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Research Article

Natural radionuclide distribution and dose assessment for soil samples collected from Talagang, Pakistan

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ABSTRACT
Human beings are persistently exposed to ionizing radiation caused by terrestrial, extra-terrestrial and anthropogenic radionuclides. In order to assess the risks associated with exposure due to the natural radioactivity in soil, a radiological environmental monitoring survey was carried out in Talagang area of district Chakwal. In the present study, activities of ^{226}Ra, ^{232}Th and ^{40}K are measured in soil samples using an HPGe based gamma spectrometry system. The measured mean specific radioactivity concentration of ^{226}Ra, ^{232}Th and ^{40}K in the studied samples was 31.08 ± 1.2 Bqkg^{-1}, 47.67 ± 2.30 Bqkg^{-1} and 558.23 ± 17.52 Bqkg^{-1}, respectively. From the measured activity concentration, radium equivalent activity, external and internal hazard indices, terrestrial absorbed dose and annual effective dose were calculated. Mean radium equivalent activity (Ra_{eq}), outdoor radiation hazard index (H_{ex}), indoor radiation hazard index (H_{in}) and absorbed dose rate (D) for the area under study were determined as 142.00 ± 5.98 Bqkg^{-1}, 0.38 ± 0.2, 0.47 ± 0.2 and 66.08 ± 2.75 nGyh^{-1} respectively. The annual effective dose equivalent (AEDE) varied in the range from 0.10 ± 0.01 mSv y^{-1} to 0.16 ± 0.01 mSv y^{-1}. On the basis of measured activity and calculated values of hazard indices, it is concluded that the surveyed area does not pose any significant radiological risk to the population and the environment.

INTRODUCTION
Naturally occurring radioactive materials are ubiquitous on earth and their radioactivity may become concentrated in a certain region/area as a result of human activities. Natural radiation at the earth's surface consists of two components, namely cosmic and terrestrial radiation. Terrestrial radiation mainly originates from the primordial radioactive nuclides originated in the early stage of the formation of the solar system. Uranium, thorium and potassium are the main elements contributing to natural terrestrial radioactivity. It is an established fact that radioactivity in the soil adds to the background level of radiation and human beings are exposed. The level of contribution to the background radiation depends on the concentration of the radioactive materials in the soil, but this amount may vary from area to area [1-3].

The naturally occurring radionuclides such as ^{238}U, ^{232}Th and ^{40}K are present in rocks and soil are one of the components of external gamma-ray exposure. These radionuclides are not uniformly distributed in the earth's crust and therefore, exposure of human being due to the radiation emitted from radioactive materials also changes. The radionuclides released into the environment through several transfer processes and reach the human body. The concentration of these naturally occurring radionuclides in the surrounding environment and associated external due to exposure to the gamma radiation depends primarily on the geological origin, environmental parameters and geographical conditions of the region [4–7].

It is now widely accepted that natural radiation accounts for the greatest part of public radiation exposure [8-10]. The exposure of human being to these naturally occurring radionuclides is an unavoidable consequence of their presence in the earth' s crust, soil, air, food and water. To ensure radiological safety of the general public, it is necessary to measure the radiation levels in the environment surrounding humans. The knowledge of naturally occurring radionuclides is useful in order to set the standards and national guidelines in the light of international recommendations. The aim of the present research work is to determine the radioactivity levels in soil samples of tehsil Talagang, district Chakwal.

Material and Methods
Fifteen samples were collected from various locations of tehsil Talagang of District Chakwal. The area under study is located between the longitudes 32° 42′ N - 33^0 42′ N and latitudes 71° 54′ E - 72° 60′ E. Longitude and latitudes of sampling locations are shown in Table 1. The sampling was carried out following the systematic grid of 20 × 20 square kilometers. The studied area is shown in Figure 1.

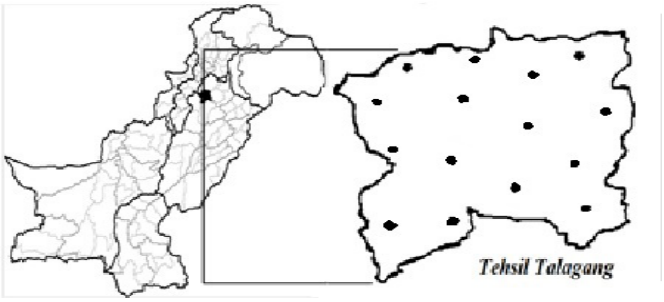

Figure 1. Sampling sites of the studied area

Sample No.	Sampling site	Longitude	Latitude	Elevation
S-1	Naka Kahoot	32°57.5′ N	72°29.8′ E	428.9 m
S-2	Mogla	33°24.0′ N	72°60.5′E	406.2 m
S-3	Ankar	32°54.5′ N	72°15.5′ E	452.9 m
S-4	kanattian	32°52.3′ N	71°56.5′ E	372.3 m
S-5	Koat Islam	32°49.5′ N	72°01.8′ E	394.1 m
S-6	sadiqabad	32°56.5′ N	71°60.9′ E	395.2 m
S-7	Trappi Nala	32°41.4′ N	71°54.2′ E	384.9 m
S-8	Gohal	32°41.7′ N	72°03.6′ E	519.9 m
S-9	Hawapura	32°47.0′ N	72°11.4′ E	562.1 m
S-10	chiaji	32°42.5′ N	72°22.1′ E	550.9 m
S-11	Jhatala	32°49.8′ N	72°22.9′ E	556.9 m
S-12	Dhok Pathan	33°08.4′ N	72°20.9′ E	376.7 m
S-13	misrial	33°42.5′ N	72°11.5′ E	365.1 m
S-14	Tamman	33°00.5′ N	72°08.0′ E	342.9 m
S-15	Shah Mohd Wali	33°03.6′ N	71°56.7′ E	256.6 m

Table 1. Longitude, latitude and elevation of sampling sites

The selected sampling sites were relatively flat, open and undisturbed. The soil samples were collected from the upper 4-6 cm layer with a coring tool. The collected samples were packed in polyethylene bags and labeled properly with date and place. In the laboratory, the roots and stones were removed from samples and oven dried at 150 ^{0}C until the sample weight became constant. The treated soil was then ground and sieved. Soil samples of about 200 g were stored in air tight cylindrical plastic containers for 4 weeks before counting to attain secular equilibrium between ^{226}Ra and ^{232}Th and their short lived progeny.

To determine the activities concentration of ^{238}U, ^{232}Th and ^{40}K, a high resolution gamma-ray spectrometer consisting of a HPGe detector (Model GC 3020 Canberra) coupled to PC based MCA card (Accuspec-A, Canberra) was used. The HPGe detector is available at HPD, PINSTECH, Nilore, Islamabad. 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 were shielded in 8 cm lead chamber with an inner lining of 0.5 cm thick copper plate to reduce the background [11-12].

The results were analyzed by using Geni-2000 software (Canberra). 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 [11-12].

Results and discussion

The activity of ^{226}Ra, ^{232}Th and ^{40}K in the soil samples have been calculated by High Purity Germanium (HPGe) detector and the correspondening results are shown in Table 2. 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. Table 2 represents the measured activity of ^{226}Ra, ^{232}Th and ^{40}K in all the samples of soil taken from different areas of tehsil Talagang of Chakwal district. The maximum and minimum activity of ^{226}Ra has been found 42.09 ± 1.29 Bqkg^{-1} in Gohal and 20.02 ± 1.13 Bqkg^{-1} in Hawapura, respectively. The mean radioactivity of ^{226}Ra in the study area is 31.08 ± 1.20 Bqkg^{-1}, which is less than the world average value of 50 Bqkg^{-1} [13].

Sr. No.	^{226}Ra (Bq kg^{-1})	^{232}Th (Bq kg^{-1})	^{40}K (Bq kg^{-1})
S-1	35.850±1.31	45.199±2.45	529.84±20.15
S-2	29.74±1.27	41.43±2.36	523.93±19.77
S-3	27.588±1.14	39.352±2.16	554.93±18.12
S-4	31.35±1.14	52.31±3.41	606.91±19.62
S-5	28.022±1.26	51.080±2.48	610.11±20.33
S-6	33.68±1.02	48.54±2.33	594.71±18.92
S-7	33.741±1.13	43.847±2.11	586.72±17.45
S-8	42.092±1.29	65.301±2.49	635.80±19.60
S-9	20.022±1.13	33.711±2.20	566.11±18.86
S-10	26.49±1.15	43.37±2.25	586.54±18.72
S-11	30.957±1.18	57.039±2.33	602.97±18.59
S-12	27.619±1.22	33.671±2.28	522.01±19.39
S-13	30.44±1.23	47.94±2.35	493.85±18.23
S-14	31.13±1.20	58.46±2.37	371.77±18.18
S-15	37.329±1.15	53.827±2.18	589.30±17.52
Mean	31.08 ± 1.20	47.67±2.30	558.23±17.52

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

Measured activity of ^{232}Th in all the samples of soil taken from a study area are also shown in Table 2. The maximum and minimum activity of ^{232}Th has been found 65.30 ± 2.49 $Bqkg^{-1}$ in Gohal and 33.67 ± 2.28 $Bqkg^{-1}$ in Dhok Pathan respectively. The mean radioactivity of ^{232}Th in the study area is 47.67 ± 2.30 $Bqkg^{-1}$, which is less than the world average value, i.e. 50 $Bqkg^{-1}$. Measured activity of ^{40}K in all the soil sample of the study area also shown in Table 2. According to the data, the maximum and minimum activity of ^{40}K has been found 635.80 ± 19.60 $Bqkg^{-1}$ in Gohal and 371.77 ± 18.18 $Bqkg^{-1}$ in Tamman respectively. The mean radioactivity of ^{40}K in the study area is 558.23 ± 17.52 $Bqkg^{-1}$ and it is higher than the mean value of the world 500 $Bqkg^{-1}$ [13].

In the 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.

Gamma Dose Rate

Gamma dose rates were calculated by using the formula given below.

$$D\ (nGy\ h^{-1}) = 427C_{Ra} + 0.662C_{Th} + 0.043C_{K}$$

Where C_K, C_{Ra} and C_{Th} are the specific activity concentrations of potassium, uranium and thorium, respectively. The variation in dose rates (D) which was determined by the formula for soil samples was found in the range of 52.76 ± 2.64 $nGyh^{-1}$ to 85.28 ± 2.92 $nGyh^{-1}$. The highest absorbed dose was found in sample of Gohal while the lowest absorbed dose was found in sample of Hawapura. The mean absorbed dose rate of the study area is 66.08 ± 2.75 $nGyh^{-1}$, which is 5.4% lower than world mean value i.e. 70 nGy h^{-1}. Table 3 shows calculated Gamma dose rate (D) of the studied area.

Radium Equivalent Activity

The radioactivity has been defined in terms of radium equivalent activity (Ra_{eq}) in $Bqkg^{-1}$ to compare the specific activity of materials containing different amounts of ^{226}Ra, ^{232}Th and ^{40}K by using the given equation.

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

Where A_{Ra}, A_{Th} and A_K are the mean activities of ^{226}Ra, ^{232}Th and ^{40}K in $Bqkg^{-1}$, respectively. Radium equivalent activity (Ra_{eq}) calculated for different soil samples investigated in the present study is given in Table 3. Radium equivalent activity (Ra_{eq}) is varying in the ranges 111.82 ± 5.73$Bqkg^{-1}$ in Hawapura to 184.43 ± 6.36 $Bqkg^{-1}$ in Gohal. The mean of radium equivalent activity in the current area is 142.00 ± 5.98 $Bqkg^{-1}$, which is less than the recommended limit.

External and internal and hazard indices

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

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

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

where A_{Ra}, A_{Th} and A_K are the activities of ^{226}Ra, ^{232}Th and ^{40}K in $Bq.kg^{-1}$, respectively. The calculated external hazard (H_{ex}) values are varies from 0.30 ± 0.2 to 0.50 ± 0.2, calculated from given equation. The current mean external hazard index is 0.38 ± 0.2which is 31.57% less than world mean value 0.5. Table 3 shows the external hazards of the sampling area.

The calculated internal hazard (H_{in}) values vary between 0.36 ± 0.2 to 0.61 ± 0.2. The lowest value found in soil samples of Hawapura and the highest value represented in soil samples of Gohal. The mean internal hazard index for the area is 0.47 ± 0.2which is less than to the world means value 0.5 [13].

Annual Effective Dose Equivalent

Annual effective dose equivalent (AEDE) was calculated from the formula given below.

$$E = Q \times T \times O \times D$$

The annual effective dose equivalent was calculated using a conversion factor of 0.7 $SvGy^{-1}$, which converts absorbed dose in air to human effective dose in adults. The variation in annual effective dose equivalent was found to be varied from 0.10 ± 0.01 $mSvy^{-1}$ to 0.16 ± 0.01 $mSvy^{-1}$. The lowest value found in soil samples of Dhok Pathan and the highest value in Gohal. The mean annual effective dose for the study area is 0.12 ± 0.01, which is less than the world mean value of 0.3 $mSvy^{-1}$[13]. Table 3 shows the dose rate, radium equivalent activity, hazard indices and annual effective dose equivalent of the studied area.

Sample #	Dose rate (nGy h^{-1})	Ra_{eq} Activity (Bq kg^{-1})	H_{ex}	H_{in}	AEDE (mSv y^{-1})
S-1	65.71±2.93	141.28±6.37	0.38±0.2	0.48±0.2	0.12±0.01
S-2	60.32±2.84	129.32±6.17	0.35±0.2	0.43±0.2	0.11±0.01
S-3	59.29±2.59	126.59±5.62	0.34±0.2	0.42±0.2	0.11±0.01
S-4	70.67±2.84	151.89±6.18	0.41±0.2	0.49±0.2	0.13±0.01
S-5	68.96±2.93	148.04±6.37	0.40±0.2	0.48±0.2	0.13±0.01
S-6	69.38±2.76	148.88±5.99	0.40±0.2	0.49±0.2	0.14±0.01
S-7	66.17±2.53	141.62±5.49	0.38±0.2	0.47±0.2	0.12±0.01
S-8	85.28±2.92	184.43±6.36	0.50±0.2	0.61±0.2	0.16±0.01
S-9	52.76±2.64	111.82±5.73	0.30±0.2	0.36±0.2	0.10±0.01
S-10	62.54±2.68	133.67±5.84	0.36±0.2	0.43±0.2	0.12±0.01
S-11	73.72±2.73	158.95±5.94	0.43±0.2	0.51±0.2	0.14±0.01
S-12	54.46±2.75	115.96±5.97	0.31±0.2	0.39±0.2	0.10±0.01
S-13	63.48±2.79	137.02±6.07	0.37±0.2	0.45±0.2	0.12±0.01
S-14	64.29±2.75	140.87±5.99	0.38±0.2	0.46±0.2	0.12±0.01
S-15	74.12±2.58	159.68±5.62	0.43±0.2	0.53±0.2	0.14±0.01
Mean	66.08±2.75	142.00±5.98	0.38±0.2	0.47±0.2	0.12±0.01

Table 3. Hazard indices and annual effective dose of the studied area area

CONCLUSION

The soil samples analyzed in the present study shows ^{226}Ra activity ranging from 20.02 ± 1.13 $Bqkg^{-1}$ to 42.09 ± 1.29 $Bqkg^{-1}$ and activity of ^{232}Th varies from 33.67 ± 2.28 $Bqkg^{-1}$ to 65.30 ± 2.49 $Bqkg^{-1}$. The activity measured for ^{40}K in all soil samples is ranged from 371.77 ± 18.18

Bqkg^{-1} to 635.80 ± 19.60 Bqkg^{-1}. Therefore, the natural radionuclide ^{226}Ra and ^{232}Th are detected in less quantity, while ^{40}K, which is an essential constituent of all cellular material, was detected in higher amount. The mean radium equivalent activity for the measured soil samples was 142.00 ± 5.98 Bqkg^{-1}. The calculated mean value of external radiation hazard index and internal radiation hazard was 0.38 ± 0.2 and 0.47 ± 0.2 respectively. The values of the radium equivalent activity and the external hazard index determined in the soil of the study area are less than the recommended safe levels. The mean absorbed dose rate and annual effective dose equivalent for the area under study was found to be 66.08 ± 2.75 nGyh^{-1} and 0.12 ± 0.01 mSvy^{-1}, respectively.

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