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Radionuclides Measurements in Some Rock Samples Collected from the Environment of Hebron Governorate -Palestine

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Abstract: Using high-resolution γ- ray spectroscopy, the activity concentrations of some radioactive isotopes such as ^{238}U, ^{232}Th and ^{40}K in different rock samples, collected from 31 quarries in Hebron Governorate, Palestine were measured. For this purpose, 62 rock samples were gathered from different quarries of the region under investigation. The measured activities of ^{238}U, ^{232}Th and ^{40}K were found to range from 21.3 to 100.5, 1.3 to 11.6 and 13 to 583 Bqkg^{-1}, with average values of 47.6, 4.2 and 100 Bqkg^{-1}, respectively. For all samples, the radium equivalent activity (Ra_{eq}), as well as other radiological effects were estimated and found to be below the recommended levels. Therefore, the results indicate that the investigated materials can be used as building construction materials without radiation threat. This study can be used as a baseline for natural radioactivity mapping in the region under investigation. The results may also be used as reference data for monitoring possible radioactivity pollution in the future.

Keywords: Natural radioactivity, Effective dose rate, Rocks, Hazard index, Palestine.

Introduction

Human beings are continuously exposed to ionizing radiations of natural origin, and life on earth has developed under the ubiquitous presence of environmental gamma and charged-particle radiation. Radiation may be one of the effects for life and biological development. It is also, however, well established that ionizing radiation may harm life and biological systems. Measurement of natural radiation background is very important to determine the environmental hazards on human health and is essential to set the standard radiation levels and national guidelines according to international recommendations [1, 2].

Natural radioactivity in geological materials, mainly rocks and soil, comes from ^{232}Th and ^{238}U series and natural ^{40}K [3]. These radionuclides have a half-life comparable to the age of the earth. Gamma radiation from these radionuclides represents the main external source of irradiation of the human body. The knowledge of radionuclides distribution and radiation levels in the environment is important for assessing the effects of radiation exposure due to both terrestrial and extraterrestrial sources. Terrestrial radiation results from radioactive nuclides present in varying amounts in soils, building materials, water, rocks and the atmosphere. Some of the radionuclides from these sources are transferred to man through the food chain or inhalation, while extraterrestrial radiation originates from outer space as primary cosmic rays [4].

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As many know, building materials are comprised of rocks, thus containing radioactive nuclides. The knowledge of the natural radioactivity of building materials is important for the determination of a population's exposure to radiations, as most of the residents spend about 80% of their time indoors [5]. The presence of radioisotopes in building materials causes external exposure for those who live in buildings. ^{226}Ra and ^{232}Th can also increase the concentration of ^{222}Rn and ^{220}Rn, as well as its isotopic daughters in buildings. ^{40}K and part of the above-mentioned radionuclides cause external exposure, while the inhalation of ^{222}Rn, ^{220}Rn and their short lived progeny leads to internal exposure of the respiratory tract to alpha particles [5, 6].

In Palestine, our laboratory previously conducted a series of studies, with the objective to determine radioactivity levels and associated dose rates from surface soils, building materials, plants and some imported granites and ceramics [7-14]. For this study, we extend our measurements to systematically cover nearly all rock samples used as primary (raw) materials in the building and construction industry in Palestine. For this purpose, the activity concentrations and radiological effects of those naturally occurring radionuclides were measured in 62 representative samples, by means of high-resolution gamma-ray spectroscopy. The results obtained were compared with the world median values and the accepted upper limits.

Materials and Methods

The Study Area

Hebron Governorate (Latitude: 31° 32' 0" N, Longitude: 35° 5' 42" E) is located in the south of the West Bank, 30 km south of Jerusalem (Fig. 1). It is the largest governorate in the West Bank in terms of size and population. Its area is about 1068 km^2, which is about 19% of the West Bank total area. The population of Hebron Governorate is 650,000 people according to the estimates of the Palestinian Central Bureau of Statistics [15]. The number of Palestinian communities in the governorate is 158, the largest of which is Hebron city, located on the Hebron Mountains. The governorate lies between 400 and 1013 meters above sea level. Hebron is a busy hub of West Bank trade, responsible for roughly a third of the areas gross domestic product, largely due to the sale of rocks from quarries. In addition to sale of rocks, local economy relies on handicraft, different industries and construction [16]. The area mainly consists of Cenomanian, Eocene, Turonian and Senonian limestones. Whilst the Cenomanian and Turonian limestones are mostly very hard and resemble marble, the Senonian and Eocene limestones are generally of soft and chalky nature [17]. The main soil type is "terra rossa". This is the most typical soil of the mountains in the governorate and soil formation on hard limestone. Its soil reaction is generally neutral to moderately alkaline, and its soil has a high content of soluble salts. Both the high iron content and the low organic matter are responsible for the red color. They are mainly of loamy texture. In addition to the "terra rossa" soils, mountain marl soils and alluvial soils are also present in considerable areas. Mountain marl soils are formed from the chalky marls of Senonian and Eocene ages [17]. Agricultural areas surround the region, where the farmers in the region usually cultivate fruits, such as grapes, figs and plums [16]. The climate is of Mediterranean type with a long hot and dry summer and a short cool and rainy winter. Accordingly, the climate of Palestine is classified as an eastern Mediterranean one. Temperatures increase to the south and towards the Jordan Valley (east) [17].

Sampling and Sample Preparation

According to the map of Palestine shown in Fig. 1, a total of 62 rock samples have been collected randomly from 32 main quarries (two samples from each site) at the area under examination. Rock samples were crushed to small pieces and ground to powder. Each sample was dried in an oven at 105 ^{0}C and sieved through a 100 mesh, which is the optimum size enriched in heavy minerals. The samples were sealed in standard 1000 ml Marinelli beakers, dry weighed and stored for a minimum period of one month in order to allow daughter products to come into radioactive secular equilibrium with their parents ^{226}Ra and ^{232}Th. Then radionuclides were counted for 1200-1440 minutes, depending on the concentration of the radionuclides.

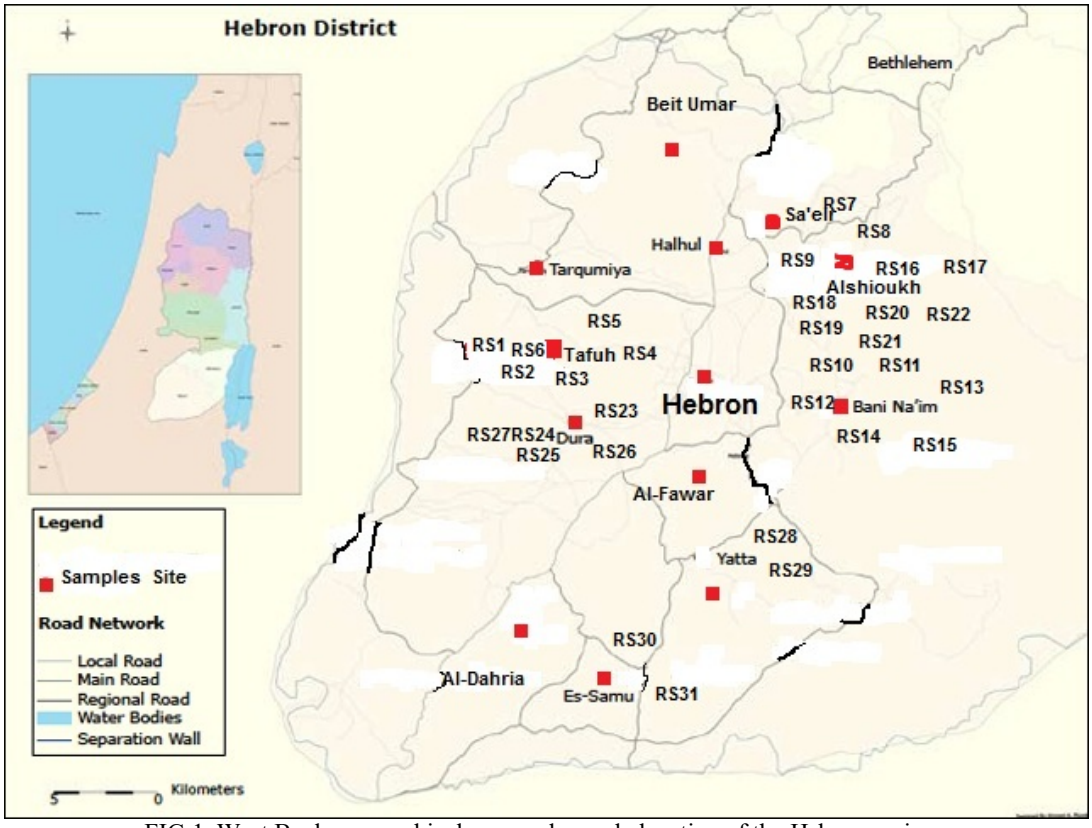

FIG.1. West Bank geographical map and sample location of the Hebron region.

Radioactivity Measurement

The concentrations of the natural radionuclides, such as ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K were measured using gamma spectroscopy with an n-type HPGe detector with 15 % relative efficiency and 1.85 keV resolution (FWHM) for the 1332 keV photons of ^{60}Co and MCA with 8000 channel. The efficiency calibrated for the spectrometry system was designed by using a mixture of radioactive sources: ^{139}Ce (166 keV), ^{203}Hg (279 keV), ^{85}Sr (514 keV), ^{137}Cs (662 keV), ^{88}Y (898 and 1836 keV) and ^{60}Co (1173 and 1333 keV) in the energy range (186–1850) keV. The calibration efficiency curve beyond 1850 keV was constructed using different energy peaks of ^{226}Ra series (^{214}Bi has peaks at 2204 and 2448 keV) in order to cover the range from 60 up to 2500 keV (16). The standard source packed in the Marinelli beaker had the same geometry as that used for measured samples. The efficiency curve for HPGe detector is shown in figure 2.

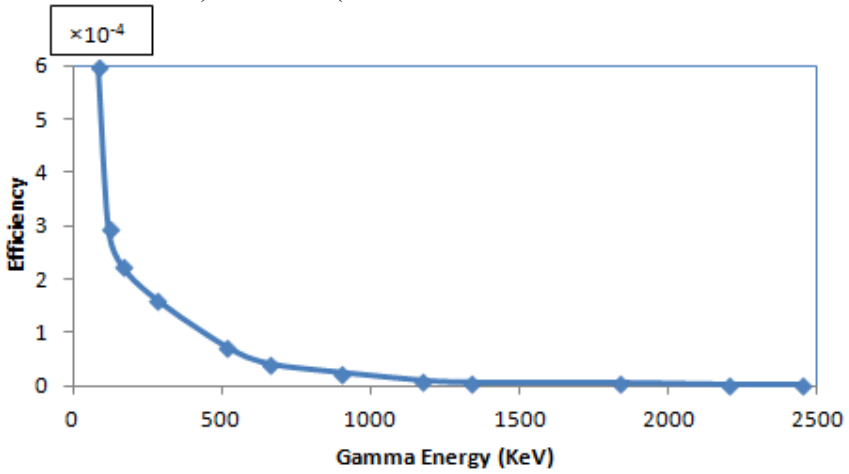

FIG.2. The photo peak efficiency curve of HPGe detector.

The activity concentrations of ^{40}K were measured using the gamma lines of 1460.8 keV. ^{238}U concentration was determined by means of its progeny full energy peak of gamma-ray lines: ^{226}Ra (186.2 keV), ^{214}Pb (295.21 keV, 352 keV) and ^{214}Bi (609 KeV, 1120.29 keV and 1764.8 keV). ^{232}Th was determined through its progeny full energy peak of gamma-ray lines: ^{228}Ac (338.6 keV, 911.2 keV and 968.9 keV),^{212}Pb (238.6 keV), ^{208}Tl (583.3 keV and 2614 keV) [11]. The software Personnel Computer Analyzer was used for the collection of the spectra. The net count rates under the most prominent full energy peak of all radionuclide daughter peaks were calculated by subtracting the background spectrum from the respective count rate obtained for the same counting time. Then, the activity of the radionuclide was calculated from the net area of prominent gamma ray energies.

Since the counting rate is proportional to the amount of the radioactivity in the samples, the activity concentration (C) can be calculated from the following equation [9]:

$$C\left(Bq/kg\right)=\frac{C_{net}}{I_{\gamma}\times\varepsilon_{ff}\times M}\ , \qquad (1)$$

where C_{net} is the net peak count rate, I_{γ} is the absolute gamma decay intensity for the specific energy photo peak (including the decay branching ratio information), E_{ff} is the absolute efficiency of the Germanium detector at this energy and M is the mass of the sample in kg.

Results and Discussion

Activity Concentrations of ^{238}U,^{232}Th and ^{40}K

The activity concentrations of natural radionuclides (^{238}U, ^{232}Th and ^{40}K) for all rock samples are determined and shown in (Table 1). The average activity concentrations of ^{238}U, ^{232}Th and ^{40}K are in the range of 21.3- 100.5 Bqkg^{-1}, 1.3 - 11.6 Bqkg^{-1} and 13.0 - 583 Bqkg^{-1}, respectively, with total average values of 47.6, 4.2 and 100 Bqkg^{-1}, respectively. The measured activity concentrations of ^{238}U, ^{232}Th and ^{40}K were compared with the values reported worldwide, as shown in Table 2. The study determined that the measured average activity concentrations of ^{238}U in this study are higher than most of the reported values from other countries, as well as the world's average value (35 Bqkg^{-1}) [18], while the average activity concentrations of ^{232}Th and ^{40}K are lower than most of the reported values from other countries, as well as the world's average values (30 Bqkg^{-1} for ^{232}Th and 400 Bqkg^{-1} for ^{40}K) [18]. The highest levels of ^{238}U radionuclides were recorded in the samples RS_1, RS_2, RS_3, RS_4 and RS_5 at the Tafuh site and in the samples RS_{23}, RS_{24}, RS_{25} and RS_{26} at the Dura site, knowing that the two sites are geographically adjacent. For ^{40}K radionuclides, the highest levels were recorded in the samples RS_1, RS_2 and RS_6 at the Tafuh site. In the present study, higher values of ^{238}U could be due to the presence of higher amounts of accessory minerals and may be the result of the presence of radioactive-rich granite, phosphate, sandstone and quartzite. The variations of radioactivity levels at different measurement locations are due to the variation of concentrations of these radioactive nuclides in the geological formations.

In all sampling sites, mean activity concentration is of the order ^{232}Th < ^{238}U < ^{40}K. Actually, the activity concentration of ^{232}Th is much lower than those of ^{238}U and ^{40}K, since ^{232}Th is more soluble in rain water. ^{238}U concentration is found to be higher than that of ^{232}Th in all the sampling sites. This may be due to the low geochemical mobility and insoluble nature in water of uranium. The ^{40}K activity dominates over ^{232}Th isotope activities, which may be due to the presence of feldspar minerals that are more concentrated in ^{40}K.

TABLE 1. The average activity concentrations of radionuclides in rock samples at different locations in Hebron region- Palestine.

Sample code	Site	Density	The activity concentrations ($Bqkg^{-1}$)		
		kg/m^3	^{238}U	^{232}Th	^{40}K
RS_1	Tafuh	1890	51.8	7.7	548.6
RS_2	Tafuh	1610	59.3	9.9	462.4
RS_3	Tafuh	1940	58.7	7.5	242.6
RS_4	Tafuh	1810	57.5	4.3	74.1
RS_5	Tafuh	1530	100.5	4.7	24.4
RS_6	Tafuh	1960	44.9	7.3	583.0
RS_7	Sa'eir	1950	35.6	4.2	63.0
RS_8	Sa'eir	1880	38.9	3.0	48.0
RS_9	Sa'eir	1620	22.5	1.4	17.5
RS_{10}	Bani Na'im	1250	44.2	4.5	51.5
RS_{11}	Bani Na'im	1450	38.7	2.6	36.8
RS_{12}	Bani Na'im	1750	31.8	2.0	24.9
RS_{13}	Bani Na'im	1740	43.0	2.9	31.5
RS_{14}	Bani Na'im	1790	72.2	4.1	45.7
RS_{15}	Bani Na'im	1840	37.3	2.0	15.7
RS_{16}	Alshioukh	1510	35.0	3.0	40.7
RS_{17}	Alshioukh	1560	42.4	2.1	19.8
RS_{18}	Alshioukh	1620	35.6	2.8	39.4
RS_{19}	Alshioukh	1460	46.6	2.7	33.7
RS_{20}	Alshioukh	1920	25.6	1.3	18.1
RS_{21}	Alshioukh	1925	44.0	2.9	32.1
RS_{22}	Alshioukh	1360	21.3	3.0	32.8
RS_{23}	Dura City	1880	77.2	2.5	39.0
RS_{24}	Karma/ Dura	1810	79.6	3.7	30.6
RS_{25}	Karma/ Dura	1940	59.1	8.7	13.0
RS_{26}	Tabaka/ Dura	1810	87.7	5.3	68.8
RS_{27}	Kraseh/ Dura	1490	33.0	11.6	271.9
RS_{28}	Yatta	1360	37.8	2.8	41.1
RS_{29}	Yatta	1350	39.6	2.7	45.2
RS_{30}	Samou	1660	44.0	3.3	51.4
RS_{31}	Samou	1710	30.0	3.4	31.9
Range	-------	1250 - 1960	21.3- 100.5	1.3 - 11.6	13.0 - 583.0
Total average	-------	1690	47.6	4.2	100

TABLE 2. Comparison of activity concentrations of rock samples at the area under investigation with other areas of the world.

Country	^{238}U ($Bqkg^{-1}$)	^{232}Th ($Bqkg^{-1}$)	^{40}K ($Bqkg^{-1}$)	References
Nigeria	39.7	62.6	604	[4]
Cyprus	1.0 - 588	1.0 – 906	50 - 1606	[19]
Brazil	31.0	73.0	1648	[20]
Germany	5.1 – 76.0	3.4 – 70.0	10 - 2070	[21]
Kenya	43.1 - 360	38.6 - 271.7	245 - 1780	[22]
Turkey	19.7	35.1	386	[23]
Iran	7.5 - 178.1	6.5 - 172.2	557 - 1539	[24]
Iraq	29.0	3.0	361	[25]
Saudi Arabia	513.1	39.1	242	[26]
India	36.6	73.2	992	[27]
Egypt	12.0 – 19.3	10 – 17.7	298.6 – 955.8	[28]
Palestine	21.3- 100.5	1.3 - 11.6	13 – 583	Present study
	47.6	4.2	100	
World average	35	30	400	[18]

Absorbed Dose Rate Measurement

Based on the radioactivity levels of ^{238}U, ^{232}Th and ^{40}K, the absorbed dose rate in air (D_r) in nGy h^{-1} at 1 meter above ground level with have contribution of terrestrial gamma radiation was calculated using the following formula [29, 30]:

$$D_r\left(nGy/hr\right) = \left.\begin{array}{l} \\ 0.427C_U + 0.662C_{Th} + 0.043C_K \end{array}\right\}, \quad (2)$$

where C_U, C_{Th} and C_K are activity concentrations ($Bqkg^{-1}$) of ^{238}U, ^{232}Th and ^{40}K, respectively, in the rock samples.

The calculated average absorbed dose rate varied from 11.2 to 50.8 $nGyh^{-1}$ with a total average value of 27.4 $nGyh^{-1}$ (Table 3). The high calculated absorbed dose rate may be due to elevated level of ^{238}U. Minimum dose rate may be due to lower amount of all the measured radionuclides. The average absorbed dose rate obtained is lower than 55 $nGyh^{-1}$ which was reported by UNSCEAR [18].

TABLE 3. The radium equivalent (Ra_{eq}), the dose rate (Dr) and the annual effective dose (AED) in rock samples.

Sample Code	Ra_{eq} ($Bqkg^{-1}$)	D_r ($nGyh^{-1}$)	AED ($\mu Svyr^{-1}$)
RS_1	105.0	50.8	62.3
RS_2	109	51.8	63.5
RS_3	88.1	40.5	49.7
RS_4	69.3	30.6	37.5
RS_5	109.1	47.1	57.8
RS_6	100.2	49.1	60.2
RS_7	46.4	20.7	25.4
RS_8	46.9	20.7	25.4
RS_9	25.8	11.2	13.8
RS_{10}	54.6	24.1	29.5
RS_{11}	45.2	19.8	24.3
RS_{12}	36.6	16.0	19.6
RS_{13}	49.6	21.6	26.5
RS_{14}	81.6	35.5	43.6
RS_{15}	41.4	17.9	23.0
RS_{16}	42.4	18.7	22.4
RS_{17}	46.9	20.3	24.9
RS_{18}	42.6	18.7	23.0
RS_{19}	53.0	23.1	28.4
RS_{20}	28.7	12.5	15.3
RS_{21}	50.6	22.1	27.1
RS_{22}	28.1	12.5	15.3
RS_{23}	83.8	36.3	44.5
RS_{24}	87.2	37.8	46.3
RS_{25}	72.5	31.6	38.7
RS_{26}	100.6	43.9	53.9
RS_{27}	70.5	33.5	41.1
RS_{28}	44.9	19.7	24.2
RS_{29}	46.9	20.6	25.3
RS_{30}	52.7	23.2	28.4
RS_{31}	37.3	16.4	20.2
Range	25.8 -109.1	11.2- 50.8	13.8 -63.5
Total average	61.2	27.4	33.6

Annual Effective Dose

In order to estimate the annual effective doses, one must take into account the conversion coefficient from absorbed dose in air into effective dose received by adults and the outdoor occupancy factor. In the UNSCEAR [18] report, a value of 0.7 $SvGy^{-1}$ was used for the conversion coefficient from absorbed dose in air to effective dose received by adults, while a value of 0.2 was used for the outdoor occupancy factor. The annual effective dose (AED) was calculated from the following equation [4]:

$$AED\left(\mu Sv/yr\right)=\left[D_r\left(nGy/hr\right)\times 24(hr/day)\times 365.25(day/yr\times 0.2\times 0.7Sv/Gy\right]\times 10^3 . \quad (3)$$

The results of the annual effective dose (*AED*) are presented in (Table 3). The highest annual effective dose rate value was found to be 63.5 μSvy^{-1}, while the lowest value was found to be 13.8 μSvy^{-1}. The total average value of *AED* is 33.6 μSvy^{-1}.The world average annual effective dose equivalent (*AED*) from outdoor terrestrial gamma radiation is 70 μSvy^{-1} [18]. Therefore, the obtained values from this preliminary study are all lower than the accepted average worldwide value.

Radium Equivalent Activity

It is important to assess gamma radiation hazards to persons associated with the use of rocks in building materials. The activities due to ^{238}U, ^{232}Th and ^{40}K are represented by a single quantity, which takes into account the radiation hazards that may be caused by a common index. This is called the radium equivalent (Ra_{eq}), and has been written as shown in the following equation [11, 30]:

$$Ra_{eq} = C_U+\left(C_{Th}\times 1.43\right)+\left(C_k\times 0.077\right). \quad (4)$$

This formula is based on the estimation that 1 Bqkg^{-1} of ^{238}U, 0.7 Bqkg^{-1} of ^{232}Th and 13 Bqkg^{-1} of ^{40}K produce the same γ-ray dose rates [2, 31]. The values of radium equivalent for different rock samples in the area under investigation were calculated using the equation above, and these values are presented in (Table 3). The produced values range from 25. 8 to 109.1 Bqkg^{-1}, with a total average value of 61.2 Bqkg^{-1}, which is lower than the recommended maximum value of 370 Bqkg^{-1} [31].

Indices for External and Internal Gamma Radiation

The external hazard index (H_{ex}) – resulting from emitted γ-rays of the soil samples – is calculated and examined according to the following criterion [29]:

$$H_{ex}=\frac{C_U}{370}+\frac{C_{Th}}{259}+\frac{C_K}{4810}\le 1 . \quad (5)$$

The value of H_{ex} must be lower than unity in order to keep the radiation hazard insignificant. The maximum value of H_{ex} must be equal to unity to correspond to the upper limit of Ra_{eq} (370 Bq kg^{-1}).

The calculated values of H_{ex} for the rock samples studied range from 0.07 to 0.29, with an average value of 0.17 (Table 4). Since these values are lower than unity, then, according to the Radiation Protection 112 report [32], rocks from these regions can be used as construction material, without posing any significant radiological threat to the population.

The internal radiation hazard index (H_{in}) provides an estimation of the exposure to radon and its daughter products and is defined as follows [29]:

$$H_{in}=\frac{C_U}{185}+\frac{C_{Th}}{259}+\frac{C_K}{4810}\le 1 . \quad (6)$$

The internal hazard index is defined so as to reduce the acceptable maximum concentration of ^{238}U to half the value appropriate to external exposures alone. Like the external hazard index, the construction materials would be safe if $H_{in} \le 1$ [2]. As shown in (Table 4), internal hazard indices for the rock samples in this study varied from 0.13 to 0.57, with an average value of 0.30. The internal hazard index for the studied rock samples is less than unity, which indicates that the investigated materials can be used as building construction materials without radiation threat.

Gamma Index Level

The European Commission has suggested a gamma index level (I_γ) for defining radiation risk from excessive gamma exposure by the following equation [33]:

$$I_\gamma=\frac{C_U}{150}+\frac{C_{Th}}{100}+\frac{C_K}{1500} . \quad (7)$$

Values of index $I_\gamma \le 2$ correspond to a dose rate criterion of 0.3 mSvy^{-1}, whereas $2 \le I_\gamma \le 6$ correspond to a criterion of 1 mSvy^{-1} [34]. Thus, materials with $I_\gamma > 6$ should be avoided as building materials, because these values correspond to dose rates higher than 1 mSvy^{-1}; the dose rate which was recommended by UNSCEAR [18]. In the current study, I_γ was calculated using equation (7). The gamma index value ranged from 0.18 to 0.80, with an average value of 0.43 (Table 4). For all measured samples used in this study, $I_\gamma \le 1$. This corresponds to an absorbed gamma dose rate of 0.3 mSvy^{-1} [32]. The gamma index calculated for all assessed samples was less than the gamma index limit.

TABLE 4. The external hazard index (H_{ex}), the internal hazard index (H_{in}), the gamma index level (I_γ) and the alpha index (I_α) in rock samples.

Sample Code	H_{ex}	H_{in}	I_γ	I_α
RS_1	0.28	0.42	0.79	0.26
RS_2	0.29	0.45	0.80	0.30
RS_3	0.24	0.40	0.63	0.29
RS_4	0.19	0.34	0.48	0.29
RS_5	0.29	0.57	0.73	0.50
RS_6	0.27	0.39	0.76	0.22
RS_7	0.13	0.22	0.32	0.18
RS_8	0.13	0.23	0.32	0.19
RS_9	0.07	0.13	0.18	0.11
RS_{10}	0.15	0.27	0.37	0.22
RS_{11}	0.12	0.23	0.31	0.19
RS_{12}	0.10	0.18	0.25	0.16
RS_{13}	0.13	0.25	0.34	0.22
RS_{14}	0.22	0.42	0.55	0.36
RS_{15}	0.11	0.21	0.28	0.19
RS_{16}	0.11	0.21	0.29	0.18
RS_{17}	0.13	0.24	0.32	0.21
RS_{18}	0.12	0.21	0.29	0.18
RS_{19}	0.14	0.27	0.36	0.23
RS_{20}	0.08	0.15	0.19	0.13
RS_{21}	0.14	0.26	0.34	0.22
RS_{22}	0.08	0.13	0.19	0.11
RS_{23}	0.23	0.44	0.57	0.39
RS_{24}	0.24	0.45	0.59	0.34
RS_{25}	0.20	0.36	0.49	0.30
RS_{26}	0.27	0.51	0.68	0.44
RS_{27}	0.19	0.28	0.52	0.17
RS_{28}	0.12	0.22	0.31	0.19
RS_{29}	0.13	0.23	0.32	0.20
RS_{30}	0.14	0.26	0.36	0.22
RS_{31}	0.10	0.18	0.26	0.15
Range	0.07- 0.29	0.13- 0.57	0.18- 0.80	0.11- 0.50
Total average	0.17	0.30	0.43	0.24

Hazard Indices for Alpha Radiation

The index dealing with the assessment of excess alpha radiation, due to radon inhalation originating from rock materials, is called alpha index or internal index (I_α) and has been developed in the following equation [3, 35]:

$$I_\alpha = \frac{C_U}{200} . \quad (8)$$

When the ^{238}U activity concentration of rock samples exceeds the value of 200 $Bqkg^{-1}$, it is possible that radon inhalation from this material could cause indoor radon concentrations exceeding 200 Bqm^{-3}. The recommended values of I_α, like I_γ, are below 0.5 and 1 [32]. The values of I_α ranged from 0.11- 0.50, with an average value of 0.24 (Table 4).These observed values are less than unity, showing that the rock materials are safe from the point of view of environmental radiation hazards.

Conclusions

The activity concentrations of ^{238}U, ^{232}Th and ^{40}K, as well as radium equivalent activity and gamma indices, were evaluated in rock samples in the Hebron region of Palestine, in order to assess the potential radiological hazards associated with building materials that are manufactured from those rocks. Such data is of value in determining the radioactivity content of buildings and the possible radiological risks associated with these structures. The variations and the spread in the data measured are a reflection of the different geological origins of the raw materials.

The results of the presented study show that the activity concentrations of ^{238}U, ^{232}Th and ^{40}K

in several samples are within the range of limit values, except some samples collected from the Tafuh and Dura sites. The average Ra_{eq} values of the studied samples are below the internationally accepted value (370 $Bqkg^{-1}$). The calculated total annual effective dose of all rock samples was lower than 70 μSvy^{-1}. As such, this study shows that the analyzed rocks (except some samples collected from Tafuh and Dura sites) do not pose any significant source of radiation hazard and are safe for use in the construction of dwellings.

Finally, one can conclude that rock materials in the Hebron region of Palestine are safe and that no health hazard effects exist to people living in the region under investigation.

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