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Assessment of Gama Dose Rates around Gaziantep City, Turkey

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ABSTRACT

In this work, the measurements were performed 1 m above the ground in air and surface soils at certain points in the city of Gaziantep located at south of Turkey. Air dose rates were carried out by portable detectors and the radioactivity content in measured by gamma spectrometry system with a NaI detector. The ambient dose rate measurements were measured in the air in the range of 6.02-10.50 nSvh^{-1} (average:7.6 nSvh^{-1}) , and mean gamma counting rate was 50.43 cps (count per second) annual over 40 stations, thus resulted in effective annual dose rate was determined to be 66.81 µSv y^{-1} and gamma counting of were found. On the other hand, as a result of gamma spectrometric analyses in the surface soil samples, average activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K were found to be 28.9, 29.5 and 255 Bq kg^{-1}, respectively. Calculated absorbed dose rate and annual effective dose values depending on the activity concentrations, were found to be 38.5 nGy h^{-1} and 47.2 µSv y^{-1}. When the measured values are compared with UNSCEAR 2000 report's worldwide average value, our result is slightly lower than these values.

Keywords: Natural radioactivity, Gamma spectrometry, Cosmic and terrestrial gamma radiation

1. Introduction

The natural long-lived (billions of years) radioactive elements and cosmic rays have created a natural radiation level in our world [1]. The most common terrestrial sources are isotopes of ^{226}Ra, ^{232}Th and ^{40}K. Therefore, measurements of natural radionuclides' concentrations and air doses give information about natural radiation level.

Gaziantep is one of the Turkey's leading cities in terms of industry, development and population. Gaziantep's city center has a population of about 1.5 million. Also, Gaziantep is the oldest city of Turkey where people live, as well as it is one of the oldest cities in the world. Literature surveying shows that absorbed dose rate was measured in Gaziantep as 50.1 nGy h^{-1} by [2], corresponding to a total gamma radiation level (of terrestrial and cosmic origin) of 61.5 µSv y^{-1}.

The activity concentrations in the surface soil samples collected from the study area were determined as 25.2, 23.7 and 289.2 Bq kg^{-1} for the natural radionuclides ^{238}U, ^{232}Th and ^{40}K, respectively [2].

The aim of this work is to evaluate soil radionuclides' radioactivity concentrations as well as environmental outdoor gamma dose rates in Gaziantep city center. The coordinates of measurement points determined by GPS device and radiation measurements were made in air with portable detectors at these points. Also, the amount of natural radioactivity in soil samples collected from points suitable for sampling in Gaziantep downtown were calculated by gamma spectrometry system.

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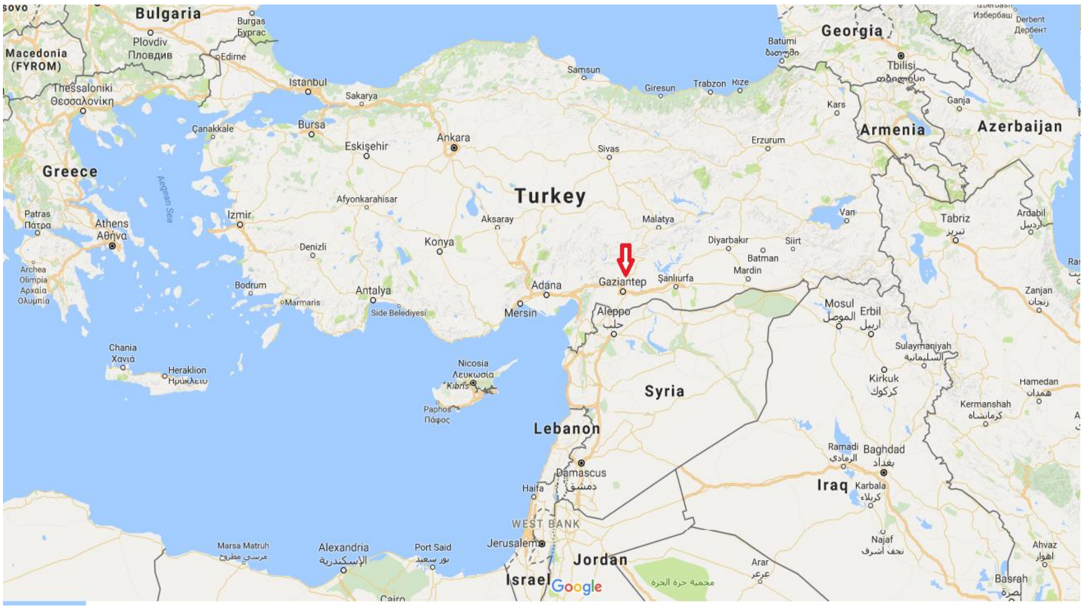

Fig. 1 *Location of Gaziantep city, Turkey (taken from Google maps database)*

2. Materials and Methods

2.1 Air Dose Measurements in Gaziantep City Center

Environmental natural radiations are due to terrestrial and cosmic radiation. Hence, from terrestrial radiation point of view mostly gamma radiation intensity varies depending on the soil type and geographical structure in the region.

In the present measurements, Thermo FH 40 G10 Dose Rate Measuring Unit (it is also used as monitor), FHZ 502 E 2”x2” NaI (Tl) probe and Magellan eXplorist 510 GPS are used. Dose rate measuring unit was used for measuring ambient equivalent dose rate of gamma and x-rays, and FHZ 502 E probe was used for high sensitivity gamma radiation measurement. The detectors were placed 1m above from the ground [3]. Radiation levels were recorded in $\mu Sv\ h^{-1}$ and gamma counting in count per second (cps). In this work, absorbed gamma dose rate in the air and gamma counting rates in terms of counts per second were determined in 40 designated stations from the various regions in Gaziantep city center. The average values of ambient dose rate and gamma counting rates in the city center are given in detail Table 1. Additionally, Fig. 4 and Fig. 5 shows counter maps of effective dose rate and gamma counting.

Soil samples were collected from the measurement points whose coordinates determined by GPS. When selecting this measurement point it was noted to be close to residential areas and to be open and flat areas. At these points, 1 kg of the soil samples from the first 10 cm of topsoil were collected from uncultivated fields.

Then, the samples were brought to the laboratory in plastic bags. All these samples were dried at 105 °C for 24 hours. After drying, each sample was placed into plastic containers of 100 ml sieving by sieve of 2 mm thick. Cover is closed and edges of cover are wrapped up with parafilm to prevent radon gas output. The prepared samples were stored to equilibrate radionuclides with their decay products for 40 days [4].

The radioactivity of ^{226}Ra, ^{232}Th and ^{40}K in samples was determined using ORTEC model gamma ray spectrometry system consisting of 3”x3” NaI(Tl) detector connected to a multichannel analyser (MCA). Detector was shielded with about 6 cm thick layer of lead in order to prevent external background radiation from the environment and calibrated with reference materials. For the correct radioactivity analysis, the energy calibration of NaI(Tl) detector should be performed before experimental measurements with known radioisotopes. Then the spectra in the computer memory will be compared with the measured spectra of collected samples. In order to make the energy calibration, the energy of the gamma rays emitted by known radioactive sources must be used. In this work the standard sources (^{137}Cs (661.6 keV) and ^{60}Co (1173 keV-1332.5 keV)) first were placed in front of the detector and then its spectrum was recorded by the computer [10].

Table 1. *Effective dose rate and gamma counting measured with portable detectors center of Gaziantep city.*

Station no	Ambient Dose Rate* (nSv h^{-1})	Gamma Counting Rate** (cps)	Station no	Ambient Dose Rate* (nSv h^{-1})	Gamma Counting Rate** (cps)
1	8.36	49.9	**21**	8.52	40.8
2	6.53	68.8	**22**	8.77	52.1
3	7.73	51.4	**23**	8.87	38
4	9.37	58.1	**24**	7.89	53.7
5	7.46	56.7	**25**	7.38	51.3
6	10.50	57.8	**26**	8.77	33.7
7	7.11	57.2	**27**	9.09	40.1
8	6.36	56.4	**28**	7.20	57.3
9	6.64	42.6	**29**	8.75	54.2
10	7.24	49.7	**30**	8.22	43.6
11	8.43	58.3	**31**	6.96	31.1
12	7.39	49.5	**32**	6.26	44.8
13	7.36	51.8	**33**	6.29	48.2
14	8.38	50.8	**34**	7.30	48.8
15	6.73	54.0	**35**	8.67	68.1
16	8.11	50.1	**36**	8.51	43.7
17	7.24	50.6	**37**	7.53	56.3
18	6.02	52.8	**38**	6.23	42.8
19	7.12	42.0	**39**	7.71	63.7
20	8.36	45.5	**40**	6.51	50.7

H(10) is defined in ICRU 51
** cps: counts per second

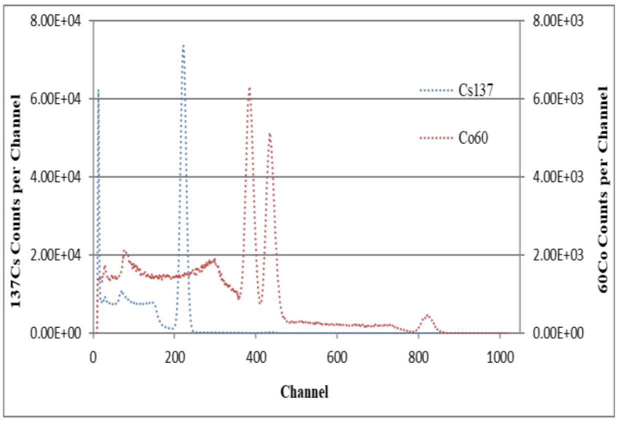

Fig.2 *^{137}Cs and ^{60}Co spectrums used for energy calibration.*

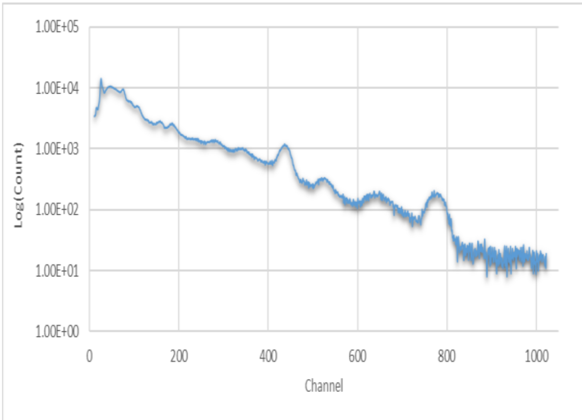

Fig.3 *A typical soil sample spectrum.*

The measurements were taken 55000 seconds by the NaI(Tl) gamma spectrometer for each sample. ^{40}K activity from its gamma peak, ^{226}Ra and ^{232}Th activities from daughter radionuclides' (^{40}K (1460keV), ^{214}Bi (609keV) and ^{218}Tl (2614keV)) peaks in secular equilibrium with themselves are determined by spectrums taken from NaI(Tl) detector gamma spectrometry system [5].

There is a relationship between activity concentrations of each radionuclide in the samples and doses which human being received from external gamma radiation sources. A great part of the environmental gamma radiation comes from radionuclides present in soil and rock.

After the samples were counted with detector, the net peak area under interested peak in the measured spectrum should be calculated to obtain the activity of the samples. In this work; a commercial Ortec ScintiVision software program was used for calculation of peak area. This program is commonly used to calculate the area of a single peak. ScintiVision peak area calculation is based on Covel Method. [6]. The Minimum

Detectable Activity (MDA) was then calculated by the following formula [6]:

$$MDA = \frac{2.71 + 3.29\sqrt{2 \times \sum_{i=l}^{h} C_i}}{\varepsilon \times T \times \gamma_d} \quad (1)$$

Where; C_i is the channel contents of background channel, l is peak lower limit, h is peak higher limit, ε is efficiency at the peak energy, T is live time of the acquisition γ_d is branching ratio. Theoretically, if a nuclide activity exceeds the lower detection limit, the peak will be calculated. For the peaks of ^{214}Bi (609keV), ^{40}K (1460keV) and ^{208}Tl (2614keV), MDA values are determined to be 9 Bq/kg , 47 Bq/kg and 15 Bq/kg, respectively.

Activity is defined as number of decayed nuclei per unit of time, and it can be determined by Eq. (2).

$$A = \frac{N_{net}}{\varepsilon t I_\gamma} \quad (2)$$

Where, calculated activity A, ε detector photo peak efficiency, t counting time, I_γ gamma emission probability per decay. N_{net} is net peak area of interest in spectrum and calculated by subtracting background radiation peak area. Specific activities of the samples were calculated by comparing the activity of the reference materials.IAEA-RGU-1, IAEA-RGK-1 and IAEA-RGTh-1. Magnitudes in experimental measurements always contain uncertainty components. They can be combined by using normal error propagation law.

2.2.1 Absorbed Dose Rate in Air

Very large proportion of contribution to natural radiation is due from activity of ^{226}Ra, ^{232}Th and ^{40}K. The dose rate conversion factors of ^{232}Th, ^{238}U and ^{40}K are used as 0.604, 0.462 and 0.0417 nGy/h per Bq kg^{-1}, respectively [7]. The contribution of terrestrial gamma radiation to absorbed doses in air can be calculated by using the following formula;

$$D(nGy/h) = 0.604 A_{Th} + 0.462 A_{Ra} + 0.0417 A_K \quad (3)$$

Where *D* is absorbed dose rate at 1 m above the ground, A_{Th}, A_{Ra} and A_K are the specific activity of ^{238}U, ^{232}Th and ^{40}K, respectively. The specific activities of the soil samples collected from Gaziantep city center and their calculated absorbed dose rates in air at 1 m above ground are given in Table 2.

Table 2. *Specific activities, gamma dose rates and annual effective doses at the stations in Gaziantep city center.*

Station no	**^{40}K (Bq kg^{-1})**	**^{232}Th (Bq kg^{-1})**	**^{226}Ra (Bq kg^{-1})**	**D (nGyh^{-1})**	**AED (μSv y^{-1}) Terrestrial**	**AED (μSv y^{-1}) Terrestrial and Cosmic**
1	106.8 ± 27.9	14.3 ± 8.2	14.9 ± 4.4	20.0	24.5	73.2
2	234.3 ± 38.7	25.8 ± 10.8	28.2 ± 5.3	38.4	47.1	57.2
3	250.3 ± 31.0	MDA	19.4 ± 4.2	27.8	34.1	67.7
5	287.8 ± 35.2	30.2 ± 8.2	28.5 ± 4.1	43.4	53.2	65.3
7	230.7 ± 34.9	26.1 ± 9.7	18.9 ± 4.7	34.1	41.8	62.3
8	274.6 ± 34.8	32.9 ± 9.1	22.8 ± 4.3	41.9	51.4	55.7
9	354.6 ± 36.4	41.7 ± 10.2	10.9 ± 4.3	45.0	55.2	58.2
10	336.1 ± 39.3	29.2 ± 9.7	29.8 ± 4.3	45.4	55.7	63.4
12	245.5 ± 35.6	31.2 ± 9.8	18.1 ± 4.7	37.4	45.9	64.7
13	480.3 ± 43.7	28.0 ± 12.8	105.3 ± 7.1	85.6	105.0	64.5
15	MDA	MDA	9.3 ± 4.1	13.9	17.1	58.9
16	180.7 ± 32.4	MDA	36.0 ± 5.1	32.6	40.0	71.0
17	107.4 ± 31.1	MDA	27.6 ± 4.6	25.6	31.4	63.4
18	229.9 ± 32.4	35.6 ± 9.7	35.1 ± 5.1	47.3	58.0	52.7

2.2.2 Annual Effective Dose

The annual effective dose is defined as the dose of radiation exposure taken by a people during a year. The annual effective dose can be calculated as follows [7 and 8];

$$\text{AED}\left(\frac{\text{mSv}}{\text{y}}\right) = \text{D}\left(\frac{\text{nGy}}{\text{h}}\right) \times 8760\text{h} \times 0.2 \times 0.7\left(\frac{\text{Sv}}{\text{Gy}}\right) \times 10^{-6} \quad (4)$$

In similar studies conducted in different countries, ratio of effective dose to absorbed dose in air is defined as 0.7 Sv Gy^{-1} for environmental gamma rays. 8760 is expressed in hours of a year and 0.2 is factor related the time spent in the external environment [7].

The annual effective doses above 1 m from the 18 station were calculated and listed in Table 2, besides counter map were given in Fig 4.

3. Results

In this work, gamma counting rates and the ambient dose rates in air, 1m above the ground were measured at 40 points in the center of Gaziantep by using portable gamma detectors. In addition, concentration of radionuclides in soil samples collected from 18 points were measured and then, depending on these values, absorbed dose rate in air and annual effective dose were calculated. The data obtained as a result of the measurements are similar to the results of previously study conducted by [2]. As a result of measurements performed using portable detectors FH 40 G10 and FHZ 502, effective dose rate (cosmic and terrestrial) varied between 5.59 nSv h^{-1} and 10.5 nSv/h with a mean value 7.62 nSv h^{-1} (66.81 μSv y^{-1}) and gamma counting varied between 31.10 s^{-1} and 68.80 s^{-1} with a mean value 50.43 s^{-1} above 1 m from the ground.

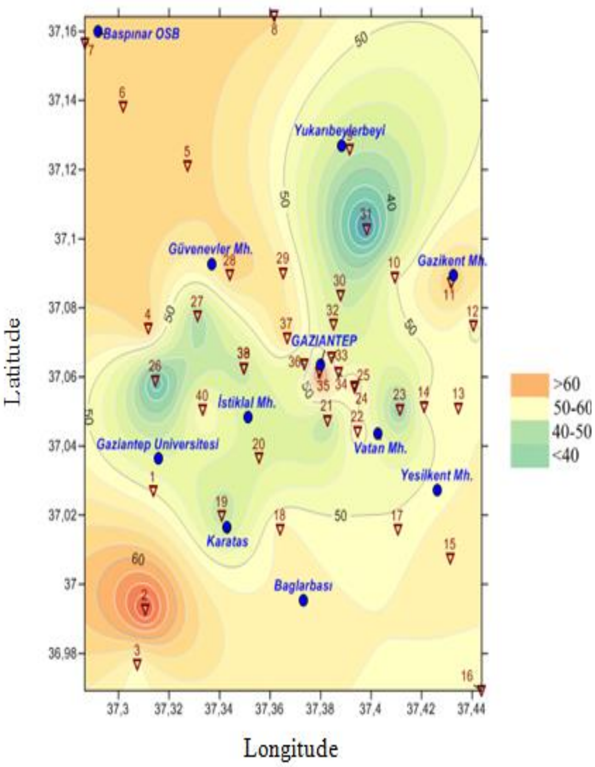

Fig. 4 *The counter map of measured effective dose rate nSv h^{-1} values on the center of Gaziantep*

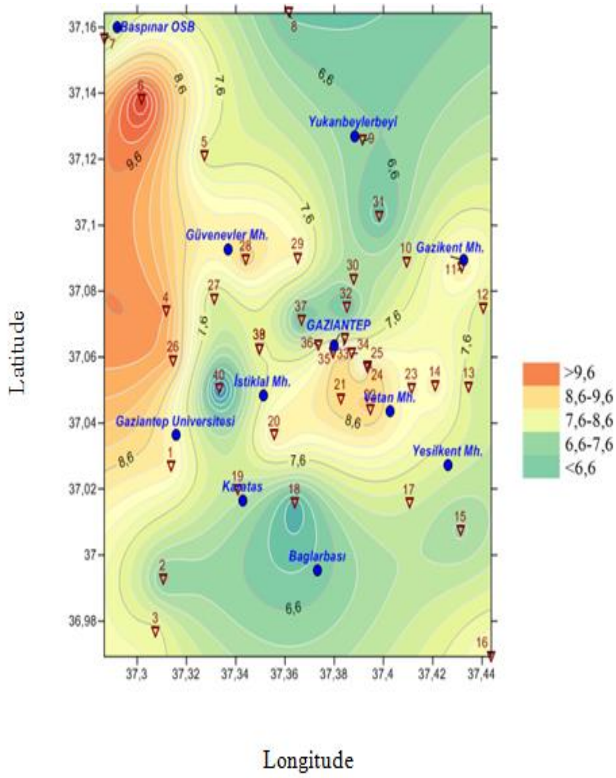

Fig.5 *The counter map of measured gamma counting s^{-1} values on the center of Gaziantep*

In measurements performed using gamma spectrometry system, the specific activities of ^{226}Ra, ^{232}Th and ^{40}K were found to be between 9.4±4.1 Bq kg^{-1} and 105.3±7.1 Bq kg^{-1}, 14.3±8.2 Bq kg^{-1} and 41.7±10.2 Bq kg^{-1}, 106.8 ± 27.9 Bq kg^{-1} and 480.3± 43.7 Bq kg^{-1}, respectively and presented in Table 2. According to specific activity results, mean activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K radionuclides for center of Gaziantep were found to be 28.9, 29.5 and 255.3 Bq kg^{-1}, respectively. The worldwide average concentrations of ^{226}Ra, ^{232}Th and ^{40}K radionuclides are reported by UNSCEAR (2000) as 35, 30, 400 Bq kg^{-1}, respectively. According to these results, specific activities of ^{226}Ra, ^{232}Th and ^{40}K at Gaziantep is slightly below the worldwide average values.

The calculated absorbed dose rate in soil samples collected from Gaziantep city center varied from 13.9 nGy h^{-1} to 85.6 nGy h^{-1} with a mean value of 38.5 nGy h^{-1}. The largest contribution to the calculated mean value absorbed dose rate in Gaziantep comes from ^{232}Th with 15.1 nGy h^{-1}.Worldwide gamma dose rate range varies between 18 nGy h^{-1} to 93 nGy h^{-1} and gamma dose rate average is 60 nGy h^{-1} [7].

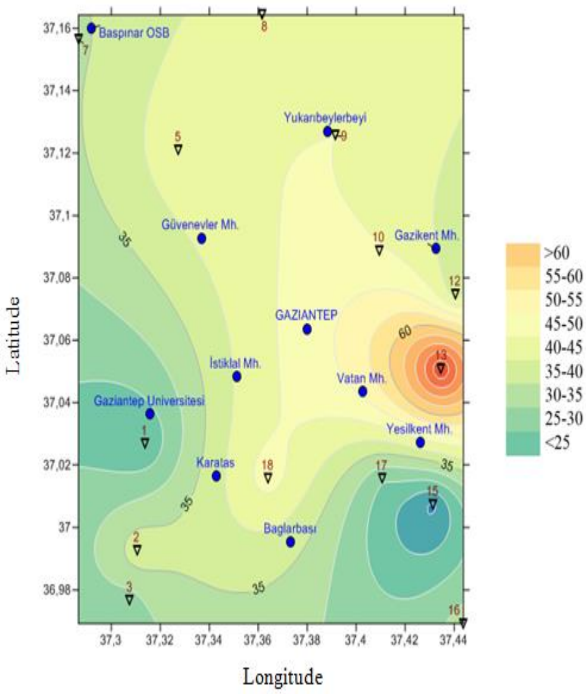

Fig. 6 *Counter map of terrestrial annual effective dose*

Table 3. *Averages (range) of activity concentrations ^{226}Ra, ^{232}Th and ^{40}K radionuclides, absorbed dose rate, annual effective dose and comparison of these results with UNSCEAR 2000 report (UNSCEAR, 2000).*

	^{226}Ra (Bq kg^{-1})	**^{232}Th (Bq kg^{-1})**	**^{40}K (Bq kg^{-1})**	**D (nGy h^{-1})**	**AED (µSv y^{-1}) (Cosmic and terrestrial)**
This work	28.9 (9.4-105.3)	29.4 (14.3-41.7)	255.3 (106.8 - 480.3)	38.5 (13.9-85.6)	66.8 (48.9-92.0)
UNSCEAR 2000	35	30	400	60	70

Above 1 m from ground the annual effective dose (terrestrial) calculated from absorbed dose rate obtained from soil samples collected from 18 points ranged between 17.1 μSv y^-1 and 105.0 μSv y^{-1}. According to these results, the average annual effective dose calculated for outdoor terrestrial gamma radiation was found as 47.2 μSv y^{-1} and the measured average outdoor gamma radiation (terrestrial and cosmic) was found as 66.8 μSv y^{-1}. The worldwide average value of annual effective dose caused by natural sources is 70 μSv y^{-1}, thus the average annual effective dose of Gaziantep city center is very close to average value of worldwide [7].

4. Conclusions

In this work, radiation dose values exposed to people living in the Gaziantep were calculated. For this purpose, air dose rate measurements and soil activity content measurements were conducted at 40 and 14 points in the city center of Gaziantep, respectively. As a result, about 1.5 million people living in the city of Gaziantep is exposed to the effective dose of about 67 μSv in a year. While about 47 μSv $y^{-1}$of these doses come from ground, the remainder is due to other radiation such as cosmic radiation. Annual effective dose value in Gaziantep is significantly lower than ICRP's limit value of 5 mSv for public [9]. Therefore, it is safe to say that there is no radiological hazard to human health in Gaziantep City caused by natural radioactivity. In addition, the results obtained in this work are also agreeable with other studies in the literature.

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Conflicts of Interest

The authors have no conflict of interest.

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