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Modeling of Naturally Occurring Radioactive Material in Beach Sands from Sivas Agar, Andhra Pradesh, India – a case Study

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Abstract: Quantification of naturally occurring radioactive elements has been performed along the beach areas of Andhra Pradesh. The concentration of radio elements ^{238}U, ^{232}Th and ^{40}K is estimated with the help of High Purity Germanium detector (HPGe). The average activity concentration of ^{238}U and ^{232}Th is 6 and 18 times higher than the prescribed value of UNSCEAR report. The calculated absorbed dose rate, annual effective dose rate, radium equivalent, hazard index, gamma index and alpha index also shows a higher than prescribed value. The thorium concentration and the absorbed dose rate values shows an increasing trend towards the northeast along the beach area. The average Th/U values are almost 4.5 times higher than the crustal ratio. Considering the tourism industry surrounding the study area based on the picturesque beaches and the heritage Buddhist stup a sites an estimation of the radioactive hazard index of the area must be known.

Keywords: Thorium, High Purity Germanium Detector (HPGe), Hazard Index, Monazite, Uranium.

1 Introduction

The background radiation of an area is built upon the ground as well as the cosmic radiation. The ground radiation is an integrated effect of the radioactive emanation from^{238}U, ^{232}Th and ^{40}K and their daughter products. These radioelements are primarily present in the crystal lattice structure of certain selected minerals like monazite, xenotime, zircon, allanite, etc. as an accessory element. Greater concentration of these minerals in an area ensures a high background radiation for that zone.

The marine sand of the east coast region of the Indian subcontinent is considered as a high background radiation area (HBRA) [1-3].The coastal placer deposits of this part of India are a rich source of heavy mineral deposits like zircon, rutile, garnet, monazite, sphene etc. The presence of the mineral monazite and zircon results in the elevated natural background radiation along the coastal areas of India. The eastern coastal region of India lies adjacent to the Eastern Ghats Mobile Belt (EGMB). The sediments are produced through the weathering and erosion of the EGMB are brought down to the coast by aeolian and river activities, and finally are deposited along the beaches by the action of wavesand currents. The composition of the beach sand mineral assemblage has a similarity with the source rocks. The EGMB comprises of types Khondalite, Charnockite, Granite and Migmatites. These rocks among other minerals consist of minerals like monazite, xenotime and zircon, which consist of radioactive elements apart from other minerals like ilmenite, garnet, magnetite, rutile, titanite, etc.

The Srikakulum district of Andhra Pradesh is noted for its tourism industry. The quant and beautiful sea beaches attract thousands of tourists every year. Apart from the sea beaches the area also has a number of Buddhist stupas among which the Salihundam stupa is likely to find a place in the Unesco World Heritage Site. Keeping this in mind an idea about the radioactive hazard index of this area should be calculated.

The present study primarily focusses on the enrichment of the radioelements ^{238}U, ^{232}Th and ^{40}K and their daughter products. It discusses various radioactive parameters that has been based on the activity concentration of the radio elements present in the study area.

2 Geology of the Study Area

The beach area of Sivasagar is in the Srikakulam district of Andhra Pradesh, India. It is located along the eastern coastal areas of India. The beach area has a prominent division of dune, berm and beach, with a total width of roughly 150 metres. The samples have been collected from

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the berm area. The latitude and longitude of the sampling areas ranged from 18°53.824'N to 18°54.176'N and from 84°36.547'E to 84°36.919'E respectively.

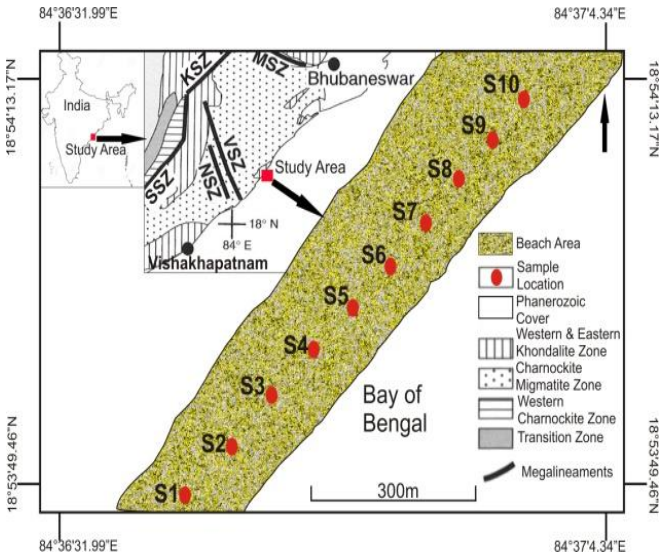

Fig. 1: Map showing the location of the study area (inset) and the sample locations from the Sivas agar beach. (Inset map modified after Dobmeier and Raith [4]

The Sivasagar beach lies adjacent to the Eastern Ghats Mobile Belts (EGMB). The principal rock types of this region area the charnockites, khondalites, granites and migmatites. Geologically the EGMB has been subdivided into the Western Charnockite zone, Western Khondalite zone, Charnockite-Migmatite zone and Eastern Khondalite zone[5]. Of these the Sivasagar beach lies adjacent to a part of the eastern khondalite rocks.

3 Methodology

Beach sand samples were collected from the Sivas agar Beach of the Srikakulum District of Andhra Pradesh. The samples were mostly collected from the berm areas at shallow depth. A total of ten sand samples have been collected along the beach area. About 500gms of these samples have been collected in ziplock bags and brought to the laboratory for further processing. In the lab these samples were dried in an oven at 80 degree centigrade for three hours and sieved through 0.355mm sieve. These samples are then preserved in a glass vial of fixed dimension and then sealed properly. It is then rested for about 28 days to attain secular equilibrium [6].

3.1 Gamma Ray Spectrometry Analysis

In order to measure the activity concentration of the radio elements ^{238}U, ^{232}Th and ^{40}K the samples are measured with the help of High Purity Germanium Detector (HPGe). The samples analyses have been performed at the Radiochemistry Division (BARC), Variable Energy Cyclotron Centre (VECC), Kolkata, India. It is analyzed in GEM series High Purity Germanium (HPGe) coaxial detector, ORTEC, USA with 50% efficiency and 1.8 keV energy resolution at 1332 keV of ^{60}Co. The measurement of activity concentration of ^{238}U,^{232}Th and ^{40}K has been done based on absolute method of analysis[7].

3.2 Absorbed Dose Rate

Radiation encountered by a person per Kilogram of their mass is known as the absorbed dose rate as received by the person. For uniformly distributed gamma radiation from natural radionuclides ^{238}U, ^{232}Th and ^{40}K the absorbed dose rate can be calculated as follows (UNSCEAR 2000 [8]

$D\ (nGyh) = 0.461A_U + 0.623A_{Th} + 0.0414A_K$

A_U, A_{Th} and A_K are activity concentrations of ^{238}U, ^{232}Th and ^{40}K inBq kg^{-1}.

3.3 Annual Effective Dose Rate

An idea about the internal and external radiation exposure is obtained by the annual effective dose rate (AED). The calculation is made by using 0.2 as the outdoor occupancy factor and 0.7 Sv Gy^{-1} as the conversion coefficient, as proposed by UNSCEAR 2000[8].

AED (mSvy^{-1}) = D (nGyh^{-1}) × 8760 (hy^{-1}) ×0.2×0.7Sv Gy^{-1}×10^{-6}

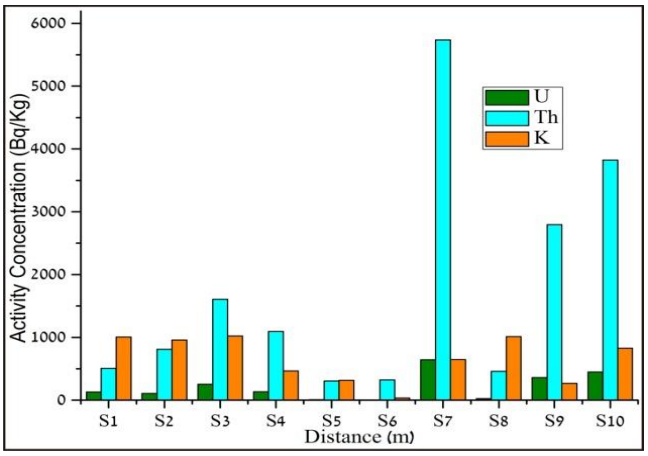

Fig. 2: Variations of activity concentrations in the study area for ^{238}U, ^{232}Th and ^{40}K respectively.

3.4 Radium Equivalent

The Radium equivalent (Ra_{eq})is calculated to compare the specific activity of materials with varying concentration of ^{238}U, ^{232}Th and ^{40}K. The calculation of $Ra_{eq}$is based on the fact that 370 (Bqkg^{-1}) of ^{238}U, 259 (Bqkg^{-1}) of ^{232}Th and 4810 (Bqkg^{-1}) of ^{40}K causes the same gamma ray dose equivalent. It is calculated by the following (UNSCEAR 2000[8].

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

3.5 Hazard Index

It is the index that indicates the external exposure due to the radioisotopes in the environment[9-10]. $H_{ex} = A_U/370 + A_{Th}/259 + A_K/4810$

$H_{ex}<1$ is considered to be within limit, and $H_{ex}>1$ is unsafe and equivalent to 370 Bq kg^{-1}.

3.6 Gamma Index

It is used to present inspection levels in the form of a concentration index or gamma index (I). It is mostly used to identify materials of concern. It is defined as follows [11].

$I= C_U/300+ C_{Th}/200+C_K/3000$

C_U, C_{Th} and C_K are activity concentrations of ^{238}U, ^{232}Th and ^{40}K in Bq kg^{-1}.

3.7 Alpha Index

The assessment of the excess alpha radiation internal exposure caused by the inhalation of naturally occurring radionuclides is known as alpha index (I_a). it is calculated as [12].

$I_{a=} C_U/200(Bqkg^{-1})$

4 Results and Discussion

The concentration of the naturally occurring radionuclides present in the beach sand samples are measured with the help of HPGe. The activity concentration of ^{238}U, ^{232}Th and ^{40}K of the beach placers is listed in Table.1. The concentration varied between 5 – 644 Bq/Kg with an average of 212 Bq/Kg for ^{238}U; 323 – 5736 Bq/Kg with an average of 1746 Bq/Kg for ^{232}Th and 36 – 1023 Bq/Kg with an average of 656 Bq/Kg for ^{40}K. Figure 2 gives us an idea about the varying activities of the radionuclides. The values are comparable to some of the high background radiation area of the world like Yangjiang in China [13] Ramsar and Mahallat in Iran [14]. The concentration of thorium is considerably higher than that of uranium and potassium. The uranium and thorium concentration of the area when compared to the value reported by UNSCEAR 2000[8] shows an enhancement of 6 and 18 times, respectively.The average absorbed dose rate is 1457nGy h^{-1}(219 – 4138 nGy h^{-1}). Figure 3 shows the varying absorbed dose rate of the samples. This kind of high dose rates are comparable to the Chavara-Neendakara Placer Deposits of Kerala and the Mahabalipuram area of Tamilnadu, India[15]. The ambient dose rate as prescribed by UNSCEAR 2000 is 55 nGy h^{-1} and the average absorbed dose rate of the beach sands of Sivasagar beach is almost~26 times higher than the ambient dose rate. This leads to a particularly high annual effective dose rate (AED) with values ranging between 0.3 $mSvy^{-1}$to 5 $mSvy^{-1}$. The average annual effective dose rate is ~2 $mSvy^{-1}$which is almost 28 times higher than the prescribed limit (UNSCEAR 2000[8]. The Radium Equivalent Activity as listed in Table 1 shows a value of range from 471 to 8896 Bq/Kg with an average of 2758 Bq/Kg which is almost 7 times higher than the exemption limit advised by UNSCEAR 2000. The hazard index (H) of the area averages to ~7 thereby crossing the prescribed limit of 1 UNSCEAR 2000 [8]. In fact all the beach sand samples collected from the area has a value greater than 1. The gamma index and alpha index of the area varies between 1.6-21 and 0.02-2.2 respectively. As per the standards presented by the European Commission 1999, the gamma index value is significantly higher than the standardized limit. Also, considering the higher than unit value of the alpha index, asper the ICRP 1994[16] regulation, the study area has a higher concentration of ^{226}Ra.

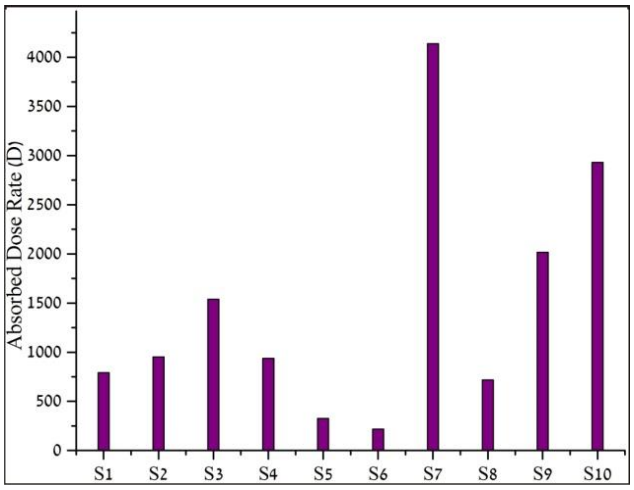

Fig. 3: Plot showing the absorbed dose rate of the beach sand samples.

The Th/U ratio of the area varies from 3.8 to 60 with an average of ~17 which is almost 4.5 times higher than the average continental crust value of 3.8 [17].Thorium concentration of the samples shows a wide variation. A close observation of figure 2 indicates that barring three samples, most of the area shows a high thorium content and hence it can be safely inferred that ^{232}Th is the major contributor for high background radiation of the area. An increasing trend of thorium is observed from sample locations S7 towards S10. This is because of the presence of the mineral monazite[3] which is a thorium phosphate. Monazite consists of thorium as an accessory mineral. The presence of monazite in the beach sands of Andhra Pradesh is because of its provenance from the Eastern Ghats Mobile Belts (EGMB) adjacent to the beach areas. Weathered rocks obtained from the hinterland lithology are brought down by the river erosion, which gets deposited along the beach due to waves and tidal activities. The uranium and potassium concentration of the beach sands do not exhibit any major variation[18].

The ratio of the equivalent concentration of thorium and uranium can be used to understand the depositional environment of a beach area. A high value of eTh/eU ratio along with a low concentration of U (Table. 1) is indicative

Table. 1 Activity concentration, absorbed dose rate, effective dose rate, radium equivalent, hazard index, gamma index, alpha index and eTh/eU ratio for sand samples collected from the beach area.

Sample Name	Th Bq/Kg	U Bq/Kg	K Bq/Kg	Absorbed Dose Rate (D)	Effective Dose Rate (AED)	Radium Equivalent Activity (Ra)	Hazard Index (H)	Gamma Index (I)	Alpha Index (I)	eTh/eU
S1	505.3137	130.3059	1004.794	790.866	0.969918	930.2736	2.512093	3.29585258	0.651529723	11.86408
S2	811.6947	107.8905	958.4059	952.2034	1.167782	1342.411	3.624805	4.73757709	0.539452721	23.01688
S3	1604.813	252.7132	1023.118	1539.87	1.888497	2626.376	7.091906	9.20748383	1.263565817	19.42826
S4	1093.404	135.0335	466.93	936.7503	1.148831	1734.555	4.683668	6.07277632	0.67516741	24.77287
S5	306.9772	7.870416	314.9925	325.2819	0.398926	471.1022	1.271998	1.66611796	0.03935208	119.3289
S6	323.467	5.371587	35.82267	218.8268	0.268369	470.6877	1.270873	1.64718104	0.026857933	184.2317
S7	5736.163	643.5967	647.6492	4138.454	5.0754	8896.178	24.02144	31.0420178	3.217983346	27.26747
S8	457.334	27.13317	1014.152	717.2865	0.87968	759.2105	2.049944	2.71516477	0.135665834	51.56679
S9	2794.428	358.3075	267.1212	2016.696	2.473276	4374.907	11.81323	15.2555372	1.791537693	23.8602
S10	3822.292	448.4515	826.9051	2930.363	3.593797	5978.001	16.14183	20.8819355	2.24225756	26.07627

of an oxidising environment. Uranium is available in two valence states +6 or +4, of these the U^{+6} state is more reactive and more prone to leaching than U^{+4}. In beach areas, around the shoreline the U^{+6} ions gets leached out due to close proximity of water, hence, the activity concentration of uranium is much less than that of thorium[19].

A comparison of the radio elemental concentration of the study area with the surrounding beaches indicates that the Sivas agar beach has a comparatively higher uranium and thorium concentration. The Bhimlipatnam and Ramakrishna beach lying towards the southwest of the study area shows an average concentration of 126 Bq/Kg and 134 Bq/Kg which is lower than the average uranium concentration (212 Bq/Kg) of the study area [3]. Also, the thorium concentration of these beaches are 1264 Bq/Kg and 909 Bq/Kg respectively which is lower than the average thorium concentration (1746 Bq/Kg) of the Sivasagar beach. This indicates an overall increasing trend of radio elements towards northeast. This is substantiated by the absorbed dose rate of the study area (Figure. 2) which also shows a trend increasing towards northeast.

5 Conclusion

The results obtained in the present study indicates that the Siva sagar beach area of the Srikakulum district contain radioactive elements ^{238}U, ^{232}Th and ^{40}K. The average activity concentration is 212 Bq/Kg for ^{238}U, 1746 Bq/Kg for ^{232}Th and 656 Bq/Kg for ^{40}K. The absorbed dose rate varies between 219 – 4138 nGy h^{-1} with an average of 1457 nGy h^{-1} which is much higher than the prescribed limit UNSCEAR report. The annual effective dose rate, radium equivalent, hazard index, gamma index and alpha index also show persistently high values. The area has a high Th/U ratio which indicates the presence of the mineral monazite. The thorium concentration as well as the absorbed dose rates of the area shows an increasing trend of radio elements towards the northeast along the beach. Also considering the high thorium concentration of the study area it can very well be said that the high background radiation of the study area is mostly an effect of the thorium enrichment.This provides a base line data for further studies for the presence of any enhancement in future.

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