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Study of Natural Radioactivity for Some Building materials used in Al Kharj Area

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Abstract: **The aim of this study is to determine the radioactivity content of different types for building materials. Twenty four samples, from both local and foreign product were collected and measured using gamma spectrometry system. The activity concentrations have been determined for radium (226Ra), thorium (232Th) and potassium (4OK) in each sample. The samples were crushed and dried in controlled furnace for around twenty four hours, and then stored for four weeks in plastic Marinelli beakers. From the measured gamma-ray spectra, activity concentrations of marble building materials 238U (0.72– 43.2Bq/kg), 232Th (0.20 –33.10 Bq/kg), 226Ra (0.43–33.1 Bq/kg) and 40K (0.70–897.2 Bq/kg) for granite 238U (0.04–315.3 Bq/kg), 232Th (0.02–186.1 Bq/kg), 226Ra (0.03–147.2 Bq/kg) and 40K (0.30 – 1482.6 Bq/kg) The results are compared with the published data of other countries and with the world average limits. It is concluded that the measured radioactivity of building materials are within acceptable levels and does not poses any risk from radiation protection point of view. The results indicated that all the samples collected used as building materials in Alkharj area are safe in general for the radioactivity levels.**

Keywords: **Radioactivity concentration, building materials, Radium Equivalent, Radiation Hazard, Annual dose.**

1. INTRODUCTION

The main sources of such exposure are the cosmic rays and the terrestrial natural radionuclide's (such as 238U radionuclide) that are occurring at trace levels in the Earth's crust. It is estimated that the absorbed dose rate in air as a result of the exposure to cosmic radiation at the sea level is ≈30 nGy/h . Building materials contain various amounts of natural radioactive nuclides. For example, materials derived from rock and soils contain mainly natural radionuclide's of the uranium (^{238}U) and thorium (^{232}Th) series, and the radioactive isotope of potassium (^{40}K).

In the uranium series the decay chain segment starting from radium (^{226}Ra) is radiologically the most important [1].

Measurement of radioactivity in the building materials is very important to determine the environmental hazards on the health of humans and is very essential to set the standard radiation levels and national guidelines according to the international recommendations [2].All types of building materials such as concrete, cement, brick, marble, granite, limestone, and gypsum, etc. cause direct radiation exposure because of their radium, thorium and potassium. The term 'granite' is used to describe all igneous rock types used as building materials in stone market, it is widely used as a building and ornamental material. [3]

The natural level of radioactivity in building materials is one of the major causes of external exposure to γ-rays. By the determination of the radioactivity level in building materials, the indoor radiological hazard to human health can be assessed. During the last decades, there has been an increasing interest in the study of radioactivity in various building materials [4]. The main sources of the external γ-radiation are the radionuclides of the Uranium, Thorium and Potassium series [3]. Naturally occurring radioactive materials (NORMs) are the major sources which cause exposure to people by ionizing radiation of about 2.3mSv/year in the average [5]. The use of such decorative granites as building materials in a home can thus result in the long-term whole-body exposure of the occupants to this radiation [6] . In this context, limits have been set on the concentrations of radionuclides in various building materials and the use of materials with abnormally high levels of radioactivity has been banned. Because of its polished surface and its availability in a variety of attractive colors, marble and ceramic are widely used as building and construction materials. It is mostly used as a lining on walls and floors in dwellings. The presence of other minerals in marble gives it a variety of attractive colors. However, usually suitable as building and ornamental materials for interior and exterior use, are hard natural stones that require harder tools to be cut, shaped and polished, compared to marble. The objective of this study is to determine the specific radioactivity concentrations of ^{238}U, ^{232}Th, ^{226}Ra and ^{40}K in some kinds of building materials used in Alkharj area.The average of radium equivalent activity (Raeq), the total absorbed dose rate (D), the external (H_{ex}), internal (H_{in}) and the representative (Iγr) hazard indices have been estimated and compared with the recommended limits from UNSCEAR data. the correlations between thorium, uranium and potassium will be shown with an aim to correlate the graphic characteristics of commercial building materials with their corresponding dose rates for natural radioactivity. These results are of great interest in the environmental radiological protection study, Local authorities can limit the use of building materials that cause a significant increase in radiation exposure due to higher levels of indoor radon, and external gamma exposure. According to international recommendations quoted in the Basic Safety Series No. 115 from the IAEA, the use of building materials containing enhanced concentrations of NORM should be controlled and restricted under the application of the radiation safety standards. Several publications deal with measuring low levels of naturally occurring radioactive isotopes in building materials rocks [7].

Table: 1 result of annual dose equivalent of natural background radiologic [8].

Radiation source	Equivalent dose per year (µSv/year)		
	Internal exposure	External exposure	Total
Ionizing radiation and neutrons		300	300
Cosmic rays and its progenies reaction	15		15
^{40}K	180		120
^{87}Rb	66		60
^{238}U series	//		
$^{238}U \rightarrow ^{234}U$	90		10
^{230}Th	7		7
^{226}Ra	7		7
$^{222}Ra \rightarrow ^{214}Po$	800		800
$^{210}Pb \rightarrow ^{210}Po$	130		130
^{232}Th series	//		
$^{232}Th \rightarrow$	143	140	3
$^{228}Ra \rightarrow ^{224}Ra$	13		13
$^{220}Pb \rightarrow ^{208}Ti$	170		170
Total ≈	2000	650	1340

2. MATERIAL AND METHODS

For this study, Twenty four samples of the most commonly used building materials were collected from different parts of Alkharj city in Saudi Arabia, the sample selection consisted of the available materials for local and foreign ceramic, marble and granite usage. These samples either local or imported are widely used as building materials.. Radioactivity in studied samples was measured using a low-level counting system consisting of a high-purity Ge detector (HPGe). It is explained elsewhere [9,10].

The concentration of ^{238}U was calculated from the activity of ^{234}Th (63.30 keV) with an emission percentage of 4.471%.While for ^{226}Ra was determined by measuring its gamma emitters ^{214}Pb (294.917 and 352.001 keV) with an emission percentage of 19.3% and 37.6% respectively and ^{214}Bi (609.312 keV) with an emission percentage of 46%. To calculate the concentration of ^{232}Th the activity of the ^{228}Ac (T½ = 6.21 h) lines at 338.4 and 911.21 keV with an emission percentage 11.1% and 26.6%, respectively were used. The concentration of the 40K was calculated using the gamma line at energy 1462.85 keV of emission percentage 10.6%. The total uncertainty (σ_{tot}) of the calculated activities is composed of the counting statistical (σ_{st}) and weighted systematic error ($\sigma_{sys,i}$) calculated by the following formula [11].

$$\sigma_{tot} = \sqrt{\sigma^2{}_{st} + \frac{1}{3}\sum_1 \sigma^2{}_{sys,i}} \qquad (1)$$

The minimum detection limits of the setup for ^{238}U, ^{232}Th, ^{226}Ra and ^{40}K were measured to be 0.05, 0.02, 0.04and 0.28 Bq/kg, respectively.

The radioactivity activity concentration (A) of individual radionuclide for a peak at energy E in studied samples will be calculated as

$$A\,(BqKg^{-1}) = \frac{(N_{Ei})net}{\epsilon_{Ei} I_{Ei} t M} \qquad (2)$$

Where $(N_{Ei})_{net}$= net photopeak area at energy (E) of radionuclide i (counts), $(N_{Ei})_{net} = (N_{Ei})_S - (N_{Ei})_B$

A = specific activity concentration of individual radionuclide i for a peak at energy E in ceramic samples $(BqKg^{-1})$

N_S = total net counts at energy E of radionuclide i (counts),

N_B = background net counts at energy E of radionuclide i (counts),

ϵ_{Ei}= the photopeak detection efficiency of a particular γ-ray energy (E),

I_{Ei} = absolute intensity corresponding to the photo peak at energy (E),

t = counting time of the ceramic sample (s)

M = mass of sample (kg)

Instrumentation: A hyper-pure germanium (HPGe) detector with high resolution gamma-ray spectroscopy low background counting system was used to determine the concentration levels of studied samples. The detector was surrounded by cylindrical lead shield of thickness 10 cm to reduce the background radiation with a movable cover. The lead shield contains an inner concentric cylinder of 0.2 cm thick copper to attenuate the X-rays stimulated in the lead shield itself. The energy calibration was carried out by using multi radioactive standard sources emitting γ-rays of precisely known energy, and then identifying the peak position in channels with this energy. The efficiency calibration of the HPGe detector was carried out over the entire energy range of interest using standard radioactive sources. The area under each identified peak of the spectra was calculated individually. The background carefully measured of Marinelli beaker with counting time 86400 s, then placed on the detector to get the same geometry. The net number of counts for each photo peak was obtained by subtracting the background counts from the total counts in the same photo peak, for 80000 seconds.

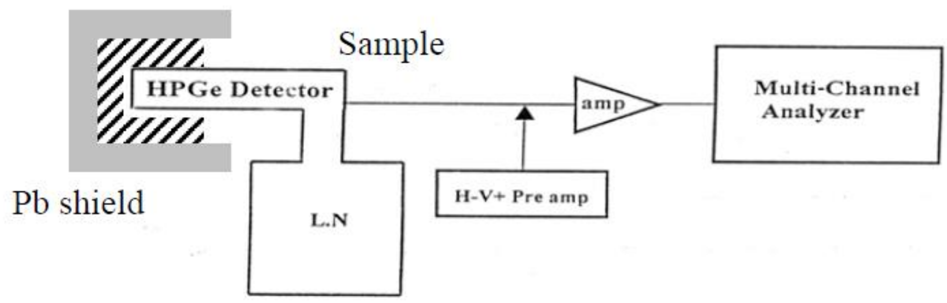


Figure1. Scheme for the measurement system using High Purity Germanium detector HPGe

Internal and External Radiation Hazard Index: Radiation hazards due to natural radionuclides of ^{40}K, ^{232}Th and ^{226}Ra may be internal or external depending upon the location of a receptor indoor or outdoor. These hazards are defined in terms of internal or indoor and external or outdoor radiation hazard index and are denoted by H_{in} and H_{ex}, respectively. Assuming 370 Bq/kg of ^{226}Ra, 259 Bq/ kg of ^{232}Th and 4810 Bq/kg of ^{40}K produce the same gamma-ray dose rate, and limiting the external γ-radiation dose up to 1.5 mSv/y, a proposed "external hazard index (H_{ex})" has been introduced [12].

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad (4)$$

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (5)$$

Where A_K, A_{Th} and A_{Ra} are the activity concentrations of ^{40}K, ^{232}Th and ^{226}Ra respectively. The indoor hazard index is calculated to determine the radiation hazards from ^{40}K, ^{232}Th and ^{226}Ra.

Gamma-radiation hazard index: The γ-radiation hazard index ($I_{\gamma r}$) is a representative level index which is defined as[13].

$$I_{\gamma r} = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \quad (6)$$

This index can be used to estimate the level of γ-radiation hazard associated with the natural radionuclides in specific materials. Values of index I ≤1 correspond to ≤ 0.3 mSv/y, while I ≤ 3 correspond to ≤ 1 mSv/y.

3. RESULTS AND DISCUSSION

Different photo peaks from uranium, thorium and potassium series samples which resolved energy photo peaks were observed. There is more than one sample for some building material types. The activity concentrations of such samples were averaged.

Table2. Activity concentration for all building materials (ceramic, marble and granite) samples (Bq/kg).

No.	Sample code	Origin	Commercial name	Activity (Bq/kg)			
				^{238}U	^{232}Th	^{226}Ra	^{40}K
	S01	Iran	Cream marvel	14.60±0.10	0.19±0.06	9.10±0.3 0	3.60±0.2
	S02	Saudi	Salmon	54.6±0.3	43.9±0.5	28.1±0.6	1468.9±0.1
	S03	Saudi	Marble	18.50±0.10	1.90±0.10	13.00±0.30	24.20±0.10
	S04	Saudi	Sweet gold	1.9±0.1	0.60±0.02	0.84±0.05	13.2± 0.91
	S05	India	Guatemala	27.90±0.01	34.0±0.2	19.10±0.1	886.10±0.1
	S06	Saudi	Saudi green	0.05±0.01	0.08±0.01	0.06±0.01	0.480±.04
	S07	Pakistan	Golden camel	10.6±0.1 0	0.91±0.11	16.30±0.3	6.90±0.10
	S08	Saudi	Royal gold	0.07±0.01	0.02±0.01	0.07±0.03	0.28± 0.03
	S09	Italy	(Paly sandro grey)	0.72±0.04	0.60±0.05	4.50±0.2	0.69±0.05
	S10	Italy	Cecelia perlato	0.06±0.03	0.07±0.01	0.04±0.01	0.51± 0.05
	S11	Italy	Sheboleno	5.01±0.10	3.89±0.40	2.80± 0.1	150.50±0.1
	S12	India	Robe	89.6±0.2	68.7±07	44.1±0.8	1375.3±0.9
	S13	Turkey	Afeon shegar	2.20± 0.01	0.26±0.04	0.41± 0.06	3.10± 0.10
	S14	China	Rosa beta	88.2±0.20	72.2±0.80	36.9±0.7 0	1216.3±0.8
	S15	Greek	Crystal	1.80±0.01	0.45±0.07	0.43± 0.06	1.70± 0.10
	S16	Italy	Gallo royal	115.9±0.20	44.8±0.40	57.1±0.10	1528.7±0.1
	S17	Spain	Cream marvel	6.70± 0.1 0	0.42±0.07	4.60± 0.11	5.30± 0.1
	S18	Spain-Italy	Rosa yoryeno	105.1±0.20	84.1±0.80	47.9±0.9	1411.1±0.9
	S19	Spain	Light Emprado	44.90±0.10	0.98±0.12	33.40±0.6	16.20± 0.2
	S20	Portugal	Rosa entema	0.58±0.08	0.04±0.01	0.08±0.04	1.4±0.10
	S21	Brazil	Azoles makoba	7.90± 0.10	21.90±0.20	2.40± 0.1	394.9± 0.3
	S22	Italy	Brachia	312.3±0.40	185.3±0.20	146.0±0.3	1192.1±0.5
	S23	France	Yellow sena	1.80± 0.01	0.87±0.10	1.20± 0.1 0	38.10± 0.1
	S24	Brazil	Bradezio (grey)	1.6±0.10	2.9± 0.50	0.24±0.03	12.9± 0.5

The average radionuclide activity concentration of building material samples are reported in Table (2). The result given in maximum concentrations of ^{238}U was in sample (S22) (Brachia) 312.3±0.40 Bq/kg and the minimum value was in sample (S06) (Saudi green) 0.05±0.01 Bq/kg.

For ^{232}Th the maximum level was observed in sample (S22) (Brachia) 185.3±0.20Bq/kg and the minimum level in sample (S08) (Royal gold) 0.02±0.01 Bq/kg. For ^{226}Ra the maximum level was observed in sample (S22) (Brachia)

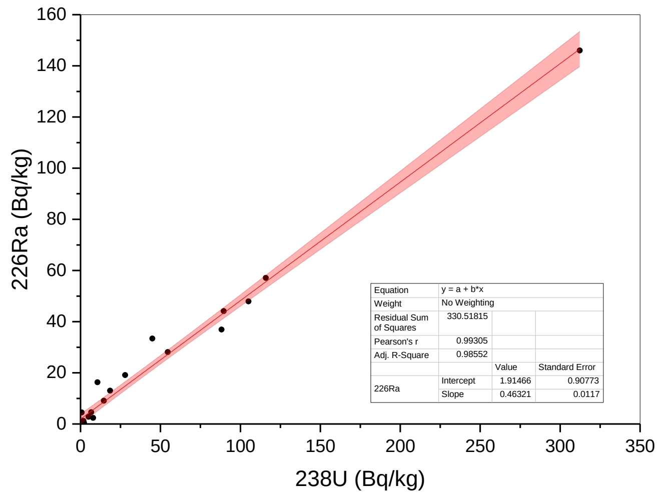
146.0±0.3 Bq/kg and the minimum level in sample (S10) (Cecelia perlato) 0.04±0.01 Bq/kg. For ^{40}K the maximum level was observed in sample (S12) (Brachia) 1375.3±0.9 Bq/kg and the minimum level in sample (S08) (Royal gold) 0.28± 0.03Bq/kg.

In order to observe a correlation between uranium and radium graph was plotted in Fig.1 , and a good correlation coefficient was determined (0.9094) which indicates the secular equilibrium between the parent and the daughter Fig.2 represents good linear correlation (correlation coefficient=0.948) between thorium and potassium concentrations.

The activity concentrations for different building materials are reported in Table (2). Maximum concentrations of ^{238}U, ^{232T}h, ^{226}Ra and ^{40}K were 314.4±0.4, 186.4±0.2 Bq/ kg,147.0 ±0.3 Bq/ kg for (G-18) (Azoles bahea) and 1531.7 ±0.1 Bq/kg for (G-13) (Carmen red) respectively.

Table3. Activity concentration for marble building material samples (Bq/kg).

Sample No.	Sample code	Origin	Commercial name	Activity (Bq/kg)			
				^{238}U	^{232}Th	^{226}Ra	^{40}K
	S01	Iran	Cream marvel	13.50±0.10	0.20±0.05	8.50±0.2 0	3.30±0.1
	S03	Saudi	Marble	17.50±0.10	1.70±0.10	12.00±0.20	23.10±0.10
	S05	India	Guatemala	29.90±0.01	33.10±0.1	18.20±0.1	897.10±0.1
	S07	Pakistan	Golden camel	9.60±0.1 0	0.87±0.11	16.30±0.3	7.90±0.10
	S09	Italy	(Paly sandro grey)	0.72±0.04	0.56±0.05	4.50±0.2	0.69±0.05
	S11	Italy	Sheboleno	4.30±0.10	3.70±0.40	2.60± 0.1	154.50±0.1
	S13	Turkey	Afeon shegar	2.10± 0.01	0.25±0.04	0.43± 0.06	2.90± 0.10
	S15	Greek	Crystal	1.70±0.01	0.46±0.07	0.44± 0.06	1.60± 0.10
	S17	Spain	Cream marvel	6.80± 0.1 0	0.41±0.06	4.50± 0.10	5.20± 0.1
	S19	Spain	Light Emprado	43.20±0.10	0.99±0.12	33.10±0.6	16.40± 0.2
	S21	Brazil	Azoles makoba	8.20± 0.10	22.80±0.20	2.30± 0.1	401.8± 0.3
	S23	France	Yellow sena	1.90± 0.01	0.86±0.10	1.10± 0.1 0	39.10± 0.1



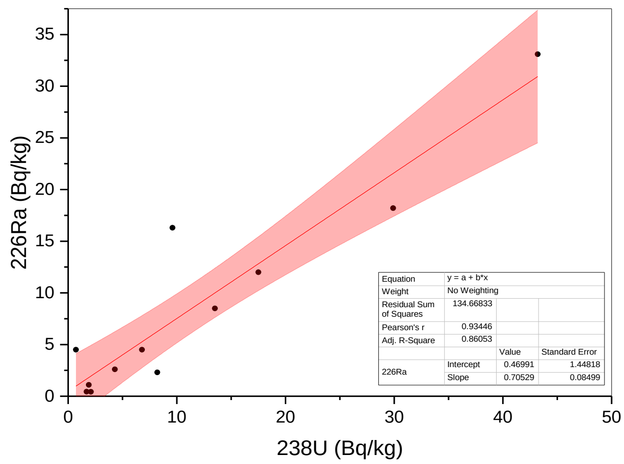


Figure1.The correlation between ^{238}U and ^{226}Ra concentration in some selected samples:

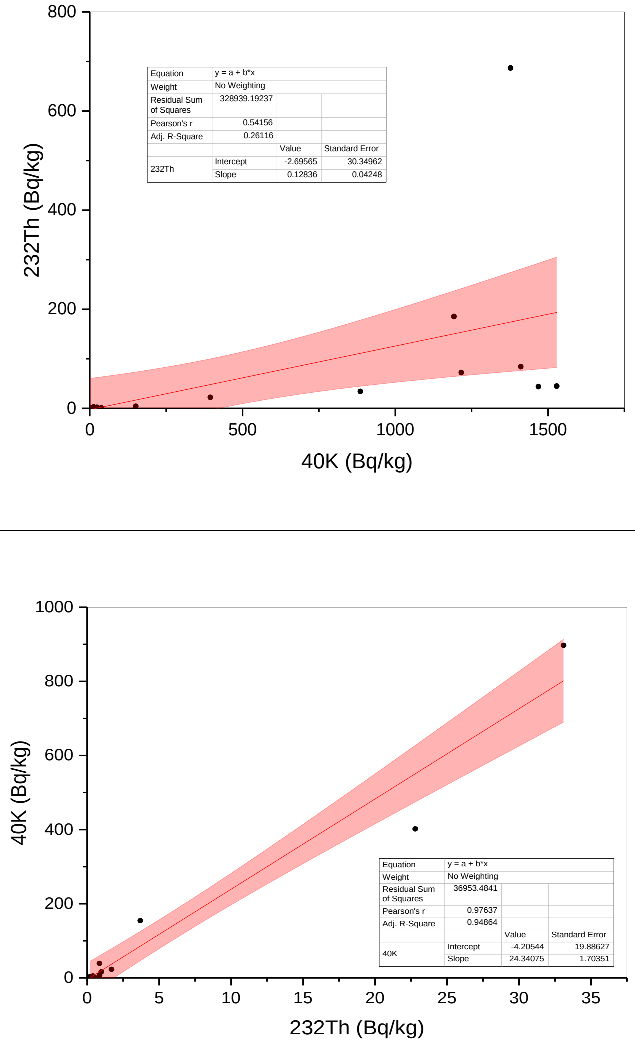


Figure2. The correlation between ^{40}K and ^{232}Th concentration in different samples.

Fig.3 shows the strong correlation between uranium and radium in granite samples under investigation (correlation coefficient=0.9898) which indicate the secular equilibrium between ^{238}U and ^{226}Ra.

Fig. 4 shows the good correlation between the concentrations of the two radioactive isotope (^{232}Th, ^{226}Ra) (correlation coefficient = 0.9395). To assess the radiological risk of the building materials used, it is useful to calculate the radium equivalent activity [14].

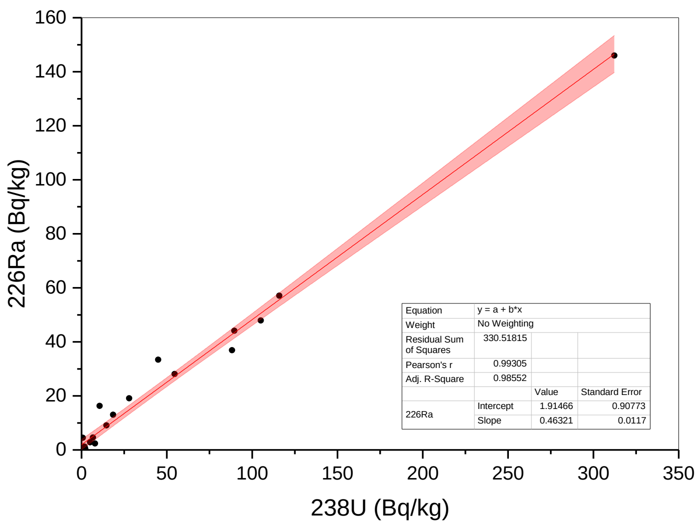
$$Ra_{eg} = (A_{Th} \times 1.43) + A_{Ra} + (A_K \times 0.077) \qquad (7)$$

WhereA_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K, respectively. The calculated values of the radium equivalent Ra_{eq} for the studied samples are given in Table (5). These values range from (S12) (Robe) 245.711 Bq/kg to (S06) (Saudi green) 0.126 Bq/kg

Table4. Activity concentration for different granite building materials samples (Bq/kg).

Sample No.	Sample code	Origin	Commercial name	Activity (Bq/kg)			
				^{238}U	^{232}Th	^{226}Ra	^{40}K
	S02	Saudi	Salmon	52.6±0.2	41.9±0.4	27.3±0.5	1482.9±0.1
	S04	Saudi	Sweet gold	1.9±0.1	0.56±0.02	0.82±0.05	12.3± 0.9
	S06	Saudi	Saudi green	0.04±0.01	0.07±0.01	0.05±0.01	0.440.04
	S08	Saudi	Royal gold	0.05±0.01	0.02±0.01	0.06±0.03	0.27± 0.03
	S10	Italy	Cecelia perlato	0.05±0.03	0.06±0.01	0.03±0.01	0.51± 0.05
	S12	India	Robe	85.6±0.2	66.7±07	44.1±0.8	1382.3±0.9
	S14	China	Rosa beta	89.2±0.20	73.1±0.7 0	37.1±0.7 0	1226.3±0.8
	S16	Italy	Gallo royal	116.9±0.20	44.6±0.40	56.1±0.10	1531.7±0.1
	S18	Spain-Italy	Rosa yoryeno	107.1±0.20	85.1±0.90	48.8±0.9	1413.1±0.9
	S20	Portugal	Rosa entema	0.56±0.07	0.03±0.01	0.07±0.04	1.3±0.10
	S22	Italy	Brachia	313.3±0.40	185.3±0.20	146.0±0.3	1192.1±0.5
	S24	Brazil	Bradezio (grey)	1.5±0.10	3.0± 0.50	0.25±0.03	13.0± 0.5

These values range from 0.050 Bq/kg (Royal gold) (S08) to 313.3 Bq/kg (S22) (Brachia).



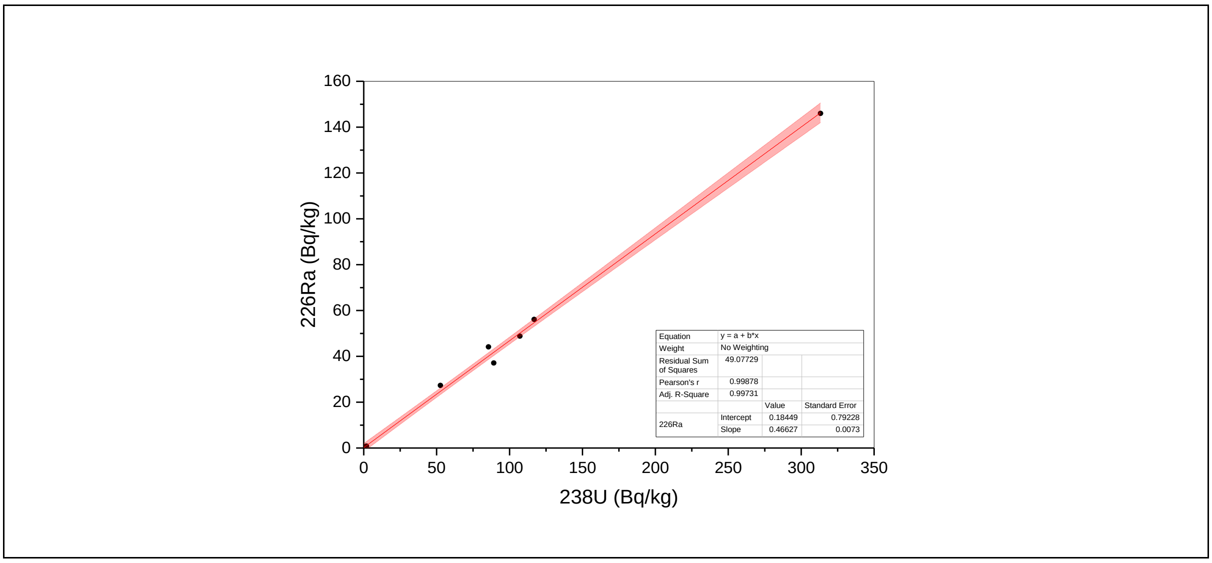


Figure3 The correlation between ^{238}U and ^{226}Ra concentration in ceramic samples.

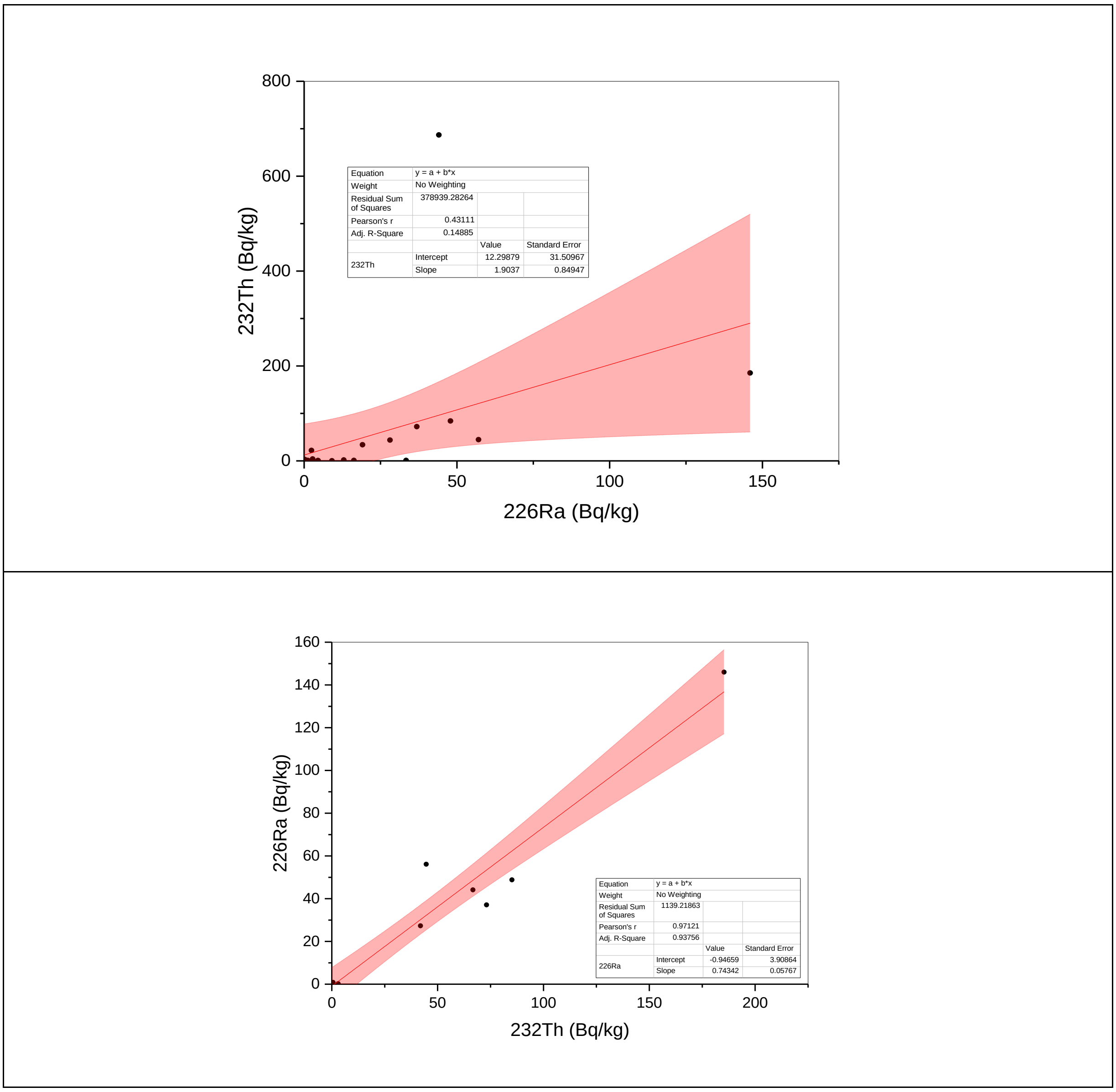


Figure 4 The correlation between ^{226}Ra and ^{232}Th concentrations in ceramic samples.

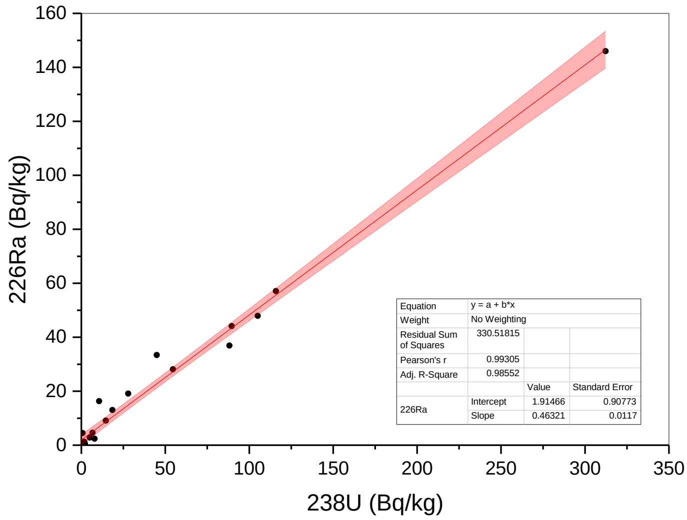
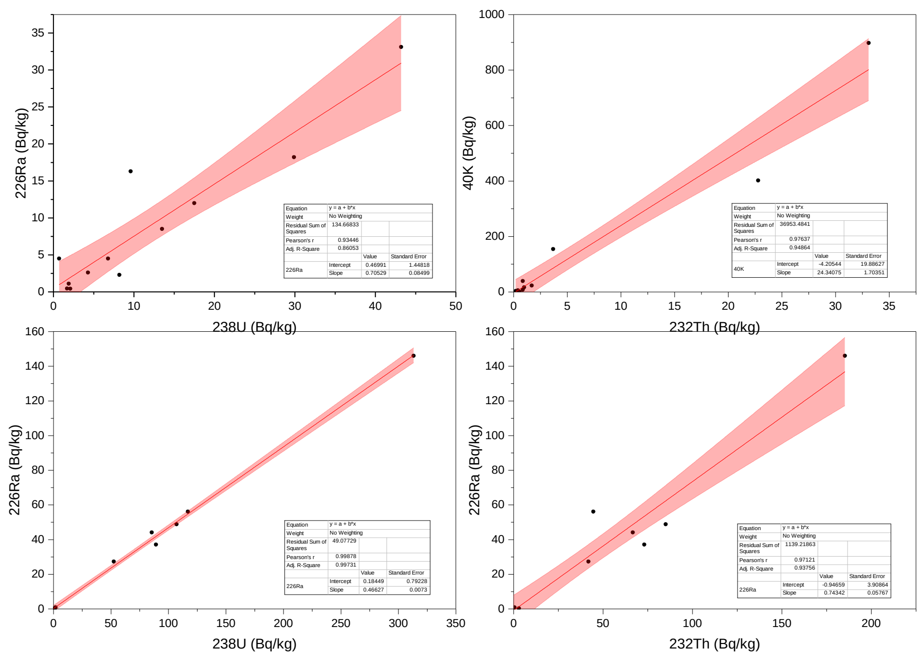


Figure4 The correlation between ^{238}U and ^{226}Ra concentration for all samples.



The value of this index must be less than unity for the radiation risk to be negligible [15].For the maximum value of H_{ex} to be less than unity, the maximum value of R_{aeq} must be less than 370 Bq/kg.

According to the calculated equation of H_{ex} [16],The values of H_{ex} for the studied marble samples range from 0.002 (S08) to 0.664 (S12) , values which indeed are less than unity and the values of H_{ex} for the studied granite samples range from 0.003 (S13) to 0.783 (S13) , values which indeed are less than unity.

The calculated values of the radium equivalent Ra_{eq} for the studied building material samples are given in Table (5).

Table5. Radium equivalent (Bq/kg), the external, internal, representative hazard indicates and dose rate (nGy/h), for different building materials samples.

No.	Sample code	Commercial name	Origin	Ra_{eq}	$H_{in} \leq 1$	$H_{ex} \leq 1$	$I_{in} \leq 1$	$DnGyh^{-1}$
	S01	Iran	Cream marvel	9.044	0.047	0.024	0.061	6.316
	S02	Saudi	Salmon	201.331	0.618	0.544	1.591	122.411
	S03	Saudi	Marble	16.211	0.076	0.043	0.112	10.061
	S04	Saudi	Sweet gold	2.563	0.009	0.006	0.019	1.791
	S05	India	Guatemala	132.914	0.408	0.359	1.039	77.561
	S06	Saudi	Saudi green	0.126	0.005	0.003	0.008	0.234
	S07	Pakistan	Golden camel	18.151	0.093	0.049	0.122	5.247
	S08	Saudi	Royal gold	0.089	0.003	0.002	0.006	0.144
	S09	Italy	Paly sandro (grey)	5.375	0.026	0.014	0.036	0.721
	S10	Italy	Cecelia perlato	1.584	0.006	0.004	0.011	1.197
	S11	Italy	Sheboleno	19.727	0.061	0.053	0.157	11.757
	S12	India	Robe	245.711	0.783	0.664	1.882	148.771
	S13	Turkey	Afeon shegar	1.009	0.003	0.002	0.007	1.219
	S14	China	Rosa beta	10.671	0.034	0.028	0.083	6.962
	S15	Greek	Crystal	1.222	0.004	0.003	0.008	1.148
	S16	Italy	Gallo royal	18.941	0.075	0.051	0.139	11.521
	S17	Spain	Cream marvel	1.245	0.005	0.003	0.008	1.547
	S18	Spain-Italy	Rosa yoryeno	5.569	0.018	0.015	0.041	3.317
	S19	Spain	Light Emprado	35.051	0.182	0.094	0.236	21.131
	S20	Portugal	Rosa entema	7.463	0.033	0.021	0.053	4.656
	S21	Brazil	Azoles makoba	65.741	0.183	0.177	0.511	38.033
	S22	Italy	Brachia	1.781	0.007	0.004	0.012	1.577
	S23	France	Yellow sena	5.382	0.017	0.011	0.031	2.488
	S24	Brazil	Bradezio(grey)	5.592	0.015	0.015	0.041	3.288

In addition to the external hazard, radon and its short-lived products are also hazardous to the respiratory organs.

The internal exposure to radon and its daughter products is quantified by the internal hazard index (H_{in}) which is given by the equation. $A_{Ra}/185 + A_{Th}/259 + A_K/4810 \leq 1$ (8)

If the maximum concentration of radium is half of the normal acceptable limit, then H_{in} will be less than 1.0 [16].For the safe use of a material in the construction of dwellings, H_{in} should be less than unity. The calculated values of H_{in} for the studied samples range from 0.003 (S13) to 0.783 (S12). Once again, all these values are less than unity. Conversion factors to transform specific activities A_K, A_U and A_{Th} of Potassium (k), Uranium (U) and Thorium (Th), respectively, in absorbed dose rate at 1 m above the ground (in nGy/h by Bq/kg) are calculated and the values are*:*

$D = 0.446A_u + 0.662\, A_{Th} + 0.048A_k$ (9)

In natural environmental radioactivity situations, the effective dose is calculated from the absorbed dose by applying the factor 0.7 Sv/Gy. The absorbed dose rates for all building materials samples is calculated and are listed in Table (5). The marble and granites are widely use d as building and covering materials, it is also possible to use an activity utilization index, proposed by [17].

and European Commission (EC), that facilitates the derivation of dose rates in air from different combinations of these three radio nuclides.

According to the (EC), the following gamma activity concentration index (Iγr) (representative level index) is derived for identifying whether a dose criterion is met: $I_{\gamma r} = A_{Ra}/150 + A_{Th}/100 + A_K/1500$ (10)

The index Iγr is correlated with the annual dose due to the excess external gamma radiation caused by superficial material. Values of index I ≤1 correspond to 0.3 mSv/y, while I ≤3 correspond to 1 mSv/y. Thus, the activity concentration index should be used only as a screening tool for identifying materials which might be of concern to be used as covering material. According to this dose criterion, materials with I ≤ 3 should be avoided, since these values correspond to dose rates higher than 1 mSv/y , which is the highest value of dose rate in air recommended for population[18].

4. CONCLUSIONS

Experimental measurements of the activity concentrations of various building material types (local and foreign) commonly used in Alkharj area have been carried out. The measured values of the activities of 40K, 226Ra and 232Th in the selected samples have been found to lie in the ranges: 0.68–897.1, 0.36–32.4 and 0.10–32.0 Bq/kg, respectively. These samples were also found to have a radium equivalent activity in the range 0.968 -132.914 Bq/kg. All of the samples were found to have hazard indices below 0.359 and 0.408 for the average external and internal hazard index, respectively. All the samples under investigation were found to have average external and internal hazard indices less than unity. The use of samples under investigation in the construction of dwellings is considered to be safe for inhabitants. Environmental monitoring should be carried out for marbles and granites where people might be exposed to radioactivity. It emphasizes the importance of accurate information concerning commercial names and origins of these marble and granites, because simple mistakes on that can produce serious economical and social consequences in the stone market sector.

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