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Measurement of Natural Radioactivity in Some Marble Samples by using (HPGe) Detector

Hasan Mohammed Abdullah
Ibn Hayyan University College, Holy Karbala, Iraq

Abstract: In this study, measurement of specific activity concentrations in ten commercial marble samples from different countries were carried out by using (HPGe) system. The results of measurements have shown that the maximum values specific activity concentrations for ^{238}U, ^{232}Th which were equal to 27.420, 30.480 Bq/kg, respectively, Brazilian origin while the maximum values specific activity concentrations for ^{40}K which were equal to 297.210 Bq/kg Iranian origin which were less than the corresponding recommended global values reported by UNSCEAR, publication. The radiation hazard indices [Ra_{eq}, D_{γ}, $(AED)_{in}$, $(AED)_{out}$, H_{in}, H_{ex} and I_{γ}] were also studied. The obtained results were also found to be less than the allowed limits given by UNSCEAR. Thus, all results obtained in the present work have shown no significant radiological hazard when the studied marble is used, for example, for construction of flooring buildings.

Key words: Radiation hazard indices, marble samples, (HPGe) system, present work, significant, construction

INTRODUCTION

It is well known that the traces of radionuclides are found in soil, water, air and human bodies, we inhale and ingest radionuclides every day of our lives and radioactive materials have been ubiquitous on Earth, since, its creation. The presence of natural radioactivity in soil results in internal and external exposure to humans. Radioactive nuclides which can be found in nature are generally categorized in two distinct families, namely of arising from either origin. The most commonly encountered radionuclides that irradiate the human body through external exposure (primarily by gamma radiation) are U-235, U-238 and Th-232 and their subsequent radioactive decay products and K-40 (UNEP., 1985), Nuclei can undergo a variety of processes which result in the emission of radiation. The most common forms of nuclear radiation are beta particles, alpha and gamma-rays, our bodies contain radioactive materials such as C-14 and K-40 (Cameron and Skofronick, 1992). The flooring materials (marble, granite, etc.) are a part of building materials that contain several amounts of natural radioactive elements. Materials obtain from rock and soil have mainly natural radionuclides of the Th-232 and U-238 chains and the radioactive isotope of K-40 (Sahin *et al*., 2017).

MATERIALS AND METHODS

Ten marble material's samples were collected from different markets and factories. The samples were chosen in terms of the widely and most common type Iraqi markets (Fig. 1). All the sampleswere pulverized into small pieces, then into fine powder by using jaw crusher (Fig. 2a). The samples were dried at 80°C for 2 h to ensure that any moisture was removed from the samples and then to obtain uniform particle sizes, a 600 μm mesh was used to sieve the samples after that samples were weighted (1 kg) and transferred to a Marinelli beaker (1 L). In the present work a (3×3) inch (HPGe) system (Fig. 2b).

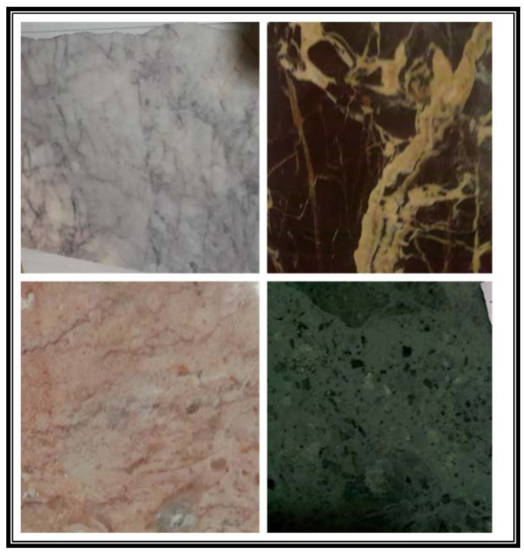

Fig. 1: Marble samples

An essential requirement for the measurement of gamma emitter is the exact identity of photo peaks presents in the spectrum produced by the detector system. The energy calibration was performed by using a standard source of 1 L capacity of Marinelli beaker of Eu-152, which has been prepared in this research with energies

(a) (b)

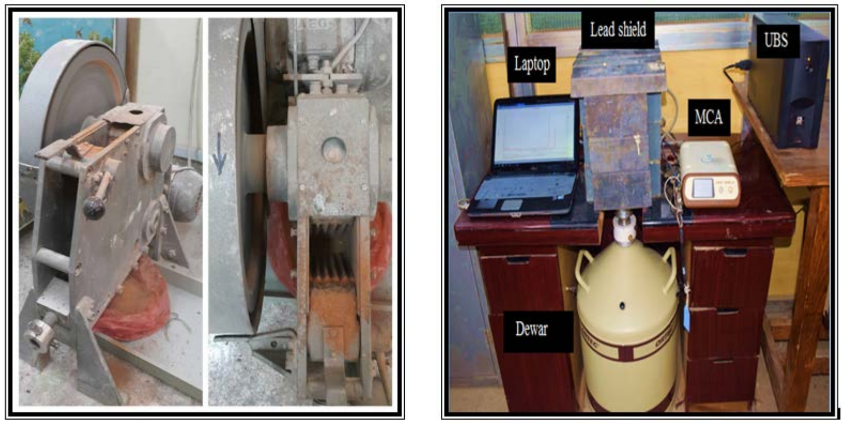

Fig. 2(a, b): (a) Jaw crusher and (b) (HPGe) system

(411.1, 1408.0, 344.3, 964.0, 444.6, 778.9, 1112.0, 121.8, 1085.8 and 244.7 keV). The energy calibration source should be counted long enough to produce well-defined photo peaks.

Determination of some gamma radiation parameters (radiation hazard indicies)

Activity concentration: The specific activity concentrations of radionuclides in marble samples were obtained by using Eq. 1 (Diab *et al*., 2008):

$$A = \frac{N\text{-}BG}{T.I_{\gamma}(E_{\gamma}).\varepsilon(E_{\gamma}).M} \quad (1)$$

Where:

- A : The specific activity of radioactive elements measured
- BG : The net peak area of the background
- (E_{γ}) : The detector efficiency at Energy (E_{γ})
- $I_{\gamma}(E_{\gamma})$: The abundance at Energy (E_{γ})
- M : The mass of the soil sample
- T : The measured time which is equal (3600 sec)

Radium equivalent (Ra_{eq}) (Diab *et al*., 2008):

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

Where, A_U, A_{Th}, A_k activity concentration of a series of thorium and potassium and uranium, respectively.

Absorbed Dose rate (D_{γ}) (Shawkat, 2000):

$$D_{\gamma} = 0.604A_{Th} + 0.0417A_K + 0.462A_U \quad (3)$$

The Annual Effective Dose (AED_{in}, AED_{out}) (El Arabi, 2005):

$$(AED)_{in} = D_{\gamma}(nGy/h)\times10^{-6}\times8760\ h/y\times(0.7\ Sv/Gy)\times0.80 \quad (4)$$

$$(AED)_{out} = D_{\gamma}(nGy/h)\times10^{-6}\times8760\ h/y\times(0.7\ Sv/Gy)\times0.20 \quad (5)$$

Internal and external Hazard index (H_{in}, H_{ex}) (El-Taher and Makhluf, 2010):

$$H_{in} = \frac{A_{Th}}{259} + \frac{A_U}{185} + \frac{A_K}{4810} \leq 1 \quad (6)$$

$$H_{ex} = \frac{A_{Th}}{259} + \frac{A_U}{370} + \frac{A_K}{4810} \leq 1 \quad (7)$$

Activity concentration Index (I_{γ}):

$$I_{\gamma} = \frac{A_{Th}}{200} + \frac{A_{Uh}}{300} + \frac{A_K}{300} \quad (8)$$

RESULTS AND DISCUSSION

The results of the present work were summarized in Table 1 from which it can be noticed that, the maximum value of specific activity of ^{238}U in the studied samples was found inmarble sample of Brazilian origin which was equal to 27.420 Bq/kg while the minimum value of specific activity of ^{238}U was found in marble sample of Iraqi origin which was equal to 14.340 Bq/kg. The present results have shown that values of specific activity for ^{238}U in all studied samples were less than the recommended value of 35 Bq/kg for the specific activity of ^{238}U (UNSCEAR, 2000).

The maximum value of specific activity of ^{232}Th in the studied samples was found in marble sample of Brazilian origin which was equal to 30.480 Bq/kg while the minimum value of specific activity of ^{232}Th was found in marble sample of Iranian origin which was equal to 18.510 Bq/kg. The present results have shown that values of specific activity for ^{232}Th in all studied samples were less than the recommended value of 30 Bq/kg for the specific activity of ^{232}Th (UNSCEAR, 2000).

Table 1: Specific activities of radionuclides with significant radiological hazard for all marble samples

						(A.E.D) (mSv/y)		Hazard index		
Origin	^{238}U (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)	Ra_{eq} (Bq/kg)	D_{γ} (nGy/h)	Indoor E_{in}	Outdoor E_{out}	H_{in}	H_{ex}	I_{γ}
China	16.750	25.480	193.570	68.091	31.200	0.153	0.038	0.229	0.184	0.248
Iraq	14.340	26.620	183.820	66.561	30.369	0.149	0.037	0.219	0.180	0.242
India	19.090	27.020	201.550	73.248	33.544	0.165	0.041	0.249	0.198	0.266
Syria	20.960	26.290	293.250	81.135	37.791	0.185	0.046	0.276	0.219	0.299
Vietnam	14.830	27.530	183.760	68.347	31.142	0.153	0.038	0.225	0.185	0.248
Italy	24.530	26.620	272.910	83.611	38.792	0.190	0.048	0.292	0.226	0.306
Iran	15.670	18.510	297.210	65.024	30.813	0.151	0.038	0.218	0.176	0.244
Oman	26.630	20.160	265.870	75.931	35.566	0.174	0.044	0.277	0.205	0.278
Spain	24.460	27.630	256.320	83.708	38.678	0.190	0.047	0.292	0.226	0.305
Brazil	27.420	30.480	243.940	89.790	41.250	0.202	0.051	0.317	0.243	0.325
Min.	14.340	18.510	183.760	65.024	30.369	0.149	0.037	0.218	0.176	0.242
Max.	27.420	30.480	297.210	89.790	41.250	0.202	0.051	0.317	0.243	0.325
Worldwide average (UNSCEAR, 2000)	35.000	30.000	400.000	370.00	55.000	1.000	1.000	1.000	1.00	1.000

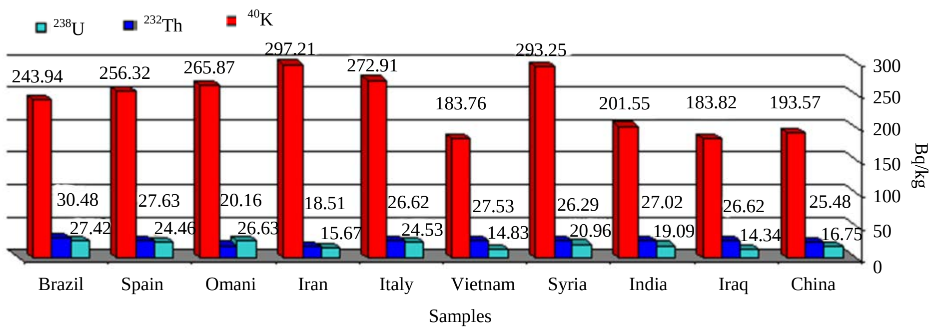

Fig. 3: Specific activity of ^{238}U, ^{232}Th and ^{40}K in all marble samples

The maximum value of specific activity of ^{40}K in the studied samples was found in marble sample of Iranian origin which was equal to 297.210 Bq/kg while the minimumvalue of specific activity of ^{40}K was found in marble sample of Vietnamese origin which was equal to 183.760 Bq/kg with . The present results have shown that values of specific activity for ^{40}K in all studied samples were less than the recommended value of 400 Bq/kg for the specific activity of ^{40}K (UNSCEAR, 2000) (Fig. 3).

The maximum value of Ra_{eq} in the studied samples was found in marble sample of Brazilian origin which was equal to 89.790 Bq/kg while the minimum value of Ra_{eq} was found in marble sample of Iranian origin which was equal to 65.024 Bq/kg. The present results have shown that values of Ra_{eq} in all studied samples were less than the recommended value of 370 Bq/kg for the (Ra_{eq}) (UNSCEAR, 2000).

The maximum value of (D_{γ}) in the studied samples was found in marble sample of Brazilian origin which was equal to 41.250 nGy/h while the minimum value of D_{γ} was found in marble sample of Iraqi origin which was equal to 30.369 nGy/h. The present results have shown that values of D_{γ} rate in all studied samples were less than the recommended value of 55nGy/h for the (D_{γ}) (UNSCEAR, 2000).

The maximum value of AED_{in} in the studied samples was found in marble sample of Brazilian origin which was equal to 0.202 mSv/y while the minimumvalue of AED_{in} was found in marble sample of Iraqi origin which was equal to 0.149 mSv/y. The present results have shown that values of AED_{in} in all studied samples were less than there commended value of 1 mSv/y for the $(AED)_{in}$ (UNSCEAR, 2000).

The maximum value of AED_{out} in the studied samples was found in marble sample of Brazilian origin which was equal to 0.051 mSv/y while the minimum value of AED_{out} was found in marble sample Iraqi of origin which was equal to 0.037 mSv/y. The present results have shown that values of AED_{out} in all studied samples were less than there commended value of 1 mSv/y for the outdoor annual effective dose equivalent (UNSCEAR, 2000).

The maximum value of H_{in} in the studied samples was found in marble sample of Brazilian origin which was equal to 0.317 while the minimum value of H_{in} was found in marble sample Iranian origin which was equal to 0.218 with an average value of 0.249±0.014. The present results have shown that values of H_{in} in all studied samples were less than the recommended value of 1 for the (H_{in}) (UNSCEAR, 2000).

The maximum value of H_{ex} in the studied samples was found in marble sample of Brazilian origin which was equal to 0.243 while the minimum value of H_{ex} was found in marble sample Iranian origin which was equal to 0.176.

The present results have shown that values of H_{ex} in all studied samples were less than the recommended value of 1 for the (H_{ex}) (UNSCEAR, 2000).

The maximum value of I_γ inthe studied samples was found in marble sample of Brazilian origin which was equal to 0.325 mSv/y while the minimum value of I_γ was found in marble sample of Iraqi origin which was equal to 0.242 mSv/y. The present results have shown that values of I_γ in all studied samples were less than the recommended value of 1 for I_γ (UNSCEAR, 2000).

The results of marble revealed the most samples have low specific activity concentration due to absence of minerals containing radioactivity but these results vary according to different origins of marbles because a marble is a metamorphic rock and different by the presence of minerals and location.

CONCLUSION

The results of the present work concerning values of the specific activity for ^{232}Th, ^{40}K and ^{238}U and determination the parameters [Ra_{eq}, D_γ, $(AED)_{in}$, $(AED)_{out}$, H_{in}, H_{ex} and I_γ], all were found to be lower than their corresponding allowed limits and hence will pose relatively none series health risk.

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