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Measurement of Natural Radioactivity in Building Material Used in Chengam of Tiruvannamalai District, Tamilnadu by Gamma-Ray Spectrometry

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ABSTRACT
The building materials used in chengam, Tiruvannamalidistrict has been measured for natural radioactivity concentration analysis using a NaI (Tl) detector based gamma ray spectrometer.The radium equivalent activity (Ra_{eq}), criteria formula (CF),indoor gamma absorbed dose (D_R) rate and annual effective dose rate (H_R) associated with the natural radionuclide are calculated to assess the radiation hazard in the building materials.The concentrations of the natural radionuclides and the calculated radiation hazards in studied samples are compared with theinternationally recommended values.The present work shows that the natural radioactivity levels in the building construction materials used in chengam of Tiruvannmalaidistrictis well below the acceptable limits. From the analysis, it was found that these materials may be safely used as construction materials and do not pose significant radiation hazards.

Key words: *Natural radioactivity, Building materials, Gamma-ray Spectrometry, Radiation Hazards*

1. INTRODUCTION

Radionuclides are found naturally in air, water and soil. They even found in us, being that we are the products of our environment. There is nowhere on Earth that you cannot find natural radioactivity. All building materials such as concrete, brick, sand, aggregate, marble, granite, limestone, gypsum etc contain mainly natural radionuclides including uranium (^{238}U) and thorium (^{232}Th) and their decay products and the radioactive potassium (^{40}K). In the ^{238}U series, the decay chain segment starting from radium (^{226}Ra) is radiologically most important and therefore, reference is often made to ^{226}Ra instead of ^{238}U.

The natural level of radioactivity in building materials is one of the major causes of external exposure to γ-rays. By the determination of the radioactivity level in building materials, the indoor radiological hazard to human health can be assessed. Knowledge of basic radiological parameters and radioactive contents in the construction materials is important since it allows us to calculate the exposure of the population of radiation from natural sources. It plays an important role in the protection measurement, geoscientific research and guidelines for the use and management of these materials. During the last decades, there has been an increasing interest in the study of radioactivity in various building materials [1-5].

Data on natural radionuclides are still very scarce in Tiruvannamalai, District. Therefore, a comprehensive study with the objective to systematically measure the terrestrial gamma radiation and determine the radiological hazard in building materials of Tiruvannamalai district is highly needed. The primary objective of the present study is to determine the concentrations of ^{40}K, ^{226}Ra and ^{232}Th in commonly used building materials collected from chengam of Tiruvannamalai district, Tamilnadu. The results were used to assess the potential radiological hazards associated with these building materials

2. MATERIALS AND METHODS

2.1. Sampling and sample Preparation

Five kind of different building materials were collected randomly from sites where housing and other building were constructed and from the building material suppliers in chengam for the measurement of the specific radioactivity of ^{226}Ra, ^{232}Th and ^{40}K. The samples were properly catalogued and marked according to the origin/location site. The samples are analysed in natural form. After crushing, powdering, coning and quartering, representative samples of maximum

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grain size 1mm were dried in an oven at about 110ºc until sample weight became constant. These samples are sealed in radon-impermeable plastic containers. The samples were then stored for more than 40 days to bring ^{222}Rn and its short-lived daughter products into equilibrium with ^{226}Ra [5].

2.2. Radiometric Analysis

All samples were subjected to gamma spectral analysis with a counting time of 20,000 secs. A 3" x 3" NaI (Tl) detector was employed with adequate lead shielding which reduced the background by a factor of about 95%.The concentrations of various nuclides of interest were determined in Bq kg^{-1} using the count spectra. The gamma-ray photo peaks corresponding to 1.46 MeV (^{40}K), 1.76 MeV (^{214}Bi) and 2.614 MeV (^{208}Tl) were considered in arriving at the activity of ^{40}K, ^{226}Ra and ^{232}Th in the samples. The detection limit of NaI(Tl) detector system for ^{40}K, ^{226}Ra and ^{232}Th are 8.5, 2.21 and 2.11 Bqkg^{-1} respectively for a counting time of 20, 000 secs.

3. RESULTS AND DISCUSSION

3.1. Specific Radioactivity

The specific radioactivity values of ^{226}Ra, ^{232}Th and ^{40}K measured in the building materials are shown in Table1.As seen from the table 1, the highest values for the specific activity of ^{226}Ra, ^{232}Th and ^{40}K are 54.09 Bq kg^{-1}(cement-1), 83.49 Bq kg^{-1} (sand) and 428.84 Bq kg^{-1} (clay) respectively while the lowest values of specific activity of the same radionuclides are BDL(Soil), 23.47 Bq kg^{-1} (Cement-2) and 149.76 Bq kg^{-1}(Cement-1) respectively. It may be seen from the Table1, the activity of ^{226} Ra varies from BDL to 54.09Bq kg^{-1} and the arithmetic mean is 20.04 Bq kg^{-1}. The activity concentration of ^{232} Th varies from 23.47 to 83.49 Bq kg^{-1}and the arithmetic mean is 55.20 Bq kg^{-1}. The activity concentration of ^{40} K varies from 149.76 to 428.84 Bq kg^{-1}and the arithmetic mean is 286.98 Bqkg^{-1}.The mean values are lower than the corresponding world-wide average values which are 35and 400 Bq kg^{-1}for ^{226}Ra and ^{40}K respectively while ^{232}Th value is slightly greater than worldwide average value (30Bq kg^{-1}) was based on the guidelines provided by UNSCEAR-2000[6].

3.2 Radium equivalent activity (Raeq)

The distribution of natural radio nuclides in the samples under investigation is not uniform. Therefore, a common radiological index has been introduced to evaluate the actual activity level of ^{226}Ra, ^{232}Th and ^{40}K in the samples and the radiation hazards associated with these radio nuclides. This index is usually known as radium equivalent activity (Ra_{eq}) [1,5].

$$Ra_{eq} = A_{Ra} + 1.43\, A_{Th} + 0.077\, A_{K} \qquad (1)$$

where A_{Ra}, A_{Th} and A_K are the specific activities of ^{226} Ra, ^{232} Th and ^{40} K respectively. In the definition, it is assumed that 10 Bq kg^{-1} of ^{226} Ra, 7 Bq kg^{-1} of ^{232}Th and 130 Bq kg^{-1} of ^{40}K produce an equal gamma ray dose [7-8]. The values of calculated Ra_{eq} shown in the table1.The calculated Ra_{eq} values ranged from 76.09 Bq kg^{-1} (Cement-2) to 151.41 Bq kg^{-1}(sand) with an average of 121.08 Bq kg^{-1}. All the values of the Ra_{eq} in the studied samples are found to be lower than the criterion limit of 370 Bq kg^{-1}[9]. The results of this study show that the average value of Ra_{eq} obtained for the building materials is 121.08 Bq kg^{-1} which is less than the recommended value (370 Bq kg^{-1}) and as such does not pose a radiological hazard when used for construction of buildings. The figure 2 shows the radium equivalent activity (Ra_{eq}) with different kinds of building materials of chengam, Tiruvannamalai district, Tamilnadu.

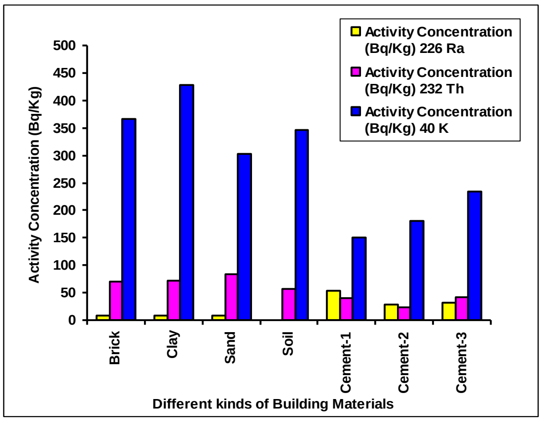

Figure 1. Activity concentration (Bq/kg) of natural radionuclidesVs different kinds of building materials.

Table1. Activity concentration, radium equivalent activity, criteria formula, absorbed gamma dose rate and Indoor and outdoor annual effective dose rate in building materials of Chengam, Tiruvannamalai District.

Materials	**Activity Concentration ($Bqkg^{-1}$)**			**Raeq ($Bq\ kg^{-1}$)**	**Criteria Formula (CF)**	**Absorbed Dose Rate DR ($nGyh^{-1}$)**	**Annual Effective Dose Rate H_R ($mSvy^{-1}$)**	
	^{226}Ra	**^{232}Th**	**^{40}K**				**Indoor**	**Outdoor**
Brick	8.95	69.93	366.56	137.18	0.185	114.48	0.561	0.141
Clay	8.72	72.19	428.84	144.97	0.195	121.74	0.597	0.150
Sand	8.71	83.49	302.68	151.41	0.204	124.07	0.608	0.153
Soil	BDL	56.24	346.39	107.10	0.144	89.58	0.439	0.110
Cement-1	54.09	39.34	149.76	121.88	0.164	105.02	0.515	0.129
Cement-2	28.61	23.47	180.73	76.09	0.103	66.60	0.326	0.082
Cement-3	31.26	41.75	233.92	108.97	0.147	93.40	0.458	0.115
Average	**20.04**	**55.20**	**286.98**	**121.08**	**0.163**	**102.12**	**0.500**	**0.1257**

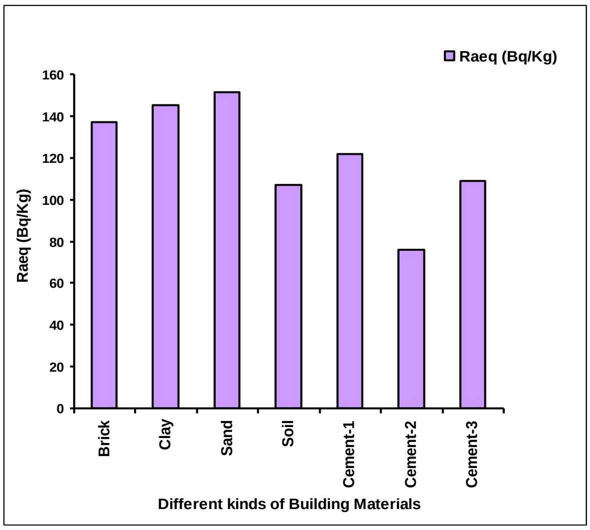

Figure 2. Different kinds of building materials Vs radium equivalent activity (Bq/kg).

3.3. Criteria formula (CF)

Based on models suggested Krisiuk and Stranden. [7-8] by a value of 1.5mGy was obtained by Kriger (1981) [10] to evaluate annual external radiation dose inside dwellings constructed of building materials, with Ra_{eq} value of 370 Bq kg^{-1}. These authors later corrected their assumptions after taking into consideration a wall of finite thickness, and applying a weighing factor of 0.7 [11] due to the presence of window and doors. This can be used as criterion formula to limit of the annual radiation dose from building materials based on the formula

$$\frac{A_{Ra}}{740\ Bq/Kg} + \frac{A_{Th}}{520\ Bq/Kg} + \frac{A_K}{9620} < 1 \qquad (2)$$

Where A_{Ra} , A_{Th} and A_K are the activities of ^{226} Ra, ^{232} Th and ^{40} K in Bq kg^{-1} respectively in building materials. Calculating the sum of the three quotients, the values for the samples in the present study ranged from 0.103 (Cement-2) to 0.204 (Sand) with an average of 0.163 (Table-1.1). The average value (0.163) of the studied samples is less than the recommended value (< 1). This indicates that gamma activity in building materials do not exceed the proposed criterion level. TheFig-3 shows the variation of criterion formula with building materials.

3.4. Absorbed dose rate (D_R)

The Absorbed Dose Rate due to γ-radiations in air at 1m above the ground surface for the uniform

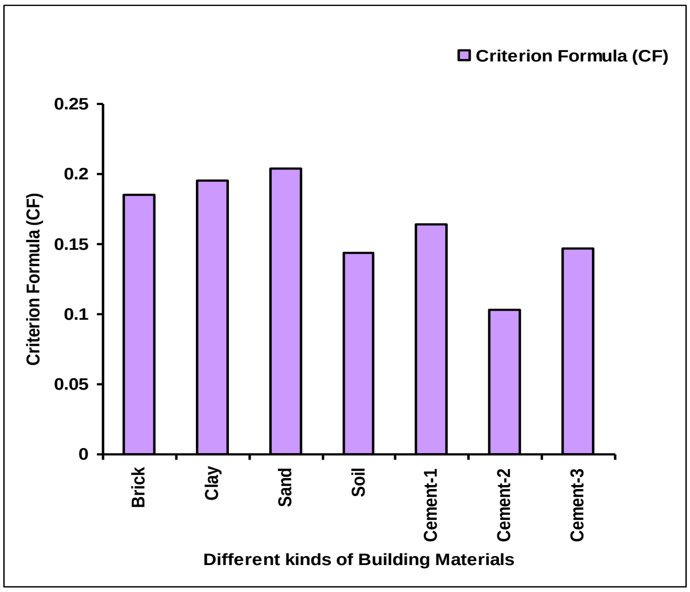

Figure 3. Different kinds of building materials Vs criterion formula (CF).

distribution of naturally occurring radio nuclides (^{226}Ra, ^{232}Th and ^{40}K) were calculated based on the guidelines provided by UNSCEAR (2000) [6]. We assumed that the contribution from other naturally occurring radio nuclides, such as ^{235}U, ^{87}Rb, ^{138}La, ^{147}Sm and ^{178}Lu, to actual dose rates were insignificant.

The conversion factors used to compute absorbed dose rate to γ-dose rate (D_R) in air per unit activity concentration in Bq kg^{-1}(dry weight) corresponds to 0.92 nGy h^{-1} for ^{226}Ra, 1.1 nGy h^{-1}for ^{232}Th series and 0.08 nGy h^{-1} for ^{40}K. Therefore, D_R can be calculated according to [6].

$$D_R(nGyh^{-1}) = (0.92xA_{Ra})+(1.1 \text{ x } A_{Th})+(0.08xA_K) \quad (3)$$

Where A_{Ra} is the activity concentration of ^{226}Ra, A_{Th} is the activity concentration of ^{232}Th and A_K is the activity concentration of ^{40}K in Bq kg^{-1}.

The estimated D_R values for all the studied samples ranged from 66.60 (Cement-2) to 124.07(Sand) nGy h^{-1}. From the data in the table 1, the estimated mean value of D_R in the studied samples is 102.12 nGy h^{-1} which is slightly higher than world average (populated-weighted) indoor absorbed gamma dose rate of 84 nGy h^{-1}. The figure 4 shows the variation of absorbed dose rate with building materials of chengam.

3.5. Annual effective dose rate (H_R)

The common materials such as soils, sand, clay and cement are the main mixing materials for building construction in Tamilnadu, the determination of annual effective dose equivalent is important. For that, the living style of the people or indoor factor of a location is considered. A typical resident in a location, both male and female, would spend about 8h of the day in office or class room or laboratory. 11h indoor and the remaining 5h outdoors. This applies to the greater part of the population in a location who are office workers or public/ students. Hence, 19/24 (0.8) and 5/24 (0.2) is adopted as the indoor (80%) and outdoor occupancy factor of 0.7 (SvGyh^{-1}) to convert absorbed dose rate (nGyh^{-1}) into annual effective dose equivalent for this study.

In order to estimate the annual effective dose rates, the conversion coefficients from the absorbed dose in air to the effective dose (0.7 SvGyh^{-1}) and the outdoor occupancy factor (0.2) and indoor occupancy factor (0.8) proposed by UNSCEAR (2000) [6].

The Annual Effective Dose (H_R) was calculated from the formula,

Indoor

H_R = D_R X 8766 h/yr X 0.8(Indoor Occupancy Factor) X 0.7 SvGyh^{-1} (Conversion Factor) X 10^{-6}

(or)

$$H_R = D_R \text{ X } 0.0049 \text{ (mSvy}^{-1}) \quad (4)$$

Outdoor

H_R = D_R X 8766 h/yr X 0.2(Outdoor Occupancy Factor) X 0.7 SvGyh^{-1}(Conversion Factor) X 10^{-6}

(or)

$$H_R = D_R \text{ X } 0.001227 \text{ (mSvy}^{-1}) \quad (5)$$

where D_R is the Absorbed Dose Rate (nGyh^{-1}).The calculated mean value of annual effective dose rate for indoor and outdoor is 0.500 and 0.125. The average values of both indoor and outdoor H_R for all the samples are lower than the recommended values. The figure 5 shows the variation of indoor and outdoor annual effective dose rate with building materials of chengam.

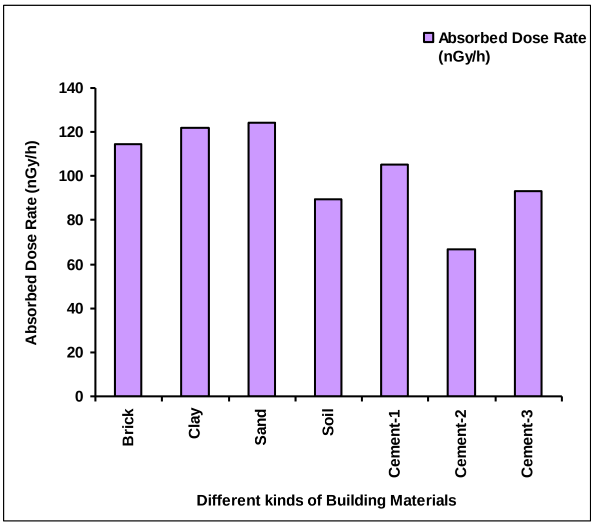

Figure 4. Different kinds of building materials Vs absorbed dose rate (nGy h^{-1}).

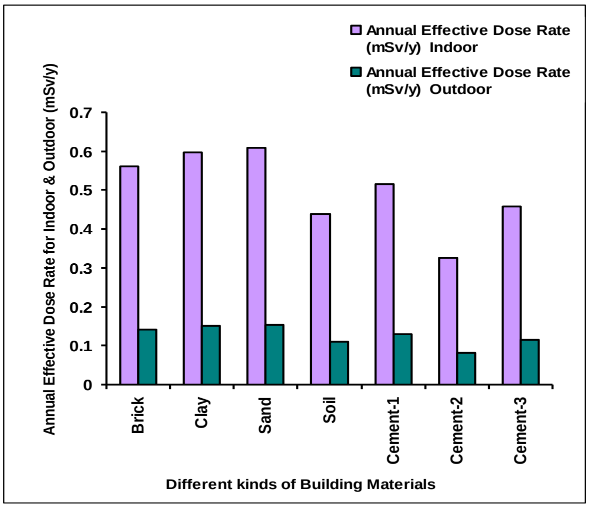

Figure 5. Different kinds of building materials Vs annual effective dose rate (mSv/y).

4. CONCLUSION

In this study, the commonly used building materials from chengam of Tiruvannmalai by radioactivity analysis were carried out to assess the radiological hazards. The values obtained in the study are within the recommended safety limits, showing that these building materials do not pose any significant radiation hazard and hence the use of these materials in the construction for dwelling purpose can be considered to be safe for the inhabitants. This study can be used as a reference for more extensive studies of the same subject in future.

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***Biographical Sketch**

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