RESEARCH ARTICLE

Environmental Radioactivity and High Incidence Rates of Stomach and Esophagus Cancer in the Van Lake Region: A Causal Relationship?

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Abstract

This study examined the incidence rates of cancer cases (averages for 2006-2010) and relationships with environmental radioactivity levels. Soil and water samples were collected from provincial and district centers of Van city and the outdoor gamma doses were determined using a portable gamma scintillation detector. Gross alpha and beta, (226)Ra, (232)Th, and (40)K activities were measured in both tap water and soil samples. Although high rates of stomach and esophagus cancers have been reported previously in Van the underlying reasons have not hitherto been defined. Incidences of cancers were highest in the Gurpınar (326.0) and Ozalp (377.1) counties ($p<0.001$). As to the results of the gross alpha and gross beta radioactivity measurements in the drinking water, these two counties also had high beta radionuclide levels: Gurpınar (140 mBq/dm^3) and Ozalp (206 mBq/dm^3). Even if within the normal range, a relation between the higher rate of the incidence of stomach and esophagus cancers with that of the higher rate of beta radionuclide activity was clear. On Spearman correlation analysis, the relation between higher beta radionuclide levels and cancer incidence was found to be statistically significant ($p<0.01$). According to the results of the analysis, Van residents receive an average 1.86 mSv/y annual dose from outdoor gamma radiation, ingestion of radionuclides in the drinking water, and indoor ^{222}Rn activity. Moreover, gross alpha and beta activities were found to be extremely high in all of the lakes around the city of Van, Turkey. Further investigations with long-term detailed environmental radiation measurements are needed regarding the relationship between cancer cases and environmental radioactivity in the city of Van.

Keywords: Gastrointestinal system cancers - environmental radioactivity - Van - Turkey

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Introduction

Humans are primarily exposed to natural radioactivity from ground, air, and water sources. In addition to natural radionuclides, UV from the sun and cosmic rays are sources of natural radioactivity. Natural radioactivity varies principally with the radioactive element content of environmental areas. The high active nucleuses of uranium (U), thorium (Th), radon (Ra), and potassium (K) are the leading elements of environmental radioactivity.

Cancer is an uncontrolled cell proliferation, which occurs with some special unrepaired DNA damage and mutations. The main reasons for cancer formations are genetic heredity, carbon monoxide pollution, environmental radioactivity, air particle pollution, and alcohol-smoking addictions (Martin-Moreno et al., 2008).

In addition to irrepressible factors such as accumulating somatic mutations with aging and genetic predisposition factors for cancer formation, preventable cancer factors such as alcohol-smoking addictions, carbon monoxide pollution caused by motor vehicles, and environmental radioactivity, should not be overlooked (Szymanska-Chabowska et al., 2002).

Because of the natural radioactivity sources of terrestrial and cosmic origin, environmental radioactivity measurements are essential in determining background radiation. The terrestrial component of the background is due to various radioactive nuclides found in the air, soil, and water, and whose prevalence varies significantly depending on the geological and geographical features of a region. Cosmic radiation originates from space and changes primarily with elevation and latitude (Kam,

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2007; Karahan, 2010; Otansev et al., 2013). The level of background radiation in a region is affected by man-made sources (atomic weapons testing, nuclear activities, and accidents) (UNSCEAR, 2000). Worldwide, the average background dose for a human being, depending on the physical and ecological features of the area, is about 2.8 mSv per year. With the estimated annual average effective dose of 1.3 mSv, radon gas is a particularly significant source of exposure to natural radiation. Since individuals spend more than 90% of their time indoors, the exposure to radon has become a significant problem (UNSCEAR, 2000).

Although differences have been noted in the incidence of gastrointestinal systems cancer (GIS: Stomach + Esophagus) between Van city, Turkey, and the world, there has been no mention regarding any decisive factors for high GIS cancers (Tuncer et al., 2001). Statistics have also been reported by Kosem et al. (Kosem et al., 2001).

Located in the eastern part of Turkey, the province of Van has been receiving attention because of both its geographical position and because it is close to the nuclear power plant (NPP), which set up Armania-Metsamor. While the effects of low-level radiation exposure are likely to be small, it is not possible to exclude completely the influences of natural radionuclides in the environment (Aslikurnaz, 2013).

The aim of this study was to determine the relationship between the cancer incidence and natural (Ra-226, Th-232, and K-40) and artificial (Cs-137) radioactivity concentrations in soil samples, gross alpha, gross beta in water samples, and the outdoor in situ gamma dose rate in Van city.

Materials and Methods

Cancer statistics and incidence

The city of Van is in the eastern region of Turkey (Figure 1). It has a population of 1,035,418 (2010) and the region covers an area of 19,060 km^2. Its elevation average is 1727 m above sea level.

A retrospective analysis was conducted on the medical records of 2651 cancer patients (1196 female and 1455 male) who were admitted to the Yuzuncu Yıl Universitesi (YYU) research hospital between January 2006 and December 2010. Records were analyzed in relationship to age, sex, tumor species, and the county address of the patient.

Gamma absorbed dose in air

Measurements of the gamma radiation level were conducted using a dose rate meter (Eberline smart portable device, ESP-2, connected with a SPA-6 model plastic scintillation detector). At each point, the reading was taken in the air for 1h at 1m above ground level; the results were recorded in units of μR/h.

Radioactivity in surface soil

Fifty-five soil samples were collected from 10 uncultivated regions at depth levels of 0-10 cm. After clearing the ground of stones, pebbles, vegetation, and roots, 1-2 kg of material from the first 10 cm of topsoil was placed in labeled polythene bags and then transferred to the laboratory where the samples were first dried in the air, and then pulverized, homogenized, and sieved through 2 mm mesh. To maintain the radioactive equilibrium between ^{226}Ra and its daughters, the homogenized samples were transferred to 1000 m Marinelli beakers and kept in them for one month. The samples were then counted for 50,000 s using a gamma spectroscopy device connected to a coaxial high purity germanium detector. The activities of the samples are shown in Table 1. After correcting for background and Compton contribution, the activity concentrations per unit mass of the radionuclides were obtained in units of Bq/kg for each soil sample.

Radioactivity in drinking water

Approximately 30 drinking water samples were collected from selected locations of the study area and then transported to the laboratory in 500 cm^3 plastic bottles. The water samples were prepared for radionuclide analyses according to the routine procedure outlined by Karahan et al. (2000). To obtain the results in Bg/l units, the samples were counted for gross alpha and gross beta radioactivity in a low-background counter (Berthold, LB770-PC 10).

Indoor ^{222}Rn activity concentrations

To calculate the contribution of the annual effective dose from the indoor radon activity concentrations, the results of the radon measurements in this study were taken from a technical report produced by the Turkish Atomic Energy Authority (TAEK Technical Report, 2000).

Statistical analysis

Descriptive statistics for the studied variables (characteristics) were presented as mean, standard deviation. The Kruskal-Wallis test was used to compare locations. A Spearman correlation analysis was conducted to examine the linear relationships among the alpha, beta, and incidence values. Statistical significance levels were considered as 5% and the SPSS (ver. 13) statistical program was used for all statistical computations.

Results

Environmental radiation in the Van city and counties

The contribution of the natural radionuclides to the absorbed dose rate in the air (ADRA) depends on the concentrations of the radionuclides in the soil. The largest amount of gamma radiation comes from terrestrial radionuclides. There is a direct connection between terrestrial gamma radiation and radionuclide concentrations in the soil. If a radionuclide activity in the soil is known, its exposure dose rate in the air, at 1 m above the ground, can be found. The conversion factors of ^{238}U, ^{232}Th, and ^{40}K are 0.427, 0.662, and 0.043 nGy h~1 per Bq kg1, respectively. The contribution of terrestrial gamma radiation to absorbed doses in the air can be calculated using the following formula (Beck HL., 1975).

$$D=0.427C_U+0.662\ C_{Th}+0.043C_K$$

Where D is the dose rate at 1 m above the ground, C_U, C_{Th}, and C_K are the activity concentrations of ^{238}U, ^{232}Th, and ^{40}K, respectively, in the soil sample. The activity

Table 1. Average Radioactivity Concentratition of, 40K 238U, 232Th and 137Cs in Van Soil Samples and Absorbed dose Rates from Gamma Radiation

Region	^{40}K (Bq/kg)	^{238}U (average) (Bg/kg)	^{232}Th Bq/kg	^{137}Cs Bq/kg	ADRA (nGy/h) Absorbed (terrestrial)	Measured Terrestrial and cosmic	AEDE (μSv/y) Terrestrial and cosmic	terrestrial
Center	386.7	17.6	19.4	9.5	38.15	104.22	127.81	46.79
Bahçesaray	738.5	35.5	78.3	1.7	98.95	127.02	155.77	121.36
Başkale	354.3	18.6	21.6	0.6	37.53	97.44	119.5	46.36
Çatak	447.6	18.7	23.9	1.9	43.19	99.18	121.63	52.97
Edremit	219.1	11.3	12.8	12.7	24.29	136.06	166.86	29.79
Gevaş	574.2	29.3	37.9	3.8	62.75	106.22	130.26	76.96
Gurpınar	423	14.7	20.4	11.6	39.41	134.24	164.63	48.33
Muradiye	528.1	17.2	26.7	8.7	48.8	88.13	108.08	59.85
Ozalp	209.4	9.6	12.1	0.7	21.18	108.75	133.37	25.97
Saray	354.3	12.1	14.7	4.3	30.65	160.95	197.38	37.59
Mean	388.1	18.4	26.7	5.5	44.49	116.21	142.59	54.55

Table 2. Gross Alpha and Gross beta Radioactivity levels and Annual Effective doses in Drinking Waters of Van

Region	Gross alpha Activity (mBq dm-^{3})	Annual effective dose (μSv)	Gross beta Activity (mBq dm-^{3})	Annual effective döşe (μSv)
Van	63±10	12.87	114±18	57.33
Center	76±11	15.53	95±17	47.85
Bahçesaray	86±12	17.57	107±16	53.89
Başkale	24±8	4.9	113±16	56.91
Çaldıran	80±8	16.35	100±14	50.37
Çatak	75±11	15.33	68±15	34.25
Edremit	76±11	15.53	95±17	47.85
Erciş	14±6	2.86	121±18	60.94
Gevaş	86±12	17.57	107±16	53.89
Gurpınar	21±8	9.4	140±19	70.51
Muradiye	86±12	17.57	107±16	53.89
Ozalp	21±8	4.29	206±32	103.76
Saray	86±12	17.57	107±16	53.89
Mean	79.4	16.73	148	74.53

Table 3. ^{222}Rn Avtivity (130 samples) Concentrations and Effective Dose

	^{222}Rn avtivity concentrations (Bq/m^{3})	Annual Effective dose (mSv/y)
Mean	65	1.63
Min	14	0.35
Max	108	2.72

concentrations of the three terrestrial radionuclides in the Van soil samples, their calculated absorbed dose rates, and their measured dose rates in the air at 1 m above the ground are given in Table 1.

The world average annual effective dose equivalent (AEDE) from outdoor terrestrial gamma radiation is 70 μSv (UNSCEAR, 1988). The annual effective dose equivalent (AEDE) can be calculated as follows: ***AEDE=ADRA×DCF×OF×T***

The most appropriate average value of the quotient of the effective dose equivalent rate to the absorbed dose rate in the air (ADRA) was taken, as in the UNSCEAR (1982) Report, to be 0.7 Sv/Gy for environmental exposure to gamma rays of moderate energy. A dose conversion factor (DCF) of 0.7 Sv Gy and an outdoor occupancy factor (OF) of 0.2 was taken as recommended by UNSCEAR (1988), wherein T is time (8760 h). The calculated AEDE values are shown in Table 1.

The measurement results of the gross-alpha and gross-beta activities for the water samples collected in this study were presented in Table 2. The beta activities are generally higher than the alpha activities. These values are significantly lower than those recommended for drinking water by WHO (2004) (500 mBq dm^{-3} for alpha activity and 1000 mBq dm^{-3} for beta activity); therefore, no action is generally needed toward reducing the radioactivity in the city of Van's drinking water.

For estimating the total annual effective dose resulting from the ingestion of radionuclides, WHO recommends the use of dose coefficients and gives the values of 2.8×10^{-4} and 6.9×10^{-4} mSv Bq^{-1} for ^{226}Ra (an alpha emitter) and ^{238}Ra (a beta emitter), respectively. These coefficients are then multiplied with the measured activity concentration, and the assumption that an adult consumes an average of 2 *l* of water per day. Annual effective results are presented in Table 2.

The summary statistics for the measurement results of indoor ^{222}Rn activity concentrations are presented in Table 3. The annual average effective dose corresponding to the measured average was calculated using the conversion factor of 9 nSv/Bg h m^{3}, as suggested by UNSCEAR (2000), together with an equilibrium factor of 0.4 and an occupancy factor of 0.8 for indoor exposure (UNSCEAR, 2000).

Cancer incidence in the Van city and counties

Incidence statistics for the most common cancers, for the city of Van, by location, sex, age, and trends were studied for the years between 2006 and 2010. The total incidence trend tended to fall from 2006 until 2010 (2006: 123.91, 2007: 114.13, 2008: 97.57, 2009: 91.37, and 2010: 83.58) (Figure 1).

Although more than 33 different types of cancer were classified by location and species, six of those-including stomach, skin-melanoma, esophagus, lung, thyroid, and breast cancer-account for over half (55.9%) of all of the cancer cases (Figure 2).

Stomach cancer was found to be the most common cancer in Van (for both males and females). If considered, the stomach and the esophagus are both part of the gastrointestinal system and if evaluated together as GIS cancers, GIS cancer represented 27.5% of total cancer cases in Van (average of 2006-2010 incidence) (Figures 3).

However, although the incidence of stomach cancer fell between the years 2006 and 2010, the number of thyroid cancer cases increased (Figure 2).

Lung cancer, which is the most common cancer in the world, is the third most common cancer among the men (Figure 3A), and the eighth most common cancer among the women (Figure 3B) in the Van city area.

While the incidence of GIS cancer changes similarly by age, other changes in cancer incidence by age are significantly different between men and women (Figures 4).

A higher cancer incidence rate was observed in the Gurpınar (326.04) and Ozalp (377.10) counties (p<0.001, Figure 5).

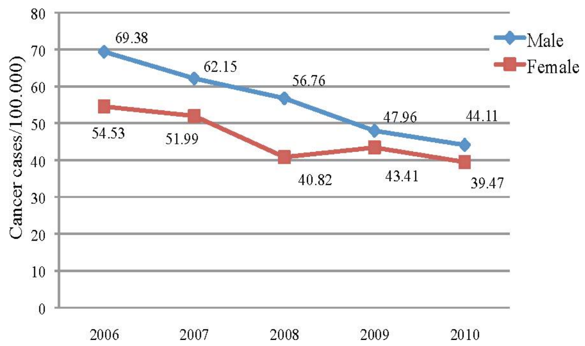

Figure 1. Cancer Incidence of VAN City (2006-2010)

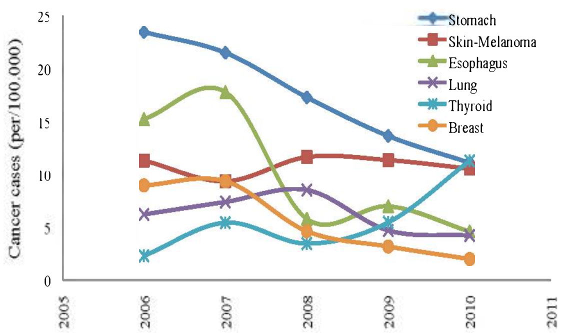

Figure 2. Different Cancer Incidence Trends in the Van City (2006-2010)

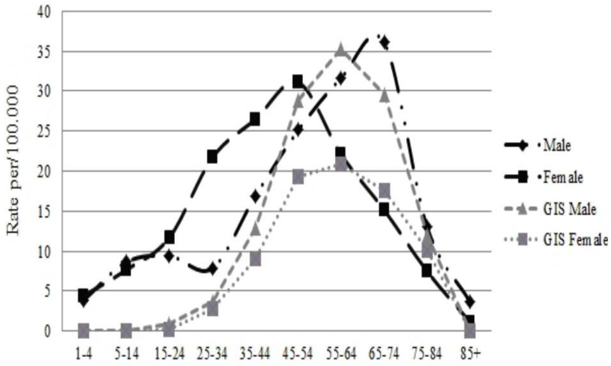

Figure 4. GIS and Non-GIS Cancer Incidence by Age in the Van City (2006-2010)

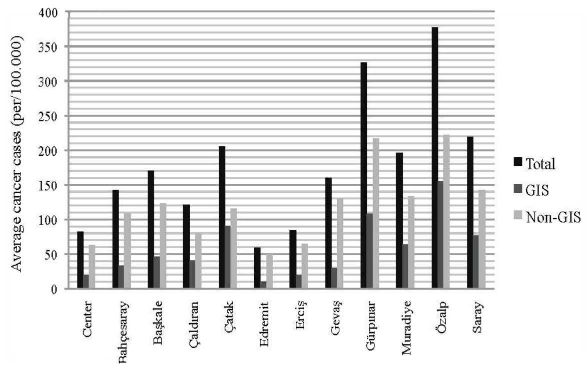

Figure 5. Incidence of Total, GIS, Non-GIS Cancer Cases in the Van City and Counties (Average 2006-2010)

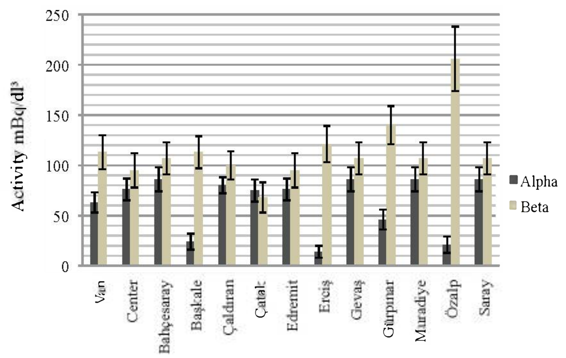

Figure 6. Gross Alpha and Gross Beta Radioactivity Levels in the Drinking Waters of Van (mBq/dm³).

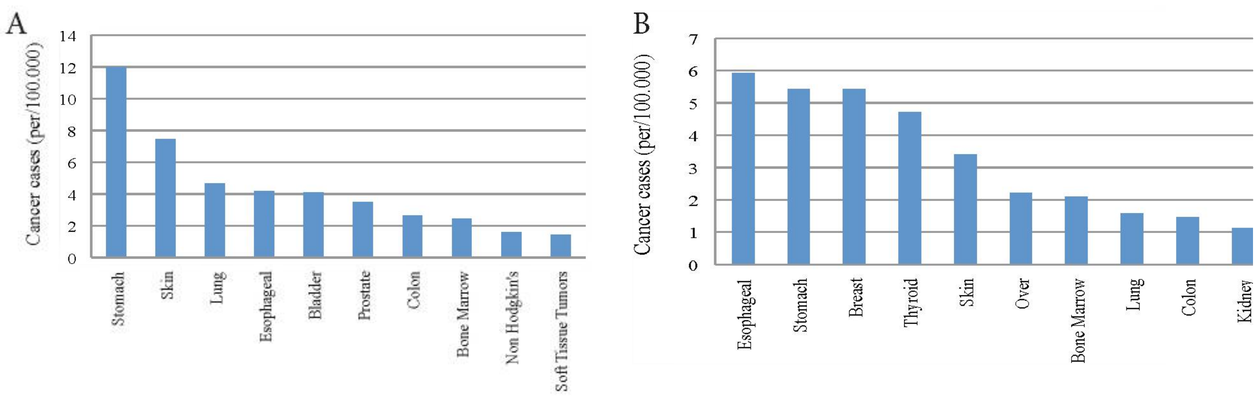

Figure 3. Incidence of the Ten Most Commonly Diagnosed Cancers in A) Males and B) Females in the Van City (Average incidence 2006-2010)

Table 4. Mean Gross Alpha and Gross beta Radioactivity in Lake Waters (Mean±S.E.M)

	Activity (mBq dm^{-3})	Activity (mBq dm^{-3})
Tatvan (geothermal)	435±25	4617±354
Erçek Lake	51±10	1335±373
Nemrut Lake	15±7	1140±52
Van Lake	26±8	7721±441
Mean	131.75	3703.25

Analysis Method: EPA 900.0 VE SM 7110C, MDA Alpha activity 0.007 Bq/L, Beta activity 0.008 Bq/L, advanced analysis for 3 samples which exceed 0.1Bq/L total alpha activity were carried out. Total indicative dose (TGD) evaluation were completed and its seems that all samples which received a dose were below the WHO limit values ''0.1mSv/year for gross alpha and 1mSv/year for gross Beta''

Table 5. Spearman Correlation Analysis For Relationship Between Cancer Incidence, Gross Alpha and Gross Beta

	Alpha	Beta	Year06	Year07	Year08	Year09	Year10	Average
Alpha	1							
Beta	-0.433	1						
Year06	-0.007	0.307	1					
Year07	-0.064	0.385	0.811**	1				
Year08	-0.15	0.392	0.776**	0.888**	1			
Year09	0.018	0.588*	0.601*	0.706*	0.629*	1		
Year10	0.1	0.663*	0.517	0.664*	0.615*	0.937**	1	
Average	-0.1	0.513	0.846**	0.916**	0.916**	0.853**	0.818**	1

*$p<0.05$, **$p<0.01$

Van is situated in a tectonically active region and all of the lake water around the region has high gross alpha and beta radioactivity levels (Table 4).

As to the results of the gross alpha and gross beta radioactivity measurements in the drinking water, two counties have higher beta radionuclide levels: Gurpınar (140 mBq/dm^3) and Ozalp (206 mBq/dm^3) (Figure 6). Even if the beta radionuclide levels are in the normal values, the relation between the higher cancer incidences with higher beta radionuclide activity is noticeable in these two counties. As to the Spearman correlation analysis, the relation between higher beta radionuclide levels and cancer incidence was found to be statistically significant (*$p<0.01$, Figures 5 and 6, Table 5).

Discussion

The relationship between environmental radioactivity and increasing cancer cases in the entire world has been shown in previous prevalence studies. Therefore, to evaluate the influence of environmental radiation on public health, it is important to determine the background radiation level (Robertson and Pengilley 2012).

In this study, the average annual background dose for Van city was measured and the total dose was calculated. According to the results, people take in an average 1.86 m.Sv/y annual dose from outdoor gamma doses, ingestion of radionuclides in the drinking water, and indoor ^{222}Rn activity concentrations in Van city.

If considered, as to radiological emergency rules; the evacuation process should apply for areas where people receive >1 mSv/h of radiation (Robertson, 2012) the annual 1.86 m.Sv/y environmental radiation dose is reasonable for public health.

Even if it is a very low environmental dose, as indicated in the literature, Hanford site studies have provided little evidence of a positive correlation of cumulative occupational radiation dose and mortality from leukemia and from all cancers except leukemia (Gilbert et al., 1993).

Therefore, the cancer incidence for the Van city area was studied and the relationship between cancer incidence and environmental radioactivity was investigated. As indicated in previous Van cancer incidence studies, gastrointestinal system cancers still represent the highest rate of all the cases between men and women (Kösem et al., 2001). However, the rate of GIS cancer incidence decreased between 2006 and 2010. The pattern of a high incidence of stomach cancer was very different from the rates in Western countries (Curado et al., 2007). Contrary to the decline in gastric cancers, the thyroid cancer incidence increased between 2006 and 2010.

Even the feeding habits and *H pylori* infections related to gastro intestinal system cancers (Hu et al., 2011; Choi, 2013), and high thyroid and GIS cancer incidence have been related to the radioactive I-131 and radioactive radioisotopes levels such as Cs-137, which is produced from artificial sources such as nuclear plants, nuclear accidents, and nuclear weapons testing (Royal, 2008).

Environmental radioactive Cs-137, which spread out to the east and east-northern region of Turkey from the Chernobyl accident is considered the main reason for the increased incidence of malignancies and thyroid cancers in Turkey and Eastern Europe (Robertson and Pengilley 2012; Tondel et al., 2006).

The higher beta radionuclide level in the drinking water, alongside the high incidence of cancer in Gurpınar and Ozalp counties, makes Cs-137 problematic as a beta radionuclide emitter.

The same GIS and thyroid cancer trends for incidence and prevalence were encountered in the literature for Korea (Jung et al., 2012). Similarly, while the highest GIS cancer incidence was decreasing, the trend was toward an increasing incidence of thyroid cancer in age-standardized cancer incidence rates during 1999-2009 in Korea.

In different parts of the world, the inclination toward similar cancer incidence may be related to increasing environmental radiation pollution or other factors. In addition to environmental factors, as is known, different research groups have hitherto seen an indication that the high intake of salt, salty meals, and barbecue foods has a relationship with a higher risk of gastric cancer (Lazarevic et al., 2010).

According to the results of this study, the residents of the city of Van take in an average 1.86 mSv/y annual dose from outdoor gamma doses, the ingestion of radionuclides in the drinking water, and indoor ^{222}Rn activity concentrations.

Importantly, the natural activity concentration of alpha and beta emitting radionuclides were within the range recommended by the World Health Organization (WHO), but the gross alpha and beta activities were found to be extremely high in all of the lakes around the city of Van, Turkey (WHO, 2004).

Detailed survey analysis, patient data entry, and continuous environmental radiation measurements are needed for a detailed analysis of the entire country of Turkey.

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