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Evaluation of Environmental Gamma Radiation Dose around Bitlis Stream, Bitlis

Bitlis Çayı Çevresindeki Çevresel Gama Radyasyon Dozunun Değerlendirilmesi

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Abstract

This investigation involved measuring gamma radiation rates at 20 distinct locations along Bitlis Stream utilizing a portable scintillation detector equipped with NaI(Tl) crystals. Alongside gamma dose rates (GDR), the annual effective dose equivalent (AED) and Excess lifetime cancer risk (ELCR) values were also calculated. The results are presented using well-structured graphs and tables for clarity and easy comparison. The mean values estimated at 1 meter above ground level for GDR, AED and ELCR were obtained as 0.112 µSv/h, 0.196 mSv/y and 0.784, respectively. These results show that GDR, AED, and ELCR measured in the study area exceed the global average limit values recommended by international health organizations. Furthermore, the findings were compared with several investigations undertaken in diverse parts of Türkiye in terms of radiological significance.

Keywords: Environmental gamma, Dose rate, Bitlis Stream.

Öz

Bu araştırma, NaI(Tl) kristalleri ile donatılmış taşınabilir bir sintilasyon dedektörü kullanılarak Bitlis Çayı boyunca 20 farklı noktada gama radyasyon hızlarının ölçülmesini içeriyordu. Gama doz hızlarına (GDR) ek olarak, yıllık etkin doz eşdeğeri (AED) ve yaşam boyu kanser riski (ELCR) değerleri de hesaplandı. Sonuçlar, netlik ve kolay karşılaştırma için iyi yapılandırılmış grafikler ve tablolar kullanılarak sunulmuştur. GDR, AED ve ELCR için yer seviyesinden 1 metre yükseklikte tahmin edilen ortalama değerler sırasıyla 0.112 µSv/h, 0.196 mSv/y and 0.784 x 10^{-3} olarak elde edilmiştir. Bu sonuçlar, çalışma alanında ölçülen GDR, AED ve ELCR değerlerinin uluslararası sağlık kuruluşları tarafından önerilen küresel ortalama sınır değerlerini aştığını göstermektedir. Ayrıca, bulgular Türkiye'nin farklı bölgelerinde yapılan çeşitli araştırmalarla karşılaştırılmıştır.

Anahtar Kelimeler: Çevresel gama, Doz hızı, Bitlis Çayı.

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1. Introduction

Cosmic rays in the atmosphere and gamma radiation emitted by natural radioactive elements found on Earth are constantly present in the environment, including soil, water, air, and biological systems. It is an inevitable fact that all living things, including humans, are exposed to this radiation (UNSCEAR 2000; ATSRD 1999; Karatepe and Kuluöztürk 2019). Gamma radiation, a form of ionizing radiation, possesses enough energy to dislodge one or more orbital electrons from atoms within the human body. This can lead to alterations that may significantly impact the normal functioning of body cells. (Hazrati et al. 2012).

The radio-isotopes found in the Earth's crust significantly contribute to the overall radiation exposure humans experience throughout their lifetime. Among these, potassium-40, thorium-232, and uranium-238 are some of the most important isotopes (Bal et al. 2018; Bahreini et al. 2020). Research carried out in many countries has shown that the level of gamma radiation is different from one region to another, depending on the specific geographical and geological characteristics of each region (Tran et al. 2020; Lee et al. 2017; Iyogi et al. 2002, Kam et al. 2016; Sumi et al. 2021). Due to radioactive ores, outdoor radiation levels exceed the global average in some regions, such as Iran, India, China, Brazil, USA and Germany, and these areas are defined as high natural background radiation zones. Such zones have been found in Iran, India, China, Brazil, USA and Germany (Sumi et al. 2021; UNSCEAR 2008).

Long-term exposure to gamma radiation is associated with significant increases in the chances of cancer and other serious human health risks. Hence, monitoring the levels of natural radionuclides as well as cosmic radiation becomes an urgent necessity concerning their possible contribution to health risks due to gamma radiation in the environment (Bal and Karatepe 2015, Tanwer et al. 2024).

This investigation, environmental gamma dose rate measurements around Bitlis Stream were carried out to evaluate the potential effects of natural radiation levels on human health in the region. Determining the radiation levels that may originate from the surrounding air, water, soil, and rock structure is important in terms of revealing the radiation risks that the local people may be exposed to. For this purpose, gamma dose rate measurements were made at selected measurement points and annual effective dose rate (AED) and Excess lifetime cancer risk (ELCR) values were calculated in line with the obtained data. In addition, comparisons were made with the limited values recommended by international organizations and other studies.

2. Materials and Methods

2.1. Study area

The Bitlis Stream, the study area, rises from Tahtali Hill in Bitlis province, passes through the city centre, and joins the Tigris River within the borders of Siirt province. The points where measurements were taken are shown in Figure 1. It is indispensable importance for the region in terms of both agriculture and settlement.

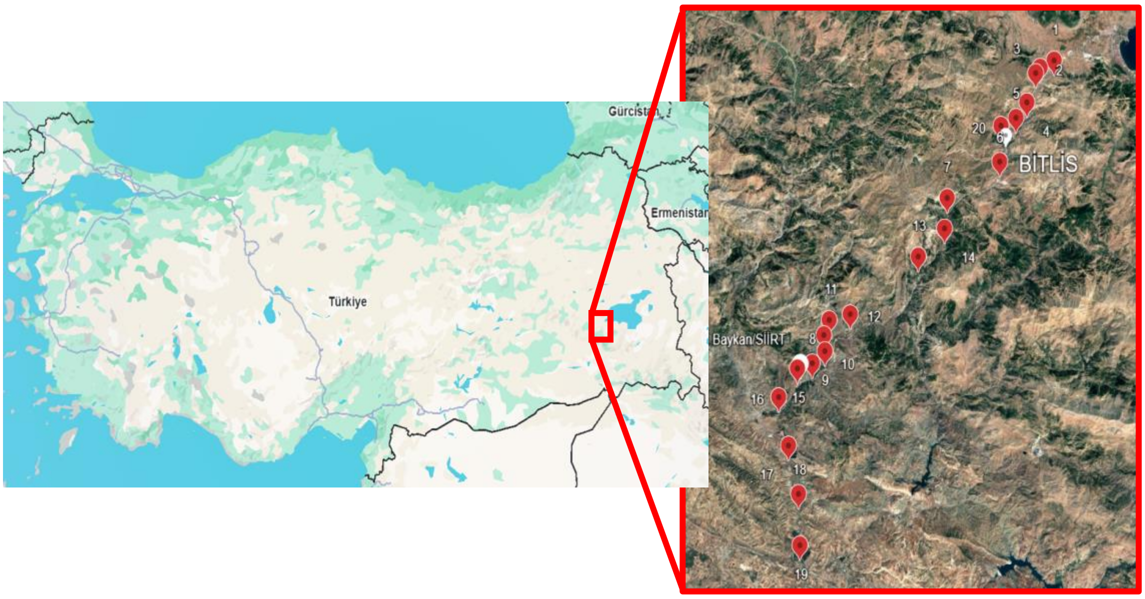

Figure 1. Map of the study area (from GoogleEarth).

2.2. Gamma Dose Measurement and Instrumentation

Measurements were conducted at 20 distinct locations along the Bitlis Stream in the Bitlis Province using a portable LUDLUM Model 2241 Digital Scaler/Rate Meter coupled with a LUDLUM Model 44-10 Probe, which is equipped with a 2″×2″ NaI(Tl) scintillation crystal (LUDLUM 2012). Measurements were conducted at each location both on the ground and at a height of 1 meter for one minute. The device measures gamma radiation in µSv/h. The average of the recorded values was calculated to determine the gamma dose rate (D) absorbed outdoors. The results are presented in Table 1.

2.3. Health Risk Assessment

The annual effective dose equivalent (AED) refers to the amount of radiation a person receives over a year when exposed to gamma radiation. This value has been calculated using the following general formula based on the outdoor absorbed gamma dose rate results (UNSCEAR 2000).

$$AED(\mu Svy^{-1}) = D(\mu Svh^{-1}) \times 0.2 \times 8760 \quad (1)$$

Here, D represents the gamma dose rate absorbed in the outdoor environment. Assuming that people spend 20% of the time they are exposed to radiation outdoors over a year (8760 hours/year), the outdoor activity factor has been taken as 0.2 (UNSCEAR 2000).

The cancer risk that living organisms may develop due to exposure to radiation sources is the lifetime cancer risk (ELCR), which has been calculated using Equation (2) (Tanwer et. al 2024).

$$ELCR = AED \times DL \times RF \quad (2)$$

Here, AED represents the annual effective dose equivalent, DL represents the average lifespan (average 70 years), and RF represents the risk factor. The International Commission on Radiological Protection (ICRP) recommends an RF value of 0.057 for humans (ICRP 2007).

3. Findings and Discussion

Environmental gamma dose rates were determined at 20 locations around the region of Bitlis Stream. Measurements were conducted at ground level and at a height of 1 meter to assess differences in dosage rates based on distance from the ground. The gamma dose rates and corresponding dose calculations are presented in Table 1. Additionally, the frequency distribution of the gamma dose rates is illustrated in Figure 2, highlighting the variability of dose rates across the sampled sites.

Table 1. D_R, AED and ELCR values at around the Bitlis Stream.

Sample Number	**Coordinates**		**Ground D_R (μSv/h)**	**Above 1m D_R(μSv/h)**	**AED (mSv/y)**	**ELCR x 10^{-3}**
	Latitude	**Longitude**				
1	38.475428	42.184277	0.198	0.189	0.331	1.321
2	38.468210	42.162366	0.228	0.201	0.352	1.405
3	38.462639	42.155513	0.219	0.180	0.315	1.257
4	38.432544	42.141256	0.185	0.171	0.300	1.197
5	38.416557	42.123981	0.216	0.200	0.350	1.397
6	38.371201	42.097933	0.123	0.115	0.202	0.806

7	38.334478	42.015534	0.168	0.150	0.263	1.049
8	38.163853	41.802451	0.072	0.061	0.107	0.427
9	38.176483	41.822436	0.062	0.058	0.102	0.407
10	38.193178	41.821011	0.059	0.050	0.088	0.351
11	38.208944	41.829523	0.031	0.027	0.047	0.188
12	38.214614	41.862695	0.109	0.115	0.202	0.806
13	38.274124	41.969403	0.099	0.090	0.158	0.630
14	38.302802	42.011080	0.137	0.124	0.217	0.866
15	38.158621	41.779129	0.086	0.068	0.119	0.475
16	38.128768	41.749510	0.064	0.059	0.103	0.411
17	38.077858	41.764032	0.100	0.090	0.158	0.630
18	38.026758	41.779030	0.079	0.072	0.126	0.503
19	37.972934	41.780376	0.073	0.070	0.123	0.491
20	38.408683	42.100730	0.160	0.151	0.265	1.057
Min			**0.031**	**0.027**	**0.047**	**0.188**
Max			**0.228**	**0.201**	**0.352**	**1.405**
Mean			**0.123**	**0.112**	**0.196**	**0.784**

The measured gamma dose rates at ground level and 1 meter above ground show notable spatial variations across the sampled sites.

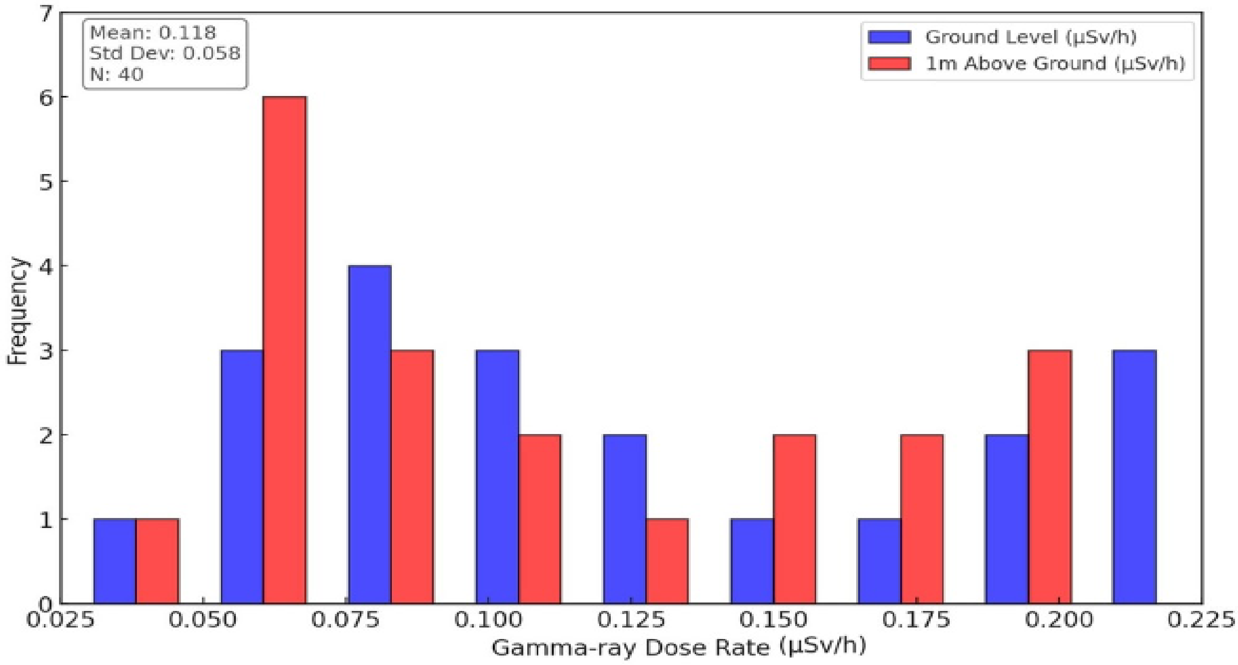

Figure 2. Frequency distribution of gamma dose rate at ground level and 1m above ground.

Ground-level gamma dose rates (DR) ranged from 0.031 to 0.228 µSv/h, with an average of 0.123 µSv/h, while values measured at 1 meter above the ground varied between 0.027 and 0.201 µSv/h, averaging 0.112 µSv/h. Compared to the UNSCEAR (2000) global reference value of 0.059 µSv/h, the measurements in this study are notably elevated. As illustrated in Figure 2, the majority of the recorded values for both heights were concentrated within the 0.050–0.075 µSv/h range. The observed decrease in dose rate with increasing height is attributed to the attenuation of gamma radiation, as ground-level measurements are influenced by direct emissions from soil and rock surfaces. In contrast, measurements taken at 1 meter height represent a mixture of scattered gamma radiation and ambient contributions, resulting in slightly lower values.

When evaluating the results within the spatial context of the study area, it is evident that certain measurement sites exhibit comparatively elevated gamma dose rates. In particular, the highest values recorded at ground level (Samples 2, 3, and 5, with 0.228, 0.219, and 0.216 µSv/h, respectively) are located in the northern section of the Bitlis Stream, where proximity to the river is relatively close and topographical slope transitions from more rugged terrain to alluvial plains. These sites may be affected by near-surface geological formations and sediment characteristics that vary along the river path.

On the other hand, lower gamma dose rates (Samples 12–15) were generally observed in the southern part of the stream, where both ground and 1-meter measurements fall below the UNSCEAR global average of 0.059 µSv/h. This pattern suggests a north-to-south attenuation trend, though the influence of altitude, soil composition, and anthropogenic factors remains to be fully clarified.

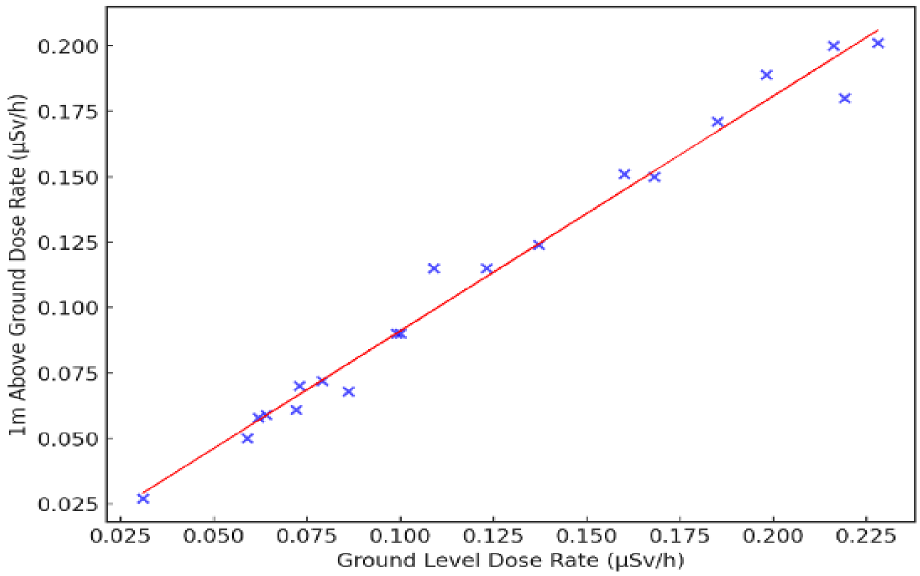

Figure 3. Correlation between gamma dose rate at ground level and gamma dose rate at 1m above ground.

Figure 3 shows a linear relationship between the ground-level dose rate and the 1m above-ground dose rate, indicating a strong positive correlation between the dose rate at ground surface level and the dose rate at 1 meter above ground level. The graph trend indicates that when the dose rate increases at the ground surface, the dose rate also increases proportionally at a height of 1 meter above the ground.

AED values estimate the potential radiation exposure for individuals frequenting these areas over a year. Calculations yielded AED values between 0.047 and 0.352 mSv/y, with an average of

0.196 mSv/y across sites. This average remains well below the 0.074 mSv/y limit recommended by the UNSCEAR, indicating a low risk of radiation exposure from environmental gamma radiation in these regions (UNSCEAR 2000).

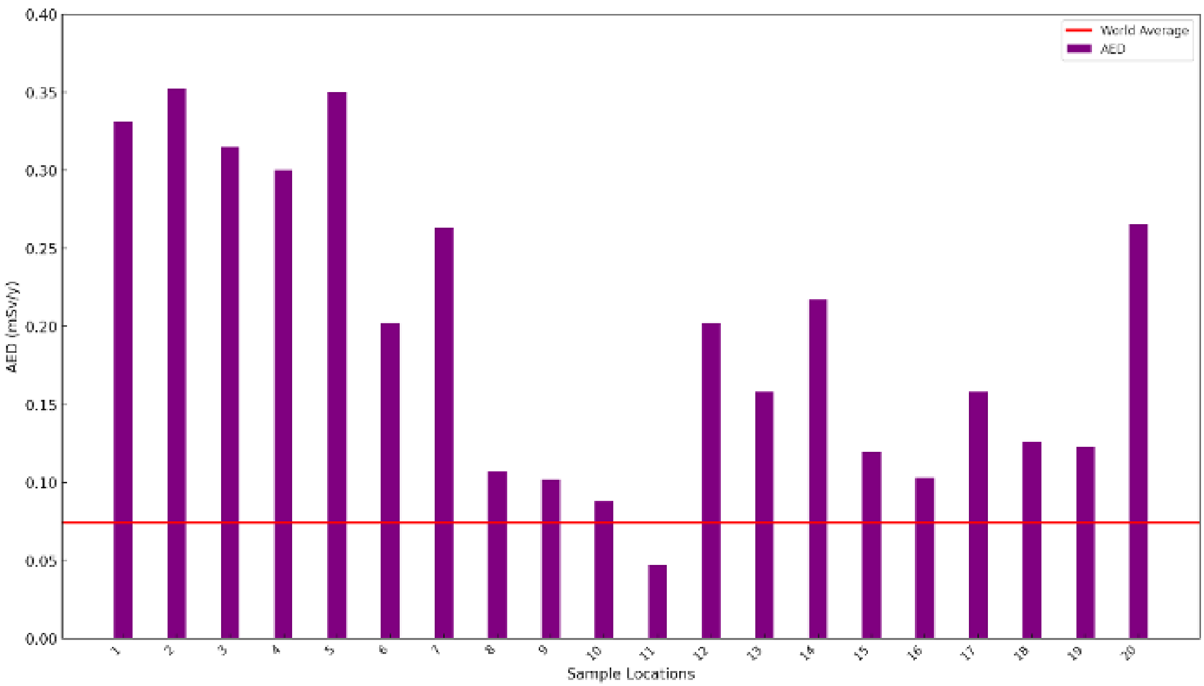

Figure 4. Annual effective dose equivalent (AEDE) rate and world average.

Figure 4 presents AED variation (mSv/y) in 20 locations, where the red line shows the world average. This graph reveals that most locations have AED values higher than the global average, indicating that the environmental radiation in these areas exceeds the global average. Locations 1, 2, 3, and 5 show AED values of almost 0.35 mSv/y, which is well above the average for the world. This situation needs to explore the causes of high radiation levels detected in those areas. Regarding the very low annual effective doses, which are below about 0.05 mSv/y, locations 10 and 11 are the least exposed to high radiation in these two studied areas.

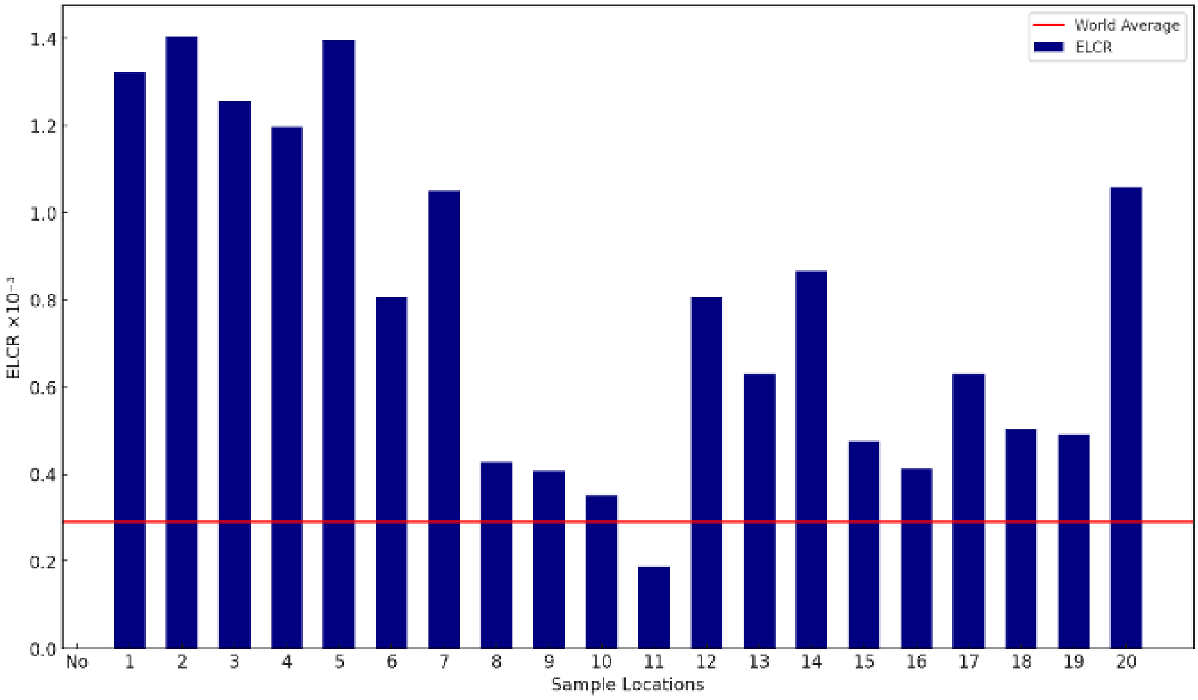

Figure 5. ELCR and world average

The estimated ELCR values ranged from 0.188×10^{-3} to 1.405×10^{-3}, with an average value of 0.784×10^{-3}, exceeding the worldwide reported mean level of 0.29×10^{-3} (Tanwer 2024). These values imply a minimal increase in lifetime cancer risk due to the gamma radiation levels observed, aligning with typical background radiation risks in natural environments.

The ELCR values in each location are shown in Figure 5, where the global average ELCR value is given as a reference. Locations 1, 2, and 5 have the highest ELCR values, which are considerably higher than the others. In these places, the ELCR value reaches up to 1.4×10^{-3}, much higher than the global average. The ELCR is approximately 0.1×10^{-3} at location 11, which is comparatively low from the global average perspective.

Table 2. Comparison of gamma dose rates, AED, and ELCR values obtained from the present study with studies in other countries.

Country	Dose rate range (mean) (µSv/h)	Annual effective dose range (mean) (mSv)	ELCR range (mean) $x10^{-3}$	References
Bangladesh	0.135	0.43	0.892	Sumi et al. 2021
Egypt	0.16	0.16	0.56	Farez et al. 2017
India	0.106	0.29-4.22	1.18-14.12	Monica et al. 2016
Iran	0.605	0.74	2.956	Eslami et al. 2016
Iraq	0.050	0.06	0.20	Mohammed 2017
Jamaica	0.008-0.230	0.557	0.163	Miller 2016
Morocco	0.009-0.091	0.05-0.56	0.19-1.96	Kassi 2018
Nepal	0.115	0.142	0.536	Mishra 2019
Nigeria	0.203	0.311	0.81	Anekwe 2020
Pakistan	0.220	0.40	1.40	Ali et al. 2019

Tanzania	0.026-0.386	0.03-0.47	0.11-1.70	Nkuba 2017
Malatya	0.048	0.058	0.21	Kayakökü 2022
Kastamonu	0.055	0.067		Kam 2007
Kahramanmaraş	0.065	0.079		Karataşlı 2019
Artvin	0.174	0.215	0.75	Kobya et al. 2015
Worldwide average	0.059	0.074	0.29	UNSCEAR 2000, Tanwer 2024
Bitlis Stream, Türkiye	**0.031-0.228 (0.123)**	**0.047-0.352 (0.196)**	**0.188-1.405 (0.784)**	**This study**

Table 2 compares the gamma dose rates, AED, and ELCR values in some countries, including Türkiye, with the world average. The gamma dose rate of Türkiye varies between 0.031 and 0.228 μSv/h, with an average value of 0.123 μSv/h, which is higher than that of the world average of 0.059 μSv/h. However, it remains lower than in some countries such as Iran (0.429–0.781 μSv/h), Nigeria (0.122–0.278 μSv/h), and Pakistan (0.189–0.269 μSv/h). Likewise, the average annual effective dose varies in the range of 0.047 to 0.352 mSv/y, with an average of 0.196 mSv/y, higher than the world average of 0.07 mSv/y. For the ELCR, this is higher in Türkiye, though below the global average, compared to some countries like Iran, Pakistan, and Bangladesh. Furthermore, it can be shown from the table that most of the country averages exceed the world's average on these parameters. When evaluated for Türkiye, the highest values among dose rate, annual effective dose and ELCR values were seen in Artvin, while the lowest values were seen in Malatya. These values are higher than the world average in Turkey, and the difference is especially evident in terms of ELCR. Artvin has been the most notable city in terms of both radiation levels and possible health risks.

4. Conclusions and Recommendations

This study assessed the environmental gamma radiation dose around Bitlis Stream to establish baseline data and assess potential health risks. The results show that the geological and geographical characteristics of the region significantly affect the gamma dose rates in the region. The measured average gamma dose rate is higher than the global average recommended by UNSCEAR (2000). In addition, the annual effective dose equivalent (AED) and lifetime cancer risk (ELCR) values also exceed the world average. This is thought to be due to the geological structure of the region.The high values in some places suggest that a closer examination of regional geological features may be useful in understanding why this is the case.

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Authors' Contributions

All authors have contributed equally to the preparation and writing of this manuscript. All authors have read and agreed to the published version of the manuscript.

Statement of Conflicts of Interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The author declares that this study complies with Research and Publication Ethics.

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