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Gamma-Ray Measurements of Naturally Occurring Radionuclides and Resulting Dose Estimation in Soil Samples Collected from District Chakwal, Pakistan

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Abstract

Soil samples were collected from four tehsils of district Chakwal, Pakistan with an aim to measure naturally occurring radio-nuclides in this region. Radioactivities of ^{226}Ra, ^{232}Th and ^{40}K are measured using high purity germanium (HPGe) based gamma ray spectrometry system. The measured mean specific activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the soil samples was 34.27 ± 1.28, 51.59 ± 2.73 Bqkg^{-1} and 606.42 ± 21.23 Bqkg^{-1}. From the measured activity concentrations of soil samples, radium equivalent activity, external and internal hazard indices, terrestrial absorbed dose, gamma representative Index, annual effective dose, annual gonadal dose equivalent, and estimated life time cancer risk were calculated. Mean radium equivalent activity (Ra_{eq}), outdoor radiation hazard index (H_{ex}), indoor radiation hazard index (H_{in}), absorbed dose rate (D) and gamma representative Index (I_{γ}) for soil were found to be 155.02 ± 6.66 Bqkg^{-1} 0.42 ± 0.2, 0.51 ± 0.2, 73.35 ± 2.69 nGyh^{-1}and 1.15 ± 0.01 respectively. The calculated annual effective dose, annual gonadal dose, and estimated life time cancer risk for soil samples were 0.13 ± 0.01 mSvy^{-1},512.78 ± 18.50 mSvy^{-1}, and 0.47 x 10^{-3} respectively. Frequency distribution and activity concentration of measured radionuclides for all sampling sites are presented. The geo statistical mapping was created to indicate the activity distribution in the studied area. On the basis of measured activity and calculated values of hazards indices, it is concluded that the surveyed area is not a major source of radiation hazards and do not pose any health problem.

Keywords:
HPGe gamma ray spectrometry, soil samples, health hazards, natural radionuclides, radium equivalent activity

1. Introduction

Naturally occurring radioactive materials are present everywhere on earth's crust and their radioactivity may be concentrated in certain area as a result of human activities. Natural radiation at earth's crust consists of two types namely cosmic and terrestrial radiation. The latter component originates from the primordial radioactive compounds associated in the early stage of the formation of the solar system is a major contributor. Uranium, thorium and potassium are the main components contributing the terrestrial radioactivity [1-5]. It is an established fact that radioactivity in the soil adds to the background level of radiation which directly effects human beings depending upon the amount of generated activity. The level of contribution to the background radiation depends on the concentration of the radioactive materials in the environmental media and may vary from area to area [5-9]. The naturally occurring radionuclides are present in soil act as the major sources of external gamma-ray exposure. The radio-nuclides get released into the environment through several decay processes and reach the human body. The concentration of these naturally occurring radio-nuclides in any region and associated external exposure depends primarily on the geological origin, environmental parameters and geographical conditions of the region [10–14]. Exposure to human being due to naturally occurring

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radionuclides is an inevitable process because of their presence in the earth's crust, soil, air, food and water. It is largely recognized that natural radiation are the major source of public radiation exposure [15-17]. Therefore, it is, necessary to measure the radiation levels in the environment surrounding humans to make sure the radiological safety of general public. The awareness about naturally occurring radionuclides is valuable in order to set the standards and national guidelines in the light of international recommendations [18-23].

The aim of the present study is to determine the radioactivity levels in soil samples of district Chakwal. In order to assess the risks associated with exposure due to the natural radioactivity, radium equivalent activity, indoor and outdoor radiation hazard indices, gamma representative index, absorbed dose rate, annual effective dose equivalent, annual gonadal dose equivalent, and estimated lifetime cancer risk were calculated for the studied area. This data would help to decide whether the studied region has normal or higher background radiation levels.

Table 1. Longitude, latitude and elevation of sampling sites

S. No	Sampling Site	Longitude	Latitude	Elevation (m)
1	Naka Kahoot	32º57′ N	72º29′ E	429
2	Adlakka	32º52′ N	72º23′ E	506
3	Dhaular	33º02′ N	72º18′ E	404
4	Akwal	33º02′ N	72º21′ E	475
5	Pachnand	32º53′ N	71º59′ E	413
6	DhokMachukhel	32º43′ N	71º57′ E	375
7	KotQazi	32º49′ N	72º00′ E	391
8	KotGulla	32º57′ N	71º54′ E	331
9	Mial	32º51′ N	72º06′ E	411
10	Nara	32º37′ N	71º57′ E	474
11	Mankewali	32º41′ N	72º03′ E	519
12	Hawapura	32º47′ N	72º11′ E	562
13	Bhilomar	32º43′ N	72º26′ E	663
14	Chakhandi	32º50′ N	72º17′ E	535
15	Nikka Rihan	33º00′ N	72º26′ E	434
16	DhokPathan	33º08′ N	72º20′ E	377
17	Patwali	33º02′ N	72º10′ E	378
18	Latti	32º 55′ N	72º04′ E	372
19	Khuhian Village	33˚ 01′ N	72˚04′ E	359
20	DhokJand	33˚03′ N	71˚56′ E	256
21	Dhudail	33˚04′ N	72˚55′ E	501
22	Narang	33˚10′ N	72˚45′ E	357
23	Roopwal	33˚03′ N	72˚32′ E	445
24	Kurpal	32˚55′ N	73˚05′ E	418
25	ChakChakora	33˚07′ N	73˚19′ E	375
26	Thoha Bahadur	32˚56′ N	72˚42′ E	536
27	Nurwal	32˚56′ N	72˚53′ E	519
28	Jamalwal	33˚04′ N	72˚47′ E	461
29	Ghanwal	32˚51′ N	73˚01′ E	478
30	Kotla	32˚59′ N	73˚03′ E	438
31	WahaliBala	32˚43′ N	73˚02′ E	797
32	Warwal	33˚08′ N	72˚31′ E	341
33	Bhaun	32˚52′ N	72˚46′ E	557
34	Noorpur	32˚39′ N	72˚34′ E	752
35	DhokMochian	32˚48′ N	72˚34′ E	552
36	ChakKhushi	32˚46′ N	72˚46′ E	669
37	Sardhi	32˚41′ N	72˚42′ E	810
38	Bharpur	32º51′ N	72˚34′ E	557
39	Jhamrah	32º42′ N	72˚37′ E	808
40	Buchal Kalan	32º41′ N	72˚38′ E	834
41	Katas	32˚43′ N	72˚57′ E	690
42	Dhok Gujar	32˚45′ N	73˚11′ E	661
43	Kariala	32˚50′ N	72˚54′ E	534
44	Dandot	32˚39′ N	72˚57′ E	687
45	Saloi	32˚44′ N	73˚05′ E	693

2. Materials and Methods

2.1. Study area

Chakwal district comprised of four tehsils, namely, Talagang, Chakwal, ChoaSaiden Shah and KallarKahar. The studied area borders the districts of Rawalpindi and Attock in the north, Jhelum in the east, Khushab in the south and Mianwali in the west. The southern portion of the district runs up into the Salt Range. Chakwal is a barani district and the terrain is mainly hilly, covered with scrub forest in the southwest, and levelled plains interspaced with dry rocky patches in the north and northeast. The total area of Ckakwal district is 6,524 km^2.The sampling area is shown in figure 1. A global positioning system was used to record the coordinates of the sampling sites [4,5].The longitude and latitude of the sampling locations ranged from 32º37′ N to 33º51′ N and71˚56′ E to 73˚19′ E, respectively. The sampling sites with longitude, latitude and elevation of the studied region are shown in table 1. Systematic soil sampling was carried out following the grid of 15 × 15 km².

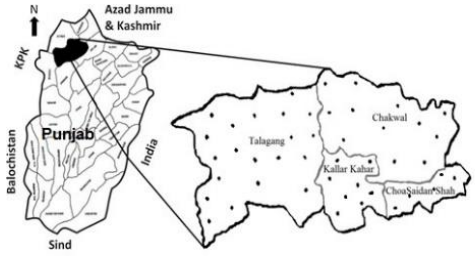


Figure 1. Sampling Sites

2.2. Sample Collection

A total of 45 samples were collected from different locations of four tehsils of District Chakwal. The sampling sites were selected to be relatively flat, undisturbed and situated sufficiently away from the public road and buildings. The samples were collected from the upper 4-6 cm layer with a coring tool. These soil samples were gathered from different adjacent sites and combined to make a single representative sample. The samples were packed in specially designed polyethylene bags and sealed properly. The collected samples were marked with date, sampling site for later identification and brought to the laboratory for processing before analysis [4,5].

2.3. Sample preparation

For activity measurements, the samples were dried at room temperature for few days under a controlled environment. The samples were then oven dried at 150 ^{0}C until the moisture of the samples removed and the sample weight became constant. The dried samples were crushed, powdered and passed through sieve having 2mm mesh size. The homogenized samples having weight of 200 g were then sealed in plastic containers. The geometrical dimensions of these samples were kept identical as that of reference material, described by the calibration requirement [4,5,9]. The samples were sealed hermetically and stored for more than 40 days for establishment of secular equilibrium between ^{226}Ra and its short lived decay products.

2.4.Gamma Spectrometry

To determine the concentration of ^{238}U, ^{232}Th and ^{40}K, a high resolution gamma-ray spectrometer consisting of HPGe detector (Model GC 3020 Canberra) coupled to PC based MCA card was used. The relative efficiency of the detector was 30% and the resolution 2.23 keV at 1332 gamma-rays of ^{60}Co. The used detector was equipped with 8192-channels and it was shielded in 8 cm lead chamber with an inner lining of 0.5 cm thick copper plate to reduce the background. The results were analyzed by using Geni-2000 software. Efficiency calibration of the detection system was evaluated with Soil-327 which was obtained from IAEA. The samples were counted for 65000 seconds. ^{40}K was analyzed by its single peak of 1460 keV. However, the analysis of ^{238}U and ^{232}Th was based upon the peaks of progeny in equilibrium with their parent radionuclides [10,13].

3. Results and Discussion

The activity of ^{226}Ra, ^{232}Th and ^{40}K in the soil samples have been measured by High Purity Germanium (HPGe) detector and the correspondence results are shown in table 2.

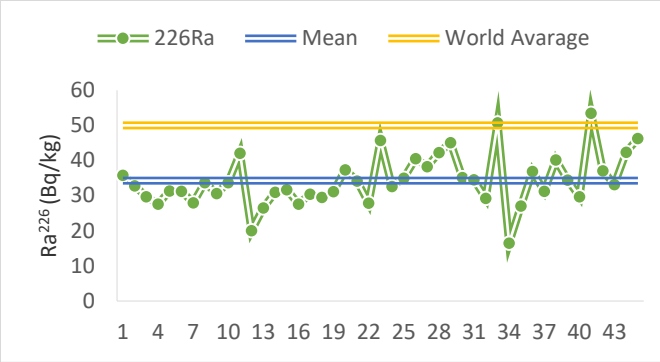
Table 2. Measured radioactive concentrations of ^{226}Ra, ^{232}Th and ^{40}K in soil samples

No of S	Tehsil	Range	^{226}Ra (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)
20	Talagang	Min	20.02 ± 1.13	33.67 ± 2.28	371.77 ± 18.18
		Max	42.09 ± 1.29	65.30 ± 2.49	635.80 ± 19.60
		Mean	31.10 ± 1.17	47.47 ± 2.35	548.97 ± 18.50
12	Chakwal	Min	27.90 ± 1.23	41.68 ± 2.16	583.78 ± 22.22
		Max	45.79 ± 1.41	65.32 ± 3.22	797.07 ± 27.04
		Mean	36.73 ± 1.25	53.88 ± 2.65	674.63 ± 25.67
08	KalarKahar	Min	16.50 ± 1.13	15.45 ± 2.81	93.32 ± 21.71
		Max	50.74 ± 1.41	79.89 ± 3.41	764.40 ± 25.33
		Mean	33.63 ± 1.71	53.90 ± 3.05	613.87 ± 22.51
05	ChoaSaidian Shah	Min	33.19 ± 1.36	47.25 ± 3.15	643.25 ± 22.34
		Max	53.51 ± 1.35	67.43 ± 3.42	686.26 ± 21.65
		Mean	42.50 ± 1.54	60.63 ± 3.29	660.56 ± 22.15
	Overall mean		**34.27 ± 1.28**	**51.79 ± 2.73**	**606.42 ± 21.23**

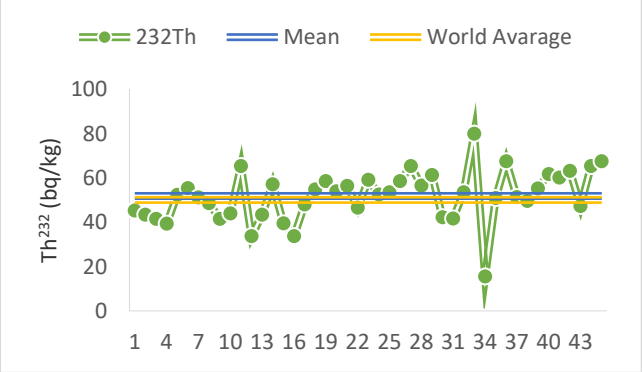
The maximum and minimum activity of ^{226}Ra has been found 53.51 ± 1.35 Bqkg^{-1} in Katas and 16.50 ± 1.13 Bqkg^{-1} in Noorpur, respectively. The mean radioactivity of ^{226}Ra in the study area is 34.27 ± 1.28 Bqkg^{-1}, which is less than the world average value of 50 Bqkg^{-1} [22]. Minimum ^{232}Th activity (15.45 ± 2.81 Bqkg^{-1}) measured in Noorpur and maximum activity (79.89 ± 3.41 Bqkg^{-1}) with mean value of 51.79 ± 2.73 Bqkg^{-1}, while the world average activity for the same is 50 Bqkg^{-1} [22].

The maximum and minimum activity of ^{40}K found to be 797.07 ± 27.04 Bqkg^{-1} in Dhudail and 93.32 ± 21.71 Bqkg^{-1} in Noorpur, respectively. The mean radioactivity of ^{40}K in the study area is 606.42 ± 21.23 Bqkg^{-1} and it is higher than the mean value of the world 500 Bqkg^{-1} [22]. In present study, it has been observed that the specific activity of natural radionuclides in the soil is not uniform but varies from area to area depending upon the geological nature and different minerals present in the soil. The detailed distribution of studied radionuclides is shown in figure 2(a, b, c). The large variations in the activity of these radionuclides are due to non-uniform distribution of the different primordial radionuclide in the soil of the study

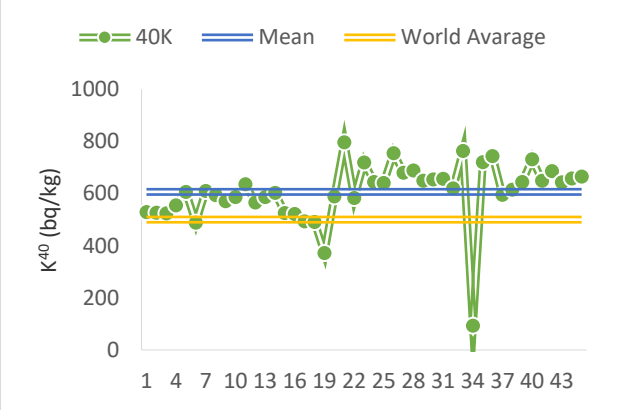
area.



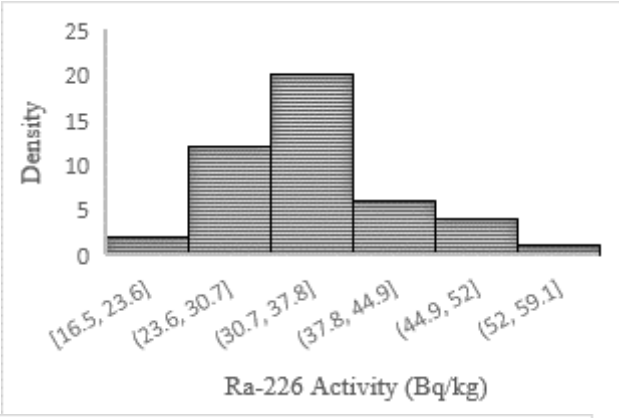
(a) Activity concentration of ^{226}Ra

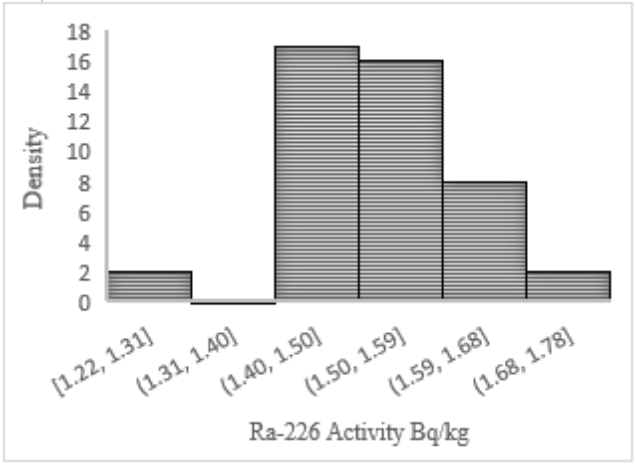


(b) Activity concentration of ^{232}Th

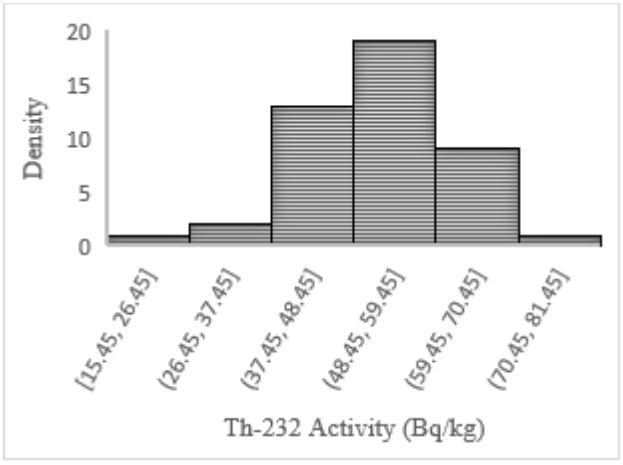


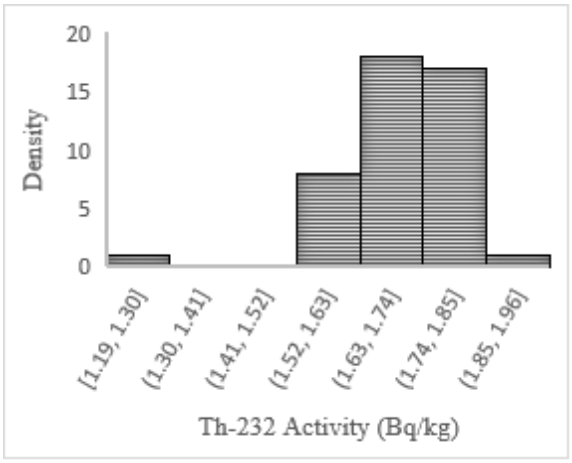
(c) Activity concentration of ^{40}K



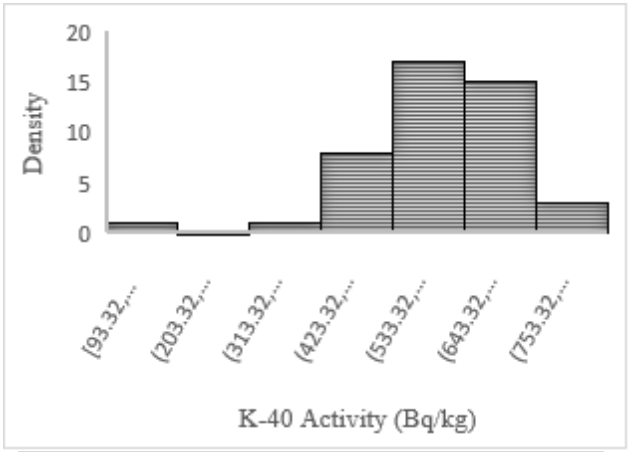


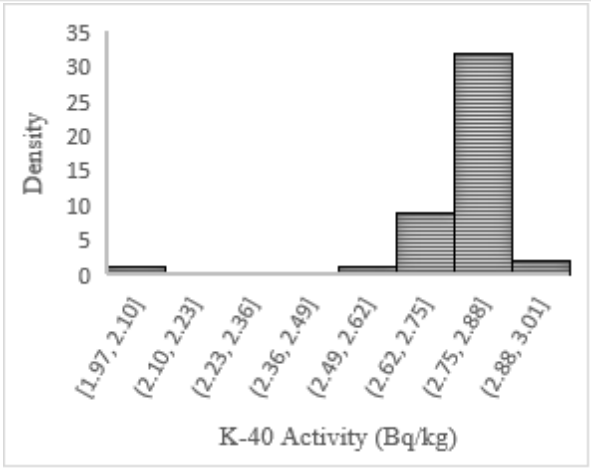
(a) Histograms for ^{226}Ra (i) Raw and (ii) Log transformed data





(b) Histograms for ^{232}Th (i) Raw and (ii) Log transformed data





(c) Histograms for ^{40}K (i) Raw and (ii) Log transformed data

Figure 3. Frequency distribution of studied radionuclides

3.1 Gamma dose rate

Gamma dose rates were calculated by using the formula [22]

$$D\ (nGy\ h^{-1}) = 0.427C_{Ra}+0.662C_{Th}+0.043C_K$$

C_{Ra}, C_{Th} and C_K are the specific activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K respectively. Average gamma dose rates of four tehsils with standard deviation, overall mean and their comparison with world standard are shown in figure 4. The calculated gamma dose rate in soil samples of the studied area is shown in table 3. The variation in dose rates for soil samples was found in the range of 21.12 ± 1.93 $nGyh^{-1}$ to 105.04 ± 2.84 $nGyh^{-1}$. The highest absorbed dose was found in Bhaun while the lowest absorbed dose in Noorpur. The mean absorbed dose rate of the study area in soil samples is 73.5 ± 2.69 $nGyh^{-1}$,which is slightly higher than world mean value 60 $nGyh^{-1}$.

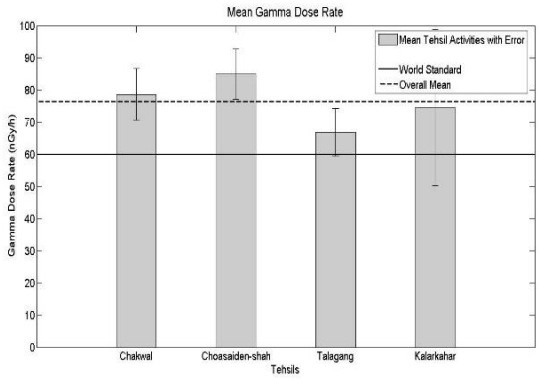


Figure 4. Comparison of average gamma dose rate of the present study

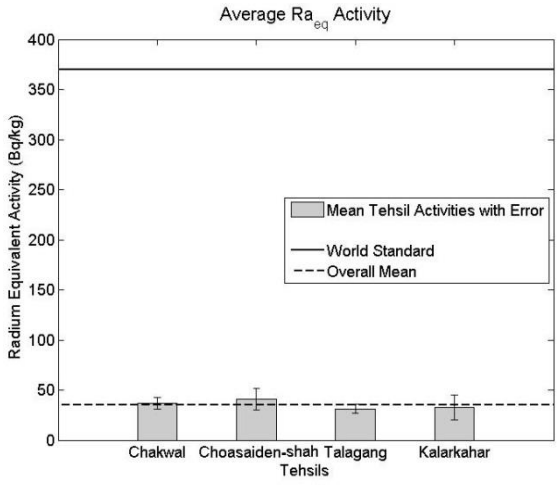


Figure 5. Comparison of average Ra_{eq} of the present study with world average

Table 3. Calculated radiological parameters on the basis of measured data

No of samples	Tehsils	Range	Ra_{eq}	D	H_{in}	H_{ex}	I_γ	AEDE	AGDE	ELCR
20	Talagang	Min	111.82 ± ± 5.73	53.84 ± 2.64	0.36 ± 0.2	0.30 ± 0.2	0.85 ± 0.01	0.10 ± 0.01	380.5 ± 19.82	0.35
		Max	184.43 ± 6.36	86.60 ± 2.92	0.61 ± 0.2	0.50± 0.2	1.36 ± 0.01	0.16 ± 0.01	602.6 ± 22.36	0.56
		Mean	141.26 ± 7.01	66.81 ± 1.97	0.47 ± 0.2	0.38± 0.2	1.05 ± 0.01	0.12 ± 0.01	466.92 ± 17.35	0.43
12	Chakwal	Min	139.46 ± 5.99	66.22 ± 2.84	0.45 ± 0.2	0.38± 0.2	1.04 ± 0.01	0.12 ± 0.01	464.22 ± 16.92	0.43
		Max	185.68 ± 7.39	87.93 ± 2.53	0.63 ± 0.2	0.50± 0.2	1.38 ± 0.01	0.16 ± 0.01	614.46 ± 20.55	0.57
		Mean	165.73 ± 6.21	78.64 ± 3.14	0.55 ± 0.2	0.45± 0.2	1.23 ± 0.01	0.14 ± 0.01	550.58 ± 21.41	0.51
08	KalarKahar	Min	45.78 ± 6.67	21.12 ± 1.93	0.17 ± 0.2	0.12± 0.2	0.33 ± 0.01	0.04 ± 0.01	144.87 ± 15.97	0.14
		Max	223.84 ± 8.08	105.04 ± 2.84	0.74 ± 0.2	0.60± 0.2	1.65 ± 0.01	0.19 ± 0.01	730.75 ± 28.01	0.68
		Mean	157.70 ± 6.98	74.56 ± 2.56	0.52 ± 0.2	0.43± 0.2	1.17 ± 0.01	0.14 ± 0.01	521.14 ± 21.22	0.48
05	ChoaSaidan Shah	Min	150.29 ± 6.66	71.56 ± 2.41	0.50 ± 0.2	0.41± 0.2	1.12 ± 0.01	0.13 ± 0.01	502.04 ± 21.13	0.46
		Max	193.94 ± 8.01	91.09 ± 2.69	0.66 ± 0.2	0.52± 0.2	1.43 ± 0.01	0.17 ± 0.01	633.80 ± 24.15	0.59
		Mean	180.06 ± 8.51	84.91 ± 3.03	0.60 ± 0.2	0.49± 0.2	1.33 ± 0.01	0.16 ± 0.01	592.17 ± 19.33	0.55
45	Overall mean	Min	45.78 ± 6.67	21.12 ± 1.93	0.17 ± 0.2	0.12± 0.2	0.33 ± 0.01	0.04 ± 0.01	144.87 ± 15.97	0.14
		Max	223.84 ± 8.08	105.04± 2.84	0.74 ± 0.2	0.60± 0.2	1.65 ± 0.01	0.19 ± 0.01	730.75 ± 28.01	0.68
		Mean	155.02	73.35 ±	0.51 ±	0.42±	1.15 ±	0.13 ±	512.7 ±	0.47

3.2 Radium equivalent activity

Radium equivalent activity (Ra_{eq}) is defined to compare the specific activity of materials containing different amounts of ^{226}Ra, ^{232}Th and ^{40}K using the equation.

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_K$$

In the above equation A_{Ra}, A_{Th} and A_K are the mean activities of ^{226}Ra, ^{232}Th and ^{40}Kin $Bqkg^{-1}$, respectively.Average radium equivalent activity of the present study and its comparison with world standard is shown in figure 5. It is clear from the figure 5 that Ra_{eq} is significantly below the world average. Radium equivalent activity calculated for different soil samples investigated in the present study are given in table 3. Radium equivalent activity varied from 45.78 ± 6.67 $Bqkg^{-1}$ to 223.84 ± 8.08 $Bqkg^{-1}$ in the studied area. The mean radium equivalent activity of the soil samples found to be 155.02 ± 6.60 $Bqkg^{-1}$.

3.3 External and internal hazard indices

The internal and external hazard indices are calculated by using the following expressions

$$H_{ex} = A_{Ra}/370 + A_{Th}/259 + A_K/4810$$

$$H_{in} = A_{Ra}/185 + A_{Th}/259 + A_K/4810$$

In the above equations A_{Ra}, A_{Th} and A_K are the activities of ^{226}Ra, ^{232}Th and ^{40}K in $Bqkg^{-1}$,respectively. Average internal and external hazard indices of the present study and their comparison with world standard are shown in figure 6. The calculated H_{ex} for soil samples varies from 0.12 ± 0.02 to 0.60 ± 0.02 with mean value 0.42 ± 0.2 and is less than world mean value 0.5.

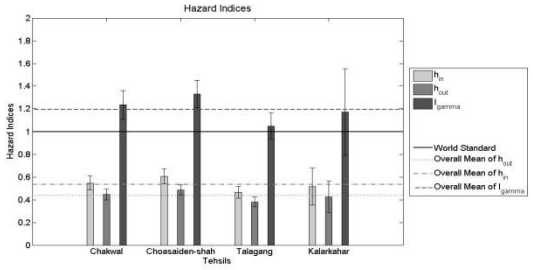


Figure 6. Comparison of hazard indices and gamma

representative index of the present study

The H_{in} for soil samples varies from 0.17 ± 0.02 to 0.74 ± 0.02. The lowest value found in soil sample of Noorpur and the highest value represent in soil sample of Bhaun. The mean internal hazards index for the area is 0.51 ± 0.2 which is equal to the world means value 0.5 [15, 20, 22]. The external and internal hazard indices for soil samples are shown in tables 3.

3.4 Gamma representative level index (Iγr)

The gamma radiation representative level index associated with natural radionuclide was calculated using the following equation [22, 23]

$$I_{\gamma r} = A_{Ra226}/150 + A_{Th232}/100 + A_{K40}/1500$$

The minimum, maximum and mean values of gamma index are 0.33 ± 0.03, 1.65 ± 0.04 and 1.15 ± 0.03 respectively. Table 3 shows the obtained values of gamma index for the studied area for all the collected samples. The obtained gamma index level is comparable to the regional calculated levels [24]. Average values of gamma representative index with comparison of world average are also shown in figure 6.

3.5 Annual effective dose equivalent

Annual effective dose equivalent (AEDE) was calculated by using the following relation.

$$E = Q \times T \times O \times D \times 10^{-6}$$

Where Q is the conversion coefficient for an absorbed dose in air to effective dose in human body (0.7 $SvGy^{-1}$), T is time in hours in one year, O is occupancy factor and D is dose rate.

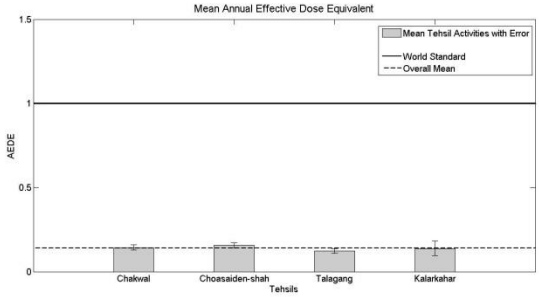


Figure 7. Comparison of average AEDE of the present study with world standard

Average annual effective dose equivalent of the present study and its comparison with world standard are shown in figure 7. The variation in annual effective dose equivalent for soil samples was found to be varied from 0.04 ± 0.01 $mSvy^{-1}$ to 0.19 ± 0.01 $mSvy^{-1}$ and shown in table 3. The lowest value found in soil samples of Noorpur and the highest value in Bhaun, respectively. The mean annual effective dose in the soil samples is 0.13 ± 0.01 $mSvy^{-1}$ which is less than the world mean value of 0.3 $mSvy^{-1}$ [22,23].

3.6 Annual gonadal dose equivalent (AGDE)

The organs of interest by UNSCEAR include, thyroid, lungs, bone marrow, bone surface cell, gonads and the female breast [25]. Hence, the annual gonadal dose equivalent can be given by

$$AGDE\ (\mu Sv/y) = 3.09\ A_{Ra226} + 4.18\ A_{Th232} + 0.314\ A_{K40}$$

The obtained results of annual gonadal dose equivalent are listed in table 3. It is obvious from the given table that AGDE varied from 144.87 ± 12.70 to 730.75 ± 16.34 μSv/y and mean value came out to be 512.78 ± 15.44 μSv/y.

3.7 Excess lifetime cancer risk (ELCR)

ELCR is calculated using the equation given below [5, 10] and the corresponding results are presented in table 3

$$ELCR = AEDE \times DL \times RF$$

Where AEDE is taken from section 3.5, duration of life (DL) is assumed to be 70 years and risk factor (RF) values attributed from ICRP 60 which is 0.05 Sv^{-1}[23, 24, 5]. Average excess lifetime cancer risk of four tehsils of present study, overall mean and their comparison with world average are shown in figure 8. The calculated range of ELCR found to be 0.14 × 10^{-3} to 0.68 × 10^{-3} with an average value of 0.47 × 10^{-3} for soil samples. The average value of ELCR in the present study is slightly higher as compared to the world average 0.29 × 10^{-3} [22]. The calculated measurements for ELCR are given in table 3.

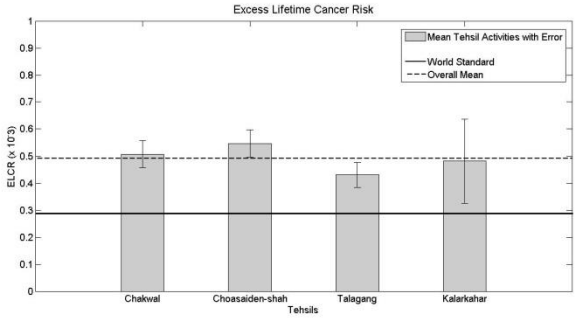
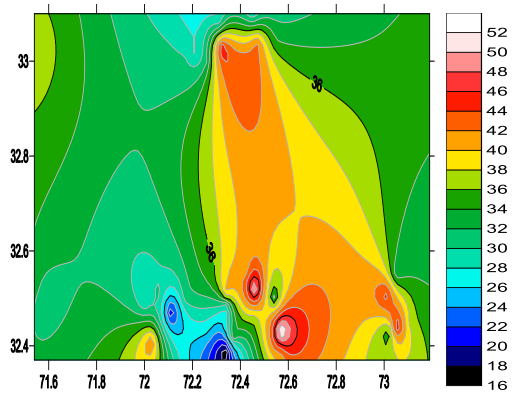


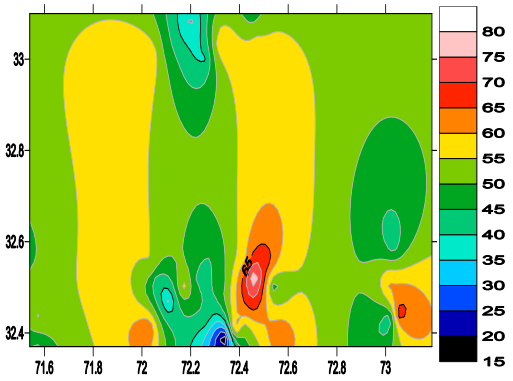
Figure 8. Comparison of average excess lifetime cancer risk of the present study

3.8 Mapping of ^{226}Ra, ^{232}Th and ^{40}K

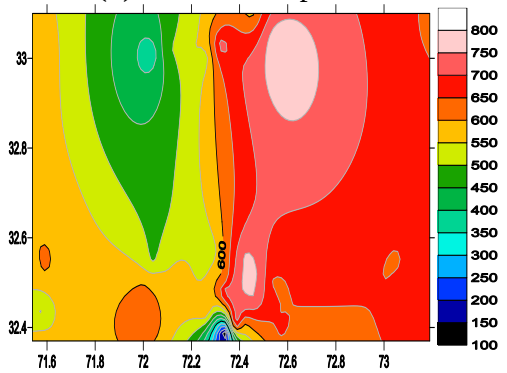
Mapping was interpolated for the un-sampled area using SURFER software version 14. The studied area was divided into 15×15 km^2 cells and represented by grid system. The maps identified for the concentration distribution of ^{226}Ra, ^{232}Th, and ^{40}K radionuclides and are shown in figures 9 (a, b, c). The enhanced activity areas are indicated with white and red color regions in the plotted map. Legend shows the detailed scale of all the values. In these maps, it is noteworthy that the activity of ^{40}K is higher than world average but comparable to other regional studies. Similarly, the radiological map created by Kriging method for ELCR at each sampling location is shown in figure 9d.



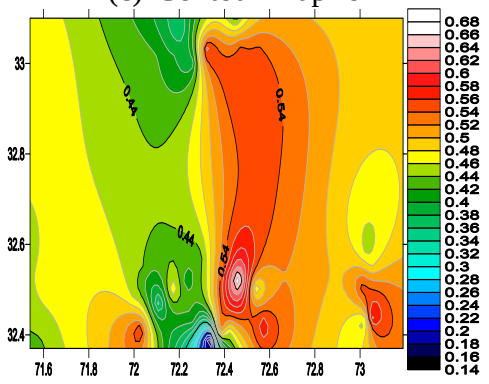
(a) Contour Map for Ra^{226}



(b) Contour Map for Th^{232}



(c) Contour Map for K^{40}



(d) Contour Map for ELCR

Figure 9. Contour maps for activity concentrations of ^{226}Ra, ^{232}Th, ^{40}K and ELCR

4 Conclusions

The study is conducted in four tehsils of District Chakwal, Pakistan to investigate the concentrations of naturally occurring radionuclides using gamma spectrometry technique. The soil samples analyzed in the present study shows ^{226}Ra activity ranging from 16.50 ± 1.13Bqkg^{-1} to 53.51 ± 1.35 Bqkg^{-1}. The activity of ^{232}Th varies from 15.45 ± 2.81 Bqkg^{-1} to 79.89 ± 2.49 Bqkg^{-1} and ^{40}K activity in soil samples ranged from 93.32 ± 21.71 Bqkg^{-1} to 797.07 ± 27.04 Bqkg^{-1}. The calculated mean radium equivalent activity was 155.02 ± 6.66 Bqkg^{-1}. The mean value of external and internal radiation hazard indices was found 0.42 and 0.51 in the present study. The mean gamma representative index and absorbed dose rate were calculated and came out to be 1.15 ± 0.01 and 73.35 ± 2.69 nGyh^{-1}. The annual effective dose, annual gonadal dose, and estimated life time cancer risk for soil samples were 0.13 ± 0.01 mSvy^{-1},512.78 ± 18.50 mSvy^{-1}, and 0.47 x 10^{-3} respectively. The measured concentration of radionuclides and calculated radiological parameters shows that the study area, do not pose any significant radiation hazard to the inhabitants of the studied area.

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