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Exposure Analysis at the Territory of Nevşehir (Cappadocia) due to Additive Gamma-rays in Air, Turkey

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Abstract: Radioactivity measurements for water, soil, and air have been completed in national and international regions. The radioactivity process is randomized and occurs naturally by primordial nuclides. Another case is hand-made reactions which realized by artificial reactions. The high rate of the total dose of radiation, whichever is exposed to humans, originates as Natural Radioactivity. In this case, environmental radioactivity measurements are important to investigate the background radiation level, especially for primordial radioactive sources. This radiation which measured outdoor gamma dose includes both cosmic rays and terrestrial elements. Terrestrial radiation can be measured via gamma-ray spectroscopy separately. By the way, cosmic effects would be calculated by subtracting terrestrial from measured outdoor gamma dose. Scientific Committee (UNSCEAR, 2000) declares the annual dose for humans as 2.4 mSv. The radionuclides present in soil samples (terrestrial components) are considered responsible for a portion of this amount (1). Rest amounts are originated water (2) and air, too.

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INTRODUCTION

Literature Survey

Over the past two decades, a few results about radioactivity levels have been published in some papers related to gamma dose rates in the air for Turkish provinces (3-14). There is no study specifically for the Nevşehir region in the literature. Therefore, the purpose of our effort is to measure dose rates in the air from different locations throughout the city and, in this way, to determine the cancer risk. The human population in this city is up to one million, and this study will be the baseline for subsequent studies about environmental radioactivity measurements. By the way, there are also stated worldwide studies in the literature. For example, Licínio MV and friends have evaluated in 2013 for Brazil (15). Another study by Ghiassi-Nejad and Mortavazi in 2002 indicates the absorbed dose rates in air (ADRA) values concerning the Ramsar region of Persia. They studied the effects of radiation on human life. The annual dose was also calculated (260 mSv), and found higher than the stipulated annual limit of 20 mSv in North Persia. Cytogenetic studies show no significant differences between people in the high background compared to people in normal background areas (16). The third study with Arnedo MA and coworkers reported the natural radioactivity of soils in the eastern Canary islands (17).

MATERIAL AND METHODS

Airborne Radiation and its Reading

Airborne radioactivity could be assigned on the spectrum on the spectrum peaks' one by one, showing the related nuclides. Radionuclides will very rapidly appear in ground-level air, and air samples can give the first indication on the nature of the contamination. Radioactive elements in the air could reduce due to human inhalation. Gamma dose rates were measured using a counter (reader: Eberline, ESP-2) as a mobile device and connected to the detector as a SPA-6 model plastic scintillator. The instrument was kept up to 1 m from the soil surface, and at the sampling point, the

measurement duration was 60 seconds. Then the average dose rates were recorded. The main instrument is ESP-2.

The detector is connected through a coaxial type MHV series. The readout function has been shown in 2×16 alphanumeric display-LCD. This ratemeter is operated by the CPU@ Intel_80C31 processor family and has external RAM- 8 KB and EPROM is 16 KB. The scintillation detector body, SPA-6, which is connected to the counter (ESP-2), was selected to optimize its output for the radiation of interest. It provides the pulse signal to the electronics in order to the readout. On the detector side, the pulse rate is proportional to the intensity of radiation. The high voltage supply offers the required bias potential to the detector. This voltage is keyboard adjustable, and it controls the correct operating voltages for different detectors. The low voltage supply regulates the operating voltage for the ESP-2 electronics, as shown in Figure 1 (18). The amplifier is linear and amplifies the probe's signal to a functional level at the amplifier output. The discriminator provides a signal on its output only if the amplifier's signal exceeds the adjustable threshold. It provides rejecting for noise and unwanted signal.

Figure 1: ESP-2 Rate meter and SPA-6 scintillation detector, Eberline (18).

Measuring Area

Cappadocia (Nevşehir), one of Turkey's central regions, is a neighbor to the capital city of Ankara. Its coordinates are between 38.154 to 38.9428 N as latitude and 34.1747 to 34.9038 E as longitude. The highest point is Ercas (1982 m), and other points are Hodul (1949 m) and Kızıldağ (1768 m). The province of Nevşehir is surrounded by 18% mountain, 25% plain, 57% plateau, and hillside. The province was settled on the west side of a large plateau formed by ash and volcanoes, in the Anatolian span. River Kızılırmak is separated into two all city of Nevşehir. The climate is terrestrial, like cold-dry winters and hot, dry summers. The region's area is 5467 km^2 (19), and its population is 0.16 million (19). Nevşehir's map is shown in Figure 2.

RESULTS

Outdoor Dose Rates as Additive (Terrestrial and Cosmic Ray Effects)

Absorbed gamma doses are originated from terrestrial and cosmic rays together. In order to obtain the absorbed gamma dose rates in the air, the instrument was kept about 1 meter upperside from ground level. It is important to know how much exposure in the air to human gonads is about this level. The human gonad is the most vulnerable organ to radiation damage. Annual doses in the air were also calculated by using the gamma dose rates. In this case, measurements were perfected for a total of 45 different points. Dose rate map was shown in Figure 3.

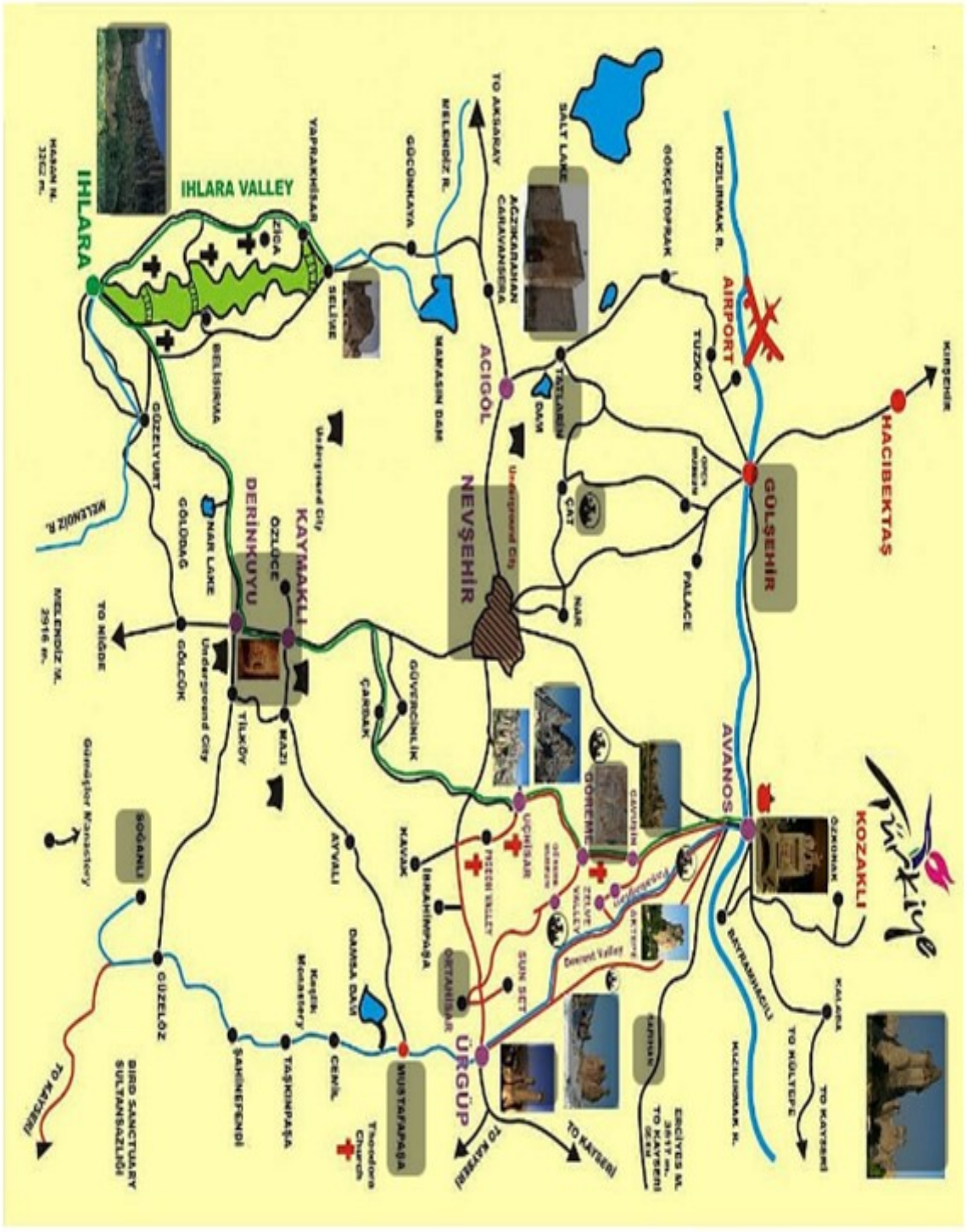

Figure 2: Regional roadMap of Nevşehir, Turkey (20).

Table 1: Dose rates, coordinates, and altitudes of Cappadocia's sampling points.

Name of measuring district	Dose Rate [nGy h^{-1}]	Latitude (pointed)	Longitude (pointed)	Altitude (meter)
Ihlara Valley	192.06	38.1540	34.1747	1180
Derinkuyu1	157.14	38.3735	34.7354	1350
Derinkuyu2	165.87	38.3737	34.7344	1350
Uçhisar1 (center)	200.79	38.6205	34.8049	1340
Uçhisar2 (center)	192.06	38.6314	34.7972	1310
Uçhisar3 (center)	165.87	38.6291	34.8070	1300
Paşabağları (Ürgüp)	192.06	38.6773	34.8560	1020
Çavuşin (Avanos)	183.33	38.6767	34.8575	1050
Göreme1 (center)	130.95	38.7274	34.8214	940
Göreme (Open air museum1)	165.87	38.6386	34.8451	1140
Göreme (Open air museum2)	192.06	38.6384	34.8453	1140
Göreme (Open air museum3)	183.33	38.6385	34.8455	1150
Göreme (Open air museum4)	200.79	38.6382	34.8457	1140
Göreme (Open air museum5)	192.06	38.6384	34.8458	1150
Göreme (Open air museum6)	226.98	38.6389	34.8461	1140
Göreme (Open air museum7)	139.68	38.6432	34.8366	1130
Göreme (Open air museum8)	157.14	38.6403	34.8450	1120
Göreme (Open air museum9)	192.06	38.6411	34.8440	1100
Göreme (Open air museum10)	174.60	38.6397	34.8448	1130
Cappadocia (central1)	174.60	38.6288	34.7158	1190
Cappadocia (central2)	183.33	38.6289	34.7228	1190
Cappadocia (central3)	**392.85**	38.6282	34.7240	1200
Cappadocia (central4)	157.14	38.6281	34.7245	1200
Cappadocia (central5)	192.06	38.6277	34.7256	1210
Cappadocia (central6)	200.79	38.6280	34.7264	1210
Cappadocia (central7)	174.60	38.6282	34.7268	1210
Cappadocia (central8)	157.14	38.6278	34.7271	1220
Cappadocia (central9)	139.68	38.6279	34.7275	1220
Cappadocia (central10)	200.79	38.6278	34.7281	1230
Cappadocia (central11)	139.68	38.6274	34.7281	1230
Cappadocia (central12)	158.89	38.6279	34.7273	1230
Cappadocia (central13)	185.08	38.6275	34.7264	1220
Cappadocia (central14)	**107.38**	38.6265	34.7250	1210
Cappadocia (central15)	139.68	38.6276	34.7241	1210
Cappadocia (central16)	200.79	38.6278	34.7223	1190
Cappadocia (central17)	157.14	38.6271	34.7203	1190
Avanos1	192.06	38.6876	34.8329	950
Avanos2	148.41	38.7017	34.8417	950
Avanos3	134.44	38.7013	34.8421	930
Avanos4	192.06	38.7027	34.8403	950
Ürgüp (Üç Güzeller)	165.87	38.6411	34.8440	1170
Ürgüp (Turasan1)	157.14	38.6329	34.9038	1130
Ürgüp (Turasan2)	183.33	38.6373	34.8446	1130
Ortahisar (Derbent)	192.06	38.6725	34.8855	1070
Hacıbektaş	**209.52**	38.9428	34.5625	1300
Nevşehir (45)	**178.69 nGy/h**	**Average value of ADRA**		

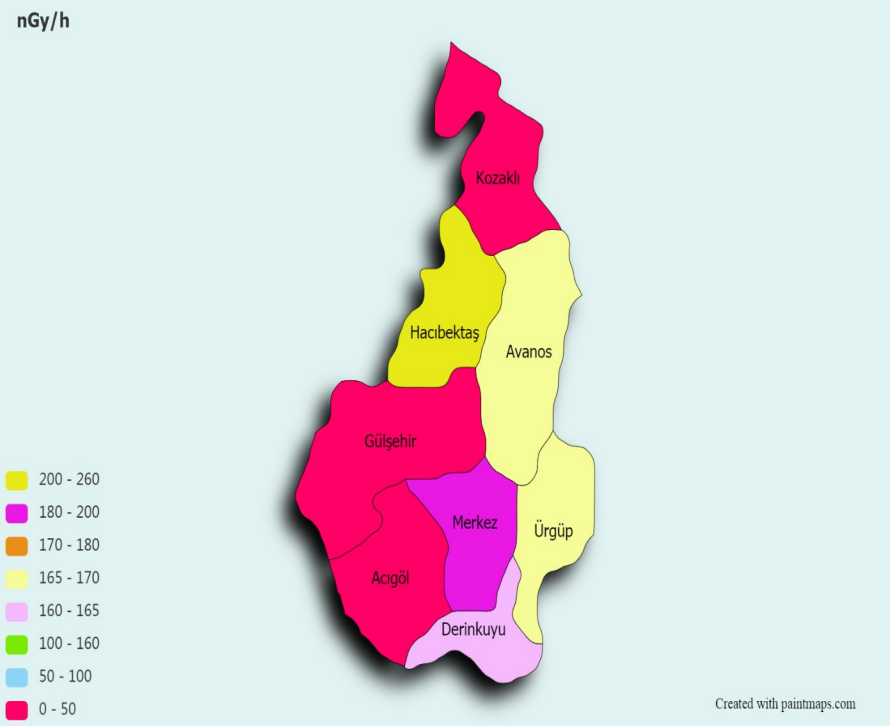

Figure 3: Outdoor Gamma Dose Rate map for Cappadocia district (Nevşehir)(21).

Calculations

Annual Effective Dose Equivalent (AEDE) and Excess Lifetime Cancer Risk (ELCR) were calculated in the literature using ADRA (1):

AEDE= ADRA* DCF* OF* T (Eq. 1)

ELCR= AEDE* DL* RF (Eq. 2)

DCF signs the dose conversion factor (0.7 Sv Gy^{-1}), OF is outdoor occupancy factor (0.2), T is the exposure time (8760 h y^{-1}). DL is the duration of life (70 years), RF is a risk factor (Sv $^{-1}$) as fatal cancer risk per Sv [calculate to stochastic effects; ICRP 60 (22)] uses the value of 0.05 for the public (ICRP, 2007).

ADRA values were handled from Table 1 and applied upper formulas. Calculated values for AEDE and also ELCR are shown in Table 2 with average altitudes as regionally**.**

Table 2: AEDE and ELCR values for Cappadocia.

Name of measuring district [number of m. point]	Av. ADRA [nGy h^{-1}]	Av. AEDE [μSv]	Av. ELCR [(x10^{-4})]	Av.Altitude (meter)
Ihlara Valley [1]	192.06	235.47	8.24	1180
Derinkuyu [2]	161.51	198.01	6.93	1350
Uçhisar [3]	186.24	228.33	7.99	1316
Paşabağları [1]	192.06	235.47	8.24	1020
Çavuşin [1]	183.33	224.76	7.87	1050
Göreme [11]	177.78	217.96	7.63	1116
Cappadocia- central [17]	180.10	220.80	7.73	1209
Avanos [4]	166.74	204.42	7.16	945
Ürgüp [3]	168.78	206.92	7.24	1143
Ortahisar [1]	192.06	235.47	8.24	1070
Hacıbektaş [1]	209.52	256.87	8.99	1300
Nevşehir [45]	**178.69**	**219.07**	**7.67**	1162

The frequency distribution of annual gamma doses is shown in the figure below (4.a.) by the related linear fitting curve and its R^2 equation. Another graphic (figure 4.b) shows the ELCR values with a logarithmic curve and its R^2 equation.

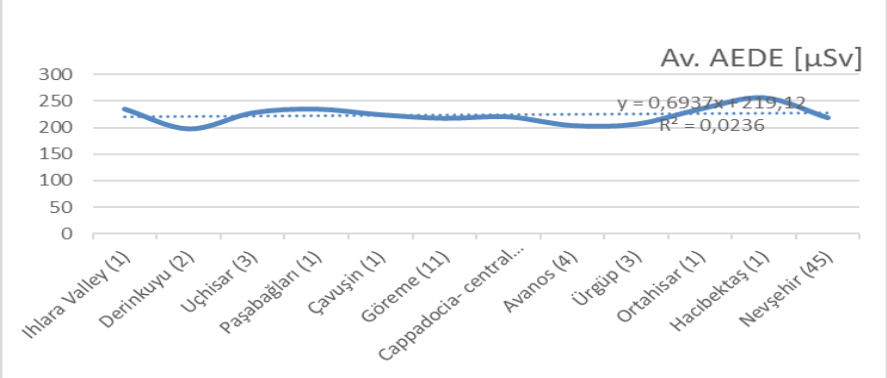

Figure 4.a.: Frequency Distribution of AEDE for Cappadocia (Nevşehir) district.

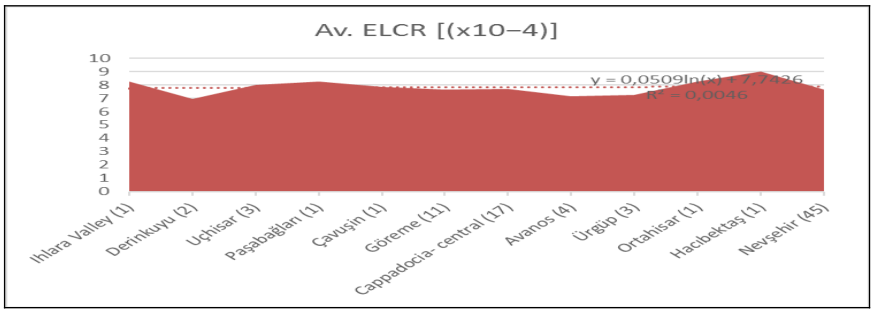

Figure 4.b.: Frequency Distribution of ELCR for Cappadocia (Nevşehir) district.

Statistics

Standard deviations

Using the group data such as AEDE and ELCR values of districts (Table 2), it is easy to calculate standard deviations. The standard deviation of AEDE is 10.31 and for ELCR is 0.36. The deviation rate is not as low as 4.7% for both AEDE and ELCR values. annual critical values are 219.07±10.31 µSv and 7.67±0.36 (x10^−4). Related bar charts are shown in Figure 5.

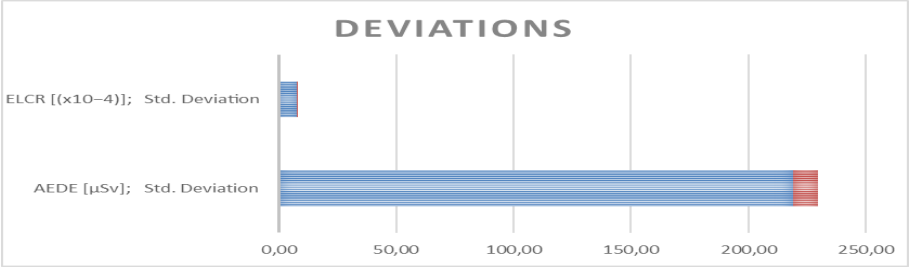

Figure 5: Bar chart for both AEDE and ELCR values and their deviations.

Comparison with literature

The data in Table 4 pertain to the Figure 6 distribution of Excess Life Time Cancer Risk corresponding to the Annual Effective Dose Equivalent.

Table 4: Comparison for AEDE and ELCR values regarding gamma dose rates.

(ref no), Region, [nm of samplings]	(AEDE) [µSv], average	ELCR [(x10^{-4})], average	Reference
(02) Hatay [39]	7.50 (only alpha)	0.26	(2)
(03) Adana	82.00	2.87	(3)
(04) Ankara [341]	71.83	2.69	(4)
(05) Artvin [204]	214.50	7.50	(5)

(06) Balıkesir [92]	156.30	6.30	(6)
(07) Bolu [74]	27.23	0.95	(7)
(08) Çanakkale [379]	81.40	2.85	(8)
(09) Edirne [14]	47.30	1.66	(9)
Kocaeli [35]	29.31	1.02	(np)
Hatay [215]	63.93	2.24	(np)
(10) IDA [75]	198.66	6.95	(10)
(11) İstanbul [105]	79.72	2.79	(11)
(12) Kastamonu [60]	58.88	2.06	(12)
(13) Şanlıurfa	74.70	2.62	(13)
(14) Van	142.59	4.99	(14)
This work [45]	219.07	7.67	(tw)
(23) Nevşehir [RESA]	306.50	10.73	(23)
(1) World	73.60	2.58	(1)
(15) R. D. J.- Brazil	90.00	3.15	(15)
(16) Ramsar- IRAN	105.00	3.68	(16)
(17) Canary I- Spain	91.95	3.22	(17)

(np): Not published yet. (tw): This work.

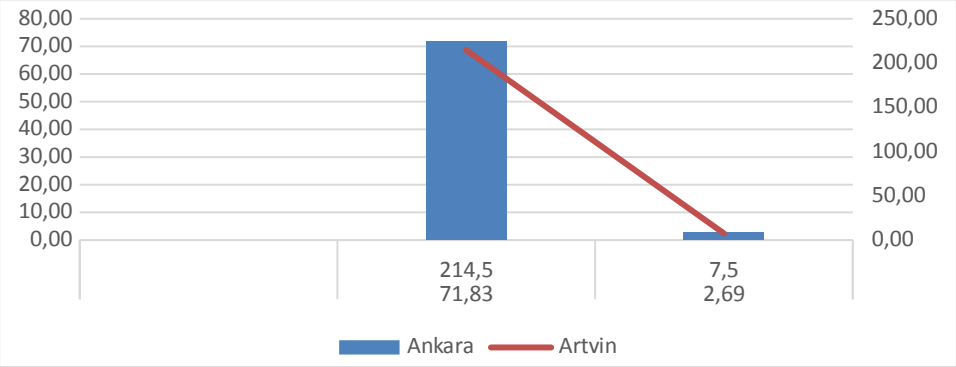

Figure 6: Graphical distribution of AEDE and ELCR [μSv; x10^{-4}].

Comparison to RESA

TAEK, the Turkish Atomic Energy Agency, periodically measures the natural radiation in the air by RESA (23) system, consisting of a Geiger detector and reader. Due to this system's locations, there is one measuring point referenced as the central county of Nevşehir province. Below pictures are referred the RESA system in Figure 7.

Figure 7: RESA; detector- counter and control center, TAEK (23).

RESA's online value was 175 nSv h^-1, which corresponds to 250 nGy h^{-1}. This dose rate indicates to AEDE value of 306.50 (μSv) and ELCR value as 8.75 (x10^{-4}). The average of our measurements is 178.69 nGy h^{-1}. Due to our measurements, the minimum rate was 107.38, and the maximum rate

was 392.85 $nGyh^{-1}$. There are a few possible reasons due to this difference. There are a few possible reasons for this difference. One of them is that our measurements are not for only one fixed point on the RESA system. Another reason could be the measurement times. Our measurements are not conducted periodically as well as RESA's. Annual doses and cancer risks were compared by the below figure, too.

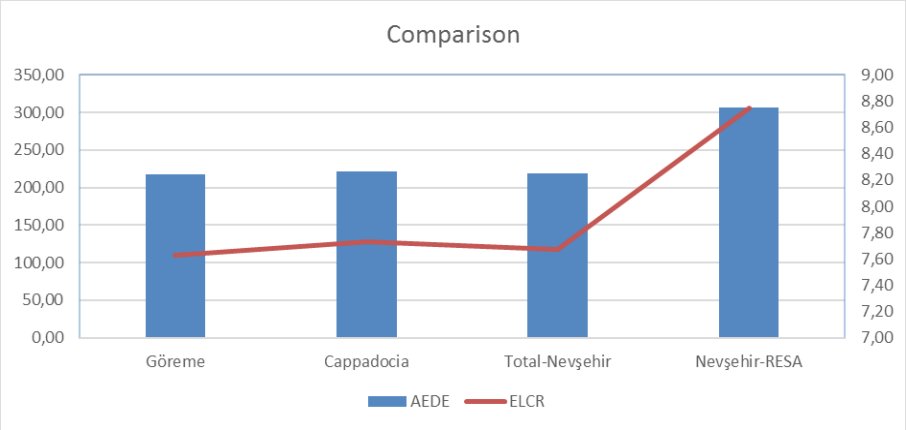

Figure 8: Horizontal Bar chart and line graphic [AEDE in μSv; ELCR, $x10^{-4}$]

CONCLUSION

Due to the measurement results, minimum, maximum, and average dose rates in Cappadocia are 107.38, 392.85, and 180.10 nGy/h, respectively. For the other touristic destinations, namely Avanos and Ürgüp, average dose rates are so close to each other as 166.74 to 168.78 nGy/h, respectively. For Hacıbektaş county, in which the minimum population of Nevşehir lives, the dose rate is 209.52 nGy/h. The average dose rate of Nevşehir is 178.69 nGy/h, and this rate refers to 219.07 μSv as the annual dose. It also refers to 7.67 ($x10^{-4}$) as a cancer risk. These values are a little higher than Artvin's values. They also refer to values three times higher than the world's references. Nevşehir is a well known tourist county without sea-sand-sun trio, so gamma-radiation levels are important for visitors as well. Nevşehir is in the middle of Anatolia, especially the north-south axis. Existing nuclear power reactor buildings in Mersin are less than 300 km away, and it is important to get setting parameters to compare after a possible radioactive fallout. The present study findings' serve as a reference for future studies.

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