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Radioactivity measurements and radiation dose assessments in soil of Al-Qassim region, Saudi Arabia

A El-Taher*[2,3] & J H Al-Zahrani[1]

[1]Physics Department, Faculty of Science for Girls, King Abdulaziz University, KSA

[2]Physics Department, Faculty of Science, Al-Azhar University, Assuit 71452, Egypt

[3]Physics Department, Faculty of Science, Al-Qassim University, Buraydah 51452, KSA

*E-mail: Atef_Eltaher@hotmail.com

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The activity concentration and the gamma absorbed dose rates of the terrestrial naturally occurring radionuclides (^{226}Ra, ^{232}Th and ^{40}K) have been determined in soil samples collected from seven different locations of Qassim region in Saudi Arabia. These were performed using a NaI(Tl) gamma-ray spectrometer. The typical concentrations of ^{226}Ra, ^{232}Th and ^{40}K were found in surface soil samples ranged from 1.4 Bq/kg (Al Asyah) to 35.3 Bq/kg (Al Badaea), from 2.5 Bq/kg (Al Maznib) to 39 Bq/kg (Al Badaea) and from 212 Bq/kg (Al Maznib) to 915 Bq/kg (Al Badaea) Bqkg^{-1}, respectively. The mean radium equivalent (Ra_{eq}) and outdoor radiation hazard index (H_{ex}) for the area under study were determined as 68.1 Bq/kg and 0.18, respectively. The total absorbed dose rate due to three primordial radionuclides lies in the range 18.6-55.5 nGyh^{-1} with a mean of 35.2 nGyh^{-1}, which yields total annual effective dose of 0.37 mSvy^{-1}. Excess lifetime cancer risk was calculated as 0.20×10^{-3}. When life expectancy was taken as 70 years, the lifetime outdoor gamma radiation was calculated as 3.02 mSv which yielded a mean lifetime cancer risk of 0.09×10^{-3} which is below the world average (0.29×10^{-3}). The measured values are comparable with other global radioactivity measurements and 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 dose, Radioactivity, Lifetime cancer risk, Saudi Arabia

1 Introduction

The exposure of the public to natural radioactivity[1] has been estimated by the UNSCEAR, 1988 which concluded an effective average annual dose equivalent to 2.4 msv y^{-1} per person. Measurement of natural radioactivity in soil is very important to determine the amount of change of the natural background activity with time as a result of any radioactive release. Monitoring of any release of radioactivity to the environment is important for environmental protection. External exposures outdoors arise from terrestrial radionuclides present at trace levels in all soils. The specific levels are related to the types of rock from which the soils originate. Higher radiation levels are associated with igneous rocks, such as granite, and lower levels with sedimentary rocks. There are exceptions, however, as some shale's and phosphate rocks have relatively high content of radionuclides. There have been many surveys to determine the background levels of radionuclides in soils, which can in turn be related to the absorbed dose rates in air. The latter can easily be measured directly, and these results provide even more extensive evaluation of the background exposure levels in different countries. 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[1] to individual in both outdoors and indoors 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. Although natural radioactivity is found in rocks and soils throughout the earth, the accession in specific areas varies relatively within narrow limits[3].

This study determined the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the soil samples from Qassim province, in Saudi Arabia. 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, Iγr, 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 Experimental Details

2.1 Location of study area

This study was carried out at Qassim province. The province is located in the center of Saudi Arabia approximately 400 km northwest of Riyadh, the capital. It is bordered by Riyadh Province to the south and east, by Ha'il Province to the north, and by Al-Madinah Province to the west. The area is surrounded by sand dunes in the west and south[4]. Table 1 presents distribution of samples in regions under study.

2.2 Samples collection and preparation

In order to measure the natural radioactivity in soil, surface soil (about 0-5 cm) samples were collected using hand auger 7 locations of Qassim region. Each sample was taken with a coring tool within area of 1 m^2, five cores were taken for each sample, one in the middle and four cores from the corner, these samples were then mixed to make a single sample after removing top layer of vegetation and roots. To get moisture free samples, they were dried in an oven at 110°C for 24 h until constant dry weight[5-9]. The dried samples were crushed and allowed to pass through micro sieves to maintain the uniform grain size to obtain affine-grained homogenous soil sample[10] for the measurement IAEA, 1989. About 400 g of the homogenized soil samples were transferred into cylindrical containers. They were carefully sealed and stored for at least 30 days before gamma ray analysis was performed to allow ^{226}Ra and its short-lived progenies to reach secular equilibrium[11].

Table 1 — Description of the area under study and samples distribution

Samples location	Sample code	Samples number	Description
Uyon Al Gawaa	UA	5	cultivated Soil
Al Badaea	AB	5	(first group)
Buraydah	BU	4	
El Bakria	EB	6	
Unayza	UN	4	reclaimed soil
Al Asyah	AS	6	(second group)
Al Maznib	AM	5	

Gamma-spectrometric measurements were performed with NaI (Tl) detector. The measuring time for gamma-ray spectra ranged was 12 h. 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. After measurement and subtraction of the background, the activity concentration was calculated[12-14]. The specific activity of ^{226}Ra was evaluated from gamma-ray lines of ^{214}Bi at 609.3, 1120.3 keV and ^{214}Pb at 351 keV, while 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 Activity calculations have been carried out using the procedure given by Lalit and Ramachandra[15]. The activity concentrations of the natural radionuclides in the measured samples (A_S) were computed using the following relation[16-18].

$$A_S \text{ (Bq kg}^{-1}) = C_a/\varepsilon\, P_r\, M_s \qquad \dots (1)$$

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 is the mass of the sample (kg).

3 Results 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 of the uranium and thorium series and ^{40}K have been investigated in the soil samples from Qassim province. The three most important primordial radionuclides investigated in the area of interest[19-20] were ^{226}Ra, ^{232}Th and ^{40}K. The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K radionuclides in soil samples collected from different parts of the studied area of Qassim province are presented in Table 2. The activity of ^{226}Ra in the soil ranged from 1.4 Bq/kg (Al Asyah) to 35.3 Bq/kg (Al Badaea) with a mean of 9.5±2.8 Bq/kg, ^{232}Th ranged from 2.5 Bq/kg (Al Maznib) to 39 Bq/kg (Al Badaea) with a mean of 12.6±3.3 and ^{40}K ranged from 212 Bq/kg (Al Maznib) to 915 Bq/kg (Al Badaea) with a mean of 546±23 Bq/kg. The ^{40}K activity is higher than ^{232}Th and ^{226}Ra in all measured samples. The mean activity concentrations values ^{226}Ra, ^{232}Th and ^{40}K (Bq/kg) in the soil samples from Qassim region are shown in Fig 1. Figure 2 shows percentage contribution to activity concentration by areas.

Table 2 — Average activity concentrations (^{226}Ra, ^{232}Th and ^{40}K) in soil from Qassim province, Saudi Arabia

Location	No. of Samples	Activity concentration in (Bq/kg) Ra-226	Th-232	K-40
Uyon Al Gawaa	5	14.3 ± 3.7 (9.8-18.3)	13 ± 3.6 (8.8-19.9)	676 ± 26 (591-776)
Al Badaea	5	20.5 ± 4.4 (14-35.3)	22 ± 4.5 (9.3-39)	747 ± 27 (628-915)
Buraydah	4	9.6 ± 3 (9-11.2)	15 ± 3.8 (7.6-24.5)	645 ± 25 (586 – 691)
El Bakria	6	8 ± 2.8 (5.4-17)	13 ± 3.4 (8-26.3)	543 ± 23 (481-635)
Unayza	4	8 ± 2.8 (4.7-11.1)	12 ± 3.5 (6.6-19.1)	595 ± 24 (336-772)
Al Asyah	6	3 ± 1.2 (1.4-5)	4 ± 2.1 (2.8-5.1)	305 ± 17 (285-367)
Al Maznib	5	3 ± 2.4 (2.2-5.4)	9 ± 2.6 (2.5-28.8)	310 ± 17.4 (212-501)
All Areas	35	9.5 ± 2.8 (1.4-35.3)	12.6 ± 3.3 (2.5-39)	546 ± 23 (212-915)

The results in parentheses correspond to the minimum and maximum values of the parameters

The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in soil samples from the studied areas have been compared with those from similar investigations in other countries and summary results are given in Table 3. The comparison shows that the values of soils under consideration are extremely low in accordance with others as shown in Fig. 3. It is found that the mean value of ^{232}Th, ^{226}Ra and ^{40}K in the present study was lower than reported for soils of Yemen, China, Turkey and Sweden, but ^{232}Th is found to be higher than reported for Jeddah, Saudi Arabia. The mean value of ^{232}Th was found nearly the same as reported for Riyadh, 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 mean value of the present study. The variations in the concentrations of the radioactivity in the soil of 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[21,22].

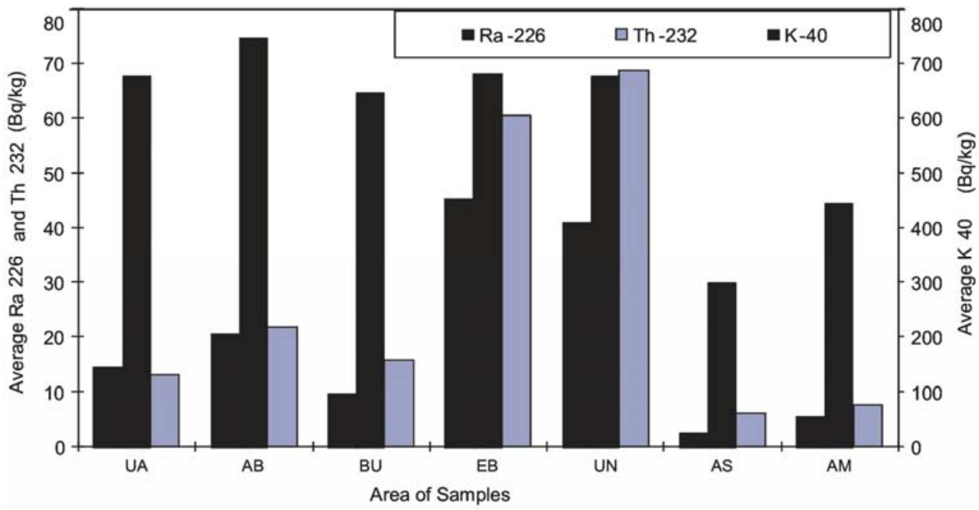

Fig. 1 — Average activity of ^{226}Ra, ^{232}Th and ^{40}K (Bq/kg) in soil from different areas in province Al-Qasseem, KSA

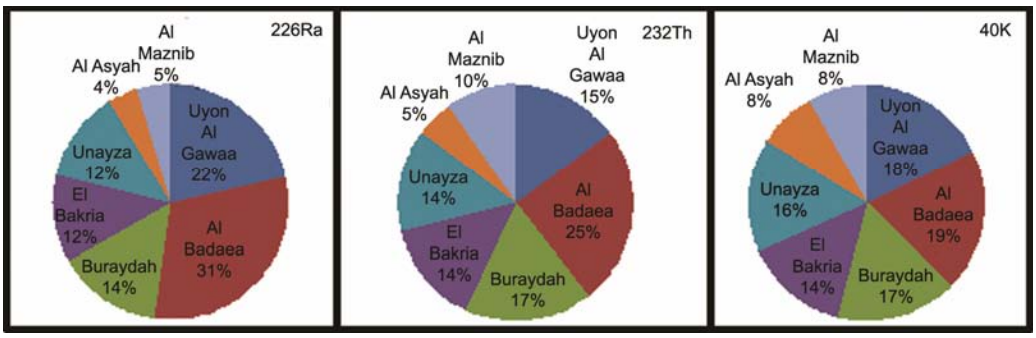

Fig. 2 — Percentage contribution to activity concentration ^{226}Ra, ^{232}Th and ^{40}K by areas

In order to test the correlations between ^{226}Ra and ^{232}Th, ^{226}Ra and ^{40}K and ^{232}Th and ^{40}K the obtained concentrations of naturally occurring radionuclides were plotted in the histogram Fig. 4. It is noted that a good correlation between ^{226}Ra and ^{232}Th was observed with a correlation coefficient of 0.547, whereas a poor correlations between ^{226}Ra with ^{40}K and ^{232}Th with ^{40}K were observed, with a correlation coefficients of 0.312 and 0.189, respectively. According to the recommended reference level of 30, 25 and 370 Bq/kg for ^{226}Ra, ^{232}Th and ^{40}K respectively, for the World average concentrations published by UNSCEAR 2000, it is noted that the obtained results in most samples are lower than the recommended reference level.

3.2. Radiological parameters

3.2.1 Radium equivalent activities (Ra_{eq})

The gamma-ray radiation hazards due to the specified radionuclides Ra, Th and K were assessed by different indices. The most widely used radiation hazard index Ra_{eq} is called the radium equivalent activity[29,30] Ra_{eq}. Ra_{eq} is a weighted sum of activities of the above three radionuclides based on the estimation that 370 Bq/kg of Ra, 259 Bq/kg of Th and 4810 Bq/kg of K produce the same γ-ray dose rates. Ra_{eq} is given by:

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

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[31]. A value of 370 Bqkg^{-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 32 (Al Asyah) to

Table 3 — Comparison of natural radioactivity concentration (Bqkg^{-1}) in the soil samples for present study with previous study reported from different countries of the world

Country	Mean activity concentration (Bqkg^{-1})			References
	^{226}Ra	^{232}Th	^{40}K	
Al Qasseem, Saudi Arabia	9.3 (1.4-35.3)	12.3 (2.5-39)	535 (212-915)	Present study
Riyadh, Saudi Arabia	14.5 (11-30)	11(7-25)	225 (89-320)	(23)
Albaha, Saudi Arabia	37 (30-45)	32(26-37)	343 (263-435)	(17)
Jeddah, Saudi Arabia	9.3	7.4	369	(24)
Yemen	44 (16.6-84.4)	58(18-113)	823(64-1667)	(25)
Egypt, National range	3-101	2-117	16-1379	(26)
Nigeria	7.8 (1-26.5)	29.4 (2.2-70)	229 (43-468)	(27)
Turkey	37 (5-111)	40(7-151)	667 (87-2084)	(28)
Algeria	50(5-180)	25 (2-140)	370 (66-1150)	(2)
Sweden	42 (14-94)	42 (12-170)	680 (560-1150)	(2)
China	32 (2-440)	41 (1-360)	440 (9-1800)	(2)
India	41(14-160	29(7 – 81)	400(38-760)	(2)
United State	40(8-160)	35(4-130)	370(100-770)	(2)
World average	32	45	420	(2)

The results in parentheses correspond to the minimum and maximum values of the parameters.

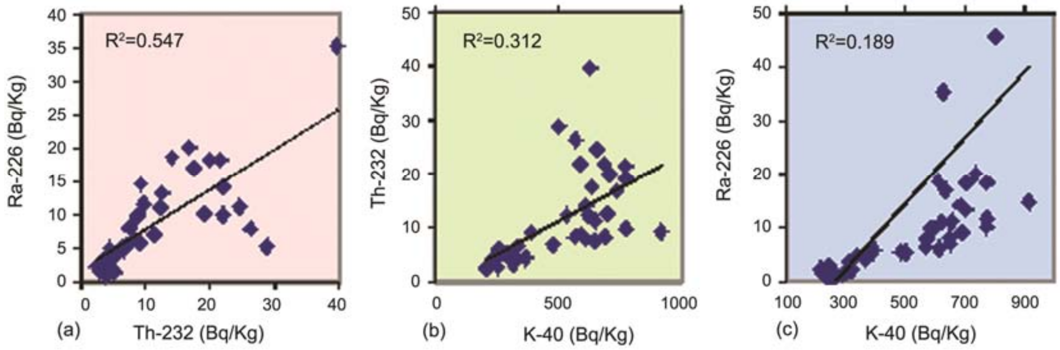

Fig. 3 — Correlations between (a) ^{226}Ra with ^{232}Th, (b) ^{226}Ra with ^{40}K and (c) ^{232}Th with ^{40}K in soil from Al-Qassim region Saudi Arabia

109 (Al Badaea) Bq/kg with an average of 68.1 Bq/kg (Table 4). These values are lower than the permissible maximum value of 370 Bq kg^{-1} NEA-OECD1979 report[32]. These discrepancies are shown in Fig. 2. All of the sites do not satisfy the criteria for a radiation.

3.2.2 Hazard index (H)

The external hazard index for samples under investigation is given by the following equation Beretka and Mathew:

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

In addition to the external irradiation radon, its short-lived products are also hazardous to the respiratory organs. The internal exposure to radon and its daughter products are quantified by the internal hazard index (H_{in}) which is given by the following equation:

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

where C_K, C_{Ra} and C_{Th} are the activity concentrations (Bq kg^{-1}) of the specific radiation. The maximum value of H_{ex} to be less than unity which corresponds to the upper limit of Ra_{eq} (370 $Bqkg^{-1}$). If the maximum concentration of radium is half than that of the normal acceptable limit then H_{in} will be less than 1. The prime objective of this index is to limit the radiation dose to dose equivalent limit of 1 mSv/y ICRP 65, report[33]. Gamma index deals with the assessment of excess gamma radiation originating from the present soils. The calculated values of H_{in} are ranged from 0.09 to 0.35 with an average of 0.21. This is lower than the recommended limit. The values of outdoor radiation hazard index (H_{ex}) vary from 0.09 to 0.29 with a mean value of 0.18, where 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 Qassim region as far as gamma radioactivity is concerned. External and internal hazard indices calculated for soil samples are presented in Table 4.

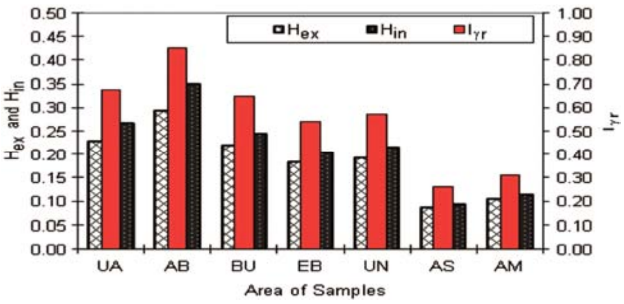

Fig. 4 — Average activity H_{ex}, H_{in} (Bq/kg) and I_r of different soil from Al-Qasseem KSA

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.

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

where C_{Ra}, C_{Th} and C_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg, respectively. $I_{\gamma r}$ varies from 0.26 to 0.85 with a mean value of 0.54 as presented in Table 4. The average hazard index (H_{ex}, H_{in}) and representative level index, $I_{\gamma r}$ are plotted in Fig. 4.

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

Location	No. of samples	Radiological hazards			
		External hazard index H_{ex}	Internal hazard index H_{in}	Representative level index $I_{\gamma r}$	Radium equivalent activity Ra_{eq} (Bq/kg)
Uyon Al Gawaa	5	0.23	0.27	0.68	85
Al Badaea	5	0.29	0.35	0.85	10
Buraydah	4	0.22	0.25	0.65	82
El Bakria	6	0.18	0.21	0.54	68
Unayza	4	0.19	0.22	0.57	72
Al Asyah	6	0.09	0.09	0.26	32
Al Maznib	5	0.11	0.11	0.31	39
All area(Average)	35	0.18	0.21	0.54	68.1

3.2.4 Absorbed dose rate

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

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

where C_{Ra}, C_{Th} and C_K are the activity concentrations (Bq 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 fractional contributions of radionuclides to the total absorbed dose rate are calculated which are varied from site to site (Fig. 1). The calculated total absorbed dose and annual effective dose rates of samples are presented 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 1.2 to 8.8, 2.9 to 14.4 and 9.1 to 33.5 nGy/h, respectively, where the upper limit is observed in Al Badaea and the lower limit in Al Asyah location. The total absorbed dose in the study area ranges from 18 nGy h^{-1} (Al Asyah) to 55.5 nGy h^{-1} (Al Bad) with an average value of 35.2 nGy/h, which is lower than the limits as recommended[33] by ICRP-65 report. The relative contribution to dose due to ^{40}K was 65.6%, followed by the contribution due to ^{226}R and^{232}Th as 11.26%, 23.14%, respectively.

3.2.5 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 Gy^{-1} with an outdoor occupancy factor of 0.2 and 0.8 for indoor UNSCEAR.2000.

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

Equation (7) simplifies into $(\text{AEDE})_{\text{out door}} = \text{D} \times 1.226 \times 10^{-3}\,(\text{mSv.y}^{-1})$

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

Eq. (8) simplifies into $(\text{AEDE})_{\text{indoor}} = D \times 4.905 \times 10^{-3}\,(\text{mSv.y}^{-1})$

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 age of the population and the climate at the location considered. In the UNSCEAR 1993 Report, the Committee used 0.7 Sv 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 UNSCEAR 2000.

As shown in Table 6, the annual effective dose equivalent from outdoor terrestrial gamma radiation ranged from 0.02 mSvy^{-1} (Al Asyah) to 0.07 mSvy^{-1} (Al Badaea) with a mean value of 0.04 mSvy^{-1}. Also, for indoor exposure, the annual effective dose equivalent had a range from 0.16 mSvy^{-1} (Al Asyah) to 0.54 mSvy^{-1} (Al Badaea) with a mean value of 0.33 mSvy^{-1}. The corresponding world average value is 0.41 mSvy^{-1} of which 0.07 mSvy^{-1}is from outdoor and 0.34 mSvy^{-1} from indoor exposure UNSCEAR, 1988. Therefore, the study area is still in the zones of

Table 5 — Air-absorbed dose rates and annual effective doses calculated for surface soil samples collected from Al Qasseem region

Location	Absorbed dose (nG h^{-1})				Annual effective dose (mSv)	
	^{226}Ra	^{232}Th	^{40}K	Total	(AEDE)out door	$(\text{AEDE})_{\text{indoor}}$
Uyon Al Gawaa	6.1	8.6	29.2	44.0	0.05	0.2157
Al Badaea	8.8	14.4	32.3	55.5	0.07	0.2721
Buraydah	4.1	10.3	27.9	42.3	0.05	0.2074
El Bakria	3.5	8.4	23.4	35.3	0.04	0.1731
Unayza	3.5	8.2	25.7	37.4	0.05	0.1833
Al Asyah	1.2	2.9	13.3	18.6	0.02	0.0840
Al Maznib	1.3	5.7	13.4	20.4	0.03	0.1002
All areas (Average)	4.0	8.1	23.1	35.2	0.04	0.173

Table 6 — Annual effective gamma doses and the excess lifetime risks of cancer

Location	Dose rate (mSv /h)	Annual dose rate (mSv /y)	life time total dose (mSv)	Excess lifetime cancer risk (ELCR)		
				Min	Max	Mean
Uyon Al Gawaa	0.44×10^{-4}	0.054	3.78	0.15×10^{-3}	0.22×10^{-3}	0.19×10^{-3}
Al Badaea	0.55×10^{-4}	0.068	4.76	0.21×10^{-3}	0.29×10^{-3}	0.24×10^{-3}
Buraydah	0.42×10^{-4}	0.052	3.63	0.22×10^{-3}	0.21×10^{-3}	0.18×10^{-3}
El Bakria	0.35×10^{-4}	0.043	3.03	0.16×10^{-3}	0.21×10^{-3}	0.15×10^{-3}
Unayza	0.37×10^{-4}	0.046	3.21	0.01×10^{-3}	0.20×10^{-3}	0.16×10^{-3}
Al Asyah	0.17×10^{-4}	0.021	1.47	0.01×10^{-3}	0.22×10^{-3}	0.07×10^{-3}
Al Maznib	0.20×10^{-4}	0.025	1.76	0.06×10^{-3}	0.09×10^{-3}	0.09×10^{-3}
All areas (Average)	0.46×10^{-4}	0.043	3.02	0.05×10^{-3}	0.18×10^{-3}	0.09×10^{-3}
World (UNSCEAR,2000)	0.46×10^{-4}	0.08	5.67			0.29×10^{-3}

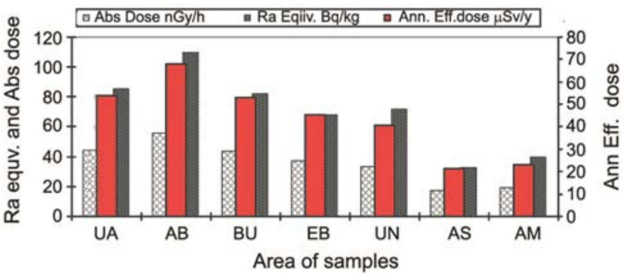

Fig. 5 — Average activity radium equivalent (Bq/kg), absorbed dose rate (nGy/h) and nnual effective dose (Sv/y) of different soil from Al-qasseem KSA

normal radiation level, which leaves the soil radioactivity there less a threat to the environment as well as the human health. Fig. 5 shows a histogram of the average values of radium equivalent (Ra_{eq}), absorbed dose rate (D_R) and annual elective dose(AEDE) for the corresponding locations under study.

3.2.6 Excess lifetime cancer risk (ELCR)

Excess lifetime cancer risk (ELCR) was calculated by using Eq. (9).

$$ELCR=AEDE\times DL\times RF \quad \dots (9)$$

where DL is duration of life (70 year) and RF is risk factor (Sv^{-1}), fatal cancer risk per Severt. For stochastic effects, ICRP 60 uses values of 0.05 for the public (ICRP, 60 report [34]. By using Eq. (6) for AEDE= 35.2 nGy h^{-1}, total annual effective gamma dose (terrestrial plus cosmic) of Al Qasseem region was calculated as 0. 37 mSv. By using Eq. (9), excess lifetime cancer risk was calculated as 0.20×10^{-3}. When life expectancy was taken as 70 years, the average lifetime outdoor gamma radiation was calculated as 3.02 mSv which yielded an average lifetime cancer risk of 0.09×10^{-3}. Potential carcinogenic effects that are characterized by estimating the probability of cancer incidence in a population of individual for a specific life time from projected intakes (and exposures) and chemical-specific dose-response data (i.e., slope factors). The additional or extra risk of developing cancer due to exposure to a toxic substance incurred over the life time of an individual[35]. Excess Life time Cancer Risk (ELCR) is calculated using the equation stated by Taskin[28] and calculated values are ranged from 0.09×10^{-3} to 0.24×10^{-3} with an average of 0.09×10^{-3}. The present average is lower than the world average (0.29×10^{-3}) UNSCEAR, 2000.

4 Conclusions

It is important to determine background radiation level in order to evaluate the health hazards. The method of gamma spectrometry had been used to measure the radioactivity concentration of 35soil samples collected from Al-Qasseem Region, Saudi Arabia. From this study, the mean activity concentrations for ^{226}Ra, ^{232}Th and ^{40}K are found to be 9.5, 12.3 and 535 $Bq.kg^{-1}$, respectively. Overall, the study showed that the measured values are lower than the values in the world wide soil. The mean value of total absorbed dose rate is 35.2 nGy/h, which is below the corresponding population-weight (world average) value of 65 $nGyh^{-1}$. Annual effective gamma doses and the lifetime risks of cancer were lower than the world's average. The value of Ra_{eq} activity was found to be less than 370 $Bqkg^{-1}$, the external hazard indices were found to be less than the acceptable limit of unity. 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. 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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