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

K. Vanasundari¹, R. Ravisankar¹*, D. Durgadevi¹, R. Kavita¹, M. Karthikeyan¹, K. Thillivelvan², B. Dhinakaran²

¹Post Graduate and Research, Department of Physics, Government Arts College, Thiruvannamalai-606603, Tamilnadu, India.
²Department of Physics, Government Arts College, Chidambaram-608102, Tamilnadu, India.
Received 6th October 2012; Accepted 5th November 2012; available online December 2012.

ABSTRACT
The building materials used in chengam, Tiruvannamalaidistrict has been measured for natural radioactivity using a NaI (TI) detector based gamma ray spectrometer. The radium equivalent activity (Ra eq), criteria formula (CF), indoor gamma absorbed dose (Dγ) and annual effective dose rate (Hα) 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 the internationally recommended values. The present work shows that the natural radioactivity levels in the building construction materials used in chengam of Tiruvannamalaidistrictis 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 (²³⁵U) and thorium (²³²Th) and their decay products and the radioactive potassium (⁴⁰K). In the ²³⁸U series, the decay chain segment starting from radium (²²⁶Ra) is radiologically most important and therefore, reference is often made to ²²⁶Ra instead of ²³⁸U.

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 ⁴⁰K, ²₂⁶⁸Ra and ²³²⁹Th 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 ²²⁶⁸Ra, ²³²⁹⁹Th and ⁴⁰⁸K. 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

*Corresponding Author:
Email: ravisankarphysics@gmail.com
grain size 1mm were dried in an oven at about 110°C 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 222Rn and its short-lived daughter products into equilibrium with 226Ra [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 (232Th), 1.76 MeV (214Bi) and 2.614 MeV (208Tl) were considered in arriving at the activity of 40K, 226Ra and 232Th in the samples. The detection limit of NaI(Tl) detector system for 40K, 226Ra and 232Th are 8.5, 2.21 and 2.11 Bq kg⁻¹ respectively for a counting time of 20,000 secs.

3. RESULTS AND DISCUSSION
3.1. Specific Radioactivity
The specific radioactivity values of 226Ra, 232Th and 40K measured in the building materials are shown in Table 1. As seen from the table 1, the highest values for the specific activity of 226Ra, 232Th and 40K 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 Table 1, the activity of 226Ra varies from BDL to 54.09 Bq kg⁻¹ and the arithmetic mean is 20.04 Bq kg⁻¹. The activity concentration of 232Th varies from 23.47 to 83.49 Bq kg⁻¹ and the arithmetic mean is 55.20 Bq kg⁻¹. The activity concentration of 40K varies from 149.76 to 428.84 Bq kg⁻¹ and the arithmetic mean is 286.98 Bq kg⁻¹. The mean values are lower than the corresponding world-wide average values which are 35 and 400 Bq kg⁻¹ for 226Ra and 40K respectively while 232Th 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 226Ra, 232Th and 40K in the samples and the radiation hazards associated with these radio nuclides. This index is usually known as radium equivalent activity (Raeq) [1,5].

\[ \text{Raeq} = \text{A}_{226} + 1.43 \text{A}_{232} + 0.077 \text{A}_{40} \]  

(1)

where \( \text{A}_{226}, \text{A}_{232}, \text{and} \text{A}_{40} \) are the specific activities of 226Ra, 232Th and 40K respectively. In the definition, it is assumed that 10 Bq kg⁻¹ of 226Ra, 7 Bq kg⁻¹ of 232Th and 130 Bq kg⁻¹ of 40K produce an equal gamma ray dose [7-8]. The values of calculated Raeq shown in the table1. The calculated Raeq 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 [9]. The results of this study show that the average value of Raeq 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 (Raeq) with different kinds of building materials of chengam, Tiruvannamalai district, Tamilnadu.

![Activity Concentration (Bq/kg) of natural radionuclidesVs different kinds of building materials.](image-url)
Table 1. 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.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Activity Concentration (Bq kg⁻¹)</th>
<th>Ra eq (Bq kg⁻¹)</th>
<th>Criteria Formula (CF)</th>
<th>Absorbed Dose Rate DR (nGyh⁻¹)</th>
<th>Annual Effective Dose Rate Hₑ (mSv y⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>²²⁶Ra</td>
<td>²³²Th</td>
<td>⁴⁰K</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brick</td>
<td>8.95</td>
<td>69.93</td>
<td>366.56</td>
<td>137.18</td>
<td>0.185</td>
</tr>
<tr>
<td>Clay</td>
<td>8.72</td>
<td>72.19</td>
<td>428.84</td>
<td>144.97</td>
<td>0.195</td>
</tr>
<tr>
<td>Sand</td>
<td>8.71</td>
<td>83.49</td>
<td>302.68</td>
<td>151.41</td>
<td>0.204</td>
</tr>
<tr>
<td>Soil</td>
<td>BDL</td>
<td>56.24</td>
<td>346.39</td>
<td>107.10</td>
<td>0.144</td>
</tr>
<tr>
<td>Cement-1</td>
<td>54.09</td>
<td>39.34</td>
<td>149.76</td>
<td>121.88</td>
<td>0.164</td>
</tr>
<tr>
<td>Cement-2</td>
<td>28.61</td>
<td>23.47</td>
<td>180.73</td>
<td>76.09</td>
<td>0.103</td>
</tr>
<tr>
<td>Cement-3</td>
<td>31.26</td>
<td>41.75</td>
<td>233.92</td>
<td>108.97</td>
<td>0.147</td>
</tr>
<tr>
<td>Average</td>
<td>20.04</td>
<td>55.20</td>
<td>286.98</td>
<td>121.08</td>
<td>0.163</td>
</tr>
</tbody>
</table>

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

$$\frac{A_{Ra}}{740 \text{ Bq/kg}} + \frac{A_{Th}}{520 \text{ Bq/kg}} + \frac{A_{K}}{9620} < 1$$  \hspace{1cm} (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. The Fig-3 shows the variation of criterion formula with building materials.

3.4. Absorbed dose rate (DR)
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).

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

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

\[
D_R(\text{nGy h}^{-1}) = (0.92xA_{Ra})+(1.1 x A_{Th})+(0.08xA_{K})
\]  

(3)

Where \(A_{Ra}\) is the activity concentration of \(^{226}\text{Ra}\), \(A_{Th}\) is the activity concentration of \(^{232}\text{Th}\) and \(A_{K}\) is the activity concentration of \(^{40}\text{K}\) 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\(^{-1}\). 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 (SvGy h\(^{-1}\)) to convert absorbed dose rate (nGy h\(^{-1}\)) 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 SvGy h\(^{-1}\)) 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

\[
H_R = D_R \times 8766 \text{ h/yr} \times 0.8(\text{Indoor Occupancy Factor}) \times 0.7 \text{ SvGy}^{-1}(\text{Conversion Factor}) \times 10^{-6}
\]  

(or)

\[
H_R = D_R \times 0.0049 \text{ (mSvy}^{-1})
\]  

(4)

Outdoor

\[
H_R = D_R \times 8766 \text{ h/yr} \times 0.2(\text{Outdoor Occupancy Factor}) \times 0.7 \text{ SvGy}^{-1}(\text{Conversion Factor}) \times 10^{-6}
\]  

(or)

\[
H_R = D_R \times 0.001227 \text{ (mSvy}^{-1})
\]  

(5)

where \(D_R\) is the Absorbed Dose Rate (nGy h\(^{-1}\)). 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.

4. CONCLUSION
In this study, the commonly used building materials from chengam of Tiruvannamalai 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.

Acknowledgements
We are grateful to Dr. B. Venkatraman, Associate Director, RSEG, Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam, Tamilnadu for his keen interest, constant support, encouragement and permission to do the radioactivity analysis in his division. And also our sincere thanks to Mr.P.Vijayagopal, Scientific Officer, Radiological Safety Division, IGCAR, Kalpakkam, Tamilnadu for his kind help in radioactivity measurements.

5. REFERENCES
Journal of Environmental Radioactivity, 39, 9-22.


*Biographical Sketch*

**Dr. R. Ravisankar**, did his B.Sc (Physics) in C. Abdul Hakeem College, Melvisharam, Vellore Dist, Tamilnadu, India and completed his M.Sc in Physics from Voorhees College, Vellore, Tamilnadu, India. He obtained his M.Phil and Ph.D degree from Annamalai University, Chidambaram, Tamilnadu, India. He has completed B.Ed and M.Ed degree from Madras and Annamalai University, respectively. He did his research work in Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam for his Ph.D programme. During his Ph.D programme, he was awarded the Best paper Award in Nuclear and Radio analytical Symposium (NUCAR) organized by Department of Atomic Energy for his research work in Instrumental Neutron Activation Analysis in the year 2003. He got the Best Teacher Award from Aruni Engineering College, Tiruvannamalai, Tamilnadu during his teaching work in the institution. He got the Best Researcher Award from SSN College of Engineering, Chennai, Tamilnadu during his inspiring teaching with research in this institution. He is having teaching experience of more than nine years in college levels. His research area of interest is Radiation Physics, Environmental Physics, Spectroscopy and Material Science. Dr. Ravisankar is conducting research in the field of Radiation physics in collaboration with Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam, Tamilnadu since the year 2000. His research area of interest is Spectroscopy, Environmental Physics and Material Science. He has published more than 70 papers in National and International conferences. He has published more than 40 papers in peer reviewed journals for his credit in research career. He has guided more than ten students in obtaining M.Phil. degree and currently guiding eight Ph.d scholars from various universities of Tamilnadu, India. At present he is working as Assistant Professor of Physics, Government Arts College, Tiruvannamalai, Tamilnadu, India.