ТЕХНІКА ТА МЕТОДИ ЕКСПЕРИМЕНТУ
ENGINEERING AND METHODS OF EXPERIMENT

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ASSESSMENT OF NATURAL RADIOACTIVITY AND ITS RADIOLOGICAL HAZARD IN SOME DECORATIVE MATERIALS IN IRAQ

Most buildings use decorative materials that are aesthetically pleasing, that may contain various amounts of radioactive elements. Thus, the human health of dwellers and workers is continuously exposed to ionizing radiation. Natural radioactivity (^{238}U, ^{232}Th, and ^{40}K) is measured in decorative materials collected from different Iraqi local markets by utilizing a shielded high counting efficiency NaI(Tl) system. Some radiological hazard indexes in all samples were calculated. The results obtained showed that the maximum value of specific activity for ^{238}U, ^{232}Th, and ^{40}K is in decorative stone and the minimum is measured in decorative alabaster. This study concluded that the natural radioactivity and radiological hazard in most samples of decorative materials were within the permissible limits by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the International Commission on Radiological Protection (ICRP), Organization for Economic Co-operation and Development (OECD), and other world reported. Therefore, most samples of decorative materials in the present study can be used without health risks according to radiation scope.

Keywords: natural radioactivity, decorative materials, building materials, γ-ray spectroscopy.

1. Introduction

Human exposure to ionizing radiation is one of the research topics that receive the most public interest. Since radiation from biological source is liable for most of the human population's overall radiation exposure [1], and natural radiation exposure for most populations is the biggest segment of all exposure and forms the basis on which exposure from a man-made source is possible [2], awareness of the dose derived from biological radioactivity is very crucial to addressing not only the health consequences but mostly the frequency of man-made sources of radiation [1]. A radiation exposure background study will be of immense significance because it is the primary human exposure source [3]. It is recognized that normal radionuclide materials are found in rocks and soil. These radionuclides may originate in the primordial period, such as ^{238}U and ^{232}Th, or their progenies and even ^{40}K. Their role in soils and rocks may simply take into account as permanent because their half-lives are quite long (up to 10^{10} yrs). The initially low concentration may further be increased by human activity, such as mining and oil exploration, to a more visible level [4]. In addition to medical exposure and cosmic radiation, the primary cause of exposure is construction materials comprising naturally occurring radionuclides. To determine the amount of public exposure, the study of environmental radioactivity in these materials is necessary even before people spend too much time (about 80 %) indoors while 20 % outdoors [5]. Construction materials and decorative elements illustrate the geology of their place of origin and thus comprise a limited quantity of radioactive materials that occur naturally, generally from the ^{238}U and ^{232}Th chains and ^{40}K [6] radionuclides. Indoor environment, high concentrations of natural radionuclides in construction materials could even result in increased dose rates. If they live in houses or buildings built using materials whose radiation doses are already above background radiation levels in the region, the radiation to which people have been exposed could increase. This may be due to fly-ash, rock, soil, sand, and red clay, used in making cement, and other building materials [7]. In Iraq there are no standards or guidelines prescribing the acceptable levels of radioactivity in decorative building materials. A diverse range of building materials is used for interior and exterior decoration purposes. Decorative materials were investigated by several studies using γ-spectroscopy [8 - 10]. The aim of the present study is to estimate and investigate the nuclear radiations due to the existence of natural radionuclides like Uranium and Thorium series as well as ^{40}K radionuclides, using NaI(Tl) detector.

2. Materials and method

2.1. Collection of samples

30 samples of decorative materials were collected in different local Iraqi markets that are commonly used in Iraqi buildings, as shown in Table 1. The Table shows the name of decorative materials samples studied, type, sample code, and origin.

Table 1. **Information on decorative materials samples**

Sample code	Sample name	Type of samples	Origin
D1	Almalij	Decorative Gypsum	Iraq
D2	Isfahan	Decorative Stone	Iran
D3	Darsaan	Decorative Gypsum	Iran
D4	Decorative Mirror	Decorative Mirrors 2 ml	China
D5	Decorative Mirror	Decorative Mirrors 4 ml	Iran
D6	Decorative Mirror	Decorative Mirrors 4 ml	China
D7	Volcavo	Decorative Stone	Brazil
D8	Wand	Decorative Stone	Iran
D9	Kanuf	Secondary Roof	Germany
D10	Belcar	Decorative Stone	Spain
D11	Almaein	Decorative Gypsum	Iran
D12	Tratonen	Decorative Stone	Iran
D13	Camelot	Decorative Stone	Iran
D14	United	Secondary Roof	Saudi
D15	Adlit	Decorative Stone	Iran
D16	KS	Tile Roof	China
D17	KS	Patterned decor corners	China
D18	Tabco	Decorative Stone	Jordanian
D19	AMB	Decorative Alabaster	Iran
D20	Merdo	Decorative Alabaster	Turkey
D21	Yunfu	Decorative Alabaster	Iran
D22	ECF	Decorative Alabaster	Turkey
D23	Berdan Kazemi	Decorative Stone	Iran
D24	Iiran zamil	Decorative Stone	Iran
D25	Benoid	Decorative Cement	Iran
D26	Cimsa	Decorative Cement	Turkey
D27	Shargh	Decorative Cement	Iran
D28	Cement	Decorative Cement	Iran
D29	Hans	Decorative Stone	China
D30	Feranas	Decorative Cement	Turkey

2.2. Sample preparation

Samples of decorative materials are wrapped in labeled polyethylene bags and moved to the Radiation Detection and Measurement Laboratory throughout the Department of Physics, Faculty of Science, Kufa University [11]. The samples will be prepared by drying and maintaining them humidity-free for testing by placing them inside of an electric oven (type LUXELL, made in Turkey) at 100 °C for 6 h to achieve a consistent weight and avoid humidity adsorption prior to radioactivity testing. The samples are automatically destroyed to achieve sufficient homogeneity, using a micro-soil grinding mill model FT102 provided by TAISITE. The samples had all been sieved (15 cm diameter sieve) through the 0.8 mm pore size diameter [11] to accomplish homogeneity. With an extremely sensitive digital weighing (SF-400, made in China) scale with a percentage of ±0.01 %, the respective net weights are estimated and registered. After that, approximately 0.75 kg of almost every sample would then be packaged in a regular hermetically sealed and dry-weighted Marinelli beaker. Before weighing, all samples were processed for four weeks to achieve secular equilibrium [12]. A 1 l polyethylene Marinelli beaker has been used in the project as a sampling and measurement container.

2.3. Measurements of system

Gamma-ray spectroscopy methods were used during the present research, based on the high penetrating strength of γ-rays in the materials. It comprises a NaI(Tl) (3"×3") crystal dimension scintillation detector (supplied by Alpha Spectra, Inc.-12I12/3) coupled with a multi-channel analyzer (MCA) (ORTEC-Digi Base) and analyzed through the MAESTRO-32 program on the PC of the laboratory. Fig. 1 shows the scheme of the experimental device used in the present study.

NaI(Tl) detector has been calibrated for energy by acquiring a spectrum from five standard sources of γ-radiations (^{22}Na, ^{60}Co, ^{54}Mn, ^{137}Cs, and ^{152}Eu) where the energy calibration curve between the energy and channel number is linear. The values of a resolution were 8.6 % for the energy of 662 keV of ^{137}Cs standard source. The specific activity of each sample was measured for ^{238}U and ^{232}Th according

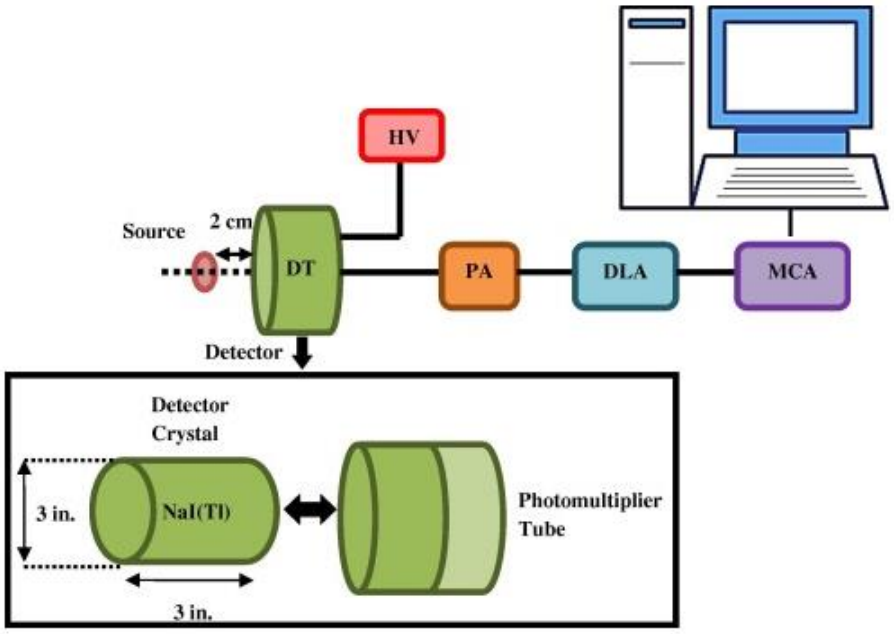

Fig. 1. The scheme of the experimental device.
(See color Figure on the journal website.)

to a secular equilibrium of ^{214}Bi (1765 keV), and ^{208}Tl (2614 keV), respectively [11, 12]. While the specific activity of ^{40}K was measured directly at a γ-line of 1460 keV [11, 12]. The properties of radioisotopes measured in the present study are shown in Table 2.

Table 2. **The properties of three radioisotopes under study [1, 6]**

Radioisotopes	Energy, keV	Half-life	γ-emission probability, %
^{214}Bi	1765	20 min	15.8
^{208}Tl	2614	3.1 min	100
^{40}K	1460	$1.248 \cdot 10^9$ yr	10.7

2.4. Calculations

2.4.1. Specific activity (A)

The specific activities of ^{238}U, ^{232}Th, and ^{40}K (A_U, A_{Th}, and A_k) radionuclides were calculated using the following equation [11, 12]:

$$A\left(\text{Bq/kg}\right) = \frac{N}{I_\gamma\ \varepsilon\ M\ T}, \quad (1)$$

where N is a net area under photopeak; I_γ is the probability of γ-decay; ε is the efficiency of the detector; M is the mass of the sample; T is time measured.

2.4.2. External hazard index (H_{ex})

The external hazard index was calculated using the following equation [13]:

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810}. \quad (2)$$

2.4.3. Internal hazard index (H_{in})

The internal hazard index was calculated using the following equation [14]:

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810}. \quad (3)$$

2.4.4. Representative level index (I_γ)

The representative level index was calculated using the following equation [15]:

$$I_\gamma = \left(\frac{1}{150}\right)A_U + \left(\frac{1}{100}\right)A_{Th} + \left(\frac{1}{1500}\right)A_K. \quad (4)$$

2.4.5. Alpha index (I_α)

The alpha index was calculated using the following equation [13]:

$$I_\alpha = \frac{A_U}{200(\text{Bq/kg})}. \quad (5)$$

2.4.6. Radium equivalent activity (Ra_{eq})

Radium equivalent activity was calculated using the following equation [16]:

$$Ra_{eq}(\text{Bq/kg}) = A_U + 1.43\ A_{Th} + 0.077 A_K. \quad (6)$$

2.4.7. Exposure rate ($\dot{X}$)

The exposure rate was calculated as the following equation [14, 17]:

$$\dot{X}(\mu R/h) = 1.90\ A_U + 2.82\ A_{Th} + 0.197 A_K. \quad (7)$$

2.4.8. Absorbed dose rate in air (D_r)

The absorbed dose rate in air 1 m was calculated using the following equation [18]:

$$D_r(nGy/h) = 0.462\ A_U + 0.604\ A_{Th} + 0.0417 A_K. \quad (8)$$

2.4.9. Annual gonadal equivalent dose (AGED)

The annual gonadal equivalent dose was calculated using the following equation [19 - 21]:

$$AGED(\mu Sv/yr) = 3.09\ A_U + 4.18\ A_{Th} + 0.314\ A_K. \quad (9)$$

2.4.10. Annual effective dose equivalent (AEDE)

Annual effective dose equivalent indoor was calculated using the following equation [22].

$$AEDE_{indoor}(mSv/yr) = \left[D_r(mGy/h) \cdot 8760\ h \cdot 0.8 \cdot 0.7\ Sv/Gy \right] \cdot 10^{-6}. \quad (10)$$

2.4.11. Excess lifetime cancer risk (ELCR)

Excess lifetime cancer risk indoor according to Duration of Life (DL = 70 yrs) and Risk Factor (RF = 0.05 yr/Sv) was calculated using the following equation [11, 16]:

$$ELCR = AEDE \cdot DL \cdot RF. \quad (11)$$

3. Results and discussions

The specific activity values of ^{238}U, ^{232}Th, and ^{40}K radionuclides for 30 decorative materials samples are tabulated in Table 3.

Table 3. **Results of specific activity for ^{238}U, ^{232}Th, and ^{40}K in present samples**

Sample code	Specific activity, Bq/kg					
	^{238}U		^{232}Th		^{40}K	
	Average	SE	Average	SE	Average	SE
D1	25.6	1.1	25.5	0.7	644.2	5.8
D2	18.1	0.8	8.5	0.3	167.6	2.5
D3	31.0	1.2	19.6	0.6	681.7	6.1
D4	26.8	1.4	2.7	0.3	346.4	5.2
D5	22.5	1.3	12.0	0.6	294.2	4.9
D6	30.1	1.6	6.8	0.5	280.6	5.0
D7	33.4	1.2	11.3	0.4	632.3	5.5
D8	40.6	1.3	20.2	0.6	573.0	5.2
D9	29.7	1.6	25.6	0.9	622.0	5.8
D10	55.1	1.8	27.5	0.8	838.2	8.8
D11	20.6	0.9	13.3	0.5	494.9	4.8
D12	18.8	1.1	5.5	0.4	104.4	2.7
D13	33.2	1.4	8.3	0.4	259.7	4.0
D14	26.9	1.3	6.9	0.4	235.3	4.1
D15	26.3	1.3	4.0	0.3	162.4	3.5
D16	24.0	1.4	3.7	0.3	326.8	5.3
D17	26.2	1.2	6.4	0.4	200.6	3.5
D18	29.1	1.2	22.8	0.6	362.2	4.4
D19	27.6	1.0	8.3	0.3	182.5	2.7
D20	6.3	0.6	8.2	0.4	234.6	3.8
D21	5.2	0.4	2.1	0.2	96.5	2.0
D22	10.7	0.6	3.5	0.2	140.4	2.3
D23	36.4	1.4	15.3	0.6	312.0	4.3
D24	31.3	1.3	5.7	0.3	158.8	3.1
D25	40.3	1.4	6.5	0.3	150.0	2.7
D26	18.6	0.8	23.7	0.6	100.6	2.0
D27	22.3	1.1	11.1	0.5	233.3	3.6
D28	7.0	0.5	2.8	0.2	189.0	2.7
D29	12.6	0.8	4.4	0.3	159.3	3.0
D30	19.4	1.0	7.0	0.4	213.1	3.4
Average ± SE	**25.19 ± 1.95**		**10.97 ± 1.40**		**313.22 ± 36.27**	
Worldwide [18]	**33**		**45**		**420**	

The values of specific activity for ^{238}U, ^{232}Th, and ^{40}K have been found to lie in the range of 5.2 ± ± 0.4 to 55.1 ± 1.8 Bq/kg with an average of 25.19 ± ± 1.95 Bq/kg, from 2.1 ± 0.2 to 27.5 ± 0.8 Bq/kg with an average value of 10.97 ± 1.40 Bq/kg and from 96.5 ± 2.0 to 838.2 ± 8.8 Bq/kg with an average value of 313.22 ± ± 36.27 Bq/kg, respectively. Obviously, Table 2 indicates that the maximum specific activity of ^{238}U, ^{232}Th, and ^{40}K was in sample D10 (Decorative Stone, Belcar, made in Spain), while the minimum was in D21 (Decorative Alabaster, Yunfu, made in Iran), respectively. The results from Fig. 2 show that the values of specific activity for ^{238}U in all samples were lower than the worldwide average of 33 Bq/kg according to the UNSCEAR 2008 Report [18], except samples D7, D8, D10, D13, D23, and D25 (see Fig. 2) were greater than the worldwide average. This fact can be ascribed to the high Uranium concentration in the phosphate rocks which form the main raw materials of decorative stone and cement. For ^{232}Th, as shown in Fig. 3, all values of specific activity were within the worldwide average (45 Bq/kg), according to the UNSCEAR 2008 Report [18]. As concerns ^{40}K radionuclide, there are seven samples (D1, D3, D7, D8, D9, 10, and D11) that were higher than the worldwide average (420 Bq/kg) [18], as seen in Fig. 4. The high specific activity of Potassium recorded may be due to the difference in the types of raw materials introduced in the manufacture of each type of decorative material, as well as may be due to the fact that the activity concentrations differ geologically in the soil of manufacture to another.

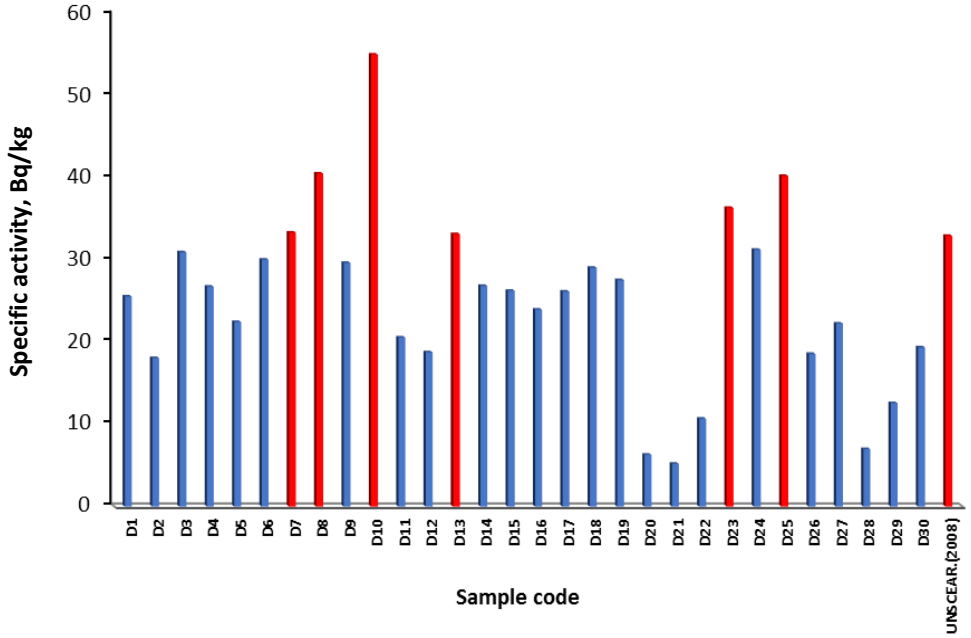

Fig. 2. Comparison of specific activity for ^{238}U with world average by UNSCEAR 2008 Report. (See color Figure on the journal website.)

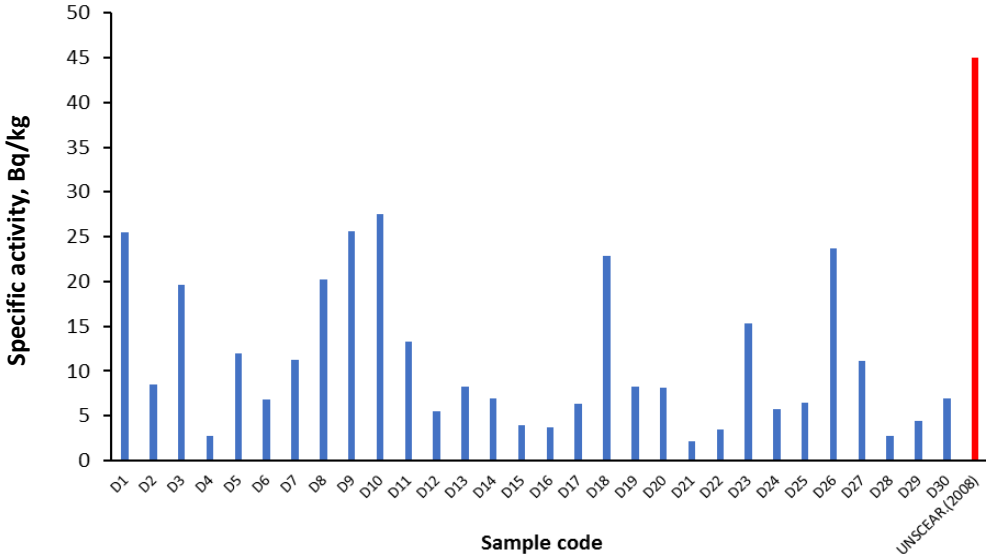

Fig. 3. Comparison of specific activity for ^{232}Th with world average by UNSCEAR 2008 Report. (See color Figure on the journal website.)

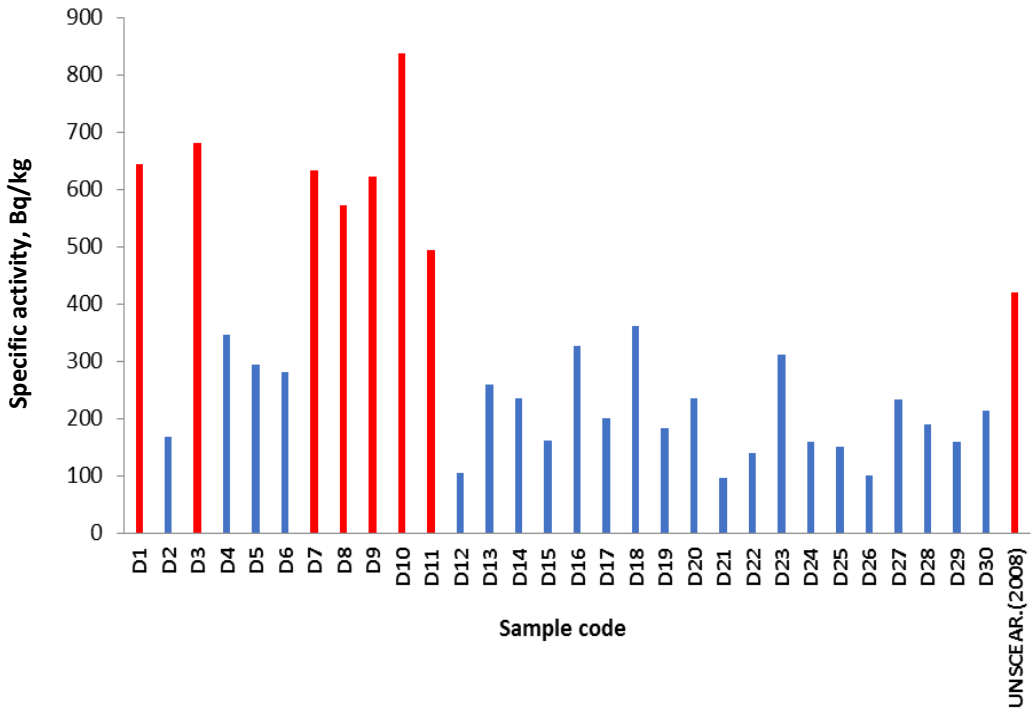

Fig. 4. Comparison of specific activity for ^{40}K with world average by UNSCEAR 2008 Report. (See color Figure on the journal website.)

Table 4. **Results of Ra_{eq}, H_{ex}, H_{in}, I_{γ}, and I_{α}**

Sample code	Ra_{eq}, Bq/kg	H_{ex}	H_{in}	I_{γ}	I_{α}
D1	111.7	0.302	0.371	0.855	0.128
D2	43.2	0.117	0.166	0.317	0.091
D3	111.5	0.301	0.385	0.857	0.155
D4	57.3	0.155	0.227	0.437	0.134
D5	62.3	0.168	0.229	0.466	0.113
D6	61.4	0.166	0.247	0.456	0.151
D7	98.2	0.265	0.356	0.757	0.167
D8	113.6	0.307	0.417	0.855	0.203
D9	114.2	0.308	0.389	0.869	0.149
D10	159.0	0.429	0.578	1.201	0.276
D11	77.7	0.210	0.266	0.600	0.103
D12	34.7	0.094	0.145	0.250	0.094
D13	65.1	0.176	0.265	0.477	0.166
D14	54.9	0.148	0.221	0.405	0.135
D15	44.5	0.120	0.191	0.324	0.132
D16	54.5	0.147	0.212	0.415	0.120
D17	50.8	0.137	0.208	0.372	0.131
D18	89.6	0.242	0.321	0.663	0.146
D19	53.5	0.145	0.219	0.389	0.138
D20	36.1	0.097	0.114	0.280	0.032
D21	15.6	0.042	0.056	0.120	0.026
D22	26.5	0.072	0.101	0.200	0.054
D23	82.3	0.222	0.321	0.604	0.182
D24	51.7	0.140	0.224	0.372	0.157
D25	61.1	0.165	0.274	0.434	0.202
D26	60.2	0.163	0.213	0.428	0.093
D27	56.1	0.152	0.212	0.415	0.112
D28	25.6	0.069	0.088	0.201	0.035
D29	31.2	0.084	0.118	0.234	0.063
D30	45.8	0.124	0.176	0.341	0.097
Average ± SE	**65.0 ± 5.8**	**0.175 ± 0.015**	**0.243 ± 0.02**	**0.486 ± 0.044**	**0.126 ± 0.009**
Worldwide	**< 370 [23]**	**< 1 [24]**	**< 1 [24]**	**< 1 [24]**	**< 1 [24]**

The results of Ra_{eq}, H_{ex}, H_{in}, I_{γ}, and I_{α} are listed in Table 4. From this Table, Ra_{eq} values vary from 15.6 to 159.0 Bq/kg with an average value of 65.0 ± ± 5.8 Bq/kg. Also, H_{ex}, H_{in}, I_{γ} and I_{α} values vary from 0.042 to 0.429 Bq/kg, with an average value of 0.175 ± 0.015 Bq/kg, from 0.056 to 0.578 Bq/kg, with an average value of 0.243 ± 0.02 Bq/kg, from 0.120 to 1.201 Bq/kg, with an average value of 0.486 ± 0.044 Bq/kg, and from 0.026 to 0.276 Bq/kg, with an average value of 0.126 ± ± 0.009 Bq/kg, respectively. Fig. 5 shows the comparison results of Ra_{eq}, H_{ex}, H_{in}, I_{γ}, and I_{α} worldwide. From it, one can see that the Ra_{eq} values in all samples are lower than the recommended maximum value of 370 Bq/kg [23], while H_{ex}, H_{in}, I_{γ}, and I_{α} values were lower than the permissible limit which equals 1 [24], except decorative stone sample (D10) has the higher value of I_{γ} which is due to a high concentration of ^{238}U. The results value of $\dot{X}$, D_r, AGED, $AEDE_{indoor}$, and ELCR in samples under study are listed in Table 5.

Table 5. **Results of $\dot{X}$, D_r, AGED, $AEDE_{indoor}$, and ELCR**

Sample code	$\dot{X}$, μR/h	D_r, nGy/h	AGED, μSv/yr	$AEDE_{indoor}$, mSv/yr	ELCR·10^{-3}
D1	247.5	54.1	388.0	0.265	0.929
D2	91.4	20.5	144.1	0.100	0.352
D3	248.5	54.6	391.8	0.268	0.937
D4	126.8	28.5	202.9	0.140	0.489
D5	134.5	29.9	212.1	0.147	0.514
D6	131.6	29.7	209.5	0.146	0.510
D7	219.9	48.6	349.0	0.239	0.835
D8	247.0	54.9	389.8	0.269	0.942
D9	251.2	55.1	394.1	0.270	0.946
D10	347.4	77.0	548.4	0.378	1.322
D11	174.1	38.2	274.6	0.187	0.656
D12	71.8	16.4	113.9	0.080	0.281
D13	137.6	31.2	218.8	0.153	0.535
D14	116.9	26.4	185.8	0.130	0.453
D15	93.2	21.3	149.0	0.105	0.366
D16	120.4	27.0	192.2	0.132	0.463
D17	107.3	24.3	170.7	0.119	0.418
D18	190.9	42.3	299.0	0.208	0.727
D19	111.8	25.4	177.3	0.124	0.436
D20	81.3	17.6	127.4	0.087	0.303
D21	34.8	7.7	55.1	0.038	0.132
D22	57.9	12.9	91.8	0.063	0.222
D23	173.8	39.1	274.4	0.192	0.671
D24	106.8	24.5	170.4	0.120	0.421
D25	124.5	28.8	198.8	0.141	0.494
D26	122.0	27.1	188.1	0.133	0.465
D27	119.6	26.7	188.6	0.131	0.459
D28	58.4	12.8	92.7	0.063	0.220
D29	67.7	15.1	107.3	0.074	0.260
D30	98.6	22.1	156.1	0.108	0.379
Average ± SE	**140.5 ± 12.9**	**31.3 ± 2.8**	**222.5 ± 20.3**	**0.153 ± 0.013**	**0.537 ± 0.048**
Worldwide	**–**	**55 [25]**	**≤ 300 [26]**	**0.42 [27]**	**–**

From this Table, it is found that the values of $\dot{X}$ were ranged from 34.8 to 347.4 μR/h, with an average value of 140.5 ± 12.9 μR/h, D_r ranged from 7.7 to 77.0 nGy/h, with an average value of 31.3 ± ± 2.8 nGy/h, the values of AGED ranged from 55.1 to 548.4 μSv/yr, with an average value of 222.5 ± 20.3, $AEDE_{indoor}$ ranged from 0.038 to 0.378 mSv/yr, with an average value of 0.153 ± ± 0.013 mSv/yr, and the values of ELCR ranged from $0.132 \cdot 10^{-3}$ to $1.322 \cdot 10^{-3}$, with an average value of $0.537 \pm 0.048 \cdot 10^{-3}$. As shown in Fig. 6, it is found that the values of D_r in all samples were within the permissible limit with a factor of 55 nGy/h [25], except for two samples (D9 and D10), these results are due to the high concentration of Uranium in these samples. Also, it is found that the values of AGED in most samples were within the permissible limit ≤ 300 [26], except for samples D1, D3, D7, D8, D9, and D10. The values of $AEDE_{indoor}$ in all samples were found lower than worldwide

(0.42 mSv/yr) [27]. At last, it may be concluded that this study shows that the values of some radiological hazards (I_γ, D_r, and AGED) for some decorative materials samples (Figs. 5 and 6) are higher than the worldwide average according to UNSCEAR 2000 Report, UNSCEAR 2008 Report, and the ICRP, so it will be recommended to reduce to use these samples in house.

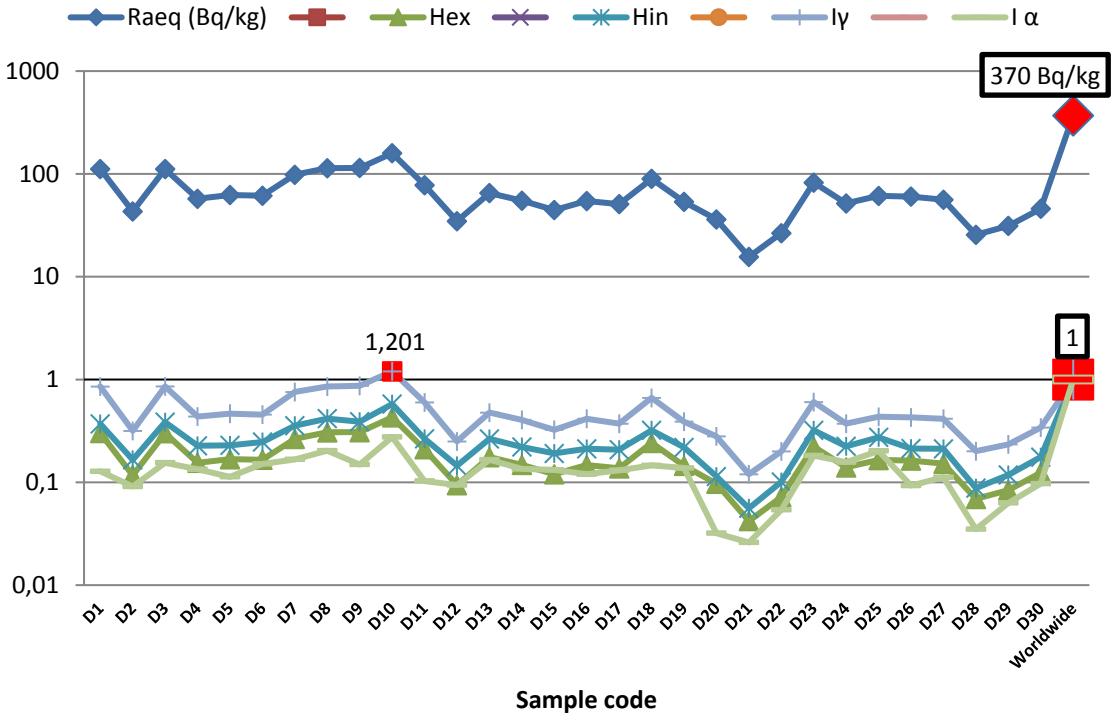

Fig. 5. Comparison of Ra_{eq}, H_{ex}, H_{in}, I_{γ}, and I_{α} with worldwide by OECD and ICRP. (See color Figure on the journal website.)

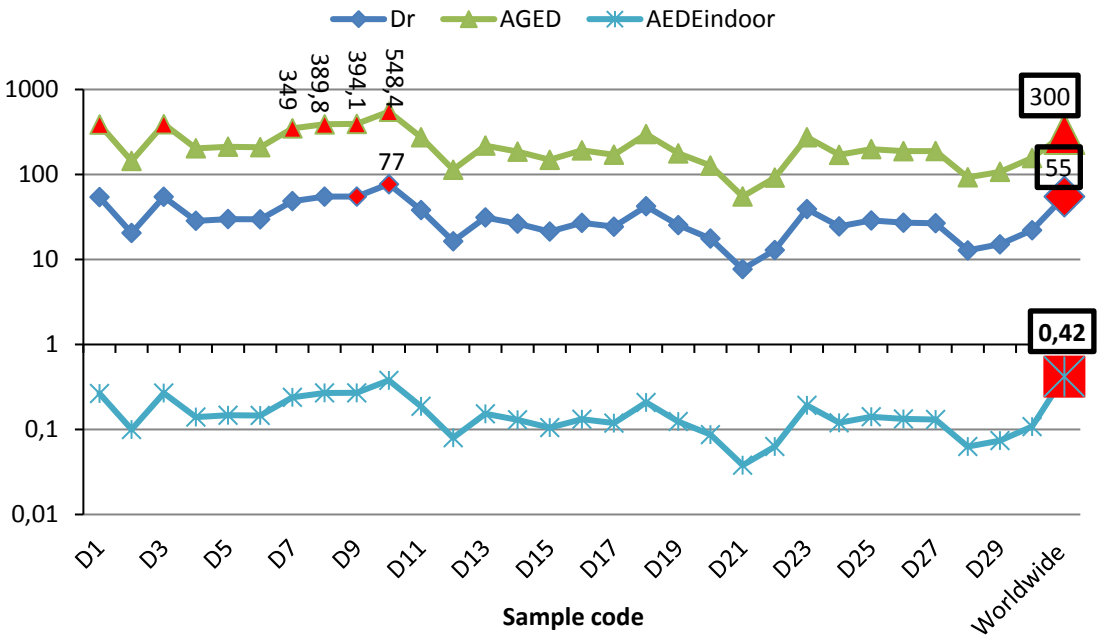

Fig. 6. Comparison of D_r, AGED, and $AEDE_{indoor}$ with worldwide by UNSCEAR Reports and ICRP. (See color Figure on the journal website.)

Table 6 shows the comparison between the results of specific activity of ^{238}U, ^{232}Th, and ^{40}K in the decorative materials collected from Iraqi markets with several countries around the world. It is found the average specific activity of ^{232}Th and ^{40}K in the present study was lower than the results of the other studies. The average value of ^{238}U in the present study was higher than in Turkey and lower than in other countries (see Table 6).

Table 6. **Comparison of the present study with other studies of many different countries**

Country	Average of specific activity, Bq/kg			Reference
	^{238}U	^{232}Th	^{40}K	
Egypt	52.2	31.2	1055.7	[28]
Iran	72	76	1193	[29]
Turkey	15.85	33.76	359	[30]
Lebanon	85.38	65.7	859.7	[31]
Italy	69	58	860	[32]
Iraq	25.19	10.97	313.22	Present

4. Conclusions

The data obtained in this study improve the suitability of the spectrometry technique for such complex samples. The specific activity in most decorative materials studied in this work is found worldwide according to UNSEAR 2008, except for some samples that have ^{238}U (D7, D8, D10, D13, D23, and D25) and ^{40}K (D1, D3, D7, D8, D9, 10, and D11). Also, it was found that most of the samples worldwide are not radiologically hazardous according to OECD, UNSEAR 2000 Report and ICRP, except for some samples that have I_γ (D10), D_r ((D9 and D10), and AGED (D1, D3, D7, D8, D9, and D10). Then, from the results of data in the present study, it is noted that sample D10 (decorative stone, made in Spain) has higher than natural radioactivity levels. Therefore, it is not recommended to use this sample, it is the main source of radiation hazards.

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ОЦІНКА ПРИРОДНОЇ РАДІОАКТИВНОСТІ ТА ЇЇ РАДІОЛОГІЧНОЇ НЕБЕЗПЕКИ В ДЕЯКИХ ДЕКОРАТИВНИХ МАТЕРІАЛАХ В ІРАКУ

У більшості будівель використовуються естетично привабливі декоративні матеріали, що можуть містити різну кількість радіоактивних елементів. Таким чином, здоров'я людей, що мешкають і працюють, піддається постійному впливу іонізуючого випромінювання. Природна радіоактивність (^{238}U, ^{232}Th і ^{40}K) виміряна в декоративних матеріалах, зібраних на різних місцевих ринках Іраку, за допомогою захищеного високоефективного детектора NaI(Tl). Для всіх проб були розраховані деякі індекси радіологічної небезпеки. Отримані результати показали, що максимальне значення питомої активності для ^{238}U, ^{232}Th і ^{40}K припадає на декоративний камінь, а мінімальне – на декоративний алебастр. Це дослідження показало, що природна радіоактивність і радіологічна небезпека в більшості зразків декоративних матеріалів були в межах, допустимих Науковим комітетом ООН з впливу атомної радіації (UNSCEAR), Міжнародною комісією з радіологічного захисту (ICRP), Організацією економічного співробітництва та розвитку (OECD) та ін. Таким чином, більшість зразків декоративних матеріалів у цьому дослідженні можна використовувати без ризику для здоров'я.

Ключові слова: природна радіоактивність, декоративні матеріали, будівельні матеріали, γ-спектроскопія.

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