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Gamma Dose Rates of Natural Radioactivity in Adana Region in Turkey

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1. Introduction

We are all exposed to ionizing radiation from natural sources at all times. This radiation is called natural background radiation. Background radiation is the radiation constantly present in the natural environment of the Earth, which is emitted by natural and artificial sources. Natural radioactivity is wide spread in the earth's environment; it exists in soil, plants, water and air. Exposure of radiation mainly come from natural radiation (85 %). The assessment of gamma radiation doses from natural sources is of particular importance because natural radiation is the largest contributor of external dose to the world population (UNSCEAR,2000; Narayana N. et al.,2007) The exposure of human beings to ionizing radiation from natural sources is a continuing and feature of life on earth inescapable (UNSCEAR Report 2000). Throughout the history of life on earth, organisms have been continuosly exposed to radiations from radionuclides produced by cosmic ray interaction in the atmosphere and radiations from naturally occuring substances that are spatially distributed in all living and non-living components of the biosphere.(Whicker F.W. And Schultz, 1982)

Environmental natural gamma radiation is formed from terrestrial and cosmic sources (Merdanoglu and Altinsoy, 2006, M.Degerlier et al., 2008) It comes from two primary sources: cosmic radiation and terrestrial sources. The worldwide average background dose for a human being is about 2.4 millisievert (mSv) per year. This exposure is mostly from cosmic radiation and natural radionuclides in the environment (including those within the body).

The main sources of natural background radiation are radioactive substances in the earth's crust, emanation of radioactive gas from the earth ,cosmic rays from outer space which bombard the earth, trace amounts of radioactivity in the body.

Sources in the Earth include sources in water, soil and food which are incorporated to the human body, to building materials, and to products that incorporate radioactive sources from nature, sources from outer space are the radiation produced by the atomic bombardment of the upper atmosphere by high-energy cosmic rays and sources in the atmosphere, such as the radon gas released from the Earth's crust, which then decays into radioactive atoms that attach to airborne dust, and other particulate (granular, powder) materials.

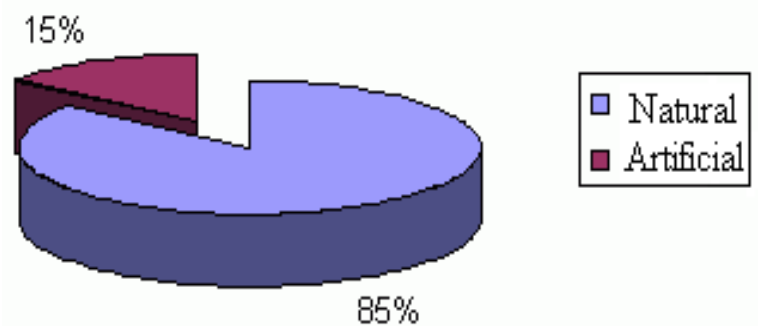

Fig. 1. Exposure radiation dose rates from natural and artificial sources

Radiation		UNSCEAR	
Type	Source	World Average (mSv)	Typical Range (mSv)
Natural	Air	1.26	0.2-10.0
	Internal	0.29	0.2-1.0
	Terrestrial	0.48	0.3-1.0
	Cosmic	0.39	0.3-1.0
	Total	2.40	1.0-13.0
Man Made	Medical	0.60	0.03-2.0
	Fallout	0.007	0-1+
	others	0.0052	0-20

Table 1. Exposure dose rates as mSv from natural and artificial sources in the World

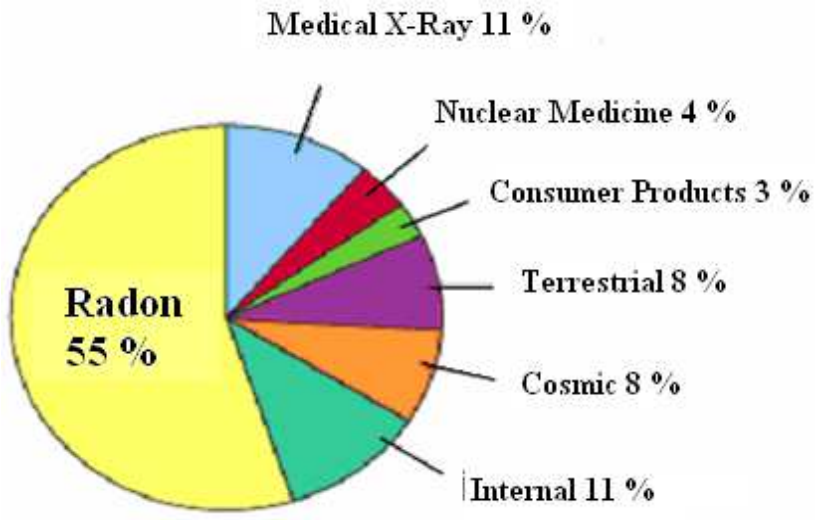

Fig. 2. Exposure dose percentage from natural and artificial radiation sources

On the ground, cosmic radiation makes up on average about 17 % of the natural background radiation to which we are all exposed. The rest consists of radon gas (50%), radiation from minerals in the soil (20 %), and radiation in our bodies from food and water (13 %).

Some radioactive materials - most of which are naturally occurring elements - are actually air pollutants. All of them, as a whole, are a relatively small proportion of the many elements and chemicals that are considered air pollution. Radon is the most significant of these elements, but most radon exposure stems from the indoor environment. Improving technology continues to minimize man-made radioactive air pollutants and monitor air quality.

2. Terrestrial

Naturally occurring radionuclides of terrestrial origin (also called primordial radionuclides) are present in various degrees in all media in the environment, including the human body itself. Only those radionuclides with half-lives comparable to the age of the earth, and their decay products, exist in significant quantities in these materials. Irradiation of the human body from external sources is mainly by gamma radiation from radionuclides in the ^{238}U and ^{232}Th series and from ^{40}K. These radionuclides are also present in the body and irradiate the various organs with alpha and beta particles, as well as gamma rays. Some other terrestrial radionuclides, including those of the ^{235}U series, ^{87}Rb, ^{138}La, ^{147}Sm and ^{176}Lu exist in nature but at such low levels that their contributions to the dose in humans are small.

Natural radionuclides in soil generate a significant componed of the background radiation exposure of the population (Karahan and Bayulken, 2000) Gamma radiation intensity in a region depends on soil and geographic structure.

External exposures outdoors arise from terrestrial radionuclides present at trace levels in all soils. The specific levels are related to the types of rock from which the soils originate. Higher radiation levels are associated with igneous rocks, such as granite and lower levels with sedimentary rocks. There are exceptions however as some shales and phosphate rocks have relatively high content of radionuclides. There have been many surveys to determine the background levels of radionuclides in soils, which can in turn be related to the absorbed dose rates in air. The latter can easily be measured directly, and these results provide an even more extensive evaluation of the background exposure levels in different countries. All of these spectrometric measurements indicate that the three components of the external radiation field, namely from the gamma emitting radionuclides in the ^{238}U and ^{232}Th series and ^{40}K, make approximately equal contributions to the externally incident gamma radiation dose to individuals in typical situations both outdoors and indoors.

The radionuclides in the uranium and thorium decay chains cannot be assumed to be in radioactive equilibrium. The isotopes ^{238}U and ^{234}U are in approximate equilibrium as they are separated by two much shorter lived nuclides, ^{234}Th and ^{234}Pa. The decay process itself may however allow some dissociation of the decay radionuclide from the source material, facilitating subsequent environmental transfer. Thus, ^{234}U may be somewhat deficient relative to ^{238}U in soils and enhanced in rivers and the sea. The radionuclide ^{226}Ra in this chain may have slightly different concentrations than ^{238}U because separation may occur between its parent ^{230}Th and uranium and because radium has greater mobility in the

environment. The decay products of ^{226}Ra include the gaseous element radon, which diffuses out of the soil, reducing the exposure rate from the ^{238}U series. The radon radionuclide in this series ^{222}Rn has a half life of only a few days but it has two longer lived decay products, ^{210}Pb and ^{210}Po, which are important in dose evaluations. For the ^{232}Th series, similar considerations apply. The radionuclide ^{228}Ra has a sufficiently long half-life that may allow some separation from its parent ^{232}Th. The gaseous element of the chain ^{220}Rn has a very short half life and long lived decay products.

The activity concentration of ^{40}K in soil is an order of magnitude higher than that of ^{238}U or ^{232}Th.

Terrestrial radiation is due to various radioactive nuclides that are present in soil, water, air and their abundance changes depending on the geological and geographical features of region (UNSCEAR Report 2000) The intensity of the terrestrial natural radioactivity varies by an order of magnitude for different regions of the world due to geological and environmental factors (Patra A.K.et al, 2006)

The variations in the abundance and distribution of the primordial radionuclides in the environment account for the spatial variations in the natural gamma radioactivity of such environments (Isinkaye M.O, et al., 2008) The terrestrial component is due to the radioactive nuclides that are present in air, soils, rocks, water and building materials in amounts that vary significantly depending on the geological and geografical features of a region.

Radionuclides when released to the atmosphere, undergo decay in transit or are deposited on Earth's surface by wet or dry deposition within relatively short periods. They are initially deposited on the upper surface of the soil, but are quickly weathered into the first few centimeters of the soil (UNSCEAR Report,2000; Isinkaye M.O et al., 2008)

In its first assessment of representative concentrations of these radionuclides in soil, in the UNSCEAR 1982. Committee suggested the values of 370,25 and 25 Bq kg^{-1} for ^{40}K, ^{238}U and ^{232}Th respectively.

Direct measurements of absorbed dose rates in air have been carried out in the last few decades in many countries of the world.

3. Cosmic

The main contributors to natural radiation are high energy cosmic ray particles incident on the Earth's atmosphere and radioactive nuclides that originated in the Earth's crust. Humans are affected by both external and internal exposures (UNSCEAR Report 2000)

Cosmic radiation is formed due to high energy particles that come from outer space and continually bombard the Earth. These cosmic rays interact with the nuclei in atmosphere, producing a cascade of interactions and secondary reaction products that contribute to cosmic ray exposures. The cosmic ray interactions also produce radioactive nuclei known as cosmogenic radionuclides (UNSCEAR 2000)

Although cosmic radiation increases with increasing altitude, it could be expected that people living at high altitudes suffer more from cosmic rays than those at sea level. Because of the Earth's magnetic field, the cosmic ray intensity varies with latitude, the lowest value being at the geomagnetic equator.

Cosmic radiation observed at a high elevation would be expected to have higher counts as a result of less atmosphere above the flight line.

The cosmic radiation originates from space as cosmic rays whose contribution to background changes mainly with elevation and latitude. Cosmic radiation consist of energetic charged particles, such as protons and helium ions, moving through space. They originate from events beyond our solar system and from the sun. When these particles enter the Earth's atmosphere they collide with, and disrupt, atoms in our atmosphere, producing secondary, less intense, radiation. By the time cosmic radiation reaches the ground its intensity has been considerably reduced.

The amount, or intensity, of cosmic radiation depends on altitude and latitude, as well as the stage of the solar cycle. The Earth's atmosphere provides considerable protection from cosmic radiation. At commercial aircraft altitudes the protective layer of the Earth's atmosphere is much thinner than it is on the ground and the intensity of cosmic radiation is approximately 100 times greater at these altitudes than it is on the ground.

The Earth's magnetic field can deflect some of the cosmic radiation away from the Earth. The shielding ability of the magnetic field is most effective over the equator and least effective over the poles. The intensity of cosmic radiation at aircraft altitudes around the equator is about three times less than at the poles.

The sun's magnetic field can also deflect cosmic radiation away from the Earth. The strength of the sun's magnetic field varies with the approximate 11 year cycle of rise and decline of solar activity (solar cycle). When solar activity is low (solar minimum), the magnetic field is less effective in deflecting cosmic radiation; cosmic radiation reaching the Earth will be more intense during solar minimum. The effect of solar activity on intensity of cosmic radiation is much smaller than that caused by altitude or latitude. The sun ejects energetic particles, such as protons (solar flares), which may also contribute to the intensity of cosmic radiation. However, only on very infrequent occasions would solar flares have sufficient energy to increase the intensity of cosmic radiation at commercial aircraft altitudes.

4. Materials and methods

In order to determine the outdoor gamma dose rates region and activity concentrations in soil samples is divided to 6 basic geographic areas in Adana region in Turkey. Each geographic area called as a sampling station. This region is located in the southern part of Turkey.

The outdoor gamma dose rates were measured by Eberline smart portable device (ESP-2) connected with and SPA-6 model plastic scintillation detector. Measurements were taken in air for two minutes at 1 m above the ground and the gamma dose rates were recorded as μRh^{-1} . The gamma absorbed doses in nGy h^{-1} were also converted to annual effective dose in mSv y^{-1} as proposed by UNSCEAR .

SPA-6's calibration was done using ^{137}Cs with an electrometer device for certain distances in the laboratory.

Sampling stations were chosen uncultivated and near to populated areas to understand the amount of dose received by the population because of absorbed gamma dose rate in air. At

each measurement a reading was taken in air for 1 h at 1 m above the ground level. The instrument calculates an average 1 h exposure rate based on the multiple measurement results. The results include both terrestrial and cosmic ray components of gamma radiation level that was recorded in units of μRh^{-1}.

Soil samples were taken with 25 cm diameter cores collected at different locations and different depths ranging from 0 to 30 cm. These samples were taken from uncultivated fields and sampling stations were chosen close to populated areas.

The soil samples were dried, pulverized, homogenized and sieved through 2 mm mesh. The meshed soil samples were transferred to Marinelli beakers of 1000 ml capacity. The soil samples were weighed, carefully sealed and stored for 30 days to allow secular equilibrium between thorium and radium and their products (Mollah et al., 1987)

Gamma spectropic measurements were performed using a coaxial HPGe detector having a 16 % relative efficiency. A detection system containing a Canberra Model 2020 Amplifier and a Canberra S-85 Multi Channel Analyzer with Model 8087 4K ADC was used for the measurements. The detector was shielded in a 10 cm thick lead well, internally lined with 2 mm thick copper and 2 mm thick cadmium foils. The overall detector resolution (FWHM) of 1,9 keV was obtained for the 1332 keV gamma line of ^{60}Co. Energy calibration and relative efficiency calibration of the gamma spectrometer were carried out using ^{109}Cd, ^{57}Co, ^{113}Sn, ^{134}Cs, ^{137}Cs, ^{188}Y and ^{60}Co calibration sources in 1000 ml Marinelli beaker covering the energy range from 80 to 2500 keV. The counting time for each sample, as well as for background was 50,000 s.

Gamma spectroscopy was used to determine the activities of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs. For concentrations of ^{232}Th and ^{238}U the following gamma transition lines were used; ^{232}Th series: ^{228}Ac (911 keV), ^{208}Tl (583.1keV); ^{238}U series : ^{214}Pb(351.9 keV) and ^{214}Bi (609.2 keV).

The contribution of natural radionuclides to the absorbed dose rate in air depends on the concentration of the radionuclides in soil. The largest part of the gamma radiation comes from terrestrial radionuclides. There is a direct correlation between terrestrial gamma radiation and radionuclide concentration in soil.

5. Results and discussions

The radionuclide activity concentrations in the soil samples taken from 6 different locations are reported in Table2. The mean activity concentrations of ^{214}Pb and ^{214}Bi of ^{238}U series are 16,81 and 14,65 Bq kg^{-1} , respectively. The mean activity concentrations of ^{228}Ac and ^{208}Tl of ^{232}Th series are 24,34 and 26,21 Bq kg^{-1}, respectively. The worldwide average concentrations of ^{238}U, ^{232}Th are reported by UNSCEAR 2000 as 35, 30 Bq kg^{-1}. The average concentrations of ^{214}Pb and ^{214}Bi of ^{238}U and ^{228}Ac and ^{208}Tl of ^{232}Th series are lower than world average. The radioanuclide activity concentrations are shown in Figure 4 for ^{214}Pb, in Figure 5 for ^{214}Bi, in Figure 6 for ^{228}Ac, in Figure 7 for ^{208}Tl. The highest value was measured in Saimbeyli town where is on a high elevated place as 28.33 Bq kg^{-1} for ^{214}Pb, 23.06 Bq kg^{-1} for ^{214}Bi of ^{238}U series and 49.87 Bq kg^{-1} for ^{228}Ac, 54.89 Bq kg^{-1} for ^{208}Tl of ^{232}Th series. The lowest value was measured in Yeniyayla (Yuregir) town as as 5.80 Bq kg^{-1} for ^{214}Pb, 4.83 Bq kg^{-1} for ^{214}Bi of ^{238}U series and 8.38 Bq kg^{-1} for ^{228}Ac, 8.36 Bq kg^{-1} for ^{208}Tl of ^{232}Th series.

The outdoor gamma dose rates was shown in Table 2 and Figure 8.The average outdoor gamma dose rates in air is 76.2 nGy h^{-1}. The highest value was measured as 134 nGy h^{-1} in Feke town. The lowest outdoor gamma dose rate was measured as 49.5 nGy h^{-1} in Karatas town.

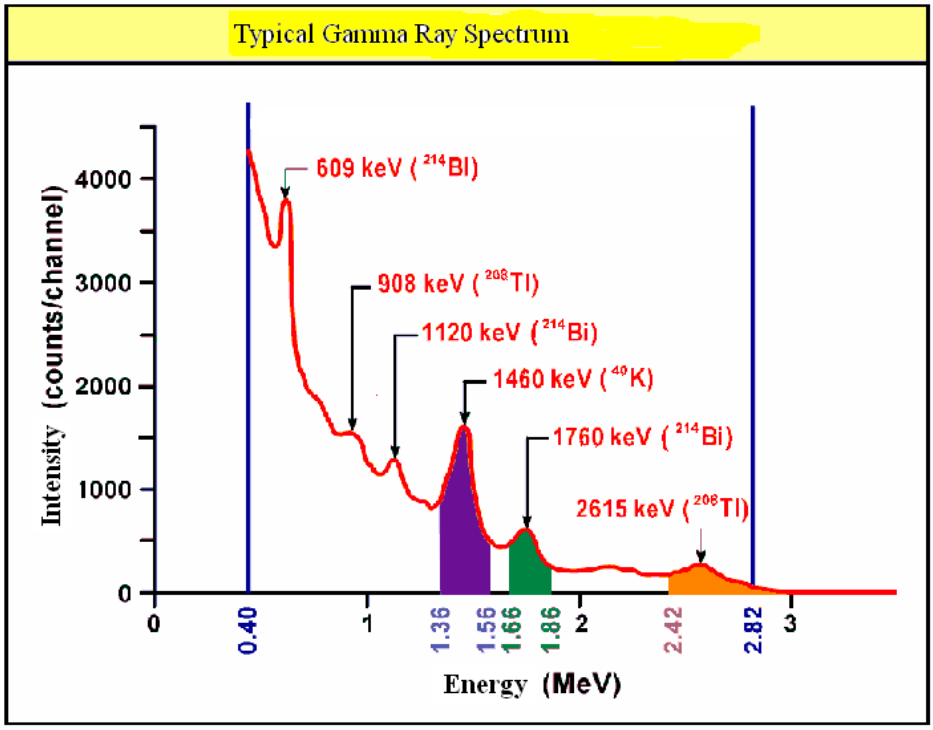

Fig. 3. Typical Gamma Ray Spectrum

	U-238 series		Th-232 Series	
	Pb-214	Bi-214	Ac-228	Tl-208
Balcali Fen Edebiyat Fakultesi	17.66	16.17	23.63	27.19
Yeniyayla (Yuregir)	5.80	4.83	8.38	8.36
Feke (Center)	22.59	21.34	39.38	43.47
Ceyhan (Center)	17.38	16.77	16.15	14.98
Karatas (Center)	9.10	9.75	8.65	8.37
Saimbeyli (Center)	28.33	23.06	49.87	54.89

Table 2. Activity concentrations in soil samples as Bq kg^{-1}

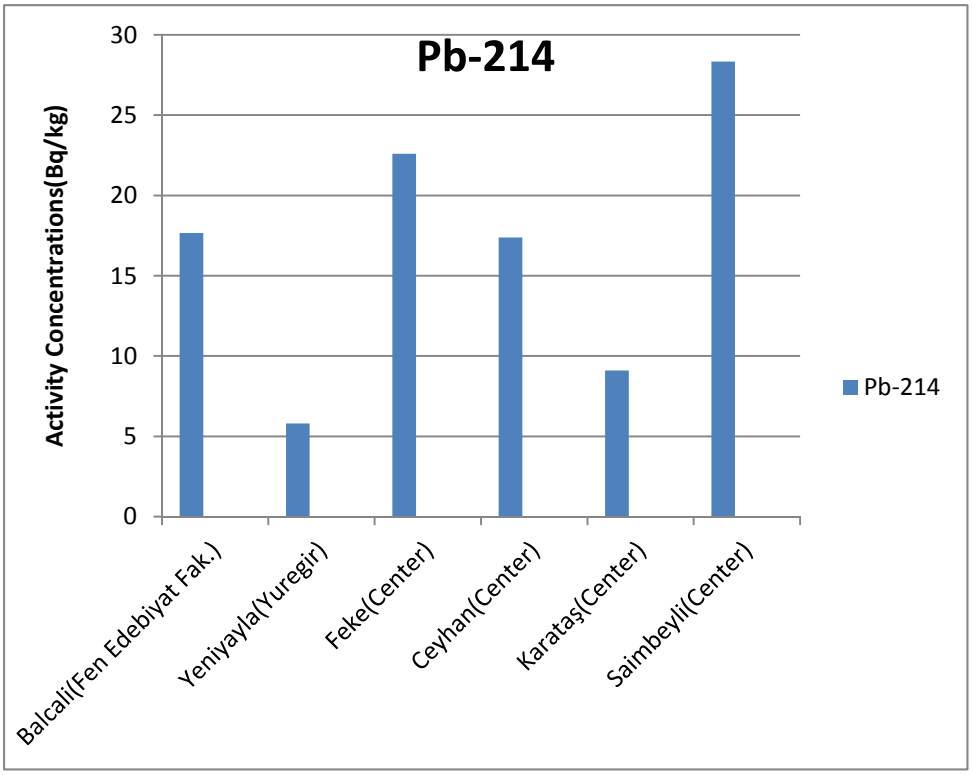

Fig. 4. Pb-214 activity concentrations (Bq kg^{-1}) in soil samplesin Adana Region

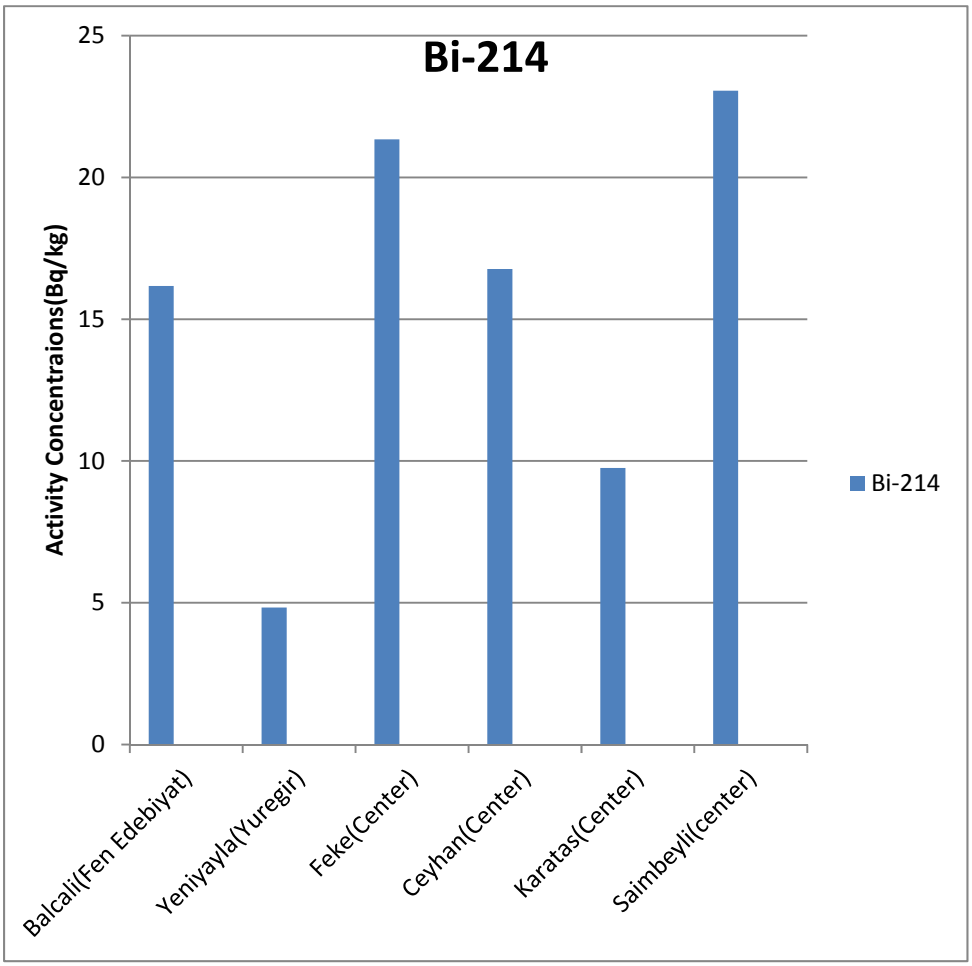

Fig. 5. Bi-214 activity concentrations (Bq kg^{-1}) in soil samples in Adana region

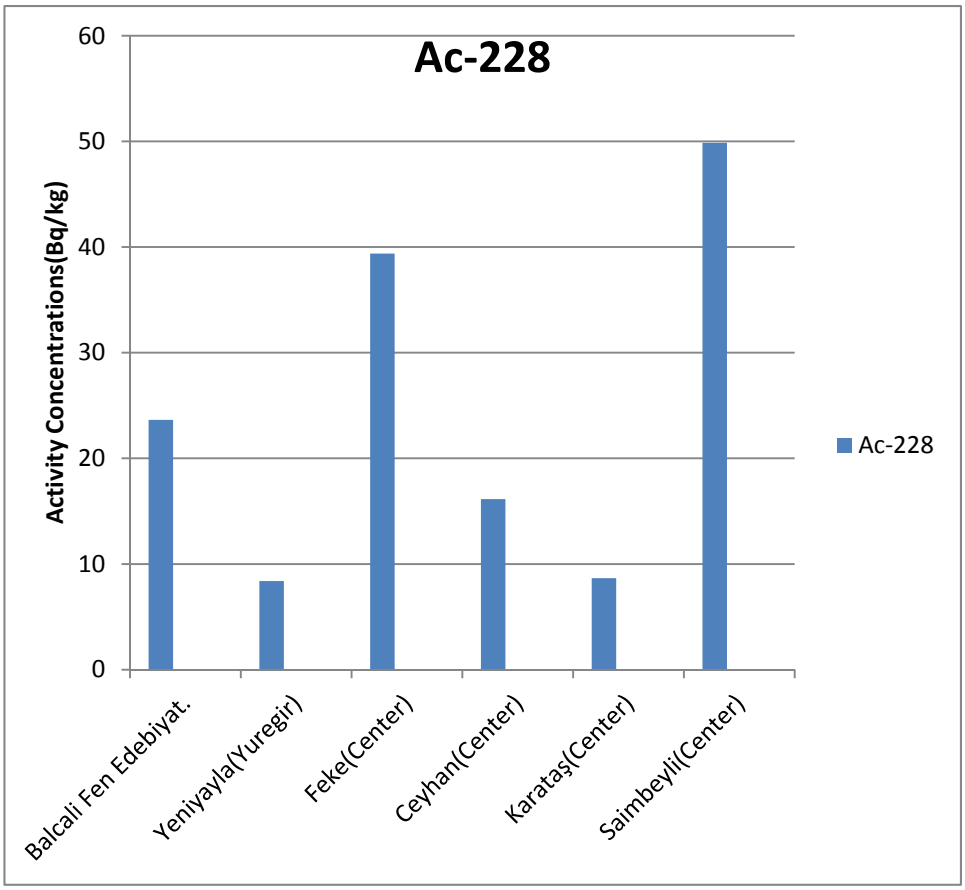

Fig. 6. Ac-228 activity concentrations (Bq kg^{-1}) in soil samples in Adana Region.

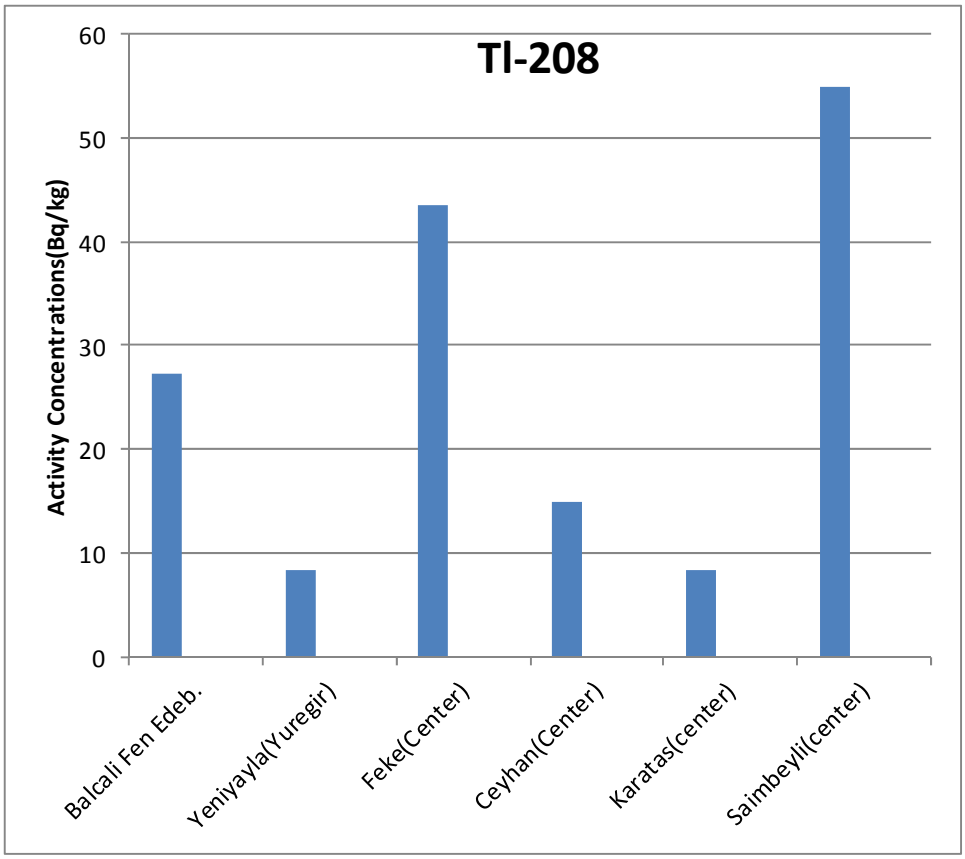

Fig. 7. Tl -208 Activity concentrations (Bq kg^{-1}) in soil samples in Adana Region

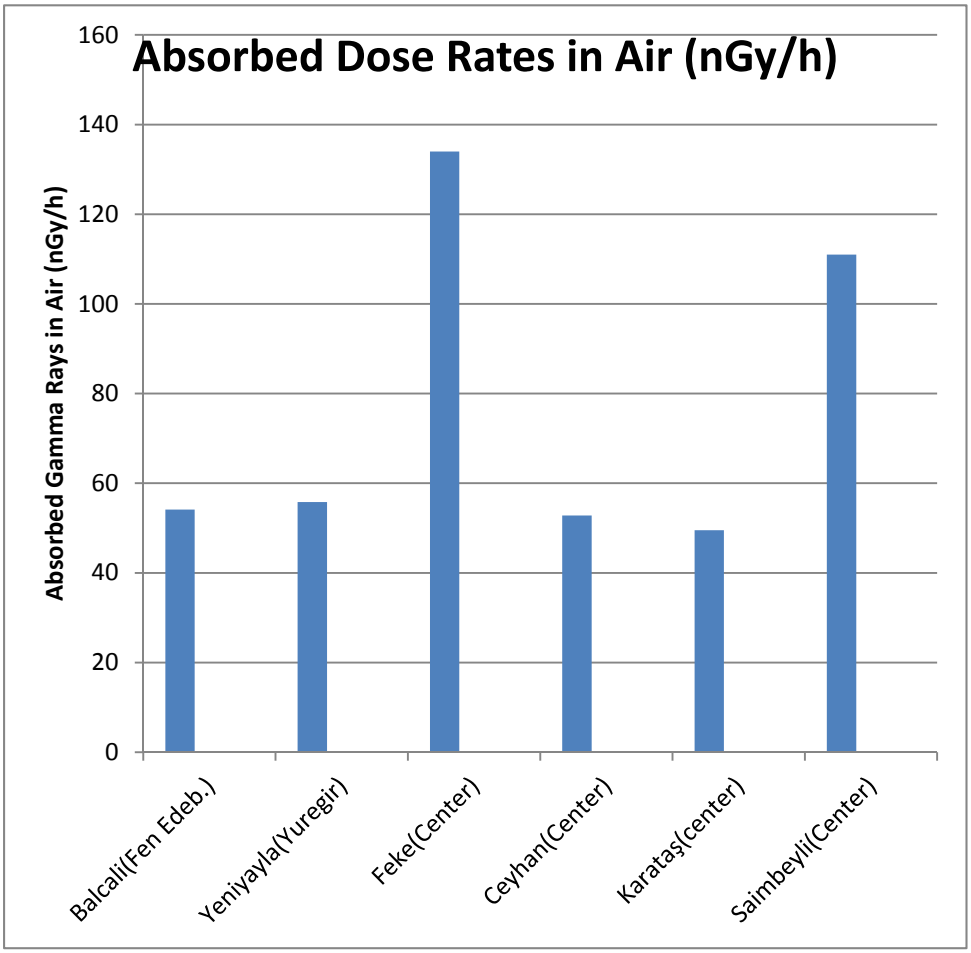

Fig. 8. Absorbed Dose Rates in Air (nGy h^{-1})

Places	Measured Absorbed Equivalent (nGy/h)
Balcali (Fen Edebiyat Fak.)	54,1
Yeniyayla (Yuregir)	55,8
Feke(Center)	134
Ceyhan(Center)	52,8
Karataş(Center)	49,5
Saimbeyli (Center)	111

Table 3. Outdoor gamma dose rates in air as nGy h^{-1}

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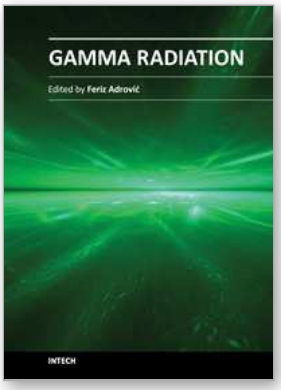

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This book brings new research insights on the properties and behavior of gamma radiation, studies from a wide range of options of gamma radiation applications in Nuclear Physics, industrial processes, Environmental Science, Radiation Biology, Radiation Chemistry, Agriculture and Forestry, sterilization, food industry, as well as the review of both advantages and problems that are present in these applications. The book is primarily intended for scientific workers who have contacts with gamma radiation, such as staff working in nuclear power plants, manufacturing industries and civil engineers, medical equipment manufacturers, oncologists, radiation therapists, dental professionals, universities and the military, as well as those who intend to enter the world of applications and problems of gamma radiation. Because of the global importance of gamma radiation, the content of this book will be interesting for the wider audience as well.

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