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Assessment of Natural Radioactivity Levels and Radiation Dose Rate in Some Soil Samples from Historical Area, AL-RAKKAH, Saudi Arabia

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Abstract

This study aims to determine the activity concentrations of naturally occurring, technically-enhanced levels of radiation and the gamma absorbed dose rates in soil samples collected across the land scape of historical area which discovered in east of Saudi Arabia at 2009 G, Called AL-RAKKAH. By using an HPGe detector gamma-ray spectrometer, the activity concentrations of ^{226}Ra ^{232}Th and ^{40}K were found in surface soil samples ranged from 17. 4 ± 1.2 Bq/kg to 28.3 ± 2.3 Bq/kg with an average value of 23 ± 1.6 Bq/kg, ranging from 1.1 ± 1.8 Bq/kg to 81.0 ± 1.7 Bq/kg with the average value 20 ± 1.4 Bq/kg and from 218 ± 11 Bq/kg to 255 ± 18 Bq/kg, with the mean value of 233 ± 12 Bq/kg respectively. The mean radium equivalent (Ra_{eq}) and outdoor radiation hazard index (H_{ex}) for the area under study were determined as 69.52 Bq/kg and 0.16 respectively. The total absorbed dose rate due to three primordial radionuclides lies in the range of 17.74 - 72.24 nGy·h^{-1} with a mean of 32.69 nGy·h^{-1}, which yields total annual effective dose of 0.37 mSv·y^{-1}. The measured values are comparable with other global radioactivity measurements and are found to be safe for public and environment. The baseline data of this type will almost certainly be of importance in making estimations of population exposure.

Keywords

Soil, Gamma Ray Spectroscopy, Radioactivity, Dose Rate, Alrakkah, Saudi Arabia

1. Introduction

During the past few years, growing attention has been devoted to studying the effect of natural radioactivity. We

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are primarily exposed to ionizing radiations emitted from natural and man-made sources. Natural radiations originate from the interaction of cosmic ray particles with the atmospheric elements and naturally occurring radioactive elements found in the earth's crust [1]. The exposure of the public to natural sources of radiation has been estimated by the [2] UNSCEAR, 1988 which concluded an effective average annual dose equivalent to 2.4 $mSv \cdot y^{-1}$ per person.

In soil, the natural radioactivity concentrations determine both natural and man-made sources which are important in radiological monitoring and radiation dose assessment for public. There have been many surveys conducted to determine the background levels of radionuclides in soils, which can in turn be related to the absorbed dose rates in air. All of these spectrometric measurements indicate that the three components of the external radiation field, namely from the gamma-emitting radionuclides in the ^{238}U and ^{232}Th series and ^{40}K, make approximately equal contributions to the externally incident gamma radiation dose to individuals in typical situations both outdoors and indoors [3] UNSCEAR 2000. Studies of natural radioactivity are necessary not only because of their radiological impact, but also because they act as excellent biochemical and geochemical tracers in the environment. Also, studies of U-series radionuclides present in nature have been of particular interest due to their relatively high biological mobility [4]. There is a lot of literature on the levels of natural radiation from soil [5]-[12]. However, the number of studies made in the Arabian Gulf is comparatively limited [13]-[17].

The aim of the present work was to determine the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the soil samples from a historical area which was discovered in east of Saudi Arabia at 2009 G, Called Al-RAKKAH. In order to understand the occurrence and distribution of natural radionuclides of soil samples in area under investigation and evaluate potential health hazards, the representative level index, $I_{\gamma r}$, the radium equivalent activity (Ra_{eq}), and the annual effective dose equivalent (AEDE) in air for all soil samples were estimated to assess the contribution of this radionuclide to public exposure.

2. Materials and Methods

2.1. Samples Collection and Preparation

In order to measure the natural radioactivity in soil, surface soil (about 0 - 10 cm) 33 samples were collected using hand auger from 7 regions ((a) North, (b) Center, (c) South, North-East (NE), North-West (NW), South-East (SE), South-West (SW) and East (E)).

AL-RAKKAH is an ancient village dating back to the period of early Islam, located on an area of 108,000 square meters in the middle of the road between the cities of Al Khobar and Dammam, eastern Saudi Arabia and it is one of the most important archaeological sites in the Eastern Province, and also located between two roads coastal and speedy, that link the two cities. It is also located near the fertilizer plant (SAFCO) previously and this was known as the site during a comprehensive survey of sites relics in 1976 and holds the No. (105/208). (Dr Ali Ghabban, Vice President for Antiquities and Museums of the General Authority for Tourism and Antiquities at a news conference Monday, 08/02/2010 in the city of Khobar) [18]. He noted the site discovery time on 12/08/1976 G during the survey work carried out by the agency of Antiquities and Museums, and took No. (105/208) as income property within the site Aramco several years ago. The site covers some sand dunes which are also covered with desert shrubs and devoid of rock formations; it is easy flat, with rising higher hills about 12.46 meters above sea level, while the low-lying areas rises at a rate of 8.5 meters.

Location is mainly residential belonging to the period of early Islam and the Umayyad period and perhaps the beginning of the Abbasid period, through reading pieces of pottery, porcelain, glass, steatite and metal pieces that can be returned for two centuries, the first and second Islamic.

The effects of the site:

- can distinguish three hills head of archaeological excavation site; first is located on the north side has been given the name of the area (a), and the second in Center and carry the name of the area (b), and third in the South has been named area (c).
- spread on the surface of the site, particularly in the area of the ancient hills of breaking pottery, porcelain, glass, can the percentage back to the early Islamic period, as you can see, extensions built with stone walls in all directions.

Exploration

- to document the process of capturing and processing the surface and the process of archaeological excavation contour map was prepared for the entire site; other retinal map divides the target site to dig a network boxes, each rib 22:00 with a break all boxes with width of one meter.
- archaeological survey was conducted to the surface of the site which picked up samples of surface in the

light of the results of this survey were selected on the region by the most points to start the drilling process.

- 24 were drilled square in the region (a) and a similar number in the region (b), has been digging Saudi team from the Archaeological Office in Dammam and under the supervision and follow-up of the sector of Antiquities and Museums Authority.
- the are close to each cluster of homes of the three that make up the village water system consisting of a well-circular shape folded stones medium-sized and irregular in its upper part and stones freely (Frosch) in its lower portion which has been brought in from the sea coast near, a well in Qatar two meters of inside an irregular understeer. Other buildings consist of an elliptical basin provider-channel rainwater to drain water flowing one to the north and the other to the south-east has been introduced in the system to build channels pottery jars to control the amount of water outflows. **Table 1** shows the presents distribution of samples in regions under study.

To get moisture free samples, they were dried in an oven at 110˚C for 24 hours until constant dry weight [19]. The dried samples were crushed and allowed to pass through micro sieves to maintain the uniform grain size to obtain a fine-grained homogenous soil sample for the measurement [20] IAEA, 1989. About 1000 gm of the homogenized soil samples were transferred into 1000 ml Marinelli containers. They were carefully sealed and stored for at least 30 days before gamma ray analysis to allow ^{226}Ra and its short-lived progenies to reach secular equilibrium [21]. Each sample was measured for 12 hours, by using gamma-ray spectrometry. The system consists of an 80% relatively efficiency high-purity germanium (HPGe) detector from Ortec and has a resolution of 2.0 at the 1.33 MeV line of ^{60}Co. The system was calibrated using a mixture source in soil matrix covering energies range from 59.5 to 1836 keV in 100 ml cylindrical plastic beaker. In order to determine the background distribution due to naturally occurring radionuclides in the environment around the detector, an empty polystyrene container was counted in the same manner as the samples. Reducing background radioactivity was achieved by surrounding the detector with a cylindrical passive lead shield of about 10 cm thickness. After measurement and subtraction of the background, the activity concentration was calculated [14] [22].

2.2. Samples Analysis

The analysis focuses on measuring ^{226}Ra, ^{232}Th, and ^{40}K activities in the soil samples. Due to the difficulty of determination the activity of ^{226}Ra and ^{232}Th directly from their very weak energy's lines, the concentrations for both of them are determined from their decay products assuming secular equilibrium between parents and daughters. The peak analysis was conducted for the most significant energy lines for each radioisotope. The determination of activity concentration of ^{226}Ra was by using the most abundant gamma rays from the lead ^{214}Pb at 295 keV (18.15%) yield and at 352 keV (35.10%) yield, and from ^{214}Bi being at 1764 keV (15.1%) yield, where the other energy lines yields are below 5% which are too small to detect with enough confidences. The activities obtained from these three lines were averaged and the mean value was considered as the activity concentration of ^{226}Ra. The specific activity of ^{232}Th was evaluated from gamma-ray lines of ^{228}Ac at 338.4, 911.1 and 968.9 keV. The specific activity of ^{40}K was determined directly from its 1460.8 keV gamma-ray line. The activity concentrations of the natural radionuclides in the measured samples (A_S) were computed using the following

Table 1. Presents distribution of samples in regions under study.

Samples location	Sample Code	Samples number	Description
North	a	5	
Center	b	5	Three hills head of archaeological excavation
South	c	5	
North-East	NE	4	
North-West	NW	4	
South-East	SE	4	Water system consists of a well-circular shape folded stones medium-sized
South-West	SW	4	
East	E	2	

relation [23]-[26].

$$A_S(Bq \cdot kg^{-1}) = C_a/\varepsilon P_r M_s \quad (1)$$

where C_a is the net gamma counting rate (counts per second), ε the detector efficiency of the specific γ-ray, P_r the absolute transition probability of Gamma-decay and M_s the mass of the sample (kg).

3. Result and Discussion

3.1. Activity Concentrations of ^{226}Ra, ^{232}Th and ^{40}K

By using gamma-ray spectrometer, activity concentrations of the natural radionuclides were investigated in the soil samples. The three most important primordial radionuclides investigated in the area of interest were ^{226}Ra, ^{232}Th and ^{40}K [7]. The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K radionuclides in soil samples are calculated and presented in **Table 2**. The activity of ^{226}Ra in the soil ranged from 17.34 Bq/kg to 28.34 Bq/kg with a mean 23 ± 1.6 Bq/kg, ^{232}Th ranged from 1.1 ± 1.8 Bq/kg to 81.0 ± 1.7 Bq/kg with a mean of 20 ± 1.4 and ^{40}K ranged from 218 ± 11 Bq/kg to 255 ± 18 Bq/kg with a mean of 233 ± 12 Bq/kg. The ^{40}K activity is higher than ^{232}Th and ^{226}Ra in all measured samples. **Figure 1** shows, the comparison of the mean activity concentrations values of ^{232}Th, ^{226}Ra and ^{40}K (Bq/kg) in different regions of soil samples. Also, the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in soil samples from the studied areas was compared with those from similar investigations in other countries and summary results were given in **Table 3**. The comparison shows that the values of soils under consideration are extremely low in accordance with others. It is found that the mean value of ^{232}Th, ^{226}Ra and ^{40}K in the present study were lower than reported for soils of Yemen, China, Turkey and Sweden, but ^{226}Ra and ^{232}Th is found that it is higher than reported for Jeddah and Riyadh, Saudi Arabia. Where ^{40}K is found that it is lower than reported for Jeddah, Saudi Arabia. The comparison of ^{40}K activity concentration shows that the values of this radionuclide in the soil of United State, Yemen, Nigeria, Algeria and China are lower than the present study mean value. The variations in the concentrations of the radioactivity in the soil of the various locations of the world, depend upon the geological and geographical conditions of the area and the extent of fertilizer applied to the agriculture lands [3] [27] [28].

3.2. Radiological Parameters

3.2.1. Radium Equivalent Activities (Ra_{eq})

The Gamma-ray radiation hazards due to the specified radionuclides ^{226}Ra, ^{232}Th and ^{40}K were assessed by different indices. The most widely used radiation hazard index Ra_{eq} is called the radium equivalent activity Ra_{eq} [36] [37]. Ra_{eq} is a weighted sum of activities of the above three radionuclides based on the estimation that 370

Table 2. Activity concentrations (^{226}Ra, ^{232}Th and ^{40}K) in soil from a historical area Al Rakkah, Saudi Arabia.

Location	No. of samples	Mean activity concentration in (Bq/kg)		
		^{226}Ra	^{232}Th	^{40}K
North	5	22.4 ± 1.5	6.6 ± 1.4	229 ± 12
Center	5	25.2 ± 1.7	81.0 ± 1.7	245 ± 7
South	5	21.1 ± 1.4	6.7 ± 1.3	255 ± 18
North-East	4	19.3 ± 1.3	4.0 ± 1.5	226 ± 11
North-West	4	23.0 ± 1.7	1.1 ± 1.8	222 ± 10
South-East	4	28.3 ± 2.3	45.7 ± 1.5	235 ± 14
South-West	4	26.6 ± 1.8	7.5 ± 1.7	230 ± 13
East	2	17. 4 ± 1.2	8.0 ± 1.3	218 ± 11
	Min	17. 4 ± 1.2	1.1 ± 1.8	218 ± 11
	Max	28.3 ± 2.3	81.0 ± 1.7	255 ± 18
	Average	23 ± 1.6	20 ± 1.4	233 ± 12

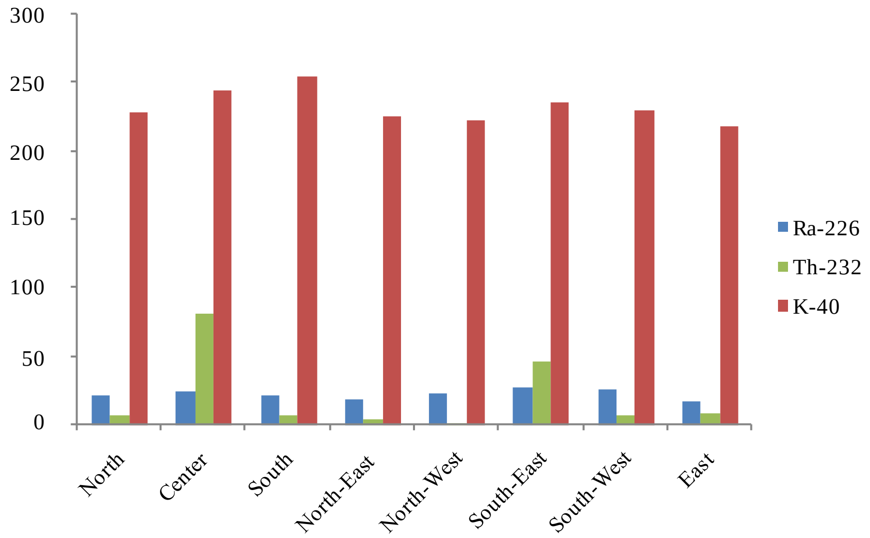

Figure 1. Average activity of ^{226}Ra, ^{232}Th and ^{40}K (Bq/kg) in soil from different regions of a historical area, Al Rakkah, Saudi Arabia.

Table 3. Comparison of natural radioactivity concentration (Bq·kg^{-1}) in the soil Samples for present study with previous study reported from different countries of the world.

Country	Mean activity concentration (Bq·kg^{-1})			References
	^{226}Ra	^{232}Th	^{40}K	
Al Rakkah East of Saudi Arabia	23	20	233	Present study
Riyadh, Center of Saudi Arabia	14.5	11	225	[28]
Tayma, north west of Saudi	30.77	27.59	161.8	[14]
Albaha, South of Saudi Arabia	37	32	343	[30]
Jeddah, West of Saudi Arabia	9.3	7.4	369	[31]
Kuwai, North region	66.6	11.3	384.5	[15]
Kuwai, south region	13.6	2.4	110.4	[15]
Oman	29.7	15.9	225	[16]
Qatar	23.2	4.5	127.1	[32]
Jordan	49	27	291	[13]
Syria	23	20	270	[3]
Iran	28	22	640	[3]
India	26.4	51.2	5.6	[9]
Pakistan	25.8	49.2	561.6	[7]
Pakistan	73.9	152.2	325.3	[5]
China	38.5	54.6	584	[10]
Japan	29	28	310	[3]
Yemen	44	58	823	[33]
Egypt, National range	37	18	320	[3]
Nigeria	7.8	29.4	229	[34]
Turkey	37	40	667	[35]
Algeria	50	25	370	[3]
Sweden	42	42	680	[3]
China	32	41	440	[3]
India	41	29	400	[3]
United State	40	35	370	[3]
World average	32	45	420	[3]

Bq/kg of ^{226}Ra, 259 Bq/kg of ^{232}Th and 4810 Bq/kg of ^{40}K produce the same γ-ray dose rates. Ra_{eq} is given by

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

The formula is based on the assumption that 370 Bq·kg^{-1} of ^{226}Ra, 259 Bq·kg^{-1} of ^{232}Th and 481 Bq·kg^{-1} of ^{40}K produce the same gamma-ray dose rate [38] A value of 370 Bq·kg^{-1} corresponds to 1 mSv·y^{-1}. The radium equivalent concept allows a single index or number which is a widely used hazard index to describe the gamma output from different mixtures of uranium, thorium and potassium in the soil samples from different locations. The calculated values are varied from 35.8 to 159.9 Bq/kg with an average of 69.52 Bq/kg (**Table 4**). These values are lower than the permissible maximum value of 370 Bq·kg^{-1} [2].

3.2.2. Hazard Index (H)

The external hazard index for samples under investigation is given by the following equation [36]

$$H_{ex} = C_{Ra}/370\ \text{Bq·kg}^{-1} + C_{Th}/259\ \text{Bq·kg}^{-1} + C_K/4810\ \text{Bq·kg}^{-1} \quad (3)$$

In addition, the external irradiation radon and its short-lived products are also hazardous to the respiratory organs. The values of outdoor radiation hazard index (H_{ex}) vary from 0.10 to 0.43 with a mean value of 0.2, which all values are less than the critical value of unity. Therefore, based on these results of radium equivalent activity and external hazard indices, one can conclude that there is no health hazard from the soil of Al-Rakkah region. External and internal hazard indices calculated for soils. The health hazard for the population in the environment results mostly from the alpha-radioactive nuclides (radon, thorn and their decay products) being present in the air. To estimate the population internal exposure associated with the natural radio nuclides in the soil, the internal hazard index (H_{in}) was calculated according to the following equation [39]:

$$H_{in} = C_{Ra}/185 + C_{Th}/259 + C_K/4810 < 1 \quad (4)$$

The criterion of this model considers that the maximum value of H_{in} equal to unity. The values of indoor radiation hazard index (H_{in}) vary from 0.17 to 0.5 with a mean value of 0.2, which all values are less than the critical value of unity and are presented in **Table 4**.

3.2.3. Representative Level Index

Radiation hazards due to the specified radionuclides of ^{226}Ra, ^{232}Th and ^{40}K were assessed by another index called representative level index, $I_{\gamma r}$. The following equation was applied to calculate $I_{\gamma r}$ for soil samples under investigation.

$$I_{\gamma r} = (1/150)C_{Ra} + (1/100)C_{Th} + (1/1500)C_K \quad (5)$$

Table 4. Average radiological hazards (H_{ex}, H_{in}, $I_{\gamma r}$ and Ra_{eq},) in soil from Al-Rakkah.

Location	Sample No.	Radiological hazards			
		Radium equivalent activity Ra_{eq} (Bq/kg)	External hazard index H_{ex}	Internal hazard index H_{in}	Representative level index $I_{\gamma r}$
North	5	49.4	0.1	0.19	0.37
Center	5	159.9	0.4	0.50	1.14
South	5	50.4	0.1	0.19	0.38
North-East	4	42.4	0.1	0.17	0.32
North-West	4	41.7	0.1	0.17	0.31
South-East	4	111.8	0.3	0.38	0.80
South-West	4	55.0	0.1	0.22	0.41
East	2	45.6	0.1	0.17	0.34
	Min	35.8	0.1	0.17	0.31
	Max	159.9	0.4	0.5	1.14
	Average	69.52	0.2	0.2	0.5

where C_{Ra}, C_{Th} and C_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg, respectively [22]. $I_{\gamma r}$ varies from 0.31 to 1.14 with a mean value of 0.5 as shown in **Table 3**. The average hazard index (H_{ex}, H_{in}) and representative level index, $I_{\gamma r}$ are plotted in **Figure 2**.

3.2.4. Absorbed Dose Rate

The absorbed gamma dose rates $D_R(nG\cdot h^{-1})$ in air at 1 m above the ground surface for the uniform distribution of radionuclides were calculated based on guidelines provided by [40] UNSCEAR (2000).

$$D_R(nG\cdot h^{-1}) = 0.427C_{Ra} + 0.623C_{Th} + 0.043C_K \quad (6)$$

where C_{Ra}, C_{Th} and C_K are the activity concentrations ($Bq\cdot kg^{-1}$) of ^{226}Ra, ^{232}Th and ^{40}K respectively, in the samples. The absorbed dose rate expresses the received dose in the open air from the radiation emitted from radionuclides concentration in Environmental materials. Also, it is the first major step for evaluating the health risk and is expressed in gray (Gy).

The calculated total absorbed dose of samples are tabulated in **Table 5**. It is observed that the absorbed dose rate calculated from activity concentration of ^{226}Ra, ^{232}Th and ^{40}K ranges between 20.06 to 71.28 with an average 32.30 $Bq\cdot kg^{-1}$.

3.2.5. The Annual Effective Dose Equivalent (AEDE)

The annual effective dose equivalent (AEDE) was calculated from the absorbed dose by applying the dose conversion factor of 0.7 $Sv\cdot Gy^{-1}$ with an outdoor occupancy factor of 0.2 and 0.8 for indoor [3] [39] UNSCEAR, 1993 & UNSCEAR, 2000.

$$(AEDE)_{outdoor} = D\ (nG\cdot h^{-1}) \times 8760\ (h\cdot y^{-1}) \times 0.7 \times (10^3\ mSv/nGy\ 10^9) \times 0.2 \quad (7)$$

Equation (7) simplifies into $(AEDE)_{outdoor} = D \times 1.226 \times 10^{-3}\ (mSv\cdot y^{-1})$

$$(AEDE)_{indoor} = D\ (nG\cdot h^{-1}) \times 8760\ (h\cdot y^{-1}) \times 0.7 \times (10^3\ mSv/nGy\ 10^9) \times 0.8 \quad (8)$$

Equation (8) simplifies into $(AEDE)_{indoor} = D \times 4.905 \times 10^{-3}\ (mSv\cdot y^{-1})$

To estimate annual effective doses, account must be taken of (a) the conversion coefficient from absorbed dose in air to effective dose and (b) the indoor occupancy factor. The average numerical values of those parameters vary with the age of the population and the climate at the location considered. A report by the UNSCEAR Committee 1993) [39], used 0.7 $Sv\cdot Gy^{-1}$ for the conversion coefficient from absorbed dose in air to effective dose received by adults and 0.8 for the indoor occupancy factor, *i.e.* the fraction of time spent indoors and outdoors is 0.8 and 0.2, respectively. The resulting worldwide average of the annual effective dose is 0.48 mSv, with the results for individual countries being generally within the 0.3 - 0.6 mSv range. For children and infants, the values are about 10% and 30% higher, in direct proportion to an increase in the value of the conversion coefficient from absorbed dose in air to effective dose [3].

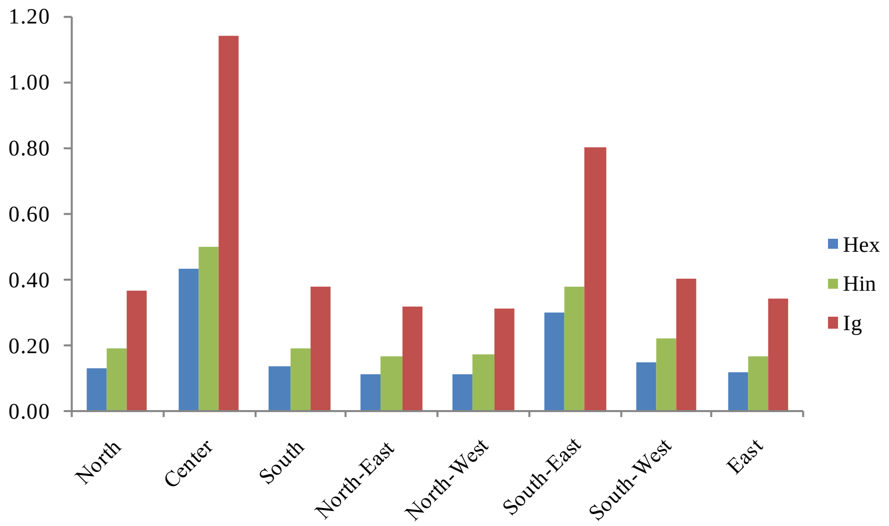

Figure 2. Average activity of H_{ex}, H_{in}, (Bq/kg) and $I_{\gamma r}$ in soil from different regions of a historical area, Al Rakkah, Saudi Arabia.

Table 5. Air-absorbed dose rates and annual effective doses calculated for surface soil samples collected from Al-Rakkah, Saudi Arabia.

Location	No. sample	Absorbed dose (nGh^{-1})				Annual effective dose (mSv/y)	
		^{226}Ra	^{232}Th	^{40}K	Total	$(AEDE)_{outdoor}$	$(AEDE)_{indoor}$
North	5	9.56	4.08	9.85	23.49	0.03	0.12
Center	5	10.77	50.46	10.54	71.78	0.09	0.35
South	5	9.02	4.17	10.98	24.18	0.03	0.12
North-East	4	8.22	2.49	9.73	20.45	0.03	0.10
North-West	4	9.80	0.70	9.56	20.06	0.02	0.10
South-East	4	12.10	28.47	10.12	50.70	0.06	0.25
South-West	4	11.34	4.67	9.90	25.91	0.03	0.13
East	2	7.40	4.98	9.39	21.78	0.03	0.11
	Min	7.40	0.70	9.39	20.06	0.02	0.10
	Max	12.10	50.46	10.98	71.78	0.09	0.35
	Average	9.8	12.5	10	32.3	0.04	0.16

As shown in **Table 5**, the annual effective dose equivalent from outdoor terrestrial gamma radiation ranged from 0.02 $mSv \cdot y^{-1}$ to 0.09 $mSv \cdot y^{-1}$ with a mean value of 0.04 $mSv \cdot y^{-1}$. Also, for indoor exposure, the annual effective dose equivalent had a range from 0.10 $mSv \cdot y^{-1}$ to 0.35 $mSv \cdot y^{-1}$ with a mean value of 0.16 $mSv \cdot y^{-1}$. The corresponding world average value is 0.41 $mSv \cdot y^{-1}$ of which 0.07 $mSv \cdot y^{-1}$ is from outdoor and 0.34 $mSv \cdot y^{-1}$ from indoor exposure [2]. Therefore, the study area is still in the zones of normal radiation level, which leaves the soil radioactivity there less a threat to the environment as well as the human health.

4. Conclusion

It is important to determine background radiation levels in order to evaluate the health hazards. The method of gamma spectrometry had been used to measure the radioactivity concentration of 33 soil samples collected from a new historical area which was discovered in east of Saudi Arabia at 2009 G, Called Al-Rakkah. From this study, the mean activity concentrations for ^{226}Ra, ^{232}Th and ^{40}K are 23, 20 and 233 $Bq \cdot kg^{-1}$ respectively. Overall, the study showed that the measured values are lower than those in the world wide soil. The mean value of total absorbed dose rate is 32.69 nGy/h, which is below the corresponding population-weight (world average) value of 65 $nGy \cdot h^{-1}$. Annual effective gamma doses are lower than the world's average. The value of Ra_{eq} activity was found to be less than 370 $Bq \cdot kg^{-1}$; the external hazard indices were found to be less than the acceptable limit of unity. Therefore, the study area is still within the zone of normal radiation level, which leaves the soil radioactivity there less of a threat to the environment as well as the human health. However, this data may provide a general background level for the area studied and may also serve as a guideline for future measurement and assessment of possible radiological risks to human health in this region.

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