Assessment of natural radioactivity and radiological hazards in Seashore rock samples from Kanyakumari District

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Abstract

Since Kanyakumari district is the high background radiation area, the present work is to find whether the radiation from the rocks in the seashore contributes for the radiation exposure for the general public as well as regular tourists. Objective of this study is to quantify the amounts of natural radioactivity present in the chosen samples. Gamma spectrometric analysis were carried out and the activity concentration were obtained for the radionuclides. An evaluation of radiological risks posed by naturally occurring radionuclides was estimated. The average activity-concentrations of ^{238}U, ^{232}Th, and ^{40}K are 31.85, 173.91, and 386.37 (Bq/kg) respectively. In this study, the yearly effective radiation dosage, air absorbed gamma radiation dose rate, and hazard index, gamma index, representative level index value, activity utilization index, annual gonald dose equivalent were estimated. Results of this were normal recommended safe and criterion limit given by UNSCEAR. Statistical method was used to study the relation between radionuclides and also calculated radiation parameters.

Keywords: Activity Concentration, Gamma Ray Spectroscopy, Effective dose, Statistical method, Radiological Hazards

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1. Introduction:

Natural radio-activity is pervasive in the environment of the Earth and may be found in a variety of geological formations, including the crust of the planet, rocks, soils, plants, water, sand, and sediments. Natural radioactive material concentrations are largely influenced by geological factors and vary by rock level across different geographic locations [1]. The environment of the earth contains a wide variety of naturally occurring radioactive materials (NORMs), such as uranium (^{238}U), thorium (^{232}Th) and their offspring, and the primordial potassium (^{40}K). Naturally occurring radioactive materials that have been technologically enhanced (TENORMs) are the main result of the manufacturing stream that generate a lot of radioactive waste with low specific activity. The main radionuclides in TENORM are, in general, uranium, thorium, and their corresponding decay products [2]. Humans are subjected to varying levels of exposure to ionising radiation from extraterrestrial sources, including cosmic radiation from the planet's outer atmosphere and land-based or organic radioactive sources, such as gamma rays discharged from 40K and radionuclides of ^{238}U and ^{232}Th through decay series present in soil, rocks, and water [3]. The body is exposed to radiation by gamma rays, and lung tissues are exposed to radiation from breathing in radon and its offspring, which causes radiological effects. Due to the spread of radionuclides in the ground, air, water, foods, building interiors, etc., it is important to monitor the natural ambient radiation level and to be aware of the dosage limits for public exposure [4]. These radionuclides' distributions have shown to be crucial for long- and short-range supply of naturally radioactive materials as energy sources, as well as estimations of the amount of background radiation to which humans are exposed [5]. For a long time, rocks have been utilised as building aggregates without anybody being aware of the radionuclide activity concentrations present or the possible radioactive dangers connected with the building materials. The source of the dispersion of the rocks and the mechanisms that concentrate them affect the spread of these naturally occurring radionuclides. The distribution of radionuclides at different levels in the environment can provide important radiological data. If radiological data about an environment had been accessible, many illnesses and diseases that might have been treated well instead would not have been assigned to other causes [6]. Since there is little information available on the radioactivity of rock samples in the Kanyakumari District, it is crucial to research. Calculate the radiological parameters (radium equivalent activity, external hazard index, and absorbed dose rate, among others) that are related to the external dose rate to assess the radiological hazards to human health as well as to check the quality of the radiation in general and to understand its impact on the environment.

2. Experimental Procedure

2.1. Study area

The samples were selected by their coloures variation and texture designs. Beach rock is a friable to well-cemented sedimentary rock that has developed along a coastline and is composed of a changeable combination of sedimentary particles with varying sizes of gravel, sand, and silt. Sites were selected without consideration to their radioactivity. Sampling site latitude and longitude are mention in bellow table.1.

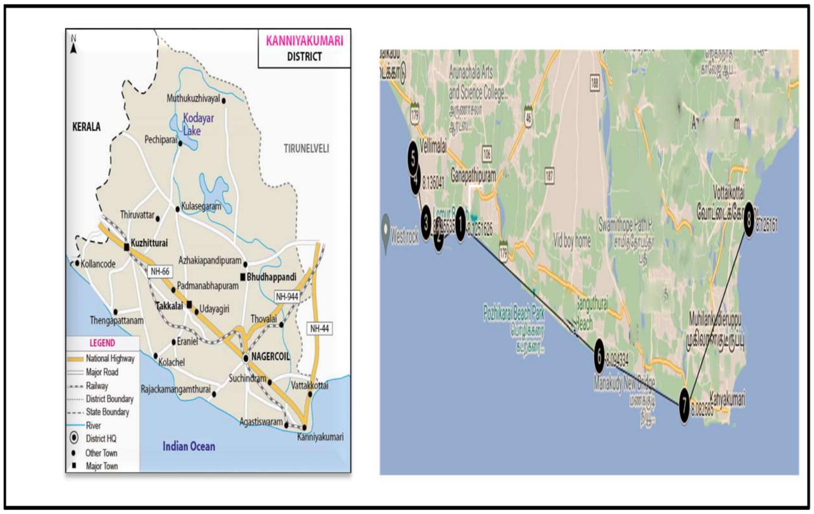
Table.1 Geographical information of sampling points

Sample Code	Location	Latitude	Longitude
KSR1	Pillaithopu- Azhikkal Beach	8.1251626	77.3392538
KSR2	Vellimalai	8.122855	77.321969
KSR3	Muttom Beach	8.125635	77.312075
KSR4	Kadiapattinam	8.136041	77.303978
KSR5	Manavalakuruchi	8.140586	77.301999
KSR6	Chothavilai Beach	8.094334	77.448492
KSR7	Kovalam Beach	8.082685	77.515362
KSR8	Kanyakumari	8.078119	77.530779
KSR9	Vattakkottai Beach	8.126161	77.566274

2.2. Sample Collection:

The rock samples were powdered after sieving and grinding. The samples were protected in a plastic container, and stored for a month to make sure that ^{226}Ra and ^{222}Rn are in radioactive balance, and its descendants had been established. The examined gathered rock samples were examined using gamma rays.

Figure .1 *Location Map of study area in the Kanykumari District*



2.3. Specific Activity(Bq/kg)

Prepared rock samples were analyzed using 3”×3” Sodium iodine [NaI(TI)] detector. The analysis of the gamma spectra obtained is performed with dedicated software, and the choice of the reference peak is made in such a way that they are sufficiently discriminated. Of the peaks that could be identified through the software, reference is made to that at 1.764 MeV for ^{214}Bi in the ^{238}U decay chain, that at 2.614 MeV for ^{208}Tl in the ^{232}Th decay chain, and one at 1.460 MeV of ^{40}K. The specific activity of the radionuclides ^{238}U, ^{232}Th, and ^{40}K was determined using the observed gamma ray count rate (CPS) using the following formula. The specific activity of the radionuclides ^{238}U, ^{232}Th, and 40K was determined using the observed gamma ray count rate (CPS) using the following formula [7].

$$A\,(Bq/Kg) = \frac{CPS}{E*I*W} \qquad \ldots(1)$$

Where A: specific activity of the samples (Bq/Kg); CPs: The net count per second; E: efficiency of the gamma-energy; I: Absolute intensity of gamma-ray. W: Net weight of sample in kilogram (kg).Table.2 shows each sample's individual radionuclide activity for the radionuclides ^{238}U, ^{232}Th, and ^{40}K. According to the findings, rock has an average activity concentration of 31.85, 173.91, and 386.37 (Bq/Kg) for ^{238}U, ^{232}Th, and ^{40}K, respectively. The measured radioactive concentrations follow the ^{238}U, ^{232}Th & ^{40}K sequence, and they vary from site to site. Geological processes, notably physical and chemical selection processes across distinct locales, are responsible for these variances in different places. ^{238}U, ^{232}Th, and ^{40}K activity ranging from BDL-91.18, 61.49, and BDL-1222.84(Bq/kg). The outcome indicates that the mean activity concentration of ^{238}U, ^{232}Th, and ^{40}K in thorium is somewhat higher than the global average value

2.4. Assessment of radiation hazards

To figure out the radiological risks to human-health, it is crucial to understand the radioactivity of these materials elements for converting some activity. Numerous formulae are used to determine A_K, A_U, and A_{Th} of ^{40}K and ^{238}U, ^{232}Th. There are several risk indices that are frequently used to calculate the gamma radiation exposures in rocks and construction materials [7].

2.4.1. Radioactive Equivalent (Ra_{eq}):

When describing the gamma emission from different uranium, thorium, and potassium combinations in rock samples collected from diverse locations, the Ra_{eq} index is frequently utilised. This equation is used to compute it [8].

$$Ra_{eq}\,(Bq/Kg) = A_U + 1.43\,A_{Th} + 0.077\,A_K \quad \ldots(2)$$

The radium equivalent values for the rock samples ranged from 104.39 to 925.77 (Bq/kg), with an average value of 307.59 (Bq/kg), as shown in table 3. In Muttom Beach, there is a minimum value, while in Kovalam Beach, there is a maximum value.

2.4.2. Dose rate (D_R)

The dose that was absorbed rates (D_R) due to gamma irradiation in airflow at 1 m above the earth's surface for the even dispersion of naturally occurring radionuclides (^{238}U, ^{232}Th, and ^{40}K) were determined based on criteria provided by [25]. Other naturally occurring radionuclides were thought to have made very minor contributions. As a result, D ($nGy.h^{-1}$) be calculated [9].

$$D_R(nGyh^{-1}) = 0.462\times A_U + 0.604\times A_{Th} + 0.0417\times A_K \quad \ldots(3)$$

dosage rate table 4 has a mean value of 137.61 nGy/h and a range of 52.42–398.74 nGy/h. World average absorbed gamma radiation rate of 81nGy/h is slightly exceeded by the estimated mean value of D_R in the analysed sample. In Muttom Beach, there is a minimum value, while in Kovalam Beach, there is a maximum value.

2.4.3. Annual effective dose

One can calculate the annual effective dose rate, E [$mSvy^{-1}$], from both indoor and outdoor gamma radiation by taking into account the conversion coefficient from the absorbed dose in the air to the effective dose [0.7 $SvGy^{-1}$], a landscape access factor of 0.2, 0.8 gained by adults, and a median value of 4.8 h spent in the mining area on a regular schedule for a year. Under these presumptions, the equation may be utilised to obtain the annual effective dose equivalent [10].

$$(A_{in})(\mu\ Sv\ y^{-1}) = D\ (nGy\ h^{-1}) \times 8760\ h \times 0.8 \times 0.7\ SvGy^{-1} \times 10^{-6} \quad \ldots(4)$$

$$(A_{out})\ (\mu\ Sv\ y^{-1}) = D\ (nGy\ h^{-1}) \times 8760\ h \times 0.2 \times 0.7\ SvGy^{-1} \times 10^{-6} \quad \ldots(5)$$

The mean value of the annual effective dose table 4 for indoor exposure was 0.68 $mSvy^{-1}$, whereas the mean value for outdoor exposure was 0.17 $mSvy^{-1}$.

2.4.4. Hazard Index

To reduce the exterior gamma-radiation exposure from construction supplies, the external hazard index is applied. According to [11], the external hazard index [H_{ex}] was derived from Equation.

$$H_{ex} = \frac{A_u}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad \ldots.(6)$$

Additionally harmful to the respiratory system are radon and its transient byproducts. Therefore, internal radon exposure and its short-lived products are measured using the internal hazard index and represented as [11].

$$H_{in} = \frac{A_u}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad \ldots.(7)$$

The radiation danger must be less than unity 1 for these indices to be considered negligible. The computed H_{ex} value ranges from 0.3 to 2.50, with a mean value that is 0.84. Additionally, the computed H_{in} has a range of 0.39 to 2.59, with a mean value that is 0.92.

2.4.5. Gamma index (I_γ)

Using the following formula, the gamma index (I_γ) suggested by the European Commission has been determined from the activity concentrations of ^{238}U, ^{232}Th, and ^{40}K in soil samples [12].

$$I_\gamma = \frac{A_u}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000} \leq 1 \qquad \text{....(8)}$$

where A_U, A_{Th}, and A_K are the activity concentrations ($Bqkg^{-1}$) of uranium (^{238}U), thorium (^{232}Th), and potassium (^{40}K), respectively. Gamma indices range from 0.42 to 3.23, with a mean value that is within the normal range at 1.10.

2.4.6. Representative level index value (RLI)

This is a distinct radiation hazard index that is used mostly for calculate the amount of the radiation-related with various radionuclide concentrations and has the following form [13, 14].

$$\mathrm{RL}I = \frac{A_u}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \leq 1 \quad \text{...(9)}$$

RLI calculated varies from 0.83-6.46 with mean value 2.21.Values of RLI ≤ 1 correspond to an annual effective dose of less or equal to 1mSv.

2.4.7. Activity utilization index (I)

An activity utilisation index (AUI) is created that is given by the following formula to make it easier to calculate by utilising the appropriate converters and various pairings of the three radionuclides in rocks, dose rates in air may be calculated [15].

$$I = \frac{A_u}{50} f_U + \frac{A_{Th}}{50} f_{Th} + \frac{A_K}{500} f_K \leq 2 \text{ ...(10)}$$

The fractional contributions to the overall exposure rate from gamma radiation in the air from the actual amounts of these radioactive substances are f_{Th} (0.4798), f_U (0.0809), and f_K (0.4392). With a median of 0.44, the computed values range from 0.1 to 1.36.

2.4.8. Annual Gonald Dose Equivalent (AGDE)

The formula that follows was used to determine the AGDE for a house's inhabitant [16].

$$\mathrm{AGDE}(\mu Sv/y) = 3.09 \times A_U + 418 \times A_{Th} + 0.0317 \times A_K \qquad \text{....(11)}$$

In a home with concentrations of ^{238}U, ^{232}Th, and ^{40}K, the typical global levels of AGDE are 35, 35, and 370 mSv/y, respectively. The United Nations Scientific Committee on the Effects of Atomic Radiation-UNSCEAR has established a standard recommendation for AGDE of 300 mSv/y. The range of AGDE is 0.36 to 2.71, with a mean of 0.95. This average number is within the global recommended value.

2.4.9. Excess Lifetime Cancer Risk (ELCR)

ELCR is used to calculate the likelihood that radon exposure inside and its offspring will increase a person's lifetime risk of acquiring cancer.

$$\mathrm{ELCR}_{Out} = \mathrm{AEDE}_{out} * DL * RF \qquad \text{...(12)}$$

$$\mathrm{ELCR}_{In} = \mathrm{AEDE}_{in} * DL * RF \qquad \text{...(13)}$$

AEDE is the Annual effective dose; DL average duration of Life (70Years) ; RF risk factor (Sv^{-1}). For stochasticeffects, ICRP uses RF as 0.05 for public [17].

3. Result and Discussion

Table .2 Total Specific Activity of ^{238}U, ^{232}Th & ^{40}K in rock samples

Sample Code	**^{238}U**	**^{232}Th**	**^{40}K**
	Bq kg^{-1}	**Bq kg^{-1}**	**Bq kg^{-1}**
KSR1	BDL	244 ± 0	BDL
KSR2	91.18 ± 52.74	26.49 ± 45.88	1222.84 ± 606.17
KSR3	35.49 ± 35.98	6.54 ± 16.01	850.72 ± 71.26
KSR4	20.1 ± 40.19	17.64 ± 21.43	1068.48 ± 287.63
KSR5	40.95 ± 63.09	87.58 ± 18.71	112.37 ± 27.56
KSR6	BDL	142.36 ±147.40	4.16 ± 5.88
KSR7	34.81 ± 49.24	622.46 ± 177.24	11.89 ± 12.62
KSR8	38.32 ± 44.96	356.63 ± 124.34	140.69 ± 5.50
KSR9	25.81 ± 34.73	61.49 ± 97.82	66.19 ± 43.17
Minimum	**BDL**	**6.54 ± 16.01**	**BDL**
Maximum	**91.18 ± 52.74**	**622.46 ± 177.24**	**1222.84 ± 606.17**
Average	**31.85**	**173.91**	**386.37**

*BDL- Bellow Detectable Limit

Table.3 Radiological Parameters for rock samples

Sample Code	Ra_{eq} $Bqkg^{-1}$	D_R $nGyh^{-1}$	Annual Effective Dose ($mSvy^{-1}$)			H_{ex}	H_{in}	GI	RLI	ELCR $\times10^{-3}$		AUI	AGEDE $mSvy^{-1}$
			IN	OUT	Total			I_γ	$I_{\gamma r}$	OUT	IN	I	
KSR1	348.92	149.81	0.73	0.18	0.46	0.94	0.94	1.22	2.44	0.63	2.56	0.5	1.02
KSR2	214.66	109.41	0.54	0.13	0.34	0.6	0.85	0.84	1.69	0.46	1.89	0.29	0.78
KSR3	104.39	55.93	0.27	0.07	0.17	0.3	0.39	0.43	0.87	0.25	0.95	0.11	0.40
KSR4	120.11	64.75	0.32	0.08	0.2	0.34	0.4	0.51	1.02	0.28	1.12	0.1	0.47
KSR5	174.05	77.35	0.38	0.09	0.24	0.47	0.58	0.61	1.22	0.32	1.33	0.28	0.53
KSR6	203.87	87.59	0.43	0.11	0.27	0.55	0.55	0.71	1.43	0.39	1.51	0.29	0.60
KSR7	925.77	398.74	1.96	0.49	1.23	2.5	2.59	3.23	6.46	1.72	6.86	1.36	2.71
KSR8	558.15	242.52	1.19	0.3	0.75	1.51	1.61	1.96	3.92	1.05	4.17	0.83	1.65
KSR9	118.38	52.42	0.26	0.06	0.16	0.32	0.39	0.42	0.83	0.21	0.91	0.19	0.36
Minimum	**104.39**	**52.42**	**0.26**	**0.06**	**0.16**	**0.3**	**0.39**	**0.42**	**0.83**	**0.21**	**0.91**	**0.1**	**0.36**
Maximum	**925.77**	**398.74**	**1.96**	**0.49**	**1.23**	**2.50**	**2.59**	**3.23**	**6.46**	**1.72**	**6.86**	**1.36**	**2.71**
Average	**307.59**	**137.61**	**0.68**	**0.17**	**0.42**	**0.84**	**0.92**	**1.10**	**2.21**	**0.59**	**2.37**	**0.44**	**0.95**

Fig.2 Radium Equivalent & Dose rate for rock samples

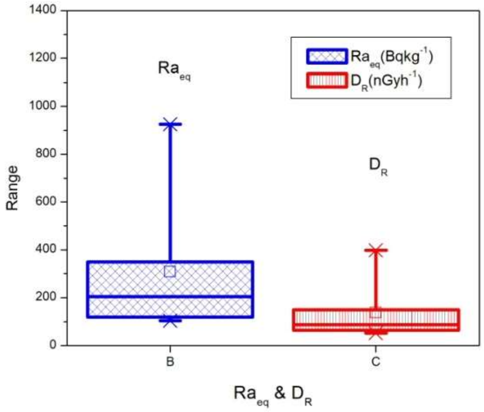


Fig.3 Annual Effective Dose for rock samples

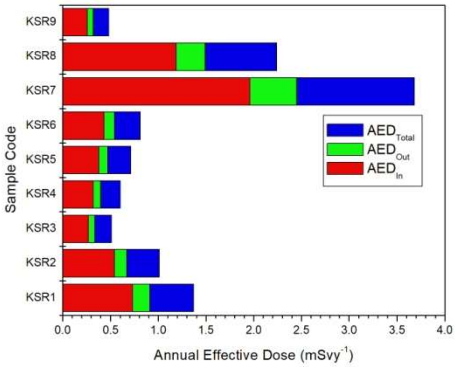


Fig.4 Radiological Parameters for rock samples

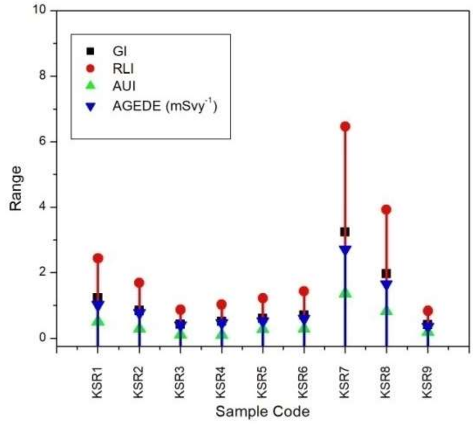
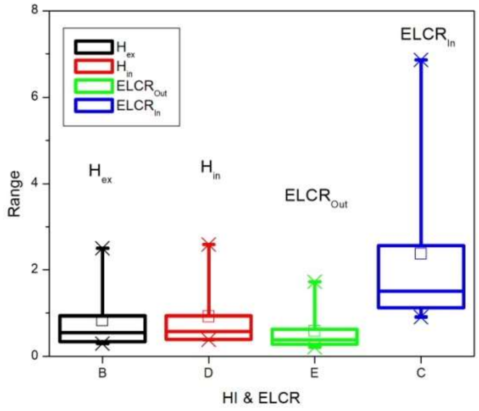


Fig.5 Hazard indices & ELCR for rock sampes



3.1. Elemental Concentration

The percentage potassium (%K) and part per million (ppm) for uranium and thorium respectively, are used to estimates the elemental concentration of potassium in rocks, soil and water. The 1460 keV gamma ray energy released by ^{40}K was utilised in gamma ray spectrometry to measure potassium. Since ^{40}K exists in nature in a constant ratio to other potassium isotopes, the determination of ^{40}K is straightforward. On the other hand, the energy lines of their daughter products were used to indirectly estimate uranium and thorium. According to the IAEA, 1 ppm Th in rock is equal to 4.06 Bq kg^{-1}, 1.0 ppm U in rock is equal to 12.35 Bq kg^{-1}, and 1% K in rock is equal to 313 Bq kg^{-1}[18].

3.2.Radiogenic Heat Production

Rock heat may be calculated using estimates of ^{40}K, ^{238}U, and ^{232}Th concentrations from gamma ray spectroscopy. Thermal energy is released when naturally occurring radionuclides in the ground disintegrate; the majority of this energy is created by the decay of ^{40}K, ^{238}U, and ^{232}Th.

The density of rock, ρ (kg m^{-3}), the concentration of radioelements C_K (% K), C_U (PPM), and C_{Th} (PPM), and the heat production (HP) of rocks are connected by [18].

$$HP= \rho(3.48\ C_K + 9.52\ C_U + 2.56\ C_{Th} * 10\text{-}^{5}\ (\mu Wm\text{-}^{3})$$

Table .4 Element Concentration and Radiogenic Heat Production (RHP $\mu W/m^{-3}$) in the Seashore rock samples from Kanyakumari District

Sample Code	U(PPM)	Th(PPM)	K%	RHP ($\mu W/m^{-3}$)
KSR1	0	60.1	0	4.38
KSR2	7.38	6.52	3.91	2.87
KSR3	2.87	1.61	2.72	1.17
KSR4	1.63	4.34	3.41	1.1
KSR5	3.32	21.57	0.36	2.51
KSR6	0	35.07	0.01	2.56
KSR7	2.82	153.32	0.04	11.95
KSR8	3.1	87.84	0.45	7.3
KSR9	2.09	15.15	0.21	1.69
Minimum	0	1.61	0	1.1
Maximum	7.38	153.32	3.91	11.95
Average	2.58	42.84	1.23	3.95

In elemental concentration Uranium range is from 0 to 7.38(PPM), thorium range is from 0 to 153.32 (PPM) and potassium range is from 0 to 3.91 (PPM) with the mean value of uranium, thorium and potassium is 2.58 (PPM), 42.84(PPM) and 1.23(PPM). Radiogenic heat production range is from 1.1 to 11.9(RHP $\mu W/m^{-3}$) with the mean value of 3.95 (RHP $\mu W/m^{-3}$)

3.3. Frequency distribution & Q-Q plot: Figures 6, 7 and 8 show the histogram and frequency distribution of all radionuclides. The histogram reveals that ^{238}U, ^{232}Th, and ^{40}K displayed some multimodality. The radionuclides' multi-model characteristics show how complex the minerals in rock samples. Figures 9,10 and 11 analyse the Q-Q plot of the activities ^{238}U, ^{232}Th, and ^{40}K. Another method to recognize different distribution types is the quantile-quantile plot.

Fig.6 Frequency Distribution for ^{238}U in rock samples

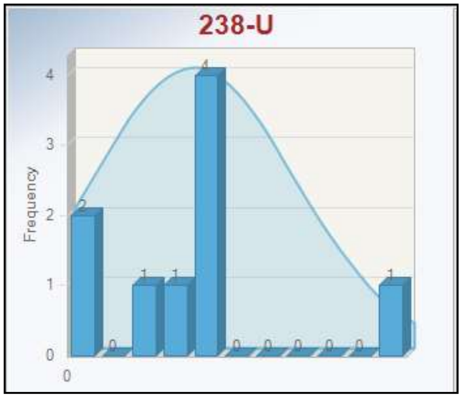


Fig.9 Q- Q plot for ^{238}U in rock samples

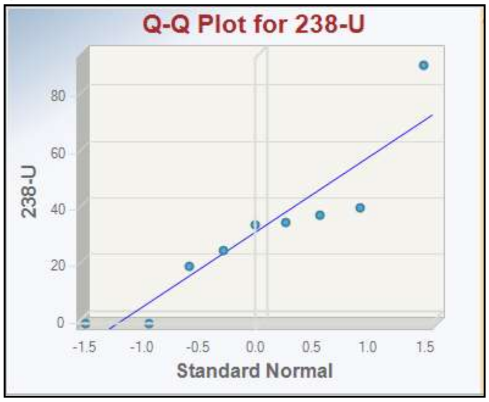


Fig.7 Frequency Distribution for ^{232}Th in rock samples

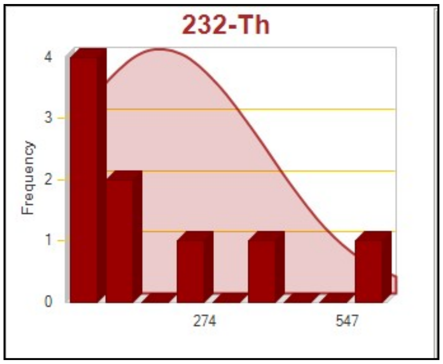


Fig.10 Q- Q plot for ^{232}Th in rock samples

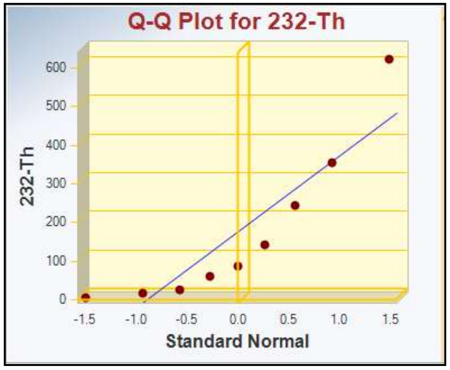


Fig.8 Frequency Distribution for ^{40}K in rock samples

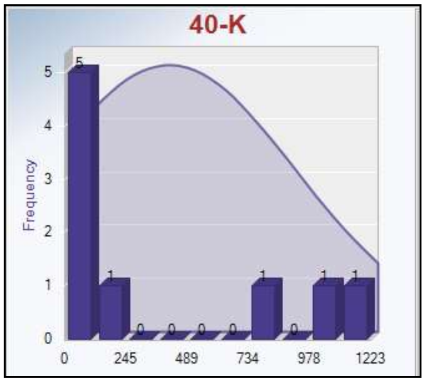
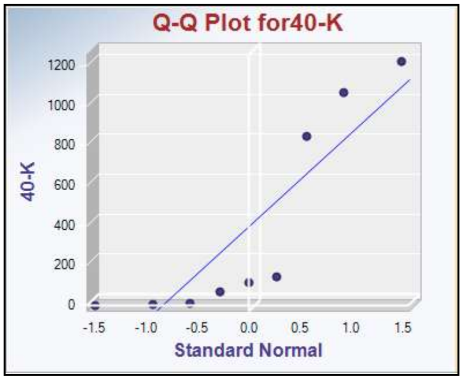


Fig.11 Q- Q plot for ^{40}K in rock samples



3.4. Statistical Analysis

Statistical analysis is the collection and interpretation of data in order to uncover patterns and trends. It is a component of data analytics. Statistical analysis can be used in situations like gathering research interpretations, statistical modeling or designing surveys and studies.

Table. 5 Statistical data that describe radionuclides

Variables	**U-238 (Bq/kg)**	**Th - 232(Bq/kg)**	**K-40(Bq/kg)**
Maximum	91.18	622.46	1222.84
Minimum	0	6.54	0
Mean	31.85	173.91	386.37
Median	34.81	87.58	122.25
Skewness	1.16	1.56	0.95
Kurtosis	2.63	2.11	-1.18
SD	27.09	204.56	506.72
Correlation (R)	0.924	0.903	0.875
Couts	9	9	9

Intercept	31.85	173.9	386.4
Slope	26.76	197.4	473.7

Skewness

In both statistics and probability theory, skewness is an indicator of the asymmetrical of probability distributions of a genuine arbitrary variable. Skewness offers several advantages. Many theories rely on the assumption that the data have normal distributions and are symmetric around the mean. The normal distribution has zero skewness. Data points might not be precisely symmetrical in practice, though. Knowing the dataset's skewness allows one to predict whether departures either a favorable or unfavorable deviation from the mean. Skewness is a measure of how asymmetrical a distribution is relative to its mean [19].

Kurtosis

A statistical measure known as kurtosis quantifies how far the tails of a distribution depart from a normal distribution. Thus, kurtosis decides whether the tails of specific distributions include the highest or lowest values. Kurtosis is a crucial descriptive statistic of the data distribution, along with skewness. However, it is important to distinguish between the two ideas. While skewness accurately assesses the symmetry of the distribution, kurtosis determines the mass of the distribution tails. In my study uranium and thorium the data has heavy tails and is more peaked around the mean, indicating the presence of outliers or extreme value and it was said to be leptokurtosis distribution. Potassium has negative value and this kind of distribution said to be platykurtic he value for kurtosis between -2 to +2 are considered acceptable in order to prove normal univarite distribution [20]

3.5. Pearson correlation

By calculating the linear Pearson correlation coefficient, correlation analysis has been conducted as a bivariation statistic to ascertain the reciprocal connections and degree of linkage within two distinct factors. Table.7 displays the findings for the Pearson correlation coefficients between all the investigated radioactive factors for rocks [21]. Due to the fact that uranium and thorium undergo the same natural decay processes, there is a weak correlation between ^{232}Th and ^{238}U. The radiological parameters absorbed the positive correlation coefficient. This suggests that there is a very significant correlation between radiological indices and radionuclides in rocks. ^{40}K is negatively correlated; this may be due to sediment process that great the mobility of the radionuclides [22]. From the correlation it shows the uranium and thorium had weak correlation, potassium has contained negative correlation and there is a good correlation between radiological parameters.

Table. 6 Pearson correlation coefficient between radioactive variables in rock samples

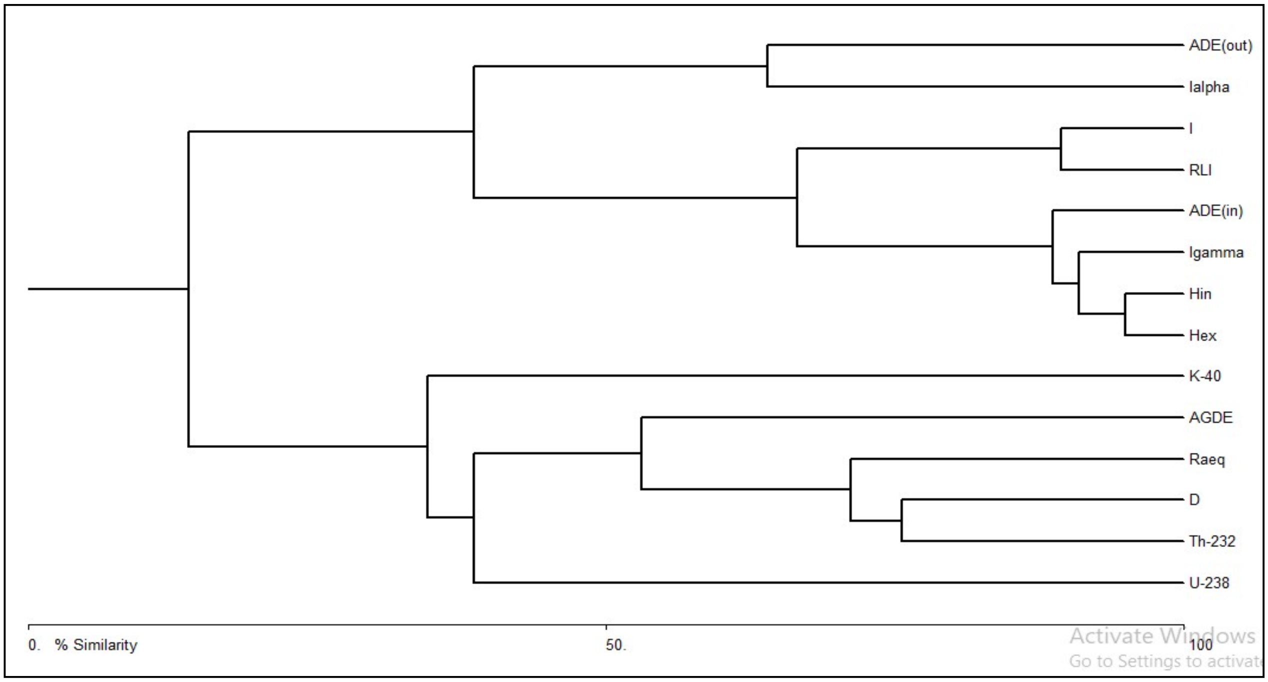
	U^{238}	Th^{232}	K^{40}	Ra_{eq}	D_R	$H_{(ex)}$	$H_{(in)}$	I_γ	I_α	RLI	I	$AED_{(in)}$	$ADE_{(out)}$	AGDE
U^{238}	1.	*	*	*	*	*	*	*	*	*	*	*	*	*
Th^{232}	-0.15	1.	*	*	*	*	*	*	*	*	*	*	*	*
K^{40}	0.48	0.58	1.	*	*	*	*	*	*	*	*	*	*	*
Ra_{eq}	0.34	0.97	-0.41	1.	*	*	*	*	*	*	*	*	*	*

D_R	0.37	0.96	-0.36	0.99	1.	*	*	*	*	*	*	*	*	*
$H_{(ex)}$	0.34	0.97	-0.40	1.	0.99	1.	*	*	*	*	*	*	*	*
$H_{(in)}$	0.43	0.95	-0.34	0.99	0.99	0.99	1.	*	*	*	*	*	*	*
I_{γ}	0.35	0.97	-0.38	0.99	0.99	0.99	0.99	1.	*	*	*	*	*	*
I_{α}	0.99	0.12	0.50	0.31	0.35	0.32	0.41	0.33	1.	*	*	*	*	*
RLI	0.35	0.97	-0.38	0.99	0.99	0.99	0.99	1.	0.33	1.	*	*	*	*
I	0.57	0.88	-0.18	0.96	0.97	0.96	0.98	0.97	0.55	0.97	1.	*	*	*
$AED_{(in)}$	0.37	0.96	-0.37	0.99	1.	0.99	0.99	0.99	0.35	0.99	0.97	1.	*	*
$ADE_{(out)}$	0.36	0.96	-0.37	0.99	0.99	0.99	0.99	0.99	0.34	0.99	0.97	0.99	1.	*
AGDE	0.26	0.18	-0.27	0.17	0.17	0.17	0.19	0.17	0.24	0.16	0.19	0.17	0.16	1.

3.6. Cluster analysis

Cluster analysis (CA) is a technique used to find and classify clusters of objects or observations that share characteristics. Although every observation or object within a cluster is the same, each cluster is different from the others. Similarity is a measure of the maximum distance between any two individual variables and the distance between clusters. While 0% indicates that the cluster regions are separated from one another, 100% similarity indicates that the clusters were at zero distance from one another during the sample measurements. Axes were used in cluster analysis to find common traits among the rock's radiological properties and naturally occurring radioisotopes [23].

Figure .12 Cluster analysis



The average linkage method along with correlation coefficient distance was applied and the derived was shown in Figure 8. All of the natural radioisotopes were represented as one group with similar characteristics as they originated from ^{232}Th and ^{238}U series. ^{40}K was identified in another cluster. The close relation between ^{238}U and ^{232}Th series members but not with ^{40}K was in accordance with the result. Cluster analysis proved to be useful semi-quantitative technique for analyzing the data and determining the linkages between rock samples from various locations [24].

Conclusion

The mean activity concentration of ^{238}U, ^{232}Th and ^{40}K in the seashore rock samples are 31.85, 173.91 and 386.37 (Bq/kg) respectively, higher than world average activity concentration. The activity concentration which indicate that $^{40}K > {}^{232}Th > {}^{238}U$ were used to estimate several radiological parameters that qualify and quantify the radiological hazards. The activity concentration of NORMs in the seashore rock samples from different region varied, which could be due to the difference in geological formation. Determination of the natural radioactivity and associated hazards in the rocks is account for monitoring the radiation background and to take care of health issue may affect environment of living thing.. The statistical analysis was also carried out to classify the risk nature in rocks. In statistical approach uranium and thorium has positive kurtosis but it was higher than +2 so the distribution is too peaked and potassium has negative value so the peak shape flatter than normal. In skewness uranium and thorium value are greater than +1 so the data is highly skewed because the data is not evenly distributed and potassium it was moderately skewed so the data is not evenly distributed around mean but it instead slightly skewed to one side. There was a weak correlation between uranium and thorium in pearson correlation, potassium has negative correlation but radiological parameters has good correlation. This work has established baseline information on the natural radioactivity status in kanyakumari district seashore rock samples, which will serve as a reference for future studies

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