Radioactivity Measurements and Radiation Dose assessments in Soil of Albaha Region (Saudi Arabia)

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Abstract: The activity concentration and the gamma absorbed dose rates of the terrestrial naturally occurring radionuclides (^{226}Ra, ^{232}Th, and ^{40}K) were determined in soil samples collected from twenty different locations of Albaha region in Saudi Arabia, 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 30.3±1.6 (sample18) to 45.3±1.9 (sample3) Bqkg^{-1} and from 26.0±1.8 (sample 17) to 37.5±1.8 (sample 18) Bqkg^{-1}and 263.2±6.4 (sample 4) to 434.9±5.4 Bqkg^{-1} sample 13) with overall mean values of 37 Bqkg^{-1},32 Bqkg^{-1}and 343 Bqkg^{-1}, respectively. The mean radium equivalent (Ra_{eq}) and outdoor radiation hazard index (H_{ex}) for the area under study were determined as 116 Bq/kg and 0.29 respectively. The absorbed dose rate due to three primordial radionuclides lies in the range from 43to 60.3 nGyh^{-1} with a mean of 50 nGyh^{-1}, which yields the annual effective dose of 63 µSvy^{-1} which is well below the permissible limit .The measured values are comparable with other global radioactivity measurements and are found to be save for public and environment .The baseline data of this type will almost certainly be of importance in making estimations of populations exposure.
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Key words: Gamma Spectrometry, Annual effective dose, External hazard index.

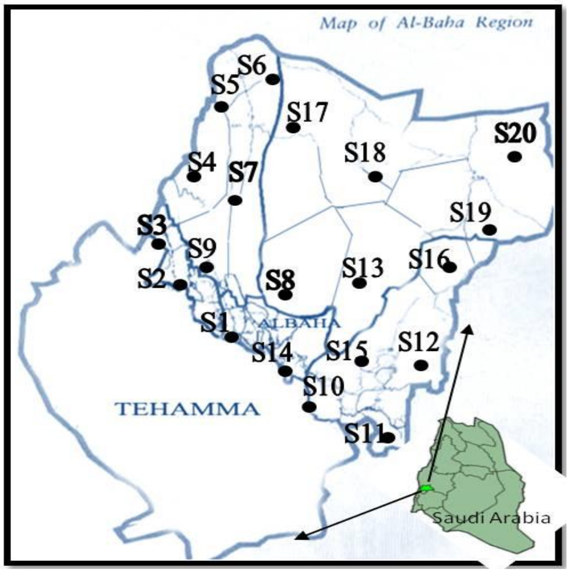
1. Introduction

The concentrations of the natural radio nuclides,^{238}U,^{232}Th,their daughter products, and ^{40}K, present in the soils, which in turn depend upon the local geology of each region in the world are causes of variation of doses (Radhakrishna *et al.*, 1993 ; Quindos *et al.*, 1994).Estimates of total radiation dose to the world population have shown that about 96% is from natural sources while 4% is from artificial sources (Chougankar *et al.*,2003).The average annual radiation dose to world population is 2.8 mSv, over 85% (2.4mSv) of this is mainly due to natural radiation, since these radionuclides are not uniformly distributed ,the knowledge of their distribution in soil play an important role in radiation protection UNSCEAR (2000) . So, it is felt necessary to study the natural radioactivity in soil to assess the dose to the population in order to know the health risks and to have a baseline for future changes in the environmental radioactivity due to human activities .In particular, it is important to assess the radiation hazards arising due to the use of soil, so, it is necessary to know the rate at which radiation is received and control the radiation hazards .The estimates of the measured radionuclide content have been made for calculating the absorbed dose rate of gamma radiation, the radium equivalent (Req), and the external hazard index (H_{ex}),which resulted from the natural radionuclides in soil. Numerous soil surveys have been carried out to test for natural radioactivity in soil at a national scale, and absorbed doses from cosmic radiation and from terrestrial radiation,(see e.g. Tahir *et al.*, 2005;Merdanoglu & *Altinsoy,2006*; Rohit *et al.*, 2007; Jabbar *et al.*, 2010;Baozhu&Yongfeng 2011;;Ahmad *et al.*, 2011). Such data can be used to establish if and where local controls are needed, also enrich the global data bank on radioactivity that will allow a more accurate estimation of global average values of dosimetric quantities.

The primary objective of the present study was to determine the natural radioactivity of ^{226}Ra, ^{232}Th and ^{40}K in soil samples of Albaha region in Saudi Arabia, where in this region, the population is associated with agriculture. Therefore, knowledge of the activity concentration levels of naturally occurring radionuclides in soils is essential for an accurate assessment of possible radiological risks to human health in this region. In addition, assessment the resultant radiation doses to the population to provide baseline data can be beneficial to the protection of local people's living environment and enlightens the local radiation regulation making.

Location of Study Area

This study was carried out at Albaha region, this area is located south-west Saudi Arabia, which lies on Longitude 41°, 42 east and latitude 19°, 20 north. Albaha region is surrounded by mountains, populated by a variety of plants, divided in Two parts,Tehamma and Alhejaz,from the villages of Alhejaz, agricultural soil samples have been collected and there is no information about radioactivity in the soils samples so far.For this reason, the concentrations of the natural radionuclides in soil samples from 20 different sampling stations in Albaha region have been determined. The geological map of the study area in Fig 1.



Fig(1). Location map of Albaha region

2. Materials and Methods

In order to measure the natural radioactivity in agricultural soil , surface soil (about 0-5 cm) sample were collected using hand auger from the highland agricultural farm area in twenty locations of Albaha 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 hours until constant dry weight (Benke and Kearfott, 1999;Veiga *et al.*, 2006). The dried samples were crushed and allowed to pass through micro sieves to maintain the homogeneous grain size soil sample for the measurement (IAE, 1994). About 500g 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 radioactive equilibrium among the daughter products of radon (^{222}Ra) and thoron (^{220}Ra) and their short- lived decay products (Mollah *et al.*,1987).The activity concentrations of ^{226}Ra,^{232}Th and ^{40}K for all homogenized and equilibrium samples were measured by a gamma ray spectrometry using a NaI (TI) detector 3x3 inch with a 1024 - chanel computer analyzer. The detector has a peak efficiency of $1.2x10^{-5}$ at1332.5Kev Co-60 and an energy resolution (FWHM)of 7.5%for 662kev, detector employed with adequate lead shielding which reduces the background radiation. 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, 1980), the activity concentrations in each sample were evaluated using the following equation:

$A_c\,(^{A}x) = C/(m\,T\,P_c\;\xi)$ ---------- (1)

where $A_c(^{A}X)$ is the activity concentration of the radionuclide ^{A}X (Bq kg^{-1}) in the sample, C the count rate obtained under the corresponding peak , m the sample mass (kg),T is the counting time(s), P_c the emission probability, and ξ is the detection absolute efficiency at a specific energy.

Assessment of radiation Hazard indices from the soil .

The concentration and distribution of ^{40}K,^{226}Ra,and ^{232}Th in soil is not uniform throughout the world, so to represent the activity concentrations of ^{226}Ra ,^{232}Th and ^{40}K by a single uantity, taking into account the following radiological radiation hazard associated with them , absorbed dose rate D_R (nGyh^{-1}) in air , annual effective dose equivalent D_{eff}(mSvy^{-1}), radium equivalent activity Ra_{eq} (Bq kg^{-1}),and external hazard index H_{ex} (Bq kg^{-1}).

To assess the real activity level of ^{226}Ra, ^{232}Th and ^{40}K in soil ,acommon radiological index has been defined in terms of radium equivalent activity (Ra_{eq}) in Bq kg^{-1} can be used , provides a very useful guideline in regulating the safety standards in radiation protection for a human population . The index was calculated through the following relation (Beretka and Mathew, 1985):

$Ra_{eq}\,(Bqkg^{-1}) = C_{Ra} + 1.43C_{Th} + 0.077C_K$ …. (2)

The formula is based on the assumption that 370 Bq kg^{-1} of ^{226}Ra, 259 Bq kg^{-1} of ^{232}Th and481 Bq $kg^{-1}$of ^{40}K produce the same gamma-ray dose rate (Stranden 1976).Avalue of 370Bqkg^{-1} coresponds to 1 mSv y^{-1}. To limit the annual external gamma-ray dose to 1.5mGy/y for the samples under investigation , the external hazard index is given by the following equation(Beretka and Mathew, 1985):

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

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 corresponds to the upper limit of Ra_{eq} (370Bqkg^{-1}).

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

D_R (nGy h^{-1}) = $0.427C_{Ra} + 0.623C_{Th} + 0.043C_K$ (4)

where C_K, C_{Ra} and C_{Th} are the activity concentrations (Bq kg^{-1})of^{40}K,^{226}Ra and^{232}Th, respectively, in the samples.

The annual effective dose equivalent was calculated from the absorbed dose by applying the dose conversion factor of 0.7 $SvGy^{-1}$ with an outdoor occupancy factor of 0.2 (UNSCEAR, 1993, 2000) :

D_{eff}(mSvy^{-1}) = D_R (nGyh^{-1}) ×8,766 h × 0.7(SvGy^{-1})× 0.2 ×10^{-6} ………. (5)

where 8,766 h is the number of hours in 1 year . 10^{-6} is conversion factor of nano and milli.

3. Results and discussion

The activity concentrations of ^{226}Ra ,^{232}Th and ^{40}Kradionuclides in soil samples collected from different locations of the studied area of Albaha region are presented in Table(1).The activity concentrations of ^{226}Ra in the soil ranged from30.3±1.6 (s. 18) to 45.2±1.9 (s. no.3) Bq.kg^{-1} with a mean 37 Bq.kg^{-1}, ^{232}Th ranged from 26.0±1.8 (s. no.17) to37.5±1.8 (s. no.18) Bqkg^{-1} with a mean of 32 Bq.kg^{-1} and ^{40}K ranged from 263.2±6.4 (s. no.4) to 434.9±5.4 (s. no.13) Bq.kg^{-1} with a mean of 343 Bq.kg^{-1}, respectively. This shows that the largest contribution to the total activity coms from ^{40}K in the study region. The average activity concentrations of terrestrial radionuclides^{226}Ra ,^{232}Th and^{40}K are within the world wide average concentrations of these radionuclides reported by UNSCEAR (2000) as 35, 30 and 400 Bq kg^{-1}, respectively.

It is interesting to compare the mean concentration of natural radioactivity of Albaha region soil with the results for different countries of the world, as shown in Table(3).The comparison of the ^{226}Ra with that of the worldwide shows that, seven countries have higher values and eight have lower values activity concentration of this radionuclide than in the soil of the understudy region. It is found that the mean value of ^{232}Th in the present study was higher than reported for soils of Turkey, South Jordan, Syria, Algeria, Egypt and Iran, but it is found that it is less than reported for Pakstan, India,China,Yemen and Nigeria. The mean value of ^{232}Th was found nearly the same as reported for Spain, Japan and United States. The comparison of ^{40}K activity concentration shows that the values of this radionuclide in the soil of China, Yemen, Iran and Egypt/Qena are higher than the present study mean value ,all other countries in comparison with the present study of Albaha region have a comparable activity concentration values.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 agreiculture lands (NCRP 1975, UNSCEAR , 2000 &Tzortzis *et al.* , 2003) .

Table (1): The values ^{226}Ra ,^{232}Th and ^{40}K activity content ,radium equivalent activity (Ra_{eq}) and External hazard index(H_{ex}) in the soil samples from Albaha region.

Sample location	Radioactivity concentration(Bqkg^{-1})			Ra_{eq} (Bq/kg)	External hazard index (H_{ex})
	^{226}Ra	^{232}Th	^{40}K		
S1	38.5±2.4	33.2±1.7	359.4±6.2	121.1	0.31
S2	30.4±2.1	33.6±1.9	376.4±6.7	102.9	0.29
S3	45.2±1.9	35.3±1.6	275.7±6.8	130.9	0.32
S4	36.9±2.0	30.9±1.9	263.2±6.4	110.0	0.27
S5	34.1±1.8	26.7±2.0	275.5±6.1	104.0	0.25
S6	40.7±2.3	36.7±1.7	317.6±7.7	123.1	0.32
S7	32.2±1.6	32.1±1.9	297.6±6.1	101.0	0.27
S8	34.2±2.3	26.9±1.8	374.7±6.6	111.9	0.27
S9	35.1±1.7	31.3±1.5	280.4±8.1	106.9	0.27
S10	43.8±2.3	29.5±2.1	312.7±6.1	130.5	0.30
S11	39.8±1.6	31.7±1.7	410.8±6.6	128.5	0.32
S12	41.3±3.2	33.9±1.5	357.7±6.9	128.0	0.32
S13	43.6±1.9	36.9±1.8	434.9±5.4	139.4	0.35
S14	42.9±3.0	32.6±2.1	361.1±8.0	131.9	0.32
S15	32.4±1.7	29.2±1.6	343.2±7.2	105.1	0.27
S16	44.2±1.8	34.7±1.7	336.7±6.2	133.2	0.32
S17	29.6±1.8	26.0±1.8	402.4±6.0	102.9	0.26
S18	30.3±1.6	37.5±1.8	380.7±5.7	102.9	0.31
S19	31.2±2.5	27.6±1.7	351.9±6.9	102.8	0.26
S20	32.4±1.5	29.6±1.9	353.5±7.2	105.9	0.28
Min. Max.	30.3±1.6 45.2±1.9	26.0±1.8 37.5±1.8	263.2±6.4 434.9±5.4	101 139	0.26 0.32
Mean	37	32	343	116	0.29

The radium equivalent activity Ra_{eq} provides a basis for comparing the activity concentrations of ^{226}Ra, ^{232}Th, ^{40}K, in soils so as to obtain the total radioactivity (Eq. 2).The results displayed in Table (1) show Ra_{eq} values varying from 101(s.no.7) to 139 (s. no.13)Bq $kg^{-1}$with a mean value of 116 $Bqkg^{-1}$. These values are lower than the permissible maximum value of 370 Bq kg^{-1} (NEA-OECD, 1979; UNSCEAR,1988). Also, external hazard indices calculated for soil samples are presented in Table (1).The values of outdoor radiation hazard index(H_{ex}) varies from 0.26(s.no.17) to 0.35(s.no.13) with a mean value of 0.29,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 Albaha region as for as gamma radioactivity is concerned. The calculated total absorbed dose and annual effective dose rates of samples are tabulated in Table(2). It is observed that the total absorbed dose rate calculated from activity concentration of ^{226}Ra ,^{232}Th and^{40}K in air ranges between 12.7(s.no.17)to 19.3 (s.no.3) , 16.2 (s.no.17) to 23.4(s.no.18) and 11.3 (s.no.4) to 18.7(s.no.13) $nGyh^{-1}$ with a mean value of 16 ,20 and 15 $nGyh^{-1}$, respectively. The total absorbed dose in the study area ranges from 43 to 60.3 $nGyh^{-1}$ with an average value of 50 $nGyh^{-1}$,which is lower the limits as recommended by ICRP (1993) .The relative contribution to dose due to ^{40}K was 29%, followed by the contribution due to ^{226}R and^{232}Th as31% ,40%, respectively. Concerning world average value determined by UNSCEAR 2000 (32%,36%,32%), respectively.

The annual effective dose equivalent from outdoor terrestrial gamma radiation ranged from 55 to 76 μSvy^{-1} with a mean value of 63 μSvy^{-1}.This is comparable to the world average value of 70μSvy^{-1} for outdoor terrestrial radiation for region of normal radiation background (UNSCEAR , 1993) .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.

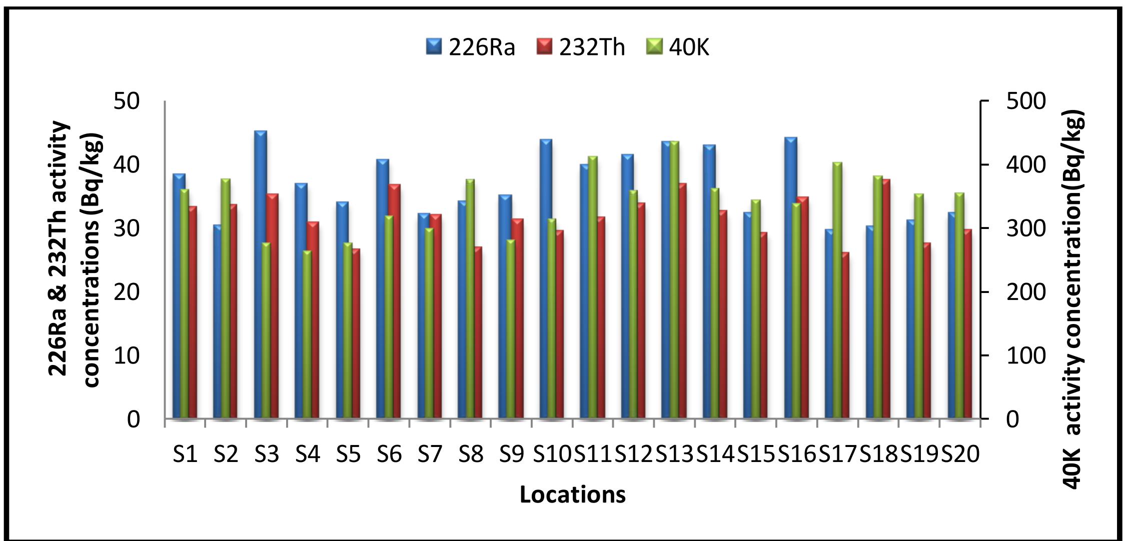
Table(2): Air- absorbed dose rates and annual effective doses calculated for surface soil samples collected from Albaha region

Sampels no.	Absorbed dose ($nGyh^{-1}$)				Annual effective dose(μSvy^{-1}) D_{eff}
	^{226}Ra	^{232}Th	^{40}K	Total (D_R)	
S1	16.4	20.7	15.5	52.6	65
S2	12.9	20.9	16.2	50.1	61
S3	19.3	22.0	11.9	53.1	67
S4	15.8	19.2	11.3	46.3	58
S5	14.5	16.6	11.9	43.0	55
S6	17.3	22.9	13.7	53.9	67
S7	13.7	20.0	12.8	46.5	57
S8	15.0	16.8	16.1	47.5	60
S9	15.0	19.5	12.1	46.5	58
S10	18.7	18.4	13.4	50.5	65
S11	17.0	19.7	17.7	54.4	69
S12	17.7	21.1	15.4	54.1	68
S13	18.6	23.0	18.7	60.3	76
S14	18.3	20.3	15.5	54.1	69
S15	13.8	18.2	14.8	46.8	58
S16	18.9	21.6	14.5	55.0	70
S17	12.7	16.2	17.3	46.1	57
S18	12.9	23.4	16.4	52.7	63
S19	13.3	17.2	15.1	45.6	57
S20	13.8	18.5	15.2	47.5	59
Range	12.7-19.3	16.2-23.4	11.3-18.7	43 - 60.3	55-76
Mean	16	20	15	50	63

Table(3): Comparison of natural radioactivity concentration ($Bqkg^{-1}$) in the soil Samples and dose rates for present study with previous study reported from different countries of the world

Country	Mean activity concentration ($Bqkg^{-1}$)			Average dose rate($nGyh^{-1}$)	References
	^{226}Ra	^{232}Th	^{40}K		
Turkey	21.0	23.5	363.5	40	Ridvan *et al.* (2011)
Pakistan	42.11	43.27	418.27	54	Hasan *et al.* ,2011
India	57	87	143	85	Singh *et al.* (2005)
China	22.1	39.0	859.1	62	LuXinwei (2006)
South Jordan	42.5	26.7	291.1	52	Ibrahim *et al.* (2009)
Syria	19	24	336	37	Al-Masri *et al.* (2006)
Yemen	44.4	58.2	822.7	90	El-mageed *et al.* (2011)
Nigeria	54.5	91.1	286.5	95	Oladele (2009)
Algeria	50	25	370	54	UNSCEAR, 2000
Egypt (Qena)	13.7	12,3	1233	65	Ahmed et al(2005)
Spain	32	33	470	76	UNSCEAR, 2000
Japan	33	28	310	53	UNSCEAR, 2000
Iran	28	22	640	71	UNSCEAR, 2000
United State	40	35	370	56	UNSCEAR, 2000
World average	30	35	420	65	UNSCEAR, 2000
Present study	37	32	343	50	

Table(3) shows a comparison of total absorbed dose rate in air found in the present study with values reported in literature for some other countries of the world .The average outdoor absorbed dose rate in air determined in the present study is nearly similar to the values reported for Pakstan ,South Jordan, Algeria ,Japan and United States, but lower than the values reported for Egypt, *India ,China ,Yemen ,Nigeria ,Spain ,Iran and the* world average ($65Bqkg^{-1}$) as shown in Table (3).However, the values found in the present study are somewhat higher than the values reported for Turky ,Syria . Activity concentrations of ^{226}Ra,^{232}Th and ^{40}K and Radium equivalent with total absorbed dose in the present study are shown in Fig(2)and Fig(3) respectively.



Fig(2) Activity concentrations of ^{226}Ra,^{232}Th and ^{40}K in soil of Albaha region

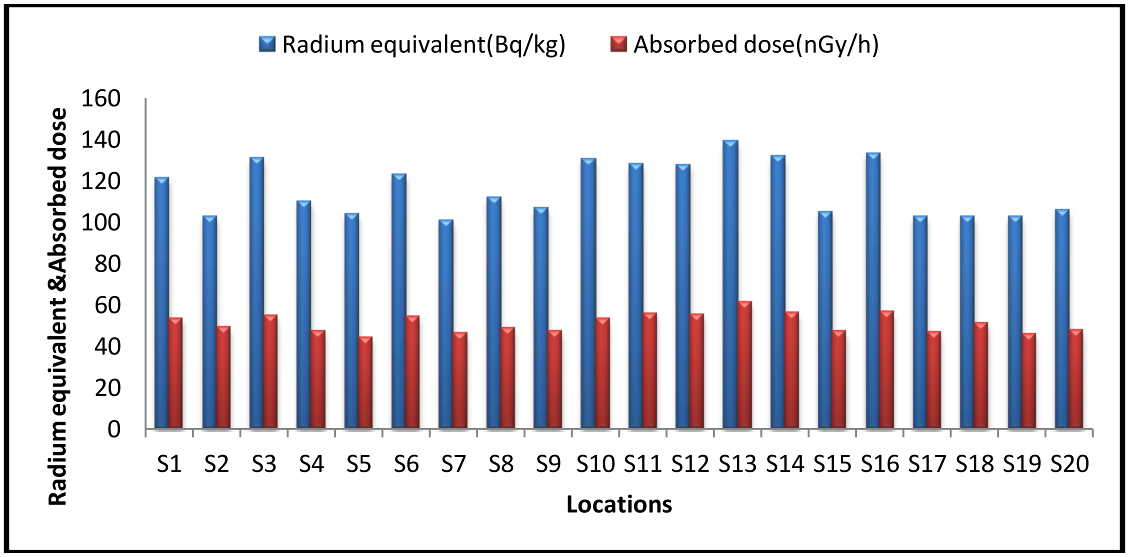


Fig.(3).Radium equivalent and Absorbed dose rate in soil samples

Conclusion

From this study, the mean activity concentrations for ^{226}Ra and ^{232}Th and ^{40}K are Bqkg^{-1} ,37 Bqkg^{-1} , 32 and 343 Bqkg^{-1},respectively.Overall ,the study showed that the measured values lower than, in the world wide soil. The mean value of total absorbed dose rate is 50 nGy/h, which is below the corresponding population-weighte(world average) value of 65nGyh^{-1}.The mean value of the annual dose 63 µSv, which is less than the average value recommended by UNSCEAR (1993).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 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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