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Monitoring of Absorbed Dose Rate in Air due to Gamma Radiation

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The research studies the levels of gamma absorbed dose in the outdoor air of Shahdol. A study was conducted utilizing a PRM 121S gamma survey meter (Model Number) in 50 different areas close to coal mines. The worldwide average of 59 nGy/h is comparatively less than the measured outdoor gamma absorbed dose rate of 65.076 nGy/h. It ranges from 43.5 to 95.7 nGy/h. In the area being studied, the average yearly effective dose is 0.798 mSv/y, which is less than the worldwide mean of 1 mSv/y. The annual effective dose varies between 0.533 and 1.173 mSv/y.

Keywords: Outdoor gamma absorbed dose rate, Annual effective dose, Gamma survey meter, Coal mines

1 Introduction

An ongoing and necessary aspect of life on Earth is the exposure of humans to ionizing radiation from natural environmental sources[1]. Numerous sources expose people to natural background radiation, including food, construction material, the air, the universe, manufacturing processes, and the body of an individual itself[2]. Additionally, human activities such as medical exposure and various artificially generated sources emit radiation [3].

Natural radiation exposures are primarily caused by terrestrial and cosmic sources[4]. The first cosmic ray particles to enter the earth atmosphere are high-energy ones[5]. High-energy particles from space that continuously bombard Earth are the source of cosmic radiation. Cosmic ray exposures are caused by a series of interactions and subsequent reaction products that result from these cosmic rays contact with atmospheric nuclei. Cosmogenic radionuclides are radioactive nuclei that are also produced by cosmic ray interaction[6].

Another significant source of radiation is terrestrial radioactive elements, which have existed since the Earth formation which can be found both within the planet interior and in the human body[5]. Terrestrial radiation arises from various radioactive nuclides found in the air, water, and soil, with their concentration differing based on the geological features as well as landscape of a specific region[1]. The level of terrestrial radioactivity emitted from the Earth differs significantly across various regions of the world, primarily due to geological characteristics and natural environmental factors[7]. Differences in natural gamma radioactivity across various environment are shaped by fluctuations in the distribution and concentration of primordial radionuclides present in the surrounding area[8].

Since the concentration of radioactive nuclides in soil varies based on geographic location, it is essential to assess dose level across various geological regions[9]. The natural origin accounts for about 80% of the world population radiation dose[5]. Inhaling radon, thoron and their progeny; consuming naturally occurring radionuclides from meals and beverages, which is being directly exposed to radiation from the earth and space are the main ways that this exposure happen[10].

Because coal and nearby geological formations include naturally occurring radioactive materials (NORM) like uranium, thorium, and their decay products, coal mining operations raise the air gamma radiation level. According to studies, gamma dose rate are greater in coal mining locations. For instance, the radiation level recorded at the Mirash-Bardh open coal mine in Kosovo ranged between 0.07 and 0.18 μSv/h, with an average measurement of 0.12 μSv/h[11].

Uranium and thorium in coal seams and the surrounding area, as well as coal combustion waste such as fly ash and bottom ash, which concentrate

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radionuclides and, if improperly managed, can result in greater ambient radiation levels, are the primary causes of increased gamma radiation. According to studies such as the one on the Tanzania Kiwira coal mine, where radionuclide activity concentration in coal and ash is above the global average, occupational exposure among coal miners and public exposure in surrounding communities are potential health hazards[12]. In order to reduce the danger of radiation exposure, these findings emphasize the necessity of routine monitoring and efficient management of coal mining and combustion residues.

Evaluating gamma absorbed dose from natural environmental sources is crucial, as radiation from nature serves as the main contributor to additional exposure for the global population[13]. The study aim to examine the level of outdoor gamma absorbed dose rate in the air and determine the overall annual dose received by local residents. These sorts of studies are expected to be useful in evaluating public exposure and to provide initial information on environmental gamma radiation exposure. The study findings are contrasted with both national and international norms.

2 Study Area

Human interaction with radiation that originates from environmental sources is a regular and inevitable aspect of life on Earth. Variable areas have variable radiation levels and primordial radionuclide activity. The goal of the study is to see dose rates in different geological region, collect critical baseline radiological data, and evaluate air radiation levels. A first-time attempt has been made in the research region for this purpose, concentrating on the Shahdol district and its environment.

The Shahdol district study area map, including the study location, is shown in Fig. 1. The northeastern Indian state of Madhya Pradesh is home to Shahdol, which has a unique character shaped by a range of topographical and geomorphological features. A wealth of natural resources and a fascinating history (Indian Journal of Geography & Environment, 2019). Its 6205 km^2 area places it between 22.3° - 24.6° N and 80.15° - 82.6° E. On average, it is 464 meters above sea level. 1,064,989 people live in the district, according to the 2011 census. Shahdol strategically occupies the eastern region of Madhya Pradesh, which borders Chhattisgarh.

The district varied topography, which includes hills, river basins, and plateaus, influences the local ecosystem and enhances its aesthetic appeal. The monsoon season, which runs from June to September, brings roughly 1200 mm of rain. Temperature here range from 10-25 °C in the winter and 30-42 °C in the summer. This subtropical climate has three distinct seasons: summer, monsoon, and winter.

The coal industry plays a significant role in the economy of Shahdol, being well known for its abundant coal reserves, particularly within Bhander Group and Barakar Formation of the Gondwana Super Group[14]. Kachari, alluvial, black, yellow, and red soil are among the various varieties of soil. The district contains a wide variety of minor minerals, including marble, stone, murum, dolerite, laterite, and river gravel[15].

3 Materials and Methods

The Outdoor Gamma absorbed dose rate were measured in 50 sites near communities and coal mines in Madhya Pradesh Shahdol area using *μR* gamma survey meter (Model No. PRM 121S). Radiation Survey Meter, type PRM-121S is a portable, battery operated μR/hr radiation survey meter. The detector used is NaI scintillator type[16]. The PRM-121S offers three measurement ranges: 0 to 50 μR/hr, 0 to 500 μR/hr, and 0 to 5000 μR/hr, providing versatility for different radiation monitoring applications and we have used 0 to 50 μR/hr. The use of this detector renders the PRM-121S highly sensitive. It is ideally suited for radiometric, geophysical and environmental reconnaissance surveys[5]. Being a field instrument, it

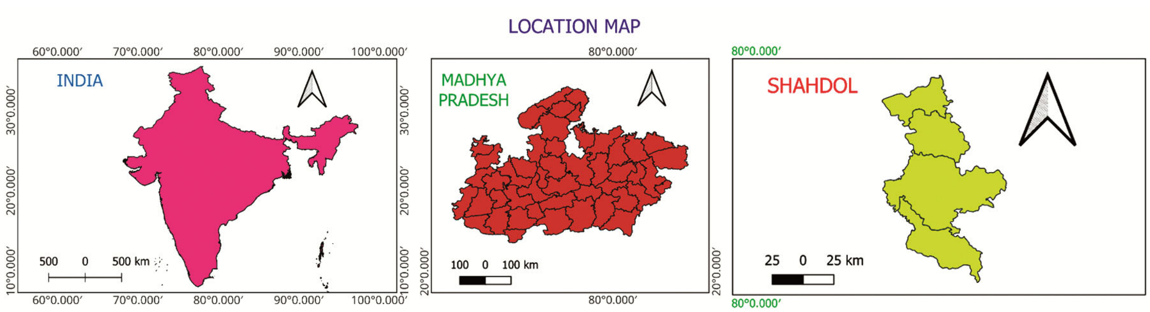

Fig. 1 — Study area map of Shahdol

operates on easily available battery cells and specially designed low current drain circuit ensures long life of the cells, the gamma radiation present in the air was assessed at a height of 1 meter above the earth surface[5]. For one hour at each measurement, a reading was taken at a height of one meter in the air. The minimal detection limit (MDL) of the gamma survey meter is 1.0 *µR/h*. The absorbed dose rate (*nGy/h*) was derived from external influence rate data measured in µR/h by applying the conversion factor of 1 *µR/h* = 8.7 *nGy/h*. This factor is based on the Roentgen definition, as outlined by[17-18].

Annual Effective Dose (AED)

For calculating AED using dose conversion ratio which is 0.7 *Sv/Gy* and an outdoor occupancy factor (OF) which is 0.2. 5 to 6 hours were spent outside by the study area resident. As previously stated, the AED for the outside terrestrial radiation was computed[19-20.]

$$AED\left(\frac{mSv}{year}\right) = D(nGy.h^{-1}) \times T(h.y^{-1}) \times OF \times CC(Sv.Gy^{-1}) \times 10^{-6} \quad \dots (1)$$

where T = time in hrs for one year (8760 hours/y),

D = Gamma absorbed dose rate,
CC = conversion coefficient,
OF = 0.2 (outdoor exposure),

The 1993 UNSCEAR[21] report determined that the conversion factor between the absorbed dose in air and effective dose received by adult is 0.7 *Sv/Gy*.

4 Results and Discussion

The average rate of environmental terrestrial gamma absorbed dose *(D)* at each of the sites selected in the Shahdol district is presented in Table 1. The typical environmental gamma absorbed dose rate is 65.076 *nGy/h*, with a range of 43.5 to 95.7 *nGy/h* as seen in Table 2. *D* average value exceeds 59 *nGy/h* i.e. global average(UNSCEAR, 2000).The highest value, 95.7 *nGy/h*, was discovered in the Udhiya region; this could be because of the high uranium content as already studied uranium concentration in this region[22]. Of the 50 samples, 35 are greater than the worldwide average limit, meaning that 70% of the samples exceed the global average value. Gamma radiation is important in coal mining sites where uranium and thorium can be found in coal, waste rock, and tailings due to the natural thorium and uranium in coal and nearby rocks, the amount of radioactive components into waste rock and dust, and the generation of radon gas from uranium decay[23].

The AED ranges 0.533 - 1.173 *mSv/y* with a mean amount of 0.798 *mSv/y*, is also computed in Table 2. AED calculated is somewhat less than the global mean, which is 1 *mSv/y* in the usual region according

Table 1 — Shahdol district annual effective dose and outdoor gamma absorbed dose rate

Locations	Absorbed dose(D) (*nGy/h*)	Annual effective dose(AED) (*mSv/y*)
Pandav Nagar	52.2	0.640
Purani Basti	60.9	0.747
Rohra Colony	78.3	0.960
Sardar Patel Nagar	87	1.067
Ward No. 22	69.6	0.854
Uraiha	78.3	0.960
Padri	60.9	0.747
Dudhi	43.5	0.533
Shivam Colony	52.2	0.640
Kudri	69.6	0.854
Kotma	60.9	0.747
Belaha	52.2	0.640
Housing Board	43.5	0.533
Chainpa	78.3	0.960
Kakarhal	87	1.067
Pongri	52.2	0.640
Hardi	60.9	0.747
Jamui	43.5	0.533
Katthi Mohalla	78.3	0.960
Dhudwar	60.9	0.747
Bartara	52.2	0.640
Kalyanpur	69.6	0.854
Saraikapa	87	1.067
Katkona	60.9	0.747
Udhiya	95.7	1.174
Aiditya Birla Coal Mines Bicharpur	78.3	0.960
Guru Kulam School Bicharpur	69.6	0.854
Majhauli	52.2	0.640
Khanhariya Khurd	78.3	0.960
Basin	60.9	0.747
Senduri	43.5	0.533
Samarth Vihar	60.9	0.747
Khairha Underground Coal Mines	69.6	0.854
Kadauha	78.3	0.960
Chirhati	60.9	0.747
Chuniya	87	1.067
Kholad	69.6	0.854
Panchgaon	52.2	0.640
Antara	78.3	0.960
Singhpur	43.5	0.533
Bodari	60.9	0.747
Arjhula	87	1.067
Jwari	69.6	0.854
Hartee	60.9	0.747
Mithauri	78.3	0.960
Kholi	52.2	0.640
Dhanpuri Open Cast Mine	43.5	0.533
Bandikhurd	69.6	0.854
Bemhauri	60.9	0.747
Baigin	52.2	0.640

to the report[24]. For this field, the study finding will seem to be a baseline to start.

Higher amount of outdoor terrestrial gamma absorbed dose rate could be due to soil composition and radioactive concentration. Coal and the associated rock formation include traces of naturally occurring radioactive elements, including uranium and thorium. Because a large amount of fine was produced during the quarrying, drilling, and crushing plant activities, and some quarries, crushing plant areas received these particles, burning coal in power plant release and redistribute these radioactive elements, potentially increasing the exposure to gamma radiation in nearby locations[25]. The radioactivity is elevated due to the tiny particles[26]. Change in environmental condition may be the cause of regional variation in outdoor gamma absorbed dose rate. As with shifting environmental conditions, precipitation, soil moisture, and snow cover all have an influence on the radon level progeny in air[27]. The data spread is moderate, as indicated by the standard deviation of 13.837 in Table 2. The distribution is somewhat skewed but generally balanced, as indicated by the geometric mean of 63.587, which is near the median of 60.9. The dataset is less likely to contain extreme outlier (negative kurtosis -0.857) and has a modest right-skewedness (positive Skewness 0.176). The distribution of dose rate (*nGy/h*) within a dataset is depicted by the box-and-whisker plot in Fig. 2. The interquartile range (IQR), shown by the yellow coloured box, covers in center 50% of the data and shows that the majority of results fall between around 55 and 75 *nGy/h*. The dataset center is indicated by the inside of the box; there is a black horizontal line, which represents the average value (60.9). A minor positive skew in the distribution is also shown by the orange square in the plot, which represents the mean dose rate (65.076), which is somewhat higher than the median. The primary range of the data is captured by the whisker, which excludes extreme values and extends about 1.5 times the IQR to the lowest and highest values. Notably, an outlier (probably at 95.7 *nGy/h*) that differs greatly from the rest of the data is represented by the red diamond at the top end of the plot. The central tendency, variability, and existence of an outlier in the dose rate observation are all concisely summarized by the plot.

Table 2 — Statistical parameter calculated from dose rate of studied area

Parameter	Value
Minimum	43.5
Maximum	95.7
Average	65.076
Standard deviation	13.837
Geometric Mean	63.587
Median	60.9
Skewness	0.176
Kurtosis	-0.857

With the sample count on the y-axis and the dose rate on the x-axis, the histogram in Fig. 3 shows the distribution of frequencies of dose rate (*nGy/h*) within the dataset. The fitted probability density function, which approximates the data distribution, is represented by the red curve layered on top of the red bar, which displays the number of samples within a particular dose rate range. The dose rate range of 60–70 *nGy/h* has the highest frequency, indicating that this is the most prevalent range in the dataset. Given that the tail on the right side of the curve (higher dose rate) is longer than the tail on the left, the distribution is roughly symmetric with a tiny positive skew. While the curve highlights the distribution smoothness and possible normalcy, the histogram sheds information on the data distribution general shape by emphasizing its central tendency and variability.

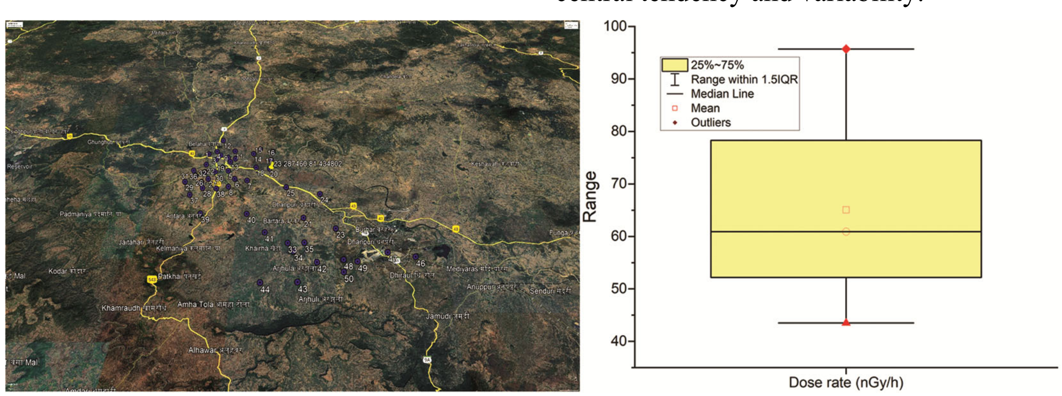

Fig. 2 — Box plot showing Shahdol natural outdoor gamma absorbed dose rate dispersion

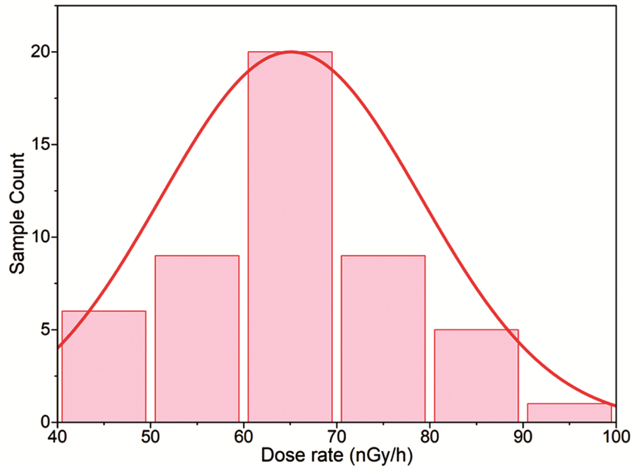

Fig. 3 — Distribution histogram of naturally occurring outdoor gamma absorbed dose in the air throughout Shahdol

Table 3 — World comparison table Outdoor absorbed dose rate

Country	Mean dose rate (*nGy/h*)	Reference
Kenya	440	[28]
USA	47	[25]
Egypt	22	[25]
Greece	56	[25]
China	62	[25]
Japan	53	[25]
Russia	65	[25]
Spain	76	[25]
World	59	[17]

Table 4 — India comparison table

Area, State	Mean dose rate (*nGy/h*)	Reference
Shimoga, Karnataka	177	[27]
Odisha	230	[29]
Karunagappally, Kerala	1800	[30]
Kolkata , West Bengal	107	[10]
Hisar, Haryana	86.3	[31]
Hyderabad , Telangana	193	[10]

Based on several research the average gamma absorbed dose rate for each country in nanogray per hour (*nGy/h*) shown in Table 3.With a mean dose rate of 440 *nGy/h*, Kenya has the highest rate in the world[28]. On the other hand, the United States, Egypt, Greece, China, Japan, Russia, and Spain have mean dose rate that range from 22 *nGy/h* (Egypt) to 76 *nGy/h* (Spain), (UNSCEAR) published figures in 1998 that support this. Spain has the highest value among these, while Egypt has the lowest. The[17] report states that the worldwide average dose rate is 59 *nGy/h*, indicating that, with the exception of Kenya, which has an abnormally high number, the majority of the listed nations fall within a similar range. Different geological formations, naturally occurring radionuclide concentration, and environmental factors affecting background radiation levels could all be responsible for these discrepancies in dose rates. The value of Spain is higher than that of the studied area, i.e., Shahdol, than the value of Kenya, according to the research data.

According to numerous research studies, the mean gamma absorbed dose rate (*nGy/h*) for different sites across Indian states is shown in Table 4. Karunagappally in Kerala has the greatest mean dose rate at 1800 *nGy/h*, so it is noticeably higher compared to the other places listed[30].Odisha has the second-highest dose rate at 230 *nGy/h*[29], followed by Hyderabad in Telangana and Shimoga in Karnataka, with respective values of 193 *nGy/h* and 177 *nGy/h*. The mean dose rate in Kolkata, West Bengal, is 107 *nGy/h*[10], whereas the lowest recorded value is 86.3 *nGy/h* in Hisar, Haryana, as reported by[31]. Geological formation, natural radionuclide concentration, and environmental factors that affect background radiation levels are the main cause of the significant diversity in dose rate among these sites. Notably, monazite-rich coastal sand, which has significant uranium and thorium content, is probably the cause of Kerala unusually high radiation level. Every area is more valuable than the one under study.

The current study can be used as a reference point to assess change.

5 Conclusion

In the Shahdol district of Madhya Pradesh, the current study assessed the outdoor terrestrial gamma absorbed dose rate in and near coal mines. The research area average outdoor terrestrial gamma absorbed dose rate was 65.076 *nGy/h*, which is greater than the global average. AED averages 0.798 *mSv/y*, with a range of 0.533 to 1.173 *mSv/y*, which is less than the global average value so the area is safe. Study data serve as a baseline against which potential future alterations can be assessed.

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