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**Muhammet Karataşlı**
Kahramanmaraş İstiklal University
muhammet.karatasli@istiklal.edu.tr
Kahramanmaraş-Türkiye

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| **ORCID ID** | 0000-0002-5893-6800 |
| **Corresponding Author** | Muhammet Karataşlı |

# ASSESSMENT OF ABSORBED GAMMA DOSE RATE AND RADIOLOGICAL HEALTH RISK IN OSMANIYE PROVINCE, TÜRKİYE

## ABSTRACT

Natural background radiation is the dominant source of continuous ionizing radiation exposure for the general population, largely driven by terrestrial gamma radiation. This study evaluates outdoor gamma radiation at the provincial scale in Osmaniye Province, southern Türkiye. Field measurements were performed at 56 sites using a calibrated portable scintillation detector positioned 1 m above ground level. At each site, three consecutive 60 s measurements were recorded and averaged. Absorbed dose rate in air (ADRA), annual effective dose equivalent (AEDE), and lifetime cancer risk (LCR) were calculated following internationally accepted frameworks, including ICRP 60, ICRP 103, and the BEIR VII model. ADRA values ranged from 19.8 to 136.3 nGy $h^{-1}$, with a provincial mean of 40.9 nGy $h^{-1}$. The corresponding mean AEDE was 50.1 µSv $y^{-1}$. All estimated dose and risk values were below UNSCEAR reference levels, indicating no measurable radiological health risk for the local population.

**Keywords:** Environmental Gamma Radiation, Absorbed Dose Rate, Radiological Risk Assessment, Lifetime Cancer Risk, Spatial Distribution

## 1. INTRODUCTION

Human exposure to ionizing radiation is unavoidable, as natural sources contribute the majority of the total annual radiation dose. Approximately 85% of the average global dose originates from natural background radiation, while anthropogenic sources account for the remaining fraction [1]. Natural background radiation is commonly divided into cosmic and terrestrial components. Cosmic radiation varies with altitude, solar activity, and geomagnetic conditions. Terrestrial radiation arises from gamma emissions of primordial radionuclides, primarily $^{238}U$, $^{232}Th$, and $^{40}K$, present in the Earth's crust [2]. Long-lived radionuclides such as $^{238}U$, $^{232}Th$, $^{226}Ra$, and $^{40}K$ are ubiquitously present in natural matrices and built environments. Terrestrial radiation arises predominantly from the decay of these primordial nuclides within the Earth's crust. By contrast, cosmic radiation originates beyond the atmosphere and is attenuated by geomagnetic and atmospheric shielding [3]. The level of natural radioactivity varies significantly from one location to another. This variability is largely controlled by geographical setting and geological structure [4]. Differences in soil composition and rock mineralogy influence the spatial distribution of radionuclides. As a result, gamma dose intensity at 1 m above ground level varies spatially and determines the absorbed dose rate in air [5]. Ionizing radiation, whether of natural or artificial origin, has sufficient energy to induce molecular damage in living

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tissues. Although low-dose exposure can often be mitigated by cellular repair mechanisms, prolonged or high-level exposure may result in DNA damage, genetic mutations, carcinogenesis, cataract formation, and other chronic health effects [6–10]. According to UNSCEAR, understanding the biological consequences of radiation exposure forms the scientific basis for effective public health risk assessment [11]. Numerous studies conducted in Türkiye have examined outdoor gamma dose rates and the contribution of naturally occurring radionuclides across different provinces. These investigations have reported pronounced spatial variability associated with geological formations, soil characteristics, and local environmental conditions [12–28]. However, several provinces remain insufficiently studied. Osmaniye Province, in particular, lacks comprehensive data on environmental gamma radiation and related radiological health risks. Accordingly, a province-scale investigation of outdoor gamma radiation was conducted in Osmaniye Province. In situ gamma exposure dose rate (GEDR) measurements were conducted, and absorbed dose rates in air (ADRA), annual effective dose equivalents (AEDE), and lifetime cancer risk (LCR) were evaluated. The analysis was performed using internationally recognized radiological protection models, including ICRP 60, ICRP 103, and BEIR VII. The resulting dataset provides region-specific baseline information that is essential for accurate radiation risk assessment and informed public health protection.

## 2. RESEARCH SIGNIFICANCE

This study provides the first comprehensive, province-scale evaluation of outdoor gamma radiation and associated radiological health risks in Osmaniye Province, Türkiye. By generating systematically acquired and statistically reliable field data, it addresses a critical regional deficiency in environmental radiation research. The findings establish a robust baseline for the assessment of natural background radiation at both regional and national levels. A key scientific contribution of this work is the integrated application of in situ gamma dose measurements with internationally recognized radiological risk assessment models. Absorbed dose rate in air, annual effective dose equivalent, and lifetime cancer risk were quantified using the ICRP 60, ICRP 103, and BEIR VII frameworks. The combined use of these models improves the robustness, consistency, and comparability of the estimated radiological risks. The results further elucidate the role of local geological conditions in controlling spatial variations in gamma dose rates. The predominance of sedimentary formations is consistent with the relatively low radiation levels observed throughout the province. Overall, this study strengthens environmental radiation monitoring efforts, supports public health risk assessment, and presents a transferable methodological framework that can be applied to other under-investigated regions.

**Highlights**

- Provides the first province-scale assessment of outdoor gamma radiation in Osmaniye Province, Türkiye.
- Supplies systematically acquired in situ gamma dose measurements addressing a critical regional data gap.
- Integrates internationally accepted radiological risk models (ICRP 60, ICRP 103, and BEIR VII) within a unified assessment framework.
- Establishes a reliable baseline for evaluating natural background radiation at regional and national scales.
- Reveals the influence of local geological characteristics on spatial variations in gamma dose rates.
- Proposes a transferable methodological approach applicable to other under-studied regions.

**3. MATERIALS AND METHODS**

Osmaniye Province is located in the southeastern Mediterranean region of Türkiye, within the Çukorava Basin, between 35° 52' and 36° 42' East longitude and 36° 57' and 37° 45' North latitude. As shown in Figure 1, Osmaniye is bordered by Adana to the west, Gaziantep to the east, Hatay to the South, and Kahramanmaraş to the North.

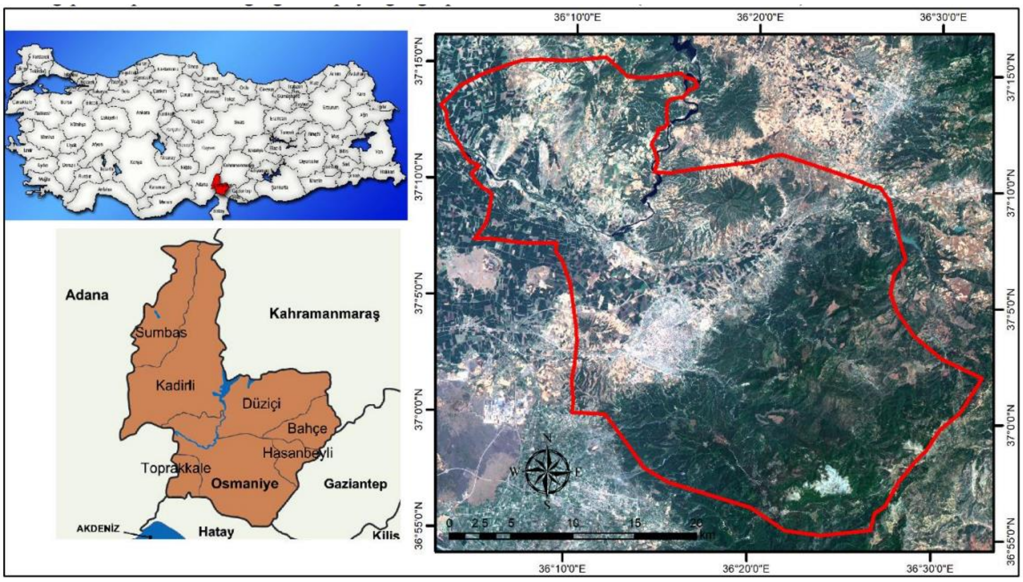


Figure 1. Research region of Osmaniye [29]

This figure illustrates Osmaniye Province and its surrounding boundaries, highlighting the locations where gamma radiation measurements were conducted. It provides a spatial overview of environmental factors that may affect radiation levels. The province is bordered by the Central Taurus Mountains to the northwest and the Amanos Mountains to the southeast and east, with an average elevation of approximately 120 m above sea level. Osmaniye covers an area of 3125 $km^2$, and its topography gradually rises from the southern lowlands toward the northern and eastern regions [30]. Table 1 summarizes the number of measurement stations, as well as the altitude and catchment area of each district.

Table 1. Distribution of measurement stations in the research region of Osmaniye Province
(Latitude, °N; Longitude, °E; Catchment area, $km^2$; Altitude, m)

| District | Latitude (N) | Longitude (E) | Population | Catchment area ($km^2$) | Altitude (m) | Number of Stations |
|---|---|---|---|---|---|---|
| Bahçe | 37.1966 | 36.5726 | 22155 | 208 | 665 | 6 |
| Hasanbeyli | 37.1317 | 36.5530 | 4782 | 168 | 800 | 4 |
| Düziçi | 37.2402 | 36.4533 | 84133 | 595 | 440 | 7 |
| Toprakkale | 37.0624 | 36.1452 | 20119 | 112 | 67 | 5 |
| Kadirli | 37.3740 | 36.0974 | 125083 | 1021 | 68 | 6 |
| Sumbas | 37.4473 | 36.0276 | 13840 | 358 | 105 | 4 |
| Center | 37.0748 | 36.0266 | 268647 | 859 | 121 | 24 |

Table 1 Number of gamma radiation measurement sites, geographic coordinates, and altitude values for districts in Osmaniye Province, along with relevant demographic parameters. The number of stations denotes the total measurement sites established within each district, while geographic coordinates and altitude values were obtained using global positioning system (GPS) measurements.

Table 2. Minimum, maximum, and mean values of gamma exposure dose rate (μR $h^{-1}$) and absorbed dose rate in air (nGy $h^{-1}$) for each district of Osmaniye Province

| | GEDR (μR/h) | | | ADRA (nGy/h) | | |
|---|---|---|---|---|---|---|
| District | Minimum | Maximum | Mean | Minimum | Maximum | Mean |
| Bahçe | 3.77 | 6.72 | 5.06 | 32.8 | 58.5 | 44.0 |
| Hasanbeyli | 3.40 | 4.76 | 3.87 | 29.6 | 41.4 | 33.7 |
| Düziçi | 2.70 | 15.70 | 6.40 | 23.5 | 136.3 | 55.7 |
| Toprakkale | 3.36 | 7.74 | 5.22 | 29.2 | 67.3 | 45.4 |
| Kadirli | 2.28 | 6.39 | 4.03 | 19.8 | 55.6 | 35.1 |
| Sumbas | 3.36 | 4.31 | 4.00 | 29.2 | 37.5 | 34.8 |
| Center | 2.61 | 6.52 | 4.29 | 22.7 | 56.7 | 37.3 |
| Region | 2.28 | 15.70 | 4.70 | 19.8 | 136.3 | 40.9 |

Table 2 Statistical summary of gamma exposure dose rate (GEDR) and absorbed dose rate in air (ADRA) for each district of Osmaniye Province, highlighting local variability associated with underlying geological and environmental conditions. Minimum and maximum values correspond to the lowest and highest readings recorded at the measurement stations within each district, while mean values were calculated as the arithmetic averages of three consecutive 60-second measurements taken at 1 m above ground level at each station. The "Region" mean represents the arithmetic average of all station means across the province. The locations of the measurement stations were determined by GPS, and spatial distribution maps were generated using the IDW interpolation technique implemented in ArcGIS (version 10.2). Gamma dose rate measurements in Osmaniye Province were conducted using a portable Eberline ESP-2 ratemeter coupled to an SPA-6 plastic scintillator via an MHV-series cylindrical connector. At each sampling location, the detector was positioned 1 meter above ground level to ensure standardized and consistent data acquisition. Measurements were recorded over 60-second intervals, and average dose rates were expressed in μR/h. The ESP-2 system, powered by an Intel 80C31 microcontroller and equipped with a 2×16 alphanumeric LCD display, converts radiation-induced pulses into count rates proportional to ambient gamma radiation intensity. Signal processing is achieved through a multistage linear amplifier and an adjustable-threshold discriminator to effectively reduce electronic noise and eliminate irrelevant signals. The system is powered by high-voltage bias for the detector and low-voltage electronics for signal processing components, ensuring stable operation under field conditions [31]. To maintain measurement accuracy, the calibration of the Eberline Smart Portable Gamma Dose Meter is performed biennially at the Secondary Standard Dosimetry Laboratory, which is accredited by the Turkish Accreditation Agency. This process ensures traceability and compliance with both national and international standards. The associated measurement uncertainty is estimated to range between ±5% and ±10%, depending on environmental conditions and instrument response characteristics. The device is shown in Figure 2.


Figure 2. Portable scintillation detector system used for outdoor gamma dose rate measurements

After averaging three independent measurements, dose rates were expressed in μR $h^{-1}$. These values were converted to nGy $h^{-1}$ using a conversion factor of 8.7 nGy $\mu R^{-1}$. The annual effective dose equivalent (AEDE) was subsequently calculated using the following equation [11].

$$AEDE = ADRA * DCF * OF * T \quad (1)$$

Here, ADRA represents the absorbed dose rate in air (nGy/h), DCF is the dose conversion factor (Sv/Gy), which is set to 0.7 for adults, OF denotes the occupancy factor, assigned a value of 0.2, and T represents the exposure time, taken as 8760 hours per year. Additionally, to determine the excess lifetime cancer risk (ELCR) for the population in the region, the following equation was applied [32].

$$LCR = AEDE * DL * RF \quad (2)$$

Here, DL denotes the average lifespan, assumed to be 70 years. RF represents the fatal cancer risk coefficient ($Sv^{-1}$), and the RF values recommended by ICRP 103 and BEIR VII were applied in this study [33], and ICRP 60 [34] have been utilized. These values for the general public are 0.057, 0.064, and 0.072, respectively. All calculations were performed under the assumption of dry soil conditions. ArcGIS-ArcMap 10.2 software was used to visualize the data through diagrams. Since the outdoor gamma dose rate measurements were conducted during the summer season, the study specifically reflects the dry soil conditions of the region

## 4. RESULTS AND DISCUSSION

In this study, absorbed dose rates in air (ADRA) were determined and radiological health risks were assessed. Gamma dose rate measurements were conducted at 56 locations across Osmaniye Province and its surroundings. At each site, three consecutive measurements were recorded for 60 s at a height of 1 m above ground level, and their arithmetic mean was used to represent the site-specific dose rate. The measured data reflect the combined contributions of terrestrial and cosmic radionuclides to outdoor gamma radiation. Gamma exposure dose rate (GEDR) values were converted to absorbed dose rates in air using a conversion factor of 8.7. The resulting GEDR and ADRA values are summarized in Table 2. Absorbed dose rates in Osmaniye ranged from 19.8 to 136.3 nGy $h^{-1}$, with a provincial mean of 40.9 nGy $h^{-1}$. An isodose map of absorbed gamma dose rates was produced for all districts of Osmaniye Province. The spatial distribution of ADRA is illustrated in Figure 3, where darker areas indicate higher levels of gamma dose absorption.

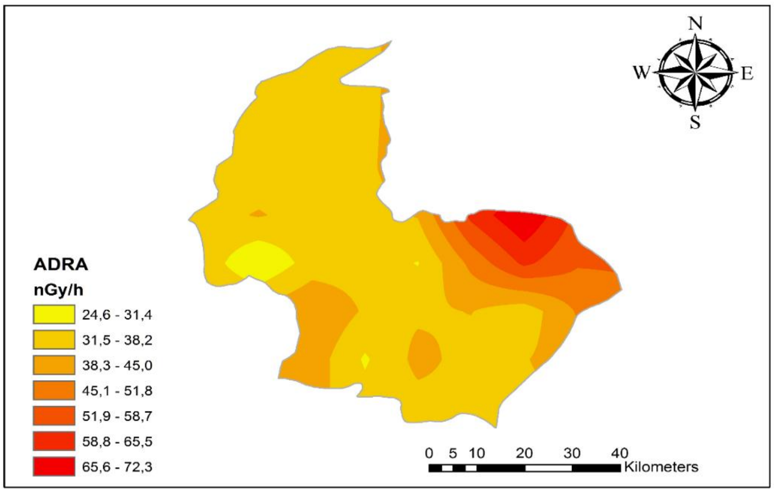


Figure 3. ADRA in Osmaniye

Figure 3 illustrates the spatial variation of absorbed dose rate in air (ADRA) across Osmaniye Province. The isodose map reveals regional patterns in gamma radiation intensity, where darker areas correspond to higher dose levels. Spatial interpolation was performed using the Inverse Distance Weighted (IDW) method. In the second phase of the study, average annual effective dose equivalent (AEDE) values were calculated using the mean absorbed gamma dose rates measured in each district. Lifetime cancer risk (LCR) was also estimated for the population based on three different radiological risk models. Absorbed dose rates were converted to annual effective doses and expressed in μSv $y^{-1}$. The calculated AEDE and LCR values are presented in Table 3. The mean AEDE for Osmaniye Province was 50.1 μSv $y^{-1}$, which is substantially lower than the public exposure limit of 1 mSv $y^{-1}$ recommended by ICRP Publication 60 [35].

Table 3. Average annual effective dose (μSv $y^{-1}$) and lifetime cancer risk (dimensionless) values for each district of Osmaniye Province

| | | Lifetime cancer risk (probability) | | |
|---|---|---|---|---|
| District | AEDE (μSv/y) | ICRP 103 | BEIR VII | ICRP 60 |
| Bahçe | 54.0 | 0.022 | 0.024 | 0.027 |
| Hasanbeyli | 41.3 | 0.016 | 0.019 | 0.021 |
| Düziçi | 68.3 | 0.027 | 0.031 | 0.034 |
| Toprakkale | 55.7 | 0.022 | 0.025 | 0.028 |
| Kadirli | 43.0 | 0.017 | 0.019 | 0.022 |
| Sumbas | 42.7 | 0.017 | 0.019 | 0.022 |
| Osmaniye/Merkez | 45.7 | 0.018 | 0.020 | 0.023 |
| Region | 50.1 | 0.020 | 0.022 | 0.025 |

Table 3 presents the annual effective dose equivalent (AEDE) values and the corresponding lifetime cancer risk (LCR) estimates for each district in Osmaniye Province. AEDE values were calculated from the mean absorbed dose rate in each district using Equation (1), while LCR values were computed using Equation (2) and estimated according to the ICRP 103, BEIR VII, and ICRP 60 models. The "Region" values represent the arithmetic averages of all district means. The average lifetime cancer risk percentages derived from the ICRP 60, ICRP 103, and BEIR VII models [32,34,36] were 0.025, 0.020, and 0.022 for Osmaniye, respectively. Finally, the ADRA and AEDE results from various provinces and districts in Türkiye, together with global data, were compiled and compared in Table 4. As shown in Table 4, the mean absorbed gamma dose rate obtained in this study is lower than the global average of 60 nGy/h [11].

When compared with other regions of Türkiye (Table 4), Osmaniye's ADRA (40.5 nGy $h^{-1}$) and AEDE (50.1 μSv $y^{-1}$) are among the lowest values recorded nationwide, comparable to Tekirdağ (43.9 nGy $h^{-1}$; 53.8 μSv $y^{-1}$) [16] and Yalova (48.1 nGy $h^{-1}$; 59 μSv $y^{-1}$) [22]. The regional variations in outdoor gamma radiation across Türkiye are primarily influenced by geological composition, altitude, and soil mineralogy. Provinces such as Balıkesir [20], Adıyaman [28], and Nevşehir [26] exhibit elevated gamma dose rates due to the presence of igneous or volcanic formations rich in uranium and thorium-bearing minerals. In contrast, Osmaniye is dominated by sedimentary rock units, particularly limestone, marl, and alluvial deposits, which typically contain lower concentrations of natural radionuclides. The relatively low gamma dose rates in these areas are consistent with observations from Tekirdağ [16] and Çorum [25], where similar lithological structures were found to reduce terrestrial gamma emissions.

Table 4. Comparison of absorbed dose rate in air (nGy $h^{-1}$) and annual effective dose equivalent (µSv $y^{-1}$) between this study, various cities in Türkiye, and the global average

| | ADRA (nGy/h) | AEDE (µSv/y) |
|---|---|---|
| İstanbul [12] | 65 | 79.7 |
| Kastamonu [13] | 54.81 | 67.21 |
| Şanlıurfa [14] | 60.9 | 74.7 |
| Kırklareli [15] | 118 | 144.7 |
| Tekirdağ [16] | 43.85 | 53.77 |
| Yalova [17] | 84 | 103 |
| Trabzon [18] | 59 | 72.4 |
| Çankırı [19] | 69.6 | 87.7 |
| Balıkesir [20] | 127 | 155.8 |
| Adana [21] | 71.2 | 87.3 |
| Yalova [22] | 48.1 | 59 |
| Konya [23] | - | 132.9 |
| Bolu [24] | 22.2 | 27.23 |
| Çorum [25] | 44.96 | 55.14 |
| Nevşehir [26] | 178.69 | 219.07 |
| Tavşanlı, Kütahya [27] | 86.96 | 106.64 |
| Adıyaman [28] | 144.3 | 177 |
| Osmaniye [Present Study] | 40.5 | 50.1 |
| World average [11] | 60 | 70 |

From a radiological protection standpoint, the mean AEDE value in Osmaniye is well below the public exposure limit of 1 mSv $y^{-1}$ recommended by the ICRP 60 [35], confirming that the population is exposed to radiation levels significantly lower than the international safety threshold. The calculated lifetime cancer risk (LCR) values, estimated using the ICRP 103, BEIR VII, and ICRP 60 models, were 0.025, 0.022, and 0.020 for Osmaniye, respectively. These are in good agreement with the LCR values reported in Bolu [24] and Çorum [25], further confirming that the province poses minimal radiological health risk. Comparative evaluation of Turkish and global data demonstrates that Osmaniye has lower environmental gamma dose rates than the world average, consistent with results obtained in other low-radiation regions of Türkiye [16 and 22]. The differences among provinces underscore the impact of local geological heterogeneity, topography, and soil structure on gamma radiation distribution [4 and 5]. Overall, the results indicate that the environmental radiation levels in Osmaniye are stable and safe for public exposure, while also providing valuable baseline data for future radiological mapping, environmental monitoring, and health risk.

## 5. CONCLUSION

This study provides a province-scale, quantitatively validated assessment of outdoor gamma radiation and associated radiological health risks in Osmaniye Province, Türkiye. The results address a significant gap in regional radiation data at the national level. Absorbed dose rate in air, annual effective dose equivalent, and lifetime cancer risk values were consistently below internationally accepted guideline limits. These findings confirm that current environmental gamma radiation levels in the province do not pose a radiological concern for the general population. Risk estimates derived from the ICRP 60, ICRP 103, and BEIR VII models showed strong agreement. This consistency demonstrates the robustness of the applied health risk assessment and indicates a stable dose–risk relationship under natural background radiation conditions. Spatial variations in gamma dose rates were primarily controlled by geological factors. Sedimentary formations, including limestone, marl, and alluvial deposits, contribute to the relatively low radionuclide content observed across the region. Although minor local variability was detected, no statistically significant high-risk areas were identified. Beyond its scientific contribution, the baseline dataset established in this study has practical implications for environmental management and public health protection. It provides a reference for long-term environmental monitoring, supports evidence-based land-use planning, and enhances early-warning capacity for potential radiological anomalies of natural or anthropogenic origin. Overall, the findings confirm the radiological safety of Osmaniye Province under current conditions and contribute to the systematic mapping of natural background radiation in Türkiye. The methodological framework presented here can be applied to other understudied regions, facilitating standardized national radiation monitoring and supporting science-based policy development.

**AUTHORS' CONTRIBUTIONS**

Muhammet Karataşli: Performed the measurements, analyzed the data, and drafted the manuscript.

**CONFLICT OF INTEREST**

There is no conflict of interest in this research.

**FINANCIAL DISCLOSURE**

The authors received no financial support for the research.

**DECLARATION OF ETHICAL STANDARDS**

The authors of this article state that the materials and methods used in this study do not require approval from an ethics committee or any legal or special permissions.

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