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Research Article

EVALUATION OF EXCESS LIFETIME CANCER RISK CAUSED BY EXTERNAL EXPOSURE DUE TO NATURAL RADIOACTIVITY IN BOLU, TURKEY

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ABSTRACT

In this study, the gamma dose rates in outdoor air at seventy-seven points around Bolu province were meausured using a counter (Eberline, ESP-2). Radiological hazards were evaluated by estimating the excess lifetime cancer risks caused by external exposure. The gamma dose rates measured varied from 11 to 68 nGyh^{-1}with an average value of 22 nGy h^{-1}. The avarege value of the corresponding outdoor annual effective dose and the excess lifetime cancer risk was found as ***27.23 µSv** and **0.95x10^{-4}**, **respectively**. These values could be compared to other studies which existed in Turkey and also in the world.*
Keywords: Outdoor gamma dose rate, natural radioactivity, scintillation detector, AEDE, cancer risk, Bolu.

1. INTRODUCTION

Radionuclides, which exposed to people, exist as naturally and artificially on the Earth. Radioactive elements stated in rocks and artificially obtained radionuclides cause the formation of environmental gamma radiation. Examining the Earth's geological structure, it is seen that there are rock beds at a certain 30 cm thickness just beneath the soil layer. It is known that a significant part of the gamma radiation is originated from the surface layer at 0-25 cm depth. Randomize events as radioactivity occurs naturally (caused by primordial nuclides) or by handmade (originates to artificial processes). The largest contribution to total radiation dose whichever received by humans comes from Natural sources. Depending on the sources like terrestrial and cosmogenic natural radioactivity; environmental measurements are required to determine the background radiation level. The terrestrial component of the background is originated from various radioactive nuclides. The levels of radionuclide (in soil, water, and air) change depending on the geological and geographical characteristics of the zone. The natural radiation consists of cosmic rays and terrestrial components. Terrestrial radiation can be measured via gamma-ray spectroscopy separately. By the way, cosmic effects would be calculated by subtracting of terrestrial from measured outdoor gamma dose, too. The United Nations Scientific Committee on

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the Effects of Atomic Radiation (UNSCEAR, 2008) estimates the global average human exposure from natural radiatio n sources as 2.4 mSv per year and the radionuclides that are present of *soil* samples (it is terrestrial component) are considered to be responsible for a portion of this amount [1]. Rest amounts are originated water and air, too. In this study, gamma dose rates, which are caused by natural radionuclides in the air, were calculated by taking measurements at 74 different locations 1 m from the ground at Bolu city and its vicinity.

2. LITERATURE SURVEY

Over the past two decades, a few results due to radioactivity levels have been published in some papers related to gamma dose rates in the air for Turkish provinces ([7] to [16]). Besides, there are many worldwide studies in the literature. As an example of them; in 2002, Ghiassi and Mortavazi have measured the absorbed gamma dose rates in the air for the Ramsar region of Persia. They have studied the effects of radiation on human life. The annual dose was also calculated that it is 260 mSv and this value is higher than the stipulated annual limit of 20 mSv in North Persia. In genetic works, the effects of this high level were obtained the difference of the blood lenfosid samples of humans [18]. Nearby, there is any study for Bolu province realized in literature. Therefore, the purpose of this study is to measure dose rates in the air from different locations throughout the province of Bolu, and then assess the cancer risk to human life by calculation of the outdoor gamma dose. The human population in this city is up to three hundred thousand and this study will be a baseline for next studies about environmental radioactivity measurements, too.

2.1. Measuring Area

Bolu region is located in the west Black Sea Region between 30º 32' and 32º 36' east longitudes, 40º 06' and 41º 01' northern latitudes (map is shown in Figure 1). Bolu is a preferred region especially for winter tourism and thermal tourism. In addition, Industrial districts located in various places, Bolu University and hospitals provide employment and intensity in the city. It is considered necessary to investigate this area as it is a region that the public has visited frequently for different reasons. The average temperature is 24.08 °C and the average rainfall is 65 mm. The region spans an area of 8276 km^2 and with a population of about 0.3 million [2].

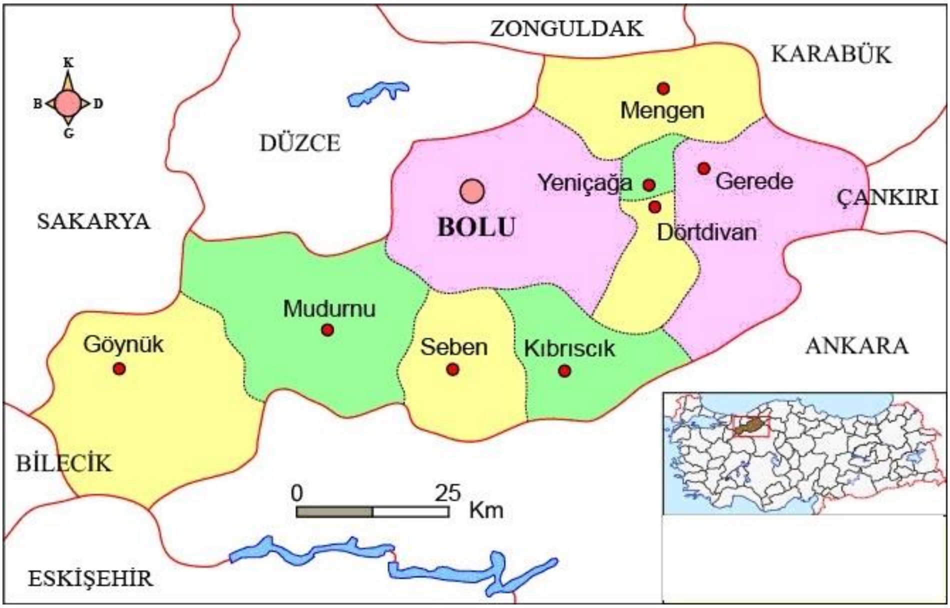

Figure 1. Regional Map of Bolu Province, Turkey [3]

2.2. Inhalation

Airborne radioactivity is important to identify the visual as a spectrum or the abundance as intensity by radionuclides making up the contamination. Radionuclides will very rapidly appear in ground-level air, and air samples can give the first indication of the nature of the contamination. Radioactive materials in the air may result in exposure to humans by inhalation.

2.3. Measuring points for gamma dose rates in air

In this study, Coordinates are assigned by the GPS instrument which Magellan Explorist 510 and these values are recorded in Table 1. Dose rate map also was shown in Figure 2, too.

Table 1. Coordinates as classified due to counties of Bolu for totally 74 different samplings

County Name (sampling pcs)	Latitude (limits)	Longitude (limits)
Bolu- center (36)	40,60505 - 40,78414	31,56857 - 31,73905
Dörtdivan (4)	40,71443 - 40,72296	32,05771 - 32,06561
Gerede (7)	40,79343 - 40,80222	32,18495 - 32,21336
Göynük (4)	40,39563 - 40,40259	30,78166 - 30,79121
Kıbrıscık (1)	40,40993	31,84785
Mengen (8)	40,93111- 40,94618	32,06432 - 32,08451
Mudurnu (5)	40,46313 - 40,46603	31,21092 - 31,21288
Seben (4)	40,40719 - 40,40875	31,57052 - 31,57283
Yeniçağa (5)	40,76986 - 40,77374	32,02476 - 32,03844
BOLU (74)	**40,39563 - 40,94618**	**30,78166 - 32,21336**

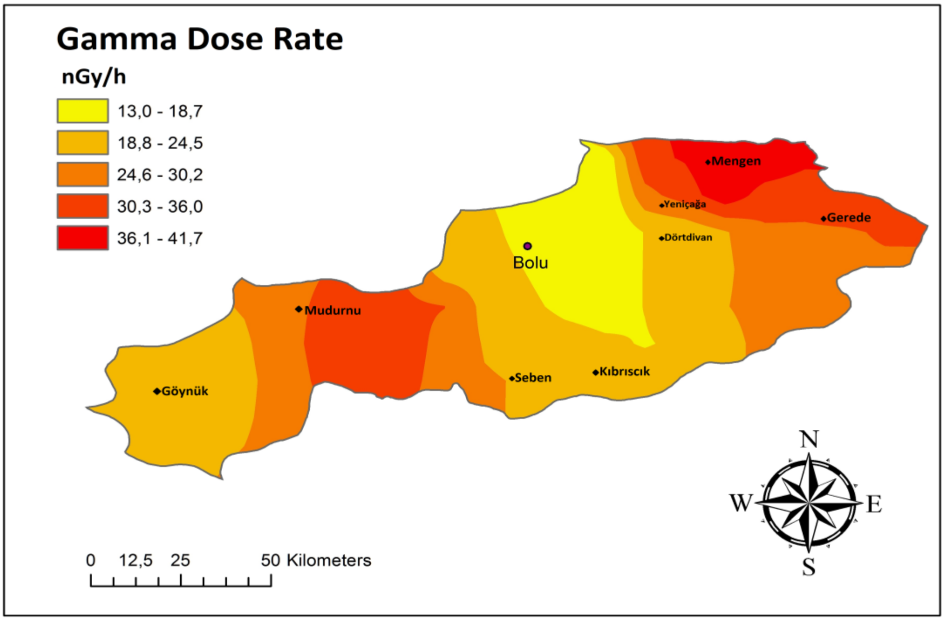

Figure 2. Map for Sampling Points in dose rate diagram [4]

2.4. Measurement System

The measurements around Bolu province were realized by using a counter (Eberline, ESP-2) portable device that required for the reading process. It is wired to SPA-6 plastic scintillator which placed in order to detect function. The instrument was kept up to 1m 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 the ESP-2. The detector is connected to the reader via an MHV-series cylindrical connector. The readout of the counter has been presented with a 2×16 alphanumeric (LCD) display. This ratemeter is operated by the CPU/Intel 80C31 processor family and has got external RAM 8KB, EPROM 16KB. The scintillator and reader were fitted to realize its output. *It is provided the pulse signal to the electronics for counting*. The pulse rate that the output of the reader, is proportional to the radiation intensity by detected by the sensor. The high voltage supply provides the required bias voltage to the SP-6. The adjustable voltage operates the optimized voltages for a large selection of detectors. The low voltage supply regulates the operating voltage for the ESP-2 electronics (Figure 3). The amplifier is a linear, adjustable gain, multistage design. It amplifies the signal from the probe to a usable level at the amplifier output. The discriminator provides a signal on its output only if the signal from the amplifier exceeds the adjustable threshold. This provides a means for rejecting noise and/or unwanted signals.

Figure 3. ESP-2 Rate meter and SPA-6 scintillation detector, Eberline [5]

3. OUTDOOR DOSE RATES AS ORIGINATED TO THE TERRESTRIAL EFFECT AND COSMIC RAY

Absorbed gamma doses are originated to terrestrial and cosmic rays together. To obtain the absorbed dose rates in air, the instrument is kept about 1-meter upperside from ground level. Because of this level; it is important that how many doses exposed in the air against human gonad. The human gonad is the more sensitive organ against radiation damage. Annual doses in the air were also calculated by using the gamma dose rates. Gamma dose rates graphic (histogram) was given in Figure 4.

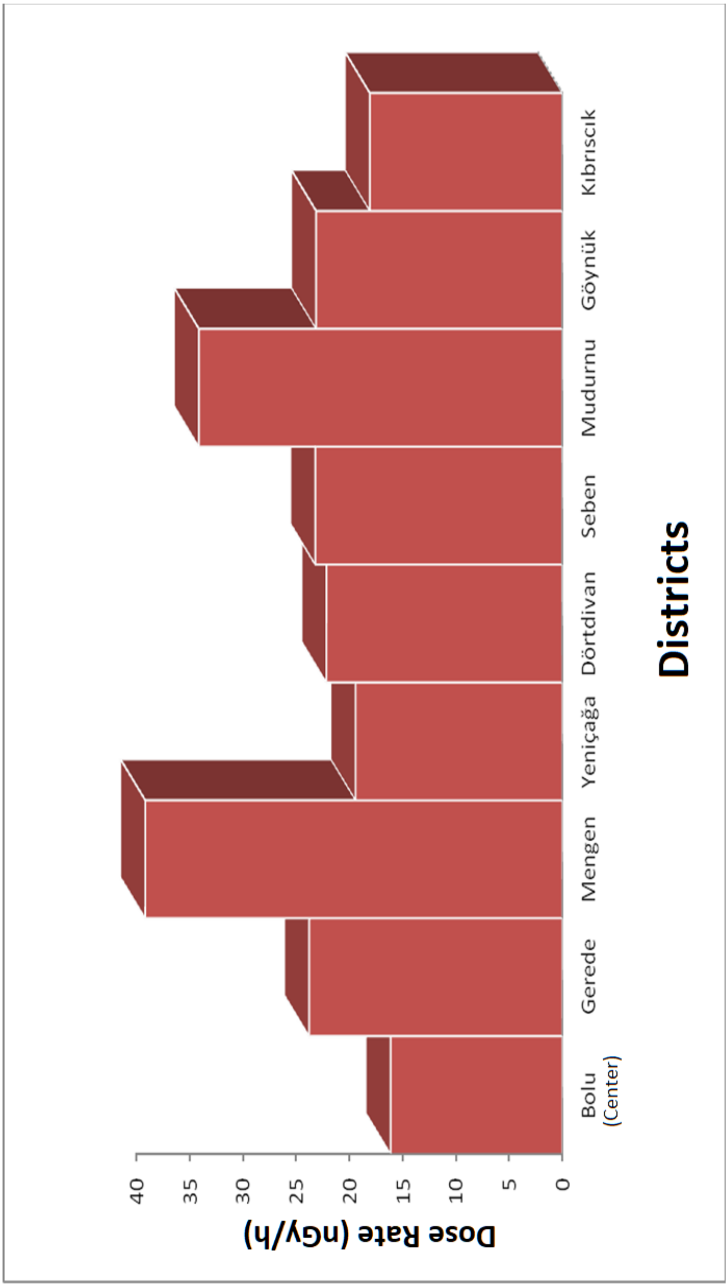

Figure 4. Average absorbed gamma dose rates of counties for Bolu province.

3.a. Determinations for AEDE by using ADRA

It is easy to calculate average annual dose (AEDE) by using average dose rates for all counties by using values given in Table 1 with ref. of (UNSCEAR, 2008), calculation of AEDE is possible by using below parameters [**1**]:

$AEDE= ADRA* DCF* OF* T$ Eq. 1

where *ADRA* refers to absorbed dose rate in the air ($nGyh^{-1}$), *A* is the activity, DCF refers to dose conversion factor ($0.7\ Sv\ Gy^{-1}$), OF is outdoor occupancy factor (0.2), T is the exposure time ($8760\ h\ y^{-1}$). *AEDE* is commonly used in an annual effective dose equivalent (μSv). These annual doses were shown for all counties in Table 2.

Table 2. ADRA and AEDE values, for a total 74 measuring points [**$nGyhr^{-1}$, μSv]**

County Name (sampling pcs)	**Absorbed Gamma Dose Rate [$nGyhr^{-1}$] ADRA, range/ average**	**Annual Effective Dose Equivalent [μSv] AEDE, average**
Bolu- center (36)	63.65-10.85/ 16.11	19.76
Dörtdivan (4)	27.60-15.60/ 22.14	27.16
Gerede (7)	45.00-15.45/ 23.76	29.14
Göynük (4)	24.40-21.10/ 23.11	28.35
Kıbrıscık (1)	18.07	22.16
Mengen (8)	68.35-20.55/ 39.14	48.01
Mudurnu (5)	53.85-28.40/ 34.11	41.84
Seben (4)	25.55-19.80/ 23.18	28.43
Yeniçağa (5)	24.75-15.90/ 19.40	23.80
BOLU (74)	**68.35-18.07/ 22.20**	**27.23**

****** Average for Bolu **[**dose rate: **22.20 $nGyhr^{-1}$**; annual dose: **27.23 μSv]**

3.b. Determination of Excess Lifetime Cancer Risk

E.L.C.R. can be calculated using by AEDE value:

$ELCR= AEDE* DL* RF$ Eq. 2

herewith *AEDE* in μSv, *DL* is the duration of life (70 years), RF refers to a risk factor (Sv^{-1}) as fatal cancer risk per Sv. The calculation for stochastic effects; ICRP 103 [6] uses values of 0.05 for the public (ICRP, 2007). AEDE&ELCR values were shown in Table 3.

Table 3. AEDE and ELCR values, for a total 74 measuring points [µSv, (x10−4)**]**

County Name (sampling pcs)	**Average Annual Doses Equivalent in µSv**	**Average Lifetime Cancer Risk [(x10^{-4})]**
Bolu- center (36)	19.76	0.69
Dörtdivan (4)	27.16	0.95
Gerede (7)	29.14	1.02
Göynük (4)	28.35	0.99
Kıbrıscık (1)	22.16	0.78
Mengen (8)	48.01	1.68
Mudurnu (5)	41.84	1.46
Seben (4)	28.43	1.00
Yeniçağa (5)	23.80	0.83
BOLU (74)	**27.23**	**0.95**

****** Average for Bolu **[**dose: **27.23 µSv**; risk: **0.95(x10^{-4})]**

4. STATISTICS AND COMPARISON

With analyzing of Table 4, it could be seen the annual dose and cancer risk for Bolu, are less than the world average. They are also less than a lot of Turkish provinces, too.

Table 4. Comparison Chart for AEDE and ELCR

[ref no], Region (Nm. of sampling)	**Average Annual Doses Equivalent in µSv**	**Average Lifetime Cancer Risk [(x10^{-4})]**	**Reference, year**
[7] Adana	82.00	2.87	Değerlier, 2008
[8] Ankara (341)	71.83	2.69	Kapdan, et al, 2018
[9] Artvin (204)	214.5	7.50	Taşkın, et al, 2015
[10] Balıkesir (92)	156.3	6.30	Kapdan, et al, 2011
[11] Çanakkale	260	9.10	Kam, et al, 2007
[12] İstanbul (105)	79.72	2.79	G.Karahan, A.Bayülken, 2000
[13] Kastamonu	67.00	2.35	Kam, et al, 2007
[14] Şanlıurfa	74.7	2.62	Kam, et al, 2007
[15] Hatay (215)	63.93	2.24	M. E. Turgay, 2015
[16] IDA villages (75)	198.66	6.95	M. E. Turgay, 2019
Bolu (74)	**27.23**	**0.95**	This study
[1] World	73.6	2.9	UNSCEAR, 2008
[17] R. Janeiro, Brasil	90.0	3.15	Licinio, et al, 2013
[18] Ramsar, Persia	105.0	3.68	Ghiassi, et al, 2002
[19] Canary Island, Spain	91.95	3.22	Arnedo, et al, 2017
[20] Yalova	59.02	2.07	Bayrak et al,2020

5. CONCLUSION

The minimum dose was calculated to 19.76 μSv for the central district of Bolu and it is a very good situation due to a higher population than the other districts live in there. The maximum dose was calculated to 48.01 μSv for the Mengen district as average. It could be said that the highest cancer risk is evaluated for the people live there for Bolu province. Radioactive sources and locations were not well known in Turkey as effectively. This is highly risky about human healthy in geography. So, this and similar studies are important to determine radioactivity levels and their cancer risk, too. In comparison to neighbor provinces as Ankara and Kastamonu, it seems too much lower than and higher quality of inhalation for the Bolu community. Besides, with this study, it is possible to say that; there is no risk on humans by inhalation. This study would be also referenced for future researches, besides it will be useful to compare with different studies for Bolu which, will be completed in the future, for example after a nuclear pollution via will be located a reactor in Sinop, such as based on a reactor leakage, attack by nuclear weapons, etc., too.

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