HAZARD ASSESSMENT OF OUTDOOR GAMMA RADIATION IN TAVSANLI, KUTAHYA REGION OF TURKIYE

by

Kevser DENIZ [1] ***and Abdullah Engin CALIK*** [2*]

[1]Department of Physics, Institute of Science Studies, Kutahya Dumlupinar University, Kutahya, Turkiye
[2]Department of Physics, Faculty of Science, Ege University, Bornova, Izmir, Turkiye

Scientific paper
https://doi.org/10.2298/NTRP2401074D

In the present study, outdoor gamma dose rates have been measured by using a NaI(Tl) scintillation detector in 20 measurement points in the Tavsanly district center of Kutahya province in Turkiye. Annual effective dose equivalents and lifetime cancer risks have been calculated from the obtained results as (106.64 6.20) μSv and (3.73 0.2) 10^{-4}, respectively. The results have been compared with those of other studies for Turkiye and the world literature

Key words: outdoor gamma dose rate, annual effective dose equivalent, lifetime cancer risk

INTRODUCTION

The significance of knowing the radiation exposure level has increased since Becquerel's 1896 discovery of radioactivity and the subsequent realization of the harmful impact of radiation on human health. Ionizing radiation, also referred to as nuclear radiation, consists of alpha and beta particles, cosmic rays, gamma and X-rays, and free neutrons. Radiation can be categorized into natural and artificial types based on their sources. The 88 % of the annual radiation dose consists of natural sources and 12 % consists of artificial sources, although it varies depending on the geographical and physical conditions of the living environment [1].

Alpha, beta particles, and gamma rays emitted from natural and artificial sources constitute terrestrial radiation. Gamma rays, which have much greater penetrability and range than alpha and beta particles, arise from differences in the energy levels of the nucleus and emit electromagnetic radiation. In daily life, humans are exposed to gamma rays from artificial and natural radiation sources, both indoors and outdoors [2].

The radiation exposure that affects humans is known as the gamma dose rate (*GDR*). It is given as the equivalent dose at a specific location once per hour and its unity is given as Rh^{-1} (1R = 258 μC/kg). The *GDR* which emanates from *vs*. natural and artificial sources. There are two main sources of natural gamma radiation: terrestrial and cosmic. The radioactive nuclides that are found in air, soil, and water are the terrestrial source [3]. Artificial radioactivity stems from biomedical sources, nuclear detonations, consumer goods, nuclear power facilities, and associated fuel cycles. Cosmic radiation contributes to background radiation through cosmic rays, with variations in elevation and altitude affecting its impact. Through interactions with the atmosphere, cosmogenic radionuclides like ^{3}H, ^{7}Be, ^{14}C, ^{22}Na, *etc*., are produced. Mainly found terrestrial radionuclides such as ^{40}K, ^{87}Rb, ^{138}La, ^{147}Sm, ^{176}Lu, and decay products from ^{238}U, ^{232}Th, and ^{235}U series [1]. Understanding their environmental distribution, especially in soils and rocks, is crucial for radiation protection and measurement [4]. In addition, small amounts of radioactivity can be detected in drinking water, although the levels and types of radioactivity present may vary depending on the specific soil and rock formations the water has traveled through. Natural or artificial radionuclides such as ^{40}P, ^{3}H, ^{14}C, ^{87}Rb, and alpha emitters like ^{226}Ra, ^{210}Po, U, Th, ^{220,222}Rn can be present in water. Natural radionuclides in the soil contribute to gamma-absorbed doses in the air, with their impact on air radiation levels varying with altitude from ground level. It's been observed that gamma rays significantly contribute to the air dose rate [5].

The Nuclear Regulatory Authority (NDK) monitors environmental natural *GDR* with the Radiation Monitoring and Warning System Network (RADISA) established at certain points in Turkiye [6]. Many studies have been conducted on this subject in the world and Turkiye. In 2017, a study on estimating the terrestrial outdoor *GDR* was carried out by the European Radio-

* Corresponding author, e-mail: engin.calik@ege.edu.tr

logical Data Exchange Platform (EURDEP) in Germany, thus aiming to create a European natural radiation map [7]. The effects of outdoor gamma radiation on pediatric cancer cases were investigated in Germany [8]. A study, including the impact of outdoor gamma radiation, cosmic rays, and radon gas was conducted for France, and with this study, a risk map was created for France in general [9]. Outdoor and indoor GDR measurements were taken at 259 points in Greece using HP-Ge and NaI gamma detectors. By comparing these measurements, a radiation map of Greece was created [10]. Outdoor terrestrial GDR values were measured in Spain and a general indoor and outdoor gamma radiation map of Spain was prepared [11]. The average outdoor *GDR* ratio was determined for the historic objects in Bosnia and Herzegovina [12]. Activity concentrations of radionuclides (^{40}K, ^{238}U, ^{226}Ra, ^{232}Th, ^{137}Cs), absorbed dose rate (*ADR*), and annual effective dose equivalent (*AEDE*) in arable soil collected in Belgrade and Pancevo, Serbia were reported [13].

Measurements of outdoor and indoor GDR values were conducted not only in Europe but also in various countries worldwide. Outdoor dose rate measurements were taken in many cities in Iran, and the average values were measured as 79.6 nSvh^{-1} in Birjand city [14], 605 nSvh^{-1} in the capital Tehran [15], and 113 nSvh^{-1} in Lorestan province [16]. It is noteworthy that the values in Tehran are quite high. Outdoor and indoor GDR values were measured in different regions of Nigeria and their effects on cancer were investigated [17-19]. In the Kerala state of India, the average outdoor *AEDE* values were measured as 4.83 mSv, and its effects on cancer risk were examined [20]. The outdoor average *GDR* was measured in and around the Reasi district of Jammu and Kashmir, India [21]. Average *GDR* values in the Terengganu state of Malaysia [22] (measurements were taken with a NaI(Tl) detector at 145 different points) and in the northern regions of Chittagong-Bangladesh [23] (measurements were taken at 21 different points), were measured. Indoor and outdoor *GDR* values were measured at 40 measurement points in Muzaffarabad, the capital of Azad Kashmir Region of Pakistan [24]. Mapping for Japan was done by measuring the *GDR* values before the 9.0 magnitude Great East Japan Earthquake that occurred in Japan on March 11, 2011 [25].

Outdoor and indoor GDR values were measured for many regions and cities in Turkiye: In Kahramanmaras, outdoor and indoor *GDR* values were measured and cancer risk was calculated [26]. The *AEDE* and excess of lifetime cancer risk (ELCR) values for Cappadocia were calculated at 219.07 µSv and 7.67 10^{-4}, respectively [27]. Outdoor *GDR* values were measured in Yalova [28], Kahramanmaras [29], Adiyaman [30], and *ADR* and ELCR were calculated. Similar measurements and calculations were done in the Tatvan, Ahlat, and Adilcevaz districts of Bitlis [31], Kazdaglary [32], capital city Ankara [33], Digor [34] and Selim [35] districts of Kars. Terrestrial *GDR* values were measured using a NaI(Tl) detector at 35 points around lignite coal deposits in Ilgin district of Konya province, and cancer risk was investigated [36]. In Artvin, measurements were taken at 204 points, and the outdoor *AEDE* values were determined as 214.5 µSv [37]. Outdoor *GDR* values were measured in Canakkale [38], 17 districts of Bursa [39], Trabzon and its districts [40], Kirklareli [41], Sanliurfa [42] and the average *AEDE* were calculated as 96.50 µSv, 110.40 µSv, 73.83 µSv, 144.00 µSv and 74.70 µSv, respectively. The activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in the building materials commonly used in the Western Black Sea region of Türkiye were measured using a germanium (HPGe) detector and indoor absorbed *GDR* and corresponding annual effective dose [43]. The *ADR* in outdoor air in the sepiolite open quarry of Beylikova, Polatli, and Sivrihisar were measured using a dose rate meter with the Geiger-Muller tube [44].

The ^{238}U, ^{232}Th, and ^{40}K activity concentrations in soil samples from various districts were measured in central [5, 45] and around Kutahya province [5, 46] with NaI(Tl) scintillation detector. The average outdoor *ADR* in air from these radionuclides was reported as 46 (range: 28-76) nGyh^{-1} and 64.2 (range: 5.3-265.3) nGyh^{-1}. The *AEDE* values were calculated to be 57 (range: 35-94) µSv and 78.7 (range: 6.4- 325.3) µSv [5, 45, 46]. Radioactivity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K for construction materials used in Kütahya province were examined [47]. The *GDR* of these materials was calculated as lower than the limitation value. The measurement of the activity concentrations of terrestrial radionuclides (^{226}Ra, ^{232}Th and ^{40}K) in fly ash samples collected from Tuncbilek lignite coal-fired thermal power plant (located in Tavsanli) was performed by using a high-purity germanium detector [48]. The *ADR*, *AEDE*, and ELCR outdoor average values were calculated as 306 nGyh^{-1} (range: 186-496 nGyh^{-1}), 0.66 mSv (range: 0.40-1.07 mSv), and 2.6 10^{-3} (range: 1.6 10^{-3}-4.3 10^{-3}), respectively.

As seen, *GDR* measurements and related calculations in different regions of Turkiye and the world are not identical because of the diverse activity of the radionuclides. The considerable difference between the measurement results in the Tuncbilek power plant and those in the center of Kutahya is noteworthy. In particular, the measurements in Tuncbilek are quite high. The objective of this study is to evaluate the outdoor *GDR* from naturally occurring radionuclides. For this purpose, in this study, outdoor *GDR* has been measured using the LUDLUM NaI(Tl) detector for a period of 12 months at 20 locations in the Tavsanli district center of Kutahya province, which has rich lignite coal deposits, underground resources, and lignite coal-fired thermal power plant. With the help of these measurements, *ADR*, *AEDE,* and ELCR have been calculated. These results can be used to investigate the hazard assessment of radioactivity on the environment and human health by comparing them with the previously obtained results for Kutahya Province.

MATERIALS AND METHODS

Properties of scintillation detector

Measurements have been taken using a LUDLUM (model 2241-3RK) portable NaI(Tl) scintillation detector located in the Nuclear Physics Research Laboratory of the Department of Physics, Faculty of Arts and Sciences, Kutahya Dumlupinar University. The device, which can measure gamma rays with energies between 60 keV and 1.25 MeV, contains a 2.5 cm diameter and 2.5 cm thick NaI crystal connected to a photomultiplier tube. The NaI crystal is placed in a 0.16 cm thick aluminum casing. The device has an operating voltage between 500 V and 1200 V, a 2.9 cm diameter magnetically protected photomultiplier, and 100 MΩ dynodes responsible for electron multiplication. Additionally, the detector has an aluminum body with a diameter of 5.1 cm and a length of 18.5 cm. The detector weighs 0.5 kg and has a dead time of 8-12 μs [49].

Measurement points

Tavsanli is a district of Kutahya province in the Inner Aegean region and is located in the northwest of Kutahya, as seen in fig. 1. Its surface area is 1899 km^2. It is approximately 45 km away from Kutahya city center. Tavsanli is located at 39° 32’ 49.2036’’ north and 29° 29’ 29.0400’’ east *GPS* coordinates.

Tavsanli district, similar to the rest of Kutahya province, has various and high reserves of underground resources. Tavsanli has notably rich lignite potential.

Tuncbilek and Seyitomer thermal power plants have made a great contribution to the industry and economy of the district. There are 198 666 000 tons of lignite reserves in Seyitomer and 317 732 000 tons in Tuncbilek [50]. The existing underground resources and reserves of Tavsanli have been given in tab. 1.

Outdoor *GDR* values have been measured periodically for 12 months in 20 neighborhoods in the Tavsanli district center of Kutahya province, which locations are given in fig. 2.

CALCULATIONS

The *GDR* measurements in units of μRh^{-1} have been taken approximately one meter above the ground (at gonad level in humans). At each measurement point, 10 different measurements have been taken at each measurement time to minimize the error. The h *GDR* as been determined for that measurement point by taking the average of these 10 measurements. The transition from *GDR* to *ADR* has been done using eq. (1). The 8.7 nGy/μR multiplier in eq. (1) is called the conversion factor that converts the μRh^{-1} *GDR* to the $nGyh^{-1}$ *ADR* [42]

$$ADR\,(\mathrm{nGyh}^{-1}) = GDR\,(\mu\mathrm{Rh}^{-1}) \times 8.7\,(\mathrm{nGy}/\mu\mathrm{R}) \quad (1)$$

To understand the biological effect of gamma rays, the *AEDE* must be calculated. The ratio of the ef-

Figure 1. Tavsanli district

Table 1. Underground resources and reserves in Tavsanli [50]

Underground resources	Reserve ($\times 10^3$ tons)
Cement raw materials	25000-30000
Fluorite	9
Silver	21500
Manganese	9
Magnesite	88.1
Lignite	516398
Bituminous shale	122170

Figure 2. The measurement points in Tavsanli

fective dose equivalent to the absorbed dose is defined as the dose conversion factor (DCF) of 0.7 Sv/Gy for gamma rays [1]. This value is used for both indoor and outdoor calculations. Another factor that should be known when calculating the effective dose equivalent for gamma rays is the amount of radiation exposure to these rays. Occupancy factor (OF) expresses how much time a person spends outdoors or indoors daily. According to the UNSCEAR 2000 report, adults spend an average of one-fifth, or 20 %, of a day outdoors. In other words, OF = 0.2 is taken as the occupancy factor for the outdoor [1]. The AEDE for gamma rays has been calculated using eq. (2)

$$AEDE\,(\text{mSv}) \quad ADR\,(\text{nGh}^{\ 1}) \quad \text{DCF} \quad \text{OF} \quad \text{T}(8760\,\text{h per year}) \; 10^{\ 3} \tag{2}$$

By observing the number of people in a group exposed to radiation, the doses they were exposed to, and the occurrence of cancer in this group, the increased cancer risk per unit dose can be estimated by comparing the doses with the expected number of cancer cases in a group whose other characteristics are similar but not exposed to radiation. This is called risk factor (RF) and its value is 510^{-2} Sv^{-1} [51]. The ELCR is calculated by multiplying the *AEDE*, life expectancy (*LE*) (70 years), and risk factor (RF)

$$\text{ELCR} = AEDE \quad LE \quad \text{RF} \tag{3}$$

RESULTS

The measurement results for the outdoors taken with the LUDNUM 2241-3RK model for 12 months in the 20 neighborhoods in Tavsanli are given in tab. 2. The measurement point names, the measured *GDR* values, and the calculated *ADR, AEDE*, and ELCR values have been given in the second, third, fourth, and fifth columns of tab. 2, respectively. The last row shows the general average of *GDR, ADR, AEDE,* and ELCR results for the Tavsanli district. As seen from tab. 2, the lowest *AEDE* and ELCR values are at the seventeenth measurement point and the highest value is at the fourth measurement point. The average value of *AEDE* and ELCR for Tavsanli have been calculated as 106.64 6.20 μSv and 0.37 0.02 10^{-3}, respectively.

Table 3 shows outdoor *AEDE* and ELCR results for some cities in Turkiye. When the table is examined, it is seen that the results in Artvin [37], Tatvan [31], and Nevsehir [27] are much higher than the results in other cities. Although the results in Tavsanli are lower than Nevsehir [27], Adiyaman [30], Tatvan [31], Kazdaglari [32], Konya-Ilgin [36], Artvin [37], Bursa [39] and Kirklareli [41] results, it is higher than the results in Yalova [28], Kahramanmaras [29], Ankara [33], Digor [34], Selim [35], Canakkale-Ayvacik [38], Trabzon [40] and Sanliurfa [42].

Table 2. The average *GDR*, *ADR*, *AEDE*, and ELCR values of 20 measurement points in Tavsanli

No	Measurement points	*GDR* [μRh^{-1}]	*ADR* [nGyh^{-1}]	*AEDE* [μSv]	ELCR (10^{-3})
1	Yeni	12.83 0.63	111.65 5.44	136.93 6.68	0.48 0.02
2	Moymul	12.43 0.62	108.10 5.37	132.57 6.58	0.46 0.02
3	D. Hastanesi	8.33 0.39	72.43 3.43	88.83 4.21	0.31 0.01
4	Ulu Camii	13.92 0.57	121.08 4.96	148.49 6.08	0.52 0.02
5	Karakova	10.02 0.73	87.15 6.39	106.87 7.83	0.37 0.03
6	Cardakli	9.98 0.93	86.86 8.05	106.52 9.87	0.37 0.03
7	Ada	9.47 0.40	82.36 3.50	101.01 4.29	0.35 0.02
8	Circircesme	8.08 0.34	70.33 2.99	86.25 3.67	0.30 0.01
9	Hanimcesme	9.57 0.59	83.23 5.14	102.07 6.30	0.36 0.02
10	Y. Beyazit	8.63 0.74	75.11 6.47	92.11 7.93	0.32 0.03
11	Subasi	8.20 0.37	71.34 3.23	87.49 3.96	0.31 0.01
12	Baglik	9.43 0.63	82.00 5.51	100.56 6.76	0.35 0.02
13	Cukurkoy	10.93 0.65	95.12 5.62	116.66 6.89	0.41 0.02
14	Durak	11.18 0.54	97.30 4.69	119.32 5.75	0.42 0.02
15	Istasyon	8.53 0.64	74.24 5.57	91.05 6.83	0.32 0.02
16	Dagcesme	10.15 0.57	88.31 4.92	108.3 6.04	0.38 0.02
17	Dedeler	7.72 0.34	67.14 2.92	82.33 3.58	0.29 0.01
18	Beykoy	10.25 0.49	89.18 4.23	109.36 5.19	0.38 0.02
19	Omerbey	9.07 0.57	78.88 4.99	96.74 6.12	0.34 0.02
20	Kavakli	11.19 0.51	97.37 4.48	119.41 5.49	0.42 0.02
	Average	10.00 0.58	86.96 5.05	106.64 6.20	0.37 0.02

Table 3. AEDE and ELCR values in different cities of Turkiye

Region	AEDE [μSv]	ELCR (10^{-4})
Nevsehir [27]	219.07	7.67
Yalova [28]	59.20	2.07
Kahramanmaras [29]	79.50	3.20
Adiyaman [30]	177.00	7.10
Tatvan-Bitlis [31]	261.00	9.14
Kazdaglari [32]	198.66	6.95
Ankara [33]	71.83	2.70
Digor-Kars [34]	96.80	3.38
Selim-Kars [35]	87.10	3.00
Konya-Ilgin [36]	132.90	5.18
Artvin [37]	214.50	7.50
Canakkale-Ayvacik [38]	96.50	3.38
Bursa [39]	110.40	4.50
Trabzon [40]	73.83	2.58
Kirklareli [41]	144.00	5.04
Sanliurfa [42]	74.70	2.61
Kutahya [5, 45]	57.00	1.99
Kutahya [5, 46]	78.70	2.75
Tuncbilek [48]	660.00	26.00
World [1]	73.60	2.58
(Present study)	106.64	3.73

CONCLUSIONS

In this study, the measurement of outdoor GDR values and the calculation of *AEDE* and ELCR in the central area of Tavsanli, located to the north of Kütahya in the inner Aegean region of Turkiye have been showed.

It has been observed that *AEDE* results for Tavþanlý varied between 82.33 μSv and 148.49 μSv and the lowest result is in the Dedeler neighborhood, and the highest one is in the Ulu Camii neighborhood. The average values of *AEDE* and ELCR have been calculated as 106.64 μSv and 3.73 10^{-4}, respectively. These results are approximately 1.5 times higher than UNSCEAR's world average of 73.6 μSv for *AED*E and 2.58 10^{-4} for ELCR. Compared to the results in Konya-Ilgin [36], where lignite deposits are abundant, the results in the present study are lower. *AEDE* results determined in Tavsanli are approximately two times larger than the results for the Kutahya center [5, 45], and 1.5 times larger than the results for Kutahya province [5, 46]. The *AEDE* results obtained for Tavsanli are approximately one-sixth of the results for Tuncbilek [48], and the ELCR results are approximately one-seventh of the results for Tuncbilek. Lignite coal is the most important energy source in Turkiye and Tavsanli is very rich in lignite coal and has two thermal power plants. The results obtained for Tuncbilek, being significantly above the world average warrant close monitoring. Tuncilek is very close to Tavsanli, and the radioactive effects here also affect the *GDR* in the city center of Tavsanli. To better assess the atmospheric radiation hazard for Tavsanli, atmospheric radon concentration should be determined along with *GDR* in the city center.

ACKNOWLEDGMENT

The authors would like to thank the Rectorate of Kutahya Dumlupinar University, Kutahya Governorship, and Tavsanli District Governorship for providing the necessary permissions for the measurements. This study is a part of the M.Sc. thesis prepared in the Physics Department, Kutahya Dumlupinar University. The authors also would like to thank Dr. H. Sirin and Dr. Y. Senturk for their editing help.

AUTHORS' CONTRIBUTIONS

K. Deniz conducted the field measurements at different locations with a LUDLUM portable NaI(Tl) scintillation detector. A. E. Calik and K. Deniz analyzed the results presented. A. E. Calik prepared the figures, tables, and text of the manuscript.

ORCID NO

K. Deniz (0009-0001-4404-9813)
A. E. Calik (0000-0003-3441-6496)

REFERENCES

[1] ***, United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2000), Annex B: Exposures from Natural Radiation Sources, United Nations Publication, New York, USA, 2000

[2] Krane, S. K., *Introductory Nuclear Physics*, John Wiley and Sons, Canada, 1988

[3] Otansev, P., *et al*., Assessment of Natural Radioactivity Concentrations and Gamma Dose Rate Levels in Kayseri/Turkey, *Radiat. Prot. Dosim., 148* (2012), 2, pp. 227-236

[4] Asha, R., Surinder, S., Natural Radioactivity Levels in Soil Samples from Some Areas of Himachal Pradesh, India Using -Ray Spectrometry, *Atmos. Environ., 39* (2005), 34, pp. 6306-6314

[5] Bayram, T., *et al*., *Environmental Radioactivity in Turkish Environment*, Cumhuriyet University Publication, Sivas, Turkiye, 2020

[6] ***, NDK (Nuclear Regulatory Authority https://www.ndk.gov.tr/radyasyon-izleme-ve-uyari-sistemi-agi-radisa, 2024

[7] Bossew, P., *et al.,* Estimating the Terrestrial Gamma Dose Rate by Decomposition of the Ambient Dose Equivalent Rate, *J. Environ. Radioact., 166* (2017), 2, pp. 296-308

[8] Spix, C., *et al.,* Background Gamma Radiation and Childhood Cancer in Germany: an Ecological Study, *Radiat. Environ. BioPhys., 56* (2017), 1, pp.127-138

[9] Billon, S., *et al.,* French Population Exposure to Radon, Terrestrial Gamma and Cosmic Rays, *Radiat. Prot. Dosim., 113* (2005), 3, pp. 314-320

[10] Clouvas, A., *et al.,* Radiological Maps of Outdoor and Indoor Gamma Dose Rates in Greek Urban Areas Obtained by *in situ* Gamma Spectrometry, *Radiat. Prot. Dosim., 112* (2004), 2, pp. 267-275
[11] Quindos, L.S., *et al.,* Estimate of External Gamma Exposure Outdoors in Spain, *Radiat. Prot. Dosim.*, *45* (1992), ¼, pp. 527-529
[12] Avdić, S., *et al*., Comparative Analysis of Gamma Dose Rates Measured by Ion Chamber in and Around the Historical Sacral Objects in Bosnia and Herzegovina, *Nucl Technol Radiat., 34* (2019), 2, pp. 157-164
[13] Mitrović, B. M., *et al*., Radionuclides and Heavy Metals in Soil, Vegetables, and Medicinal Plants in Suburban Areas of the Cities of Belgrade and Pancevo, Serbia, *Nucl Technol Radiat., 34* (2019), 3, pp. 278-284
[14] Zarghani, H., Jafari, R., Assessment of Outdoor and Indoor Background Gamma Radiation, the Annual Effective Dose and Excess Lifetime Cancer Risk in Birjand, Iran, *Jundishapur J Health Sci.*, *9* (2017), 3, pp. 1-4
[15] Eslami, A., *et al.,* A., Outdoor Gamma Radiation Measurement in Order to Estimate the Annual Effective Dose and Excess Lifetime Cancer Risk for Resydents of Tehran, Iran, *JAPH*, *1* (2016), 4, pp. 243-250
[16] Gholami, M., *et al.,* Gamma Background Radiation Measurement in Lorestan Province, Iran, *Iran. J. Radiat. Res., 9* (2011), 2, pp. 89-93
[17] Asere, A. M., Ajayi, I. R., Estimation of Outdoor Gamma Dose Rates and Lifetime Cancer Risk in Akoko Region, Ondo State, Southwestern Nigeria, *IOSR-JESTFT*, *11* (2017), 5, pp. 49-52
[18] Ononugbo, C. P., Mgbemere, C. J., Dose Rate and Annual Effective Dose Assessment of Terrestrial Gamma Radiation in Notre Fertilizer Plant, Onne, Rivers State, Nigeria, *IJERMT, 5* (2016), 9, pp. 30-35
[19] Ononugbo, C. P., *et al*., Estimation of Indoor and Outdoor Effectyve Doses from Gamma Dose Rates of Residential Buildings in Emelogu Vyllage in Rivers State, Nigeria, *IRJPAP, 3* (2015), 2, pp. 18-27
[20] Monica, S., *et al.,* Estimation of Indoor and Outdoor Effective Doses and Lifetime Cancer Risk from Gamma Dose Rates Along the Coastal Regions of Kollam District, Kerala, *Radiat. Prot. and Environ.*, *39* (2018), 1, pp. 38-43
[21] Kaur, M., *et al*., Seasonal Variation of Indoor and Outdoor Gamma Dose Rates of Reasi District of Jammu and Kashmir, *Nucl Technol Radiat., 33* (2018), 1, pp. 106-111
[22] Garba, N. N., *et al.,* Terrestrial Gamma Radiation Dose Rates and Radiological Mapping of Terengganu state, Malaysia, *J. Radioanal Nucl. Chem.*, *303* (2015), 3, pp. 1785-1792
[23] Hossain, A., *et al.,* Measurement of Absorbed Outdoor Dose Rate Due to Gamma Radiation in Northern Part of Chittagong City Corporation, *IJSTR*, *3* (2014), 5, pp. 98-100
[24] Rafique, M., Ambient Indoor/Outdoor Gamma Radiation Dose Rates in the City and at High Altitudes of Muzaffarabad (Azad Kashmir), *Environ Earth Sci., 70* (2013), 4, pp. 1783-1790
[25] Furukawa, M., Shingaki, R., Terrestrial Gamma Radiation Dose Rate in Japan Estimated Before the 2011 Great East Japon Earthquake, *Radiation Emergency Medicine, 1* (2012), 1-2, pp. 11-16
[26] Kucukonder, E., *et al.,* Direct Gamma Dose Rate Measurement and Assessment of Excess Lifetime Cancer Risk, *Radiat. Prot. Dosim.*, *199* (2023), 17, pp. 2136-2147
[27] Turgay M. E., *et al.*, Exposure Analysis at the Territory of Nevsehir (Cappadocia) Due to Additive Gamma-Rays in Air, Turkey, *JOTCSA, 9* (2022), 2, pp. 321-330
[28] Bayrak, K., *et al.,* Investigation of Outdoor Gamma Dose Rates in Yalova, Turkey, *European Journal of Science and Technology*, *18* (2020), Mar-Apr, pp. 568-573
[29] Karataþlý, M., Determination of Outdoor Absorbed Gamma Dose Rates of Kahramanmaras Province, Turkey, *Cumhuriyet Sci. J.*, *40* (2019), 1, pp. 102-107
[30] Karataply, M., Assessment of Outdoor Radioactivity and Health Risk in Adiyaman Province of Turkey, *Cumhuriyet Sci. J.*, *40* (2019), 3, pp. 772-780
[31] Karatepe, Kuluozturk, M. F., Gamma Dose Measurements in the Beach Sands of Tatvan, Ahlat and Adilcevaz, *Sakarya University Journal of Science*, *23* (2019), 6, pp. 1173-1176
[32] Turgay, M. E., Cancer Risk Determination for IDA Villages by Using Annual Gamma Doses in air, around Edremit & Ayvacik districts; Balikesir & Canakkale, Turkey, *European Journal of Science and Technology*, *15* (2019), Mar., pp. 433-439
[33] Kapdan, E., *et al.,* Outdoor Radioactivity and Health Risk Assessment for Capital City Ankara, Turkey, *J. Radioanal Nucl. Chem., 318* (2018), 2, pp. 1033-1042
[34] Bilgici Cengiz, G., Oztanryover, E., Analysis of natural Radioactivity Levels in Soil Samples and Dose Assessment for Digor District, Kars, Turkey, *Caucasian Journal of Science*, *5* (2018), 1, pp. 30-39
[35] Bilgici Cengiz G., Assessment of Natural Radioactivity Levels and Radiological Effects in Soil Samples of Selim District, *Kafkas University Institute of Natural and Applied Science Journal*, *10* (2017), 1, pp. 37-47
[36] Erdogan, M., Manisa, K., Assessment of Outdoor Terrestrial Gamma Dose Rates in the Konya-Ilgin-Cavupcu lignite deposit (Turkey), *Süleyman Demirel University Journal of Science*, *11* (2016), 2, pp. 89-93
[37] Kobya, Y., *et al.,* Evaluation of Outdoor Gamma Dose Rate and Cancer Risk in Artvin Province, Turkey, *Hum. Ecol. Risk Assess.*, *21* (2015), 8, pp. 2077-2085
[38] Turhan, *et al.,* Car-Borne Survey of Natural Background Gamma Dose Rate in Canakkale Region, Turkey, *Radiat. Prot. Dosim. 148* (2012), 1, pp. 45-50
[39] Karahan, G., Risk Assessment of Baseline Outdoor Gamma Dose Rate Levels Study of Natural Radiation Sources in Bursa, Turkey, *Radiat. Prot.Dosim.*, *142* (2010), 2, pp. 324-331
[40] Kurnaz, A., *et al.,* Indoor and Outdoor Gamma Dose Measurements for Specific Counties of Trabzon-Turkey, *AIP Conf. Proc.*, *1203* (2010), Jan., pp. 379-381
[41] Taskin, H., *et al.,* Radionuclide Concentrations in soil and Lifetime Cancer Risk Due to Gamma Radioactivity in Kirklareli, Turkey, J. *Environ. Radioact.*, *100* (2009), 1, pp. 49-53
[42] Bozkurt, A., *et al.,* Assessment of Environmental Radioactivity for Sanliurfa Region of Southeastern Turkey, *Radiat. Measurem.*, *42* (2007), 8, pp. 1387-1391
[43] Turhan, S., *et al.,* Natural Radiation Exposure and Radon Exhalation Rate of Building Materials Used in Turkey, *Nucl. Technol. Radiat., 33* (2018), 2, pp. 159-166
[44] Hancerlioglu, A., *et al*., Radiometric Properties of Sepiolite Minerals from Quarries in Central Anatolia of Turkey, *Nucl Technol Radiat., 34* (2019), 2, pp. 149-156
[45] Sahin, L., Cavas, M., Natural Radioactivity Measurements in Soil Samples of Central Kutahya (Turkey), *Radiat. Prot. Dosim., 131* (2008), 4, pp. 526-530
[46] Sahin, L., *et al*., Assessment of Radiological Hazard Parameters Due to Natural Radioactivity in Soils

from Granite-Rich Regions in Kutahya Province, Turkey, *Isot. Environ. Health Stud., 53* (2017), 2, pp. 212-221
[47] Cetinkaya, H., *et al*., Radioactivity Content of Building Materials Used in Kutahya Province, Turkey, *Radiat. Prot. Dosim., 198* (2022), 3, pp. 167-174
[48] Turhan, Jamasali, Y., Evaluation of Radiological Health Risk Caused by the Use of Fly Ash in Cement and Concrete Production and its Storage, *International Journal of Environmental Health Research,* (2024), Jan., pp. 1-16 https://doi.org/10.1080/09603123.2023.2301051
[49] ***, LUDLUM Measurements, Inc. Ludlum Model 2241-3RK Technical Manuel. Section 1, 1-3, 2016
[50] ***, The Institute of Mineral Research and Exploration (MTA) https://www.mta.gov.tr/v3.0/sayfalar/bilgi-merkezi/maden_potansiyel_2010/kutahya_madenler.pdf, 2010
[51] ***, International Commission On Radiological Protection (ICRP), Recommendations of the International Commission on Radiological Protection, ICRP Publication 60. Ann. ICRP 21(1-3), 1990

Received on April 22, 2024
Accepted on June 20, 2024

Кевсер ДЕНИЗ, Абдулах Енгин ЧАЛИК

ПРОЦЕНА ОПАСНОСТИ ОД СПОЉАШЊЕГ ГАМА ЗРАЧЕЊА У ОКРУГУ ТАВШАНЛИ, ПРОВИНЦИЈЕ КУТАХЈА У ТУРСКОЈ

У овом раду приказане су јачине гама доза на отвореном, мерене коришћењем NaI(Tl) сцинтилационог детектора у 20 мерних тачака, у окружном центру Тавшанли, провинције Кутахја у Турској. Годишњи еквиваленти ефективне дозе и животни ризици од рака израчунати су из добијених резултата као (106.64   6.20) μSv и (3.73   0.2) 10^{-4}, респективно. Резултати су упоређени са резултатима других студија за Турску и свет.

Кључне речи: јачина гама дозе на отвореном, годишњи еквивалент ефективне дозе, животни ризик од рака