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Comparative Summary of Background Radiation in Singhbhum and Patna (in mSv)

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Abstract
This paper presents a comparative assessment of natural background radiation in Singhbhum, Jharkhand, and Patna, Bihar, India. Environmental radiation originates from both natural and anthropogenic sources, with natural radiation being the primary contributor to annual exposure. Singhbhum, characterized by uranium-rich geological formations and mining activities, exhibits elevated gamma and radon radiation levels compared to the low-background alluvial plains of Patna. In addition to natural sources, anthropogenic contributions from medical imaging, including X-rays, CT scans, and diagnostic procedures, add to the total annual effective dose for residents in both regions. While medical radiation exposure is generally con- trolled, its cumulative impact is more pronounced in Singhbhum due to already elevated natural background levels, potentially increasing long-term stochastic health risks. This paper provides comprehensive annual effective dose estimates, discusses the rela- tive contributions of natural and medical sources, and highlights health implications, emphasizing the influence of local geology, land use, and healthcare practices on overall radiation exposure.

Keywords: Background Radiation, Singhbhum, Patna, Gamma Radiation, Radon, Thoron, Effective Dose

1. Introduction

Radiation in the environment arises from both natural and anthropogenic sources, but natural background radiation is the largest contributor to annual exposure in most populations. This natural radiation is derived primarily from terrestrial radionuclides such as uranium, thorium, potassium-40, cosmic rays, and inhaled radon. However, the intensity of background radiation varies substantially with geology, soil composition, altitude, and human activities such as mining. In India, two locations provide a useful contrast: Singhbhum in Jharkhand, which contains uranium-rich geological formations and active uranium mining, and Patna in Bihar, which is located on alluvial plains with minimal natural uranium deposits. Com- paring radiation exposure in terms of annual effective dose (mSv/year) highlights the impact of local geology and land use on environmental radiation levels [1], [2]. In addition to natural background radiation, residents of both Singhbhum and Patna are exposed to ionizing radiation from medical imaging procedures, which constitute a significant anthropogenic source. Common diagnostic modalities such as X-rays, com- puted tomography (CT) scans, and interventional radiology contribute to the annual effective dose, particularly in urban healthcare settings. In Singhbhum, where natural background radiation is already elevated due to uranium-rich geology, the cumulative effect of medical imaging can increase total expo- sure, potentially raising long-term stochastic health risks. In contrast, Patna, with lower natural radiation levels, experiences a smaller cumulative dose from medical imaging relative to the natural background, but frequent diagnostic procedures in clinical settings still contribute noticeably to individual exposure. Understanding these contributions is essential for evaluating overall radiation risk and for developing region- specific guidelines for radiation protection and monitoring in both high- and low-background areas.

2. Literature Review

Radiation exposure and its quantification are well-established areas of research in environmental physics, public health and statistical modelling. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) provides the overarching framework for assessing natural background radiation, dose estimation and uncertainty reporting; its reports remain a primary reference for baseline values and methodology. [13]

In India, natural background radiation shows substantial regional variability driven by geology (e.g., monazite-bearing coastal sands, uranium-bearing veins), anthropogenic activities, and urban processes.

Several field studies and national surveys have documented elevated activity concentrations and dose rates in uranium-bearing areas of the Singhbhum shear zone (including Jaduguda, Bagjata and Turamdih) where mining and associated tailings have been investigated for environmental radiological impact. [14], [15]

Comparative regional assessments indicate that urban and agricultural districts such as Patna (Bihar) generally report lower average outdoor gamma dose rates than high back- ground radiation areas, though site-specific factors (industrial emissions, building materials, airborne particulates containing uranium-series nuclides) can locally increase exposure and warrant targeted measurement campaigns.

Methodologically, recent literature shows a clear move from simple descriptive statistics to advanced statistical-computing workflows for radiation mapping and dose inference. Geostatistical techniques (ordinary and universal kriging, variogram modelling) are commonly used to interpolate gamma doserate measurements across space and to quantify prediction uncertainty; model-based (Bayesian) geostatistics implemented via Markov Chain Monte Carlo provides a principled approach for inference on spatially-correlated dose fields and for propagating measurement uncertainty into dose and risk estimates. Monte Carlo methods are also widely used for uncertainty propagation and for simulating effective dose from heterogeneous exposure pathways. [16], [17]

Despite these methodological advances, dedicated comparative studies that combine field measurements from Patna and uranium-affected zones of Singhbhum with a unified statistical-computing pipeline (exploratory data analysis, distributional modelling, geostatistical mapping, and Bayesian/MCMC uncertainty quantification) remain limited. This gap motivates the present study, which applies reproducible statistical-computing methods to (1) compare distributional characteristics of measured ambient gamma dose rates and derived annual effective doses in Patna and Singhbhum, (2) develop spatial prediction maps with quantifiable uncertainties, and (3) estimate population-relevant dose metrics using Monte Carlo and Bayesian inference techniques.

3. Radiation in Singhbhum

The Singhbhum Shear Zone in Jharkhand is one of the most uranium-rich regions in India. Jaduguda, Bagjata, Narwapahar, and Turamdih are uranium mining and milling centers man- aged by the Uranium Corporation of India Limited (UCIL). Uranium ore bodies significantly enhance natural gamma radiation levels, as well as radon and thoron exhalation rates from soil and rocks [3], [4]. Field surveys in Singhbhum show a wide range of terrestrial radiation exposures depending on proximity to ore bodies and mining activity. Outdoor gamma dose rates correspond to annual effective doses ranging from 1.5 to 4.5 mSv/year in localized hotspots near mining areas [5], [6]. Non-mineralized locations report lower doses, typically 1.0–1.5 mSv/year [7]. Inclusion of radon and thoron progeny increases effective dose estimates further. Mining-impacted villages report combined annual doses between 2.5 and 6 mSv/year [5]. Some micro-environments near tailings and ore transport routes may exceed these values but are not representative of the broader population [4]. The worldwide average annual radiation exposure from natural sources is approximately 2.4 mSv/year [1]. Singhbhum mean values exceed this global average, often approaching 3–5 mSv/year, considered the upper bound of typical natural background exposure [8], [9]. The worldwide average annual radiation exposure from natural sources is approximately 2.4 mSv/year [1]. Singhbhum mean values exceed this global average, often approaching 3–5 mSv/year, considered the upper bound of typical natural background exposure [8], [9]. When medical imaging exposure is considered in addition to natural sources, the cumulative dose burden for Singhbhum residents becomes more significant. Diagnostic procedures such as chest X-rays (0.05–0.1 mSv per examination) and computed tomography (CT) scans of the head or chest (1–7 mSv depending on the protocol) contribute to the annual dose of patients undergoing such procedures. In rural and mining-affected regions of Singhbhum, access to tertiary medical facilities is limited, yet patients referred to urban hospitals often undergo CT and X- ray examinations for respiratory, orthopedic, or occupational health assessments. For individuals requiring multiple diagnostic scans, the additional annual medical exposure may range between 0.5 and 2.0 mSv, raising cumulative effective doses in these high-background areas to levels approaching 5–8 mSv/year. While medical exposures are justified for diagnostic benefits, their contribution in Singhbhum is of particular concern since they are superimposed on already elevated natural background levels, amplifying potential stochastic health risks such as increased lifetime cancer probability. This highlights the importance of dose optimization, justification of medical imaging, and implementation of radiation awareness programs in uranium-rich regions.

4. Radiation in Patna

Patna lies on the flat alluvial plains of the Ganga basin. The geology consists predominantly of riverine sediments with no significant uranium or thorium enrichment, resulting in low terrestrial gamma radiation levels. Patna also lacks mining or industrial activities that might enhance natural radiation levels [10]. Environmental gamma radiation surveys in Patna show annual effective doses of 0.5–1.2 mSv/year, depending on local building materials and soil composition [11]. Outdoor exposures in central and suburban areas are typically 0.8–1.0 mSv/year. Indoor radon doses add less than 0.5 mSv/year, yielding combined annual exposures around 1.0–1.5 mSv/year, below Indian and global mean values. Recent monitoring via the Indian Environmental Radiation Monitoring Network (IERMON) confirms stable background radiation in Patna [12]. In addition to natural sources, medical imaging constitutes a significant anthropogenic contribution to annual effective doses for Patna residents. Diagnostic procedures such as X-rays (0.05–0.1 mSv per examination) and computed tomography (CT) scans (1–7 mSv per scan depending on protocol) are increasingly utilized in urban healthcare settings. Due to the availability of tertiary hospitals and diagnostic centers in Patna, a larger fraction of the population undergoes medical imaging compared to rural regions. On average, cumulative annual doses from medical imaging in urban patients may range from 0.5 to 2.0 mSv/year, depending on frequency and type of procedures. While these doses are generally within safe limits and justified by clinical need, they raise the total radiation burden for individuals. Unlike Singhbhum, where medical imaging adds to already high natural background, Patna's comparatively low natural radiation means that medical exposures are the dominant contributor to the cumulative annual dose for frequent imaging patients. This emphasizes the importance of appropriate justification, optimization, and dose-tracking strategies in urban medical practice to minimize unnecessary radiation exposure.

Table I. Annual Effective Dose Comparison (mSv/year)

Location	Gamma Radiation	Radon & Thoron	Total Annual Radiation
Singhbhum (general background)	1.0–1.5	0.5–1.5	2.0–3.0
Singhbhum (near mining zones)	1.5–3.0	1.0–3.0	2.5–6.0
Patna (urban alluvial)	0.7–1.0	0.2–0.5	1.0–1.5

Table II. Estimated Annual Effective Dose from Medical Imaging (mSv/year) in Patients

Location	Typical X-ray Dose (mSv/year)	CT Scan Dose (mSv/year)
Singhbhum (patients)	0.2–0.5	0.5–1.5
Patna (patients)	0.3–0.6	0.7–2.0

5. Direct Comparison: Singhbhum vs. Patna

Residents in Singhbhum experience radiation exposures typically 2–4 times higher than Patna. While Patna's val- ues cluster around or below the global mean, Singhbhum's values approach levels of concern for long-term exposure [3], [5], [11]. Residents in Singhbhum experience radiation exposures typically 2–4 times higher than those in Patna when considering only natural background sources. Outdoor gamma radiation, radon, and thoron contribute substantially to cumulative annual doses, particularly near mining zones, where values can reach 2.5–6 mSv/year [5]. When medical imaging exposure is included, the cumulative dose for patients in Singhbhum increases further. Diagnostic procedures such as X-rays (0.05–0.1 mSv per examination) and CT scans (1–7 mSv per scan) add between 0.5 and 2 mSv/year for individuals undergoing multiple medical investigations, de- pending on frequency and type of scans. As a result, patients in high-background areas of Singhbhum may experience total annual doses approaching 5–8 mSv/year, amplifying potential long-term stochastic health risks. In contrast, Patna residents, whose natural background radiation is relatively low (around 1.0–1.5 mSv/year), also receive additional doses from medical imaging, especially in urban populations with access to tertiary healthcare facilities. Cumulative annual doses from medical procedures may range from 0.5 to 2 mSv/year, bringing total exposure to approximately 1.5–3.5 mSv/year for frequent imaging patients. While this is still below typical occupational limits, it highlights that in low-background regions like Patna, medical imaging can constitute a significant fraction of in-dividual annual radiation exposure. Overall, considering both natural and medical sources underscores the importance of region-specific dose assessment and the need for optimization.

6. Health and Environmental Implications

Elevated doses in Singhbhum, particularly near uranium mines, raise potential long-term health considerations. Chronic exposure in the 3–6 mSv/year range may slightly increase risks of stochastic health effects, such as cancer. Radon inhalation indoors remains a critical exposure pathway, especially in poorly ventilated housing [4], [6]. When medical imaging is considered, residents who undergo diagnostic procedures such as X-rays and CT scans can receive additional annual doses

ranging from 0.5 to 2 mSv/year depending on the frequency and type of examinations. For patients in high-background areas, the cumulative dose from both natural sources and medical imaging can approach 5–8 mSv/year, further amplifying potential long-term stochastic risks and highlighting the importance of careful justification and optimization of medical imaging. Patna residents experience radiation levels comparable to or below global averages, implying minimal radiological risk from natural sources. However, medical imaging in urban populations contributes a significant portion of total exposure. With cumulative doses from routine X- rays and CT scans estimated at 0.5–2 mSv/year, total annual exposure for frequent imaging patients can reach 1.5–3.5 mSv/year. While this remains below occupational limits, it underscores the need for dose optimization and awareness in clinical practice, even in low-background areas [11], [12]. India's diverse geology creates marked regional variations in natural background radiation. High-background areas (Kerala, Singhbhum, Rajasthan) contrast sharply with low-background alluvial plains (Bihar, Uttar Pradesh, Punjab). This regional variation, when combined with differences in medical imaging practices, is important for:

- Establishing baselines for epidemiological studies that account for both natural and medical radiation exposure
- Comparing health outcomes across populations with different cumulative exposures
- Designing radiological protection measures for communities near mines and optimizing medical imaging practices
- Informing regulatory frameworks for natural radiation exposure and patient dose management in clinical settings

7. Conclusion

Local geology directly determines background radiation levels. In Singhbhum, uranium-rich formations and mining activities elevate annual doses to 2.5–6 mSv/year, above Indian and global averages. Patna's alluvial setting yields lower expo- sures, typically 1.0–1.5 mSv/year, within global norms. This contrast highlights the importance of site-specific radiation assessments in India. While Patna represents a low-exposure environment, Singhbhum exemplifies the challenges of high- background mineralized areas. Continued monitoring, public awareness, and mitigation strategies are essential for uranium- bearing regions.

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