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ARTICLE

Assessment of Natural Radionuclides in Local and Imported Cements in Erbil Governorate, Kurdistan Region- Iraq

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Abstract: A total of 10 cement samples were collected from the manufactures and markets. Spectrometry analysis of Sodium Iodide NaI (Tl) detector was used for measuring the samples' specific activity. The obtained specific activities of (^{226}Ra, ^{232}Th and^{40} K) were (35, 30 and 400) Bq/kg, respectively, which are below the critical values suggested by UNSCEAR2000. The radiological hazard indices of radium equivalent activities (Ra_{eq}), the indoor absorbed dose $D_{in}(nGyh^{-1})$, the internal annual effective dose equivalent (E_{in}) and the internal index (H_{in}) were calculated. All of the obtained values were below the world wide recommendation values. Fortunately, from the analyzed results, it was concluded that the local and imported cements in Erbil governorate will make no risk when used in building constructions.

Keywords: Radionuclides, Gamma-ray spectrometer, Cement.

Introduction

Radioactivity can be regarded as a process by which an unstable atomic nucleus loses energy by emitting radiation, such as an alpha particle, beta particle and gamma ray [1].

All living organisms are continuously exposed to natural background radiation mainly coming from external background radiation, due to ^{238}U, ^{232}Th and ^{40}K, which are present in the earth's crust [2].

Building raw materials and products are derived from rock and soil that contain various amounts of natural radionuclides. They are considered as the source of direct radiation, since people spend more than 80% of their time indoors [3].

The radioactive contamination in building raw materials was specified and recognized as the major source of gamma indoor exposure [4].

Cement has been used widely throughout the world as a basic material in building constructions. Many local and international studies have been conducted to investigate and assess the natural radioactivity due to cement [5-10].

Erbil, the capital of Kurdistan region-Iraq, lives a huge investment period in the infra-structure building and dwelling constructions; so, beside the local products, different imported raw materials including cements were inserted into markets. Thus, it is very important to study the activity concentration of primordial radionuclides (^{238}U, ^{232}Th and ^{40}K) in cement types existing in Erbil governorate, and to calculate the derived radiological parameters.

Materials and Methods

A total of 10 samples from the available cement types in Erbil markets were taken, see Table 1. From each cement type, 1.1 kg had been taken and left in a sealed Marinelli beaker for one month to reach secular equilibrium, where the rate of decay of the daughters becomes equal to that of the parents. This step is necessary to ensure that radon gas is confined within the volume and the decay products will also remain in the sample.

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TABLE 1. Cement types used in the study.

Sample code	Name	Color	Origin
S1	DELTA	white	Kurdistan-Sulaymanyah
S2	ILAM	green	Iran
S3	White Portland cement	white	Iran
S4	ÇiMSA WHITE	white	Iran
S5	Baomix 101	green	Turkey
S6	Ademix 333	brown-red	Turkey
S7	Kurdistan Cement	green	Kurdistan-Erbil
S8	Kalekim 1054	white	Turkey
S9	SIBRE	brown-green	Turkey
S10	YaTIS	white	Turkey

Gamma Ray Spectrometry Analysis

The gamma spectrometer that exists in the post-graduate nuclear laboratory at Salahaddin University-Erbil consists of a 3″×3″ NaI (Tl) detector (SILENA type model 3S3), a preamplifier, an amplifier, a multi-channel analyzer of 512 channels of (CASSY type and model 524058) and a high voltage power supply (521681 LYBOLD) with the range and operating voltage of 0-1500 (800 Volts). The detector resolution was measured by full width at half maximum (FWHM) of 7.4 at the 662 KeV gamma line of ^{137}Cs. The detector is shielded by two layers starting with copper (20mm) and lead (10 cm) in order to reduce background radiation. The energy calibration for NaI (Tl) gamma ray spectrometry was carried out using the point source of ^{226}Ra with its progenies: ^{214}Pb (242, 295 and 352 KeV) and ^{214}Bi (609 and 1120 KeV). Full energy peak efficiency calibration was performed using the three standard well-known activity sources of ^{137}Cs, ^{60}Co and ^{152}Eu. A CASSY software program was used to acquire and analyze the spectrum. The cement samples were counted within the calibrated spectrometer for 21600 sec. The obtained net cement spectra (after subtracting the background) have been analyzed using indirect methods to determine the specific activities of ^{238}U and ^{232}Th.The sample concentrations of (^{238}U, ^{232}Th and ^{40}K) for the cements were determined in Bq/kg from gamma ray photo peaks of 352 KeV (^{214}Pb), 911 KeV (^{228}Ac) and 1460 (^{40}K). The activity concentration in cement samples was calculated using the following equation [5].

$$A_s = \frac{Ns}{\varepsilon_\gamma\, I_\gamma\, t\, m_c}\,(Bq\ Kg^{-1})\ , \tag{1}$$

where Ns is the net peak area at a certain energy, ε_γ is the efficiency of the detector for a specific gamma ray energy, $I\gamma$ is the emission probability of radionuclide of interest, t is the total counting time and m_c is the mass of the sample.

Results and Discussion

The measured activity concentrations of three naturally occurring radionuclides (^{226}Ra, ^{232}Th and ^{40}K) in different cement samples are given in Table 2. The results are provided as a bar graph in Fig. 1.

TABLE 2. Specific activities of primordial radionuclides in cement samples.

Sample code	^{238}U Bq/kg	^{232}Th Bq/kg	^{40}K Bq/kg
S1	11.804±0.143	3.98±0.167	109.432±1.661
S2	18.678±0.18	4.308±0.174	192.974±2.206
S3	19.009±0.181	2.152±0.123	30.461±0.876
S4	18.958±0.181	3.191±0.15	100.369±1.591
S5	11.284±0.14	7.416±0.228	486.029±3.501
S6	20.768±0.189	2.678±0.137	7.654±0.439
S7	16.444±0.169	2.94±0.144	150.554±1.948
S8	9.234±0.126	2.089±0.121	16.073±0.637
S9	11.548±0.141	2.735±0.139	102.86±1.61
S10	14.162±0.156	3.359±0.154	140.95±1.885

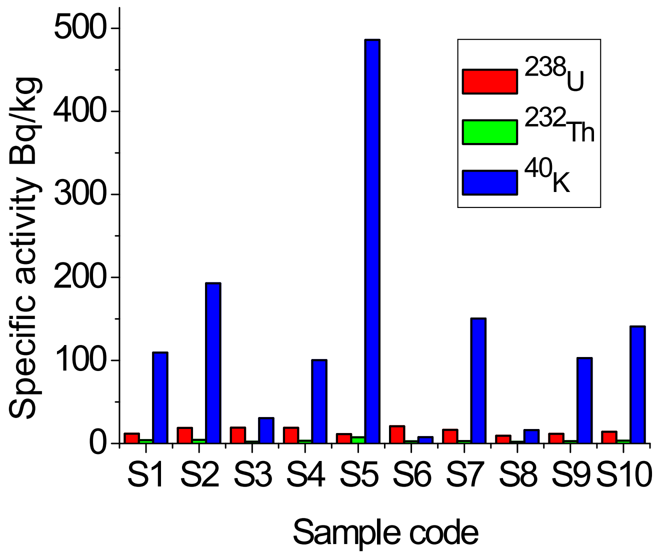

FIG. 1. ^{238}U, ^{232}Th and ^{40}K activity concentrations across sample codes.

As can be seen from Table 2, the activity concentrations of ^{226}Ra and ^{232}Th of cements were lower than those of the world average for soil of 35 Bqkg^{-1} and 30 Bqkg^{-1}, respectively [2]. For all cement samples under investigation, the measured ^{232}Th activities were in the range 2.08-7.41 Bq /kg, lower than the ^{238}U activities, while the observed ^{40}K activities were in the range 30.4-486 Bq/kg.

Determination of Hazard Indices

Radium Equivalent Activity (Ra_{eq})

The distribution of natural radioactivity in building material is not uniform; so, the specific activity of ^{226}Ra, ^{232}Th and ^{40}K can be represented by a single quantity (Ra_{eq}) which is introduced by [11] and mathematically calculated as

$$Ra_{eq.} = A_{Ra} + 1.43A_{Th} + 0.077A_K \quad (2)$$

where A_{Ra}, A_{Th} and A_K are the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K, respectively. It has been assumed that 1 Bq/kg of ^{226}Ra, 0.7 of ^{232}Th and 13 Bq/kg of ^{40}K produces the same gamma ray dose rate.

The measured values of Ra_{eq} of cement samples ranged from 13.45 (S8) to 59.3 (S5) Bq/kg, as shown in Table 3, which are all below the admissible level of 370 Bq/kg suggested by [2]. Table 4 presents a comparison of the reported values of mean radium equivalent for selected cements obtained in other countries with those determined in the present study.

TABLE 3. The radioactive doses and radiological hazard indices of primordial Radionuclides in cement samples.

Sample code	$Ra_{eq.}$ (Bq/kg)	$D_{in}(nGyh^{-1})$	E_{in}(mSv/y)	H_{in}
S1	25.922	24.172	0.118	0.101
S2	39.697	37.665	0.184	0.157
S3	24.433	22.437	0.109	0.117
S4	31.251	29.195	0.142	0.135
S5	59.314	57.975	0.284	0.19
S6	25.187	22.800	0.111	0.124
S7	32.242	30.656	0.149	0.131
S8	13.459	12.150	0.059	0.061
S9	24.873	22.034	0.117	0.104
S10	30.254	28.226	0.142	0.133

TABLE 4. Comparison of mean radium equivalent values with those of previous studies.

Country	$Ra_{eq.}$ (Bq/kg)	References
Iran	103.32	[10]
Nigeria	98.1	[12]
Iraq	68.21	[13]
Turkey	73	[14]
India	102.011	[6]
Egypt	63.4	[7]
Slovakia	47.1	[8]
Italy	159	[15]
Greece	132	[15]
Netherlands	174	[15]
Erbil, Kurdistan	30.46	Present work

Indoor Annual Effective Dose Rate (E_{in})

Indoor Annual Effective Dose Rate can be defined as the amount of dose received by individuals inside buildings. (E_{in}) can be obtained from the indoor absorbed dose $D_{in}(nGyh^{-1})$ given as:

$$D_{in}(nGyh^{-1}) = 0.926A_{Ra} + 1.1A_{Th} + 0.081A_K \ . \quad (3)$$

The calculated $D_{in}(nGyh^{-1})$ values are shown in Table 3.

Using the dose conversion factor (0.7) and the time (0.8) of stay in the indoor during the year, the indoor annual effective dose is defined as follows [7]:

$$E_{in}(mSv\ y^{-1}) = D_{in}(nGyh^{-1}) \times 8760h \times 0.8 \times 0.7Sv\ Gy^{-1} \times 10^{-6} \ . \quad (4)$$

Table 3 presents the calculated E_{in} for cements. E_{in} values varied from 0.059 (S8) to 0.284 (S5) mSv/y. All the obtained values are below the average recommendation value of 0.41 mSv/y declared by [2] for indoor annual effective dose rates.

Internal Hazard Index (H_{in})

Internal exposure of radon and its progenies is defined by estimating internal hazard index, which is given by the formula [7]:

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \ . \quad (5)$$

The H_{in} values are shown in Table 3. The range of H_{in} varied from 0.061(S8) to 0.19 (S5) with an average value of 0.287. All the obtained values of H_{in} are well below the critical value of one. This means that there are no risks to inhabitants owing to harmful effects of ionizing radiation from the natural radionuclides in cements; so, hazards can be neglected [7].

Conclusion

The specific activity of the three radionuclides ^{226}Ra, ^{232}Th and ^{40}K has been determined for local and imported cements in Erbil governorate. Based on the activity concentrations, the indoor dose rate was estimated for individuals in dwellings. The indoor dose rate was increased over life period for all cement samples. Fortunately, all the obtained values are well below the critical values presented by EPA. So, the cements used in Erbil governorate are safe and do not pose any radiological risks to dwellers.

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