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Evaluation of Natural Radioactivity and Associated Radiological Hazards in Soil Samples from Sand Quarries in Basra Governorate, Iraq

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Abstract

Gamma ray spectra of natural radioactivity from ^{238}U and ^{232}Th series and from ^{40}K are important to assess the potential hazard of radiation exposure. Activity concentrations of natural radionuclides in soil collected from sand quarries, were measured using a gamma ray spectrometer NaI(Tl). Specific activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the studied soil samples raged from 0.86 Bq/kg to 17.8 Bq/kg, 0.4 Bq/kg to 18.5 Bq/kg and 102.3 Bq/kg to 855.6 Bq/kg respectively. The radium equivalent activity, hazard indices and the annual effective dose rate were calculated and compared with the internationally accepted limits. The annual effective dose rate in the quarries was found to be less than the upper recommended limit by international committees.

Keywords

Soil, Quarries, Gamma Spectroscopy, Radium Equivalent, Hazard Indices

1. Introduction

A quarry is a place from which dimension stone, rock, construction aggregate, riprap, sand, gravel, or slate has been excavated from the ground. A quarry is the same thing as an open-pit mine from which minerals are extracted. Soil is composed of particles of broken rock that have been altered by chemical and mechanical processes that include weathering, erosion and precipitation. It is a mixture of mineral and organic materials that are in solid, gaseous and aqueous states. Soil is commonly referred to as earth or dirt; technically, the term dirt should be restricted to displaced soil. Soil forms a structure that is filled with pore spaces and can be thought of as a mixture of solids, water and air (gas). Most soils have a density between 1 and 2 g/cm^3. Little of the soil of planet Earth is older than the Tertiary and most no older than the Pleistocene. Soil is collection of natural bodies occupying portion of the earth's surface that support plants and contains mixture of mineral mater, organic matter, water and air. Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. The composition of sand is highly variable, depending on the local rock sources and conditions, but the most common constituent of sand in inland continental settings and non-tropical coastal settings is Silica (silicon dioxide). The second most common form of sand is calcium carbonate, for example aragonite, which has mostly been created, over the past half billion years, by various forms of life like coral and shellfish. It is, for example, the primary form of sand apparent in areas where reefs have dominated the ecosystem for millions of years, like the Caribbean. The variation amount of specific activity level in soil sample is related to the type of rock from which soil or sand are originated [1, 2].

Sand, clay, gravel and rocks are the row of the building material that occurs occasionally in soil. Soil depth ranged from just a few centimeters to tens of meter as in the case of the quarries. Since sand is natural granular material resulting from earth rocks disintegration, it should contains naturally radionuclides: radon gas, ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K [3, 4]. Gamma radiation emitted from naturally occurring radionuclides, also called terrestrial background radiation represent the main of external dose of world population [5, 6]. The knowledge of natural radionuclides concentration levels and their distribution in the environment is of great interest in several fields of science [7]. Natural radionuclides are

present in all rocks in varying amounts depending on their concentration levels in source rock materials. It is known that the radionuclides ^{238}U, ^{235}U and ^{232}Th may become incorporated in igneous materials when they are originally formed from the molten state. The use of sand in building materials rich in gamma-emitting primordial radionuclides may cause substantial exposures to those inhabiting dwellings built with these products [8, 9]. The activities in the quarries bring large amount of buried materials containing naturally occurring radioactive materials (NORM) to the surface of the environment [10].

The present study aims at investigation naturally occurring radionuclides and exposure levels to gamma radiation at the Basra Governorate sand quarries. The men dig pits approximately 10 to 30 m deep and diameter 50 to 75 m to excavate the soapstone. The results are of general interest since sand and gravels are used as building and finishing materials.

The main geological feature of investigated area

Basra region is the southern part of Iraq, neighbouring Iran from the east and Kuwait, Saudi Arabia and Arabian Gulf from the west and south. The soil of Basrah region is mostly represented by the coarse-grained sediments up to 30m, which consist of sand, gravel, igneous rocks, marine sediment and river sediments. Basrah governorate is located between 47°30′E and 48°45′ E and 29°45′ N and 30° 45′ N. The present area of study, shown in figure 1, is located between 47° 45′ and 47° 0’ E 30° 15′ N and 30° 30′ N.

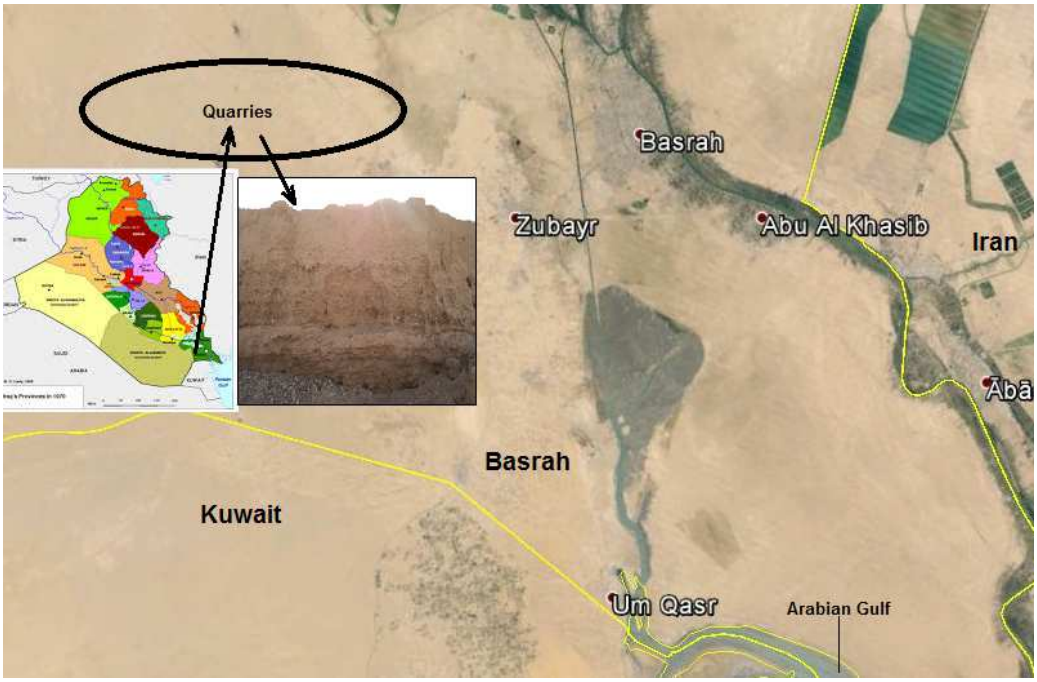

Figure 1. *The location of the quarries at Basrah Governorate, Iraq.*

2. Materials and Methods

Soil was collected at each sampling location in quarries from different depth. About 600-800 gm of each sample was heated by oven at 110°C for 24h to remove moisture, crushed into fine powder and sieved. Samples were put inside Marinalli beakers and then stored for four weeks to allow the equilibrium between ^{226}Ra and ^{222}Rn. The activity concentration of ^{226}Ra, ^{228}Ra, ^{238}U, ^{232}Th and ^{40}K was estimated from the gamma spectrum using Na(Tl) detector 3x3 inch with a 1024 channel computer analyzer USX supplied by Spectrum Technique Company. The detector was employed with lead shielding, 5 cm thickness, which reduced the background. The detector was calibrated using standard sources of ^{57}Co (peak 122 keV), ^{137}Cs (peak 662 keV) and ^{60}Co (peaks 1173, 1333 keV). The detector resolution is about 8% at 662 keV of ^{137}Cs. The efficiency calibration was achieved using eight standard sources include the calibration sources. The system was running freely, for 12 h live time, to evaluate the background spectrum. The Marinalli beaker contains sample was placed over the detector for counting.

Activity concentration A_i of any gamma-rays line taken to represent this parameter for the environmental radionuclides has been calculated using the relation [11].

$$A_i = \frac{Net\ count}{\varepsilon \times I_\gamma \times M \times t} \quad (1)$$

where ε is absolute gamma peak efficiency of the detector at this particular gamma-ray energy, I_γ decay intensity for the specific energy peak (including the decay branching ratio information), M the mass of the sample in kg and t is the counting time of the measurement in second.

To evaluate activity concentrations of natural radionuclides, one has to determine the belong city of each peak according to gamma decay of each natural isotope [12]. For ^{226}Ra; the weighted average of gamma ray concentrations for the lines; ^{214}Pb 295 keV (18.2%), 352 keV (35.1%) and ^{214}Bi 609 keV (46.1%), 1120 keV (15%), 1760 keV (15.4%) and 2204 keV

(4.98%). The peak of 186 keV assumed to be from ^{235}U since it has slight effect on the total concentration after subtracting the background, 42.8% for Ra and the rest for ^{235}U. The determination of existence of ^{232}Th was achieved by the weighted average for the lines; ^{212}Bi 338 keV (12%), 911 keV (29%), 964 keV (5.05%) and 969 keV (17%). The case of ^{238}U is recognized by ^{234m}Pa1001 keV (83%), 766 keV (29%). For ^{40}K, this directly determined using 1460 keV (10%) peak.

Calculation of activities, hazard indices and dose parameters

Radium equivalent (Ra_{eq}) activity is used to assess the hazards associated with materials that contain ^{226}Ra, ^{232}Th and ^{40}K in Bq kg^{-1}, which is, determined by assuming that 370 Bq kg^{-1} of ^{226}Ra or 260 Bq kg^{-1} of ^{232}Th or 4810 Bq kg^{-1} of ^{40}K produce the same γ dose rate. The Ra_{eq} of a sample in (Bq kg^{-1}) can be determined using the following relation [13];

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

The published maximal permissible Ra_{eq} is 370 Bq kg^{-1} [8].

The external and internal hazard indices are an evaluation of the hazard of the natural gamma radiation. The prime objective of this index is to limit the radiation dose to the admissible permissible dose equivalent limit around 1mSvy^{-1}. In order to evaluate this index, one can use the following relations [13]

$$H_{ex} = (A_{Ra}/370) + (A_{Th}/259) + (A_k/4810) \quad (3)$$

$$H_{in} = (A_{Ra}/185) + (A_{Th}/259) + (A_k/4810) \quad (4)$$

In order to estimate the annual effective dose rate in air, the conversion coefficient from absorbed dose in air to effective dose received by an adult must be considered. This value is published in UNSCEAR 2000 and UNSCEAR 1993, to be 0.7 SvGy^{-1} for environmental exposure to gamma rays of moderate energy. The outdoor occupancy factor is about 0.2 [14]. The annual effective dose equivalent is given by the following equation [13];

$$AEDE_{out}(mSv/y) = D(nGy/h) \times 8760(h/y) \times 0.2 \times 0.7(Sv/Gy) \times 10^{-6} \quad (5)$$

Where

$$D\left(\frac{nGy}{h}\right) = 0.0417A_K + 0.462A_{Ra} + 0.606A_{Th} \quad (6)$$

The world average annual effective dose equivalent (AEDE) from outdoor or indoor terrestrial gamma radiation only is 0.560 mSv/year [UNSCEAR] [14].

Table 1. *The activity concentration of ^{238}U and ^{232}Th progenies specific activities in Quarry 1 samples.*

No	Sample ID	^{238}U progeny specific activities (Bq/Kg)			^{232}Th progeny specific activities (Bq/Kg)			
		^{234m}Pa	^{214}Pb	^{214}Bi	^{228}Ac	^{212}Bi	^{212}Pb	^{208}Ti
1	Q1A1	< MDL	16.2±5.4	5.6±1.1	0.9	< MDL	213.7±51.2	8.1±0.6
2	Q1A2	< MDL	14.3±4.8	5.0±1.1	0.5	< MDL	205.0±49.1	7.7±0.6
3	Q1A3	< MDL	14.2±4.8	4.4±1.1	0.6	< MDL	204.9±49.1	15.2±1.2
4	Q1A4	< MDL	23.8±7.9	8.9±1.1	2.9±0.7	0.4	16.8±4.0	9.4±0.7
5	Q1B1	0.14	11.5±3.8	2.3±1.1	3.0±0.8	0.1	166.0±39.7	5.1±0.4
6	Q1B2	< MDL	10.3±3.4	3.3±1.1	27.4±7.8	0.2	20.3±4.9	4.9±0.4
7	Q1B3	< MDL	10.3±3.5	3.4±1.1	3.0±0.8	0.2	20.3±4.9	4.9±0.4
8	Q1B4	0.3	13.0±4.3	0.9	3.0±0.8	< MDL	23.1±5.5	5.5±0.4
9	Q1C1	< MDL	15.8±5.3	3.4±1.1	2.0±0.6	0.2	107.1±25.7	5.7±0.4
10	Q1C2	< MDL	15.8±5.3	1.7±1.1	1.0±0.3	0.2	94.7±22.7	2.8±0.2
11	Q1C3	< MDL	15.8±5.3	1.7±1.1	1.0±0.3	0.2	94.70±22.7	2.79±0.2
12	Q1C4	0.2	15.9±5.3	10.2±1.1	3.5±1.0	0.3	157.30±37.7	17.66±1.4

Table 2. *The activity concentration of ^{238}U and ^{232}Th progenies specific activities in Quarry 2 samples.*

No.	Sample ID	^{238}U progeny specific activities (Bq/Kg)			^{232}Th progeny specific activities (Bq/Kg)			
		^{234m}Pa	^{214}Pb	^{214}Bi	^{228}Ac	^{212}Bi	^{212}Pb	^{208}Ti
1	Q2A1	0.19	18.6±6.2	8.7±1.1	1.2±0.1	0.2	163.6±39.2	9.4±0.7
2	Q2A2	0.4	18.7±6.3	7.9±1.1	1.1±0.1	< MDL	246.7±59.1	17.1±1.3
3	Q2A3	0.4	18.7±6.3	7.9±1.1	1.1±0.1	< MDL	246.7±59.1	17.2±1.3
4	Q2A4	< MDL	18.3±6.1	9.6±1.1	5.6±1.6	0.5	63.3±15.1	< MDL
5	Q2B1	0.4	5.8±1.9	10.5±1.1	1.9±0.2	0.6	83.5±20.0	1.3±0.1
6	Q2B2	0.4	1.9±0.4	2.8±1.1	2.5±0.3	0.8	63.1±15.1	0.7±0.1
7	Q2B3	0.4	1.8±0.4	2.7±1.1	2.5±0.3	0.8	63.1±15.1	0.6±0.1
8	Q2B4	0.5	11.7±3.9	21.9±1.1	1.0±0.1	0.3	113.7±27.2	2.2±0.2
9	Q2C1	0.2	9.7±3.2	4.6±1.1	0.28	< MDL	31.5±7.5	7.1±0.6
10	Q2C2	< MDL	3.1±1.0	0.4	0.02	< MDL	14.9±3.6	1.0±0.1
11	Q2C3	0.1	18.1±6.0	2.6±1.1	0.12	< MDL	62.8±15.0	2.7±0.2
12	Q2C4	0.3	1.1±0.2	10.0±1.1	0.43	< MDL	113.3±27.1	10.0±0.8

Table 3. *The activity concentration of ^{238}U and ^{232}Th progeny specific activities in Quarry 3 samples.*

No.	Sample ID	^{238}U progeny specific activities (Bq/Kg)			^{232}Th progeny specific activities (Bq/Kg)			
		^{234m}Pa	^{214}Pb	^{214}Bi	^{228}Ac	^{212}Bi	^{212}Pb	^{208}Ti
1	Q3A1	0.1	1±0.3	3.0±1.1	0.2	< MDL	3.4±0.8	0.9
2	Q3A2	0.5	8.2±2.7	11.0±1.1	0.3	< MDL	28.4±6.8	6.7±0.5
3	Q3A3	0.5	8.3±2.7	10.9±1.1	0.3	< MDL	28.3±6.8	6.7.0.5
4	Q3A4	< MDL	0.3±0.1	1.1±1.1	1.1±0.1	0.3	< MDL	0.4
5	Q3B1	0.16	7.6±2.5	3.8±1.1	2.8±0.8	< MDL	126.9±30.4	6.5±0.5
6	Q3B2	< MDL	8.8±2.9	2.3±1.1	0.74	< MDL	72.3±17.3	4.9±0.4
7	Q3B3	0.23	8.8±2.9	2.3±1.1	0.7	< MDL	72.2±17.3	4.9±0.4
8	Q3B4	0.1	6.3±2.1	5.4±1.1	4.8±1.4	< MDL	181.9±43.6	8.0±0.6
9	Q3C1	0.2	12.1±4.1	6.0±1.1	2.3±0.7	0.1	51.8±12.4	5.2±0.4
10	Q3C2	0.3	12.7±4.3	1.7±1.1	0.7	0.2	109.3±26.2	11.0±0.9
11	Q3C3	0.4	12.7±4.3	1.8±1.1	0.7	0.2	109.2±26.2	11.0±0.9
12	Q3C4	0.3	11.4±3.8	1.6±1.1	0.6	0.2	98.5±23.6	9.9±0.8

3. Results and Discussions

Tables 1 to 3 represent the calculated specific activities for ^{238}U and ^{232}Th progenies in quarries 1, 2 and 3 respectively, using equation (1). In some cases, we reported the minimum detectable activity (MDA) since the specific activity was below the detectable limit.

The activities of ^{214}Pb ($T_{1/2}$=26.8min) and ^{214}Bi ($T_{1/2}$=19.9min) in uranium series for all samples have been found to be generally much larger than ^{234m}Pa ($T_{1/2}$=1.17min) and ^{214}Pb larger than ^{214}Bi as shown in Figure 2. In thorium series, ^{212}Pb ($T_{1/2}$=10.64h) is much larger than ^{228}Ac ($T_{1/2}$= 6.15h), ^{212}Bi ($T_{1/2}$= 60.55min) and ^{208}Ti ($T_{1/2}$= 3.05min) as shown in Figure 3. We can explain this pheromone by the half live of lead, which is greater than bismuth in both series. This is because of the differences in the half live of a certain radioactive isotopes. In other words, one can accumulate the remaining quantity of the longer half live isotopes littler than the shortest one. On the other hand, the activities of ^{232}Th in all samples have been found to be generally larger than those of ^{238}U progenies as shown in Figure 4. This difference in the presence of the two series in the sample of quarries is due to the distribution of radionuclide in soil or sand which is not the same (random distribution), varying in intensity radiation and quantity of radionuclide. This distribution is related to the geochemical nature of soil or sand. Generally, the magnitude and distribution of natural-gamma-ray activity is related to lithology. A comparison between the specific activities of all progenies in ^{238}U and ^{232}Th radioactive series is presented in figure 4.

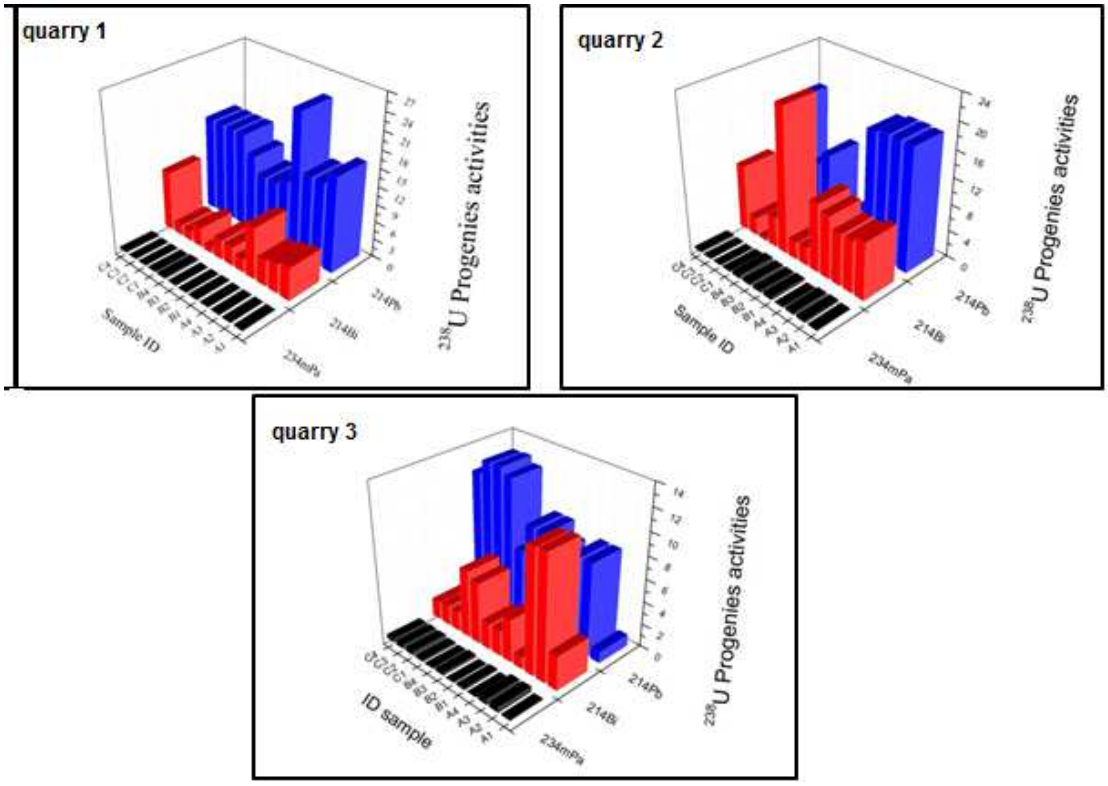

Figure 2. *The ^{238}U progenies in three quarries in Basrah Governorate.*

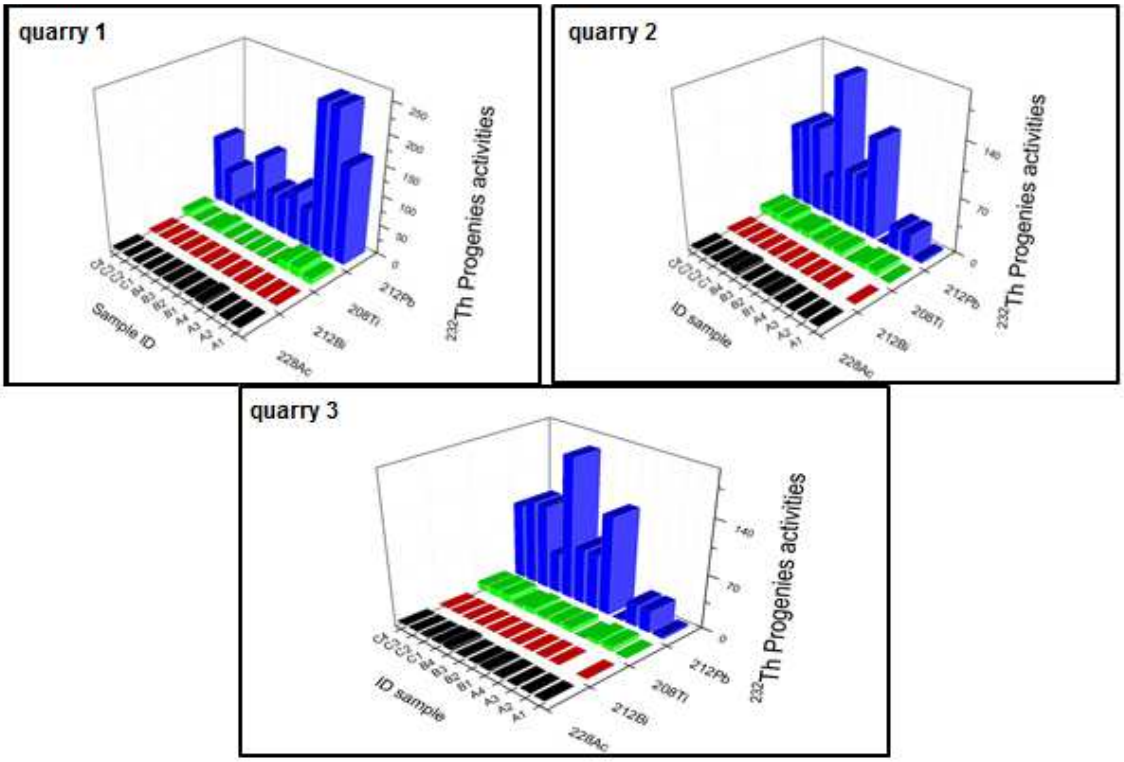

Figure 3. *The ^{232}Th progenies for the three quarries in Basra Governorate.*

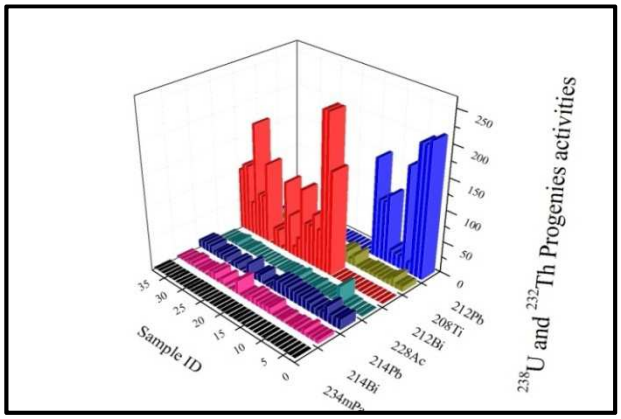

Figure 4. *The activity concentration of ^{238}U and ^{232}Th progeny specific activities in all Quarries samples.*

^{226}Ra, ^{238}U, ^{232}Th and ^{40}K activity concentration of relevance to this work are mainly gamma ray emitting nuclei. While ^{40}K can be measured by its own gamma ray, ^{226}Ra, ^{238}U and ^{232}Th radionuclide emit low energy gamma radiation with very low probability and very long life time, Thus, it is not possible to measure ^{226}Ra, ^{226}Ra and ^{232}Th directly by own gamma rays. However, it is possible to measure gamma ray activities of their short life time decay products. Therefore, ^{226}Ra, ^{238}U and ^{232}Th activities concentration were determined from their daughter products indirectly under equilibrium conditions. The specific activity concentration of ^{226}Ra, ^{232}Th, ^{238}U and ^{40}k for the three quarries are presented in tables 4, 5 and 6.

Table 4. *The activity concentration of ^{226}Ra, ^{232}Th, ^{238}U and ^{40}K in Quarry 1 samples.*

No.	Sample ID	Natural of sample	^{226}Ra (Bq/Kg)	^{232}Th (Bq/Kg)	^{238}U (Bq/Kg)	^{40}K (Bq/Kg)
1	Q1A1	soil	9.8	16.8	< MDL	763
2	Q1A2	soil	8.7	16	< MDL	783.6
3	Q1A3	soil	8.4	16	< MDL	783.6
4	Q1A4	soil	14.8	2.9	< MDL	679.9
5	Q1B1	sand	6	14.5	0.14	794
6	Q1B2	sand	6.1	18.5	< MDL	830.5
7	Q1B3	sand	6.2	3.4	< MDL	830.45
8	Q1B4	sand	5.7	3.6	0.3	745.2
9	Q1C1	sand	8.4	9.5	< MDL	855.6
10	Q1C2	sand	7.4	7.9	< MDL	638.3
11	Q1C3	sand	7.4	7.9	< MDL	638.3
12	Q1C4	sand	12.4	14.2	0.2	734.1

Table 5. *The activity concentration of ^{226}Ra, ^{232}Th, ^{238}U and ^{40}K in Quarry 2 samples.*

No.	Sample ID	Natural of sample	^{226}Ra (Bq/Kg)	^{232}Th (Bq/Kg)	^{238}U (Bq/Kg)	^{40}K (Bq/Kg)
1	Q2A1	soil	12.7	13.3	0.2	619
2	Q2A2	soil	12.2	19.5	0.4	715.6
3	Q2A3	soil	12.2	19.5	0.4	715.6
4	Q2A4	soil	13.1	8.4	< MDL	503
5	Q2B1	sand	8.6	7.7	0.4	252.8
6	Q2B2	sand	2.5	6.6	0.4	122
7	Q2B3	sand	2.4	6.6	0.4	122
8	Q2B4	sand	17.8	9.4	0.5	449
9	Q2C1	sand	6.7	2.6	0.2	466.9
10	Q2C2	sand	1.5	1.2	< MDL	102.3
11	Q2C3	sand	8.8	4.9	0.1	599.6
12	Q2C4	sand	6.5	8.9	0.3	335

Table 6. *The activity concentration of ^{226}Ra, ^{232}Th, ^{238}U and ^{40}K in Quarry 3 samples.*

No.	Sample ID	Natural of sample	^{226}Ra (Bq/Kg)	^{232}Th (Bq/Kg)	^{238}U (Bq/Kg)	^{40}K (Bq/Kg)
1	Q3A1	soil	2.2	0.4	< MDL	178.5
2	Q3A2	soil	9.9	2.4	0.5	401.3
3	Q3A3	soil	9.8	2.4	0.5	401.2
4	Q3A4	soil	0.8	0.7	0.02	262.9
5	Q3B1	sand	5.3	11.4	0.2	343.8
6	Q3B2	sand	4.9	6	< MDL	297.9
7	Q3B3	sand	4.9	5.9	0.2	297.9
8	Q3B4	sand	5.8	16.8	0.1	390.2
9	Q3C1	sand	8.4	5.4	0.2	331.4
10	Q3C2	sand	6.1	8.8	0.3	368.6
11	Q3C3	sand	6.1	8.8	0.4	368.6
12	Q3C4	sand	5.5	7.9	0.3	332.3

The average activity concentrations for ^{226}Ra in soil and sand are 9.54 Bq/kg and 6.72 Bq/kg, respectively. The average activity concentrations for ^{232}Th in soil and sand are 9.85 Bq/kg and 8.27 Bq/kg, respectively. The average activity concentrations for ^{40}K in soil and sand are 567.28 Bq/kg and 468.61 Bq/kg, respectively. It is found that, in most samples the activity concentration in soil is higher than sand as shown in Figure 5. This may be due to the difference in density and particle size. The measured values in the present work show a very low average activity concentration for ^{226}Ra and ^{232}Th, in contrast with UNCEAR. The average activity concentration for ^{40}K is higher than the recommended value in UNSCEAR.

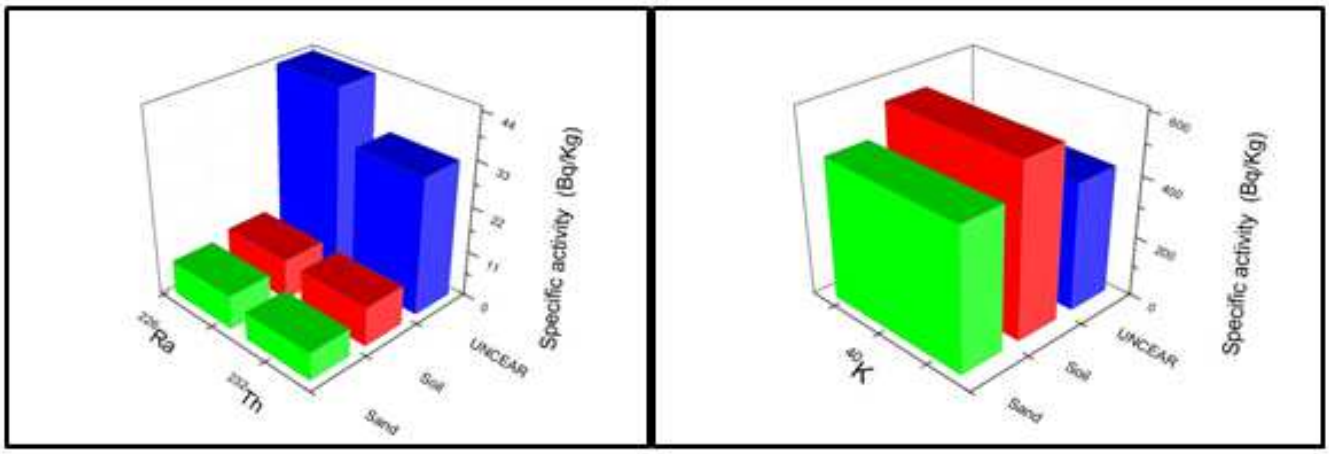

Figure 5. *Concentrations of ^{226}Ra, ^{232}Th and ^{40}K in soil and sand quarries.*

^{226}Ra and ^{232}Th have fixed mass and activity ratios with their decay products in a closed system. A closed system can be defined as a given volume of solid, such as rock, or of a solid and liquid, such as rock and water, where no net gain or loss of radioactive decay products occurs by transporting in or out of the system. Within decay series, if no intermediate decay product is lost from the system, secular equilibrium is reached after a period dependent on the half-lives of isotopes in the series (approximately 10 half-lives of longest-lived intermediate radionuclide of the decay series).

Secular equilibrium describes a state in which activities of all members of a decay series are equal, and mass ratios are

fixed at some constant value. In an open system, transport of some decay products or parent radionuclide out of the system occurs, and secular equilibrium no longer prevails. Differences in the chemical properties of radionuclide within a decay series may result in partitioning of the radionuclide within a closed physical-chemical system. Physical mechanisms associated with radioactive decay, however, may cause one isotope to move in or out of a system more easily than another. A detailed analysis of our results indicates that there are some degree of positive correlation between the activity concentration of ^{226}Ra and ^{214}Pb (R=0.95) and (R=0.96) between ^{232}Th and ^{212}Pb as shown in Figures 6 and 7. These positive and excellent correlations are expected because ^{214}Pb and ^{212}Pb are progenies of ^{226}Ra and ^{232}Th, respectively. This leads us to the modelling of the distribution of radioactivity nuclei in soil.

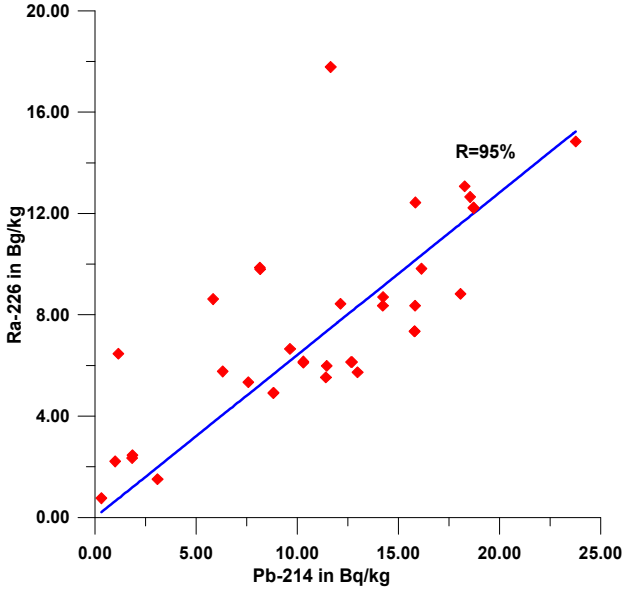

Figure 6. *Correlations between ^{226}Ra and ^{214}Pb.*

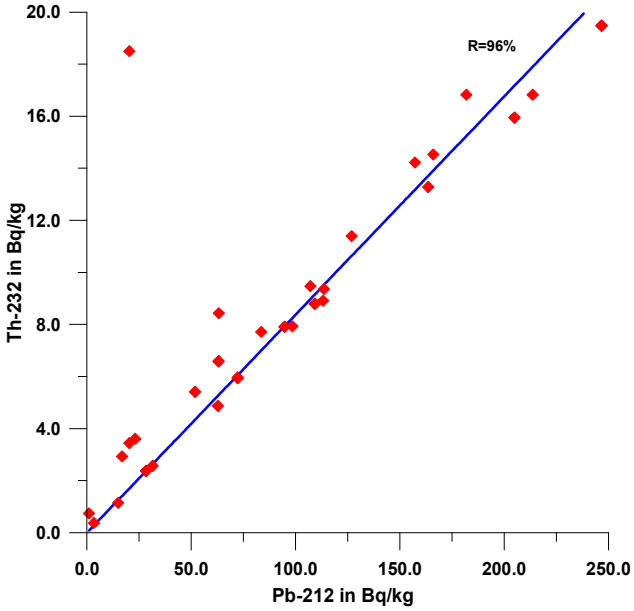

Figure 7. *Correlations between ^{232}Th and ^{212}Pb.*

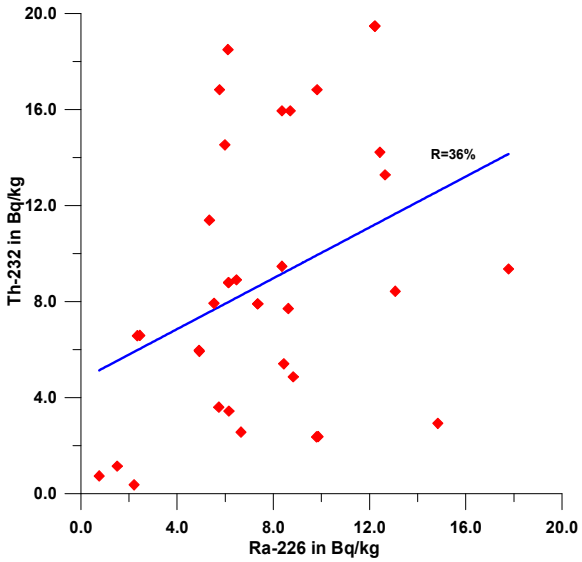

Figure 8. *Correlations between ^{226}Ra and ^{232}Th.*

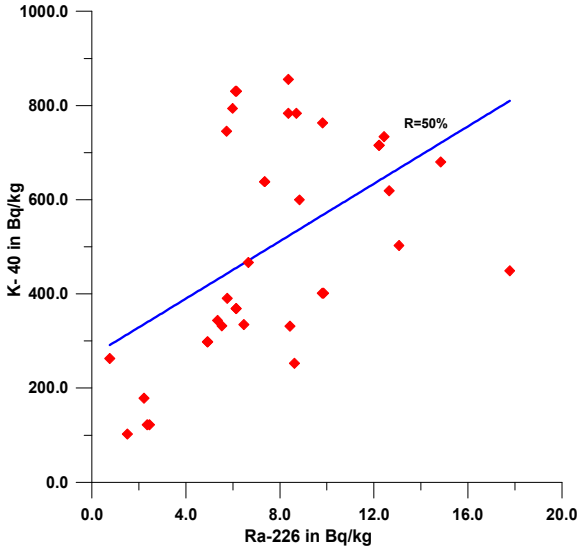

Figure 9. *Correlations between ^{40}K and ^{226}Ra.*

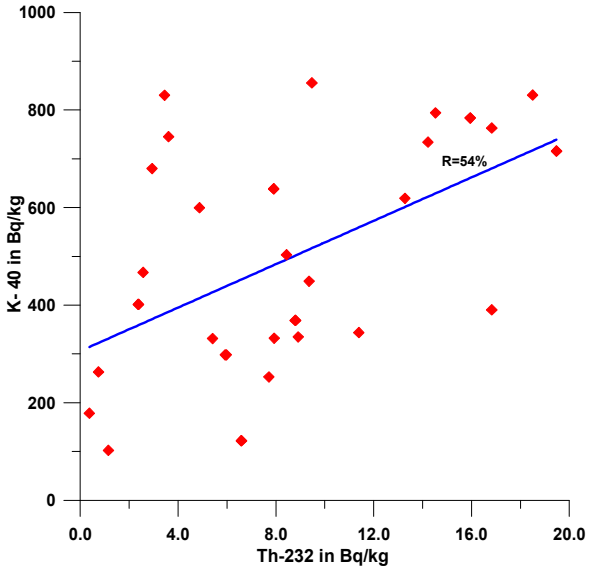

Figure 10. *Correlations between ^{40}K and ^{232}Th.*

Since the distribution of natural radionuclide in the soil or the sand of the study area is not uniform, we expect no correlation between radionuclides belong to different series. But, in fact, some week positive correlations were found between ^{226}Ra, ^{232}Th and ^{40}K as shown in Figures 8, 9 and 10.

Radioactive Hazard Indicates

The distribution of natural radioactivity in the soil is not uniform. Uniformity with respect to exposure to radiation has been defined in terms of radium equivalent activity Ra_{eq} in Bq/kg to compare the specific activity of materials containing different amount of ^{226}Ra, ^{232}Th and ^{40}K. Radium equivalent activity is related to the external gamma dose and internal dose due to radon and its daughters. The maximum value of radium equivalent activity in building construction materials must be less than 370 Bq/kg for safe use and the maximum value of external hazard index H_{ex} allowed is unity corresponding to the upper limit of Ra_{eq} (370 Bq/kg) . Tables 7-9 present the radiation hazard indices obtained from ^{226}Ra, ^{232}Th and ^{40}K activity concentration in quarries samples.

Figures 11 to 14 represent the calculations the radiation hazard quantities: the radium equivalent Ra_{eq}, external hazard index H_{ex}, absorbed dose rate D and the annual effective dose rates $AEDE_{indoor}$ for corresponding measured samples of Tables 4-6. In figures 11 to 14; the red horizontal line correspond to Ra_{eq} =370 Bq/kg, H_{ex} =1, D=60 nGy/h and $AEDE_{indoor}$=0.41mSv/y world median values respectively. The most of radiation risk quantities for all samples of quarries are lower than the world median values.

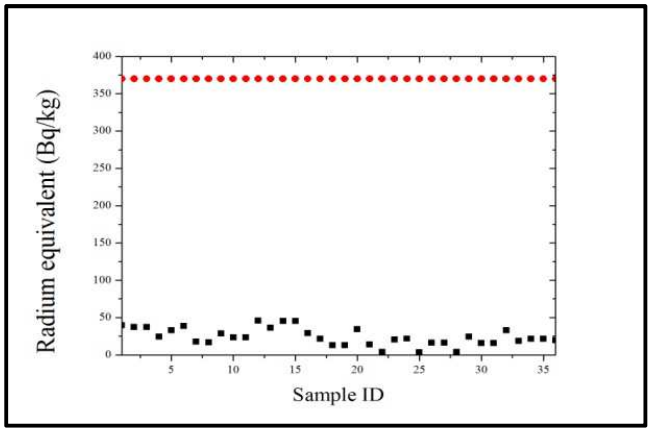

Figure 11. *Radium equivalent.*

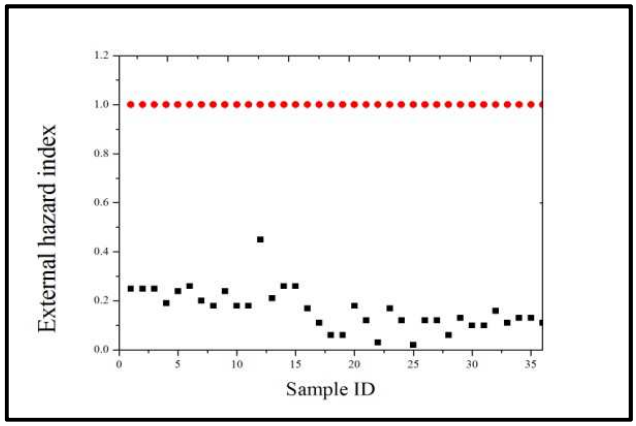

Figure 12. *External hazard index.*

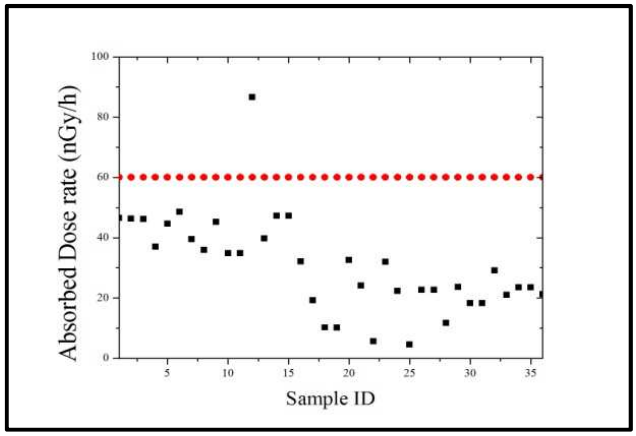

Figure 13. *Absorbed dose rate.*

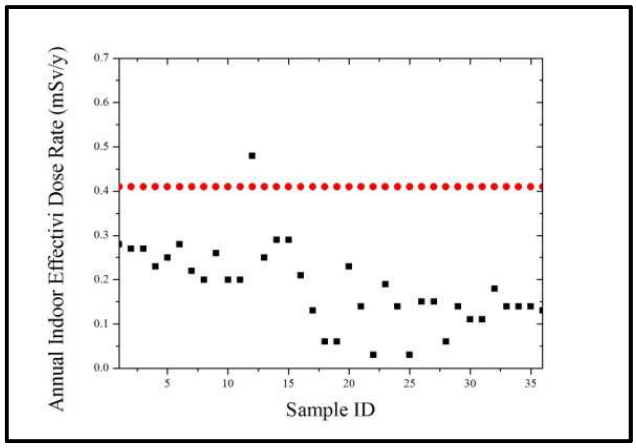

Figure 14. *Annual indoor effective dose.*

Table7. *The radiation hazard quantities in Quarry 1 samples.*

Sample ID / Radiation risk quantity	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4
Ra_{eq}(Bq/kg)	39.76	37.55	37.20	24.26	32.87	38.95	17.46	16.63	28.50	23.58	23.57	46.12
H_{ex}	0.25	0.25	0.25	0.19	0.24	0.26	0.20	0.18	0.24	0.18	0.18	0.45
H_{in}	0.28	0.27	0.27	0.23	0.25	0.28	0.22	0.20	0.26	0.20	0.20	0.48
I_{gamma}	0.37	0.37	0.37	0.29	0.36	0.39	0.31	0.29	0.36	0.28	0.28	0.69
I_{alpha}	0.05	0.04	0.04	0.07	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.06
D(nGy/h)	46.53	46.34	46.18	36.98	44.65	48.63	39.55	35.91	45.27	34.79	34.79	86.65
$AEDE_{indoor}$(mSv/y)	0.23	0.23	0.23	0.18	0.22	0.24	0.19	0.18	0.22	0.17	0.17	0.43
$AEDE_{outdoor}$(mSv/y)	0.06	0.06	0.06	0.05	0.05	0.06	0.05	0.04	0.06	0.04	0.04	0.11

Table 8. *The radiation hazard quantities in Quarry 2 samples.*

Sample ID / Radiation risk quantity	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4
Ra_{eq}(Bq/kg)	36.41	45.57	45.59	29.00	21.59	12.80	12.71	34.61	13.92	3.94	20.40	21.78
H_{ex}	0.21	0.26	0.26	0.17	0.11	0.06	0.06	0.18	0.12	0.03	0.17	0.12
H_{in}	0.25	0.29	0.29	0.21	0.13	0.06	0.06	0.23	0.14	0.03	0.19	0.14
I_{gamma}	0.31	0.38	0.38	0.25	0.15	0.08	0.08	0.26	0.19	0.04	0.25	0.18
I_{alpha}	0.06	0.06	0.06	0.07	0.04	0.01	0.01	0.09	0.03	0.01	0.04	0.03
D(nGy/h)	39.69	47.25	47.26	32.11	19.18	10.20	10.16	32.59	24.10	5.66	32.02	22.34
$AEDE_{indoor}$(mSv/y)	0.19	0.23	0.23	0.16	0.09	0.05	0.05	0.16	0.12	0.03	0.16	0.11
$AEDE_{outdoor}$(mSv/y)	0.05	0.06	0.06	0.04	0.02	0.01	0.01	0.04	0.03	0.01	0.04	0.03

Table 9. *The radiation hazard quantities in Quarry 3 samples.*

Sample ID / Radiation risk quantity	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4
Ra_{eq}(Bq/kg)	3.35	16.35	16.27	3.84	24.27	15.74	15.70	32.83	18.72	21.55	21.55	19.43
H_{ex}	0.02	0.12	0.12	0.06	0.13	0.10	0.10	0.16	0.11	0.13	0.13	0.11
H_{in}	0.03	0.15	0.15	0.06	0.14	0.11	0.11	0.18	0.14	0.14	0.14	0.13
I_{gamma}	0.04	0.18	0.18	0.09	0.19	0.15	0.15	0.23	0.17	0.19	0.19	0.17
I_{alpha}	0.01	0.05	0.05	0.00	0.03	0.02	0.02	0.03	0.04	0.03	0.03	0.03
D(nGy/h)	4.52	22.72	22.69	11.76	23.68	18.30	18.28	29.10	20.99	23.52	23.52	21.20
$AEDE_{indoor}$(mSv/y)	0.02	0.11	0.11	0.06	0.12	0.09	0.09	0.14	0.10	0.12	0.12	0.10
$AEDE_{outdoor}$(mSv/y)	0.01	0.03	0.03	0.01	0.03	0.02	0.02	0.04	0.03	0.03	0.03	0.03

4. Conclusions

The present investigation has been carried out to establish a base line data regarding concentration levels of naturally occurring radionuclides of ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K in the row building materials and the corresponding radiation doses in sand and marvels quarries in Basra Governorate. Measured mean activity concentrations at the three quarries are comparable to those measured on a worldwide scale. However, it has been recommended that no matter how low, all levels of ionizing radiation are hazardous to human health. Calculated results of external radiation doses are also lower than the world average of UNSECEAR which is about 0.56 mSv per year. The data obtained from the present work may be useful for the introduction of radiation safety standards by the local authorities for the protection of workers and general population from radiation risk owing to terrestrial sources.

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