

Spatial Distribution of Ambient Gamma Dose Rates in the Antharasanahalli Industrial Estate, Tumkur, Karnataka, India: A Radiological Assessment

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Abstract

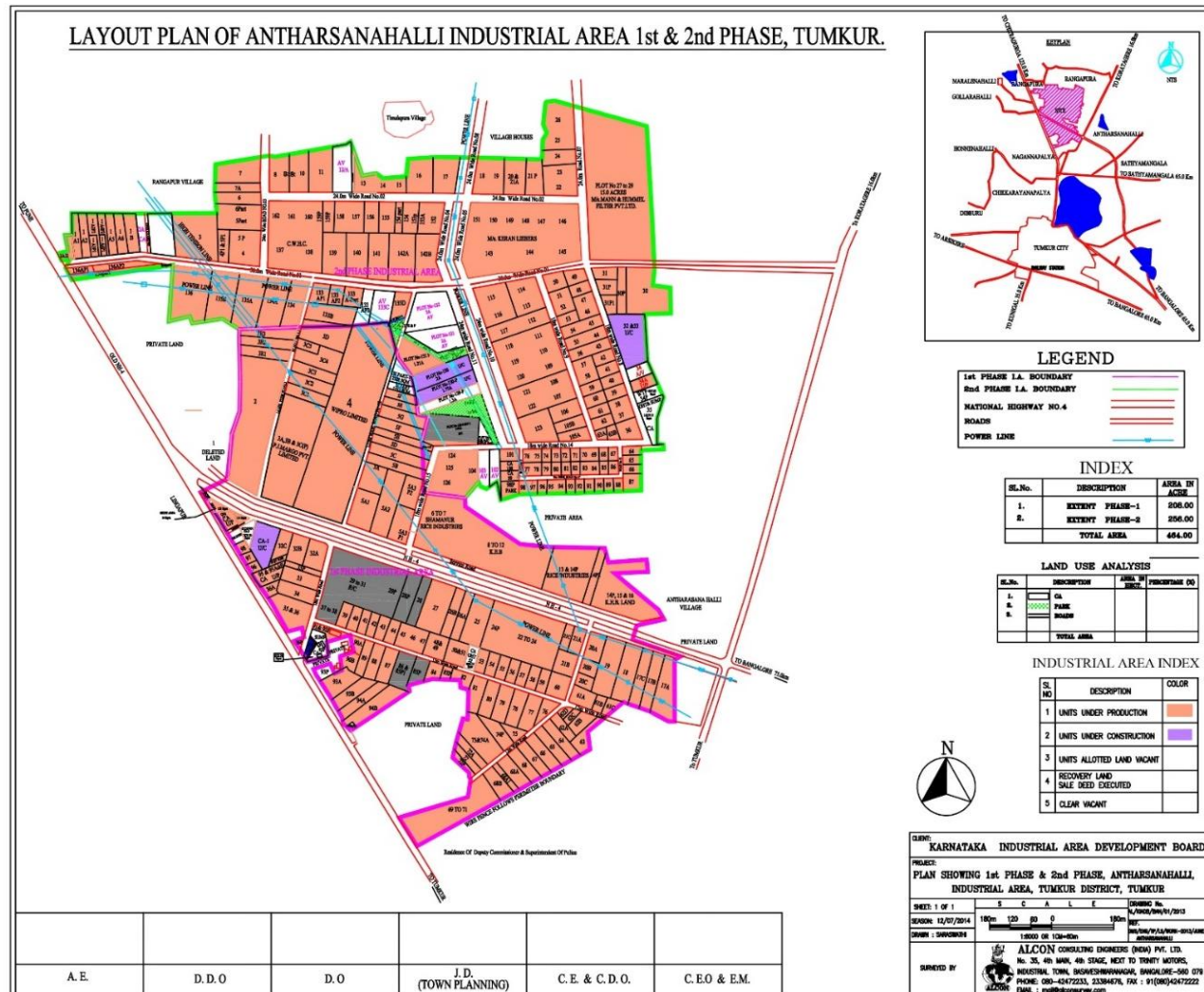
Natural background gamma radiation in industrial environments can be influenced by geological conditions, construction materials, and manufacturing activities. This study evaluated ambient gamma radiation levels in the Antharasanahalli Industrial Estate, located about 5 km from Tumkur city, Karnataka. Measurements were conducted at fifteen representative locations using a calibrated ER-709 portable radiation survey meter with a NaI(Tl) scintillation detector at a height of 1 m above ground. Exposure dose rates were converted into absorbed dose rates and annual effective doses using UNSCEAR-recommended conversion factors. Indoor exposure dose rates ranged from 14.0–18.2 $\mu\text{R h}^{-1}$ and outdoor values from 12.0–16.1 $\mu\text{R h}^{-1}$, corresponding to absorbed dose rates of 121.8–158.34 and 104.4–140.07 nGy h^{-1} , respectively. The estimated annual effective dose ranged from 0.73 to 0.95 mSv y^{-1} , well below the worldwide average natural background dose of 2.4 mSv y^{-1} . These findings provide baseline radiological data and indicate that ambient gamma radiation levels in the study area pose no significant health risk to workers or the public.

Keywords: Ambient gamma radiation; Environmental radioactivity; Industrial estate; Absorbed dose rate; Annual effective dose; Radiological assessment.

Introduction

Natural background radiation is continuously present in the environment and originates mainly from terrestrial radionuclides, cosmic radiation, and naturally occurring radioactive materials (NORM). The levels of environmental gamma radiation vary with geological formations, soil composition, altitude, and the use of construction materials. Although background radiation is a natural phenomenon, industrial development can influence local radiation levels through excavation, processing of mineral resources, and storage of raw materials, disposal of industrial wastes, and the use of building materials containing naturally occurring radionuclides. Monitoring ambient gamma radiation is an essential component of environmental radiation protection because it provides baseline information for assessing radiation exposure to workers and the general public. Periodic radiation surveys also help identify any changes in environmental radiation associated with expanding industrial activities. Consequently, ambient gamma dose rate measurements have become an important tool for evaluating environmental quality and supporting radiological safety programs. Antharasanahalli Industrial Estate, located near Tumkur city, Karnataka, is one of the major industrial estates developed by the Karnataka Industrial Areas Development Board (KIADB). The estate comprises engineering, machinery manufacturing, food-processing, chemical, specialty carbon, packaging, plastic, and other manufacturing industries. The diversity of industrial operations makes the area suitable for investigating possible variations in ambient gamma radiation levels. The

Study Area



Antharasanahalli Industrial Estate is situated approximately 5 km northwest of Tumkur city in Karnataka, India, along the Tumkur–Sira National Highway (NH-48). The industrial estate has been developed by the Karnataka Industrial Areas Development Board (KIADB) and covers an area of approximately 208 acres. It comprises nearly 120 industrial plots occupied by a wide range of small-, medium-, and large-scale industries. The estate accommodates diverse industrial sectors, including engineering and machinery manufacturing, metal fabrication, food and agro-processing, rice milling, edible oil processing, biofuel production, specialty carbon manufacturing, chemical industries, packaging units, plastic industries, wood-processing units, and other ancillary manufacturing facilities. These industries contribute significantly to the economic development of the Tumkur region while generating a variety of industrial raw materials and products. The geology of the study area is predominantly characterized by granitic and gneissic formations, which naturally contain radionuclides such as uranium, thorium, and potassium-40. In addition, industrial construction materials and processed raw materials may contribute to minor spatial variations in ambient gamma radiation levels. Therefore, systematic monitoring of ambient gamma radiation is essential to establish baseline radiological information and evaluate any possible environmental impact associated with industrial development. The present investigation was carried out at fifteen

representative locations distributed throughout the industrial estate to obtain a comprehensive assessment of ambient gamma radiation levels. The selected monitoring locations adequately represent the major industrial sectors and provide reliable baseline data for future environmental radiation surveillance and radiological risk assessment in the Antharasanahalli Industrial Estate.

Methodology

Ambient gamma radiation measurements were carried out at fifteen representative locations within the Antharasanahalli Industrial Estate using a calibrated ER-709 portable radiation survey meter equipped with a NaI(Tl) scintillation detector. Prior to field measurements, the instrument was calibrated according to the manufacturer's recommendations, and background radiation levels were verified to ensure measurement reliability. At each sampling location, the detector was positioned approximately **1 m above ground level** in an open area away from buildings, trees, and other large structures to minimize shielding effects. The instrument was allowed to stabilize before recording measurements. Three consecutive readings were obtained at each location, and the average value was used for subsequent analysis. The geographical coordinates of all sampling locations were recorded using a handheld GPS receiver. The measured exposure dose rates ($\mu\text{R h}^{-1}$) were converted into absorbed dose rates (nGy h^{-1}) using the standard exposure-to-dose conversion factor. Indoor and outdoor annual effective doses were estimated using the conversion coefficient of **0.7 Sv Gy^{-1}** and occupancy factors of **0.8** for indoor exposure and **0.2** for outdoor exposure, following the methodology adopted in the manuscript. The total annual effective dose was obtained by summing the indoor and outdoor effective doses.

The collected data were statistically analysed to determine the minimum, maximum, mean and standard deviation of the measured radiation levels. The calculated absorbed dose rates and annual effective doses were compared with internationally reported background radiation values to evaluate the radiological status of the study area.

Dose Calculation Equations:

Absorbed Dose Rate

$$D (\text{nGy h}^{-1}) = X (\mu\text{R h}^{-1}) \times 8.7$$

Where,

$D \rightarrow$ Absorbed dose rate (nGy h^{-1})

$X \rightarrow$ Exposure rate ($\mu\text{R h}^{-1}$)

Indoor Annual Effective Dose

$$E_{\text{in}} (\text{mSv y}^{-1}) = D_{\text{in}} \times 8760 \times 0.8 \times 0.7 \times 10^{-6}$$

Where,

$E_{\text{in}} \rightarrow$ Indoor annual effective dose (mSv y^{-1})

$D_{\text{in}} \rightarrow$ Indoor absorbed dose rate (nGy h^{-1})

8760 $\rightarrow$ Hours in one year

0.8 $\rightarrow$ Indoor occupancy factor

$0.7 \text{ Sv Gy}^{-1} \rightarrow$ Dose conversion coefficient

$10^{-6} \rightarrow$ Conversion factor from nGy to mSv

Outdoor Annual Effective Dose

$$E_{out} \text{ (mSv y}^{-1}\text{)} = D_{out} \times 8760 \times 0.2 \times 0.7 \times 10^{-6}$$

Where,

$E_{out} \rightarrow$ Outdoor annual effective dose (mSv y⁻¹)

$D_{out} \rightarrow$ Outdoor absorbed dose rate (nGy h⁻¹)

0.2 $\rightarrow$ Outdoor occupancy factor

Total Annual Effective Dose

$$E_{total} \text{ (mSv y}^{-1}\text{)} = E_{in} + E_{out}$$

Results and Discussion

Location	Exposure Dose		Absorbed Dose		Effective Dose		
	Indoor ($\mu\text{R h}^{-1}$) (D_{in})	Outdoor ($\mu\text{R h}^{-1}$) (D_{out})	Indoor (nGy h ⁻¹) (D_{in})	Outdoor (nGy h ⁻¹) (D_{out})	Indoor (mSv y ⁻¹) (E_{in})	Outdoor (mSv y ⁻¹) (E_{out})	Total (mSv y ⁻¹) (E_{Total})
L1	14.0	12.0	121.8	104.4	0.6	0.13	0.73
L2	14.2	12.2	123.54	106.14	0.61	0.13	0.74
L3	14.5	12.5	126.15	108.75	0.62	0.13	0.75
L4	14.9	12.8	129.63	111.36	0.64	0.14	0.78
L5	15.2	13.1	132.24	113.97	0.65	0.14	0.79
L6	15.5	13.4	134.85	116.58	0.66	0.14	0.8
L7	15.8	13.7	137.46	119.19	0.67	0.15	0.82
L8	16.1	14.0	140.07	121.8	0.69	0.15	0.84
L9	16.4	14.3	142.68	124.41	0.7	0.15	0.85
L10	16.7	14.6	145.29	127.02	0.71	0.16	0.87
L11	17.0	14.9	147.9	129.63	0.73	0.16	0.89
L12	17.3	15.2	150.51	132.24	0.74	0.16	0.9
L13	17.6	15.5	153.12	134.85	0.75	0.17	0.92
L14	17.9	15.8	155.73	137.46	0.77	0.17	0.94
L15	18.2	16.1	158.34	140.07	0.78	0.17	0.95

The measured ambient gamma radiation levels at the fifteen monitoring locations in the Antharasanahalli Industrial Estate are presented in **Table 1**. Indoor exposure dose rates ranged from **14.0 to 18.2 $\mu\text{R h}^{-1}$** , while outdoor exposure dose rates varied from **12.0 to 16.1 $\mu\text{R h}^{-1}$** . The corresponding absorbed dose rates ranged from **121.80 to 158.34 nGy h^{-1}** for indoor measurements and **104.40 to 140.07 nGy h^{-1}** for outdoor measurements. The calculated indoor annual effective dose varied from **0.60 to 0.78 mSv y^{-1}** , whereas the outdoor annual effective dose ranged between **0.13 and 0.17 mSv y^{-1}** . Consequently, the total annual effective dose was found to range from **0.73 to 0.95 mSv y^{-1}** .

The measured radiation levels exhibited moderate spatial variation among the sampling locations. The highest indoor exposure dose rate (**18.2 $\mu\text{R h}^{-1}$**) was observed at **Location L15**, whereas the lowest value (**14.0 $\mu\text{R h}^{-1}$**) was recorded at **Location L1**. Similarly, outdoor exposure dose rates increased from **12.0 $\mu\text{R h}^{-1}$** at **L1** to **16.1 $\mu\text{R h}^{-1}$** at **L15**. This variation indicates that ambient gamma radiation is not uniformly distributed throughout the industrial estate. Such spatial differences may be associated with variations in local geological conditions, soil characteristics, and the types of construction materials present at different locations. The calculated absorbed dose rates followed the same trend as the measured exposure dose rates because they were obtained using the standard exposure-to-dose conversion factor. Indoor absorbed dose rates were consistently higher than outdoor values, reflecting the higher indoor exposure measurements recorded during the survey. Likewise, the indoor annual effective doses were greater than the outdoor annual effective doses because of the higher indoor occupancy factor (0.8) used in the dose calculations. The estimated total annual effective dose ranged from **0.73 to 0.95 mSv y^{-1}** , indicating only moderate variation across the study area. These values provide baseline information on the external gamma radiation environment of the Antharasanahalli Industrial Estate. The results suggest that ambient gamma radiation levels are relatively uniform throughout the study area, with no individual monitoring location exhibiting exceptionally high external gamma radiation compared with the other surveyed sites. The data generated in the present investigation establish a useful baseline for future environmental radiation monitoring within the industrial estate. Periodic monitoring of ambient gamma radiation is recommended to identify any long-term changes associated with industrial expansion, changes in land use, or modifications in industrial processes. Such baseline information will support future radiological assessments and environmental management programs in the region.

Conclusion

The present study evaluated ambient gamma radiation levels at fifteen representative locations in the Antharasanahalli Industrial Estate, Tumkur, Karnataka, using a calibrated ER-709 portable radiation survey meter. The measured exposure dose rates were converted into absorbed dose rates and annual effective doses using the methodology described in this study. Indoor exposure dose rates ranged from 14.0 to 18.2 $\mu\text{R h}^{-1}$, while outdoor values ranged from 12.0 to 16.1 $\mu\text{R h}^{-1}$. The corresponding annual effective dose varied from 0.73 to 0.95 mSv y^{-1} , providing baseline data on the external gamma radiation environment. Spatial variations in radiation levels were attributed to local environmental conditions and the distribution of industrial facilities. No monitoring location exhibited unusually elevated ambient gamma radiation levels. These findings establish the current radiological status of the industrial estate and provide a reference dataset for future environmental radiation monitoring. Periodic monitoring is recommended to assess long-term radiological trends and support environmental radiation protection and sustainable industrial development.

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