Measuring natural radioactivity of bricks used in the constructions of Tehran

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ABSTRACT

Naturally occurring radionuclides have different amount of activity concentration for ^{226} Ra, ^{232}Th and ^{40}K in building materials. In this study, natural radioactivity has been measured for bricks used in Tehran. For this work, 9 samples of three types of bricks, clay brick (CB), making the facade brick (MFB) and firebrick (FB) has been selected from different regions and factories in Tehran. Gamma rays analyzed by high purity germanium (HPGe) detector and spectroscopy system. As the results show, the maximum value of the mean ^{226} Ra, ^{232}Th and ^{40}K for clay brick has been 17, 9 and 422Bq/kg respectively. Maximum of radium equivalent activities (Ra_{eq}) were calculated 62.81Bq/kg that less than the level has been determined 370Bq/kg for building materials. Other type of bricks had low amounts compared to clay bricks. The calculation results show that the bricks are safe for inhabitants because hazard indexes for gamma were below the standard was been introduced. The results of this research compared with other studies in different countries.

Keywords: Radioactivity measuring; Brick; Tehran; Gamma ray spectrometery; Hazard index

INTRODUCTION

Background radiation is one of the effective environmental factors that is very important in human's life. Natural radioactivity in building materials is a source of indoor radiation exposure. Determination of population exposures is necessary. The most important source of external and internal radiation exposure in buildings is caused by the gamma rays emitted from series of the Uranium, Thorium and ^{40}K naturally occurring from building materials. The activity concentration measured by researchers in different worldwide locations such as India [1, 5], Saudi Arabia [2], Sri Lanka [3], Egypt [4], Malaysia [6], China [7, 8], Australia [9], Tanzania [10] Pakistan [11, 12], Bangladesh [13], U.S.A [14] and etc. The content of ^{226}Ra, ^{232}Th and ^{40}K in these materials is major interest with regard to the radio activity indoors. Bricks and other building material produce significant external and internal dose rates in the range of $nGyh^{-1}$ [15]· The absorbed dose rate in air from cosmic radiation outdoors is about $30nGy.h^{-1}$[14].
External exposures to gamma radiation outdoors arise from terrestrial radio nuclides occurring at trace levels in all ground formations. Therefore, then natural environmental radiation mainly depends on geological and geo graphical conditions [15, 16]. Measurement of natural radio activity from these building materials and consequently, the determination of the dose rate help firstly to implement precautionary measures whenever the dose is found to be above the recommended limits. Secondly, knowledge of gamma radioactivity is required by the building construction association to adopt preventive measure to tone down the harmful effects of ionizing radiation.

MATERIAL AND METHODS

A total of 9 samples of three common building bricks in Tehran, clay brick (CB), making the facade brick (MFB) and firebrick (FB) were selected from different parts of Tehran. The samples had making with different brickworks from provinces Yazd, Isfahan and Tehran.
First, Samples were heated 100°C for 24 hours to get moisture then every of samples separately were crushed and milled to powder. For homogenizing, the chopped mixture was sifted. Then 4 samples provided, three sample (CB, MFB, FB) separately and other one mixture of them. The mixtures were homogenized and then carefully sealed and stored for at least 30 days

before gamma ray analysis to reach secular equilibrium between ^{226}Ra and its decay products. 200 g of each sample was placed inside the detector system. The concentration of the natural radioactivity ^{226}Ra, ^{232}Th and ^{40}K in the brick samples, were measured using the gamma ray spectrometer. The technique used for measurement is a direct γ counting method and were used gamma ray spectrometer high pulse germanium (HPGe). At first, the spectrometer was calibrated with ^{137}Cs source. To determine the activity concentration of ^{232}Th, the gamma ray line ^{228}Ac (338,911,970,974.8KeV) and ^{208}Tl (583.2KeV) were used. To determine the activity concentration of ^{226}Ra from uranium series lines γ-ray ^{214}Pb (352KeV) and ^{214}Bi (609,768.4, 1120, 1238, 1764.5KeV) and to determine ^{40}K isotope activity 1461KeV was measured.

Radium equivalent activity

Radium equivalent activity (Ra_{eq}) is a common radiological index has been defined to assess the real activity level of ^{226}Ra, ^{232}Th and ^{40}K in soil and clay bricks. This quantity provides a very useful guideline in regulating the safety standards in radiation protection for a human population. The upper limit unity for Ra_{eq} is equivalent 370Bq/kg corresponds to 1 $mSv.y^{-1}$. The distribution of ^{226}Ra, ^{232}Th and ^{40}K in building materials is not uniform. Uniformity in respect of exposure to radiation has been defined in terms of radium equivalent activity in Bq/kg to compare the specific activity of materials containing different amounts of ^{40}K, ^{226}Ra, ^{232}Th defined according to the estimation 370Bq/kg ^{226}Ra, 259Bq/kg ^{232}Th or 4810Bq/kg ^{40}K produce the same gamma ray dose rate for calculate Ra_{eq} had been used Eq.1Or 2:

$$Ra_{eq} = 370\left(\frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810}\right) \quad (1)$$

Or

$$Ra_{eq} = C_{Ra} + 1.43\, C_{Th} + 0.077\, C_K \quad (2)$$

Where C_{Ra} is the ^{226}Ra activity concentration (Bq/kg), C_{Th} is the ^{232}Th activity concentration (Bq/kg) and C_k is the ^{40}K activity concentration (Bq/kg) [14, 15].

Dose rate measurement

Dose, includes absorbed dose rate and effective dose rate. If we assume dose distribution is uniform around the air to calculate absorbed dose rate in air at height of 1m above of ground for ^{238}U, ^{232}Th series and ^{40}K radioisotope had been used Eq.3:

$$D = 0.52813 C_{Th} + 0.38919 C_{Ra} + 0.03861 C_K \quad (3)$$

Where: C_{Th}, C_{Ra} and C_K are the activity concentration of ^{232}Th, ^{226}Ra, ^{49}K in ($Bq.kg^{-1}$) and D in (nGy/h) respectively [17,18, 19].

To calculate annual effective dose rate (D_{eff}) should be considered three effect factors. One of them is conversion factor (CF) that converts the absorbed dose in air to the corresponding effective dose (CF = 0.7). Other one is outdoor occupancy factor (OF) due to the people spend (80%) of their time in buildings (OF=0.8) and this factor for indoor is 0.2. Third factor is the ratio of indoor to outdoor gamma dose rates (*R* = 1.4). The annual effective dose rate in (Sv/y) used Eq. (4):

$$D_{eff} = D \times CF \times OF \times R \times 8760 \quad (4)$$

Where: D is the dose rate in (Gy/h) and 8760 is hours in year [20, 19].

Hazard indexes for gamma and alpha radiation

European Commission (EC) proposed an index that named gamma index (I_γ). This index is used to verify whether the guidelines of EC for building material usage are met. I_γ is calculated from Eq.5:

$$I_\gamma = \frac{C_{Ra}}{300} + \frac{C_{Th}}{200} + \frac{C_K}{3000} \le 1 \quad (5)$$

Where: C_{Th}, C_{Ra} and C_K are the activity concentration of ^{232}Th, ^{226}Ra and ^{49}K in ($Bq.kg^{-1}$), respectively [21, 19].

Alpha index have been proposed for assessment alpha radiation that emitted radon gas at building materials. This index proposed by Krieger (1981) and Stoulos et al (2003). I_α like I_γ is below 0.5 and 1. Alpha index is calculated from Eq. 6: [22, 18].

$$I_\alpha = \frac{C_{Ra}}{200} \quad (6)$$

Internal hazard and external hazard indexes

Internal hazard index (H_{in}) is used for consideration the internal radiation from radon ^{222}Rn and its daughter in building material. The H_{in} calculated from Eq.7: [23].

$$H_{in} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad (7)$$

External gamma radiation (H_{ex}) is dose product by building material radio nuclides such as clay brick and etc. The H_{ex} equivalent upper limit of 1 mSv/y and calculated by Eq. 8: [24].

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \leq 1 \qquad (8)$$

RESULTS

Naturally occurring radio nuclides are distributed in basic building material (BBM) such as clay brick, gypsum and etc. in this study, Natural activity were measured for ^{226}Ra, ^{232}Th and ^{40}K from different brand of bricks used in Tehran. Measured results are presented in Table 1.

The absorbed dose rate and effective dose rate were calculated as well as hazard indexes for gamma, alpha radiation, internal and external hazard indexes were calculated. The results are presented in table 2. The activity concentrations of ^{226}Ra, ^{232}Th, ^{40}K as well as the calculated radium equivalent (Ra_{eq}) have been compared with the data reported by other countries. The results are presented in table 3.

Table1. Natural radioactivity of bricks and clay bricks in Tehran

bricks	Number Of samples	Series uranium and thorium		radionuclide	Ra_{eq}
		C_{Ra} (Bq/kg)	C_{Th} (Bq/kg)	C_K (Bq/kg)	
		mean	mean	mean	
CB	3	17 ± 1	9 ± 0.7	422 ± 11	62.81
MFB	3	11 ± 0.8	2 ± 0.6	112 ± 6	22.58
FB	3	15 ± 0.4	5 ± 0.9	235 ± 8	40.49
mixture	9	14.8 ± 0.9	5.5 ± 0.7	148.41 ± 9	34.07

Table2. Values of radiation hazard parameters in the investigated bricks type

Bricks	Parameter of radiation from brick types					
	D_γ (nGy/h)	D_{eff} (mSv/y)	I_γ	I_α	H_{in}	H_{ex}
CB	27.44	0.188	0.14	0.085	0.212	0.168
MFB	9.66	0.066	0.084	0.055	0.102	0.060
FB	17.55	0.12	0.15	0.075	0.149	0.108
mixture	14.39	0.098	0.12	0.074	0.132	0.092

Table3. A comparison between natural radioactivity of bricks in Tehran and other parts of the world

Country	Mean activity concentration			references
	C_{Ra} (Bq/kg)	C_{Th} (Bq/kg)	C_K (Bq/kg)	
Kuwait	12	7	332	Bou-Rabee F, Bem H (1996)
Algeria	65	51	675	Amrani D, Tahtat M (2001)
china	59	50	714	Xinwei L (2005)
Pakistan	23	35	431	Faheem M, Mujahid SA, Matiullah M (2008)
Greece	23	35	431	Papaefthymiou H, Gouseti O (2008)
Saudi Arabia	37	32	343	Al-Zahrani JH (2012)
This study	14.8	5.5	148.41	

DISCUSSION

The activity concentration in brick types depend on amount of uranium, thorium and potassium in soil that the building material is constructed them. In this work, the natural activity of bricks was measured and amount of radioactivity were variable for every types of bricks. The maximum of the activity results for CB and minimum activity results for MFB. The CB has maximum function in Tehran buildings. This factor is one of operating factors that increased the indoor background radiations in buildings. Natural activity of CB is 17, 9 and 422 Bq/kg for C_{Ra}, C_{Th} and C_K respectively and radium equivalent activity (Ra_{eq}) were calculated for CB 62.81 Bq/kg that below the allowable level of 370 Bq/kg for building materials. MFB and FB have a low level of activity compared to CB and radium equivalent activities (Ra_{eq}) were calculated for MFB and FB 22.58 and 40.49 Bq/kg respectively. Radium equivalent activities were calculated for mixture of them and were obtained 34.07 Bq/kg. None of them were not excessive from 370 Bq/kg and every of bricks in Tehran are safety for Tehran people. The absorbed dose rate and effective dose rate were calculated maximum of them 27.44nGy/h and 0.188mSv/y respectively.

As Table (2) shows alpha and gamma indexes have the maximum 0.15 and 0.085 for I_γ and I_α respectively that are below the recommended level of 0.5 and 1. According to the calculations done in Table (2) the maximum value of H_{in} and H_{ex} are 0.212 and 0.168 that are below unity. This measurement and calculations showed all of bricks in Tehran building are safely.

CONCLUSION

This study showed that all the bricks commonly used in the construction of buildings in Tehran are safety**.** Gamma spectroscopy is suitable method for measuring the activity of a radioisotope**.** In this research, the concentration of the natural radioactivity ^{226}Ra, ^{232}Th and ^{40}K for mixture of bricks 14.8, 5.5, 148.41 Bq/kg also radium equivalent activity (Ra_{eq}) were calculated 34.07 Bq/kg**.** Radium equivalent activity for all type of bricks and mixture are satisfactorily lower than allowable level of 370 Bq/kg. Hazard indexes H_{in} and H_{ex} are below unity and I_γ and Iα are below the recommended values.

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