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A Study on Activity Concentration of Natural Radionuclide of Building Materials in Kochi

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ABSTRACT

The study of natural radiation exposure is of importance because it accounts for the largest contribution to the collective dose for the world population from all sources. Extent of exposure to natural radiation depends on the occupation, type of dwelling, location of habitation, and lifestyle of the population. All building materials contain various amounts of natural radionuclides as they are derived from the rocks and soils, which always contain natural radionuclides of Uranium (^{238}U), and Thorium (^{232}Th) series, and the radioactive isotope of Potassium (^{40}K). In the present study, activity concentration of natural radionuclides in the locally used building materials in Kochi area was investigated with an aim of evaluating the radiation hazard arising due to the use of these materials in the construction of dwellings. The activity concentration of (^{232}Th), (^{238}U) and (^{40}K) in the samples were analyzed using gamma spectrometry. The measured activity of the selected building materials ranges from 40 ($Bq\,kg^{-1}$) to 380($Bq\,kg^{-1}$) for (^{40}K), 10$Bq\,kg^{-1}$ to 30 $Bq\,kg^{-1}$ for ^{226}Ra and 9 ($Bq\,kg^{-1}$) to 110 ($Bq\,kg^{-1}$) for ^{232}Th. The values obtained in the present study were compared with early reported values. Based on the ^{40}K, ^{226}Ra and ^{232}Th gamma activity obtained, the absorbed gamma dose rate and radium equivalent activity were calculated. The radium equivalent activity for all building materials measured in the present study is found to be less than the limit value of 370 $Bq\,kg^{-1}$.

Key words: Natural radionuclides, Building materials, Kochi, Radiation Hazards
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INTRODUCTION

Radioactive materials occur naturally and because of their widespread distribution from many sources they give rise to very large radiological effect to public. The building materials derived from rocks and soils, which always contain natural radionuclides of Uranium (^{238}U), and Thorium (^{232}Th) series, and the radioactive isotope of Potassium (^{40}K), gives both external and internal radiation exposure to the inhabitants of dwellings built with such materials. The gamma radiation arising from the walls, floors and ceilings, and Radon and Thoron and their progeny are the major sources of radiation exposures. The worldwide average indoor effective dose due to gamma rays from building materials is estimated to be about 0.4 mSv per year (Charles, 2001). As individuals spend more than 80% of their time indoors the internal and external radiation exposure from building materials creates prolonged exposure situations. The absolute and relative concentrations of U, Th and K in construction materials can vary dramatically depending on source (Faul, 1954). Industrial waste or by-products contain high concentrations of Naturally Occurring Radioactive Materials (NORM). Fly ash, coal slag, phosphogypsum etc, river sediments for flooring, plastering and in melding bricks were extensively used in building materials. The present study investigated the activity concentration of natural radionuclides in locally used building materials in Kochi area and thereby evaluating the radiological hazard parameters and was compared with recommended values.

MATERIALS AND METHODS

The city of Kochi is Kerala's second largest city and is part of an extended metropolitan region, which is the largest urban agglomeration in Kerala. It is the most densely populated city in the state. Kochi is also home for several major and minor industries. The industrial typology includes fertilizer, pesticide, radioactive mineral processing, chemical and allied industries, petroleum is refining, heavy metal processing and fish processing. Different types of commonly used building material samples were collected from Kochi area. The collected samples were then crushed in mortar and allowed to pass through sieves to maintain uniformity in grain size. The fine samples were then packed in a polythene vessel and weighed to obtain the activity concentration of radionuclides. The bottles containing processed soil samples were sealed hermetically externally, so that the over pressure produced inside by the ^{222}Rn decay should not result in leakage of gas. These samples were kept for one-month period so as to ensure secular equilibrium and were subjected to gamma spectrometric analysis. ^{40}K, ^{226}Ra, ^{232}Th activities were measured using $5'' \times 4''$ $NaI(Tl)$ gamma ray spectrometer. The crystal detector is optically coupled to a $1K$- multichannel analyzer. The spectrometer was calibrated regularly both in terms of energy response and counting efficiency. The IAEA reference materials $RGU-1, RGTh-1$ and $RGK-1$ were employed for the efficiency calibration of the system. The spectra were recorded for 20,000 sec each and the analysis was performed with the help of computer software. The activity concentration of ^{232}Th, ^{226}Ra and ^{40}K were determined from the count spectrum of the corresponding samples. The activity of ^{40}K was determined from the $1461keV$ photo peak, the activity of ^{226}Ra from $1764\,keV$ gamma line of ^{241}Bi and that of ^{232}Th from $2614keV$ gamma line of ^{208}Tl.

MEAN RADIUM EQUIVALENT ACTIVITY CONCENTRATION INDEX (RAEQ)

In order to compare the specific activities of materials containing different concentrations of radium, thorium and potassium, the radium equivalent activity concentration index, Raeq, was calculated according to Equation 1 (Beretka & Matthew, 1985; Yang et al., 2005).

$$Raeq = CRa + 1.423CTh + 0.077CK \qquad (1)$$

Where CRa, CTh, and CK are the specific activities of ^{226}Ra ^{238}U, ^{232}Th and 40K (in Bqkg-1) respectively. This equation is based on the estimate that 1BqKg-1 of ^{226}Ra (^{238}U), 0.7 BqKg-1 of ^{232}Th or 13 Bq Kg^{-1} of ^{40}K generate the same γ- ray dose rate.

RADIATION HAZARD INDICES:

In order to measure the radiation hazards, one can define radiation hazard indices. (i) the external radiation hazard, Hex and (ii) internal radiation hazard, Hin, as follows

(I) EXTERNAL RADIATION HAZARD (HEX)

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

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{258} + \frac{A_K}{4810} \qquad (2)$$

Where A_{Ra}, A_{Th} and A_K are the activities of ^{226}Ra, ^{232}Th and ^{40}K in Bq Kg-1. The values of the indices should be < 1.

(II) INTERNAL RADIATION HAZARD (HIN)

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 Hin, which has been defined as shown below.

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad (3)$$

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, Hin should be less than unity (Krieger, 1981)

RESULT AND DISCUSSION

The activity concentration of ^{232}Th, ^{226}Ra and ^{40}K in $Bq\,kg^{-1}$ in the different building material samples analyzed are presented in table 1. Upon comparing, marginally high activity levels were observed in sand samples. The marginally high activity of radionuclides in sand samples may be because of the reason that the sand is a constituent of rocks and soils which always contain natural radionuclides.

Table 1: Activity concentration of primordial radionuclides in the building material samples

Sample Name	^{40}K Activity ($Bq\,kg^{-1}$)	^{226}Ra Activity ($Bq\,kg^{-1}$)	^{232}Th Activity ($Bq\,kg^{-1}$)
Cement	72	13	15
Clay Brick	221.7	16.2	78.6
Red oxide	54.6	10	13.1
Lime	40.1	14.3	33.5
Putty	95.4	17.4	9
Metal Sand	168.2	25	71
Sand	380	30	110

To assess the radiation hazards arising owing to the use of these samples in the construction of buildings, radiation hazard parameters (Raeq, Hex and Hin) have been calculated and are also presented in the Table 2. The calculated Raeq value ranges from 32.9 ($Bq\,kg^{-1}$) (Red oxide) to 216.6 (sand) ($Bq\,kg^{-1}$). The maximum value of Raeq in building materials must be less than ($370\,Bq\,kg^{-1}$) for safe use (Charles, 2001). In the present study, for all samples, the Raeq was found to be less than the recommended value ($370\,Bq\,kg^{-1}$) and the activities as such do not pose any radiological hazard when used for construction of buildings. Another hazard parameter, external hazard index (Hex) calculated in the present study varies from 0.1 to 0.6 The value of this index must be less than unity for the radiation hazard to be negligible; i.e., the radiation exposure caused by the radioactivity from construction materials is limited to 1.5 mSv y-1(Xinwei, Lingqing, Xiaodan, Leipeng, & Gelian, 2006). The Hex calculated in the present study is found to be less than unity. In addition to the external hazard, radon and its short-lived products are also hazardous to the respiratory organs. The internal exposure to radon and its daughter product is quantified by a hazard index, namely, internal hazard index, Hin. The Hin calculated in the present study varies from 0.1 to 0.7, indicating that the internal hazards are less than the critical value.

Table 2: Radiation Hazard Parameters calculated for building material samples analyzed

Sample Name	Raeq ($Bq\,kg^{-1}$)	Radiation Hazard Indices	
		Hex	Hin
Cement	40.0	0.1	0.1
Clay Brick	145.7	0.4	0.4
Red oxide	32.9	0.1	0.1
Lime	65.3	0.2	0.2
Putty	37.6	0.1	0.1
Metal Sand	139.5	0.4	0.4
Sand	216.6	0.6	0.7

CONCLUSION

The activity concentration of ^{232}Th, ^{226}Ra and ^{40}K in various type of building materials commonly used in the Kochi area have been investigated and radiation hazard parameters were evaluated and compared with international recommended values to assess the radiation hazard. Among the different samples analyzed, a marginally high activity level was observed in sand samples. The value of Raeq activity for all samples was less than the recommended limits. The external and internal hazard index calculated shows an average value less than the recommended limits $(i.e < 1)$ indicating that samples analyzed does not pose any radiological hazard. So from the present study it can be concluded that the use of building materials analyzed in the present study for the construction of buildings is unlikely to give rise to any significant radiation to the occupants.

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