DETERMINATION AND MAPPING OF BACKGROUND RADIATION IN KIRKLARELİ PROVINCE IN TERMS OF HUMAN HEALTH and ENVIRONMENTAL POLLUTION

Dr. M. Bülent Onuk[1]
Biologist Halim Taşkın[2]
Dr. Çiğdem Cerit[1]
Dr. Mehmet Bilgin[1]

[1] Provincial Directorate of Health, Kırklareli
[2] Çekmece Nuclear Research and Training Center, İstanbul

The purpose of this study is to determine the radioactivity concentrations, gamma radiation dose rates, and in-house radon concentrations of soil and water samples taken from the Kırklareli province.

The investigation field comprises the whole province including 8 districts, 20 counties and 177 villages within the provincial boundaries of Kırklareli. Spring water and water networks (a total of 220 units) of the province are entirely within the context of the research. Area sampling method is used for direct gamma measurements and for soil samples. On the other hand, houses are selected through cluster sampling method for in-house radon measurements.

220 water and 177 soil samples were taken and radon measurements were carried out in 315 houses and direct gamma measurements were carried out in 230 locations. The average alpha activity was calculated as 0.0405 ± 0.0382 Bq/m3. Alpha activity of 12 samples among these 220 samples (5.5%) exceeds the limit value. The average in-house radon concentration was calculated as 71.01 ± 39.85 Bq/m3 for the province. All of the evaluated detectors were found to be lower than 400 Bq/m3, which is the limit value of concentration allowed in Turkey for closed spaces. However, 50 of 301 detectors (%16.6) exceeded 100 Bq/m3 which is the limit value of concentration determined by the WHO. Within the context of the present study, it was ascertained that the building type and the construction material of ceiling have influence on radon concentration ($p<0.05$). The average dose rate of gamma radiation was calculated to be 135.086 ± 38.648 nGy/hour for the province. Average

radioisotope activity concentrations of soil samples are respectively estimated as 36.504±17.540 Bq/kg for ^{226}Ra; 25.428±10.892 Bq/kg for ^{238}U; 39.864±18.382 Bq/kg for ^{232}Th, 666.98±281.01 Bq/kg for ^{40}K and 7.954±5.349 Bq/kg for ^{137}Cs.

Although the average limit values are lower than the limit values required by the WHO and other international organizations, when we assess the results of the measurements and analyses individually; it is seen that these limit values are slightly exceeded. In drinking water above the limit values, seasonal change in radioactivity must be followed and a training regarding regular ventilation in houses must be arranged for those in which radon concentrations are higher than the limit value. Since the fact that knowledge concerning radioactive sources is inadequate in Turkey makes radiological risk estimation difficult as far as protection of human health is concerned, it is important that similar studies are conducted in all provinces to identify natural background radiation.

Key words: Natural radioactivity, Gamma dose rate, Total alpha and beta, In-house radon concentration, Annual active dose.

1. Introduction

Environment is quite important for human health. There are various agents which can affect human health either directly or indirectly. Cohort type cancer studies such as havef indicated that environmental factors are more influential than genetic susceptibility in cancer formation (2). Therefore, it is very important for public health that the environmental polluters are investigated and determined. Natural radiations in the environment, nuclear tests, accidents and possible leakages from nuclear power stations also result in serious problems for environment and human health.

Radioactive materials released due to the Chernobyl nuclear reactor accident in Ukraine in 1986 spread to almost all over Europe and even to further regions. Thousands of people living within 30 km area surrounding the reactor were exposed to hundreds mSv of radiation dose and hence more than 160,000 people were evacuated from the region within the first three weeks (3). Radioactive cloud caused by the reactor also reached our country and resulted in environmental contamination in some regions by falling onto the ground through rain. Due to extreme rains during the passage of clouds, a critical group of 100,000 people were exposed to a dose higher than Turkey's average across our boundary with Bulgaria and Greece in Thrace and in some parts of Eastern Black Sea Region. It was determined that in this group adults were exposed to an average of 0.6 mSv radiation dose and babies between 0-1 year were exposed to an average of 0.350 mSv (4).

On the other hand, humans and other living things always live within a radioactive environment during their entire life due to cosmic radiations from space and natural radioactive elements such as Uranium, Thorium and Potassium originating from the earth's crust. It is known that especially an important portion of gamma radiations originates from the surface layer at 0-25 cm depth. In the world, every substance comprises more or less radioactive atoms; earth's crust, inhaled air, food and the solar system are natural sources of radiation. In addition, radioactive materials used in medicine and industry, nuclear tests, leakages and accidents in nuclear power stations also cause increase in level of background radiation. Background radiation level of a location varies according to the geographical and geological structure, altitude, and mineralogical structures of soil and rocks. Radioactivity of soil, water and air of a region has to be determined in order to determine the background radiation of that location. In literature, there are a lot of studies performed for this purpose. Some of these studies are local whereas some of them are regional. Almost all of these studies cover only one of these subjects and they were performed for the purpose of determining the natural radionuclides existing in soil, water, or air.

As is known, the risk of cancer is directly proportional with the amount of the radiation dose received. The radiation exposed by people must be limited and the dose must be determined so as to decrease or control the risk of cancer. Kırklareli province was examined because of both its geographical status and its being one of our provinces which were contaminated after the accident in the Chernobyl nuclear power station. Turkey is under the risk of exposure to radioactive contamination especially because of the nuclear power stations established in the neighboring countries. That is why it is very important to determine levels of natural background radiation for our public and all other living things. Therefore, the main purpose of this study is to determine the level and provide mapping of the background radiation in the Kırklareli province. Our aim is to ascertain natural gamma radiation dose rates, in-house radon concentrations, total alpha and beta radioactivity in waters, natural radioactive isotopes comprised by soil samples and concentration of ^{137}Cs radioisotope produced by fusion.

2. Method and Instrument

2.1. Field and duration of the research

Kırklareli province is at the northwest of Turkey and it is one of our three provinces which are entirely in Thrace. It is surrounded by the Black Sea at the east, by Edirne at the west, by Bulgaria at the north and Tekirdağ province at the south. The province comprises 8 districts including the central district, 177 villages and 20 counties, and field of research was determined as all of this area including 205 settlement units. According to the general population census of the State Statistics Institute (DİE) in 2000, the provincial population was 315 211, the number of houses was 86 175 and the number of buildings used as domiciles was 36 354. (5)

The study was carried out in three different time periods within 1.5 years, and had been executed between July, 1st 2004 and January, 31st 2006. The first phase of the study included site studies, on-site measurements, collection of samples and putting these samples under protection in laboratory. In the second phase, samples of soil and water were analyzed in the laboratory and radon detectors were distributed. In the final phase, radon detectors were collected back; samples were analyzed together with other samples, and the results were recorded and evaluated. Natural radioactivity concentrations of Kırklareli province were determined by means of laboratory-based methods. Dose rates of external gamma radiation, radionuclide concentrations in soil and water samples and in-house radon concentrations were determined in the laboratory studies. Coordinates of measurement places were determined and recorded by the GPS (Global Positioning System) device.

2.2. Type and universe of the research and sample selection

This is a study of sectional type. Total alpha and beta activities in drinking water and in-house radon levels, gamma dose rates and radioisotope activity concentrations in the soils of the Kırklareli province were searched in a sectional manner.

The universe of the research comprises the whole Kırklareli province including 8 districts, 177 villages and 20 counties (an area of 6550 km2) and a total population of 315 211 according to the 2000population census.

The sample size and sample selection were determined on the basis of the following issues:

1. Radioactivity in drinking water,
2. In-house radon level,
3. Gamma measurement on land and determination of the radioisotope content of soil.

1. Drinking Waters: Since all spring and network waters, which meet drinking water requirement of settlement units within the research universe, are considered as worth to research; they were entirely covered by the research (200 networks and spring waters).

2. Determination of in-house radon levels: In the research universe, there were 36 354 buildings being used as domicile according to DİE's building census data of 2000. Also according to the same data, the total population of central districts was 126 860, the number of houses was 35 996. The population of villages and corners was 140 414, the number of houses was 36 474. Central districts constitute 48 % and villages constitute 52 % of the general population. On the other hand, 49.7 % of houses were established in the city and 50.3 % of them were in counties and villages.

Determination of the sample size: Our latest data regarding the number of buildings in the research universe belongs to results of "DİE Building Census in 2000". In this case, size of sample was determined on the basis of the formula n= (t1-α)2 (x)2/ S2 and as a result n was calculated as 287 (1). However, taking possible losses during laboratory studies into account; the size of sample was increased by 10 % (28 buildings) and raised to 315.

Ground floors had been used during the research. Different applications were adapted for rural and urban areas. Urban areas were separated into 53 clusters and each district was regarded as a cluster. In proportion with the cluster volume, 48.9 % of detectors (154) were used for the urban area.

Since villages are smaller and more dispersed settlement units, each settlement unit was listed as a cluster during sample selection. Clusters close to each other were eliminated so as to provide full coverage of the area. Each cluster comprises one house. 161 of total detectors (51.1 %) were used for counties and villages.

315 units of CR-39 radon detectors could be obtained from Çekmece Nuclear Research and Training Centre Health Physics Department for this study. Since urban and rural populations and house numbers were close to each other, 154 of detectors were used for cities and 161 of them were used for counties and villages. The sample size was 315 houses for the province. The sample size constituted 0.9 % of total number of buildings. Only 301 of 315 detectors which had been distributed to 315 houses could be utilized (95.5 %). Families of sample houses were informed about the research in detail; and a questionnaire including 10 questions was used to collect data regarding buildings and households (1).

3. Direct gamma measurements and radioactivity in soil: Settlement units were separated into portions in such a manner that each settlement

unit constituted a cluster. Thus, 205 settlement units comprising 8 districts, 20 counties and 177 villages were completely assessed. Measurement numbers were determined in accordance with the area of settlement units. Measurement distances and coordinates were determined and recorded by the GPS device. Arithmetic average of measurement results, which were obtained from three different points in each settlement unit, were estimated and recorded; and hence 690 measurements including 230 points in 206 settlement units were made. According to direct measurement results, soil samples were taken from 117 points that were selected among 230 measurement points through a random process and whose geological structures were different.

2.3. Instrument

Total activity of drinking water samples were estimated by using a Berthold branded, gas-flow LB770- PC 10 channeled low level proportional counter; in-house radon concentrations were estimated by using passive CR-39 nuclear track detectors; gamma radiation dose rates were estimated by using an Eberline Smart portable scintillation detector, and radionuclide concentrations of soil samples were estimated by using the Gamma Spectrometry System.

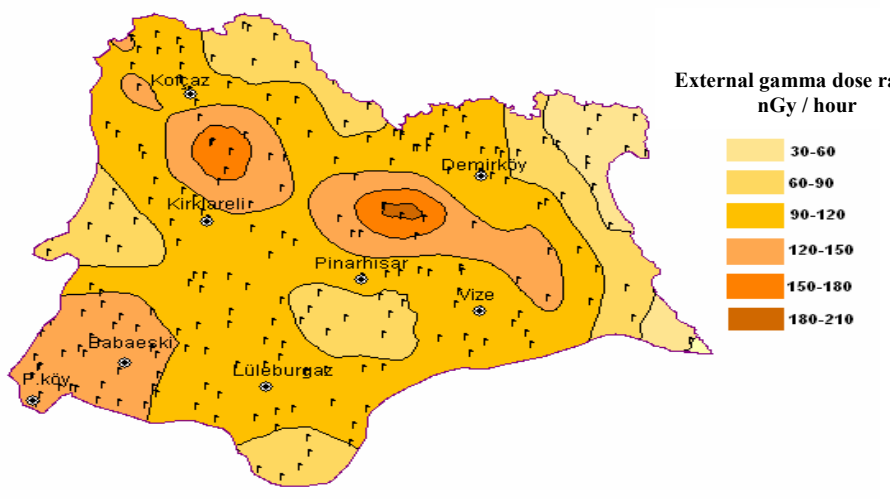
3. Results and Discussion

Analyzes were performed by the Çekmece Nuclear Research and Training Centre, and hence external gamma dose rates, natural radioactivity levels of soil and water samples, and in-house radon concentrations were determined for the Kırklareli province.

3.1. Environmental gamma radiation dose rates and its assessment

Environmental gamma radiation varied from a region to another and even between regions close to each other. This is because all soil and rock remnants comprised natural radioactive elements such as uranium and torium and these elements had dispersed to environmental soils after a very long geological process. When we examined the averages of the districts separately, the Pehlivanköy district had the highest average, namely, 163,555 ± 17.103 nGy/h. According to data which we obtained by gamma spectrometric analysis of soil samples from this region, it was determined that the average Ra-226 and U-238 concentrations of this region was higher than the averages of other districts. K-40, Th-232 and Cs-137 concentrations were similar to the concentrations of other districts. If we take measurements into consideration independent of each other, the highest measurement belonged to environs of Kurudere village of Pınarhisar (320 nGy/h) and the second highest measurement belonged to north of Çukurpınar village of central district (27 nGy/h). Gamma dose rates which were measured along the zone extending in the southeast-northwest direction to the south of Yıldız Mountains were higher than those of other regions. As a result of the analysis of soil samples taken from these regions, it was found that this situation results from natural Th-232, Ra-226, K-40, and U-238 radionuclides. Data of external gamma dose rates was processed in “MAPINFO” software program

and consequently a map of the gamma dose rate intensity was drawn (Map 1).

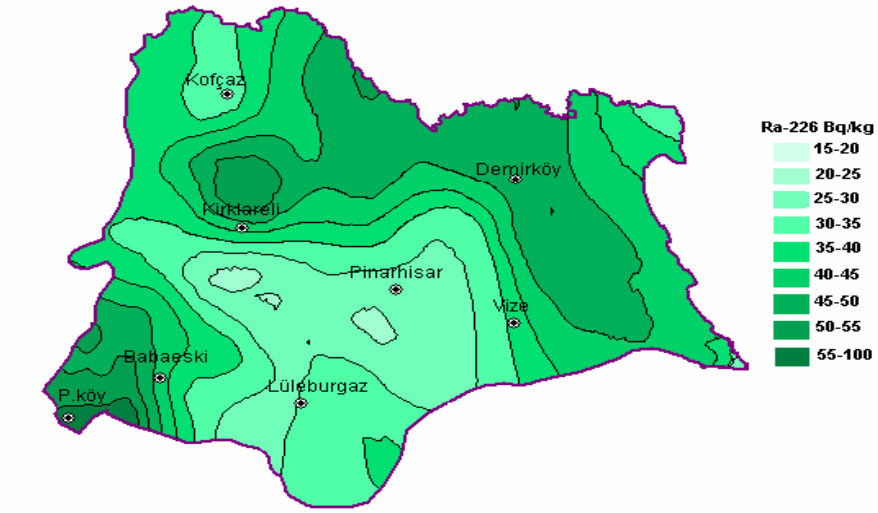


Map 1. Geographical distribution of land gamma dose rates in the surface soil of the Kırklareli province (flagged places indicate measurement points)

Especially in the last decade, gamma radiation measurement studies have been carried out at 1 m above the ground level in many countries. The average of the measurements carried out in the intensely-populated regions of the world is approximately 59 nGy/hour. The absorbed gamma dose rates measured in air have been generally determined as between 10 and 200 nGy/hour (6). Since their main sources are originated from land and space, environmental natural gamma radiations are directly related with concentrations of radioisotopes existent in the soil structure of a region. In the majority of the Kırklareli province, the altitude is approximately 200 m above the sea level, but the Ergene basin is plain (altitude decreases until 20 m), and the province is mountainous in general with forests to the north and east. The average environmental gamma radiation value of Kırklareli was determined to be 135 nGy/hour. This rate is higher than the world average (59 nGy/hour). This is because of the radionuclides existing in soil. Especially Th-232, Ra-226 and K-40 radioisotopes are relatively more intense than others. Naturally, the more intensive these elements are, the higher gamma dose rates are obtained. When Th-232, Ra-226 and K-40 concentrations distribution maps are compared with the maps of gamma dose rates; it is clearly seen that there is a direct relation between them.

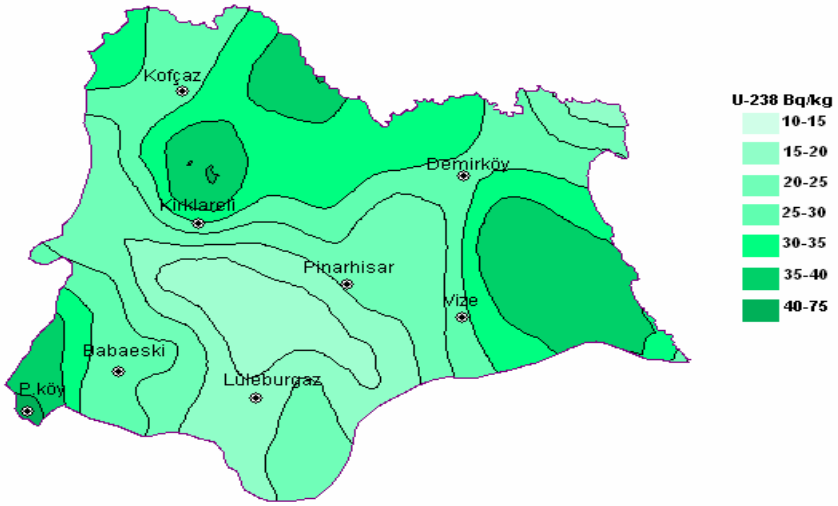
3.2. Radioactivity Levels Determined in Soil

In general, radionuclide concentrations in soil vary from each other regionally to a great extent. This is because of the geological structure of the soil. Previous studies had shown that there is a direct relation between the geological structure and radionuclide concentration of soil. ^{226}Ra concentration, whose world average is 35 Bq/kg (3), was found as 36,504±17,540 Bq/kg as the average in the province. When the averages of districts are considered separately, Pehlivanköy is the district where the ^{226}Ra concentration exists most intensively (51.605±20.899 Bq/kg). The highest concentration has been measured within the boundaries of Eriklice village which is attached to the central district (111 Bq/kg).



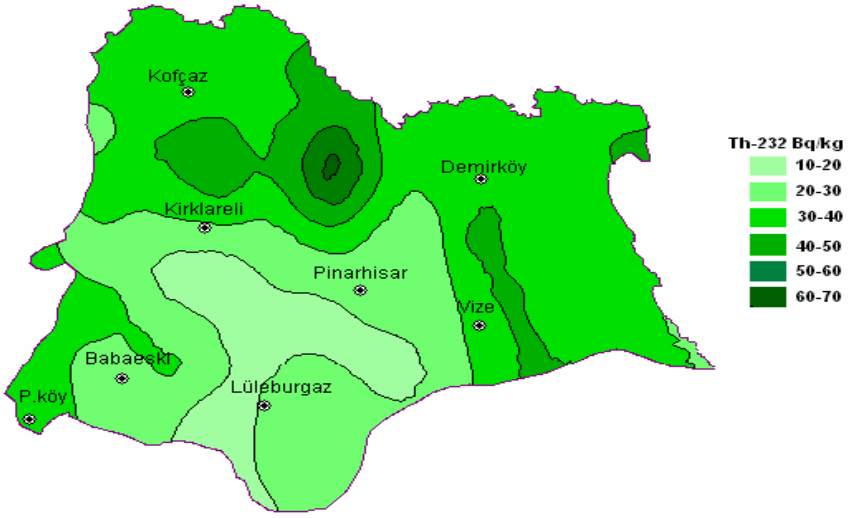
Map 2. Geographical distribution of radium concentration in the surface soil of the Kırklareli province (Ra-266)

^{238}U concentration, the world average of which has been determined to be 35 Bq/kg (3), was estimated as 25.428±10.892 Bq/kg for the average of the province. Pehlivanköy is the district where the concentration is the highest (34.767±16.317 Bq/kg). The highest concentration levels at the measurement points are respectively as follows: 73.3 Bq/kg in Pehlivanköy, 72.7 Bq/kg in Malkoçlar (Kofçaz), and 70.5 in Eriklice (Central District).



Map 3. Geographical distribution of uranium concentration (U-238) in the surface soil of the Kırklareli province

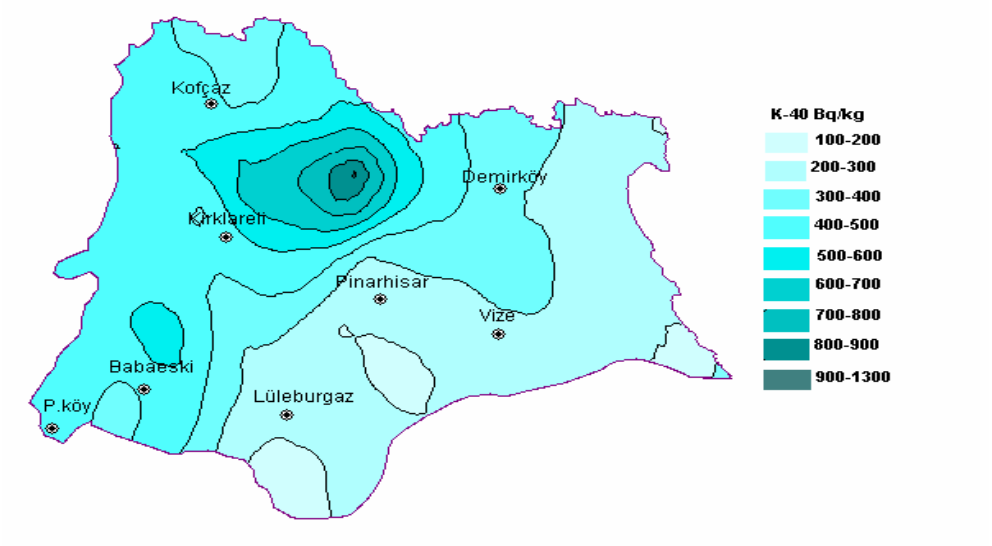
Th-232 concentration, whose world average is 30 Bq/kg (3), has been estimated as 39.864±18.382 Bq/kg for the average of the province. Demirköy has the highest concentration level among all districts. The highest concentrations are respectively measured as follows: 151,2 Bq/kg in İğneada 123.9 Bq/kg in Çukurpınar, and 88.0 Bq/kg in Çağlayık (Central District).



Map 4. Geographical distribution of Thorium (Th-232) concentration in the surface soil of the Kırklareli province

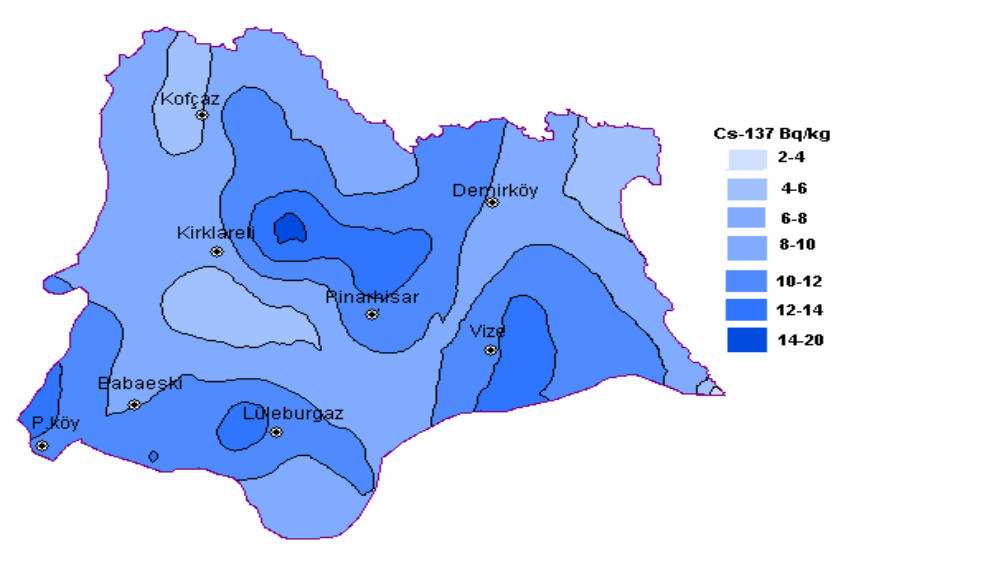
Average rates of uranium series in this study are very close to the average rates of the world (3). The average ^{226}Ra concentration is determined as 36.504±17.540 Bq/kg in this study, the world average of the same radionuclide is 35 Bq/kg'dir (3). The average uranium level is 25.428±10.892 Bq/kg, and the world average is 35 Bq/kg. Uranium, radium and radon are radionuclides naturally existing in our surrounding. Any acute influence of them on humans has not been determined yet; however, it has been determined by experiments on animals that they cause damage on kidneys and the upper respiratory system. Long term (chronic) uranium, radium and radon inhalation results in respiratory system sicknesses as well as chronic lung sickness and also acute leucopenia, anemia, necrosis of mouth and many other damages (7, 8). The most significant influence of them is causing cancer. If radium is taken in through the mouth, it gives rise to bone, skull and nasal tumors; on the other hand, uranium can cause lung cancer, lymphatic and hematopoietic system tumors (8, 9, 10). Therefore, domiciles on soils which are rich in terms of radium and uranium should be strictly inspected and gamma dose rates and radon levels of such domiciles should be determined. Concentration values of ^{232}Th are higher than concentration values of ^{238}U in the soil of Kırklareli. The average concentration rates of ^{232}Th are slightly higher than the world average. The average of the Kırklareli province is 39.864±18.382 Bq/kg, and world average is 30 Bq/kg (3). Exposure to thorium can cause pancreas, liver, bone, kidney, spleen and especially lung cancers and also leukemia. (9)

In worldwide measurements, it has been ascertained that the activity concentration of ^{40}K, which naturally exists in soil, is significantly higher than the activity concentrations of ^{238}U and ^{232}Th (11). Sample soils of Kırklareli also comprise a much higher ^{40}K activity concentration than other radioisotope concentrations. The average K-40 concentration is 666.98±281.01 Bq/kg for the province, and 400 Bq/kg for the world. The highest concentration level is detected in the central district and estimated as 825.22±384.17 Bq/kg. This rate is higher than the average world rate of ^{40}K which is calculated as 370 Bq/kg and 400 Bq/kg respectively in the 1982 and 2000 reports of UNSCEAR. Map 5 indicates distribution of K-40 activity concentration in Kırklareli soil.



Map 5. Geographical distribution of potassium concentration (K-40) in the surface soil of the Kırklareli province

^{137}Cs is released to atmosphere as a result of nuclear tests and accidents in nuclear power stations. It is known that most of the radioactive fallout is accumulated in the soil (12). As is known, many countries including Turkey was affected by pollution caused by radioactive materials released from the Chernobyl settling area of Ukraine due to a reactor accident occurred in 1986. Influences of accident are clearly detected in Black Sea costs and Thrace region of our country. In that period, concentration of ^{137}Cs was calculated as 45 Bq/kg in Saray district (TAEK, 1988). In this study, the average concentration rate is measured as 7.954±5.349 Bq/kg for the province. Regions mostly affected by ^{137}Cs are the central district, Vize and Demirköy districts and surrounding settlement areas. Some settlement units with relatively higher ^{137}Cs rates are determined as follows: 37.9 Bq/kg in environs of Boztaş village within Demirköy district, 35.9 in Üsküp county and 19.1 Bq/kg in Beypınar village within the central district, 26.6 Bq/kg in Kumköy village within the Pehlivanköy district, 22.7 Bq/kg in Kocayazı district of Kofçaz province, and 18.8 Bq/kg in Küçük Yayla village of Vize district. In Map 6, geographical distribution of ^{137}Cs in Kırklareli in soil is indicated. As can be seen from the map, influences of ^{137}Cs contamination caused by the Chernobyl Accident still continue in a reduced manner.

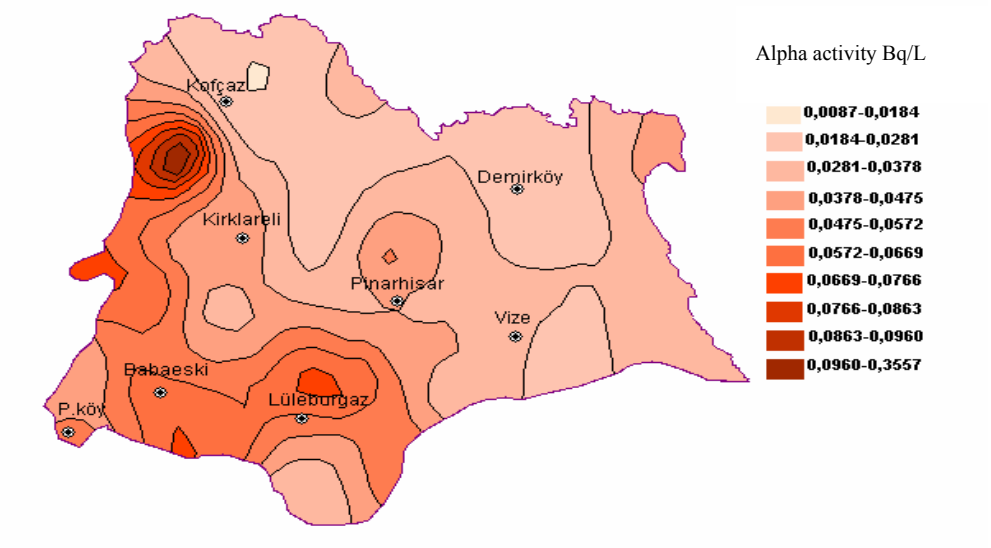


Map 6. Geographical distribution of cesium concentration (Cs-137) in the surface soil of the Kırklareli province

3.3. Radioactivity levels determined in waters

Radioactivity measurements were initially carried out for thermal waters used by limited number of people. In the light of new information obtained from studies regarding biological influences of radiation on living things, ICRP (International Commission on Radiological Protection) developed new dimensions within the context of radiation protection (13). In this respect, it was accepted that there was no threshold dose for stochastic influences of radiation and that public health could be negatively affected due to continuous exposure of general public to radiation even if this exposure is a low-dose one. Therefore, intensity of studies for measuring radioactivity in drinking waters has increased so as to clarify low-doses which may be exposed by humans (14, 15). According to radioactivity limits for drinking waters, suggested by the World Health Organization (WHO) and USA Environmental Protection Agency (EPA), limit for total alpha is 0.1 Bq/L and limit for total beta is 1 Bq/L. TS-226 report which was prepared by the Turkish Standards Institution (TSE) in 1984 comprised suggestions of WHO exactly (16). Limit rates suggested by the World Health Organization are determined by taking into account an ordinary person who consumes water in his/her entire life but who does not have any health problem due to radiation dose in drinking water. In this study, the concentrations in drinking waters were generally found as lower than the suggested value. 108 of 220 (94.5 %) water samples were lower than limit rates determined by the

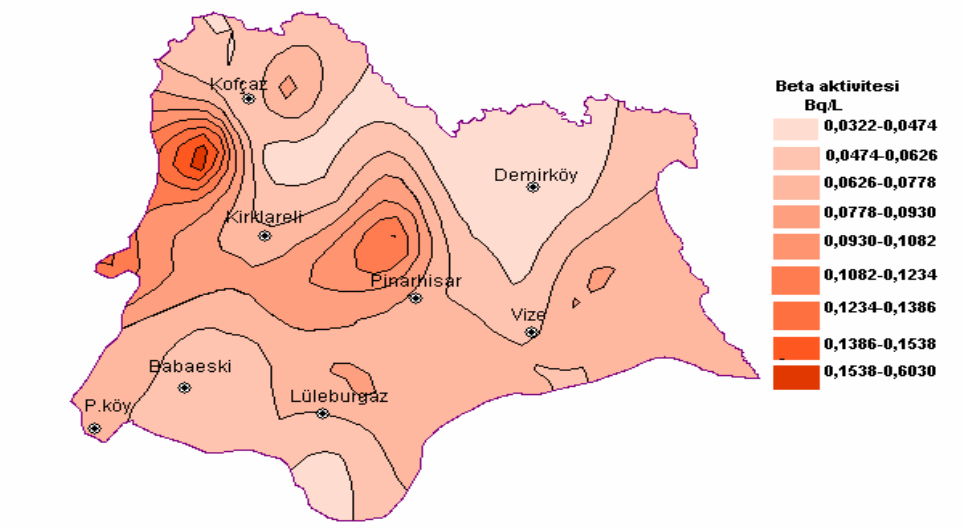
WHO and they were considered as drinkable in terms of radiation health. However 12 units of them (5.5 %) had higher alpha rates than limit rates suggested by the WHO; these are respectively as follows: Çayırdere (0.1014 Bq/L), Büyük Karıştıran (0.1014 Bq/L), Pehlivanköy (0.103Bq/L) Minnetler (0.1083Bq/L), Karaağaç (0.1127Bq/L), Eskitaşlı (0.1149Bq/L), Arızbaba (0.1219Bq/L), Eskibedir (0.1249Bq/L), Sinanlı (0.1301 Bq/L), Nadırlı (0.1363Bq/L), Yenitaşlı (0.1417Bq/L) and Yoğuntaş (0.4461 Bq/L). Especially Yoğuntaş spring water was 4.5 times higher than the upper limit suggested by the WHO. As a result of the advanced analysis carried out by taking water from this spring again; it was determined that 60 % of the alpha activity resulted from Radium (Ra-226). Dialogue was established with the Provincial Directorate of Health and the villagers were warned about this issue. Researches regarding subject source are presently going on.



Map 7. Geographical distribution of alpha radioactivity concentrations in waters of the Kırklareli province

It is observed that total beta activities of all samples are lower than the suggested limit rates. (Map 8.)

Beta activity Bq/L



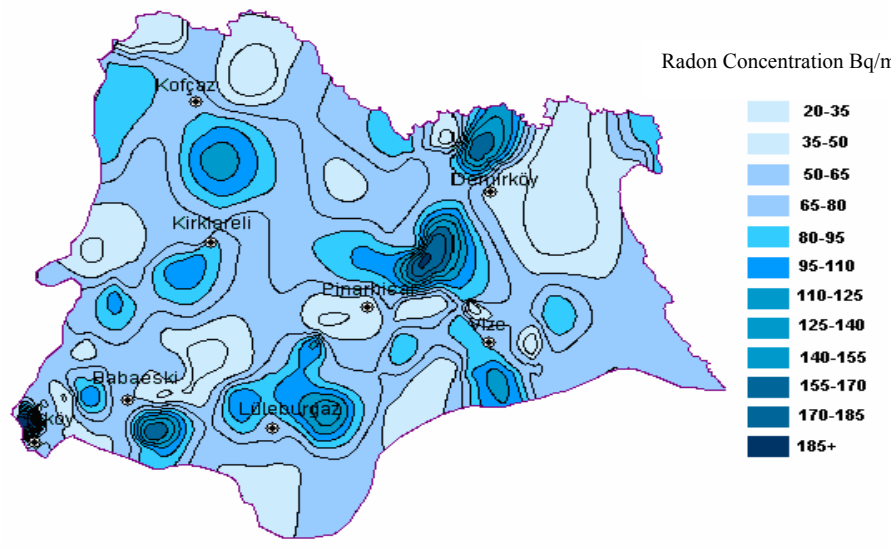
Map 8. Geographical distribution of beta radioactivity concentrations in waters of the Kırklareli province

3.4 Assessment of measured in–house radon concentrations

Most of the human life is spent in closed spaces. Domiciles where humans spend most of their times are significantly important for human health among these spaces. Negative influences of inadequate domicile conditions on health have been known for at least 150 years (17). Radon gas is the primary contributor to equivalent dose taken by humans from natural radiation sources. Since the principle source of ^{222}Rn is uranium, radon concentrations vary from one region to another on the earth's cluster. Some average values which are obtained by in-house radon measurements in Turkey are as follows: 73 Bq/m3 in İstanbul, 85 Bq/m3 in Erzurum, 160 Bq/m3 (49) in Çanakkale, 29 Bq/m3 (50) in Antalya, 69 Bq/m3 in Adana, 89 Bq/m3 in Trabzon, 106 Bq/m3 in Kars, 70 Bq/m3 in Zonguldak, 122 Bq/m3 in Yatağan, 131 Bq/m3 in Dikili, 187 Bq/m3 in Dinar (16, 18). Until now, ÇNAEM has carried out in-house radon measurement in totally 60 provincial centers and districts. According to the current results, the average in-house radon concentration is 68±39 Bq/m3 in Turkey (16, 18). In UNSCEAR 1988 report, the average in-house radon concentration was given as 40±25 Bq/m3 in the world. In this study, in-house radon concentrations were determined to be between 20 – 337 Bq/m3 in Kırklareli. The arithmetical average of in-house radon concentration is 71.01±39.85 Bq/m3 for Kırklareli's houses. This rate is higher than world average and close to Turkey's average. The upper limit

rate of radon concentration is determined to be 400 Bq/m3 by ICRP, as 400 Bq/m3 by European Union, and as 100 Bq/m3 by the World Health Organization (WHO). In Turkey this rate is determined as 400 Bq/m3 by Radiation Security Regulation in Turkey (19). Under these circumstances, the average in-house radon concentration in Kırklareli did not exceed rates permitted by TAEK and WHO. However, if we take 301 houses into consideration one by one, 50 (16.61 %) of them have radon concentrations higher than 100Bq/m3 which is the limit rate determined by the WHO. When we examine in-house radon concentrations of Kırklareli in three different categories as low (0-49 Bq/m3), medium (50-100 Bq/m3) and high (100> Bq/m3); then there are 96 low level houses (31.9 %); 155 medium level houses (51.5 %) and 50 (16.6 %) high level houses. Here the medium concentration group was the largest one. A 10-question survey was held so as to obtain further information regarding houses (1). The purpose was to determine the factors which are influent on radon concentration by assessing data derived from these surveys through SPSS program. It was detected that the building type (apartment with basement, apartment without basement, detached house with basement, detached house without basement), and ceiling construction materials (concrete, wood, other) are related with radon concentration ($p<0.05$). There are lots of variables causing increase of in-house radon concentrations. These can be examined in three general sections which are related with building; concentration of Ra-226 in soil, on which the building is constructed, and life styles and behaviors of residents. Since radon gas results from decay of Ra-226 radionuclide; there is a direct relation between Ra-226 concentration comprised by construction materials of buildings and concentration of radon gas. Heating systems, windows, age of building, cracks on ground or walls, etc. are indirectly influential. Ground soil is also directly related with in-house radon concentration. Since it is a gas, radon can easily enter into a building from very small cracks, connection points of walls, water and sewer pipes. Since houses with higher Ra-226 concentrations automatically comprise higher in-house radon concentrations; residents of such houses are required to ventilate their houses frequently. Advisory reports of International Commission on Radiological Protection (ICRP), dated 1977 and 1990, accept that there is no threshold dose for stochastic influences (formation of cancer and genetic influences) of radiation and there is a linear connection between dose and influence; hence the permitted dose levels are minimized and it is suggested that any and all needless exposures to radiation doses must be avoided (20). UNSCEAR reports issued by the United Nations Scientific Committee on Influences of Atomic Radiation also agree on the opinion that public health can be negatively affected due to continuous exposure of the general public to

radiation even if this exposure is a low-dose one (21). Within the context of epidemiological and statistical studies, it has been claimed that a certain portion of cancer incidences can result from ionizing radiations (22). Especially, almost 20 % of lung cancer cases are claimed to result from dose intaken by lung bronchus as a result of inhalation of radioactive ^{222}Rn gas in air and its decay products. Long term inhalation of radon can cause chronic lung disorder, pneumonia, lung fibrosis, decrease in lung function and lung cancer (7, 8, 9). International Commission on Radiological Protection issued report no 65 regarding "Protection against Radon-222 at home and at work" after examining the topic of exposure to radon (23). In this report, exposure to radon is limited, limit rates are suggested and an action level is determined for annual dose. It is suggested that action level shall be limited between 3 and 10 mSv. The radon concentration corresponding to these dose rates is determined as a rate between 200-600 Bq/m3 for houses (by taking duration spent at home as 7000 hours and balance factor as 0.4), and is determined as between 500-1500 Bq/m3 for working places. Moreover, hourly, annual and whole life doses are calculated in accordance with the average radiation concentration rates in houses of Kırklareli and whole life cancer risk of a person is also calculated by taking average human life as 70 years. Within this context, the average dose rate is 0.17 x10-3 mSv/hour (mSv=milisivert), the annual dose is 1,250 mSv, the whole life dose (for 70 years) is 87,56 mSv and the whole life cancer risk (for 70 years) is 0,620 % for the province. When we take the averages of districts and the province (1,250 mSv) into consideration according to obtained results, the annual limit for active dose, which is determined as 3mSv by ICRP, is not exceeded.



Map 9. Geographical distribution of radon concentrations in houses of the Kırklareli province

Due to insufficient knowledge about radioactive sources in Turkey, it is very difficult to estimate radiological risks in terms of human health. That is why it is very essential to carry out similar studies in other provinces and to determine background radiations fort he sake of human health.

This study, in which coordinates of sampling and measurement points are determined by GPS device and in which identical maps are drawn by transferring obtained data to Mapinfo program together with related coordinates, is the very first study of its scope within our country.

Reference:

1. Taşkın, H., "Determination and Mapping of Background Radiation of Kırklareli in Terms of Human Health and Environmental Pollution (İnsan Sağlığı ve Çevre Kirliliği Açısından Kırklareli İlinin Fon Radyasyonunun Belirlenmesi ve Haritalandırılması)", Graduate Thesis, MÜ, SBE, 2006

2. Lichtenstein, P.; Holm, N. V.; Verkasalo, p. K.; Iliadou, A.; Kaprio, j.; Koskenvuo,M.; Pukkala, E.; Skytthe, A.; Hemminki, K. Environmental and heritable factors in the causation of canser- Analyses of cohorts of twins from Sweden, Denmark, and Finland. N.Engl. J. Med. 343: 78-85; 2000.
3. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2000),Sources and Effects of Ionizing Radiation. Volume I: Sources, United Nations, New York, 2000
4. Turkish Atomic Energy Authority (Türkiye Atom Enerjisi Kurumu), "Measurements of Radiation and Radioactivity in Turkey after Chernobyl (Türkiyede Çernobil Sonrası Radyasyon veRadyoaktivite Ölçümleri)", TAEK, 1998
5. State Institute of Statistics (Devlet İstatistik Enstitüsü), Buildig Census in 2000 (2000 Yılı Bina Sayımı) –Ankara, 2000
6. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2000),Sources and Effects of Ionizing Radiation. Volume I:Sources, United Nations, New York, 2000
7. Agency for Toxic Substances and Disease Registry (ATSDR). Toxicological Profile for Uranium (Update). Public Health Service, U.S. Department of Health and Human Services, Atlanta, GA. 1999.
8. Agency for Toxic Substances and Disease Registry (ATSDR). Toxicological Profile for Radon. Public Health Service, U.S. Department of Health and Human Services, Atlanta, GA. 1990.
9. Agency for Toxic Substances and Disease Registry (ATSDR). Case Studies in Environmental Medicine. Radon Toxicity. Public Health Service, U.S. Department of Health and Human Services, Atlanta, GA. 1992.
10. Çelebi, N., ALKAN, H., Evaluation of Natural Radiation in the Kestanbol Spa Region. Radiation Protection Dosimetry Vol.69, No. 3, 227-230, 1997
11. Bohus-Saja, L.; Gomez, J.; Capote, T.; Greaves, E. D.; Herrera, O.; Salazar, V. And Smith A. J. Environ. Radioactivity, 35, 305-312, 1997
12. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 1982), Report to the General Assembly, p:88-89, 1982
13. International Commission of Radiological Protection. ICRP Publication., No.26 Oxford Pergamon Pres, 1977
14. Asikainen, M., Kahlos, H., International Radiation Doses from Radioactivity of Drinking Water in Finland. Health Physics, Vol. 39, 1980
15. Malanca, A.; Repetti, M.; Macedo, R. H Gross Alpha and Beta-activities in Surface and Ground Water of Rio Grande do Norte, Brazil Appl. Radiat. Isot. 49, 893-898, 1998
16. Turkish Standards Institution (Türk Standartlar Enstitüsü), Drinking Waters (İçme Suları), TS 226/1965, UDK 663-7:543, III. Edition, 1979
17. Teodere D.F., Edwards J.N., Housing, Stres and Well-Being, Evidence From Thailand. Soc.Sci. Med., 36, 1417-28,1993.
18. TAEK "Radon Research in Turkish Houses (Türkiye Evlerinde Radon Araştırması)" 2005 Annual Report (2005 Yılı Raporu), 2005
19. TAEK, Radiation Security Regulation (Radyasyon Güvenliği Yönetmeliği), 24.03.2000, No: 23999, Article 37. 2000
20. Çelebi, N., Taşdelen, M., Kopuz, G., Uluğ, A., Measurements of Radon Concentration in Antalya Houses (Antalya Evlerinde Radon Konsantrasyonu Ölçümleri), 2000- GAP-Congress of Environment, Vol.2,1053-1058, 2000
21. Evans, R.D. Engineers' Guide to the Elementary Behavior of Radon Daughters. Health Physics.17:229-256, 1969
22. Fabrikant, I. J., Radon and Lung Cancer: The BEIR IV Report. Health Physics. 59:89-97, 1990
23. International Commission on Radiological Protection, Protection Aganist Radon –222 at Home and at Work. Annals of the ICRP, ICRP Publication, No.65, Pergamon, Oxford, 1993