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RESEARCH ARTICLE

EVALUATION OF RADIATION HAZARD INDICES DUE TO THE ROCK SAMPLES OF WESTERN GHATS OF SOUTH TAMILNADU.

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Abstract

Determination of the natural radioactivity has been carried out, by means of NaI (Tl) gamma ray spectrometer in rock samples collected from Western Ghats in south TamilNadu. Rocks in the study region are mainly used as construction materials. For the present study, the evaluation of environmental radioactivity and also estimation of the radiological parameters were carried out in the rock samples. Radiological parameters such as absorbed dose rate (D_R), radium equivalent activity (Ra_{eq}), hazard indices (H_{in} and H_{ex}) and radioactive level index (I_γ) were calculated to know the complete radiological hazardous nature. The range of activity concentration of ^{238}U, ^{232}Th and ^{40}K were 0.44 Bq/kg to 50.83 Bq/kg, 0.211 Bq/kg to 293.67 Bq/kg and 233.49 Bq/kg to 2091.70 Bq/kg respectively. Concentration of radionuclide ^{232}Th and all the calculated radiological parameter are higher in site L_{22} due to the presence of Monazite and also higher than the world recommended level.

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Introduction:-

Many areas in the world possess high levels of natural radiation. The high radiation levels are due to the presence of naturally occurring radioactive minerals in the rocks, soils, water, etc. Hence, humans should be aware of their natural environment with regard to the radiation health effects. Therefore now a days, human exposure to ionizing radiation is one of the scientific subjects that attracts public attention, since radiation of natural origin is responsible for most of the total radiation exposure of the human population (Ramasamy et al., 2013). The most important places among the well documented high natural background (NBR) areas of the world are Guarapuri in Brazil, Yangjiang in China and Chavara and Manavalakurichi in India (Singh et al., 2007). In India we have high-background radiation areas along the South West coast. According to Paul and Gupta, the Monazite deposits occur throughout the erstwhile south Travancore region comprising parts of Kerala and Kanyakumari district, TamilNadu. The Presence of monazite deposits on the coastal areas of Kerala and TamilNadu is due to the weathering of rocks in Western Ghats (Shanthi et al., 2009), (Manigandan et al., 2014).

The radioactivity of rocks contributes to the external gamma dose rate that human receive from the environment (Rodrigo et al., 2009). Cosmic rays and terrestrial gamma rays are the two prominent contributors to the external radiation. The cosmic rays come from the celestial environment whereas terrestrial gamma rays come from the isotopes of ^{238}U, ^{232}Th and ^{40}K present in the soil, rock, granites, and water etc (Kerur et al., 2010). The natural radioactivity depends mainly on geological and geographical conditions of the environment (Orgun et al., 2007).

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Radioactivity is common in the rocks and soils that make up or planet, in the water in the oceans, and even in our building materials and homes. It is just everywhere (Uosif et al., 2015). Large variations in dose rates of both cosmic and terrestrial radiation are found depending on where the measurements are made. Measurements and studies of samples are very important to determine the amount of change of natural background activity with time as a result of any radioactive release.

Fig 1:- Location of the study area.

Monitoring of any release of radioactivity to environment is important for environmental protection. Also natural radioactivity measurements are necessary not only due to its radiological impacts, but also because it acts as excellent biochemical and geochemical tracers in the environment. Therefore the assessment of radiation doses from natural radioactive sources is of particular importance as it is the largest contributor to the external dose of the world population (El-Taher et al., 2007).

Western Ghats (are also known as Sahyadi) is a mountain range that runs parallel to the western coast of the Indian peninsula located entirely in India. The range starts near the border of Gujarat and Maharashtra and runs through the states of Maharashtra, Goa, Karnataka, Kerala and TamilNadu ending at Kanyakumari at the tip of India (Google maps).

The main objective of this study is to: (i) determine the concentration of natural radionuclides (^{238}U, ^{232}Th and ^{40}K) in the rocks of Western Ghats, India; (ii) Calculate the important radiological parameters to assess the complete radiological hazardous nature of the rocks.

Sampling and Sample Preparation:-

For the present study, rock samples were collected from 24 places of Western Ghats in Kanyakumari district and numbered as L_1 to L_{24}. Fig. 1 shows the location of the study area. Each sample nearly 1kg in weight was washed in distilled water and dried in an oven at nearly 110°C to ensure that moisture was completely removed. About 250-300g from each samples were crushed, homogenized, sieved, which is the optimum size enriched for heavy minerals. Weighted samples were placed in polyethylene beakers of 100ml volume each. The beakers were completely sealed for 4 weeks to reach secular equilibrium of the daughters with the parent (ASTM., 1983), (ASTM., 1986). After attainment of secular equilibrium each sample was counted for 2000s.

Measurement:-

The activity concentration of gamma ray emitting radionuclides was performed by high efficiency 5” x 5” NaI (Tl) Gamma Ray Scintillation Detector. Energy Calibration was done using Standard sources of known gamma ray energies and activities. The activities of various radionuclides were determined in Bq/kg using the count spectra obtained from each of the samples. The main sources causing gamma radiations in rocks are Thorium (^{232}Th), Uranium (^{238}U) and Potassium (^{40}K). The three characteristic gamma ray energies associated with these elements are 2.614Mev for Thorium, 1.764Mev for Uranium and 1.461Mev for Potassium (Verma et al.). The gamma ray spectrum was recorded using a computer based multi channel analyzer and processed using the TMCA32 software.

Activity Concentrations of the Natural Radionuclides:-

The activity concentrations of the natural radionuclides in the measured samples were computed using the relation (Uosif et al., 2015),

$$A\ (Bq/kg) = \frac{Np}{e * \eta * m}$$

Where Np is the net Gamma counting rate(sample counts- background counts) (counts per second), e is the abundance of the gamma line in a radionuclide, η is the measured efficiency for each gamma line observed for the same number of channels either for the sample or the calibration source and m is the mass of the sample in Kilograms.

Radiological Parameters:-

In the present study, the expected environmental impacts of the radionuclides are investigated in terms of Dose Rates, Radium Equivalent Activity External and Internal hazard indices and a radioactivity level index.

Absorbed Dose Rate (nGy/h):-

The Absorbed dose rate (D_R) due to gamma ray emission from the main primordial radionuclides from the rock samples were evaluated using the formulae provided by United Nations Scientific Committee on Effect of Atomic Radiation (UNSCEAR, 2000).

In order to convert the activity concentration to absorbed dose rate in air 1m above the ground surface for uniform distribution of naturally occurring radionuclides, dose coefficients of 0.92 nGy/h per Bq/kg for ^{238}U, 1.1 nGy/h per Bq/kg for ^{232}Th and 0.080 nGy/h per Bq/kg for ^{40}K were used (Mahur et al., 2008).

$$D_R\ (nGy/h) = 0.462C_U + 0.604C_{Th} + 0.0417\ C_K$$

Where C_U is the activity concentration of ^{238}U, C_{Th} is the activity concentration of ^{232}Th and C_K is the activity concentration of ^{40}K in Bq/kg and D_R is the dose rate in nGy/h.

Radium Equivalent Activity (Ra_{eq}):-

Radium equivalent activity is the quantity representative of external gamma radiation dose associated with the material. Ra_{eq} compares the specific activities of samples containing different concentrations of ^{238}U, ^{232}Th and ^{40}K. It is evaluated using the equation (Beretka et al., 1985)

$$Ra_{eq} = C_U + 1.43C_{Th} + 0.077C_K \leq 370\ Bq/kg$$

Where C_U is the activity concentration of ^{238}U, C_{Th} is the activity concentration of ^{232}Th and C_K is the activity concentration of ^{40}K in Bq/kg.

The External and Internal Hazard Indices:-

The external hazard index (H_{ex}) was used to measure the external hazard due to the emitted gamma radiation. It was calculated by the equation (Tufail et al., 1992),

$$H_{ex} = C_U/370 + C_{Th}/259 + C_K/4810 \leq 1\ nGy/h$$

Where H_{ex} is the external hazard index in nGy/h and C_U is the activity concentration of ^{238}U, C_{Th} is the activity concentration of ^{232}Th and C_K is the activity concentration of ^{40}K in Bq/kg. The upper limit of this index is ≤ 1 nGy/h.

The internal hazard index (H_{in}) was used to control the internal exposure to ^{222}Rn and its radioactive progeny. It was calculated by the equation (Tufail et al., 1992),
$H_{in} = C_U/185 + C_{Th}/259 + C_K/4810 \leq 1$ nGy/h

Radioactive Level Index (I_γ):-
The radioactivity level index is used to estimate the level of radiation risk, especially gamma rays associated with natural radionuclides in specific materials. It is defined as (Nuclear Energy Agency., 1979)
$I_\gamma = C_U/150 + C_{Th}/100 + C_K/1500 \leq 1$ nGy/h

Where Iγ is the radioactivity level index and C_U is the activity concentration of ^{238}U, C_{Th} is the activity concentration of ^{232}Th and C_K is the activity concentration of ^{40}K in Bq/kg. The safety value for this index is ≤ 1.

Results and Discussion:-

Activity Concentration of Radionuclides

The activity concentration of radionuclides in the studied area is given in table.1. The activity concentration ranges for ^{238}U, ^{232}Th and ^{40}K are 0.44 Bq/kg to 41.23 Bq/kg with an average of 19.39 Bq/kg, 0.21Bq/kg to 293.28 Bq/kg with an average of 46.62 Bq/kg and 233.49 Bq/kg to 2091.70 Bq/kg with an average of 1052.05 Bq/kg respectively. The high radioactivity in the studied area was due to the presence of higher amount of zircon, iron oxides and other radioactive materials (El-Arabi et al., 2007). The distribution of ^{238}U and ^{232}Th are controlled by the presence of such these radioactive minerals (Cuney et al., 1987). Mean activity concentration is in the order $^{238}U < ^{232}Th < ^{40}K$. Here concentration of ^{40}K is very much higher than ^{238}U and ^{232}Th. The activity concentration of ^{238}U is higher in 5 sampling sites, compared with the world average value (33 Bq/kg). The activity concentration of ^{232}Th in 10 sampling sites is higher than world average value (45 Bq/kg). The presence of these higher values clearly indicates that the rich distribution of heavy minerals in the study area (Ramasamy et al, 2013). Fig .2 shows the statistically significant correlation between the ^{238}U and ^{232}Th activity concentration.

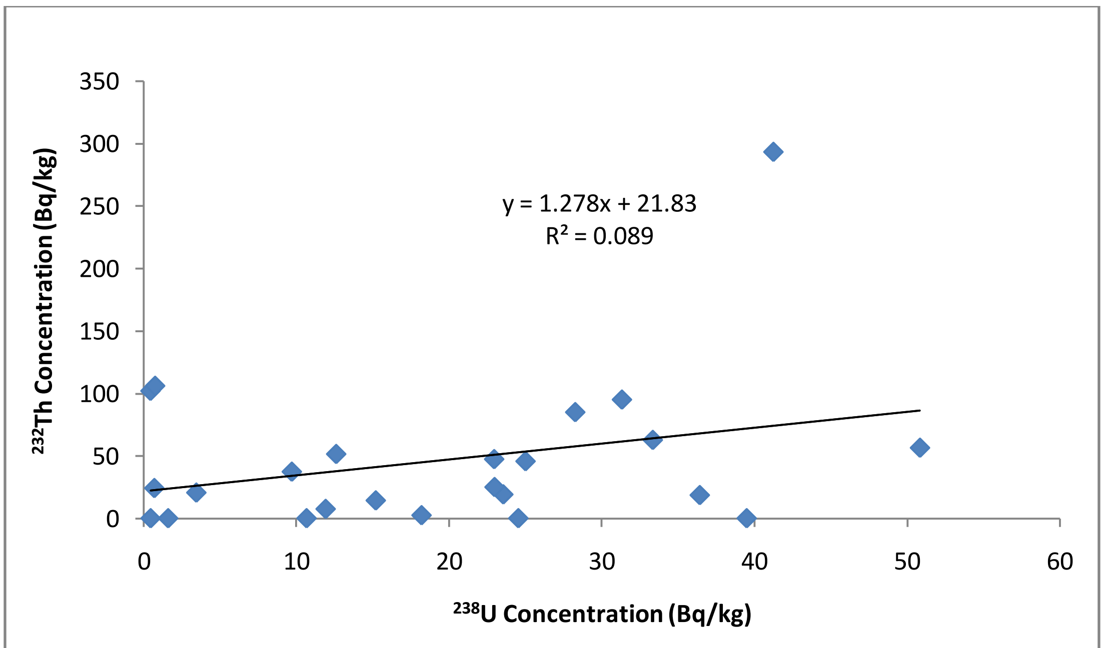

Fig 2:- Correlation between ^{238}U and ^{232}Th

Table 1:- Activity Concentration of rock samples in different places.

Sl.No	Sample Location	Activity Concentration (Bq/kg)		
		^{238}U	^{232}Th	^{40}K
1.	L_1	3.44 ± 0.88	20.75 ± 0.98	1660.48 ± 2.44
2.	L_2	10.66 ± 0.29	0.22 ± 0.05	233.49 ± 2.98
3.	L_3	22.95 ± 0.25	47.53 ± 0.61	801.97 ± 2.35
4.	L_4	0.45 ± 0.57	0.211 ± 0.07	1033.67 ± 1.77
5.	L_5	0.44 ± 1.34	102.22 ± 1.84	1362.07 ± 2.44
6.	L_6	18.19±1.17	2.61 ± 0.65	975.28 ± 3.36
7.	L_7	9.7 ± 1.56	37.51 ± 0.68	1219.72 ± 2.25
8.	L_8	0.74 ± 0.38	106.28 ± 1.72	1900.69 ± 3.82
9.	L_9	36.41 ± 1.09	18.74 ± 0.69	1019.05 ± 3.01
10.	L_{10}	24.99 ± 1.22	45.88 ± 0.89	507.41 ± 2.25
11.	L_{11}	12.06 ± 0.84	51.66 ± 2.06	1007.76 ± 4.74
12.	L_{12}	11.91 ± 0.96	7.66 ± 0.41	705.66 ± 2.96
13.	L_{13}	33.333 ± 0.96	62.91 ± 0.77	1224.62 ± 2.03
14.	L_{14}	28.25 ± 1.15	85.18 ± 1.66	987.82 ± 2.75
15.	L_{15}	23.545 ± 0.32	19.29 ± 0.91	2091.7 ± 4.19
16.	L_{16}	31.312 ± 1.01	95.24 ± 1.69	813.8 ± 4.99
17.	L_{17}	50.83 ± 0.15	56.66 ± 1.25	746.02 ± 3.97
18.	L_{18}	22.97 ± 0.32	25.18 ± 1.21	444.25 ± 3.07
19.	L_{19}	15.19 ± 0.79	14.48 ± 0.76	864.55 ± 2.59
20.	L_{20}	1.597 ± 0.24	0.21 ± 0.41	568.4 ± 3.07
21.	L_{21}	0.692 ± 0.14	24.36 ± 1.72	1755.05 ± 3.51
22.	L_{22}	41.23 ± 1.47	293.67 ± 2.06	1006.82 ± 1.68
23.	L_{23}	39.481 ± 0.51	0.22 ± 0.025	1148.51 ± 2.32
24.	L_{24}	24.527 ± 0.78	0.23 ± 0.081	1170.50 ± 0.93

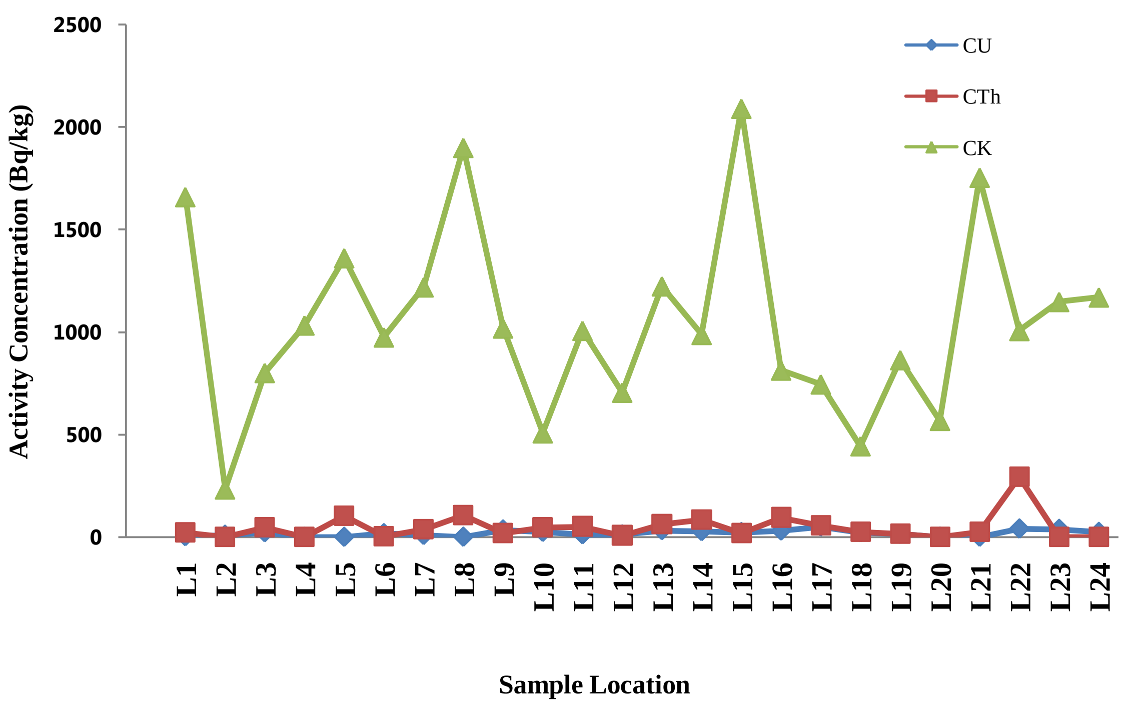

Fig 3:- Activity Concentration of ^{238}U, ^{232}Th and ^{40}K.

The activity concentration of ^{40}K is higher than the world average value (420 Bq/kg) (UNSCEAR, 2000). Among 24 sample locations, only one sample location is lower than the world average value. Among these three radionuclides ^{40}K is more dominant in the studied area. This is due to the abundance of potassium is proportional to the silica content of the rocks (Ahmed et al., 2006), (Sannappa et al, 2010). Fig.3 shows the random distribution of radionuclides in the studied area.

Radiological Parameters:-

In order to know the radiological effect of the present study area, the different radiological indices are to be calculated and details of calculations are given in Table 2

Table 2:- Absorbed Dose Rate (D_R), Radium Equivalent Activity (Ra_{eq}), Hazard Indices (H_{in} and H_{ex}) Radioactive level Index (Iγ).

Sample Location	D_R (nGy/h)	Ra_{eq} (Bq/kg)	Hazard Indices (nGy/h)		(I_γ)
			H_{in}	**H_{ex}**	
L_1	83.731	160.971	0.444	0.434	1.33
L_2	14.800	28.957	0.108	0.078	0.228
L_3	73.260	152.665	0.477	0.412	1.162
L_4	43.544	80.346	0.218	0.216	0.694
L_5	119.900	251.496	0.681	0.680	1.93
L_6	50.737	97.021	0.313	0.262	0.797
L_7	78.473	157.248	0.451	0.425	1.252
L_8	145.045	299.075	0.809	0.809	2.334
L_9	70.850	141.672	0.485	0.382	1.109
L_{10}	60.877	129.673	0.420	0.350	0.963
L_{11}	79.639	164.070	0.478	0.443	1.272
L_{12}	39.688	77.222	0.242	0.208	0.626
L_{13}	105.152	217.597	0.681	0.588	1.667
L_{14}	106.586	226.120	0.691	0.611	1.698
L_{15}	110.110	212.196	0.639	0.573	1.744
L_{16}	106.897	230.167	0.709	0.622	1.703
L_{17}	89.352	189.292	0.654	0.512	1.402
L_{18}	44.596	93.185	0.316	0.252	0.701
L_{19}	52.016	102.466	0.319	0.276	0.822
L_{20}	24.624	45.669	0.127	0.123	0.391
L_{21}	88.637	170.668	0.462	0.461	1.418
L_{22}	241.366	538.707	1.570	1.459	3.882
L_{23}	66.302	128.226	0.457	0.346	1.031
L_{24}	60.347	114.978	0.379	0.311	0.946

Table 3:- Comparison of Activity Concentrations with those found in Similar Studies.

Country	Activity(Bq/kg)			Ra_{eq} (Bq/kg)	I_γ	Reference
	^{238}U	**^{232}Th**	**^{40}K**			
Western Ghats (Kanyakumari Dist)	**19.39**	**46.62**	**1052.05**	**167.07**	**1.3**	**This Study**
Western Ghats (Nilgiri District)	26.26	53.61	231.93	118.6	1.47	(Manigandan et al., 2014)
Azad Kashmir	37.32	38.57	465.62	126.30	-	(Rafique et al., 2014)
India	64	93	124	206.5	1.4	(Singh et al.,2005)
Algeria	47.01	43	329	132	0.95	(Wassila et al.,2011)
Brazil	1.69	5.32	34.15	12	0.1	(Becegato et al.,2008)
Egypt	13.7	12.3	1233	126.2	1.04	(Ahmed et al., 2005)
Pakistan	27.39	31.16	602.77	142.71	1.02	(Akhtar et al., 2005)

Absorbed Dose Rate (nGy/h)

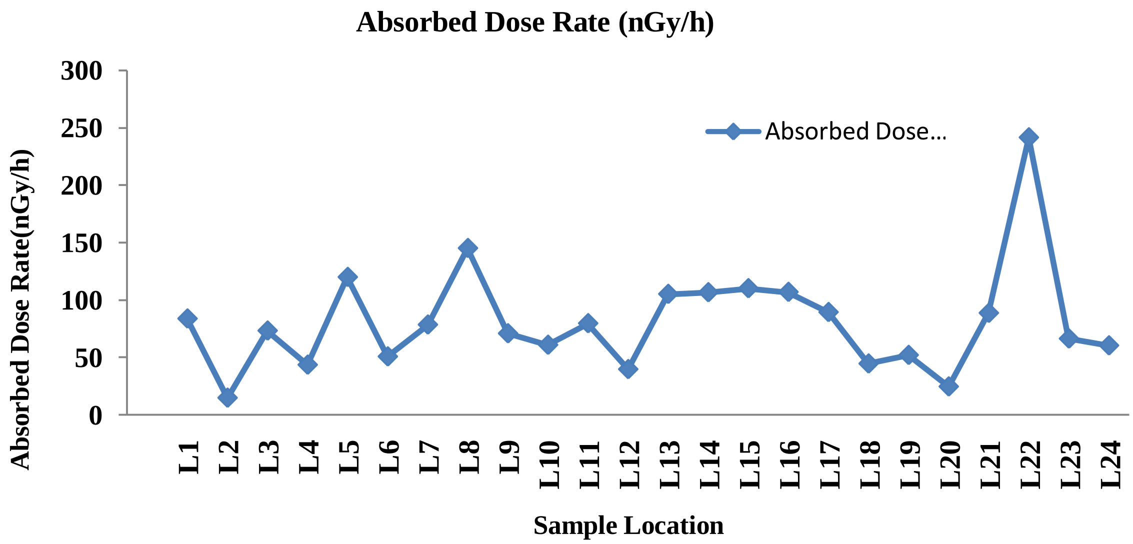

Fig 4:- Distribution of Absorbed Dose Rate

The calculated absorbed dose rate values were tabulated in Table.2. The calculated values are ranged from 14.80 nGy/h to 241.37 nGy/h with an average of 81.52 nGy/h. The lower value was observed in sample location L_2 (14.80 nGy/h), while the highest value was observed in L_{22} (241.37 nGy/h). Only in 7 locations the absorbed dose rate is lower than the world average value (57 nGy/h), whereas the remaining 17 locations are much higher than the world average value. Fig. 4 shows the variation of absorbed doses in the sample locations.

Radium Equivalent Activity (Bq/kg):-

The Radium equivalent activity in Bq/kg is tabulated in table.2. Radium equivalent activity values varied from 28.96 Bq/kg to 538.70 Bq/kg with an overall average value of 167.07 Bq/kg. From these results Raeq is relatively high at the sample location L_{22} (538.70 Bq/kg), which due to the higher concentration of ^{232}Th. This value is higher than the recommended maximum value of world average 370 Bq/kg (UNSCEAR., 2000).

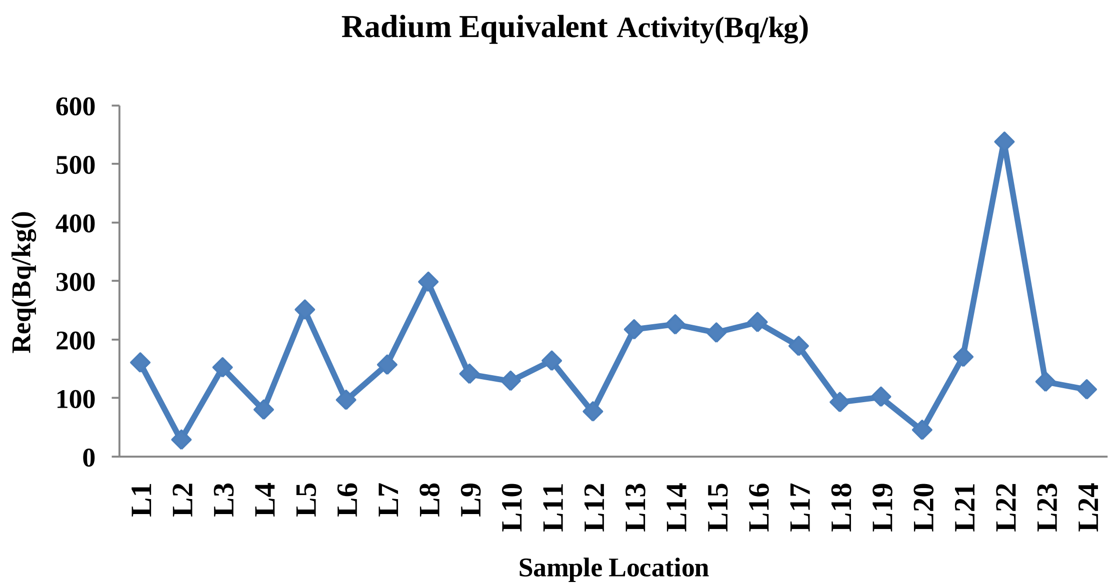

Fig 5:- Distribution of Radium Equivalent Activity

Fig.5 shows the distribution of radium equivalent activity for the study area. On comparing with the values were measured in some other countries were lower than the calculated values of this work. Comparison table is shown in table.3.

Hazard Indices (H_{ex} and H_{in}):-
The Hazard indices of the rock samples in the studied area were also calculated. The objective of this calculation is to limit the radiation dose to permissible dose equivalent limit of 1mSv/y (ICRP., 1990). The hazard indices values (H_{ex} and H_{in}) were tabulated in table.2. As given in table.2, Hex values varied from 0.08 to 1.46 with an average of 0.45 and Hin values were varied from 0.11 to 1.57 with an average of 0.51.

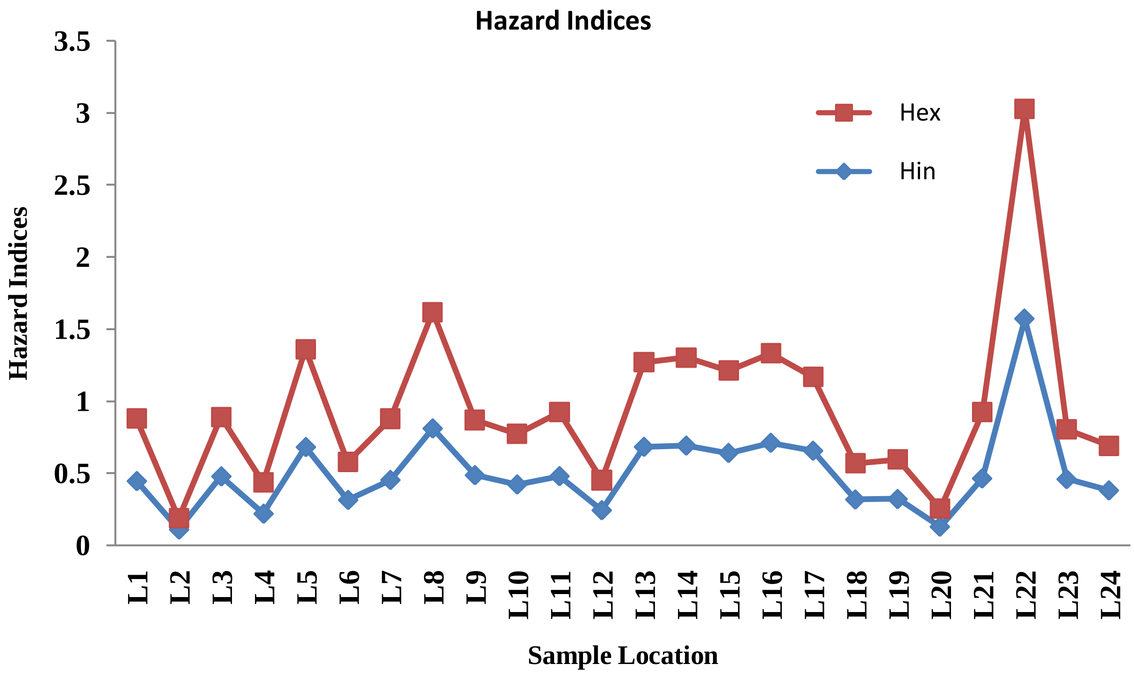

Fig 6:- Distribution of Hazard Indices.

Here H_{ex} and H_{in} must not exceed the limit of unity for the radiation hazard to be negligible. But in our case one place L_{22} shows the Hex and H_{in} values higher than unity. Fig.6 shows the distribution of hazard indices for the sample locations.

Radioactive level index (I_γ):-
Radioactive level index (I_γ) is used to estimate the level of a gamma radiation hazard associated with natural gamma ray emitters in the samples (Oladel et al., 2009). These values were tabulated in table.2. According to the data were given in table.2, the values varied from 0.23 to 3.88 with an average of 1.3. Here many places have shown the higher radioactive index than the safety level.

Conclusion:-
This study presents the activity concentration of ^{238}U, ^{232}Th and ^{40}K, absorbed dose rate, radium equivalent activity; hazard Indices and radioactive level index of rock samples from the selected regions of Western Ghats in south TamilNadu. The mean activity concentration of ^{238}U, ^{232}Th and ^{40}K measured in this study were 19.39 Bq/kg, 46.62 Bq/kg and 2091.70 Bq/kg respectively. The activity concentration of ^{40}K was highest in all the locations. The average value of absorbed dose rate was 81.562 nGy/h and radium equivalent activity was 167.07 Bq/kg. Hazard indices (H_{in} and H_{ex}) values in the study area were lower than the recommended values and the mean value of Hin and Hex were 0.51 and 0.45 respectively. Radioactive level index in the study area were varied from 0.23 to 3.88 with an average of 1.3. All the radiological parameters calculated in this study were below the recommended limits with the exception of one location. The only one location L_{22} were shown high radiological parameters than the world recommended values. Hence these results will use as a baseline data for rock samples of Western Ghats in south TamilNadu.

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