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# Measurement of Gamma Emitting Radionuclides in Environmental Samples of Talagang Tehsil-District Chakwal

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**Abstract:** Due to constant exposure of Human beings to radiation caused by terrestrial, extra-terrestrial and anthropogenic radio nuclides, it is necessary to determine/estimate the activity of various radio nuclides in environmental media such as vegetation, soil, and water. In the present research, the activities of $^{226}$Ra, $^{232}$Th and $^{40}$K are measured in soil, vegetation and water samples, collected from Talagang Tehsil-District Chakwal of Pakistan using a HPGe based gamma spectrometry system. The measured mean activity of $^{226}$Ra, $^{232}$Th and $^{40}$K in soil samples was found to be 31.19±1.2, 47.00±2.30 and 589.31±17.52 Bqkg$^{-1}$, respectively. The measured mean activity of these radionuclides in all water samples was found to be below minimum detectable activity. The measured mean activity of $^{226}$Ra, $^{232}$Th and $^{40}$K in vegetation samples was 19.92±3.09, 25.36±8.11 and 4982.94±85.68 Bqkg$^{-1}$, respectively. No anthropogenic $^{137}$Cs was detected in these environmental samples. Mean radium equivalent activity (Raeq), external radiation hazard index (Hex), internal radiation hazard index (Hin) and absorbed dose rate (D) for the area under study were determined as 142.92 Bqkg$^{-1}$, 0.38, 0.47 and 66.47 nGyh$^{-1}$, respectively. The annual effective dose equivalent (AEDE) varied in the range from 0.03 to 0.12 mSv y$^{-1}$. It is concluded that the surveyed area do not pose any significant radiological risk to the population and environment.

**Keywords:** High Purity Germanium Detector, Radium, Thorium, Potassium, Radium Equivalent Activity, Hazard Indices

## 1. Introduction

Radiation of natural origin at the earth's surface consists of two components, namely cosmic rays and radiation of the radioactive nuclides in the earth's crust. The latter component, the terrestrial radiation, originates mainly from the so-called 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. Uranium has two primary isotopes $^{238}$U (T=4.47x10$^{9}$ y) and $^{235}$U (T=7.07x10$^{8}$ y) which, at present, occur in the proportion of 99.3% $^{238}$U and 0.7% $^{235}$U. Both exhibit long and complex decay series. Thorium (T = 1.41x10$^{10}$ y) has only one isotope, while potassium has three isotopes ($^{39}$K, $^{40}$K, $^{41}$K), with $^{40}$K (T = 1.28x10$^{10}$ y) being the only radioactive isotope of natural abundance of (0.012% of potassium).

Knowledge about the radiation of natural origin is very important being the largest source of population dose and its assessment is important as a baseline with which radiation protection standards may be formulated. Additionally, natural radiation involves the entire global population. The exposure of men to these naturally occurring radio nuclides is, and has been, an unavoidable consequence of their presence in the earth' s crust, surface, soil, air, food and water.

It is now widely accepted among experts that natural radiation accounts for the greatest part of public radiation exposure. Moreover, the common understanding of the exposure of man to the natural radiation environment in the 1960s was fairly simple compared with the current understanding.

Due to the increased public concern and awareness about radioactive pollution, the aim of the present research work

was to determine the radioactivity levels in a variety of environmental samples of tehsil Talagang –district Chakwal of Punjab Province of Pakistan. Present study is a joint collaborative work between Department of Physics, Federal Urdu University of Arts Science and Technology and Health Physics Division, PINSTECH Islamabad.

The main objective of this study is to estimate the type and amount of natural and fallout radioactivity levels in the soil and other environmental samples and to establish base line data. A radiological environmental monitoring survey has already been accomplished for some other specific areas of Pakistan. The results are published elsewhere [1-12].

## 2. Material and Methods

Thirty samples were collected from various locations of Tehsil Talagang of District Chakwal. The area under study is located between the longitudes of 32° 34′ and 330 72′ N and latitudes of 71° 48′ E and 72° 32′ E as shown in Table 1. The sampling was carried out following the systematic grid of 25x25 square kilometers. The total area covered is approximately 1198 square miles. Three type of environmental media were collected from the area under study i.e. soil, water and vegetation. The sampling sites were chosen to be relatively flat, open and undisturbed. The soil samples were taken from the upper 5 cm layer with a coring tool. Vegetation was collected from different places in the selected site and was combined to make a single representative. In order to prevent contamination with soil, the vegetation sample was cut to a height of 5 cm from the ground. The soil and vegetation samples were collected in polyethylene bags and labeled properly (date and place). Water samples were collected in 2-liter cans. After collection, the samples were stored to avoid degradation, spoiling or other decomposition.

***Table 1.*** *Coordinates of sampling sites.*

| S. # | Sampling site | Longitude | Latitude | Elevation |
|---|---|---|---|---|
| | Naka Kahoot | 32°57.5′ N | 72°29.8′ E | 428.9 m |
| | Ankar | 32°54.5′ N | 72°15.5′ E | 452.9 m |
| | Koat Islam | 32°49.5′ N | 72°01.8′ E | 394.1 m |
| | Trappi Nala | 32°41.4′ N | 71°54.2′ E | 384.9 m |
| | Gohal | 32°41.7′ N | 72°03.6′ E | 519.9 m |
| | Hawapura | 32°47.0′ N | 72°11.4′ E | 562.1 m |
| | Jhatala | 32°49.8′ N | 72°22.9′ E | 556.9 m |
| | Dhok Pathan | 33°08.4′ N | 72°20.9′ E | 376.7 m |
| | Tamman | 33°00.5′ N | 72°08.0′ E | 342.9 m |
| | ShahMuhammad Wali | 33°03.6′ N | 71°56.7′ E | 256.6 m |

In the laboratory, after removing the roots and stones, soil samples were oven dried at 150°C until the sample weight became constant and then they were ground and sieved. About 200 g of soil samples were stored in air tight cylindrical plastic containers for at least 4 weeks before counting, so that secular equilibrium can be attained between the progeny and the $^{226}$Ra. In order to remove all organic matter, the vegetation samples were ashed in a muffle furnace at a temperature of 350°C. For ashing operation, as recommended, stainless steel trays were used.

In the case of water samples, evaporation was carried out on a hot plate for volume reduction from 2 liter to 125 ml. In order to maintain the homogeneity of the water samples and to avoid adsorption of radio nuclides on the walls of the container, all the samples were acidified with 0.1 N $HNO_3$. The temperature for evaporation was kept below the boiling point of water. Samples were transferred and stored in air tight containers for over 30 days to allow for Ra—Rn equilibrium before radiometric analysis [13].

To estimate the activity levels of $^{40}$K, $^{226}$Ra, $^{232}$Th and $^{137}$Cs a high resolution gamma-ray spectrometer consisting of a HPGe detector 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 detector was equipped with 8192-channels and was shielded in an 8 cm lead chamber with an inner lining of 0.5 cm thick copper plate to reduce the background [14]. The results were analyzed by using Geni-2000 software. Efficiency calibration of the detection system was done with Soil-327, obtained from IAEA. Every sample was counted for 65000 seconds. A background sample was normally analyzed at the start of each month and background counts were then subtracted from the total counts to obtain sample counts during that period. $^{40}$K and $^{137}$Cs were analyzed by their single peaks of 1460 and 661 keV, respectively. However, the analysis of $^{226}$Ra and $^{232}$Th was based upon the peaks of progeny in equilibrium with their parent radio nuclides.

## 3. Results and Discussion

The activity of $^{226}$Ra, $^{232}$Th and $^{40}$K in the soil, water and vegetation samples have been measured and the corresponding results are shown in Table 2. The large variations in the activity of these radio nuclides are due to non-uniform distribution of the different primordial radionuclide in the soil of the study area. The activity of $^{226}$Ra, $^{232}$Th, $^{40}$K and $^{137}$Cs in the water samples of different areas has been measured and it was found that that measured activity of $^{226}$Ra, $^{232}$Th, $^{40}$K and $^{137}$Cs in all the samples of water taken from different areas of tehsil Talagang of Chakwal district, are below or equal to the minimum detectable activity of the detector. Table 2 represents the measured activity of $^{226}$Ra, $^{232}$Th and $^{40}$K in all the sample of soil and vegetation 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$^{-1}$ inGohal and 20.02±1.13 Bqkg$^{-1}$ in Hawapura respectively. The mean radioactivity of $^{226}$Ra in the study area was 31.47±1.20 Bqkg$^{-1}$, which is less than the world average value, i.e. 50 Bqkg$^{-1}$ [15].

***Table 2.*** *Specific activity measured in soil, water and vegetation samples.*

| Sampling Site. No. | Media | Specific Activity (Bq kg$^{-1}$) | | |
|---|---|---|---|---|
| | | $^{226}$Ra | $^{232}$Th | $^{40}$K |
| | Soil | 35.850±1.31 | 45.199±2.45 | 529.84±20.15 |
| 1 | Water | ≤MDA | ≤MDA | ≤MDA |
| | Vegetation | 25.49±3.71 | 28.24±0.21 | 5933.07±78.76 |
| | Soil | 27.588±1.14 | 39.352±2.16 | 554.93±18.12 |
| 2 | Water | ≤MDA | ≤MDA | ≤MDA |
| | Vegetation | ≤MDA | 17.36± 0.24 | 8115.21±152.85 |
| | Soil | 28.022±1.26 | 51.080±2.48 | 610.11±20.33 |
| 3 | Water | ≤MDA | ≤MDA | ≤MDA |
| | Vegetation | 15.15± 5.08 | 38.02±0.22 | 3185.05±94.70 |
| | Soil | 33.741±1.13 | 43.847±2.11 | 586.72±17.45 |
| 4 | Water | ≤MDA | ≤MDA | ≤MDA |
| | Vegetation | 29.90± 3.74 | 51.77±0.20 | 5842.55±78.50 |
| | Soil | 42.092±1.29 | 65.301±2.49 | 635.80±19.60 |
| 5 | Water | ≤MDA | ≤MDA | ≤MDA |
| | Vegetation | 12.74±3.63 | 22.36±0.22 | 4530.13±74.62 |
| | Soil | 20.022±1.13 | 33.711±2.20 | 566.11±18.86 |
| 6 | Water | ≤MDA | ≤MDA | ≤MDA |
| | Vegetation | ≤MDA | ≤MDA | 4267.03±81.98 |
| | Soil | 30.957±1.18 | 57.039±2.33 | 602.97±18.59 |
| 7 | Water | ≤MDA | ≤MDA | ≤MDA |
| | Vegetation | 10.48±2.68 | 24.30±0.15 | 2106.05±51.15 |
| | Soil | 27.619±1.22 | 33.671±2.28 | 522.01±19.39 |
| 8 | Water | ≤MDA | ≤MDA | ≤MDA |
| | Vegetation | ≤MDA | ≤MDA | 2950.01±58.45 |
| | Soil | 31.13±1.20 | 58.46±2.37 | 371.77±18.18 |
| 9 | Water | ≤MDA | ≤MDA | ≤MDA |
| | Vegetation | 25.76±3.97 | 47.97±7.70 | 6947.13±86.15 |
| | Soil | 37.329±1.15 | 53.827±2.18 | 589.30±17.52 |
| 10 | Water | ≤MDA | ≤MDA | ≤MDA |
| | Vegetation | ≤MDA | 15.77±9.25 | 5953.12±99.70 |

Measured activity of $^{232}$Th in all the samples of soil taken from 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 47.00±2.30 Bqkg$^{-1}$, which is less than the world average value, i.e. 50 Bqkg$^{-1}$ [15]. Table 2 also represents the measured activity of $^{40}$K in all the soil sample of the study area. 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 589.31±17.52 Bqkg$^{-1}$ and it is higher than the mean value of the world i.e., 500 Bqkg$^{-1}$ [15]. Table 2 represents the measured activity of $^{137}$Cs in all the soil, water and vegetation samples of the study area, less than the minimum detection limit of the detector.

In present study, it has been observed that the specific activity of natural radionuclides in the soil is not uniform but varies from soil to soil depending upon the geological character and different minerals present in the soil. Similarly, the activity of $^{226}$Ra, $^{232}$Th and $^{40}$K in the vegetation sample of different sites of Tehsil Talagang has been also represented in the Table 2. The maximum and minimum activity of $^{226}$Ra has been found 29.90±3.74 Bqkg$^{-1}$ in Trappi Nalaand 10.48±2.68 Bqkg$^{-1}$ in Jhatala respectively. The mean radioactivity of $^{226}$Ra in the study area is 19.92±3.09 Bqkg$^{-1}$. In all the samples of vegetation taken from study area the maximum and minimum activity of $^{232}$Thhas been found to be 51.77±0.20 Bqkg$^{-1}$ and 17.36±0.24 Bqkg$^{-1}$ in Trappi Nala and Ankar respectively. The mean radioactivity of $^{232}$Th in the study area is 25.36±8.11 Bqkg$^{-1}$. Similarly, the maximum and minimum activity of $^{40}$K has been found to be 8115.21±152.85 Bqkg$^{-1}$ in Ankar and 2106.05±51.15 Bqkg$^{-1}$ in Jhatala respectively. The mean radioactivity of $^{40}$K in the study area is 4982.94±85.68 Bqkg$^{-1}$.

# 4. Measurements of Radioactivity Parameters

### *4.1. Gamma Dose Rate*

The variation in dose rates (*D*) which was determined by the formula given below for soil samples was found in the range of 85.28 nGyh$^{-1}$ to 52.76 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 66.47 nGyh$^{-1}$, which is 5.31% lower than world mean value i.e. 70 nGy h$^{-1}$, Table 3 listed the calculated Gamma dose rate (D) of the study area.

***Table 3.*** *Radiation doses measured in soil samples.*

| Soil # | Dose rate (nGy h$^{-1}$) | $Ra_{eq}$ Activity (Bq kg$^{-1}$) | $H_{ex}$ | $H_{in}$ | AEDE (mSv y$^{-1}$) |
|---|---|---|---|---|---|
| S-1 | 65.71 | 141.28 | 0.38 | 0.48 | 0.12 |
| S-2 | 59.29 | 126.59 | 0.34 | 0.42 | 0.11 |
| S-3 | 68.96 | 148.04 | 0.40 | 0.48 | 0.13 |
| S-4 | 66.17 | 141.62 | 0.38 | 0.47 | 0.12 |
| S-5 | 85.28 | 184.43 | 0.50 | 0.61 | 0.16 |
| S-6 | 52.76 | 111.82 | 0.30 | 0.36 | 0.10 |
| S-7 | 73.72 | 158.95 | 0.43 | 0.51 | 0.14 |
| S-8 | 54.46 | 115.96 | 0.31 | 0.39 | 0.10 |
| S-9 | 64.29 | 140.87 | 0.38 | 0.46 | 0.12 |
| S-10 | 74.12 | 159.68 | 0.43 | 0.53 | 0.14 |
| Max | 85.28 | 184.43 | 0.50 | 0.61 | 0.16 |
| Min | 52.76 | 111.82 | 0.30 | 0.36 | 0.10 |
| Mean | 66.47 | 142.92 | 0.38 | 0.47 | 0.12 |

$$D(nGyh^{-1}) = 0.46C_{Ra} + 0.62C_{Th} + 0.04C_K \quad (1)$$

Where D is the absorb dose rate, $C_{Ra}$, $C_{Th}$ and $C_K$ are the activity of $^{226}$Ra, $^{232}$Th and $^{40}$K [15].

### *4.2. Radium Equivalent Activity*

The radioactivity has been defined in terms of radium equivalent activity (Raeq) 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. Radium equivalent activity (Raeq) calculated for different soil samples investigated in the present study are given in Table 3. Radium equivalent activity (Raeq) is varying in the ranges 184.43 Bq kg$^{-1}$ in Gohal to 111.82 Bqkg$^{-1}$ in Hawapura.

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.077C_K \quad (2)$$

Where $C_{Ra}$, $C_{Th}$ and $C_K$ are the specific activities of $^{226}$Ra, $^{232}$Th and $^{40}$K (Bq kg$^{-1}$) respectively [13]. The mean of radium equivalent activity in the current area is 142.92 Bqkg$^{-1}$, less than the 370 Bqkg$^{-1}$ which is the safe limit as recommended by the Organization for Economic Cooperation and Development [15].

### *4.3. External Hazards Index*

The calculated external hazard (*H*ex) values are varies from 0.50 to 0.30, calculated from given equation, the lowest value is 0.30 in Hawapura and the highest value is 0.50 in Gohal.

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (3)$$

The mean value for sampling area is 0.38. The current mean external hazard index is 0.38, 31.57% less than world mean value i.e. 0.5 [13]. Table 3 shows the external hazards of the sampling area.

### *4.4. Internal Hazards Index*

The calculated internal hazard ($H_{in}$) values varies between 0.20 to 0.35, calculated from equation, the lowest value found in soil sample of Hawapuraand the highest value represent in soil sample of Gohal. The mean internal hazards index for the area is 0.27, which is less then to the world mean value i.e. 0.5 [13] as listed in Table 3. Therefore, based on $H_{in}$ and $H_{ex}$ results; we can say there is no health hazard from the soil of selected areas of Tehsil Talagang.

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (4)$$

### *4.5. Annual Effective Dose Equivalent*

Annual effective dose equivalents (AEDE) were calculated from the formula given below and are shown in Table 3. The variation in Annual effective dose equivalent was found to be 0.10 mSvy$^{-1}$ to 0.16 mSvy$^{-1}$, which represents the lowest value in soil samples of Dhok Pathan and the highest value in soil sample of Gohal. The mean annual effective dose for the study area is 0.12, which is negligible compare to world mean value of 0.3 mSvy$^{-1}$ [13].

$$AEDE\left(\frac{mSv}{y}\right) = D\left(\frac{nGy}{h}\right) \times 8760\left(\frac{h}{y}\right) \times 0.3 \times 0.7\left(\frac{Sv}{Gy}\right) \times 10^{-6} \quad (5)$$

# 5. Conclusion

Over all, the concentration of all the radio nuclides are less than the safe limit, they do not pose any health problem to the inhabitants of the study area. However, the data may provide a general background level for the area studied and may also serve as a guideline for future measurement and assessment of radio nuclides in case of any radiological emergency. All results of the present work indicate that the area under investigation has a normal level of natural background.

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