



Natural Background Gamma Radiation Levels and Radiological Implications in the Vicinity of Proposed Uranium Mining Sites in Nalgonda District, Telangana, India: A Comprehensive Review

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Abstract

The Nalgonda district in Telangana, India, hosts significant uranium mineralization, particularly in the Chitrial and Lambapur-Peddagattu areas, raising concerns about potential increases in environmental radioactivity once mining commences. This review on natural background gamma radiation levels in Devarakonda town and surrounding villages, including Megavath Thanda, Peddamula, Dasarlapally, and Kothapally. Measurements using μ R-survey meters, thermoluminescence dosimeters (TLDs), and high-purity germanium (HPGe) gamma spectrometry revealed consistently elevated absorbed dose rates: indoor averages ranging from 1336 to 2357 $\mu\text{Gy y}^{-1}$ and outdoor from 1999 to 2207 $\mu\text{Gy y}^{-1}$, approximately 2–4 times the Indian national average ($775 \pm 355 \mu\text{Gy y}^{-1}$) and well above the global terrestrial outdoor average ($\sim 510 \mu\text{Gy y}^{-1}$). Annual effective doses to residents varied from 0.94 to 1.68 mSv y^{-1} , exceeding the global terrestrial contribution of 0.48 mSv y^{-1} . Soil radionuclide analyses showed ^{238}U and ^{232}Th activities often 2–5 times world averages (35 and 30 Bq kg^{-1} , respectively), with radium equivalent activities and hazard indices occasionally surpassing recommended limits. Building materials (stone and mud walls) and local geology contributed significantly to indoor elevations. These baseline data establish a pre-mining reference, highlight the need for ongoing monitoring, and underscore public health considerations in high-background regions. Comparisons with other Indian uranium-prospective areas (e.g., Jaduguda, Tummalapalle) and global high-background zones reinforce the importance of integrated radiological assessments.

Keywords: Gamma Radiation; Absorbed Dose Rate; Annual Effective Dose; Uranium Mineralization; Nalgonda District; Terrestrial Radionuclides; Radiological Hazard Indices

Introduction

All human populations are continuously exposed to natural background radiation, which contributes nearly 80% of the average global annual effective dose of about 2.4 mSv . A major component of this exposure originates from terrestrial radionuclides—primarily uranium-238, thorium-232, and potassium-40—present in rocks, soils, and building materials. The worldwide outdoor terrestrial contribution is approximately 0.48 mSv per year (UNSCEAR, 2000; 2008), while indoor levels may be higher due to the use of locally sourced construction materials. In regions where uranium mineralization is geologically concentrated, natural background radiation levels can become significantly elevated. Such conditions are observed in parts of Telangana, particularly in Nalgondadistrict, where uranium deposits occur. Notable prospects, including the Chitrial and Lambapur–Peddagattu blocks, have been identified and investigated by the AtomicMinerals Directorate for Exploration and Research (AMDER), Hyderabad.

Recent radiological surveys conducted in and around Devarakonda using survey meters, thermoluminescence dosimeters (TLDs), and gamma spectrometry reveal elevated indoor and outdoor dose rates compared with national and global averages. Soil analyses also indicate enhanced concentrations of uranium and thorium in

several locations. Although the estimated annual effective doses remain within the broader range reported for high natural background radiation areas, the findings highlight the importance of establishing a comprehensive pre-mining baseline.

This study synthesizes recent investigations to evaluate terrestrial radiation levels, radionuclide distribution, and associated radiological hazards in the proposed uranium mining region. The results provide essential baseline data for long-term environmental monitoring and public health assessment in the context of future mining activities.

Materials and Methods

All six studies followed almost identical field and laboratory protocols, a deliberate choice that makes their results directly comparable. Researchers from Osmania University and partner colleges spent weeks in each village, knocking on doors, explaining the work in simple Telugu, and installing instruments only after families gave their consent. The same two complementary approaches were used everywhere: one for quick, on-the-spot readings and another for long-term, integrated exposure. This “active-plus-passive” strategy is standard in environmental radiation work because no single method captures the full picture. Instant readings catch daily fluctuations; integrated dosimeters average out seasonal changes and give the dose that people actually experience over months.

Field measurements of ambient gamma dose rate

The active instrument was a portable micro-R survey meter (Nucleonix Systems, Hyderabad) fitted with a 2.54 × 2.54 cm NaI(Tl) scintillation crystal coupled to a photomultiplier tube. It reads exposure rates from 1 to 10 000 $\mu\text{R h}^{-1}$. In every house and courtyard the team took readings at ground level and at one metre height — the standard breathing height for adults — both inside the main living room and outside in the open yard. They repeated the measurements three or four times over the course of a full year (once each season) so that any monsoon dampness or summer dryness would be reflected in the averages. The raw readings in micro-roentgen per hour were converted to absorbed dose rate in air using the well-established factor 1 Gy = 114 Roentgen (UNSCEAR, 2000). Annual effective dose was then calculated with the occupancy factors recommended by the same agency: 0.8 for indoors (most people in these villages spend the majority of their time inside) and 0.2 for outdoors, multiplied by the tissue weighting factor 0.7 Sv Gy⁻¹.

For the passive method the team used thermoluminescence dosimeters (TLDs) prepared with CaSO₄:Dy phosphor powder supplied by Renintech Laboratories, Mumbai. Each dosimeter consisted of 40 ± 2 mg of annealed powder sealed in a pair of brass capsules inside a weather-proof PVC jacket. Before deployment every batch was calibrated against a known gamma source at the Nuclear Fuel Complex, Hyderabad. In each selected house a pair of TLDs was hung about 1.5 feet below the ceiling — high enough to avoid dust and low enough to represent the living space. The dosimeters stayed in place for exactly three months, after which they were collected, read on a standard TL reader, and replaced with a fresh set. The light output was converted to absorbed dose using the calibration curve established for that batch. Because the TLDs integrate over 90 days, they automatically smooth out daily and weekly variations and give a realistic picture of the dose a family actually receives.

This combination of techniques proved powerful. The survey meter gave immediate feedback during fieldwork (useful when talking to worried householders), while the TLDs provided the long-term average that matters for health-risk calculations. In every village the two methods agreed within 15–20%, giving the team confidence that the numbers were solid.

Soil sampling and laboratory analysis of radionuclides

To understand why the dose rates were high, the researchers collected soil from the same locations where dose measurements were made. At each site they dug down to one metre depth (below the plough layer and root zone), took about one kilogram of soil, air-dried it, sieved it to 150 μm , and packed 250 g into airtight PVC containers. The containers were sealed and left for 30 days so that radon and thoron daughters could reach secular equilibrium with their parents. After that waiting period the samples went to the gamma spectrometry laboratory at Osmania University.

The instrument was a high-purity germanium (HPGe) detector with 30–40% relative efficiency and energy resolution better than 2 keV at 1.33 MeV. Each sample was counted for 20 000–50 000 seconds. The activity of ²²⁶Ra was determined from the 609.3 keV peak of ²¹⁴Pb, ²³²Th from the 583.2 keV peak of ²⁰⁸Tl, and ⁴⁰K directly from its 1460.8 keV gamma line. Background and efficiency corrections were applied using standard IAEA soil reference materials. The minimum detectable activities were typically 2–3 Bq kg⁻¹ for uranium and thorium and 10 Bq kg⁻¹ for potassium.

Once the activity concentrations (C_{Ra}, C_{Th}, C_K in Bq kg⁻¹) were known, several standard radiological indices were calculated so that the data could be compared with safety guidelines used worldwide:

Absorbed dose rate in air at 1 m height: $D \text{ (nGy h}^{-1}\text{)} = 0.462 C_{\text{Ra}} + 0.604 C_{\text{Th}} + 0.0417 C_{\text{K}}$

Radium equivalent activity (a single number that expresses the combined hazard): $Ra_{\text{eq}} \text{ (Bq kg}^{-1}\text{)} = C_{\text{Ra}} + 1.43 C_{\text{Th}} + 0.07 C_{\text{K}}$

External hazard index: $H_{\text{ex}} = (C_{\text{Ra}} / 370) + (C_{\text{Th}} / 259) + (C_{\text{K}} / 4810)$

Internal hazard index (taking account of radon inhalation): $H_{\text{in}} = (C_{\text{Ra}} / 185) + (C_{\text{Th}} / 259) + (C_{\text{K}} / 4810)$

Annual effective dose from soil radionuclides (outdoor occupancy 0.2): $AED \text{ (mSv y}^{-1}\text{)} = D \times 8760 \times 0.2 \times 0.7 \times 10^{-6}$

These formulas are exactly the ones used by UNSCEAR and the International Atomic Energy Agency, so the results slot straight into global databases.

Quality control and statistical treatment

Every survey meter was calibrated annually at the manufacturer's laboratory. TLD batches included control dosimeters kept in a low-background lead shield to check for transit dose. Gamma spectrometer efficiency and energy calibration were verified weekly with standard sources. All measurements were done in triplicate wherever possible, and the standard deviation reported in every table reflects both instrument uncertainty and real spatial variation.

Data were analysed with standard statistical packages. Frequency distributions, geometric means, and correlation coefficients (especially between survey-meter and TLD results) were calculated to check consistency. Box-and-whisker plots and normal probability plots helped visualise whether the radiation levels followed a Gaussian distribution or showed the influence of a few "hot" houses.

Because the same instruments, calibration procedures, and calculation formulas were used in all six studies, the numbers can be pooled and compared directly. That consistency is what turns six separate village surveys into one coherent regional picture — the first of its kind for the Chitral uranium prospect. In short, the methods were chosen for reliability, simplicity, and direct relevance to the daily lives of the people who live there. The combination of instant readings, three-month integrations, and precise soil analysis gives a complete, trustworthy picture of the natural radiation environment before any mining begins.

Ambient Gamma Dose Rate Measurements

µR-Survey Meter: A portable NaI(Tl) scintillation detector ($2.54 \times 2.54 \text{ cm}^2$ crystal) measured instantaneous exposure rates ($1\text{--}10,000 \mu\text{R h}^{-1}$) at ground level and 1 m height, indoors and outdoors. Readings were taken quarterly over one year at multiple locations per site and converted to absorbed dose rate using $1 \text{ Gy} = 114 \text{ Roentgen}$ (Suman et al., 2020, 2021).

Thermoluminescence Dosimeters (TLDs): $\text{CaSO}_4\text{:Dy}$ phosphor-based TLDs provided integrated three-month exposures, calibrated at the Nuclear Fuel Complex, Hyderabad. Dosimeters were placed 1.5 ft below ceilings in representative dwellings and read using a TL reader (Nambi et al., 1985; Sreenath Reddy et al., 2010).

Occupancy factors of 0.8 (indoor) and 0.2 (outdoor) and a conversion coefficient of 0.7 Sv Gy^{-1} were applied to estimate annual effective dose (AED) per UNSCEAR (2000) recommendations.

Soil Radionuclide Analysis

Soil samples (250 g, $150 \mu\text{m}$ grain size) collected at 1 m depth were sealed for secular equilibrium and analyzed via HPGe gamma spectrometry. Activity concentrations of ^{226}Ra (609.3 keV), ^{232}Th (583.2 keV), and ^{40}K (1460.8 keV) were quantified. Derived parameters included:

Absorbed dose rate (nGy h^{-1}) = $0.462 C_{\text{Ra}} + 0.604 C_{\text{Th}} + 0.0417 C_{\text{K}}$ (UNSCEAR, 2000)

Radium equivalent activity (Ra_{eq}) = $C_{\text{Ra}} + 1.43 C_{\text{Th}} + 0.07 C_{\text{K}}$ (Beretka and Mathew, 1985)

External hazard index (H_{ex}) = $C_{\text{Ra}}/370 + C_{\text{Th}}/259 + C_{\text{K}}/4810$

Internal hazard index (H_{in}) = $C_{\text{Ra}}/185 + C_{\text{Th}}/259 + C_{\text{K}}/4810$

Annual effective dose from soil (mSv y^{-1}) using standard conversion factors.

All studies followed identical protocols, enabling direct comparison.

Results

Absorbed Dose Rates

Table 1 summarizes absorbed dose rates and AED across the studied locations. Indoor rates consistently exceeded outdoor values, with study-area averages 2–4 times the Indian national average (57 nGy h^{-1} or $\sim 500 \mu\text{Gy y}^{-1}$; Nambi et al., 1986) and global outdoor terrestrial average ($\sim 59 \text{ nGy h}^{-1}$; UNSCEAR, 2000).

Table 1. Summary of gamma absorbed dose rates and annual effective doses in Nalgonda study sites

Location	Indoor ($\mu\text{Gy y}^{-1}$) SM/TLD	Outdoor ($\mu\text{Gy y}^{-1}$) SM	Avg. Absorbed Dose ($\mu\text{Gy y}^{-1}$)	AED (mSv y^{-1}) SM / TLD	Reference
Devarakonda Town	2240 \pm 535 / 2394 \pm 468	2178 \pm 288	2227 \pm 469	1.56 / 1.68	Reddy et al. (2021a)
Megavath Thanda	2132 \pm 137 / 1833 \pm 289	1999 \pm 162	2105 \pm 142	1.47 / 1.28	Suman et al. (2021)
Peddamura	1336 \pm 426 / 1413 \pm 248	~1170 (est.)	~1413	0.94 / 0.99	Suman et al. (2023)
Dasarlapally	2357 \pm 595 / 2307 \pm 598	2207 \pm 612	2327 \pm 505	~1.63 / ~1.62	Suman et al. (2020)
Surrounding 7 villages	2040 (233 nGy h ⁻¹) / 2780 (318 nGy h ⁻¹)	1787 (204 nGy h ⁻¹)	~2200	1.95 (TLD)	Srinivas Reddy et al. (2021)
Kothapally	1989 \pm 335 / 1499 \pm 293	~1800 (est.)	~1989	1.39 / 1.00	Suman et al. (2025)

*SM = μR -survey meter; est. = estimated from ratios; national avg. 775 $\mu\text{Gy y}^{-1}$ (~88 nGy h⁻¹).

Frequency distributions were near-normal in most sites, with slight positive skewness attributable to building material variability. Stone and mud walls yielded higher indoor rates (273 \pm 41 and 241 \pm 51 nGy h⁻¹) than brick (225 \pm 34 nGy h⁻¹), confirming material influence (Srinivas Reddy et al., 2021).

Soil Radionuclide Activities and Hazard Indices

Soil analyses (Table 2) revealed elevated ²³⁸U and ²³²Th in most villages, often 2–5 times world averages. Potassium was variable but generally comparable to global levels.

Table 2. Average soil radionuclide concentrations and derived parameters

Location	²³⁸ U (Bq kg ⁻¹)	²³² Th (Bq kg ⁻¹)	⁴⁰ K (Bq kg ⁻¹)	Ra_eq (Bq kg ⁻¹)	H_ex	H_in	Soil AED (mSv y ⁻¹)
Megavath Thanda	74 \pm 5	123 \pm 11	168 \pm 12	261	0.71	0.91	0.71
Peddamura	163 \pm 12	176 \pm 14	586 \pm 46	455	1.24	1.68	1.26
Kothapally	167 \pm 26	153 \pm 10	370 \pm 26	411	1.12	1.57	1.13
World Avg. (UNSCEAR, 2000)	35	30	400	370	<1	<1	0.48 (terrestrial)

Radium equivalent activities exceeded 370 Bq kg⁻¹ in some samples from Peddamula and Kothapally, with H_ex and H_in occasionally >1, indicating potential radiological concern (Beretka and Mathew, 1985; UNSCEAR, 2000).

Discussion

Comparison with National and Global Benchmarks

The observed dose rates in Nalgonda (average ~2200 $\mu\text{Gy y}^{-1}$) are among the highest reported in non-monzonite areas of India. For context, Hyderabad and surroundings averaged ~104 nGy h⁻¹ indoors (Sreenath Reddy et al., 2010), while Kerala's high-background monazite sands reach 2–3 mSv y⁻¹ (Nair et al., 2009; Thomas et al., 2022). In uranium-prospective regions, similar elevations occur: Gogi (Karnataka) ~91 nGy h⁻¹ (Karunakara et al., 2014), Tummalapalle (Andhra Pradesh) baseline studies show localized spikes (Rana et al., 2022), and Jaduguda (Jharkhand) reports 53–464 Bq kg⁻¹ for U/Th/K (Maharana et al., 2010). Globally, high-background areas in Iran (Ardebil: 1.73 mSv y⁻¹; Hazrati et al., 2012), Vietnam (0.46 mSv y⁻¹ average; Inoue et al., 2020), and Nigeria (1.21 mSv y⁻¹ mean; Peter et al., 2016) show comparable or lower values.

The indoor/outdoor ratio (0.72–1.54, average ~1.1) is lower than the global 1.4, suggesting limited radon/thoron progeny contribution in well-ventilated dwellings but highlighting building material dominance (Suman et al., 2020).

Influencing Factors

Geology: Proximity to Srisailem outlier granite and uranium anomalies drives elevated primordial radionuclides (Rajaraman et al., 2013).

Building Materials: Stone and mud walls, common in rural Nalgonda, contain higher activity than brick or cement (Srinivas Reddy et al., 2021; consistent with findings in Meghalaya uranium areas; War et al., 2008, 2012).

Seasonal and Spatial Variability: Normal distributions with minor skewness reflect localized mineralization; temporal studies elsewhere link variations to radon exhalation (Tchorz-Trzeciakiewicz and Olszewski, 2019).

Radiological and Health Implications

AED values ($0.94\text{--}1.95\text{ mSv y}^{-1}$) exceed the global terrestrial average but remain below ICRP public limit (1 mSv y^{-1} above background; ICRP, 2007). However, combined with radon/thoron (separate studies report elevated levels in the same dwellings; Suman et al., 2021), total exposure may approach or exceed 2.4 mSv y^{-1} . Long-term low-dose effects include stochastic risks (lung cancer, leukemia), though epidemiological evidence in similar Indian settings is limited (Nagaraja et al., 2022; Shankamma et al., 2022). Pre-mining baselines are critical for post-mining impact assessment (Srinivas et al., 2017; Raghavendra et al., 2014).

Recommendations

Implement continuous monitoring networks using TLD grids and real-time spectrometers.

Promote low-activity building materials and improved ventilation.

Conduct epidemiological studies on local populations.

Integrate findings into regulatory frameworks for uranium mining (AERB guidelines).

Future research should expand to radon/thoron mapping, groundwater radioactivity, and dose reconstruction using optically stimulated luminescence (OSL) in bricks.

Conclusion

The reviewed studies establish that natural background gamma radiation in Nalgonda's uranium-prospective villages is significantly elevated due to geological factors and traditional construction materials. Absorbed dose rates and effective doses are 2–4 times national averages, providing a robust pre-mining baseline. While current levels pose limited acute risk, cumulative exposure warrants vigilance. This synthesis, contextualized with 150+ global and Indian studies, underscores the value of localized, multi-method assessments for radiation protection in mineralized regions. Proactive mitigation and long-term surveillance will safeguard public health as mining develops.

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Author Contributions

MSR conceived the concept, wrote and approved the manuscript.

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