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EVALUATION OF GAMMA RADIOACTIVITY LEVELS AND ITS RADIOLOGICAL HAZARDS OF BEACH AND INTERTIDAL SEDIMENTS

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Abstract: There has been great concern about the health risks associated with the exposure due to the natural radioactivity present in coastal sediments all over the world. In this context, 35 beach and intertidal sediment samples were collected from north east coast of Tamilnadu, India, in order to evaluate their natural radioactivity. The activity concentrations of natural radionuclides such as ^{238}U, ^{232}Th and ^{40}K in sediment samples were determined by gamma ray spectrometer and the mean values are compared with recommended and reported values. In order to evaluate the radiological hazard of the sediment, the absorbed dose rate, annual effective dose rate, hazard index, representative level index and excess lifetime cancer risk have been calculated and discussed. Average of all the calculated radiological parameters are within the recommended level for both beach and intertidal samples. However, some extreme values are also observed in Devanampattinam (S_6) and Mahabalipuram (S_{22}) beach due to the presence of black sands. No harmful radiation effects are pose to the public and tourists going to the beaches for recreation or to the sailors and fishermen involved in their activities in the area as a results of the activity of beach and intertidal sediments.

Keywords: Natural radioactivity, Beach and Intertidal sediments, absorbed dose rate, hazard index

1. INTRODUCTION

Natural radioactivity is present in the environment right from the time of formation of the universe. Ionizing radiation should have played a great role in the evolution of all the components, living and non-living of earth as we see it today. The effective dose due to this ionizing radiation for members of the public varies substantially depending on where they live, occupation, personal habits, etc. (Selvasekarapandian et al., 2000). It is remarkably effective in causing biological damage and it is injury to living tissue results from the transfer of energy to atoms and molecules in the cellular structure. It causes atoms and molecules to become ionized or excited. These excitations and ionizations can produce free radicals, break and produce new chemical bonds, cross-linkage between macromolecules and damage molecules that regulate vital cell processes (e.g. Deoxyribonucleic acid - DNA, Ribonucleic acid – RNA and proteins). Also, it damages DNA and causes mutation and chromosomal changes in cells and organisms. Damage by radiation or radiomimetic agents leads to cell transformation (a stage in cancer development) and cell death (UNSCEAR, 2000).

Mother Nature has gifted mankind with lot of precious gifts. Common coastal environment is one of them because of their socioeconomic and environmental significance. Good coastal environmental quality is essential to sustaining coastal and marine ecosystems, commercial and recreational fisheries and economic growth in coastal communities. The health of coastal and marine ecosystems is depends on natural radioactivity levels of coastal sediments. Akram et al., (2006) reported that the accumulation of radio nuclides in the marine costal environment raises many problems concerning safety of biotic life, food chain and ultimately humans. So, from the natural risk point of view, it is necessary to know the level of natural radioactivity of public exposures in the coastal sediments (beach and intertidal) is of great importance.

During the last few decades, the coastal environment of North east coast of Tamilnadu in India has experienced intense developments in industry, tourism, transport, urbanization and aquaculture. In the view of this, two different coastal environmental matrices (beach and intertidal sediments) from north east coast of Tamilnadu were collected. The objective of this study is to (a) determine the activity concentrations of naturally occurring gamma emitting radioactive elements such as ^{238}U, ^{232}Th and ^{40}K in beach and intertidal sediment samples and (b) calculate the associated radiological hazard indexes such as absorbed dose rate, annual effective dose rate, hazard index, representative level index and excess life time cancer risk.

2. MATERIALS AND METHODS

2.1. Study Area and Sample Collection

This study took place in north east coast of Tamilnadu, is bordered on the east by the Bay of Bengal (Fig. 1). The total study area spread over from Portnovo (Lat: 11º 30' 59"N; Long: 79º 46'18"E) to Marina beach of Chennai city (Lat: 13º 03' 55"N; Long: 80º 17'24"E), which covers an area about 200km. Some famous beaches (Marina, Kovalam, Arovil and Silver), historical place (Mahabalipuram) and Chemical Industries (SIPCOT) are located in this study area.

Beach and intertidal sediment samples were collected during April 2008. The total study area covers about 200km, from which 35 successive locations were selected and numbered as S_1 to S_{35}. The sample location were recorded in terms of degree - minute – decimals (Latitudinal and Longitudinal position) using Hand-held Global Positioning System (GPS) (Model: GARMIN GPS-12) unit. Each location is separated by a distance of 5-6 km approximately. At each sampling location two sub sampling sites were selected: One sample was collected from 10-20m away from the high tide, when it makes towards the road side (beach) and another one was from intertidal region.

2.2. Sample Preparation

The collected samples were dried in an oven at 100-110ºC for about 24h and sieved through a 2-mm mesh-size sieve to remove stone, pebbles and other macro-impurities. The homogenized sample was placed in a 500g airtight PVC container. The inner lid was placed in and closed tightly with outer cap. The container was sealed hermetically and externally using cellophane tape and kept aside for about a month to ensure equilibrium between Ra and its daughter products before being taken for gamma ray spectrometric analysis.

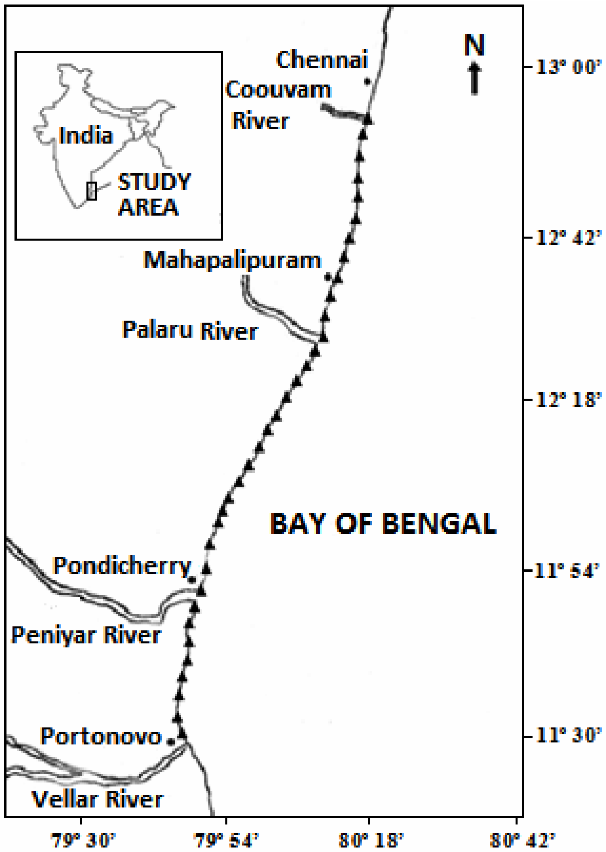

Figure 1 Geographic location of North east coast of Tamilnadu where the sediment samples were collected.

2.3. Instruments and techniques

To estimate the activity levels of the ^{238}U, ^{232}Th and ^{40}K in the samples, a gamma ray spectrometer in the laboratory of Health and Safety Division, Indira Gandhi Centre for Atomic Research, Kalpakkam was used in the present investigations. NaI (Tl) crystal detector of size 3" X 3" along with a 8K multichannel analyzer was used to record the gamma spectra. Standard sources of natural Uranium (1997.56Bq), natural Thorium (1237.28 Bq) and KCl (5181.59 Bq) with a standard 250ml container from International Atomic Energy Agency (IAEA) were used for calibrating the gamma ray spectrometer. These standards were obtained from environmental survey laboratory, Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam. With the counting time of

10,000 seconds for each sample, the below detectable limit (BDL) were 21.2Bqkg^{-1} for ^{40}K, 5.5 Bqkg^{-1} for ^{238}U and ^{232}Th.

3. RESULTS AND DISCUSSION

Activity concentration (Bq/kg) of ^{238}U, ^{232}Th and ^{40}K radio nuclides in beach and intertidal sediments samples are presented in table 1. The measured activity concentrations for beach samples are ranged from BDL to 30.42±7.90 Bqkg^{-1} for ^{238}U, BDL to 218.64±8.02 Bqkg^{-1} for ^{232}Th and 212.6±24.68 to 423.43±26.52 Bqkg^{-1} for ^{40}K. In similar way, for intertidal samples are ranged from BDL to 20.83±7.23 Bqkg^{-1} for ^{238}U, BDL to 113.71±7.84 Bqkg^{-1} for ^{232}Th and 210.27±24.42 to 434.32 Bqkg^{-1} for ^{40}K. Large variations among the radionuclide concentration in different sites have been observed. It may be due to mineralogy and drainage pattern of the study area since five river estuaries (Vellar, Ponnaiyar, Palar, Adyar and Cooum) are located in this study area. In all sampling sites, mean activity concentration is of the order $^{238}U < ^{232}Th < ^{40}K$. Actually, concentration of ^{238}U is very lower than the ^{232}Th and ^{40}K, because ^{238}U is soluble in water and leached before final deposition in sediments. ^{232}Th concentration found to be higher than concentration of ^{238}U in all the sampling sites. This may be due to the low geochemical mobility and insoluble nature in water of thorium.

Table 1 The Activity concentrations of ^{238}U, ^{232}Th and ^{40}K with their uncertainties for beach and intertidal sediments

Site Number	Activity concentrations of Beach sediments			Activity concentrations of Intertidal sediments		
	^{238}U (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)	^{238}U (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)
S_1	7.94±5.58	12.33±4.33	243.74±25.54	6.69±5.06	28.08±4.83	215.50±26.64
S_2	7.28±4.38	10.58±4.63	224.48±24.62	6.44±4.62	30.89±5.61	237.41±26.09
S_3	6.46±4.62	11.24±4.74	214.36±24.86	5.92±4.77	29.64±4.72	211.43±24.52
S_4	6.31±4.42	9.46±4.34	236.68±24.71	6.03±4.92	24.59±5.87	270.76±25.17
S_5	15.16±5.40	96.42±6.60	242.27±24.76	8.84±5.09	16.76±4.94	256.74±24.18
S_6	26.99±7.23	185.46±7.68	238.32±34.21	12.28±5.24	96.27±6.84	300.58±25.64
S_7	11.42±5.62	10.69±4.64	224.46±24.38	5.97±4.76	8.33±4.22	297.43±25.73
S_8	6.37±4.47	7.80±4.05	238.33±24.50	BDL	BDL	275.73±24.17
S_9	6.24±4.46	6.72±4.08	216.51±24.64	BDL	BDL	210.27±24.42
S_{10}	BDL	BDL	212.60±24.68	5.79±4.69	7.06±5.09	214.68±24.63
S_{11}	6.33±4.39	8.34±4.28	239.44±24.72	6.16±5.33	8.07±4.67	331.86±25.50
S_{12}	6.51±4.30	6.65±4.06	226.67±24.74	5.73±4.92	10.69±5.34	276.59±25.61
S_{13}	6.68±4.40	5.98±4.08	234.91±24.74	5.79±4.76	5.76±4.07	255.41±24.20
S_{14}	6.34±4.52	7.36±4.62	222.62±25.64	6.25±5.31	6.54±4.78	243.24±24.71
S_{15}	6.42±4.40	6.98±4.48	232.47±25.04	6.06±4.90	9.03±5.01	228.39±25.65
S_{16}	6.54±4.57	7.04±4.56	218.72±24.34	5.84±4.95	8.44±5.16	284.31±25.40
S_{17}	6.44±4.56	6.84±4.24	213.36±24.18	6.32±5.13	7.79±4.07	213.36±24.87
S_{18}	7.02±4.60	7.94±4.84	226.74±25.43	6.88±5.06	10.68±4.67	247.52±25.61
S_{19}	6.98±4.84	7.26±4.26	246.40±26.40	6.49±5.01	13.08±4.78	284.93±26.74
S_{20}	6.51±4.72	7.42±4.17	241.59±24.36	BDL	12.01±4.45	263.22±26.33
S_{21}	8.96±5.26	10.94±4.92	246.54±25.06	6.85±5.16	8.62±4.74	257.38±24.61
S_{22}	30.42±7.90	218.64±8.02	254.62±26.08	20.83±7.23	113.71±7.84	284.64±25.91
S_{23}	7.36±5.02	19.79±4.48	335.29±26.58	8.98±6.33	10.47±4.82	272.63±25.62
S_{24}	6.89±4.51	16.63±4.62	324.65±24.67	9.62±4.94	76.37±7.45	284.44±25.49
S_{25}	6.36±4.48	12.61±4.48	294.65±25.12	6.88±4.67	18.83±4.40	281.04±25.49
S_{26}	6.49±4.57	9.45±4.69	304.72±24.69	BDL	14.26±4.75	278.35±24.62
S_{27}	BDL	16.28±4.76	326.24±24.96	5.94±4.69	9.40±4.69	313.11±26.34
S_{28}	6.06±4.42	18.73±4.62	348.61±24.89	5.84±4.72	10.24±4.57	294.88±25.73
S_{29}	8.78±5.06	24.33±4.75	423.43±26.52	BDL	13.67±4.33	424.70±27.49
S_{30}	7.84±5.02	17.68±4.64	376.45±27.96	6.19±4.88	8.97±4.82	367.24±26.94
S_{31}	7.04±5.51	13.92±4.40	353.49±26.86	7.67±5.44	90.71±7.84	271.59±27.29
S_{32}	6.38±4.61	14.67±4.31	340.44±25.49	7.95±5.39	7.46±4.57	284.69±26.63
S_{33}	BDL	15.48±4.24	348.03±25.80	8.67±5.37	12.89±4.27	325.86±25.72
S_{34}	6.34±4.49	12.37±4.80	364.82±25.68	5.90±4.78	6.97±4.30	380.41±27.62
S_{35}	BDL	8.56±4.94	422.43±26.00	BDL	BDL	434.32±34.13

The ^{40}K activity concentration dominates over ^{238}U and ^{232}Th elemental activities like what normally happen in soil. Lower activity concentrations are observed in intertidal sediments when compared with activity concentration of beach sediments. These lower concentrations of radionuclides may be due to grain size and its associated mineralogy of the sediment (El-Kammar et al., 2007). Based on the field observation, sand and gravel mixture on the intertidal environments could be higher. It can be derived from the varying energy levels of between the uprushing and backwashing waves. With the uprush of breaking waves, larger amount of both sand and gravel are being deposited on the backshore whilst during the backwash wave energy decreases, and only a small portion of sand is transported offshore. McCubbin et al., (2004) reported that the highest concentrations of most radionuclides in Irish Sea sediments are associated with fine-grained material and lowest concentrations are associated with sands. On the lines of Ergin et al., (2007), the heavy mineral fractions are highly concentrated in fine sands than medium to coarse sands. In the present study, lower activity concentrations of radionuclides was observed in intertidal sediments which may be due to presence of higher amount of sands in intertidal environments than beach.

In beach and intertidal, the maximum activity concentration of ^{238}U (30.42±7.90 Bqkg^{-1}; beach and 20.83±7.23 Bqkg^{-1}; intertidal) and ^{232}Th (218.64±8.02 Bqkg^{-1}; beach and 113.71±7.84 Bqkg^{-1}; intertidal) are observed in Mahabalipuram (S_{22}), which is one of the famous historical and tourism place. According to El-Arabi (2005), uranium and thorium in beach sand are contained mainly in resistant heavy minerals such as monazite, zircon and xenotime. In the present study, higher values of ^{238}U and ^{232}Th could be due to the presence of black sands, which are enriched in the mineral monazite (Uosif et al., 2008).

The highest activity concentration of ^{40}K (434.32±34.13 Bqkg^{-1}) is found in intertidal sediments at site no.S_{35} (Marina). In the case of beach samples, the highest ^{40}K (434.32±34.13 Bqkg^{-1}) concentration is found in Kovalam beach (S_{29}). According to Orgun et al., (2007), ^{40}K occurs in major minerals such as feldspar and micas. Also, Tsabaris et al., (2007) reported that the highest activity concentration of ^{40}K may be due to the presence of higher amount of clay minerals. In the present study, the highest activity concentration of ^{40}K may be due to presence of higher amount of feldspar and clay minerals. The activity concentration of ^{40}K is higher in northern side of the study (S_{22} to S_{35}) area when compared to southern side (S_1 to S_{21}). This may be due to the abundance of feldspar and clay minerals in northern side of the study area. The lowest concentration of all measured radio nuclides is found at Pudhuchery (S_{10}) for beach samples and Veeramampattinam (S_9) for intertidal samples. Sediments collected from Puduchery (S_{10}) and Veeramampattinam (S_9) had higher coarser and sandy in nature. According to Jankovic et al., (2008), the lowest activity concentration of the radionuclides in sediments may be due to the high composition of quartz.

3.1. Comparison with other literatures

The activity results of the present study along with other investigations made in various coastal around different countries of the world are presented in table 2. The activity concentration of ^{238}U of the present study is lower than that of all reported countries except sea sand, Hong Kong (Table 2). The mean activity concentration of ^{232}Th of the present study is higher than that of Red sea coast, Egypt, Sudan coast (Sam et al., 1998), coastal sands, Kuwait (Saad & Al- Azmi, 2002) and sea sand, Hong Kong (Tso & Leung, 2000). Safaga beach sediments, Egypt (Uosif et al., 2008), Red sea coast, Egypt (Harb, 2008), Beach soil, Bangladesh (Alam et al., 1999), Sea sand, Bangladesh (Chowdhury et al., 1999), Red seashore sediment, Egypt (El-Mamoney & Khater, 2004) and beach sand, USA (NCRP, 1975) have higher ^{40}K activity concentration when compared with present study (Table 2).

According to UNSCEAR (2000) report, the world average data for ^{238}U, ^{232}Th and ^{40}K in sediments is 33 Bqkg^{-1}, 45 Bqkg^{-1} and 420 Bqkg^{-1} respectively. If one compares these values with the present study, the mean activity concentrations of ^{238}U, ^{232}Th and ^{40}K are 0.253, 0.545 and 0.657(for beach samples) and 0.214, 0.478 and 0.671(for intertidal samples) times the world average values respectively.

In the same way, present values of ^{238}U, ^{232}Th and ^{40}K are 0.292, 0.384 and 0.690(for beach samples) and 0.246, 0.336 and 0.705 times the Indian average values (28.67 Bqkg^{-1} for ^{238}U, 63.83 Bqkg^{-1} for ^{232}Th, 400.00 Bqkg^{-1} for ^{40}K) respectively (UNSCEAR, 2000).

3.2. Radiological Parameters

It is of great importance to detect the ^{238}U, ^{232}Th and ^{40}K natural radionuclides to assess their hazards to the human.

Table 2 Comparison of activity concentrations of ^{238}U, ^{232}Th and ^{40}K in present study samples from north east coast of Tamilnadu, India and other studies in different coastal regions of the world

Sl.No	Location	Mean Activity Concentration (Bq/ kg)			Reference
		^{238}U	^{232}Th	^{40}K	
1	World	33	45	420	UNSCEAR, (2000)
2	India	28.67	63.83	327.6	UNSCEAR, (2000)
3	Ullal in Karnataka, India	374	158	158	Radhakrishna et al., (1993)
4	Chhatrapur beach, Orissa, India	220	2500	120	Mohanty et al., (2004)
5	Coastal Karnataka, India	249.2	489.6	55	Narayana et al., (1994)
6	Safaga beach, Egypt	--	177	815	Uosif et al., (2008)
7	Read sea coast, Egypt	23.1	7.2	338	Harb, (2008)
8	Sudan coast	29.6	6.02	158.4	Sam et al., (1998)
9	Coastal sediments, The Netherlands	606	560	80	De Meijer et al., (2001)
10	Coastal sand, Kuwait	36	6	227	Saad and Al-Azmi, (2002)
11	Preta beach, Brazil	121	239	110	Freitas et al., (2004)
12	Beach soil, Bangladesh	19	36.7	458	Alam et al., (1999)
13	Sea sand, Bangladesh	14.5	34.8	302	Chowdhury et al., (1999)
14	North Sinai coast, Egypt	56	83.4	88	Seddeek et al., (2005)
15	Red seashore sediment, Egypt	24.7	31.4	428	Harb, (2008)
16	Coastal sand, Egypt	32.2	44.3	96	Ibrahim et al., (1993)
17	Sea sand, Hong Kong	7	9	245	Tso & Leung 2000
18	Beach sand, USA	37	26	<296	NCRP, (1975)
19	North east coast of Tamilnadu, India				
	Beach sediments	8.31	24.53	275.97	Present study
	Intertidal sediments	7.08	21.51	282.13	Present study

Exposures to radiation from the beach sediments are assessed by calculating different radiological indices and are given below. Even though total activity concentration of radionuclides is calculated, it does not provide the exact indication about the total radiation hazards.

The radiological parameters are

(a) Absorbed dose rate (D)
(b) Annual effective dose equivalent (AEDE)
(c) Hazard index (H)
(d) Representative level Index (Iγ)
(e) Excess lifetime cancer risk (ELCR)

3.2.1. Absorbed dose rate

The measured activity concentration of ^{238}U, ^{232}Th and ^{40}K are converted in to doses by applying the conversion factors 0.462, 0.604 and 0.0417 for uranium, thorium and potassium respectively (Ramasamy et al., 2010). These factors are used to calculate the total dose rate (D) (nGy h^{-1}) using the following equation

$$D= (0.462C_U + 0.604\ C_{Th} +0.0417\ C_K) \quad nGy\ h^{-1}$$

Where C_U, C_{Th} and C_K are the activity concentrations (Bq/kg) of ^{238}U, ^{232}Th and ^{40}K in sediments respectively. The calculated absorbed dose rate for beach and intertidal samples are presented in table 3 and 4 respectively. The average absorbed dose rate for beach and intertidal samples is 30.18 and 28.03 nGyh^{-1} respectively. These are lower than the world average value (51 nGyh^{-1}; UNSCEAR, 2000). Maximum dose rate 156.73 nGyh^{-1} is calculated for Mahabalipuram beach samples (S_{22}) (Table 3). This may be presence of higher amount of black sands (Uosif et al., 2008). Minimum dose rate 14.63nGy h^{-1} was calculated from Veeramampattinam (S_9) intertidal samples (table 4). This may be presence of higher amount of quartz.

3.2.2. *The Annual Effective Dose Equivalent (AEDE)*

To estimate the annual effective dose equivalent, the conversion coefficient from absorbed dose to effective dose, 0.7 SvGy^{-1} and outdoor occupancy factor of 0.2 proposed by UNSCEAR (2000) are used. The effective dose rate in units of mSv y^{-1} is calculated by the following formula (Harb, 2008).

$$AEDE\ (mSv\ y^{-1}) = D\ (nGy\ h^{-1}) \times 8760\ h \times 0.2 \times 0.7\ SvGy^{-1} \times 10^{-6}$$

The calculated annual effective dose equivalent values are presented in table 3 for beach samples and table 4 for intertidal samples. The calculated AEDE values for beach samples are ranged from 0.019 to 0.192mSv y^{-1} with mean value of 0.037mSv y^{-1}and it is ranged from 0.018 to 0.111mSv y^{-1} with an average of 0.034mSv y^{-1} for intertidal samples. These average values are lower than the world average value of 0.48mSv y-1 (Akram et al., 2006).

3.2.3. Hazard Index (H)

In order to assess the health effects from the radioactivity of the earth's surface materials containing ^{238}U, ^{232}Th and ^{40}K, the activity of these nuclides is converted into a single quantity termed as Hazard Index. The prime objective of this index is to limit the radiation dose to dose equivalent limit of 1 mSv/y (ICRP 60, 1990). The hazard index is calculated using the given equation:

$$H = (C_U/370 + C_{Th}/259 + C_K/4810) \leq 1$$

Where, C_U, C_{Th} and C_K are the mean activity concentrations of ^{238}U, ^{232}Th and ^{40}K (Bq/Kg) respectively. H must not exceed the limit of unity for the radiation hazard to be negligible.

The calculated values of this index are given in table 3 for beach samples and table 4 for intertidal samples. The hazard index of all site samples are less than unity (permissible level) (Orgun et al., 2007).

3.2.4. Representative level index (Iγ)

In this study, the Representative level index is calculated using the below equation and it is defined by NEA-OECD, (1979).

$$I\gamma = (C_U/150 + C_{Th}/100 + C_K/1500)$$

Table 3 Radiological Hazard Indices for beach sediments

Site Number	Radiological Hazard Indices				
	Absorbed Dose (nGy/h)	AEDE (mSv/y)	Hazard index (H)	Representative Level index (Iγ)	Excess Life Time Cancer Risk (ELCR) x 10^{-3}
S_1	21.28±6.26	0.026±0.008	0.12±0.037	0.33±0.098	0.091±0.027
S_2	19.11±5.85	0.023±0.007	0.11±0.035	0.30±0.092	0.082±0.025
S_3	18.71±6.03	0.023±0.007	0.10±0.036	0.29±0.095	0.080±0.026
S_4	18.50±5.69	0.023±0.007	0.10±0.034	0.29±0.089	0.079±0.024
S_5	75.34±7.51	0.092±0.009	0.46±0.045	1.22±0.119	0.323±0.032
S_6	134.43±9.41	0.165±0.012	0.84±0.056	2.19±0.148	0.577±0.040
S_7	21.09±6.42	0.026±0.008	0.12±0.038	0.33±0.100	0.091±0.028
S_8	17.59±5.53	0.022±0.007	0.10±0.033	0.28±0.087	0.076±0.024
S_9	15.97±5.55	0.020±0.007	0.09±0.033	0.25±0.087	0.069±0.024
S_{10}	15.63±3.50	0.019±0.004	0.08±0.021	0.24±0.057	0.067±0.015
S_{11}	17.95±5.64	0.022±0.007	0.10±0.034	0.28±0.089	0.077±0.024
S_{12}	16.48±5.47	0.020±0.007	0.09±0.032	0.26±0.086	0.071±0.023
S_{13}	16.49±5.53	0.020±0.007	0.09±0.033	0.26±0.087	0.071±0.024
S_{14}	16.66±5.95	0.020±0.007	0.09±0.035	0.26±0.093	0.072±0.026
S_{15}	16.88±5.78	0.021±0.007	0.09±0.034	0.26±0.091	0.072±0.025
S_{16}	16.14±5.89	0.020±0.007	0.09±0.035	0.25±0.093	0.069±0.025
S_{17}	16.00±5.68	0.020±0.007	0.09±0.034	0.25±0.089	0.069±0.024
S_{18}	17.49±6.11	0.021±0.007	0.10±0.036	0.27±0.096	0.075±0.026
S_{19}	17.88±5.91	0.022±0.007	0.10±0.035	0.28±0.092	0.077±0.025
S_{20}	17.56±5.72	0.022±0.007	0.09±0.034	0.27±0.089	0.075±0.025
S_{21}	21.03±6.45	0.026±0.008	0.12±0.038	0.33±0.101	0.090±0.028
S_{22}	156.73±9.58	0.192±0.012	0.98±0.058	2.56±0.150	0.673±0.041
S_{23}	29.34±6.13	0.036±0.008	0.16±0.036	0.47±0.096	0.126±0.026
S_{24}	26.77±5.90	0.033±0.007	0.15±0.035	0.42±0.093	0.115±0.025
S_{25}	22.84±5.82	0.028±0.007	0.13±0.035	0.36±0.091	0.098±0.025
S_{26}	21.41±5.97	0.026±0.007	0.12±0.036	0.34±0.094	0.092±0.026
S_{27}	25.98±5.99	0.032±0.007	0.14±0.036	0.42±0.094	0.111±0.026
S_{28}	28.65±5.87	0.035±0.007	0.16±0.035	0.46±0.092	0.123±0.025
S_{29}	36.41±6.39	0.045±0.008	0.20±0.038	0.55±0.100	0.156±0.027
S_{30}	30.00±6.29	0.037±0.008	0.17±0.037	0.48±0.099	0.129±0.027
S_{31}	26.40±6.32	0.032±0.008	0.14±0.037	0.42±0.099	0.113±0.027
S_{32}	26.00±5.80	0.032±0.007	0.14±0.034	0.42±0.091	0.112±0.025
S_{33}	26.40±5.69	0.033±0.007	0.15±0.034	0.42±0.089	0.115±0.024
S_{34}	25.61±6.04	0.031±0.007	0.14±0.036	0.41±0.095	0.110±0.026
S_{35}	25.33±6.22	0.031±0.008	0.14±0.037	0.40±0.098	0.109±0.027
Minimum	15.63±3.50	0.019±0.004	0.08±0.021	0.24±0.057	0.067±0.015
Maximum	156.73±9.58	0.192±0.012	0.98±0.058	2.56±0.150	0.673±0.041
Mean	30.17±6.17	0.037±0.030	0.17±0.036	0.48±0.096	0.130±0.026

Table 4 Radiological Hazard Indices for Intertidal sediments

Site Number	Radiological Hazard Indices				
	Absorbed Dose (nGy/h)	AEDE (mSv/y)	Hazard index (H)	Representative Level index (Iγ)	Excess Life Time Cancer Risk (ELCR) x 10^{-3}
S_1	29.04±6.37	0.036±0.008	0.17±0.038	0.47±0.100	0.12±0.027
S_2	31.53±6.61	0.039±0.008	0.19±0.040	0.51±0.104	0.14±0.028
S_3	29.45±6.08	0.036±0.007	0.17±0.036	0.48±0.095	0.13±0.026
S_4	28.93±6.87	0.035±0.008	0.17±0.041	0.47±0.108	0.12±0.029
S_5	24.91±6.34	0.031±0.008	0.14±0.038	0.40±0.099	0.11±0.027
S_6	76.35±7.62	0.094±0.009	0.47±0.046	1.24±0.120	0.33±0.033
S_7	20.19±5.82	0.025±0.007	0.11±0.035	0.32±0.091	0.09±0.025
S_8	17.36±1.01	0.021±0.001	0.09±0.005	0.28±0.016	0.07±0.004
S_9	14.63±1.02	0.018±0.001	0.08±0.005	0.23±0.016	0.06±0.004
S_{10}	15.89±6.27	0.019±0.008	0.09±0.037	0.25±0.099	0.07±0.027
S_{11}	21.56±6.35	0.026±0.008	0.12±0.038	0.34±0.099	0.09±0.027
S_{12}	20.64±6.57	0.025±0.008	0.11±0.039	0.33±0.103	0.09±0.028
S_{13}	16.80±5.67	0.021±0.007	0.09±0.034	0.27±0.089	0.07±0.024
S_{14}	16.98±6.37	0.021±0.008	0.09±0.038	0.27±0.100	0.07±0.027
S_{15}	17.78±6.36	0.022±0.008	0.10±0.038	0.28±0.100	0.08±0.027
S_{16}	19.65±6.46	0.024±0.008	0.11±0.039	0.31±0.102	0.08±0.028
S_{17}	16.52±5.87	0.020±0.007	0.09±0.035	0.26±0.091	0.07±0.025
S_{18}	19.95±6.23	0.024±0.008	0.11±0.037	0.32±0.098	0.09±0.027
S_{19}	22.78±6.32	0.028±0.008	0.13±0.038	0.36±0.099	0.10±0.027
S_{20}	20.77±3.79	0.025±0.005	0.12±0.023	0.33±0.062	0.09±0.016
S_{21}	19.10±6.27	0.023±0.008	0.11±0.037	0.30±0.098	0.08±0.027
S_{22}	90.17±9.16	0.111±0.011	0.55±0.055	1.47±0.144	0.39±0.039
S_{23}	21.84±6.90	0.027±0.008	0.12±0.041	0.35±0.107	0.09±0.030
S_{24}	62.43±7.85	0.077±0.010	0.38±0.047	1.02±0.124	0.27±0.034
S_{25}	26.27±5.88	0.032±0.007	0.15±0.035	0.42±0.092	0.11±0.025
S_{26}	22.76±3.90	0.028±0.005	0.13±0.023	0.36±0.064	0.10±0.017
S_{27}	21.48±6.10	0.026±0.007	0.12±0.036	0.34±0.096	0.09±0.026
S_{28}	21.18±6.01	0.026±0.007	0.12±0.036	0.34±0.094	0.09±0.026
S_{29}	28.51±3.76	0.035±0.005	0.16±0.022	0.46±0.062	0.12±0.016
S_{30}	23.59±6.29	0.029±0.008	0.13±0.037	0.38±0.099	0.10±0.027
S_{31}	69.66±8.39	0.085±0.010	0.43±0.051	1.14±0.133	0.30±0.036
S_{32}	20.05±6.36	0.025±0.008	0.11±0.038	0.32±0.099	0.09±0.027
S_{33}	25.38±6.13	0.031±0.008	0.14±0.036	0.40±0.096	0.11±0.026
S_{34}	22.80±5.96	0.028±0.007	0.12±0.035	0.36±0.093	0.10±0.026
S_{35}	23.97±1.42	0.029±0.002	0.13±0.007	0.38±0.023	0.10±0.006
Minimum	14.63±1.02	0.018±0.001	0.08±0.005	0.23±0.016	0.06±0.004
Maximum	90.17±9.16	0.111±0.011	0.55±0.055	1.47±0.144	0.39±0.039
Mean	28.03±5.83	0.034±0.007	0.16±0.035	0.45±0.092	0.12±0.025

Where, C_U, C_{Th} and C_K are the mean activity concentrations of ^{238}U, ^{232}Th and ^{40}K (Bq/Kg) respectively in sediments. The calculated Iγ values for beach and intertidal samples are presented in table 3 and 4. This values being 0.24 to 2.56 for beach samples and 0.23 to 1.47 for intertidal samples. Average value for Iγ is 0.48 (for beach) 0.45 (for intertidal samples). These are lower than the world average (0.66Bq kg^{-1}: Harb, 2008). No exceedance of the recommended upper limit is noted. However, three locations (S_5, S_6 and S_{22}) in beach environment and four locations (S_6, S_{22}, S_{24} and S_{31}) in intertidal environment samples are exceeded the recommended exemption level for exposure to external gamma radiation. This exemption in the three sites may be due to the higher concentration of ^{232}Th.

3.2.5. Excess Lifetime Cancer Risk (ELCR)

Excess Lifetime Cancer Risk (ELCR) is calculated using below equation and statistical data are presented in table 3 (for beach samples) and table 4 (for intertidal samples).

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

Where AEDE, DL and RF is the annual effective dose equivalent, duration of life (70 years) and risk factor (Sv^{-1}), fatal cancer risk per sievert. For stochastic effects, ICRP 60 uses values of 0.05 for the public (Taskin et al., 2009).

The calculated average value of ELCR is 0.13 x 10^{-3} for beach samples and 0.12 x 10^{-3} for intertidal samples. These average values are lower than the world average (0.29 x 10^{-3}) (UNSCEAR, 2000). However, elevated values are observed in Devanampattinam (S_6) and Mahabalipuram (S_{22}) samples.

All the calculated radiological parameters in intertidal samples are lower when compared with beach samples. Akram et al., (2007) was investigated radioactivity level of shallow marine (tidal) sediments off the Sindh coast. They calculated some radiological parameters for the collected sediments and reported that the calculated parameters were lower. The present results of intertidal sediments are matched with above study (Akram et al., 2007).

4. CONCLUSION

The average concentration of natural radionuclides (^{238}U, ^{232}Th and ^{40}K) for studied beach and intertidal samples are within the world and Indian average values. However, some extreme values are also observed in site no. S_6 and S_{22} due to the presence of black sands. Lower activity concentrations are observed in intertidal samples, when compared with beach samples. These lower concentrations of radionuclides may be due to sandy nature of samples and leachable nature of radionuclides due to the wave action. Average of all calculated radiological parameters are within the recommended level for both beach and intertidal samples. Nevertheless, some radiological risk may exist for tourist and local people in Devanampattinam (S_6) and Mahabalipuram (S_{22}), since exceedance of recommended level for all radiological parameters (except hazard index) is observed in above sites.

On the basis of lower levels of natural radioactivity, beaches of the north east coast of Tamilnadu in India can be considered as a less natural back ground radiation area except Devanampattinam (S_6) and Mahabalipuram (S_{22}). It is concluded that no harmful radiation effects are pose to the public and tourists going to the beaches for recreation or to the sailors and fishermen involved in their activities in the area as a results of the activity of beach and intertidal sediments.

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