Estimation of the Radiation Hazard Indices from the Natural Radioactivity of Building Materials.

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ABSTRACT

The activity concentrations of uranium, thorium and potassium can vary from material to material and it should be measured as the radiation is hazardous for human health. Thus first studies have been planned to obtain radioactivity of building material used in the Tema city region of Egypt. The radioactivity of some building materials used in this region has been measured using a γ-ray spectrometry, which contains a NaI (Tl) detector connected to MCA. The specific activity for ^{226}Ra, ^{232}Th and ^{40}K, from the selected building materials, were in the range 7±0.4–64±3.2, 4±0.2–55±2.7 and 116±5.8– 404±20 Bqkg^{-1}, respectively. Absorbed dose rate in air, annual effective dose, radium equivalent activities, external hazard index and excess lifetime cancer risk associated with the natural radionuclide are calculated to assess the radiation hazard of the natural radioactivity in the building materials.

Key word: *Natural radionuclides, building materials and hazard index.*

INTRODUCTION

Human beings are continuously exposed in their houses and ionizing radiation emitted by from building materials. Materials derived from rock and soil contains mainly the natural radionuclides of the uranium (^{238}U) and thorium (^{232}Th) series, and ^{40}K. These radionuclides can cause external and internal radiation exposure to occupants. The external exposure is caused by direct gamma radiation. The internal radiation exposure, affecting the respiratory tract, is due to radon and radon decay products which emanate from building materials (1). Knowledge of the basic radiological parameters such as radioactive content in building materials is important in the assessment of possible radiation exposure to the population. This knowledge is essential for the development of standards and guidelines for the use of these materials.

MATERIALS AND METHODS

Sampling and sample preparation

In order to obtain samples used as building materials in Tema city which located in upper Egypt, manufacturers, building material suppliers and sites where houses and buildings were under construction in thirteen regions were visited; the samples were obtained from these locations; 2 red clay-brick, one lime-brick, 2 gravel, 3 clay-brick and 4 sand samples were collected from seven regions. Building material samples were oven dried at a temperature of 110 °C for 12 h and sieved through a 200 mesh. The dried samples were transferred to polyethylene Marinelli beakers of 197 cm^3 capacity. Each sample was left for at least 4 weeks to reach secular equilibrium between radium and thorium, and their progenies (2, 3).

Gamma spectrometric analysis

Activity measurements have been performed by gamma ray spectrometer, employing a scintillation detector (3×3 inch). It is hermetically sealed assembly, which includes a NaI (Tl) crystal, coupled to PC-MCA Canberra Accuspec. To reduce gamma ray background, a cylindrical lead shield (100 mm thick) with a fixed bottom and movable cover shielded the detector. The lead shield contained an inner concentric cylinder of copper (0.3 mm thick) in order to absorb X-rays generated in the lead. In order to determine the background distribution in the environment around the detector an empty sealed beaker was counted in the same manner and in the same geometry as the samples. The measurement time of activity or background was 43200s. The background spectra were used to correct the net peak area of gamma rays of measured isotopes. A dedicated software program (4).

The ^{226}Ra radionuclide was estimated from the 609.3 keV (46.1%) γ-peak of ^{214}Bi, 351.9 keV (36.7%), 1120.3 keV (15%), 1728.6 keV (3.05%) and 1764 keV (15.9%) γ-peak of ^{214}Pb. The 186 keV photon peak of ^{226}Ra was not used because of the interfering peak of ^{235}U with energy of 185.7 keV. ^{232}Th radionuclide was estimated from the 911.2 keV (29%) γ -peak of ^{228}Ac and 238.6 keV (43.6%) γ -peak of ^{212}Pb. ^{40}K radionuclide was estimated using 1,461 keV (10.7%) γ -peak from ^{40}K itself. The below detectable limit (BDL) were 25.2 $Bqkg^{-1}$ for ^{40}K, 6.5 $Bqkg^{-1}$ for ^{226}Ra and 5.7 $Bqkg^{-1}$ for ^{232}Th. All procedures were described in previous publications (5).

RESULTS AND DISSECTION

Radioactivity measurements

The results for the activity concentrations of natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K in the building material samples are summarized in Table 1. The highest values of ^{226}Ra, ^{232}Th were found in Red Clay-brick, while the highest value of ^{40}K was found in Lime-brick.

Table 1: Activity concentration $Bqkg^{-1}$of ^{226}Ra, ^{232}Th and ^{40}K in samples.

	^{226}Ra	^{232}Th	^{40}K
Red Clay-brick 1	42±2.1	43±0.2	178±8.9
Red Clay-brick 2	204±10.2	221±11.1	346±17.3
Red Clay-brick 3	35±1.7	24±1.2	258±12.9
Lime-brick	48±2.5	1±0.3	872±43.6
Clay- brick 1	64±3.2	24±1.2	203±10.2
Clay- brick 2	33±1.7	37±2.8	404±20.2
Clay- brick 3	64±3.2	24±0.3	203±8.6
Gravel 1	47±2.3	16±0.8	321±16.1
Gravel 2	9±1.2	4±0.8	123±7.4
Sand 1	52±2.6	55±2.7	167±8.3
Sand 2	19±1	7±0.3	128±6.4
Sand 3	10±0.5	4±0.2	116±5.8
Sand 4	17±1	70±0.3	121±6

Radium equivalent activity (Ra_{eq})

To compare the radiological effects of the building material samples, which contain ^{226}Ra, ^{232}Th and ^{40}K, a common index is required to obtain the sum of activities. This index is usually called the radium equivalent activity (Ra_{eq}) as given in the following expression (6).

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

where, A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in $Bqkg^{-1}$,respectively. It has been assumed that 370 $Bqkg^{-1}$ of ^{226}Ra, 259BqBq.kg^{-1} of ^{232}Th and 4810 $Bqkg^{-1}$ of ^{40}K produce the same gamma doses in Eq. (1). The maximum value of Ra_{eq} in building materials samples is required to be less than the limit value of 370 $Bqkg^{-1}$ recommended by the Organization for Economic Cooperation and Development for safe use, i.e., to keep the external dose below 1.5$mSvy^{-1}$. Table (2) shows that, the values of Ra_{eq} are less than the 370 $Bqkg^{-1}$, except for Red Clay-brick 2.

Air-absorbed dose rates (D)

The absorbed dose rates in outdoor (D) due to gamma radiations in air at 1m above the ground surface for the uniform distribution of the naturally occurring radionuclides (^{226}Ra, ^{232}Th and ^{40}K) were calculated based on guidelines provided by (7). The conversion factors used to compute absorbed γ-dose rate (D) in air per unit activity concentration in Bq/kg (dry-weight) corresponds to 0.427 nGyh^{-1} for ^{226}Ra (of U- series), 0.662 nGyh^{-1} for ^{232} Th and 0.043 nGyh^{-1} for ^{40}K.

$$\mathbf{D = 0.427C_{Ra} + 0.662\ C_{Th} + 0.043\ C_K \quad nGyh^{-1},} \qquad \mathbf{(2)}$$

Where C_{Ra}, C_{Th} and C_K are the concentration in (BqKg^{-1}) of radium, thorium and potassium respectively. Table 2 gives the results for the absorbed dose rate in air for building materials samples.

Table (2): Radium equivalent, the dose rate, hazard index, annual effective dose rate and excess lifetime cancer risk.

	Ra_{eq} Bq/kg	D nGy/h	H_{ex} nGy/h	A. Eff. µSv/y	ELCR
Red Clay-brick 1	117.2	52.8	0.3	64.1	2.2E-04
Red Clay-brick 2	546.7	242.2	1.5	293.9	1.0E-03
Red Clay-brick 3	89.2	41.4	0.2	50.3	1.8E-04
Lime-brick	116.6	59.1	0.3	71.8	2.5E-04
Clay- brick 1	114.0	52.5	0.3	63.8	2.2E-04
Clay- brick 2	117.0	54.4	0.3	66.1	2.3E-04
Clay- brick 3	114.0	52.5	0.3	63.8	2.2E-04
Gravel 1	94.6	44.8	0.3	54.3	1.9E-04
Gravel 2	24.2	11.7	0.1	14.2	5.0E-05
Sand 1	143.5	64.2	0.4	77.9	2.7E-04
Sand 2	38.9	18.3	0.1	22.3	7.8E-05
Sand 3	24.7	11.9	0.1	14.4	5.0E-05
Sand 4	37.2	17.8	0.1	21.6	5.5E-05

External radiation hazard (H_{ex})

The external hazard index is an other criterion to assess the radiological suitability of a material. It is defined as follows (8):

$$H_{ex} = C_{Ra}/370 + C_{Th}/259 + C_K/4810 \qquad (3)$$

where C_{Ra}, C_{Th} and C_K are the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K, respectively, in $Bqkg^{-1}$ .The values of the indices should be <1. It is observed in Table 2 that the values of H_{ex} is below the criterion value (<1), except for Red Clay-brick 2.

Annual effective dose (A. eff.)

Annual estimated average effective dose equivalent received by a member was calculated using a conversion factor of 0.7 $SvGy^{-1}$, which was used to convert the absorbed rate to human effective dose equivalent with an outdoor occupancy of 20% and 80% for indoors (9). The annual effective dose was determined as follows:

$$\text{Annual effective dose rate} = D \times T \times F \qquad (4)$$

Where D is the calculated dose rate (in $nGyh^{-1}$), T is the outdoor occupancy time (0.8x24 h x365.25 d≈7013 hy^{-1}), and F is the conversion factor (0.7×10^{-6} $SvGy^{-1}$). The experimental results of annual effective dose rate are presented in table 2. The International Commission on Radiological Protection (ICRP) has recommended the annual effective dose equivalent limit of 1 $mSvy^{-1}$ for the individual members of the public and 20 $mSvy^{-1}$ for the radiation workers (10).

Excess lifetime cancer risk (ELCR):

Excess lifetime cancer risk (ELCR) was calculated using the following equation and presented in Table 2.

$$ELCR = AEDE \times DL \times RF \qquad (5)$$

where AEDE, DL and RF is the annual effective dose equivalent, duration of life(70 years) and risk factor (Sv^{-1}), fatal cancer risk per sievert. For stochastic effects, ICRP60 uses values of 0.05 for the public (11). The calculated value of ELCR showed that, the highest value ware in Red Clay-brick 2.

CONCLUSION

The specific radioactivity values of ^{226}Ra, $^{232}Th$and ^{40}K measured in commonly used building materials used for the construction purposes in Tema city, upper Egypt have been determined by gamma-ray spectrometer. For each sample in this study, the specific activity, radium equivalent activity, annual radiation dose, external hazard and excess lifetime cancer risk have been determined to assess the radiological hazards from the building materials. The calculated radium equivalent activity (Ra_{eq}) values for all the building materials examined are lower than the recommended maximum level of radium equivalent of 370 $Bqkg^{-1}$, except in Red Clay-brick 2.

The external (H_{ex}) hazard index has been determined to be less than the recommended value, except in Red Clay-brick 2. The values obtained in the study are with in the recommended safety limit, showing that the building materials do not pose any significant radiation hazard and hence the use of these materials in the construction of dwelling is considered 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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