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RISK ANALYSIS AND ANNUAL EFFECTIVE DOSE DUE TO TERRESTRIAL AND COSMIC RADIATION IN THE REGION OF NIĞDE PROVINCE (TURKEY)

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Abstract. *The radiation exposure for people and all living things is inevitable. Most of these exposures are due to natural sources. Terrestrial and cosmic radiation sources are the most important contribution to these exposures which originated from the fractionation of U-238, Th-232, gamma radiation of K-40 and high-energy cosmic particles incident on the earth's atmosphere. The main contribution to these exposures comes from terrestrial sources. Terrestrial radionuclides are found in various concentrations in the crust of the earth depending on geological conditions of the region. They also cause exposure risks externally due to their gamma-ray emissions. This study assesses the terrestrial and cosmic radiation dose rates from the naturally occurring radionuclides in the region of Niğde province of Turkey. The measurements were performed on the surface soil using NaI(Tl) scintillation type gamma-ray detector. The external annual effective doses and cancer risk for people living in the region are also calculated from such terrestrial and cosmic gamma radiation dose rates for each individual.*

Key words: *Natural Radiation, Terrestrial and Cosmic Radiation, Gamma Dose Rate, Annual Effective Dose, Cancer Risk, Niğde Province, Turkey*

1. INTRODUCTION

Radiation is an energy emission that comes from a radioactive source and travels through space and may be able to penetrate various materials. Light, radio, and microwaves are types of radiation that are called nonionizing radiation. Cosmic rays, x-rays, gamma-rays, UV-rays (partly), alpha and beta particles and neutron are called ionizing radiation. Gamma photons are the most energetic photons in the electromagnetic spectrum. They are emitted from the nucleus of some unstable (radioactive) atoms. Also, all living organisms are subject to a lifelong ionizing radiation. Natural radiation includes external radiation, which are terrestrial and cosmic radiations, and internal radiation. The most important contribution to natural radiation exposures comes from radioactive nuclides that originated from the crust of earth. The naturally occurring radionuclides U-238, Th-232 and K-40 are the main sources of radiation in soil and rocks. The human body is exposed to the gamma radiation from external sources which are mainly radionuclides in the U-238 and Th-232 natural radioactive series and gamma radiation of K-40 radionuclide. These radionuclides are found in various concentrations depending on geological conditions of the region. They may cause external exposure risk due to their gamma-ray emission. They are also present in the human body and they irradiate various organs with alpha and beta particle radiations, as well as gamma electromagnetic radiation [1].

The paper shows results of the outdoor gamma dose rate in the region of Niğde province, the external annual effective doses and cancer risk for people living in the region. This study draws a general picture of the gamma radiation due to terrestrial and cosmic sources.

2. STUDY AREA AND GEOLOGICAL SETTING

The study region, Niğde province is surrounded by the provinces of Aksaray, Nevşehir, Kayseri, Adana, İçel and Konya in central Anatolia, Turkey. The region is also known as a part of the Cappadocia region. Its location is 37° 25' N - 38° 58' N parallels and 33° 10' E - 35° 25' E meridians. The Niğde province has six sub-districts which are central of Niğde, Altunhisar, Bor, Çamardı, Çiftlik and Ulukışla. The region has high mountain sequences of the Aladağlar in the east, where the highest summit is Demirkazık Mountain (3,756 m) and the Bolkarlar in the south, where the highest summit is Medetsiz Mountain (3,524 m). The Bolkarlar and Aladağlar are also parts of central Taurus Mountains in the Mediterranean region. Besides, the

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northwest region is covered with a caldera complex of Melendiz Mountain (2,963 m) in addition to volcanic structures of Hasan Mountain (3,268 m), Keçeboyduran Mountain (2,727 m) and Göllü Mountain (2,172 m) [2].

As for the geology of the region, in the study area, Upper Cretaceous to Middle Eocene aged magmatic-volcanic rocks and sedimentary rocks are widespread. Baş et al (1992) perhaps made most detailed and valuable work in between Ulukışla and Çamardı area. The authors named the magmatic rocks in the area as 'Ulukışla magmatits' and classified the plutonic rocks as diorite-gabbro and monzonite, the extrusive rocks as basalt-andesite, latite-andesite, latite and trachyte. Baş et al (1992) comments (based on the major and trace element results of the plutonic and volcanic rocks outcropped in the region) the rocks were produced by magmatic arc and the rocks were partly influenced by the mantle [3].

3. Materials and Method

Outdoor terrestrial and cosmic gamma dose rates and the altitude of the each measurement location at 34 locations were measured in the region of Niğde (Figure 1) in the summer of 2017.

The measurements were performed for about 1 minute at a height of 1 meter above the surface soil using a portable survey meter (RadEye™ NBR High Sensitivity Gamma Radiation Monitor) connected with a plastic NaI(Tl) gamma ray scintillation detector [4]. The main function of the crystal is to convert gamma ray to the photons of visible light process called scintillation. Outdoor gamma dose rates (OGDR) in the air were measured as a unit of μSv/h. Also, the annual effective dose equivalents (AEDE) were calculated using Equation 1 [5]. The annual effective dose equivalents in μSv/h include both of the cosmic ray and terrestrial components of the gamma radiation. In equation 1, DCF and OF are the dose conversion factor (DCF) from the absorbed dose to the effective dose and outdoor occupancy factor, respectively. [1]. As shown in Equations 1, the calculations for occupational factor and dose conversion factor are assumed to be 0.2 and 0.7 for adults according to the UNSCEAR 2000 datas [1].

$$AEDE = OGDR(\mu Sv/h) \times OF(0.2) \times T(8760\ h) \quad (1)$$

The estimation of lifetime cancer risk (LTCR) was calculated by equation (2):

$$ELCR = AEDE \times LE \times RFSE \quad (2)$$

LE is the lifetime expectancy at birth by Niğde province (78 years) [6], and RFSE is the risk factor for stochastic effects of the common population. The risk factor per Sievert is used as values of 0.05 Sv^{-1} according to the ICRP 1990 reports [7,8].

4. Results and Discussion

In the study, we measured external outdoor gamma dose rate with the altitude of the each measurement location in the region of Niğde province of Turkey as shown Figure 1 and Table 1.

The results of the outdoor gamma dose rate due to terrestrial and cosmic radiation in Niğde region are varied from 0.04 μSv/h (location# 27) to 0.54 μSv/h (location# 24) for 72 locations as shown in Table 1. The annual effective dose equivalent values and excess lifetime cancer risk for people living in the region were also calculated from such terrestrial and cosmic gamma radiation dose rates for each individual (Figure 2).

The main contribution to the calculated annual effective dose values comes from terrestrial sources. The average annual dose equivalent and excess lifetime cancer risk were calculated as 213.65 μSv and 7.48×10^{-4}, respectively. The average annual effective dose equivalent and excess lifetime cancer risk for people living in the region were found to be approximately three times higher than the world average of 0.07 mSv (average worldwide exposure to external terrestrial radiation) and 2.45×10^{-4}, respectively [1]. Terrestrial and cosmic radiations depend on geological conditions and altitude of the region. In our opinion, the high gamma dose measurement locations could be resulted by two geological reasons. The first probability is that there have been some fault zones along such as either active or non-active (especially northwest and east of the region) and having mountains in volcanic structure (especially north-west of the region) the high concentration localities. And second reason could be the presence of thicker plutonic (granitic, monzogranitic) settlement below the higher radioactive concentration measurement points when compared to other localities. According to the results, the highest annual effective dose equivalent rate was found to be 946.08 μSv in the Bekçili village of Çamardı district of Niğde whose highest value of the absorbed dose is also in as shown Figure 1 and 2. It can be related that the village region takes place in the region of granitic area known as Central Anatolian Massif. Because of that, higher radiation levels are associated with igneous rocks, such as granite, and lower levels with sedimentary rocks; however, some shales and phosphate rocks have a relatively high content of radionuclides as an exception [1]. In addition to general reasons, this value can be related to the fact that Bekçili region is at the highest altitude since the gamma dose rate value also includes cosmic radiation. However, the measured gamma dose values in the region generally do not depend on the altitude of the locations.

It is possible to observe such situations in some other regions of Turkey. For example, while the annual effective dose equivalent value in Kütahya changes between 96.4 μSv (Çavdarhisar region) and 1091.2 μSv (Simav region) [9], the average of this value for Artvin is 214.5 μSv [10] and for Ilgın district of Konya is 132.9 μSv [11]. The value for other countries is 740 μSv for Tehran (Iran) [12], 330 μSv for Selama district of Malaysia [13]. Besides, the average of cancer risk for some cities of Turkey and other countries was found to be 7.5×10^{-4} in the study done in Artvin (Turkey) [10], 22.9×10^{-4} in the region of Tehran (Iran) [12], 5.18×10^{-4} in the region of Ilgın district of Konya

(Turkey) [11]. This value for Selama district of Malaysia is about 5 times higher than the world average [13].

Table 1. Outdoor gamma dose rate, annual effective dose equivalent and lifetime cancer risk for people living in the region of Niğde.

No	City/District	Location	Altitude (m)	Gamma Dose Rate (μSv/h)	Annual Effective Dose (μSv/a)	ELCR Excess Lifetime Cancer Risk x 10^{-4}
1	Altunhisar	Akçaören	1236	0.12	210.24	7.36
2	Altunhisar	Akçaören	1236	0.12	210.24	7.36
3	Altunhisar	Centrum	1236	0.12	210.24	7.36
4	Altunhisar	Centrum	1236	0.12	210.24	7.36
5	Altunhisar	Uluören	1510	0.11	192.72	6.75
6	Altunhisar	Uluören	1510	0.12	210.24	7.36
7	Altunhisar	Uluören	1550	0.16	280.32	9.8
8	Bor	Bereket	1048	0.14	245.28	8.59
9	Bor	Bereket	1050	0.22	385.44	13.49
10	Bor	Centrum	1206	0.11	192.72	6.75
11	Bor	Centrum	1206	0.08	140.16	4.91
12	Bor	Çukurkuyu	1243	0.11	192.72	6.75
13	Bor	Çukurkuyu	1243	0.07	122.64	4.29
14	Bor	Kaynarca	1231	0.1	17.2	6.13
15	Bor	Kaynarca	1231	0.08	140.16	4.91
16	Bor	Kemerhisar	1089	0.09	157.68	5.52
17	Bor	Kemerhisar	1089	0.09	157.68	5.52
18	Bor	Klavuz	1443	0.07	122.64	4.29
19	Bor	Klavuz	1443	0.07	122.64	4.29
20	Bor	Postallı	1430	0.24	420.48	14.72
21	Bor	Postallı	1430	0.11	192.72	6.75
22	Bor	Seslikaya	1064	0.1	175.2	6.13
23	Bor	Seslikaya	1064	0.1	175.2	6.13
24	Çamardı	Bekçili	1968	0.54	946.08	33.11
25	Çamardı	Bekçili	1600	0.09	157.68	5.52
26	Çamardı	Centrum	1497	0.08	140.16	4.91
27	Çamardı	Demirkazık	1545	0.04	70.08	2.45
28	Çamardı	Demirkazık	1545	0.05	87.6	3.07
29	Çamardı	Üçkapılı	1892	0.18	315.36	11.04
30	Çamardı	Üçkapılı	1892	0.12	210,24	7.36
31	Çiftlik	Centrum	1554	0.14	245.28	8.59
32	Çiftlik	Kula	1568	0.15	262.8	9.20
33	Çiftlik	Kula	1560	0.11	192.72	6.75
34	Niğde	Centrum	1230	0.11	192.72	6.75
35	Niğde	Centrum	1230	0.07	122.64	4.29
36	Niğde	Gölcük	1310	0.13	227.76	7.97
37	Niğde	Gölcük	1310	0.13	227.76	7.97
38	Niğde	İçmeli	1480	0.23	402.96	14.10
39	Niğde	İnli	1355	0.14	245.28	8.59
40	Niğde	İnli	1355	0.14	245.28	8.59
41	Niğde	Karaatlı	1383	0.09	157.68	5.52
42	Niğde	Karaatlı	1383	0.15	262.8	9.20
43	Niğde	Karaatlı	1383	0.15	262.8	9.20
44	Niğde	Kömürcü	1448	0.17	297.84	10.42
45	Niğde	Kömürcü	1448	0.22	385.44	13.49
46	Niğde	Orhaneli	1603	0.06	105.12	3.68
47	Niğde	Orhaneli	1603	0.09	157.68	5.52
48	Niğde	Tepeköy	1332	0.13	227.76	7.20
49	Niğde	Tepeköy	1332	0.15	262.8	9.20
50	Niğde	Uluağaç	1440	0.05	87.6	3.07
51	Niğde	Uluağaç	1440	0.09	157.68	5.52
52	Ulukışla	Centrum	1490	0.11	192.72	6.75
53	Ulukışla	Centrum	1490	0.19	332.88	11.65
54	Ulukışla	Çanakçı	1410	0.18	315.36	11.04
55	Ulukışla	Çanakçı	1410	0.28	490.56	17.17
56	Ulukışla	Çiftehan	1006	0.09	157.68	5.52
57	Ulukışla	Çiftehan	1006	0.09	157.68	5.52
58	Ulukışla	Çiftehan	1006	0.09	157.68	5.52
59	Ulukışla	Darboğaz	1331	0.05	87.6	3.07
60	Ulukışla	Darboğaz	1331	0.13	227.76	7.97
61	Ulukışla	Eminlik	1368	0.1	175.2	6.13
62	Ulukışla	Eminlik	1368	0.1	175.2	6.13
63	Ulukışla	Güney	1331	0.15	262.8	9.20
64	Ulukışla	Güney	1331	0.11	192.72	6.75
65	Ulukışla	Ovacık	1434	0.11	192.72	6.75
66	Ulukışla	Ovacık	1434	0.11	192.72	6.75
67	Ulukışla	Tekneçukuru	1386	0.11	192.72	6.75
68	Ulukışla	Tekneçukuru	1386	0.1	175.2	6.13
69	Ulukışla	Tepeköy	1255	0.05	87.6	3.07
70	Ulukışla	Tepeköy	1255	0.06	105.12	3.68
71	Ulukışla	Yeniyıldız	1542	0.06	105.12	3.68
72	Ulukışla	Yeniyıldız	1542	0.06	105.12	3.68

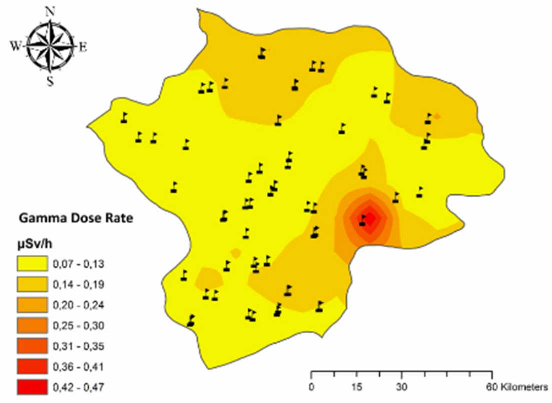

Figure 1. Gamma dose rate distribution in the study region

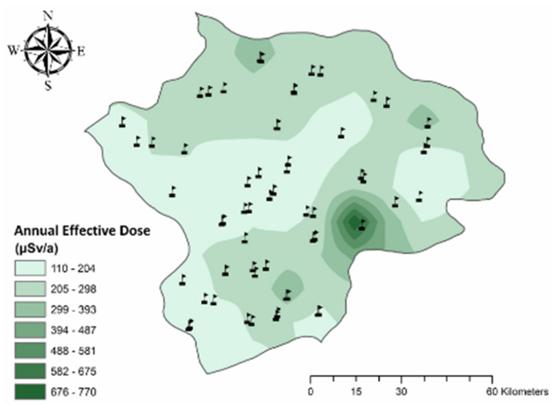

Figure 2. Annual effective dose value distribution for the people living in the region

5. Conclusion

In this study, we measured the terrestrial and cosmic radiation dose rates from the naturally occurring radionuclides in the region of Niğde province of Turkey. The average annual effective dose equivalent and excess lifetime cancer risk for people living in the region were found to be 213.65 µSv and 7.48 x 10^{-4}, respectively. These values are approximately three times higher in comparison to the world average. This situation can be related to the fact that the study area has some active and non-active fault zones, thicker plutonic settlement and volcanic and high altitude mountains. For this reason, these measurements and risk analyses should be repeated in this region in the years to come.

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