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# An Evaluation of Natural Radioactivity and Its Associated Health Hazards Indices of Coastal Sediments from Rameshwaram Island, Tamilnadu, India

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**Abstract:** The natural radioactivity activity concentrations of $^{238}$U, $^{232}$Th and $^{40}$K were measured by gamma spectrometry in coastal sediment samples from Rameshwaram Island of Tamilnadu, India using a NaI(Tl) detector. The activity concentrations of natural radionuclides in sediment samples were within the worldwide range. The radiological hazards due to natural radionuclides content such as absorbed dose rate ($D_R$), annual effective dose rate ($H_R$), activity utilization index (AUI), internal radiation hazard ($H_{in}$) and external radiation hazard ($H_{ex}$) inthe sediment samples were calculated. The calculated radiological parameters are compared with recommended safety limits and internationally approved values. From the analysis, it is concluded that no harmful radiation effects are posed due to activity of coastal sediment to public going for recreation on the beaches or sailors and fisherman involved in their activity of the study area from the coastal sediments.

**Keywords**: Natural Radioactivity, Sediment, Radiological Parameters.

## 1 Introduction

Human beings have always been exposed to natural radiations beneath the surface and above the Earth. The exposure of natural radiations is due to naturally occurring radionuclides such as $^{238}$U, $^{232}$Th and $^{40}$K.Their concentrations in soil, sediments, sands and rocks depend upon the geology of each region in the world. In coastal area, natural radionuclides are measured in seawater, suspended particulate matters, sediments, and sands. The activity concentration of natural radionuclides in coastal sediments gives the useful information in marine research

Sediment plays a predominant role in aquatic radioecology and they are accumulating and transporting contaminants within the geographic area [1]. Sediments are indicator of radiological contamination in the environment.Hence, considerable interest has been given for the determination of natural radioactivity in beach sediments for many researchers throughout the world [1-2].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 [3].

The prime objectives of the present work is (i) to determine the activity concentrations of $^{238}$U, $^{232}$Th, and $^{40}$K in sediment samples collected from Rameshwaram Island of Tamilnadu, India using gamma ray spectrometry (ii) to evaluate radiological hazard indices for the determination on the effects of natural radionuclides in sediments and (iii) to establish the baseline data for natural background radiation level in the study area.

## 2 Materials and Methods

### *2.1 Sample Collection*

Sediment samples were collected in and around Rameshwaram Island, Tamilnadu during pre-monsoon condition. The pre-monsoon condition is best choice for the sediment collection when the textures and ecological studies can be clearly observed. The collection of sediment samples may indicate a unimodal and bimodal distribution. Sediment deposits are transported and shifted due to long shore current action in pre-monsoon. Sediments were collectedusing a Peterson grab sampler.The uniform quantity (2 kg) of sediment samples was collected from all the sampling locations and transported to laboratory.

### *2.2 Sample Preparation*

The collected samples were air dried at room temperature in the open air, then brought to the laboratory, where each sample were dried in an oven at 105˚C to get constant mass.

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Sediment samples were crushed, homogenized and sievedthrough a 200micro meshwhich is optimum size to enrich heavy minerals [4]. A volume of 250 $cm^3$ of each sample was transferred to radon impermeable PVC cylindrical container and containers were sealed tightly with vinyl tape to prevent the possible escape of radon gases. Samples were then stored a period of 4 weeks to reach secular equilibrium between ($^{226}Ra$) and ($^{228}Ra$) and their progenies.

## 3 Gamma ray Spectroscopic Analysis

All the selected samples were subjected to gamma spectral analysis with a counting time of 20,000 secs. A 3" x 3" NaI(Tl) detector was employed with adequate lead shielding which reduced the background by a factor of about 95%. The concentrations of various nuclides of interest were determined in Bq $kg^{-1}$ using the count spectra. The gamma- ray photo peaks corresponding to 1.46 MeV ($^{40}K$), 1.76 MeV ($^{214}Bi$) and 2.614 MeV ($^{208}Tl$) were considered in arriving at the activity of $^{40}K$, $^{226}Ra$ and $^{232}Th$ in the samples. The detection limit of NaI(Tl) detector system for $^{40}K$, $^{226}Ra$ and $^{232}Th$ are 8.5, 2.21 and 2.11 Bq $kg^{-1}$, respectively for a counting time of 20,000 secs.

## 4 Results and Discussions

### *4.1 Activity concentrations of $^{238}U$, $^{232}Th$ and $^{40}K$ in the sediments*

The determined activity concentrations of $^{238}U$, $^{232}Th$ and $^{40}K$ in the sediment samples are given in Table 1. All values are given in Bq $kg^{-1}$ of dry weight. The activities range and mean values (in brackets) for $^{238}U$, $^{232}Th$ and $^{40}K$ are $\leq$ 2.21 – 43.82 (9.59), $\leq$ 2.11 - 120.6 (17.64) and 174.53 – 464.02 (298.47) Bq $kg^{-1}$ respectively. The wide variations of the activity concentration values are due to their presence in the marine environment and their physical, chemical and geo chemical properties [5].

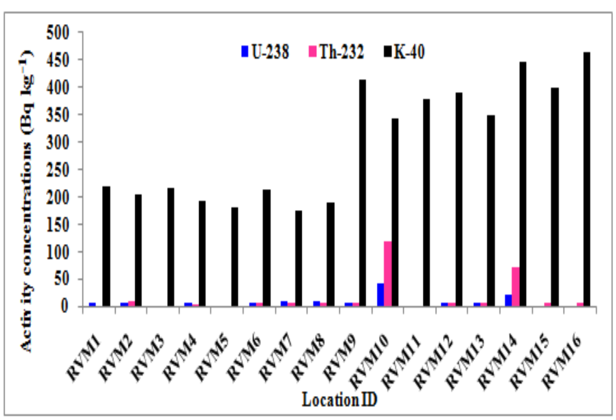


**Fig 1.** Variation of activity concentration (Bq $kg^{-1}$) with different sampling locations.

The results showed that the mean activity of $^{238}U$, $^{232}Th$ and $^{40}K$ is lower than the worldwide average values (35 Bq $kg^{-1}$ for $^{238}U$, 30Bq $kg^{-1}$ for $^{232}Th$ and 400 Bq $kg^{-1}$ for $^{40}K$,) [6]. Table 2 lists the comparison of activity concentration in different states of India with present work. Fig 1 shows the variation of activity concentration with different sampling locations.

## 5 Evaluation of radiological hazard effects

The evaluation of radiological implications of the activity concentration levels of the natural radionuclides in the sediments is important assessment for radiation hazards.Therefore radiological parameters are computed.

### *5.1 Absorbed gamma dose rate ($D_R$)*

The greatest part of the gamma radiation comes from terrestrial radionuclides. It is the first major step for evaluating the health risk and is expressed in gray (Gy).The contribution of natural radionuclides to the absorbed dose rate in air ($D_R$) depends on the natural specific activity concentration of $^{238}U$, $^{232}Th$ and $^{40}K$. The conversion factors used to compute absorbed gamma dose rate ($D_R$) in air per unit activity concentration in Bq $kg^{-1}$ (dry weight)corresponds to 0.462 nGy $h^{-1}$ for $^{238}U$, 0.604 nGy $h^{-1}$ for $^{232}Th$ and 0.042 nGy $h^{-1}$ for $^{40}K$.

$$D_R\ (\text{nGy h}^{-1}) = 0.462\ A_U + 0.604\ A_{Th} + 0.042\ A_K \quad (1)$$

Where, $A_U$, $A_{Th}$ and $A_K$ represent the activity concentrations of $^{238}U$, $^{232}Th$ and $^{40}K$ in Bq $kg^{-1}$ respectively in the samples.Using the above equation $D_R$ had been calculated and tabulated (Table 1). The absorbed dose rate values ranged between 18.80 to 200.34 with a mean value of 52.12 nGy $h^{-1}$.This mean value is less than the world average absorbed dose rate of 84nGy $h^{-1}$. Fig.2. shows the absorbed dose rate with different locations.

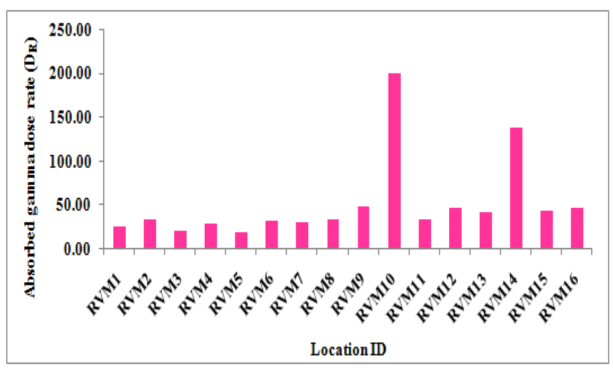


**Fig.2.** Absorbed gamma dose rate (DR) with difference locations

### *5.2. Annual effective dose rate ($H_R$)*

The annual effective dose rate (AEDE) in resulting from the absorbed dose rate values ($D_R$) was calculated using the following formula [15]

**Table 1.** Activity concentrations (Bq kg$^{-1}$) and associated Radiological Parameters of sediment from Rameshwaram Island, Tamilnadu, India.

| S. No | Sample ID | Activity Concentration (Bq kg$^{-1}$) | | | Absorbed dose rate $D_R$ (nGyh$^{-1}$) | Annual effective dose rate $H_R$ (mSv y$^{-1}$) | Activity Utilization Index AUI (I) | Internal Radiation hazard $H_{in}$ | External Radiation hazard $H_{ex}$ |
|---|---|---|---|---|---|---|---|---|---|
| | | $^{238}$U | $^{232}$Th | $^{40}$K | | | | | |
| 1 | RVM1 | 7.21 | 2.11 | 218.93 | 26.47 | 0.0326 | 0.1104 | 0.0926 | 0.0732 |
| 2 | RVM2 | 7.7 | 10.31 | 204.59 | 34.79 | 0.0428 | 0.2128 | 0.1240 | 0.1033 |
| 3 | RVM3 | 2.21 | 2.11 | 215.7 | 21.61 | 0.0266 | 0.0639 | 0.0649 | 0.0590 |
| 4 | RVM4 | 7.52 | 6.46 | 194.66 | 29.60 | 0.0364 | 0.1638 | 0.1061 | 0.0858 |
| 5 | RVM5 | 2.21 | 2.11 | 180.54 | 18.80 | 0.0231 | 0.0610 | 0.0576 | 0.0517 |
| 6 | RVM6 | 7.48 | 7.79 | 214.29 | 32.59 | 0.0401 | 0.1811 | 0.1151 | 0.0950 |
| 7 | RVM7 | 10.62 | 6.58 | 174.53 | 30.97 | 0.0381 | 0.1922 | 0.1191 | 0.0905 |
| 8 | RVM8 | 10.82 | 8.24 | 189.07 | 34.14 | 0.0420 | 0.2153 | 0.1296 | 0.1005 |
| 9 | RVM9 | 7.67 | 8.65 | 413.7 | 49.67 | 0.0611 | 0.2099 | 0.1609 | 0.1403 |
| 10 | RVM10 | 43.82 | 120.6 | 342.03 | 200.34 | 0.2464 | 1.8903 | 0.7736 | 0.6570 |
| 11 | RVM11 | 2.21 | 2.11 | 378.14 | 34.61 | 0.0426 | 0.0774 | 0.0987 | 0.0928 |
| 12 | RVM12 | 8.36 | 8.13 | 389.37 | 47.78 | 0.0588 | 0.2079 | 0.1575 | 0.1351 |
| 13 | RVM13 | 8.12 | 6.95 | 348.78 | 43.02 | 0.0529 | 0.1881 | 0.1432 | 0.1214 |
| 14 | RVM14 | 23.14 | 74.2 | 446.72 | 138.65 | 0.1705 | 1.1474 | 0.5044 | 0.4430 |
| 15 | RVM15 | 2.21 | 9.13 | 400.46 | 44.11 | 0.0543 | 0.1641 | 0.1305 | 0.1246 |
| 16 | RVM16 | 2.21 | 6.88 | 464.02 | 46.72 | 0.0575 | 0.1422 | 0.1350 | 0.1291 |
| **Average** | | **9.59** | **17.64** | **298.47** | **52.12** | **0.0641** | **0.3267** | **0.1821** | **0.1564** |

**Table 2.** Comparison of activity concentration of present work within India.

| S. No. | Name of the Location | Activity concentration (Bqkg$^{-1}$) | | | References |
|---|---|---|---|---|---|
| | | $^{238}$U | $^{232}$Th | $^{40}$K | |
| 1 | East coast of Tamilnadu (coastal sediment) | BDL | 14.29 | 360.23 | [7] |
| 2 | NE Coast, Tamilnadu, India | 35.12 | 713.6 | 349.6 | [1] |
| 3 | NE Coast, Tamilnadu, India | 8 | 25 | 275 | [8] |
| 4 | Orissa, India | 350 | 2000 | 200 | [9] |
| 5 | Eastern Orissa, India | 350 | 2825 | 180 | [10] |
| 6 | Kalpakkam, Tamilnadu, India | 112 | 1456 | 351 | [11] |
| 7 | Coastal Karnataka of South India | 61-316.7 | 20.1-62.3 | 14.3-48.6 | [12] |
| 8 | Ullal, Karnataka, India | 374 | 158 | 158 | [13] |
| 9 | Visakhapatnam, India | - | 100-400 | 300-600 | [14] |
| 10 | India | 28.67 | 63.83 | 327.6 | [6] |
| 11 | **Rameshwaram Coastline, Tamilnadu** | **9.59** | **17.64** | **298.47** | **Present work** |

**Ann. Eff. dose rate(mSvy$^{-1}$) = $D_R$(nGyh$^{-1}$) ×8760h × 0.7 SvGy-1 × 0.2 × 10$^{-6}$**

$$H_R = D_R \times 0.00123 \quad (2)$$

The annual effective dose (Table 1) ranged between 0.0231 mSv y$^{-1}$ to 0.2464 mSv y$^{-1}$ with a mean value of 0.0641 mSv y$^{-1}$. The obtained mean value from this study (0.044 mSv y$^{-1}$) is lower than the world average value [15]. This indicates that the sediment samples satisfy the criteria for a radiation safety point of view. Fig 3 shows the variation of annual effective dose equivalent ($H_R$) in different locations.

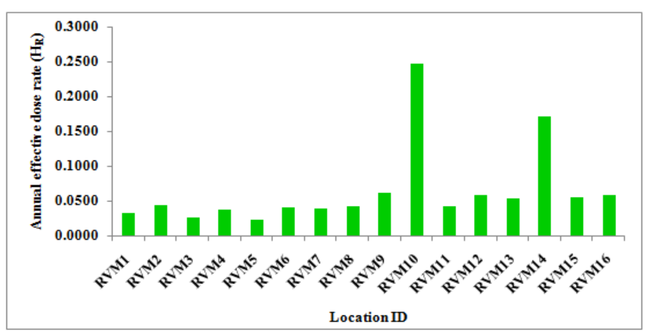


**Fig 3.** Annual effective dose rate ($H_R$) with Different Locations.

### *5.3 Activity Utilization Index (AUI)*

The calculation of dose rates in air from different combinations of the three radionuclides in the studied material can be computed by applying the appropriate conversion factors, an activity utilization index (AUI) can be calculated. The activity utilization indexis given by the following expression [16]:

$$\mathbf{AUI} = \frac{\mathbf{A_U}}{\mathbf{50\ Bq/kg}}\mathbf{f_U} + \frac{\mathbf{A_{Th}}}{\mathbf{50\ Bq/kg}}\mathbf{f_{Th}} + \frac{\mathbf{A_k}}{\mathbf{500\ Bq/kg}}\mathbf{f_K} \qquad (3)$$

Where $A_U$, $A_{Th}$ and $A_K$ are the mean activity concentrations of $^{238}U$, $^{232}Th$ and $^{40}K$ in sediment samples and $f_U$, $f_{Th}$ and $f_K$ are the fractional contributions to the total dose rate of $^{238}U$, $^{232}Th$ and $^{40}K$ respectively.

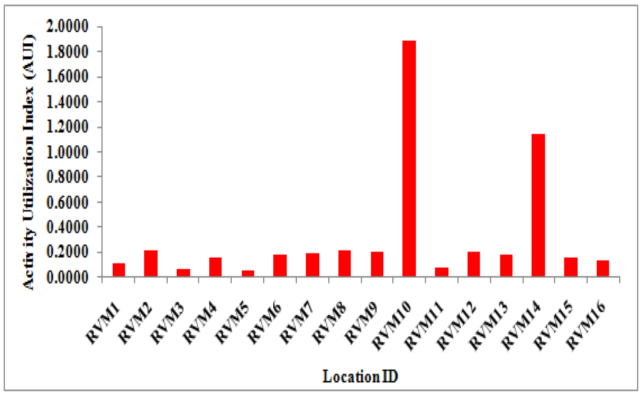


**Fig 4.** Activity Utilization Index (AUI) in different locations.

The calculated values of AUI are shown in the table 1 andranging from 0.0610 to 1.8903 with an average of 0.3267. The obtained values of all sample exhibit that AUI < 2, which corresponds to an annual effective dose < 0.3 mSv $y^{-1}$ [16]. Hence the sediment sample may be used for building constructions. Fig 4 shows the variation of Activity Utilization Index (AUI) in different locations

### *5.4 Internal hazard index ($H_{in}$)*

The internal exposure caused by radon ($^{222}Rn$, the daughter product of $^{226}Ra$) and thoron ($^{220}Rn$, the daughter product of $^{224}Ra$) is hazardous to the respiratory organs. This hazard can be quantified by the internal hazard index ($H_{in}$) [17]

$$\mathbf{H_{in}} = \frac{\mathbf{A_U}}{\mathbf{185\ BqKg^{-1}}} + \frac{\mathbf{A_{Th}}}{\mathbf{259\ BqKg^{-1}}} + \frac{\mathbf{A_k}}{\mathbf{4810\ BqKg^{-1}}} \qquad (4)$$

where $A_U$, $A_{Th}$ and $A_K$ are the activity concentrations of $^{238}U$, $^{232}Th$ and $^{40}K$ in the sediments respectively. The values of $H_{in}$ ranged from 0.0576 to 0.7736 with a mean value of 0.182 which is less than the permissible limit (<1). This implies that no significant radiation hazards associated with the sediments. Fig 5 shows the sampling locations versus Internal hazard index ($H_{in}$) and External hazard index ($H_{ex}$).

### *5.5 External hazard index ($H_{ex}$)*

The external hazard index is an additional criterion to assess the radiological suitability of a material. The external hazard index due to gamma radiation was calculated using the formula.

$$\mathbf{H_{ex}} = \frac{\mathbf{A_U}}{\mathbf{370\ BqKg^{-1}}} + \frac{\mathbf{A_{Th}}}{\mathbf{259\ BqKg^{-1}}} + \frac{\mathbf{A_K}}{\mathbf{4810BqKg^{-1}}} \qquad (5)$$

where $A_U$, $A_{Th}$ and $A_K$ are the activity concentrations of $^{238}U$, $^{232}Th$ and $^{40}K$ in the sediments. The results of $H_{ex}$ values of the sediment samples are given in Table 2. The obtained $H_{ex}$ value of the present work ranged between 0.0517 to 0.6570 with an average value 0.1564.The obtained value is lower when compared to 0.84 of China, 0.40 of Firtina River, Turkey [18-19].

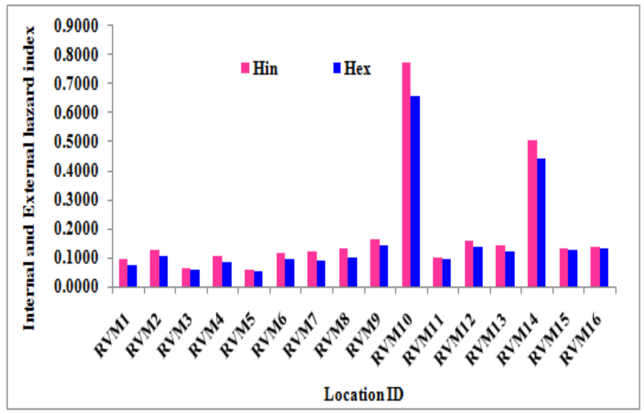


**Fig 5.** Locations ID versus Internal and External hazard index ($H_{in}$& $H_{ex}$).

From the analysis, the external hazard index values does not exceed the acceptable limit which is less than unity ($H_{ex}$<1) and indicates that these radiation hazards may not cause any harmful to people living in the study area.

## 6 Conclusion

The natural radioactivity and associated radiation hazards such as absorbed dose rate ($D_R$), annual effective dose rate ($H_R$), activity utilization index (AUI), Internal radiation hazard ($H_{in}$) and external radiation hazard ($H_{ex}$) were calculated in sediment samples of Rameswarem Island, Tamilnadu, India. The activity concentrations and radiation indices werebelow safetyvalues. Hence sediments of Rameswaremdo not pose significant radiological health risk.

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