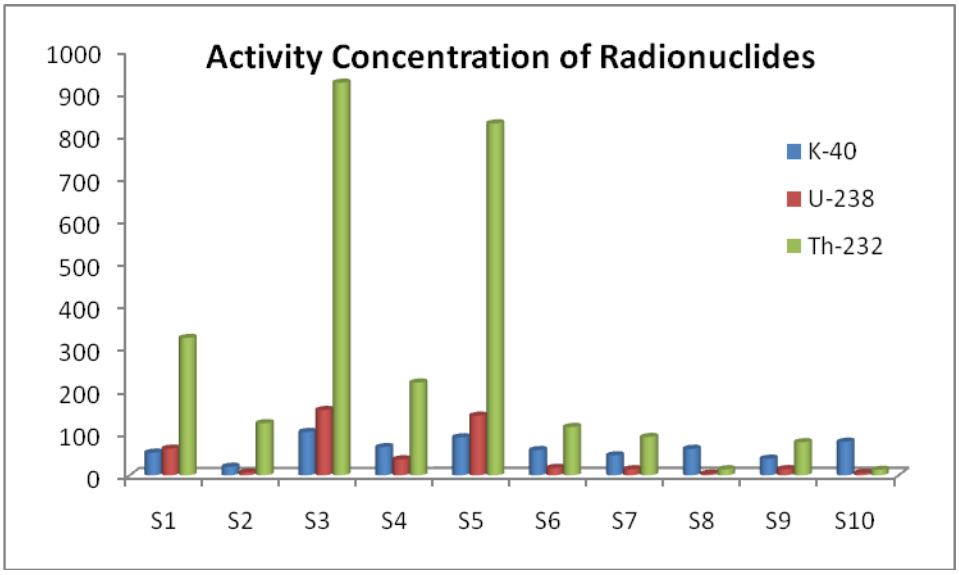
Specific Activity

The natural radioactivity concentration of ^{238}U, ^{232}Th and ^{40}K measured in different locations are given in Table : 1. As can be seen the highest value of specific activities of ^{238}U, ^{232}Th and ^{40}K are 153.63, 102.05 and 924.22 Bq/kg respectively while the lowest value of the specific activities of the same radionuclides are 3.69, 20.17 and 12.86 Bq/kg. The variation of the activity concentration in the studied location may due to the mineral content. The high value of ^{40}K in S3 may due to the potash minerals. The distribution of natural radionuclides is not uniform. Graph1. Show the variation of activity concentration at different sampling locations. Therefore, a common radiological index has been introduced to evaluate the radiation hazards associated with these radionuclide's. In Graph 2 the mean activity concentration of radionuclide's of ^{238}U, ^{232}Th and ^{40}K are 45.04 Bq/kg, 272.53 Bq/kg and 61.74 Bq/kg.

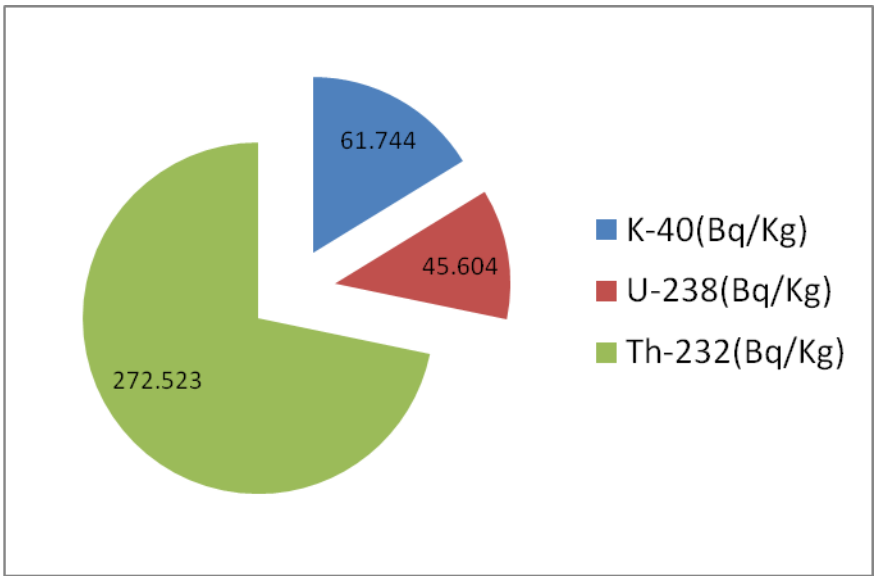
Table 1. Natural activity concentrations of ^{238}U, ^{232}Th and ^{40}K,in coastal samples

Location	Activity Concentration in the Shore Sand			
	K -40 (Bq/kg)	U -238 (Bq/kg)	Th-232 (Bq/Kg)	Radium Equivalent
S1	53.31	62.78	323.29	529.18
S2	20.17	6.53	122.49	305.88
S3	102.05	153.63	924.22	1483.13
S4	66.27	37.51	218.3	354.77
S5	89.33	140.32	828.22	1331.61
S6	59.23	17.5	113.85	184.86
S7	46.93	14.13	90.25	146.8
S8	62.27	3.69	13.96	28.46
S9	38.91	14.55	77.79	128.78
S10	78.97	5.4	12.86	29.86

Graph 1. Activity concentration of the radionuclide for the locations



Graph 2. Average Activity concentration of the radionuclide



Radium equivalent Activity

Radium equivalent concentration is the quantity representative of external γ irradiation dose associated with the sand. In order to compare the specific activity of the sand containing different amount of ^{238}U, ^{232}Th and ^{40}K, the radium equivalent activity Ra_{eq} is used to defined by the following expression UNSCEAR [10].

$$\mathbf{Ra_{eq}\ (Bq/kg) = A_U + 1.43\ A_{Th} + 0.077\ A_K}$$

Where, A_U, A_{Th} and A_K are the activity concentration of ^{238}U, ^{232}Th and ^{40}K respectively.

It is based on the fact that 370 Bq /kgof ^{238}U, 259 Bq/kg of ^{232}Th and 4810 Bq/kg of ^{40}K produce the same g-ray dose equivalent. Column 5 of Table 1 summarizes the Raeq results for all the samples studied. These values ranging from 28.46 Bq/kg to 1483.13 Bq/kg. The high Raeq values calculated in S3 may be attributed to the high concentration of the two radionuclides ^{232}Th and ^{40}K in these materials as shown in Table 1. From the results it is evident that there are considerable variations in the Raeq of different samples.

Representative level index value

This is another radiation hazard index primarily used to estimate the level of g radiation associated with different concentrations of some specified radionuclides and can be expressed as follows

$$RLI = \frac{A_U}{150Bq/kg} + \frac{A_{Th}}{100Bq/kg} + \frac{A_K}{1500Bq/kg}$$

Where, A_U, A_{Th} and A_K are the activity concentration of ^{238}U, ^{232}Th and ^{40}K respectively.

The representative level index values, as estimated using the above formula for the samples, are listed in Table 2. These values ranging from0.25 to 12.38 with an average of 3.68. except three locations (S1, S3 & S5), the values of RLI for the coastal samples do not exceed unity[11].It should be noted that all the RLI value observed fall within a very narrow range, the upper limit for the representative level. This confirms that the samples under investigation exhibit a very low gamma radiation level. The researcher feels that these locations affected by Tsunami might be the reason for slight variation than the other locations.

Activity utilization index (AUI)

In order to facilitate the calculation of dose rates in air from different combinations of the three radionuclides in soils and by applying the appropriate conversion factors, an activity utilization index (AUI) is constructed that is given by the following expression [12]

$$AUI = \frac{A_U}{50Bq/kg} f_U + \frac{A_{Th}}{50Bq/kg} f_{Th} + \frac{A_K}{500Bq/kg} f_K$$

Considered; f_{Th} (0.604), f_U (0.462) and f_K (0.041) are the fractional contributions to the total dose rate in air due to gamma radiation from the actual concentrations of these radionuclides. The calculated values vary from 0.21 (S8) to 12.59 (S3) with an average of 3.72. This value shows that AUI < 2, which corresponds to an annual effective dose < 0.3 mSv/y [13].

Excess lifetime cancer risk (ELCR)

Excess lifetime cancer risk (ELCR) is calculated using the following equation and presented in

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

where AEDE, DL and RF are the Annual Effective Dose Equivalent, duration of life (70 years) and risk factor (0.05 Sv_1), respectively. For stochastic effects, ICRP 60 uses values of 0.05 for the public [14]. The calculated range of ELCR is 2.719 $\times 10^{-3}$ to 0.237×10^{-3} with an average of 0.808 $\times 10^{-3}$ for samples. This average value of ELCR is more twice than the world average (0.290 $\times 10^{-3}$) [15]. The calculations of Radiological Indices are given in Table 2 as per the procedure given by Shanthi etal [16].

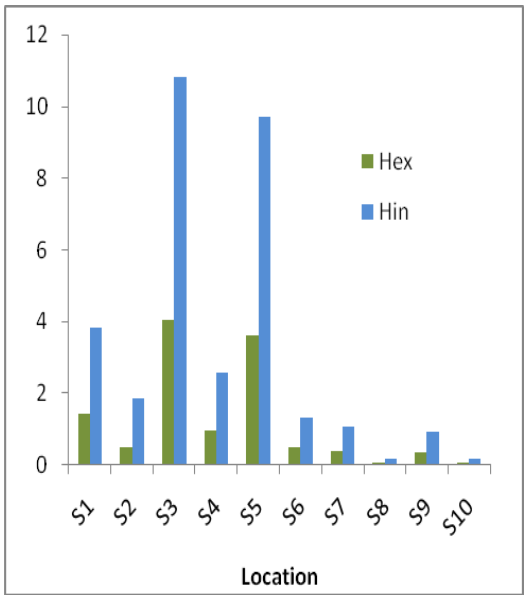
Table .2 Radiological parameters in coastal samples

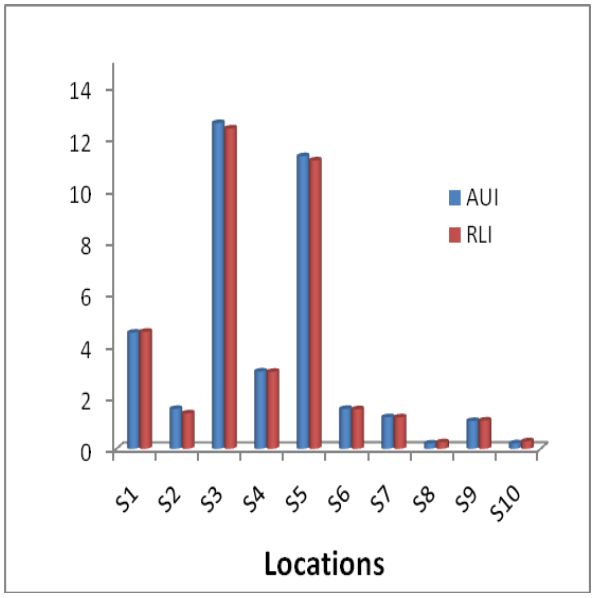
AEED µSv/yr	AGDE µSv/yr	Hex	Hin	AUI	RLI	ELCR $\times 10^{-3}$
277.79	1562.08	1.44	3.82	4.49	4.52	0.972
95.47	538.52	0.50	1.86	1.54	1.37	0.334
776.91	4370.00	4.04	10.81	12.59	12.38	2.719
186.37	1049.21	0.97	2.57	2.99	2.98	0.652
697.61	3923.60	3.63	9.70	11.31	11.15	2.441
97.30	548.57	0.50	1.34	1.54	1.53	0.340.

77.28	435.64	0.40	1.06	1.22	1.22	0.270
15.64	89.31	0.08	0.19	0.21	0.25	0.54
67.87	382.34	0.35	0.93	1.08	1.09	0.237
16.65	95.24	0.08	0.19	0.21	0.29	0.582

Graph 3. Sample Locations with variation of External and Internal hazard Index

Graph 4. Sample Locations with variation of AUI and RLI





The calculated AEED values are quoted in Table 2. The average, minimum and maximum values for outdoor were found to be 230.89 µSv/yr, 15.639 µSv/yr, 776.9146 µSv/yr respectively. The external and internal hazard index must be less than unity in order to keep the radiation hazard to be significant. The calculated external hazard values are between 0.08 and 4.04 and the internal hazard values are in between 0.18 and 10.80. The mean value of the external and internal hazard index is (1.20 & 3.25) greater than the recommended limit. Three locations exceed the recommended limit. This exceedance in these sites is due to the higher concentration of radionuclides. Graph 3. Shows sample locations with variation of external and internal hazard index. Graph 4. Sample Locations with variation of AUI and RLI

Basic Statistics

Statistical behavior of the measured data which includes the range (minimum-maximum), arithmetic mean (AM), arithmetic standard deviation (SD), median, mode, skewness, kurtosis and the type of frequency distribution for the three radionuclides for all the samples. The basic statistics show that the AM of activity concentrations are different from each other but are close within the SD. The precipitation affects the natural radioactivity of the soils, when rain water mixes with SO_2 of the air, then rain become

acidic. Acid rain causes accelerated mobilization of many materials in samples, especially ^{238}U [17].

In Probability theory and Statistics, Skewness is a measure of the asymmetry of the probability distribution of a real valued random variable. Skewness has benefits in many areas. Many models assume normal distribution; i.e., data are symmetric about the mean. The normal distribution has a Skewness of zero. However, in reality, data points may not be perfectly symmetric. Therefore, an understanding of the Skewness of the dataset indicates whether deviations from the mean are going to be positive or negative. Skewness characterizes the degree of asymmetry of a distribution around its mean [18]. Positive Skewness indicates a distribution with an asymmetric tail extending towards values that are more positive. Negative Skewness indicates a distribution with an asymmetric tail extending towards values that are more negative. Lower Skewness value form generally normal distributions. All the radionuclides have the Positive Skewness values which indicates asymmetric distribution.

Kurtosis is a measure of the peakedness of the probability distribution of a real-valued random variable. It characterizes the relative peakedness or flatness of a distribution compared with the normal distribution. Positive Kurtosis indicates a relatively peaked distribution. Negative Kurtosis indicates a relatively flat distribution. Higher Kurtosis means more of the variance is the result of infrequent extreme deviations, as opposed to frequent modestly sized deviations. In the present case ^{238}U and ^{232}Th have a positive Kurtosis which indicates relatively peaked distribution. ^{40}K has a negative Kurtosis which indicates relatively flat distribution.

Conclusion

Measurement of natural radioactivity in soil is very important to determine the amount of change in natural background with time as a result of any radioactive release. Monitoring of any release of radioactivity to the environment is important for environmental protection. The important radiological concentration consequence of natural radioactivity in the soil is the effect of gamma rays on the human body. The measurements shows that the values of the absorbed dose rates in air in the investigated area are lower than the recommended limit by the United Nations Scientific Committee on the Effect of Atomic Radiation. From the above discussion, we can see that there is no radioactive hazard for human beings working and living in this area.

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