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Study of gamma spectroscopy and radiological health hazards of primordial radionuclides in granite samples of district Swabi, Pakistan

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Abstract:
This research evaluates natural radioactivity levels of Primordial Radionuclides ^{226}Ra, ^{232}Th, and ^{40}K and the associated radiological hazards in granite samples of District Swabi, Pakistan. This was accomplished by employing a High Purity Germanium (HPGe) gamma-ray detector, and a total of 20 granite samples were analysed. Average specific activity levels were determined to be 4.470, 11.812, and 140.738 Bq/kg for ^{232}Th, ^{226}Ra, and ^{40}K, respectively. As a result, a total average activity of 157.021 Bq/kg was found in the Swabi granite samples. Given their possible health risks, such as cancer, and the long-term effects of continual exposure through breathing, it is critical to investigate the radiological dangers posed by these primordial radionuclides. ^{232}Th activity is 3%, ^{226}Ra is 7%, and ^{40}K is 90% of the total. The measured activity concentrations were then used to determine the radium equivalent, the excessive lifetime cancer risk, and different indoor and outdoor radiological hazard indices. The estimated values for these indices were discovered to be well within the safe ranges advised by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). As a result, the study found that granite from the Swabi district is considered safe for construction use.

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1. Introduction

Depending on the kind, dose, and length of exposure, radiation can have both beneficial and detrimental effects on living things. Sunlight, heat, radio waves, and X-rays are examples of electromagnetic waves or particles that can be used to transmit energy. Furthermore, radiation can also be produced by man-made sources, such as nuclear reactors, X-ray devices, and radioactive materials. When evaluating radiation exposure's effects on living things, it is critical to take into account all of the connected aspects (Dutch, 2018).

A high-resolution gamma spectroscopy system with a High Purity Germanium (HPGe) detector was used to monitor the gamma radiation in 20 samples of granite taken from the different locations of District Swabi, KPK, Pakistan, in order to evaluate the levels of natural radioactivity. Due to its widespread use as a building material in Pakistan, granite, an igneous rock with various colours and primordial radionuclides, was chosen as the primary material for this research. Nevertheless, it's crucial to note that using granite exposes people to the risk of radiation exposure (EPA, 2024). Therefore, the primary purpose of this research is to measure naturally occurring radioactivity in a sample of granite from Swabi, Khyber Pakhtunkhwa area using HPGe detector to investigate the results further using various calculations to identify health hazards.

The district of Swabi is located in Pakistan's KPK province. It is situated between the Indus and Kabul Rivers. It was a tehsil within the Mardan District before it was established into a district in 1988. Pashto is the primary language of 96% of the populace. There were 1,625,477 people living in the district as of the 2017 census, including 815,828 men and 809,550 women. In comparison to the urban population, which was 275,964, the rural population was 1,349,513 (83.02%). The overall literacy rate was 59.06%, with males having a rate of 73.99% and females of 44.35%. The district had 086 members of religious minorities (Pakistan Bureau of Statistics, 2017). The climate of Swabi is warm and temperate, with hot, muggy summers and pleasant winters. The Köppen Climatic Classification System places Swabi's climate in the humid subtropical category. Swabi experiences an average annual temperature of 22.2 °C and a total of 639 millimetres of precipitation. November is the driest month in Swabi, with an average rainfall of just 12 mm, while August has the highest average rainfall of 137 mm.

2. Mineralogical studies Swabi granite

Many building materials that are extracted in Pakistan are frequently classified as granites. The construction supplies discovered in Swabi, a city in KPK, Pakistan, have also been classified (Younis *et al.*, 2021). Examining and identifying minerals found in granite samples is a part of mineralogical studies. Granite is a type of coarse-grained igneous rock made mostly of mica, quartz, and feldspar. Granite can come in a variety of shapes and colours, depending on the precise mineral makeup. Techniques like petrographic analysis, X-ray diffraction (XRD), electron microscopy, and chemical analysis are frequently used in the mineralogical study of granite (Younis *et al.*, 2018). These techniques aid in identifying and describing the minerals found in the granite samples. In order to comprehend the mineral makeup and properties of the granite found in Pakistan's Khyber Pakhtunkhwa province's Swabi district, Swabi granite can also contain accessory minerals in addition to these primary minerals, depending on the particular geological circumstances of its development. These auxiliary minerals could include garnet, pyroxene, amphibole, hornblende, and other substances (Wasim *et al.*, 2016).

3. Materials and techniques for radiological studies

3.1. Collection and preparation of samples

We collected a total of 20 granite samples from five different locations in Swabi, namely Shear Dara, Shaikh Jana, Tee Gari, Natyan and Kanpur. The materials were broken up into small pieces using the cup milling technique (Figure 1), which were then ground into a fine powder. The samples were then thoroughly dried for two hours at 110°C. The materials were weighed after drying, and then they were put into Marinelli beakers (Figure 1). These beakers were carefully sealed, and each sample was 1 kg. Before performing the measurements, the Marinelli beakers were kept undisturbed for 45 days to guarantee secular equilibrium. Prior to the measuring process, this waiting period allowed for the correct development of equilibrium conditions.

Figure 1: (a) Granite samples in raw form, (b) Crashed to small pieces, (c) Processing in vibrating cup mill, and (d) Powder form enclosing into Marinelli beaker

(a) (b) (c) (d)

3.2. Activity concentration

The existence of primordial radionuclides in granite samples was examined in the research carried out in the Swabi district of the KPK region using an HPGe detector, and to further investigate the results using various calculations to identify health hazards (Ali *et al.*, 2012). Uranium-238, Thorium-232, and Potassium-40 were three radionuclides that were present. The radionuclides utilised for calibrating the detector in the HPGe system, which was made up of a PC-MCA and an amplifier coupled to a hermetically sealed assembly, were described in detail in previous research papers. To ensure precise and accurate results, the calibration technique used radionuclides obtained from IAEA Soil-375 (American Cancer Society, n.d.). In granite samples taken from district Swabi in the KPK region, the total activity concentration of the primordial radionuclides' uranium-238, thorium-232, and potassium-40 has been detected. The formula below was used to calculate the activity concentration of each sample for thorium, radium, and potassium, which is displayed in Table-1 (Trevisi *et al.*, 2018).

$$Activity = \frac{N-B}{\varepsilon\,T\,M\,A} \quad (1)$$

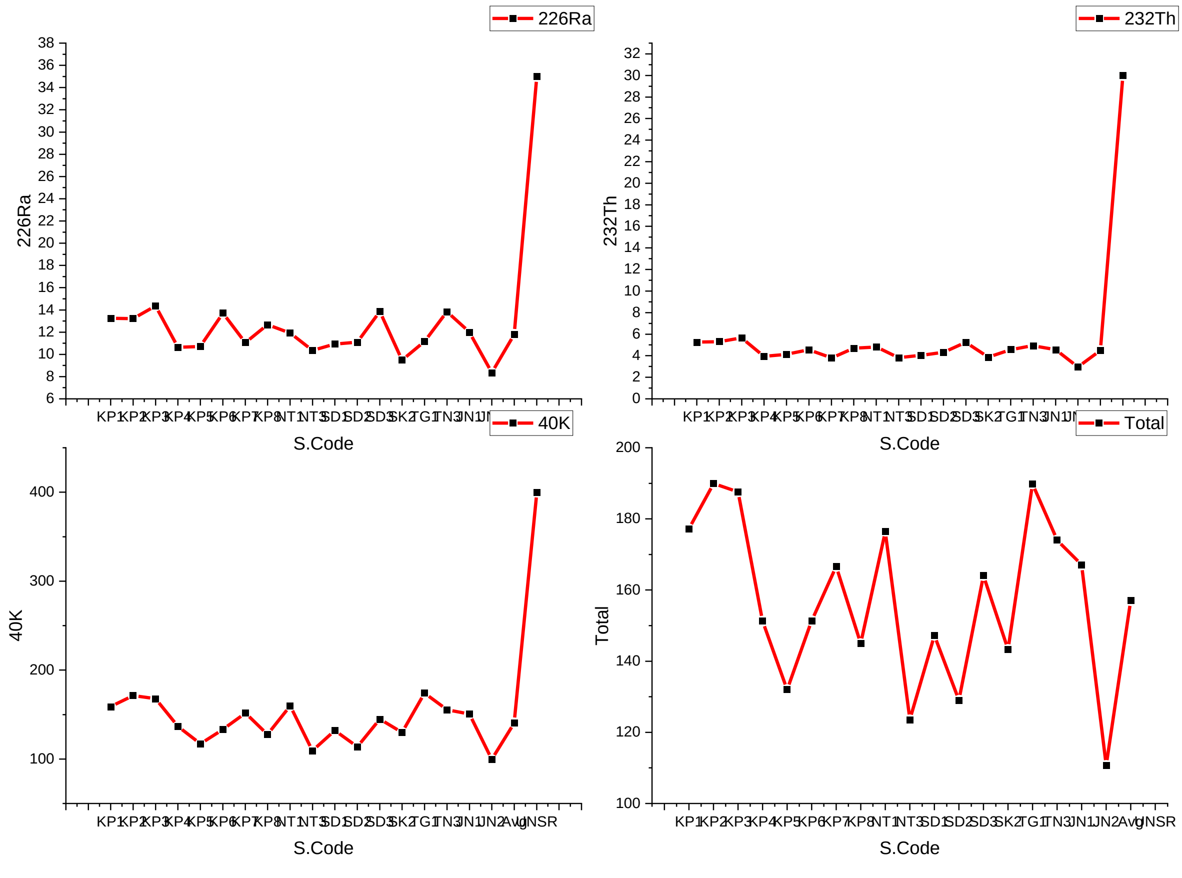
Where N is the number of counts for the sample, B is background counts, Ɛ is the efficiency of the detector, T is the time, which is 15000 seconds for each sample, A is the abundance of each element, and M is mass of each sample that is almost 1kg.

It is evident from Table-1 that the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in the Swabi granite samples all fall within the acceptable range specified by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

Table-1: Activity concentration of granite samples

Sample Code	Locations	Activity (Bq/kg)			Total (Bq/kg)
-	-	^{226}Ra	^{232}Th	^{40}K	-
KP1	Khanpur	13.24 ± 0.44	5.24 ± 0.288	158.72 ± 1.71	177.21 ± 2.44
KP2	Khanpur	13.22 ± 0.44	5.31 ± 0.286	171.36 ± 1.64	189.90 ± 2.38
KP3	Khanpur	14.36 ± 0.42	5.65 ± 0.28	167.64 ± 1.66	187.65 ± 2.37
KP4	Khanpur	10.62 ± 0.49	3.92 ± 0.33	136.71 ± 1.84	151.27 ± 2.68
KP5	Khanpur	10.71 ± 0.41	4.13 ± 0.32	117.19 ± 1.99	132.03 ± 2.81
KP6	Khanpur	13.72 ± 0.44	4.56 ± 0.31	133.07 ± 1.86	151.36 ± 2.61
KP7	Khanpur	11.06 ± 0.49	3.79 ± 0.34	151.78 ± 1.75	166.63 ± 2.57
KP8	Khanpur	12.67 ± 0.46	4.69 ± 0.30	127.59 ± 1.90	144.96 ± 2.67
NT1	Natyan	11.91 ± 0.47	4.82 ± 0.30	159.75 ± 1.70	176.49 ± 2.47
NT3	Natyan	10.36 ± 0.50	3.82 ± 0.34	109.34 ± 2.05	123.53 ± 2.90
SD1	Sher Dara	10.92 ± 0.41	4.04 ± 0.33	132.28 ± 1.87	147.25 ± 2.69
SD2	Sher Dara	11.09 ± 0.49	4.31 ± 0.32	113.62 ± 2.02	129.02 ± 2.82
SD3	Sher Dara	13.85 ± 0.44	5.24 ± 0.29	144.95 ± 1.79	164.06 ±2.51
SK2	Surkawy	9.47 ± 0.53	3.86 ± 0.33	129.95 ± 1.89	143.29 ± 2.75
TG1	Teghary	11.16 ± 0.49	4.56 ± 0.31	174.11 ± 1.63	189.84 ± 2.42
TN3	Teghary	13.85 ± 0.45	4.94 ± 0.29	155.27 ± 1.73	174.07 ± 2.46
JN1	Jany	12.00 ± 0.47	4.55 ± 0.31	150.50 ± 1.75	167.05 ± 2.53
JN2	Jany	8.35 ± 0.56	2.97 ± 0.38	99.39 ± 2.15	110.71 ± 3.10
Average		11.81 ± 0.47	4.47 ± 0.31	140.73 ± 1.81	157.02 ± 2.59
UNSCEAR		35	30	400	

Figure 2: Total activity concentration of Radium, Thorium, and Potassium



The activity concentrations of radium, thorium, and potassium are illustrated graphically in the accompanying using origin software together (Figure 2) with the global average for granite and the UNSCEAR-recommended limits. Sample KP1 has the highest activity concentration of ^{226}Ra, whilst sample JN2 has the lowest. In a similar manner, the activity concentration of potassium is highest in sample KP2 and lowest in sample JN2, while the activity of ^{232}Th is highest in sample KP2 and lowest in sample JN2.

4. Results and discussion

4.1. Activities of gamma rays in Dir granite

The findings in Table-1 show that the quantities of ^{226}Ra, ^{232}Th, and ^{40}K activity in the Swabi granite samples are substantially below the safety limits recommended by the UNSCEAR. In particular, the activity concentration of ^{226}Ra varies from 8.351 Bq/kg to 14.363 Bq/kg, that of ^{232}Th from 2.972 Bq/kg to 5.651 Bq/kg, and that of 40K from 99.394 Bq/kg to 174.110 Bq/kg in Swabi granite. According to these results, the natural radioactivity levels in the granite samples from Swabi do not pose any severe health hazards to the general public because they are substantially below the permissible limits set by international radiation safety regulations. The measurements were done utilising the UNSCEAR 2008 standard data, ensuring the correctness and dependability of the activity concentration values. This analysis contributes to understanding the levels of natural radioactivity in the area's geological formations. It offers essential information to protect the safety and well-being of the local inhabitants (Sherar *et al.*, 2021). It is also important to note that all of the values for ^{232}Th and ^{226}Ra found in the Swabi granite samples are considerably lower than the global average activity for granite, which is 42 Bq/kg for ^{226}Ra and 73 Bq/kg for ^{232}Th (Tsapaki *et al.*, 2018). The UNSCEAR standard, which sets a limit of 50 Bq/kg for both radionuclides, is also met by the lower activity concentrations of ^{232}Th and ^{226}Ra in our samples (Rahman *et al.*, 2013).

4.2. Calculations of radiological hazard indices

The term “radiological danger” radiation exposure primarily concerns how it affects living things. Table-2 and Figure 3 usually provide the measures of radioactive hazards and their health impacts. The health exposure indices developed by UNSCEAR and the European Commission (EC) were investigated by Beretka and Mathew. These hazard indices are intended to evaluate any potential health concerns connected to exposure to ^{226}Ra, ^{232}Th, and ^{40}K activity concentrations inside and outside buildings in the open air. Beretka and Mathew's study analysed these indices to learn more about the possible health effects of radionuclide exposure from natural sources such as rocks and soils (International Atomic Energy Agency, 2018). The risk for cancer and other diseases increased by radiological hazards, which represent a severe threat to human health. Additionally, especially in areas contaminated with radioactive materials, these radiological dangers can significantly negatively influence the environment. In order to protect human health and ensure that the proper steps are taken to reduce possible risks, it is necessary to evaluate the combined activity of ^{226}Ra, ^{232}Th, and ^{40}K in Naturally Occurring Radioactive Material (NORM) which can better understand and manage the radiological threats posed by NORM by precisely measuring the activity concentrations of these radionuclides, allowing us to take the required precautions to safeguard both human populations and the environment (NIST, 2021).

Indoor health risks can be considerably decreased by putting into practice procedures like ensuring proper ventilation, performing routine cleaning and maintenance, and refraining from using hazardous products and substances. On the other hand, when people are exposed to radiation while working in busy locations or surroundings, it can cause health risks. These outdoor hazards include the radiation equivalent (R_{aeq}), outdoor hazard index (H_{out}), external dose (D_{out}), annual effective exposure (E_{out}), and Excessive Lifetime Cancer Risk (ELCR), among other characteristics. The methods used in Swabi Granite to calculate various health metrics are shown in Table-2. Formulas based on the activity of potassium, thorium, and radium were used to compute the annual effective doses of Swabi Granite for indoor and outdoor environments. The indoor and outdoor radiological health hazard indices for Swabi Granite are given in Table-3 (Krane, 1991).

Table-2: Formulas for radiological health hazards

Indices/Units	Formula/references	World's average of building materials	Limit/references
Radium Equivalent (Ra_{eq}) (Bq Kg^{-1})	$[\frac{A_{Ra}}{370}+\frac{A_{Th}}{259}+\frac{A_K}{4810}]\times 370$ (Beretka & Mathew, 1985; Ibrahim, 1999)	159.8	370 UNSCEAR 1988 and 2000
Outdoor hazard index (H_{out}) (Bq Kg^{-1})	$\frac{A_{Ra}}{370}+\frac{A_{Th}}{259}+\frac{A_K}{4810}$ (Beretka & Mathew, 1985; Ibrahim, 1999)	0.43	≤1 (Beretka & Mathew, 1985)
External dose(D_{out}) (nGy h^{-1})	$0.427A_{Ra}+0.60462A_{Th}+0.0432A_K$	74.15	51 UNSCEAR 2000
Annual effective dose (E_{out}) (mSvy^{-1})	$D_{out}\times 1.227\times 10^{-3}$ UNSCEAR 2000	0.09	1;20 for radiation workers ICRP 1990
Excessive Lifetime Cancer Risk ($ELCR_{out}$)	$E_{out}\times LE\times RF$ (LE is life expectancy and RF is fatal risk factor per Sievert, that is 0.05) (Beretka & Mathew, 1985)	0.32×10^{-3}	0.29×10^{-3} UNSCEAR 2000
Indoor Hazard Indices			
Indoor hazard index (H_{in}) (Bq Kg^{-1})	$[\frac{A_{Ra}}{185}+\frac{A_{Th}}{259}+\frac{A_K}{4810}]$ (Beretka & Mathew 1985; Krieger 1981)	0.57	≤1 (Krieger, 1981)
Indoor External dose(D_{in}) (nGy h^{-1})	$0.92A_{Ra}+1.1A_{Th}+0.081A_K$ EC 1999	141	NEA-OECD 1979 International limit 55 and world's average 84 (Belign & Aycik, 2015)
Annual effective dose (E_{in}) (mSv y^{-1})	$D_{in}\times 4.905\times 10^{-3}$ UNSCEAR 2000	0.69	2 UNSCEAR
Excessive Lifetime Cancer Risk ($ELCR_{in}$)	$E_{in}\times LE\times RF$ (LE is life expectancy and RF is fatal risk factor per Sievert, that is 0.05)	2.42 ×10^{-3}	1.19×10^{-3} (Orgun *et al.*, 2005)

The health risk indexes for Swabi Granite are presented in the Table-3 below. The first column displays the sample numbers, followed by five columns showing the indoor health hazard indices. Additionally, next five columns are displaying the outdoor health hazard indices. The World Granites Average (WGA) and the Building Material Average (BMA) are also given in the Table-3.

Table-3. Calculated radiological health hazards

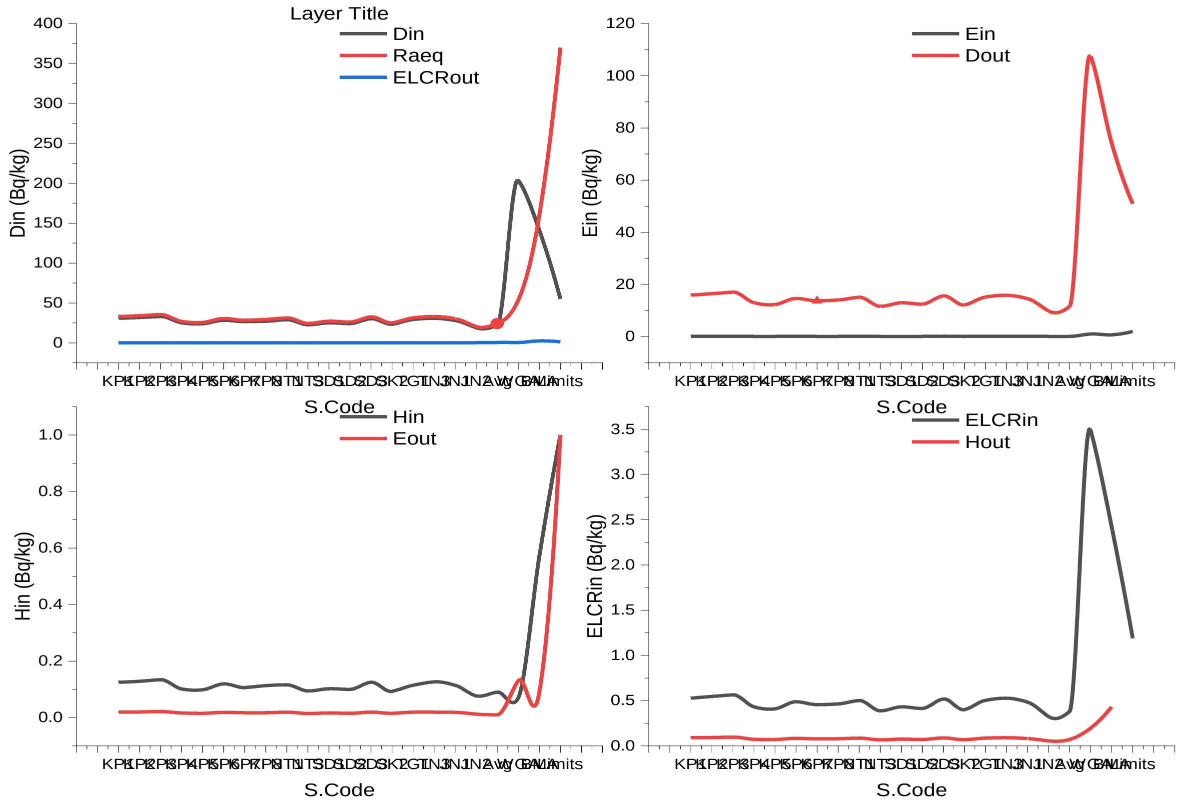
Sample code	D_{in}	E_{in}	H_{in}	$ELCR_{in}$	Ra_{eq}	D_{out}	E_{out}	H_{out}	$ELCR_{out}$
KP1	30.651	0.150	0.125	0.527	32.946	15.905	0.020	0.089	0.068
KP2	31.726	0.156	0.128	0.545	34.003	16.468	0.020	0.092	0.071
KP3	32.842	0.161	0.134	0.564	35.332	17.040	0.021	0.095	0.073
KP4	25.032	0.123	0.101	0.430	26.751	12.982	0.016	0.072	0.056
KP5	23.775	0.117	0.098	0.408	25.629	12.331	0.015	0.069	0.053
KP6	28.288	0.139	0.119	0.486	30.476	14.644	0.018	0.082	0.063
KP7	26.494	0.130	0.106	0.455	28.159	13.732	0.017	0.076	0.059
KP8	27.031	0.133	0.113	0.464	29.194	14.011	0.017	0.079	0.060
NT1	29.049	0.143	0.116	0.499	31.096	15.081	0.019	0.084	0.065
NT3	22.485	0.110	0.094	0.386	24.232	11.655	0.014	0.065	0.050
SD1	25.085	0.123	0.102	0.431	26.882	13.008	0.016	0.073	0.056
SD2	24.036	0.118	0.100	0.413	25.990	12.466	0.015	0.070	0.054
SD3	30.115	0.148	0.125	0.517	32.501	15.615	0.019	0.088	0.067
SK2	23.364	0.115	0.093	0.401	24.991	12.130	0.015	0.068	0.052
TG1	29.228	0.143	0.114	0.502	31.086	15.179	0.019	0.084	0.065
TN3	30.600	0.150	0.126	0.526	32.854	15.858	0.019	0.089	0.068
JN1	28.090	0.138	0.114	0.483	30.082	14.571	0.018	0.081	0.063
JN2	18.904	0.093	0.077	0.325	20.242	9.798	0.012	0.055	0.042
Average	22.18	0.11	0.09	0.38	24.13	11.57	0.01	0.07	0.38
WGA	203.34	1.00	0.07	3.49		107.49	0.13		0.46
BMA	141.00	0.69	0.57	2.42	159.8	74.15	0.09	0.43	2.42
Limits	55.00	2.00	1.00	1.19	370	51.00	1.00	≤1	1.19

5. Atmosphere and radon gas

The layer of gases that makes up the Earth's atmosphere is separated into a number of distinct geographic zones based on height. The lowest zone is known as the troposphere, which is located between 6 and 9 miles, or 10-15 kilometres, above the Earth's surface (Sutton *et al.*, 1993). In the troposphere, where the majority of the Earth's air mass is located, radon gas, a naturally occurring radioactive gas, is created due to the decay of uranium and thorium in rocks, soil, and water. It has no taste, colour, or fragrance; thus, it is impossible to identify without proficient equipment. Radon can infiltrate buildings through fractures in the foundation, gaps around pipes and cables, and breaches on floors and walls (EPA, 2016). The high radon gas exposure levels may cause health problems. Radon, the second-leading cause of lung cancer after smoking, causes thousands of lung cancer deaths every year (WHO, 2023). When the radon gas is inhaled, it decomposes and releases the radioactive particles that can injure the lining cells of the lungs, increasing the chance of developing the lung cancer (UNSCEAR, 1993).

According to our investigation, the radium equivalent was far lower than the permitted level of 370 Bq/kg, at only 24.13 Bq/kg. The calculated outdoor external dose of 11.57 nGy/h, the outdoor Annual effective dose of 0.01 mSv/y, and the outdoor excessive lifetime cancer risk of 0.38 x 10^{-3} are all significantly lower than the global average for health hazards. It's important to note that radon, a natural gas that accumulates in the atmosphere and building materials, has been associated with lung cancer (Korany & Yousef, 2019).

Figure 3: Radiological health hazards



6. Discussion

The analysis of the gamma radiation emitted by radioactive elements found in granite is made possible by the useful technique of gamma-ray spectroscopy. Important details regarding the mineralogy, radioactivity, and geological history of the rock can be discovered using this method. Small levels of radioactive isotopes including potassium, thorium, and uranium are present in granite naturally (Lindstrom *et al.*, 1990). These radioactive components can be precisely detected and quantified by gamma-ray spectroscopy, offering important insights into the composition of the rock and any radiological risks (Likuku, 2003).

The average activity concentrations for ^{226}R, ^{232}Th, and ^{40}K in the Swabi granite are 11.812 Bqkg^{-1}, 4.470 Bqkg^{-1}, and 140.738 Bqkg^{-1}, respectively. Compared to the global average values for granites, which are 42 Bq/kg for ^{226}Ra, 73 Bq/kg for ^{232}Th, and 1055 Bq/kg for ^{40}K, the activity concentrations found in this study are much lower. Additionally, they are below the global average for building materials, which is 500 Bq/kg for ^{40}K and 50 Bq/kg for both ^{226}Ra and ^{232}Th. Swabi granite has an indoor absorbed dose index (D_{in}) of 22.18 nGyh^{-1}, which is lower than average for building materials and all granite varieties globally (203.34 nGyh^{-1}). It has a threshold of 55 nGyh$^{-1,}$ according to UNSCEAR. The effective indoor dose (Ein) of Swabi granite is 0.11 mSvy^{-1}, which is smaller than the 0.69 mSvy^{-1} average global value for granites and construction materials. The ELCR, which results from radiation absorption, is the possibility that a person may develop cancer at some time in their lives. The Estimated Lifetime Cancer Risk (ELCR) is 0.38× 10$^{-3,}$ which is low as compared to the UNSCEAR lifetime cancer risk (1.19 ×10^{-3}) (Choubedar, 2000). The average outdoor absorbed dose (D_{out}) for Swabi granite is considerably lower at 11.57 nGy/h compared to the global averages for materials (76.05 nGy/h) and granites (107.49 nGy/h). It also fails to meet the UNSCEAR 2000 standard of 51 nGy/h (Almayahi, 2019). The average outdoor annual effective dosage (E_{out}) for Swabi granite is 0.01 mSv/y, which is substantially lower than the World Granite Average (WGA) limit and acceptable limit for building materials.

Excessive Lifetime Cancer Risk (ELCR) is exceedingly unlikely to occur in the Swabi Granite region, with a 0.38 x 10^{-3} chance per individual. This is much less than the global average of the Granite value (0.46×10^{-3}) and significantly less than the worldwide average of the WBA (1.31×10^{-3}) for the chance of cancer occurrence. The risk of contracting cancer as a result of granite radiation is thought to be extremely low among people of the Swabi region, according to the ELCR (out) statistics stated above. When utilised as a building material, Swabi granite has no negative impact, and living near natural radiation sources is unlikely to raise a person's chance of contracting cancer (Ramsiya *et al.*, 2017). Finally, it is decided that the radioactive danger indices found in Swabi granite are appropriate for secure use as construction materials in accordance with the dose threshold limits set forth by UNSCEAR. As a result, the granite in Swabi is below the standard radiological limit. Because Swabi granite does not provide any substantial radiation concerns, using it as a construction material is safe (Tzortzis *et al.*, 2013).

7. Conclusions

The usage of granite in construction has greatly expanded during the last three to four decades. The granite from the northern regions satisfies Pakistan's needs for the material. Radionuclides are present in granite by nature. The natural radioactivity levels in Swabi granite have been assessed using the HPGe gamma-ray spectrometer. The data show that the average activity concentrations for ^{226}Ra, ^{232}Th, and ^{40}K are 11.812 Bq/kg, 4.470 Bq/kg, and 140.738 Bq/kg, respectively. As shown in Table 1, the average activity concentrations of ^{232}Th, ^{226}Ra, and ^{40}K are less than the global granite average and UNSCEAR's recommended limits of 50 Bqkg-1 for ^{232}Th, ^{226}Ra, and 500 Bqkg^{-1} for ^{40}K, respectively.

The average radium equivalent (Raeq) is calculated to be 24.13 Bq/kg, which is below the permitted limit of 370 Bqkg^{-1}. The average outdoor hazard index (0.078), external dose (14.026 nGy/h), and annual effective dose (0.132 mSv/y) in Swabi granite are below the global averages of 1, 51 nGy/h, and 1 mSv/y, respectively. In Swabi Granite, the average measured value of outdoor excessive lifetime cancer risk (ELCR) is 0.060×10^{-3}, which is less than the UNSCEAR-set limit of 0.29 x 10^{-3}. According to this calculation of the Swabi granite's outdoor hazard indices, a resident of Swabi has no risk of radioactive hazard. The average indoor hazard index is 0.110, below the required unity level. The average indoor external dose is 27.044 nGy/h, and the average indoor annual effective dose is 0.132 mSv/y, both of which are below the UNSCEAR limits for the general public. The indoor excessive lifetime cancer risk (0.464 x 10^{-3}) is lower than the 2.42 x 10-3 safety limit suggested by UNSCEAR. The average indoor hazard index of 0.09 is lower than the criterion limit of unity. The mean values of the indoor external dose of 22.18 nGy/h and indoor annual effective dose of 0.132mSv/y are the UNSCEAR limits. The indoor excessive lifetime cancer risk calculation of 0.464 x 10^{-3} is lower than the safety limit of 2.42 x 10^{-3} proposed by UNSCEAR. It can be concluded that Swabi granite does not pose any substantial threat to human health and is safe to use as a construction material.

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References

Ali, M., Iqbal, S., Wasim, M., Arif, M., & Saif, F. (2013). Soil radioactivity levels and radiological risk assessment in the highlands of Hunza, Pakistan. *Radiation Protection Dosimetry*, *153*(3), 390–399. https://doi.org/10.1093/rpd/ncs102

Almayahi, B. (2019). *Use of gamma radiation techniques in peaceful applications.* Intech Open.

American Cancer Society. (n.d.). Radiation exposure and cancer risk. https://www.cancer.org/cancer/risk-prevention/radiation-exposure.html

Choubedar, F. (2000). *Use of radio-nuclides (unsupported 210Pb, 7Be and 137Cs) in air, rain and undisturbed soil as environmental tools.* Edinburgh Research Archive. https://era.ed.ac.uk/handle/1842/13381

Dutch, D. R. (2018). Natural radioactivity, radiation exposure. *The JRI Briefing Paper No. 37*. https://jri.org.uk/wp-content/uploads/2018/08/BP37_Natural_Radioactivity_Dutch.pdf

EPA. (2016). A citizen's guide to radon. *United States Environmenal Protection Agency (EPA)*. https://www.epa.gov/sites/default/files/2016-12/documents/2016_a_citizens_guide_to_radon.pdf

EPA. (2024, October 1). Radiation Basics. *United States Environmenal Protection Agency (EPA)*. https://www.epa.gov/radiation/radiation-basics

International Atomic Energy Agency. (2018). Radiation protection and safety of radiation sources. https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1578_web-57265295.pdf

Krane, K. S. (1991). *Introductory nuclear physics*. John Wiley.

Korany, K., & Yousef, H. (2019). Assessment of radiological hazard indices in Abu Rusheid area, south eastern desert, Egypt, using gamma ray spectroscopy. *Arab Journal of Nuclear Sciences and Applications*, *52*(2), 132–141. https://journals.ekb.eg/article_29186.html

Likuku, A. S. (2003). *The Influence of topography and vegetation canopy on the deposition of atmospheric particulates Studied with 210Pb and 137Cs soil inventory measurements*. Doctoral dissertation, University of Edinburgh. https://researchhub.buan.ac.bw/handle/13049/159

Lindstrom, R. M., Lindstrom, D. J., Slaback, L. A., & Langland, J. K. (1990). A low-background gamma-ray assay laboratory for activation analysis. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, *299*(1-3), 425–429. https://doi.org/10.1016/0168-9002(90)90818-Q

NIST. (2021). *Radioactivity group*. National Institute of Standards and Technology. https://www.nist.gov/pml/radiation-physics/radioactivity

Pakistan Bureau of Statistics. (2017). Pakistan population census district wise. https://www.pbs.gov.pk/census-2017-district-wise

Rahman, S. U., Rafique, M., Jabbar, A., & Matiullah. (2013). Radiological hazards due to naturally occurring radionuclides in the selected building materials used for the construction of dwellings in four districts of the Punjab province, Pakistan. *Radiation Protection Dosimetry*, *153*(3), 352–360. https://doi.org/10.1093/rpd/ncs109

Ramsiya, M., Joseph, A., & Jojo, P. J. (2017). Estimation of indoor radon and thoron in dwellings of Palakkad, Kerala, India using solid state nuclear track detectors. *Journal of Radiation Research and Applied Sciences, 10*(3), 269–272. https://doi.org/10.1016/j.jrras.2017.05.004

Sherar, M. A. S., Visconti, P. J., Ritenour, E. R., & Haynes, K. W. (2021). *Radiation protection in medical radiography* (9th Ed.). Elsevier. https://evolve.elsevier.com/cs/product/9780323825030?role=student

Sutton, G. A., Napier, S. T., John, M., & Taylor, A. (1993). Uranium-238 decay chain data. *Science of the Total Environment, 130*, 393–401. https://doi.org/10.1016/0048-9697(93)90094-M

Tsapaki, V., Balter, S., Cousins, C., Holmberg, O., Miller, D. L., Miranda, P., ... & Vano, E. (2018). The International Atomic Energy Agency action plan on radiation protection of patients and staff in interventional procedures: achieving change in practice. *Physica Medica*, *52*, 56–64. https://doi.org/10.1016/j.ejmp.2018.06.634

Trevisi, R., Leonardi, F., Risica, S., & Nuccetelli, C. (2018). Updated database on natural radioactivity in building materials in Europe. *Journal of Environmental Radioactivity, 187*, 90-105. https://doi.org/10.1016/j.jenvrad.2018.01.024

Tzortzis, M., Tsertos, H., Christofides, S., & Christodoulides, G. (2003). Gamma-ray measurements of naturally occurring radioactive samples from Cyprus characteristic geological rocks. *Radiation Measurements, 37*(3), 221–229. https://doi.org/10.1016/S1350-4487(03)00028-3

UNSCEAR. (1993). Sources and effects of ionising radiation. *United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) Report to the General Assembly with Scientific Annexes*. https://www.unscear.org/docs/publications/1993/UNSCEAR_1993_Report.pdf

Wasim, M., Iqbal, S., & Ali, M. (2016). Radiological and elemental analysis of soils from Hunza in Central Karakoram using gamma-ray spectrometry and k 0-instrumental neutron activation analysis. *Journal of Radioanalytical and Nuclear Chemistry*, *307*, 891–898. https://doi.org/10.1007/s10967-015-4220-4

WHO. (2023). Radon. *World Health Organization (WHO)*. https://www.who.int/news-room/fact-sheets/detail/radon-and-health

Younis, H., Qureshi, A. A., Manzoor, S., & Anees, M. (2018). Measurement of radioactivity in the granites of Pakistan: a review. *Health Physics, 115*(6), 760–768. https://doi.org/10.1097/HP.0000000000000917

Younis, H., Ahmad, F., Shehzadi, R., Asghar, I., Ahmad, T., Ajaz, M., ... & Haj Ismail, A. A. K. (2021). Study of radioactivity in Bajaur Norite exposed in the Himalayan tectonic zone of Northern Pakistan. *Atmosphere*, *12*(11), 1385. https://doi.org/10.3390/atmos12111385