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ESTIMATION OF RADIATION EXPOSURE IN ENVIRONMENTAL SOIL SAMPLES FROM THIRUMULLAVARAM COASTAL REGION, KERALA

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ABSTRACT

The objective of this analysis was to find out the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K of soil samples collected from Thirumullavaram coastal region of Kerala and to calculate the radiological effect caused by this radioactivity. The activity concentrations of this natural radionuclide were measured using gamma-spectroscopy system having NaI(Tl) scintillators.The activity concentrations for ^{226}Ra, ^{232}Th, and ^{40}K, from the selected samples, ranged from below detectable level to 15.23±2 $BqKg^{-1}$, 21.59±3 $BqKg^{-1}$, 60.23±7 $BqKg^{-1}$ for ^{226}Ra, ^{232}Th and ^{40}K, respectively. Radium equivalent activities, absorbed dose rate, Indoor and Outdoor annual effective dose rate and the values of hazard indices were calculated for the measured samples to assess the radiation hazards. The results show that the entire sample possesses radiation hazards well below the safe limit. Hence the probability of occurrence of any of the health effects of radiation is low. Hence, measurements have been taken as representing baseline values of these radionuclides contain in the soil of this studying area.

KEYWORDS: Soil, Specific activity, Hazard indices, Gamma ray spectrometry

Radioactive material is found throughout nature. Detectable amounts occur naturally in soil, rocks, water, air, and vegetation. Hence Man is always exposed to ionizing radiation from naturally occurring radioactive materials (NORM). The natural radionuclide can be inhaled and ingested into the body from these sources may cause health problems. Besides to this internal exposure, individuals also get external exposure from radioactive resources that remain outside the body and from cosmic radiation from space .The worldwide average natural dose to humans is about 2.4 millisieverts (mSv) per year (Ramassay et al., 2004).The natural radioactivity in soil comes from U and Th series and natural K andthese doses vary depending upon the concentrations of the natural radio nuclides, ^{238}U, ^{232}Th, their daughter products and ^{40}K, present in the soils and rocks, which in turn depend upon the local geology of each region in the world (UNSCEAR, 2000). The continuous exposure to radioactive nuclide like radium and thorium through breathing has a number of health harms such as chronic lung diseases, acute leucopoenia, anemia and necrosis of the mouth (FEPA, 1991). Radium causes bone weakening, cranial and nasal tumors. Other diseases caused by radioactivity exposure include lung cancer, pancreas, hepatic, bone, skin, kidney cancers, cataracts, sterility, atrophy of the kidney and leukemia (Taskin et al., 2009).The radiological implication of these radionuclides is due to the gamma ray exposure of the body and irradiation of lung tissue from inhalation of radon and its daughters. Therefore, the assessment of gamma radiation dose from natural sources is of particular importance as natural radiation is the largest contributor to the external dose of the world population (UNSCEAR, 1988).The awareness of natural radioactivity existing in soil enables one to evaluate any possible radiological risk to mankind by coming in contact with soil using the radiation health hazard indices.

The present studies give an insight of the activity concentration of the natural radioactive nuclides namely, ^{226}Ra, ^{232}Th and ^{40}K of soil samples of Thirumullavaram and hence to determine the health hazard indices by evaluate the annual effective dose equivalent (outdoor), internal and external hazard indices, radium equivalent activity, representative gamma index and excess cancer exposure risk. The gamma spectroscopic measurement technique is adopted for the measurement.

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MATERIALS AND METHODS

A total of 14 samples of soil are collected Thirumullavaram for the measurement of natural radiation. These samples were crushed to get fine powder and moisture content is completely removed by heating at 110°C in an oven. The sample is then homogenized and sealed in radon impermeable airtight can with capacity of 305cm^3 for more than 30 days to reach secular equilibrium were the rate of decay of the daughter becomes equal to that of the parent. All samples were analyzed using a gamma spectrometer with NaI(Tl) based detector. The samples were counted for 10000seconds. The spectrum was stored in a PC based multichannel analyzer. Radiometric measurements were carried out for the determination of radionuclides present in the samples.

Determination of Natural Radioactivity

The activity concentrations of the radionuclides ^{226}Ra, ^{232}Th and ^{40}K for the samples were determined using the equation (Rati et al., 2010).

$$Activity(Bq) = \frac{\text{CPSX100X100}}{BI\ \ X\,Eff} \qquad \text{..........(1)}$$

Where cps is the net count per second; BI is the branching intensity and E_{ff} is the efficiency of the detector.

Radium Equivalent Activity (Ra_{eq})

Radium equivalent activity is an index that has been introduced to evaluate the specific activities of ^{226}Ra, ^{232}Th and ^{40}K by a single quantity (Pankaj Bala et al., 2014). It is generally defined as

$$Ra_{eq} = C_{Ra} + 1.43\, C_{Th} + 0.077 C_k \qquad \text{.........(2)}$$

Where C_{Ra}, C_{Th} and$C_k$are activities of ^{226}Ra, ^{232}Th and ^{40}K respectively in BqKg^{-1}. The radium equivalent activity is defined on the assumption that 10BqKg^{-1} of ^{226}Ra, 7 Bqkg^{-1} of ^{232}Th and 130 Bqkg^{-1} of ^{40}K produce the same gamma ray dose rates. The maximum value of radium equivalent must be less than 370BqKg^{-1} for the safe limit.

Estimation of Absorbed Dose Rate

The absorbed dose rates (D) in air at above the ground surface for the uniform distribution of radionuclides (^{226}Ra, ^{232}Th and ^{40}K) was calculated using the following equation (Thabayneh et al., 2013).

$$D(\text{nGyh}^{-1}) = (0.462\, C_{Ra} + 0.621\, C_{Th} + 0.0417\, C_K) \qquad \text{............(3)}$$

Where the numerical values 0.462, 0.621 and 0.417 are the dose conversion factors for converting activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K into doses.

External and Internal Hazard Index

The value of external hazard index should be less than or equal to unity for the safe use of samples, which corresponds to the upper limit of Ra_{eq}370BqKg^{-1} for limiting the dose from samples to 1.5mGyy^{-1}. External hazard index can be calculated using the equation (Beretka et al., 1985)

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \leq 1 \qquad \text{..........(5)}$$

Internal exposure to ^{222}Rn and its radioactive progeny is controlled by the internal hazard index (H_{in}) and is obtained by the equation (Krieger ., 1981), for the safe use of a material in the construction of dwellings internal hazard index should be less than unity.

$$H_{in} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \leq 1 \qquad \text{..........(5)}$$

Annual Effective Dose Rate

The annual effective dose rate is determined by considering the conversion coefficient from absorbed dose in air to effective dose 0.7 SvGy^{-1} and the indoor occupancy factor of 0.8 and the outdoor occupancy factor of 0.2 proposed by UNSCEAR 2000. The annual effective dose was calculated from the equation (Thabayneh et al., 2013)

Indoor (mSvy^{-1})
= D (nGyh^{-1}) x 8766 hy^{-1} x 0.8 x 0.7 (SvGy^{-1}) x 10^{-6} ….(6)

Outdoor (mSvy^{-1})
= D (nGyh^{-1}) x 8766 hy^{-1} x 0.2 x 0.7 (SvGy^{-1}) x 10^{-6} .....(7)

Where D is the Absorbed dose rate in nGyh^{-1}.

Radioactivity Level Index

The radioactivity level index is used to represent the γ radiation hazards associated with the natural radio nuclide. The representative level of Iγwas obtained by the equation (Khalil M Dabayneh ., 2008).

$$I\gamma = \frac{C_{Ra}}{150} + \frac{C_{Th}}{100} + \frac{C_K}{1500} \qquad \text{.........(8)}$$

Alpha Index

The index is used for the assessment of internal hazard due to the radon inhalation originating from samples and is defined by the equation (Mohanty et al., 2004),

$$I\alpha = \frac{C_{Ra}}{200} \qquad \text{.........(9)}$$

Where C_{Ra} is the activity concentration of radium in and its recommended limit is 200BqKg^{-1}. Hence for the safe limit for avoiding internal hazard the value of $I_\alpha$chosen to be less than unity.

RESULTS AND DISCUSSION

Table 1 show the values of specific activity of the soil samples collected from Thirumullavaram Coastal region of Kollam district, Kerala. The estimated value of radionuclide content of soil samples varies from the below detectable ranges to a maximum level of 15.23±2 BqKg^{-1}, 21.59±3 BqKg^{-1}, 60.23±7 BqKg^{-1} for ^{226}Ra, ^{232}Th and ^{40}K respectively. These radioactivity concentration values obtained in these samples are lower than the world average value of 400 Bqkg^{-1} for ^{40}K, 35Bqkg^{-1} for ^{226}Ra and 30Bqkg^{-1} for ^{232}Th (UNSCEAR, 2000).

Table 2, represents the radium equivalent values which were found to vary from 2.10 to 42.39 Bqkg^{-1}. The lowest value was found in SC3 while the maximum value was found in SC6. The radium equivalent values for the analyzed samples are less than the international average value 370 Bq kg^{-1} (UNSCEAR, 2000).As shown in Table 2, the absorbed dose rate values were found to vary from 1.23 to 19.28 nGy h^{-1}. The lowest value was found in Sample Code 3 (SC3) sample while the maximum value was found for SC6. The absorbed dose rate values are below the permissible level 55 nGy h^{-1}(UNSCEAR, 2000).The results of indoor, outdoor and total annual effective dose rates for samples are listed in Table 2 shows that the total values for each sample are less than the corresponding worldwide value of 1 mSv y^{-1}.The calculated values of H_{ex} range from 0.01 to 0.12. In all the Soil samples studied, the external hazard index is $H_{ex} \leq 1$. Therefore, the area under study is safe and soil samples of the district can be used for construction purposes, which do not pose any health risk. . Internal exposures to radon are very hazardous this can lead to respiratory diseases like asthma and cancer. The calculated values of internal hazard of samples under investigation, shown in table 2, ranges from 0.01 to 0.14. H_{in}should be less than unity for the radiation hazard to be negligible.The calculated values of representative level index and alpha index for all the samples are given in Table2 which shows that the values for selected samples were lower than the international values. According to these results the health effects due to radiation exposure caused by radionuclide such as ^{226}Ra, ^{232}Th and ^{40}K are negligible.

CONCLUSION

Gamma ray spectrometry was used to determine activity concentration due to naturally occurring ^{226}Ra, ^{232}Th and ^{40}K radioisotopes and the associated radiation hazard levels in 14 of soil samples from Thirumullavaram coastal region, Kerala. The estimated activity concentrations were lower than the world average values. It is concluded that no harmful radiation effects were posed to the population who live in the study area. The average dose rates and other calculated hazard indices were lower than the average national and world recommended values, therefore, did not pose health risks to the population of the area.

Table 1: The activity concentrations of radionuclides in soil samples collected from Thirumullavaram, Kerala

Sample Code (SC)	^{226}Ra (BqKg^{-1})	^{232}Th(BqKg^{-1})	^{40}K (BqKg^{-1})
SC 1	5.90±1	BDL	27.24±3
SC 2	6.45±1	BDL	36.27±4
SC 3	BDL	BDL	29.95±3
SC 4	7.42±2	15.53±2	43.50±6
SC 5	7.38±2	BDL	BDL
SC 6	7.30±2	21.59±3	60.23±7
SC 7	10.23±2	14.89±2	50.42±5
SC 8	4.84±1	BDL	34.85±3
SC 9	11.23±2	14.50±2	48.56±5
SC10	9.88±2	15.21±2	29.67±3
SC11	15.23±2	BDL	28.98±3
SC12	4.78±1	14.79±2	BDL
SC13	BDL	16.97±3	BDL
SC14	12.03±2	14.32±3	24.32±3

Table 2: The radium equivalent activity (Raeq), the absorbed dose rate (D), the annual effective dose rate, external (Hex) and internal (Hin) hazard indices, radioactivity level index (Iγ) and alpha index (Iα) of the soil samples collected from Thirumullavaram coastal region, Kerala

SAMPLE CODE (SC)	Raeq (BqKg^{-1})	D (nGyh^{-1})	Annual Effective Dose Rate (mSvy^{-1})		H_{ex}	H_{in}	I_{γ}	I_{α}
			Indoor	Outdoor				
SC 1	7.81	3.84	0.02	0.00	0.02	0.04	0.02	0.03
SC 2	8.99	4.46	0.02	0.01	0.02	0.04	0.03	0.03
SC 3	2.10	1.23	0.01	0.00	0.01	0.01	0.02	-
SC 4	32.67	14.88	0.07	0.02	0.09	0.11	0.19	0.04
SC 5	7.38	3.40	0.02	0.00	0.02	0.04	0.00	0.04
SC 6	42.39	19.28	0.09	0.02	0.12	0.14	0.26	0.04
SC 7	35.05	16.06	0.08	0.02	0.10	0.12	0.19	0.05
SC 8	7.28	3.66	0.02	0.00	0.02	0.03	0.03	0.02
SC 9	35.36	16.20	0.08	0.02	0.10	0.13	0.18	0.06
SC10	33.71	15.25	0.07	0.02	0.09	0.12	0.18	0.05
SC11	17.26	8.21	0.04	0.01	0.05	0.09	0.03	0.08
SC12	25.93	11.42	0.06	0.01	0.07	0.08	0.15	0.02
SC13	24.27	10.57	0.05	0.01	0.07	0.07	0.17	-
SC14	34.21	15.47	0.08	0.02	0.09	0.13	0.17	0.06

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