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Measurement of Natural Radioactivity in Brick samples of Namakkal, Tamilnadu, India using Gamma-ray Spectrometry

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ABSTRACT

In India, bricks as building materials are mainly prepared by clay using the deposited sediments of rivers, and the radionuclide contents in bricks and brick-making clays should vary with origin and geological condition. Primordial radionuclides in building materials are one of the sources of radiation hazard in dwellings made of these materials. It is important to measure the natural radioactivity due to gamma rays from building materials and consequently to determine the dose rate from these materials. This helps to important precautionary measures whenever the dose rate is found to be above the recommended limits. The aim of this work was to measure the specific activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in bricks and brick making clay from Namakkal, Tamilnadu, India using gamma ray spectrometer. The radiation hazard of the total natural radioactivity in the studied brick and clay was estimated by different approaches. From the analysis, it is found that these bricks may be safely used as construction materials and do not pose significant radiation hazards.

Keywords: Natural radioactivity, Bricks, Gamma-ray Spectrometry, Radiological Hazards

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INTRODUCTION

Naturally occurring radionuclides in building materials are the sources of external and internal radiation exposure in dwellings. The external radiation is caused by gamma radiation originally from the member of uranium and thorium decay chains and from ^{40}K. The internal radiation exposure, affecting the respiratory tract, is due to radon and its daughters which are exhaled from building materials. 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. Information about the presence of uranium, thorium and decay products in the environmental radiation context has been increasing. The knowledge of the distribution of these radionuclides in soil, rock and building materials plays an important role in the protection measurement, geoscientific research and guidelines for the use and management of these materials. Most countries carry out nationwide surveys to assess the level of radioactivity so as to compile data for possible radiological hazards and to take necessary action.

Bricks are made of soil/clay and are baked in kilns. They have been used for building materials from the days of Moenjodara in the Indo-Pak subcontinent. Bricks of age 4000yr have been founded in some cities of the Middle East and other parts of Asia. The radionuclide content of building bricks is studied by many workers in many countries [1-10]. Bricks are also the largest component (about 80% by volume) of building materials used for construction of dwellings in India. Almost all the houses are constructed from the baked or unbaked bricks. This study is a part of continuing work in which various building materials. Collection of red brick and brick making clays around the city of Nammakkal have been made and the activity concentrations of the natural gamma emitting radionuclides determined in these samples. The radium equivalent activities and the hazard indices were also calculated in order to decide whether they are acceptable according to NEA-OECD [11] criteria. The results were also compared with the data available in the literature for other countries of the world.

MATERIALS AND METHODS

2.1. Sampling and sample preparation:

Samples of building materials (red brick & brick making clay) were collected from fabrication and kiln sites [Alanganatham (BR-1), K.V.Pudur (BR-2) & Perumalkovil Medu (BR-3) of Namakkal Area, Tamilnadu, India]. The samples were properly catalogued and marked according to the origin/location site. After crushing, powdering, coning and quartering, representative samples of maximum grain size 1mm were dried in an oven and in a furnace at about 110^{o}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 ^{222}Rn and its short-lived daughter products into equilibrium with ^{226}Ra.

2.2. Radiometric Analysis:

All the selected samples were subjected to gamma spectral analysis with a counting time of 20,000 secs. A 3" x 3" NaI(Tl) detector available at Radiation Safety Section, Radiological Safety Division. Indira Gandhi Centre for Atomic Research, Kalpakkam, Tamilnadu, India 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.

RESULTS AND DISCUSSIONS

3.1. Specific Radioactivity:

The specific radioactivity values of ^{226}Ra, ^{232}Th and ^{40}K measured in the building materials are shown in Table-1. As seen from the table, the highest values for the specific activity of ^{226}Ra, ^{232}Th and ^{40}K are 22.27, 19.4 and 392.55 Bq kg^{-1} measured in BR-1 while the lowest values of specific activity of the same radionuclides are BDL and 93.83 Bq kg^{-1} BR-3 respectively.

3.2. Radium Equivalent Activity(Ra_{eq}):
The distribution of natural radionuclides 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 radionuclides. This index is usually known as radium equivalent activity [12]

$$Ra_{eq} = A_{Ra} + 1,43A_{Th} + 0,077A_K \quad \text{--------} \quad (1)$$

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 [13-14]. The values of calculated Ra_{eq} for bricks and brick making clay shown in the fourth columns of the table-1. The calculated Ra_{eq} values range from 19.76 (clay-2) to 80.44 (Brick-1) Bq kg^{-1} with an average of 39.30 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} [11]. The results of this study show that the average value of Ra_{eq} obtained for the building materials is 39.30 Bq kg^{-1} which is less than the recommended value (370Bq kg^{-1}) and as such does not pose a radiological hazard when used for construction of buildings. Comparison of activity concentrations and radium equivalents (Bq kg^{-1}) in clay bricks in different areas of the world are reported in Table-2.

Based on models suggested by Krisiuk et al [13] and Stranden [14] , a value of 1.5mGy was obtained by Kriger [24] 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 [25] due to the presence of window and doors. This can be used as criterion to limit the annual radiation dose from building materials based on the formula

$$\frac{A_{Ra}}{740\ \text{Bq/Kg}} + \frac{A_{Th}}{520\ \text{Bq/Kg}} + \frac{A_K}{9620\ \text{Bq/Kg}} < 1$$

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 0.026 to 0.108 with an average of 0.052 (Table-1). The average value (0.052) 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.

3.3. Radiation Hazard Indices:
In order to measure the hazards one can define radiation hazard indices [26]. (i) the external radiation hazard, H_{ex} and (ii) internal radiation hazard, H_{in}, as follows

(i) External Radiation Hazard (H_{ex})

The external hazard index is another criterion to assess the radiological suitability of a material. It is defined as follows.

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{258} + \frac{A_K}{4810}$$

where A_{Ra}, A_{Th} and A_K are the activities of ^{226}Ra, ^{232}Th and ^{40}K in Bq Kg^{-1}. The values of the indices should be <1. It is observed in table-1 that the mean value (0.106) of H_{ex} are below the criterion value (<1).

(ii) Internal Radiation Hazard(H_{in})

The internal hazard index is a criterion for index radiation hazard. In addition to gamma rays, ^{222}Rn plays an important role for internal exposure in a room. Effectively, the radio toxicity of ^{238}U is increased by a factor of two to allow for the contribution from ^{222}Rn and its short lived progeny. The internal exposure due to radon and its daughter products is quantified by the internal hazard index H_{in}, which has been defined as shown below

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810}$$

The internal hazard index is defined so as to reduce the acceptable maximum concentration of ^{238}U to half the value appropriate to external exposures alone. For the safe use of materials in the construction of dwellings the following criterion was prosoped by kriger [24].

$$H_{in} \leq 1$$

The mean value of H_{in} is determined to be 0.139 which is less than one which indicates that the internal hazards are less than the critical value.

Table-1 Activity Concentration of Primordial radionuclides in brick and brick making clay of Namakkal , Calculated Radium equivalent (Raeq) activity, Criteria Formula and Values of hazard indices

Material	Activity Concentration (Bq/Kg)			Ra_{eq} (Bq/Kg)	Criteria Formula	Radiation Hazard Indices	
	^{26}Ra	^{232}Th	^{40}K			H_{ex}	H_{in}
Brick-1	22.27	19.4	392.55	80.23	0.108	0.216	0.276
Brick-2	15.25	BDL	228.88	32.87	0.044	0.088	0.129
Brick-3	17.54	BDL	93.83	24.72	0.033	0.066	0.161
Clay-1	BDL	10.01	276.71	35.62	0.048	0.096	0.096
Clay-2	BDL	3.44	192.74	19.76	0.026	0.057	0.057
Clay-3	BDL	17.12	235.59	42.62	0.057	0.115	0.115
Mean	-	-	-	39.30	0.052	0.106	0.139

Table-2 Comparison of activity concentrations and radium equivalents (Bq kg^{-1}) in clay bricks in different areas of the world

Country	**A(Ra)**	**A (Th)**	**A(K)**	**Ra_{eq}**	**Reference**
Australia	41	89	681	220	[12]
China	41	52	717	171	[15]
Egypt	20	14	204	56	[16]
Finland	78	62	962	241	[11]
Germany	59	67	673	207	[11]
Greece	49	24	670	135	[17]
Netherlands	39	41	560	141	[18]
Norway	104	62	1058	276	[14]
Sweden	96	127	962	352	[11]
Sri Lanka	35	72	585	183	[19]
Kuwait	6.6	6.6	332	41.6	[20]
Malaysia	233	229	685	612	[21]
Bangladesh	29	52	292	127	[22]
Pakistan	45	61	692	187	[7]
Present Work	18.3	19.4	238.4	45.94	-
World	35	30	400	-	[23]

CONCULSION

The brick and brick making clay samples used for the construction purposes in Namakkal have been investigated for gamma ray activity. The radiation hazard of the total natural radioactivity in the studied brick and brick making clay was estimated by different approaches. The value of Ra_{eq} activity on average is less than the recommended limits. Moreover, the external and internal hazard indices have been determined to be less than one showing that bricks and brick making clays from the study area do not pose sources of radiation and that these materials are used for building construction.

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