Th. Geeta Devi[1],
Th. Basanta Singh[1],
S. Nabadwip Singh[2]

Assessment Of Ambient Gamma Radiation In The Imphal Valley, Manipur: A Geospatial Analysis And Correlation With Geogenic Factors

Journal of Electrical Systems

Abstract: A comprehensive assessment of outdoor ambient gamma radiation levels was conducted across the Imphal East and Imphal West districts of Manipur, India. This study, covering a broader area and more sampling sites than previous investigations, aimed to establish an updated geospatial dataset of terrestrial absorbed dose rates using a portable survey meter. Measurements were taken at 200 selected sites, representing diverse residential, agricultural, and institutional areas. The recorded absorbed dose rates in air ranged from 0.701 to 1.781 milligray per year (mGy/y), with a mean value of approximately 1.25mGy/y. These values, when converted, correspond to an average annual effective dose of approximately 1.0 mSv, which is notably higher than the nationwide average for India but remains well within the global average values recommended by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Spatial variations were observed, which are attributed to the unique geogenic factors of the region, including the underlying Disang and Barail Group formations and the fluvio-lacustrine alluvial soils known to be enriched in naturally occurring radioactive materials, particularly primordial radionuclides. This dataset serves as a valuable supplement to existing soil radioactivity studies, providing a critical baseline for future radiological monitoring, health risk assessments, and environmental safety studies in this geologically distinct region of Northeast India.

Keywords: Imphal East, Imphal West, Survey meter, gamma radiation, geogenic factors

1. Introduction

1.1. Natural Background Radiation: Sources and Significance

Radiation is an ubiquitous component of the natural environment, to which all living organisms are continuously exposed.[1] This natural background radiation (NBR) is primarily derived from two main sources: cosmic radiation, which originates from extraterrestrial sources and interacts with the Earth's atmosphere, and terrestrial radiation, which emanates from the decay of naturally occurring radionuclides present in the Earth's crust, soil, rocks, and building materials.[2] The primordial radionuclides of primary interest for terrestrial radiation are the decay series of uranium (238U), Thorium (232Th) and a single radionuclide, Potassium (40K), all of which have half-lives comparable to the age of the Earth.[2] The levels of terrestrial radiation vary significantly depending on local geological, environmental, and geographical factors, making systematic measurement essential for establishing baseline data on public radiation exposure and for monitoring any potential anthropogenic radiological contributions [1].

The assessment of ambient gamma dose rates provides a direct measure of external exposure from these terrestrial sources.[1] The variations observed in a given region are not random phenomena but rather a direct signature of the underlying geology. The presence and concentration of primordial radionuclides are dictated by the mineralogy of the parent rock material from which the local soil is derived. Consequently, a comprehensive geospatial mapping of these dose rates functions as a form of radiological geochemical mapping, providing insights into the distribution of naturally occurring radioactive materials (NORMs) within the lithosphere.[3] This is particularly important for regions with unique or complex geological formations where a comprehensive radiological baseline has not been established.

[1]Department of Physics, Manipur International University, Ghari -795140, Manipur, India.
[2]Department of Physics, Oriental College (Autonomous). Takyel, Imphal-795001, Manipur, India

1.2. National and Regional Radiological Context

India, with its diverse geological landscape, presents a wide range of natural background radiation levels. The Bhabha Atomic Research Centre (BARC) has conducted a nationwide survey covering over 45,000 sampling grids to assess the existing exposure situation. This extensive mapping effort found the mean absorbed dose rate for the entire country to be 96 ± 21 nGy/h.[4] This value is comparable to the global database and falls well within the international average [4].

However, certain regions in India, known as High Background Radiation Areas (HBRAs), exhibit significantly elevated dose rates. These areas, particularly the monazite-rich coastal sands of Kerala and Odisha, have been extensively studied.[1] In the Karunagappally area of Kerala, dose rates have been found to vary from 700 to 9562 nGy/h.[11] Similarly, studies in the eastern coastal area of Odisha have reported dose rates in situ ranging from 0.25 to 1.2 mμ Sv/ h [5], with mean absorbed dose rates of 1925 ± 718 nGy/h.[6]. The radiological status of a given region, therefore, must be positioned against this national backdrop to accurately evaluate its public health implications. While the BARC survey provides a crucial country-level average, its large grid size (36 km^2) may not capture the fine-scale variations that exist in smaller, geologically distinct regions.[4] This highlights the need for focused, high-density surveys in specific areas to provide a more accurate local average and a detailed understanding of the factors influencing radiation levels.

1.3. Geographical and Geogenic Setting of Imphal Valley

The Imphal Valley, located in the Indian state of Manipur, is a unique geographical feature. It is an irregular, almost oval-shaped canyon surrounded by hill ranges and is located at an average elevation of approximately 786 meters above mean sea level (MSL).[7]. The valley is a fluvio-lacustrine plain, believed to have been formed by the siltation of an ancient lake, with rivers such as the Imphal, Iril, and Thoubal flowing through it.[7]. The parent material of the soil in the valley is derived from the weathering of the surrounding hill ranges, which consist of the Late Cretaceous to Eocene-aged Disang Group and the Oligocene-aged Barail Group.[8,13]

The geological characteristics of these formations provide a crucial context for understanding the potential for elevated background radiation. The Disang Group is composed of dark grey splintery shales with interbedded fine sandstones[8,12]. Geochemical analysis of these shales indicates that they are enriched in certain oxides, including a notably high concentration of K_2O. K-40 is a naturally occurring radioactive isotope of potassium, and its abundance in the parent rock material directly influences its concentration in the derived soils.[2]. The soil in the Imphal Valley is described as alluvial, consisting of black carbonaceous clay, silt, and sand.[7]. This composition is significant because clay and loam soils are known to bind tightly to potassium, preventing its leaching and leading to a persistent, elevated radioactive signature.[9]. Thus, the specific lithology of the surrounding hills and the nature of the valley's soil provide a clear causal link to the presence of higher-than-average terrestrial radiation.

The present study is a crucial methodological and spatial extension of this foundational work. While the previous study provided valuable data on radionuclide concentrations in soil, this research employs a portable survey meter to conduct an extensive, high-density geospatial assessment of ambient gamma radiation in air across a much wider area. By measuring at 200 sites, this study captures a finer resolution of spatial variation that a 20-point survey may not have detected. The objective of this research was to generate an updated, systematic dataset of outdoor ambient gamma radiation, assess its spatial variations, and provide a scientific reference for future radiological and environmental safety studies in Manipur. This research, therefore, does not claim to be the first of its kind but rather seeks to provide a comprehensive in-situ dataset that complements and expands upon the existing knowledge base, offering a more complete radiological picture of the region.

2. Materials and Methods

2.1. Study Area

The study was conducted in the Imphal East and Imphal West districts of Manipur, located at the core of the Imphal Valley. The districts have a combined geographical area of 1,267 $km^{2.}$ The valley region is characterized by fertile alluvial plains and scattered hillocks, and it serves as the socio-economic and political centre of the state, with a relatively high population density. The measurements were carried out at a wide variety of locations, including residential, agricultural, institutional, and roadside areas, to ensure a representative sample of the ambient environmental conditions. The spots of the survey in these two districts are shown in the Figure 1 and 2.

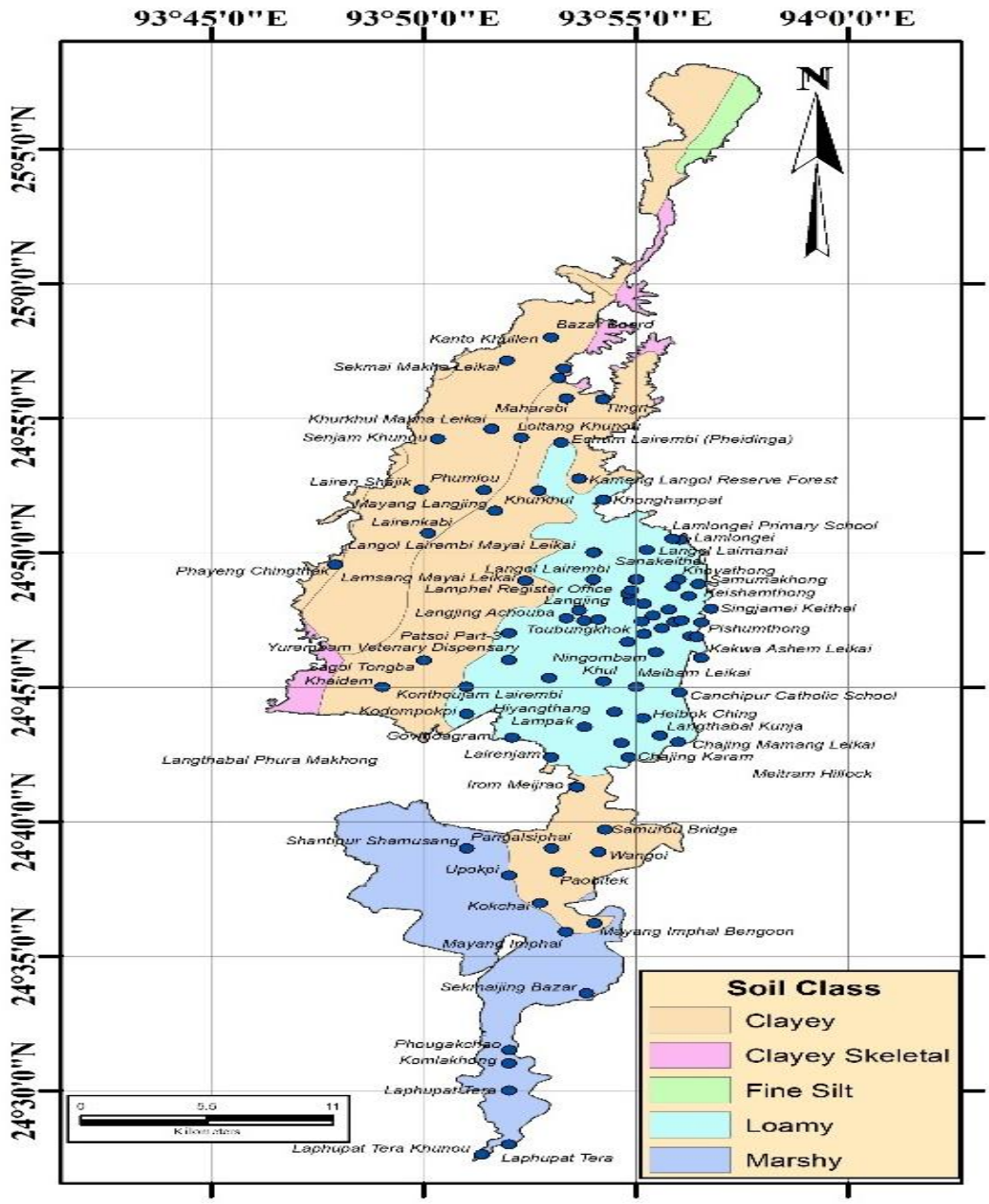

Figure 1: Map showing the locations of sampled sites against the soil types in Imphal West District, Manipur.

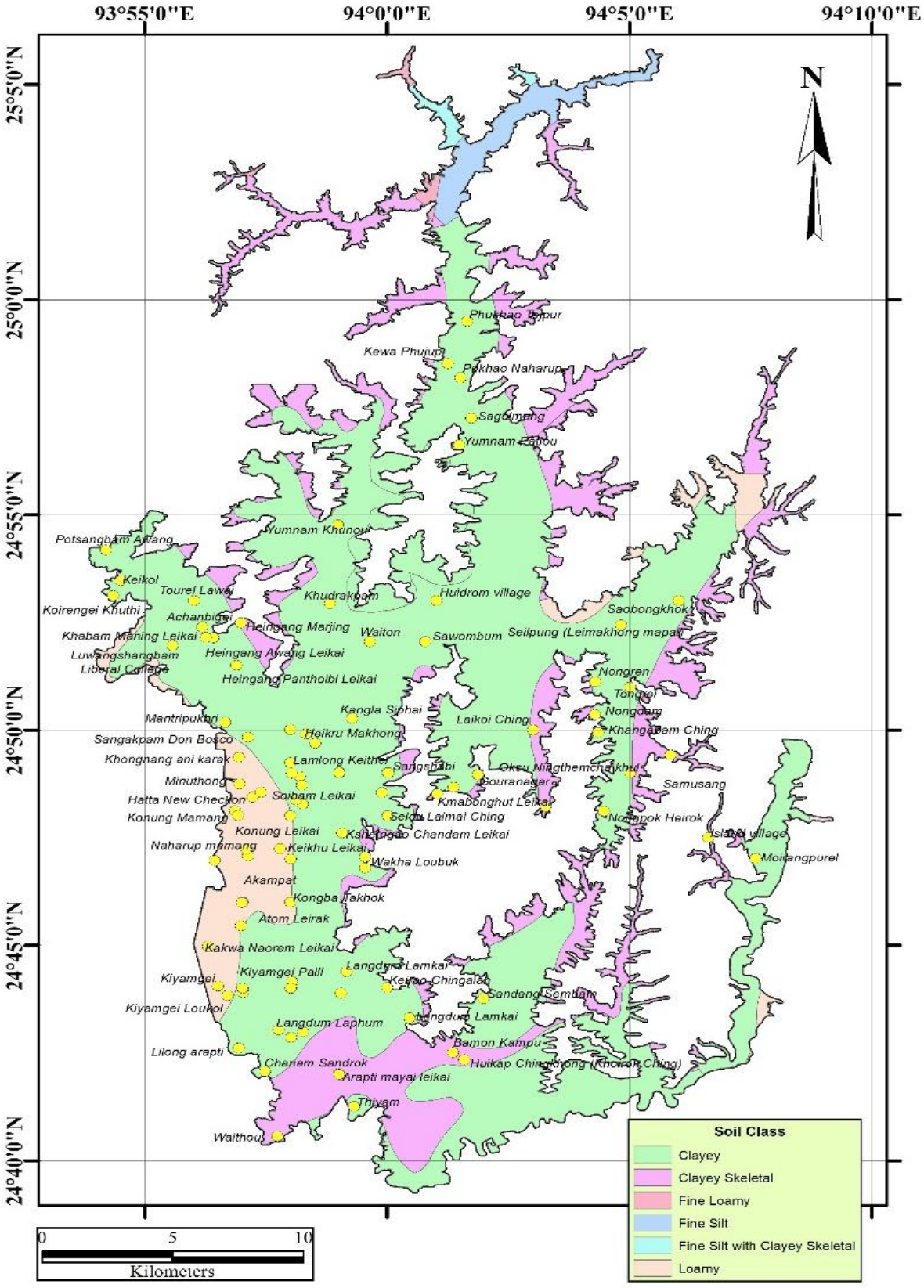

Figure 2: Map showing the locations of sampled sites against the soil types of Imphal East District, Manipur.

2.2. Measurement of environmental Radiation dose using Micro Survey Meter

The radiation mapping was performed using a portable survey meter. This device, which is both safe and comfortable to operate, was used to measure the background radiation at 200 different locations across the study area. For each measurement, the survey meter was held at a height of 1 meter above the ground surface. To ensure accuracy and minimize statistical fluctuations, five separate readings were taken at each site, and the average of these five measurements was recorded as the radiation dose for that specific location. The geographical coordinates of longitude and latitude for each measurement site were determined using a Global Positioning System (GPS) device. Measurements were conducted during daytime hours, from 9:00 a.m. to 5:30 p.m. The value of the environmental dose rate at the Imphal West and Imphal East districts is presented in Tables 1 and 2.

Table 1: Environmental absorbed dose rate measurement at different sites of Imphal West by using a Survey Meter.

LOCATION	Maximum dose rate (mG/y)	Minimum dose rate (mG/y)	Average dose rate (mG/y)	Soil type
Kwakeithel Thockchom Leikai	2.160 ±0.051	0.584 ± 0.046	1.197±0.051	Loamy
Meitram Hillock	1.957 ±0.051	0.788±0.088	1.080±0.051	Loamy
Lairenjam (Lairen shajik)	1.723±0.051	0.438±0.0876	1.020±0.051	Clayey
Department of Radiation Oncology, RIMS	1.956 ±0.051	0.672±0.046	1.050±0.088	Loamy
Langjing	1.810 ±0.051	0.438±0.088	1.020±0.051	Loamy
Sagolband Bijoy Govinda	1.664 ±0.088	0.496±0.046	0.993±0.051	Loamy
Yaiskhul Sawaijam Leirak	1.606 ±0.051	0.701±.139	0.993±0.101	Loamy
Khurkhul Makha Leikai	1.810 ±0.051	0.467±0.077	0.993±0.134	Clayey
Koujeng Leima	1.518 ±0.051	0.730±0.046	0.992±0.051	Clayey
Lairenkabi	1.606 ±0.051	0.584±0.150	0.905±0.101	Clayey
Lamsang Mayai Leikai	1.489 ±0.088	0.526±0.088	0.905±0.101	Clayey
Langol Lairembi Mayai Leikai	1.664 ±0.175	0.234±0.046	0.964±0.088	Clayey
Langol Leirembi	1.635 ±0.051	0.292±0.046	0.934±0.134	Clayey
Maharabi	1.518 ±0.051	0.584±0.046	0.934±0.051	Clayey
Mayang Imphal Bengoon	1.460 ±0.051	0.555±0.150	0.964±0.088	Clayey
Phayeng Chingthak	1.460 ±0.051	0.701±0.088	0.934±0.051	Clayey
Phumlou	1.606 ±0.051	0.555±0.068	0.934±0.051	Clayey
Bamdir Mayai Lekai	1.723 ±0.051	0.321±0.068	0.934±0.134	Loamy
Changangei Maning Lekai	1.285 ±0.051	0.584±0.150	0.934±0.051	Loamy
Heibok Ching	1.723 ±0.134	0.496±0.068	0.905±0.051	Loamy
Heiyangthang Lampak	1.518 ±0.050	0.263±0.107	0.934±0.051	Loamy
Kokchai	1.577 ±0.088	0.467±0.137	0.934±0.134	Loamy

Konthoujam Leirembi	1.810 ±0.051	0.496±0.046	0.934±0.051	Loamy
Lamlongei	1.577±0.088	0.234±0.046	0.964±0.088	Loamy
Lamphel Home guard Headquater	1.635 ±0.051	0.438±0.088	0.905±0.101	Loamy
Lamphel near Home Guard's Headquarters	1.635 ±0.051	0.467±0.046	0.964±0.088	Loamy
Lamphel Women's Police Station	1.314 ± 0.000	0.642±0.046	0.993±0.051	Loamy
Lamphelpat Near Police Station	1.285 ±0.051	0.584±0.0461	0.964±0.175	Loamy
Langol Laimanai	1.460 ±0.051	0.496±0.046	0.934±0.134	Loamy
Langol Leimanai	1.431 +0.051	0.526±0.088	0.934±0.051	Loamy
Langthabal Mantrikhong	1.606 ±0.051	0.526±0.139	0.934±0.051	Loamy
Meitei Langol Mayai Leikai	1.431 ±0.051	0.467±0.046	0.964±0.088	Loamy
Meitei Langol Mayai Lekai	1.489 ±0.088	0.467±0.046	0.992±0.051	Loamy
Ningombam Khul	1.810 ±0.051	0.555±0.092	1.020±0.101	Loamy
Samumakhong	1.810 ±0.051	0.438±0.088	0.934±0.134	Loamy
Sangaiporou	2.248 ±0.051	0.555±0.046	0.905±0.101	Loamy
Tera Sapam Leirak	1.810±0.051	0.263±0.139	0.993±0.051	Loamy
Tera Yengkhom Leirak	1.518 ±0.051	0.350±0.088	0.964±0.172	Loamy
Thangmeiband Yumnam Leikai	1.927 ±0.088	0.292±0.079	0.934±0.051	Loamy
Thangmeiband Yumnam Lekai	1.898 ±0.0501	0.350±0.088	0.993±0.051	Loamy
Shantipur Shamusang	1.402 ±0.088	0.496±0.150	0.905±0.101	Marshy
Irom Meijarao	1.314 ±0.088	0.496±0.068	0.847±0.051	Clayey
Kameng Langol Reserved Forest	1.518 ±0.051	0.409±0.068	0.818±0.101	Clayey
Kheidem	1.635 ±0.051	0.379±0.046	0.876±0.088	Clayey
Leiren Shajik	1.343 ±0.051	0.526±0.088	0.849±0.051	Clayey
Mayang Langjing	1.372 ±0.051	0.321±0.137	0.847±0.134	Clayey
Sekmai Makha Leikai	1.869 ±0.051	0.496±0.204	0.847±0.051	Clayey
Senjam Khunou	1.080 ±0.482	0.438±0.1752	0.905±0.051	Clayey
Yurembam Veterinary Dispensary	1.518 ±0.051	0.292±0.068	0.818±0.051	Clayey
Bapura	1.197 ±0.051	0.234±0.077	0.876±0.088	Loamy
Chajing Karam	1.577 ±0.051	0.409±0.068	0.934±0.101	Loamy
Chajing Mamang Leikai	1.694 ±0.134	0.292±0.092	0.818±0.051	Loamy
Echum Leirembi (Pheidinga)	1.372 ±0.134	0.467±0.137	0.876±0.175	Loamy

Govindagram	1.577 ±0.088	0.526±0.088	0.847±0.051	Loamy
Haoreibi kangjeibung	1.022 ±0.051	0.438±0.0876	0.934±0.051	Loamy
Kakwa Asem Leikai	1.577 ±0.088	0.584±0.146	0.847±0.051	Loamy
Keishamthong	1.548 ±0.051	0.467±0.077	0.905±0.134	Loamy
Khondonpokpi	1.402 ±0.051	0.321±0.046	0.905±0.051	Loamy
Khonghampat	1.285 ±0.051	0.409±0.046	0.849±0.051	Loamy
Khongnang Ani Karak, Chingmeirong	1.314 ±0.088	0.496±0.068	0.876±0.175	Loamy
Khoyathong	1.869 ±0.051	0.467±0.046	0.934±0.101	Loamy
Kwakeithel Chabungbam Leikai	1.606 ±0.051	0.467±0.150	0.905±0.051	Loamy
Kwakheithel Thounoujam Leikai	1.518 ±0.051	0.467±0.092	0.934±0.101	Loamy
Lamlongei Primary School	1.372 ±0.051	0.496±0.046	0.905±0.220	Loamy
Langthabal kunja	1.518 ±0.051	0.438±0.088	0.905±0.134	Loamy
Loitang Khullen	1.080 ±0.051	0.350±0.088	0.876±0.087	Loamy
Loitang Khunou	1.372 ±0.134	0.467±0.077	0.847±0.134	Loamy
Maibam Lekai	1.402 ±0.088	0.379±0.046	0.934±0.101	Loamy
Pishumthong	1.752 ±0.088	0.555±0.136	0.905±0.051	Loamy
SanaKeithel	1.578 ±0.088	0.613±0.139	0.905±0.134	Loamy
Sanakheithel, Lamphel	1.548 ±0.051	0.467±0.077	0.905±0.051	Loamy
Singjamei Keithel	1.226 ±0.088	0.584±0.068	0.905±0.134	Loamy
Thaoda Babok Leikai	1.752 ±0.088	0.555±0.077	0.847±0.134	Loamy
Toubungkhok	1.752 ±0.088	0.730±0.068	0.905±0.051	Loamy
Laphupat Tera Khunao	1.489 ±0.088	0.321±0.046	0.905±0.134	Marshy
Pangalsiphai	1.460 ±0.051	0.642±0.046	0.847±0.051	Marshy
Upokpi	1.577 ±0.088	0.496±0.046	0.934±0.101	Marshy
Langjing Achouba	1.343 ±0.051	0.292±0.0461	0.730±0.101	Clayey
Paobitek	1.489 ±0.088	0.234±0.068	0.730±0.051	Clayey
Patsoi Part -3	1.314 ±0.088	0.292±0.092	0.701±0.152	Clayey
Samurou Bridge	1.46 ±0.051	0.409±0.046	0.701±0.088	Clayey
Sangol Tongba	1.285 ±0.051	0.584±0.046	0.730±0.101	Clayey
Tingri	1.314 ±0.088	0.409±0.068	0.730±0.051	Clayey

Bazar Board	1.922 ±0.088	0.438±0.088	0.759±0.051	Clayey skeletal
Canchipur Catholic School	1.402 ±0.088	0.467±0.077	0.759±0.133	Loamy
Konjeng Lekai	1.577 ±0.088	0.321±0.068	0.818±0.134	Loamy
Lalambung Makhong	1.694 ±0.051	0.526±0.088	0.788±0.088	Loamy
Langthabal Phuramakhong	1.548 ±0.051	0.379±0.046	0.788±0.175	Loamy
Sagolbang Nepra Menjor Leirak	1.460 ±0.134	0.292±0.046	0.759±0.051	Loamy
Uripok Sakhi Devi School	1.372 ±0.051	0.409±0.068	0.818±0.051	Loamy
Komla Khong	1.168 ±0.051	0.321±0.046	0.818±0.134	Marshy
Phaugakchao	1.577 ±0.088	0.409±0.046	0.886±0.051	Marshy
Sekmaijing Bazar	1.3724 ±0.134	0.496±0.068	0.788±0.087	Marshy
Kanto Khullen	1.372 ±0.051	0.175 ±0.107	0.730±0.051	Clayey
Wangoi	1.168 ±0.051	0.496±0.068	0.759±0.051	Clayey
Lamphel Register Office	1.285 ±0.051	0.496±0.122	0.701±0.087	Loamy
Laphupat Tera	1.139 ±0.088	0.467±0.046	0.730±0.051	Marshy
Laphupat Tera	1.110 ±0.051	0.379±0.046	0.730±0.134	Marshy
Mayang Imphal	1.256 ±0.051	0.321±0.068	0.730±0.051	Marshy

Table 2: Environmental absorbed dose rate measurement at different sites of Imphal East District using Survey Meter.

LOCATION	Max dose rate (mGy/yr)	Min dose rate (mGy/yr)	Avg dose dose rate (mGy/yr)	Soil type
Heikru Makhong	1.8104 ± 0.134	0.6132 ± 0.088	1.7812 ± 0.051	Clayey
Porompat, Directorate of Environment & Climate Change	1.9272 ± 0.088	0.6132 + 0.076	1.2264±0.088	Clayey
Keirao Wangkhem	2.0148 ± 0.088	0.7271 ± 0.051	1.0804 ±0.101	Clayey
Koirengei Khuthi	1.8396 ± 0.175	0.6424 ± 0.961	1.0804 ±0.051	Clayey
Nongdam	2.3360 ± 0.051	0.3796 ±0.051	1.168 ±0.051	Clayey
Bashikhong Loumanbi	1.7228 ± 0.134	0.3504 ±0.088	1.0804 ±0.134	Clayey
Hatta New checkon	1.4016 ± 0.088	0.6132 ±0.088	1.0220 ±0.134	Loamy
Khundrakpam	1.9272 ± 0.263	0.3504 ±0.088	1.0512 ±0.088	Clayey
Kiyamgei Palli	2.2484 ± 0.051	0.7008 ±0.088	1.022 ±0.051	Clayey
Konung Mamang	1.5768 ± 0.088	0.6424 ± 0.051	1.0804 ±0.051	Loamy

Sangshabi	1.6936 ± 0.051	0.6132 ±0.088	1.0220 ±0.051	Clayey
Soibam Lekai	1.5184 ± 0.051	0.5840 ± 0.134	1.0512 ±0.175	Clayey
Top Makha Lekai	1.5184 ± 0.134	0.6424 ± 0.051	1.022 ±0.051	Clayey
Wakha Nongdam Sanglen	1.4600 ± 0.051	0.5840± 0.051	1.0512 ±0.088	Clayey skeletal
Achanbigei	1.5476 ± 0.051	0.3504± 0.088	1.0512 ±0.088	Clayey
Arapti Mayai Lekai (Ema Ereima Laiphum)	1.7520 ± 0.088	0.6132 ± 0.088	0.9636 ±0.088	Clayey skeletal
Chanam Sandrok	1.6060 ± 0.051	0.7592 ± 0.051	0.9052+0.051	Clayey skeletal
Chingambam Leikai	1.4308 ± 0.134	0.5548 ± 0.051	0.9928±0.051	Clayey skeletal
Heingang Awang Leikai	1.7520 ± 0.088	0.4380 ± 0.088	0.9344±0.051	Clayey
Huidrom village	1.2264 ± 0.088	0.6716 ± 0.134	0.9052±0.101	Clayey
Khabam Maning Leikai	1.5768 ± 0.088	0.5548± 0.051	0.876±0.088	Clayey
Khongkham Lekai	1.5768 ± 0.175	0.5840 ± 0.051	0.9344±0.051	Clayey
Khongman Zone 5	1.3140 ± 0.175	0.4380 ±0 .088	0.9052±0.101	Clayey
Khongman Zone -5	1.2556 ± 0.182	0.5256 ± 0.088	0.9344±0.051	Clayey
Kongpal Mamang Lekai	1.7228 ± 0.134	0.5256 ± 0.088	0.9052±0.051	Loamy
Konung Leikai	1.8688 ± 0.182	0.6424 ± 0.051	0.9344±0.051	Clayey
Porompat DC	1.9272 ± 0.088	0.4380 ± 0.088	0.876±0.088	Clayey
Samusong	1.5768 ± 0.088	0.2628 ± 0.088	0.9052±0.051	Clayey
Taramphai Chiru Khul	1.4892 ± 0.088	0.7300 ± 0.051	0.9928±0.051	Clayey skeletal
Thayom Kom khul	1.4892 ± 0.088	0.6716 ± 0.051	0.9344±0.051	Clayey skeletal
Tourel Lawai (Mongjam)	1.6644 ± 0.263	0.4380 ± 0.088	0.9344±0.051	Clayey
Yaingaipokpi Shanti Khongbal	1.7520 ± 0.175	0.3796 ± 0.051	0.9344 ±0.051	Clayey
Okram Chuthek	1.5184 ± 0.051	0.5840 ± 0.051	0.8468 ±0.134	Clayey
Atom leirak	1.4308 ± 0.051	0.3212 ± 0.051	0.9052 ±0.051	Loamy
Huikup Chingkhong(Khoirok Ching)	1.6936 ± 0.051	0.2920 ± 0.134	0.8468 ±0.051	Clayey skeletal
Keirao Chingalan	1.6936 ± 0.221	0.3212 ± 0.051	0.8760 ±0.175	Clayey
Kiyamgei Laokol	1.4016 ± 0.175	0.3796 ± 0.051	0.8468 ±0.051	Loamy

Kiyamgei Thong	1.4892 ± 0.088	0.4964 ± 0.134	0.9052 ±0.051	Loamy
Kongba Takhok	1.4892 ± 0.175	0.2336 ± 0.051	0.9052 ±0.051	Loamy
Nongpok Heirok	1.1388 ± 0.080	0.2920 ± 0.051	0.9052 +0.051	Clayey
Porampat TV tower	1.3140 ± 0.088	0.5256 ± 0.088	0.8468 ±0.051	Clayey
Seilpung (Leimakhong mapal)	1.314 0± 0.175	0.3212 ± 0.051	0.8468 ±0.051	Clayey
Chingkhei ching	1.4016 ± 0.088	0.5840± 0.051	0.8760 ±0.088	Clayey skeletal
Gouranagar	1.4016 ± 0.088	0.3796 ± 0.051	0.9052 ±0.051	Clayey skeletal
Heingang Marjing	1.6936 ± 0.134	0.6132 ± 0.088	0.8760 ±0.088	Clayey skeletal
Island village	1.4892 ± 0.175	0.3212 ± 0.051	0.9052 ±0.051	Clayey skeletal
Kakwa Naorem Leikai	1.3432 ± 0.134	0.4964 ± 0.051	0.9344 ±0.101	Loamy
Kangla Siphai	1.5184 ± 0.134	0.2920 ± 0.051	0.8760 ±0.088	Clayey
Keikol	1.6060 ± 0.134	0.2628 ± 0.088	0.9052 ±0.134	Clayey
Keirao mating Mayai Lekai	1.5768± 0.088	0.4672 ± 0.051	0.8760 ±0.088	Clayey
Khongman UNACCO school	2.1024 ± 0.088	0.3212 ±0.051	0.8468 ±0.051	Clayey
Khongman, Zone1	2.1024 ± 0.088	0.3212 ±0.051	0.8760 ±0.088	Clayey
Khongnang ani karak	1.4016 ± 0.088	0.5256 ± 0.088	0.6716 ±0.513	Loamy
Laikoi Ching	1.4892 ± 0.088	0.4380 ± 0.088	0.8760 ±0.088	Clayey skeletal
Lilong Arapti	1.4016 ± 0.088	0.5256 ±0.088	0.876 ±0.175	Clayey
Luwangshangbam Liberal College	1.5768 ± 0.088	0.6716 ± 0.101	0.8760 ±0.175	Clayey
Mantripukhri	1.4016 ± 0.088	0.5256 ± 0.088	0.9052 ±0.051	Clayey
Oksu Ningthemcha khul	1.5184 ± 0.221	0.3212 ± 0.134	0.8468 ±0.134	Clayey skeletal
Potsangbam Awang	1.5476 ± 0.101	0.4088 ± 0.134	0.9052 ±0.051	Clayey
Sagolmang	1.6060 ± 0.051	0.3504 ± 0.088	0.9052 ±0.051	Clayey
Sangakpam Don Bosco School	1.6936 ± 0.134	0.3504 ± 0.088	0.8468 ±0.051	Clayey
Selou Langmai Ching	1.3140 ± 0.088	0.6132 ± 0.088	0.9052 ±0.051	Clayey skeletal
Singjamei Bheighavati Lekai	1.6352 ± 0.101	0.3504 ± 0.088	0.8760 ±0.088	Clayey
Takhel Panthoibi Bazar	1.2556 ± 0.051	0.4380± 0.088	0.8468±0.134	Clayey skeletal

Thiyam	1.6352 ± 0.051	0.2336 ± .1012	0.8760 ±0.088	Clayey
Thoubalkhong Thongkhong	1.1972 ± 0.134	0.3796 ± 0.051	0.8760 ±0.088	Clayey
Tongrei	1.7228 ± 0.182	0.5548 ± 0.051	0.8468 ±0.051	Clayey
Waithou	1.606 ± 0.134	0.4088 ± 0.134	0.8468 ±0.051	Clayey skeletal
Waiton	1.5768 ± 0.088	0.4380 ± 0.088	0.8468 ±0.134	Clayey
Wakha Loubuk	1.5476 ± 0.051	0.3212 ± 0.134	0.8468 ±0.134	Clayey
Wangkhei Koijam Leirak	1.5768 ± 0.088	0.3504 ± 0.088	0.9052 ±0.051	Clayey
Yumnam Khounou	1.3432 ± 0.101	0.3504 ± 0.088	0.8468 ±0.051	Clayey
Yumnam Patlou	1.4308 ± 0.134	0.4088 ± 0.134	0.9052 ±0.051	Clayey
Heikrumakhong Thangjam Lekai	1.3724 ± 0.051	0.5256 ± 0.088	0.8176 ±0.051	Clayey
Heingang Panthoibi Leikai	1.4016 ± 0.088	0.2044 ± 0.051	0.7884 ±0.088	Clayey
Kambongput Leikai	1.1388 ± 0.088	0.4672 ± 0.051	0.8176 ±0.051	Clayey skeletal
Keikhu	1.3140 ± 0.088	0.4380 ± 0.175	0.8176 ±0.051	Loamy
Kewa Phujup	1.4892 ± 0.175	0.5256 ± 0.088	0.7592 ±0.051	Clayey
Khanarok	1.3432 ± 0.051	0.3504 ± 0.088	0.7300 ±0.101	Clayey
Khurai Thongam Lekai	1.3432 ± 0.134	0.4380 ± 0.088	0.8176 ±0.051	Clayey
Kongba Kheitri Leikai	1.1388 ± 0.175	0.4380 ± 0.088	0.7884 ±0.088	Clayey
Kongba Laishram Leikai	1.4892 ± 0.088	0.4964 ±0.134	0.8176 ±0.051	Clayey
Kshetrigao Chandam Lekai	1.0804 ± 0.134	0.4380 ± 0.088	0.8176 ±0.051	Clayey
Lamlong Keithel	1.1096 ± 0.051	0.2044 ± 0.051	0.7884 ±0.088	Clayey skeletal
Langdum Laiphum	1.3140 ± 0.175	0.5840 ± 0.101	0.7592 ±0.051	Clayey
Langdum Lamkai	1.0804 ± 0.051	0.4672 ± 0.051	0.7592 ±0.134	Clayey
Minuthong	1.5184± 0.051	0.3504 ± 0.088	0.7592 ±0.051	Loamy
Moirang Kampu	1.1096 ± 0.221	0.2628 ± 0.088	0.8176 ±0.051	Clayey
Moirangkampu Mayai lekai	1.2848 ± 0.134	0.5840 ± 0.134	0.8176 ±0.051	Clayey
Moirangpurel	1.1680 ± 0.051	0.4672 ± 0.134	0.7592 ±0.051	Clayey
Naharup mamang	1.1972 ± 0.051	0.3796 ± 0.051	0.8176 ±0.051	Loamy
Phukhao Naharup	1.2848 ± 0.051	0.4088 ± 0.051	0.8176 ±0.051	Clayey
Sandang Sembam maring Khul	1.0512± 0.088	0.6132± 0.175	0.7592 ±0.051	Clayey skeletal

Urup Awang Leikai	1.4308± 0.051	0.3796± 0.051	0.8176 ±0.051	Clayey
Nongren	1.6644 ± 0.081	0.3504 ± 0.088	0.8760 ±0.088	Clayey skeletal
Bamon kampu Leitangbi leikai	1.1972 ± 0.134	0.4964± 0.101	0.7592 ±0.051	Clayey skeletal
Keirao Leital	1.0512 ± 0.175	0.6132 ± 0.088	0.7008±0.088	Clayey
Khangabam Ching	1.2264 ± 0.088	0.5256 ± 0.088	0.7300 ±0.134	Clayey skeletal
Phukhao Tejpur	1.314 0± 0.088	0.4964± 0.134	0.7592 ±0.051	Clayey
Saobungpok	1.0512 ± 0.175	0.2336 ± 0.134	0.7300 ±0.051	Clayey
Sawombung(Yourrubung)	1.6352 ± 0.101	0.4088 ± 0.051	0.7592 ±0.101	Clayey

3. Results and discussion

The survey conducted across 200 sites in the Imphal East and Imphal West districts yielded a systematic dataset on ambient gamma radiation levels. The recorded absorbed dose rates in air were found to range from 0.7008 to 1.7812 mGy/y.

3.1. Geospatial Distribution and High/Low Radiation Sites

The geospatial analysis of the collected data revealed a clear pattern of spatial variations in background radiation levels. In Imphal West, the highest absorbed dose rate of 1.197 mGy/y was recorded at Kwakeithel Thockchom Lekai, located at coordinates 24.78655096 N and 93.92681821 E, with an altitude of 780 meters above MSL. Conversely, the minimum dose rate for Imphal West was 0.7008 mGy/y, recorded at the Lamphel Register Office (24.80999926 N, 93.91486881 E, altitude 777 meters above MSL) and Summurou Bridge (24.66188063 N, 93.90449586 E, altitude 781meters above MSL).

In Imphal East, a higher maximum dose rate of 1.7812 mGy/y was observed at Heikru Makhong, located at 24.8319128 N and 93.9720538 E, at an altitude of 784 meters above MSL. The minimum dose rate for this district was 0.672 mGy/y at Khongnang Ani Karak (24.8228914 N, 93.9489189 E, altitude 786 meters above MSL). These geospatial variations suggest that the distribution of naturally occurring radioactive materials is not uniform across the valley and is likely influenced by specific, localized geogenic factors. The findings of this study provide a critical baseline for contextualizing the radiological environment of the Imphal Valley within national and global standards.

4. Conclusion

This research provides a valuable and comprehensive geospatial dataset of outdoor ambient gamma radiation levels in the Imphal East and Imphal West districts of Manipur. The findings indicate that the average absorbed dose rate in the region is approximately 109 nGy/h, which is higher than the national average for India but remains well within the global average for natural background radiation as reported by UNSCEAR.The observed spatial variations in dose rates are a direct consequence of the region's specific geogenic factors, including the underlying Disang and Barail Group formations and the clay-rich alluvial soils, which are known to be enriched in primordial radionuclides, particularly 40 K. This study effectively demonstrates the crucial link between local geology and the distribution of ambient gamma radiation.

The finding data in this study complement the existing research on soil radioactivity by providing a high-resolution, in-situ radiological baseline. The findings serve as a critical reference for future radiological monitoring, which is essential for evaluating public radiation exposure and for assessing the potential impacts of future developmental activities in the region. To build upon this work, future research should aim to conduct simultaneous soil sampling and laboratory analysis alongside ambient dose rate measurements to more precisely correlate the two datasets. Additionally, expanding the survey to include measurements of indoor radon concentrations and to cover other districts in Manipur would contribute to a more comprehensive radiological map of the state.

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