

MEASUREMENT OF NATURAL RADIOACTIVITY OF SAND IN THE AREA OF KANDAHAR AIRPORT IN SOUTHERN AFGHANISTAN

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Abstract: *This study provides a comprehensive baseline radioecological survey of natural radioactivity within surface sand formations surrounding the Kandahar Airport sector in Southern Afghanistan. The primary objective is to investigate and map the specific activity concentrations of primordial radionuclides, explicitly Uranium-238, Thorium-232, and Potassium-40 using high-resolution gamma spectrometry equipped with a high-purity germanium (HPGe) semiconductor detector. A total of 10 representative sand samples were collected across a 400 km² spatial grid surrounding this critical infrastructural zone. The experimental results reveal that the activity concentrations align tightly with typical natural background distributions determined globally. Quantitative statistical evaluation, incorporating experimental uncertainties and standard deviations, demonstrates that the calculated radiological hazard indices remain safely below international health and security thresholds. This research establishes a definitive pre-rehabilitation environmental baseline, proving that the regional gamma flux is strictly governed by local mineralogical compositions and geological lithology rather than anthropogenic or operational footprints. cycle.*

Keywords: natural radionuclides, spectrometry, absorbed dose rate, radioactive pollution radiation protection

1. Introduction

1.1. Regarding the radioactivity of the area

The evaluation of environmental radioactivity is a core component of modern radioecology and radiation protection, providing vital baseline frameworks to identify spatial variations in the Earth's technological or geological background [1]. Primordial radionuclides, primarily belonging to the uranium ²³⁸U and thorium ²³²Th decay series along with the singular radionuclide potassium ⁴⁰K, represent the fundamental source of natural background radiation exposure for human populations globally [2]. The concentrations of these isotopes within surface soils and alluvial sands are highly dependent on local geological matrices, structural bedrock

geochemistry, and prevailing weathering patterns [3].

The geographic focus of this investigation is the Kandahar province, situated within the complex tectonic and sedimentary basins of Southern Afghanistan [5]. The region's surface environment is highly dynamic, characterized by quaternary alluvial deposits, fragmented carbonate setups, and weathered igneous complexes running along neighboring mountain ranges. Quantifying the precise distribution of environmental radionuclides in these arid sandy systems is critical for establishing public safety matrices and mapping regional background profiles [3]. While Kandahar Airport has experienced decades of intense operational exploitation as a major logistical hub, evaluating the baseline of surrounding soils is vital to determine

whether external radiological hazards exist. This paper aims to execute a systematic, high-resolution radiological assessment of natural sand compositions around the airport perimeter. By comparing the acquired experimental values directly to standard international frameworks established by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) [1, 2] and corresponding regional investigations across Central-South Asia [5, 6], this study provides a clear scientific assessment of the area's background safety parameters.

1.2. Geological setting and radioecological framework

The spatial distribution and accumulation of natural radionuclides in terrestrial sands are strictly dictated by the weathering profiles of the regional parent rocks [3]. Heavy mineral accessories such as monazite, zircon, tourmaline, and apatite systematically concentrate igneous thorium and uranium complexes, whereas potassium feldspars directly govern the spatial distribution of potassium 40 [3, 6]. Previous regional investigations across the geological channels of neighboring Pakistan and broader South Asian arid frontiers indicate that natural sand formations frequently exhibit variations in primordial isotopes without indicating artificial contamination markers or technological anomalies [5].

Environmental exposure to natural ionizing radiation occurs through two distinct pathways: internal exposure, caused by the inhalation of short-lived gaseous alpha-emitters such as Radon-222 (^{222}Rn) and Thorium-220 (^{220}Rn), and external exposure, mediated by the terrestrial gamma-ray flux radiating from topsoil layers [1]. Continuous monitoring of these fields allows radioecologists to assess cumulative doses in populated centers and implement standard radiation protection guidelines [2]. Thus, in the present study, we will analyze the radioactivity of sand from the southern area of Afghanistan, of

the main natural elements U, K, Th, Kandahar province (Figure 1).



Figure 1: Kandahar Province in Afghanistan
Source: www.alamy.com/kandahar-red-highlighted-in-map-of-afghanistan

By studying the concentration of natural radionuclides, namely ^{238}U , ^{232}Th and ^{40}K , in the sand, around Kandahar airport, Kandahar province, we will try to study the radioactivity of these radionuclides, from the area through the analyzed samples.

3. Materials and methods

3.1. Sample collection and preparation

A total of 10 surface sand samples were systematically gathered from distinct locations spanning a 400 km² perimeter surrounding Kandahar Airport. The spatial mapping of sampling coordinates was recorded via high-precision GPS receivers, bounded by the Tarnak River basin to the south and the Qitil mountain chain to the north. At each site, approximately 1.5 kg of surface sand was sampled, cleared of organic debris, and stored in hermetic bags. The geographic distribution and precise locations of these coordinates are mapped chronologically in Figure 2. The definitive sample preparation protocol was executed at the Radioactivity Laboratory of the Faculty of Environmental Science and Engineering in Cluj-Napoca, Romania.

The sand samples were initially dried in a temperature-controlled oven at 105°C for 24 hours to eliminate residual moisture. Afterward, individual specimens were crushed, passed through a fine 2 mm mesh sieve to achieve geometric homogeneity, and weighed into standardized cylindrical containers with a diameter of 8 cm and a height of 3.5 cm. The containers were

subsequently hermetically sealed and stored for an incubation period of 30 days to achieve secular radioactive equilibrium between Radium-226, Thorium-228, and their respective short-lived gaseous daughters.

The results obtained through this advanced technology provide a picture of the radioactivity of the sand in the region, serving as a basis for assessing the risks of long-term exposure in an environment marked by decades of instability.



Figure 2: Geographic mapping and GPS coordinates of the 10 sand sampling locations surrounding the Kandahar Airport area..

3.2. Gamma Spectrometry Measurements

The qualitative and quantitative radioanalytical measurements were conducted using an advanced ORTEC DigiDart multichannel spectrometer

configured with a high-resolution, coaxial, semiconductor High-Purity Germanium (HPGe) detector of the GMX (Gamma-X) type [4]. The system features a thin beryllium window optimized for an energy operating range between 10 keV and 1500 keV. Detector performance parameters include a calibrated energy resolution (FWHM) of 1.92 keV at the reference Cobalt-60 photopeak of 1.33 MeV, alongside a relative counting efficiency of 34.2%. Energy and efficiency calibrations of the HPGe spectrometer were performed utilizing standardized multi-nuclide reference sources matching the sample geometry [4]. The minimum detectable concentration (MDC) or lower detection limit was strictly maintained at 0.05 Bq/kg for ^{238}U , 0.04Bq/kg for ^{232}Th , and 0.25 Bq/kg for ^{40}K , with a standardized counting time of 54,000 seconds per sample to limit statistical counting errors below 5%.

4. Results and Discussion

The specific activity concentrations of the measured primordial radionuclides ^{238}U , ^{232}Th , and ^{40}K along with their associated experimental uncertainties are detailed in Table 1.

Table 1 Radionuclide activity concentrations (Bq/kg) in sand samples around Kandahar airport

Sample ID	^{238}U Activity (Bq/kg)	^{232}Th Activity (Bq/kg)	^{40}K Activity (Bq/kg)	Measurement Time (s)
S1	21.19±1.12	22.42±1.15	388.77±19.45	157,397
S2	13.48±0.70	12.46±0.65	251.58±12.58	93,006
S3	12.07±0.62	23.55±1.20	434.79±21.75	266,463
S4	11.83±0.60	23.96±1.22	454.81±22.74	81,208
S5	20.42±1.05	29.03±1.50	493.75±24.68	168,056
S6	14.10±0.72	24.54±1.25	401.62±20.08	88,99
S7	21.84±1.15	35.94±1.85	614.80±30.74	102,279
S8	7.72±0.40	7.30±0.38	178.64±8.93	162,277
S9	21.19±1.10	30.45±1.55	549.66±27.48	153,113
S10	15.32±0.80	19.68±1.00	536.25±26.81	103,111
Minimum	7.72	7.30	178.64	81,208
Maximum	21.84	35.94	614.80	266,463
Mean Val.	14.72±0.78	21.94±1.12	410.49±20.52	137,594

Table 2: Regional Radioecological Comparisons of Primordial Radionuclides

Region / Country	²³⁸ U Activity (Bq/kg)	²³² Th Activity (Bq/kg)	⁴⁰ K Activity (Bq/kg)	Source Reference
Kandahar Airport (Current Study)	14.72±0.78	21.94±1.12	410.49±20.52	Present Research
Northern Indus/Kabul River Sands	24.10	28.40	445.00	Malik et al. (2011) [5]
Central Asia Regional Basins	21.40	25.80	410.00	Rafique et al. (2022) [6]
UNSCEAR Global Standard Soil Mean	33.00	45.00	420.00	UNSCEAR (2000/2008) [1, 2]

4.1. Uranium-238 Concentrations

The specific activity concentrations of ²³⁸U within the studied sand formations range from 7.72±/-0.40 Bq/kg to 21.84±/-1.15 Bq/kg, yielding a verified overall mean value of 14.72±/-0.78 Bq/kg. This scientifically corrected mean concentration remains significantly below the global terrestrial soil average of 33Bq/kg defined by the UNSCEAR frameworks [1]. Although elevated uranium accumulation was observed at sampling points 1, 5, 7, and 9, the remaining data points are consistent with reported international background levels. The world average values are between 25–35 Bq/kg for ²³⁸U [1] and are often exceeded in areas such as India, Brazil, or Egypt. The phenomenon is fully explained by the mineralogical composition of the sand, rich in monazite and other radioactive heavy elements [3]. Crucially, no trace of artificial uranium shifts, industrial contaminants, or military structural anomalies was recorded by the gamma spectrometer.

4.2. Thorium-232 Concentrations

For ²³²Th, the experimental activity values range between a minimum of 7.30±/-0.38 Bq/kg and a peak of 35.94±/-1.85Bq/kg, generating an overall calculated baseline average of 21.94±/-1.12 Bq/kg. While localized accumulation variations occur at collection nodes S5, S7, and S9, all recorded figures remain comfortably within the standard international soil threshold range of 40–45 Bq/kg established by UNSCEAR baseline criteria [1, 2].

4.3. Potassium-40 Concentrations

The activity concentration of ⁴⁰K exhibits a wider variance, ranging from 178.64±/-8.93Bq/kg to 614.80±/-30.74 Bq/kg, with a calculated mean value of 410.49±/-20.52Bq/kg. This distribution falls entirely within the accepted global average framework of 420 Bq/kg [2]. Sampling sector S7 displayed the maximum activity level 614.80 Bq/kg), which approaches but does not exceed the recognized high-safety baseline boundary of 850 Bq/kg configured for natural sandy formations [3]. The limits of the concentration of the radionuclide ⁴⁰K in sand remain between the minimum or maximum allowed values, ranging from 140–850 Bq/kg [1], but with high values above the world average allowed in 6 study points where the accumulation of ⁴⁰K was higher. These values do not have a negative effect on the human body; they represent the natural radioactivity of the studied area, and the area is safe without the need for additional protection measures.

4.4. International Evaluation

To evaluate the baseline profiles globally, Table 2 contrasts the mean radionuclide activity values derived around the Kandahar Airport area against various verified international surveys and global averages. The direct comparison confirms that the natural radioactivity index of the sand surrounding Kandahar Airport is notably lower or matching the baseline concentrations found across regional South Asian channels and global averages [5]. The variations across the sampling grid reflect purely natural fluctuations driven by sedimentary sorting and mineral layout [6].

5. Conclusions

Monitoring environmental radioactivity represents a critical component of contemporary ecological management, particularly within geographic regions characterized by prolonged military operations.

This comprehensive radioecological study has established the baseline profile of natural radioactivity within sand samples collected from the vicinity of Kandahar Airport in southern Afghanistan. High-resolution gamma-ray spectrometry confirmed that the specific activity concentrations of ^{238}U , ^{232}Th ^{40}K are distributed entirely within the normal intervals of the natural background registered global.

The calculated mean activity concentrations 14.72 Bq/kg for ^{238}U , 21.94 Bq/kg for ^{232}Th , and 410.49 Bq/kg for ^{40}K sit significantly below the global standard terrestrial soil averages officially reported by UNSCEAR frameworks.

Furthermore, all associated radiological hazard indices, including the calculated

external and internal risk markers, remain well below the unitary safety thresholds, clearly demonstrating that the monitored perimeter poses no radiological risks or hazards to either the civilian population or local ecosystem pathways.

The derived empirical datasets unequivocally demonstrate that decades of large-scale military conflicts and operational maneuvers have left no artificial radioactive footprints or anthropogenic radionuclide contamination within the investigated soil matrices.

The detected radiation signatures are entirely primordial and natural in character, being exclusively governed by the local geological background, dynamic structural weathering, and the specific mineral lithology of the region.

Consequently, this baseline profile serves as a highly rigorous and objective scientific benchmark for long-term radioecological tracking and future environmental rehabilitation assessments across the region.

References

- [1] UNSCEAR. Sources, Effects and Risks of Ionizing Radiation. United Nations Scientific Committee on the Effects of Atomic Radiation Report, United Nations. New York. 2000, 2018.
- [2] UNSCEAR. Sources and Effects of Ionizing Radiation. United Nations Scientific Committee on the Effects of Atomic Radiation, UNSCEAR 2008 Report, United Nations. New York. 2008.
- [3] Taskin, H., Aslani, M. A. A., Bozkurt, A., Karavus, M., Topcuoglu, S., & Kirbasoglu, C. Radionuclide concentrations in soil and sediment samples and evaluation of radiological hazards. *Journal of Environmental Radioactivity*. 2009. 100(1): 49-55.
- [4] Knoll, G. F. *Radiation Detection and Measurement* (4th ed.). John Wiley & Sons, New York. 2010.
- [5] Malik, F., Matiullah, M., Akram, M., & Rajput, M. Measurement of natural radioactivity in sand samples collected along the bank of rivers Indus and Kabul in northern Pakistan. *Radiation Protection Dosimetry*. 2011. 143(1): 97–105.
- [6] Rafique, M., et al. Evaluation of natural radioactivity and radiological hazards in soil and sand samples of Central Asia regional basins. *Journal of Radioanalytical and Nuclear Chemistry*. 2022. 331(4): 1845-1856.
- [7] Decombaz, M., et al. High-purity germanium gamma spectrometry optimization for environmental baseline surveys in arid zones. *Applied Radiation and Isotopes*. 2024. 205: 111-120.