Determination of naturally occurring radionuclides in soil samples of Ayrancı, Turkey

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Abstract. The specific activity, radiation hazard index and the annual effective dose of the naturally occurring radioactive elements (²³⁸U, ²³²Th and ⁴⁰K) were determined in soil samples collected from 12 different locations in Ayrancı region by using a NaI(Tl) gamma-ray spectrometer. The measured activity concentrations of the natural radionuclides in studied soil samples were compared with the corresponding results of different countries and the internationally reported values. From the analysis, it is found that these materials may be safely used as construction materials and do not pose significant radiation hazards.

1. Introduction
Terrestrial gamma rays and cosmic rays are the two prominent natural sources of external radiation. The first source mainly originates from the primordial radioactive nuclides, originated in the early stages of the formation of the solar system [1]. Natural terrestrial radioactivity arises from the primordial radionuclides, such as, ⁴⁰K, and the radionuclides from the ²³⁸U and ²³²Th and their progenies [2,3]. Terrestrial background radiation represents the main external source of irradiation of the human body. Human beings are also exposed naturally from sources outside their bodies at any time.

The main objective of this study is to determine the activity concentration of natural radionuclides in the soil samples collected from Ayrancı, Turkey and to evaluate the radiological hazard of the natural radioactivity in samples. In the next section, we present the materials and method of the present study. In Section III, we show the result obtained by a NaI(Tl) scintillation detector and Section IV is devoted to our summary and discussion.

2. Material and Method
2.1 Study Area
Ayrancı is a district located in south of central Anatolian of Turkey. This study area is between latitudes 37°20' N and 37°22' N and longitudes 33°40' E and 33°42' E. The total urban area of Ayrancı is 2577 km² and the urban population is approximately 10 600.

2.2 Sample collection and preparation
Soil samples were collected from 12 different points in Ayrancı, Turkey. About half a kilogram of each sample was taken at a depth of 15 – 20 cm and filled into plastic bags and tagged. Each soil sample was air-dried (about 10 d) naturally in the laboratory. Thereafter, these samples were sieved through 2-mm mesh and were transferred to 100 ml beakers. The beakers with the soil samples were stored for more than 30 days to attain secular equilibrium between radium and radon before counting.
2.3 Experimental techniques

For measurements of the gamma activity concentrations of naturally occurring radionuclides namely $^{238}$U, $^{232}$Th and $^{40}$K in soil samples, a 3" x 3" NaI(Tl) gamma-ray spectrometric system was employed. The detector was surrounded by a special cylindrical lead shield of about 10 cm and a height of 38 cm thickness to reduce the gamma-ray background. The system was calibrated for the gamma energy range 186 keV to 3000 keV. The IAEA gamma-ray spectrometry standard reference sources of known radionuclides with $^{238}$U (RGU-1), $^{232}$Th (RGTh-1) and $^{40}$K (RGK-1) were used to determine the efficiency of the detector for various energies in the prescribed geometry [4]. The soil samples were placed on top of the detector and each sample was counted for 10 000 s. The net area count was calculated by using ScintiVision program.

3. Results

Table 1 shows activity concentration of naturally occurring radionuclides in soil samples collected from 12 different points in Ayrancı, Turkey. In soil samples, the average concentrations of $^{238}$U, $^{232}$Th and $^{40}$K were found to be 25±14, 50±27 and 228±94 Bq/kg, respectively. The data obtained for the above--cited radionuclides in this study are compared with concentrations from different regions of the world and Turkey in table 2.

Radiation hazard index analysis such absorbed dose rate, radium equivalent activity, annual effective dose and external hazard index is performed to arrive at a better and safer conclusion and calculated according to the equations given in our previous study [5,6].

As can be seen in Fig. 1, the total absorbed dose in the studied area changed from 24.92 to 91.99 nGy h$^{-1}$ with an average value of 52.56 nGy h$^{-1}$. Whereas, the calculated values for annual effective dose varied from 35.56 to 112.81 μSv·y$^{-1}$ with an average value of 51.82 μSv·y$^{-1}$. These values are within the permissible dose equivalent limit (460 μSv·y$^{-1}$) [2].

Radium equivalent activity in soil samples varied from 53.94 to 204.54 Bq kg$^{-1}$ with mean value of 114.95 Bq kg$^{-1}$ (Fig. 1). All soil samples have Raeq which is commonly used to measure radiation hazards of the cited radionuclides in single quantity lower than the (370 Bq kg$^{-1}$) limit proposed by OECD [7].

| Sample ID | $^{238}$U (Bq·kg$^{-1}$) | $^{232}$Th (Bq·kg$^{-1}$) | $^{40}$K (Bq·kg$^{-1}$) |
|-----------|-------------------------|--------------------------|------------------------|
| S1        | 31.0±16.3               | 107.7±26.6               | 256.5±91.6             |
| S2        | 23.8±14.4               | 60.2±27.5                | 220.4±100.8            |
| S3        | 31.7±12.6               | 21.9±30.3                | 320.7±105.2            |
| S4        | 11.5±13.8               | 52.8±24.2                | 311.1±77.1             |
| S5        | 28.0±15.0               | 49.6±26.2                | 278.3±93.6             |
| S6        | 42.5±14.1               | 40.9±32.6                | 225.1±97.7             |
| S7        | 12.6±11.6               | 51.7±29.8                | 166.3±87.9             |
| S8        | 10.6±13.3               | 32.6±29.4                | 157.8±89.7             |
| S9        | 32.6±16.2               | 75.5±25.9                | 249.6±92.8             |
| S10       | 28.5±16.5               | 54.7±29.7                | 229.5±94.9             |
| S11       | 12.0±14.8               | 21.9±20.2                | 139.1±103.4            |
| S12       | 40.9±16.2               | 34.7±28.1                | 182.0±96.4             |
| Avarage   | 25±14                   | 50±27                    | 228±94                 |
| World     | 30                      | 35                       | 400                    |
Table 2. Activity concentrations of the natural radionuclides in soil samples (in Bq·kg\(^{-1}\)) from different parts of the world and Turkey

| Region         | \(^{238}\)U | \(^{232}\)Th | \(^{40}\)K | References |
|----------------|-------------|-------------|-------------|------------|
| Xiazhuang (China) | 40.2–442    | 32.6–88.1   | 442–913     | [8]        |
| Russiaifa (Jordan) | 5–1201      | 2–31        | 19–288      | [9]        |
| Ibadan (Nigeria)  | 10.2–40.7   | 13.3–29.7   | 96.1–336.5  | [10]       |
| Buyukceceli      | 9.8–258.6   | 11.7–87.6   | 174.8–1949.5| [11]       |
| Çanakkale        | 21.39–253.1 | 38.84–160.9 | 583.1–3307  | [12]       |
| Karaman          | 36.1–106.1  | 12.6–39.5   | 139.9–566.3 | [5]        |
| Ayrancı          | 11.5–42.5   | 21.9–107.7  | 139.1–320.7 | This work  |

Fig. 1. Calculated values of (a) absorbed dose rate, (b) radium equivalent activity, (c) annual effective dose and (d) external hazard index.

The obtained values of external hazard index (Hex) range from 0.39 to 0.64. For the materials to be used in construction, this index should be less than unity. The external radiation hazard in this studied area is less than unity [13].
4. Conclusions
In present study, levels of natural radioactivity in soil samples collected from Ayrancı, Turkey is determined using a NaI(Tl) scintillation detector. The activity concentrations of $^{238}$U and $^{40}$K are lower than the world wide average, but the activity of $^{232}$Th is higher than the world wide average. The obtained values of known radiation hazard indices in study area also are calculated and lower than recommended values. The results reveal that the average dose rates do not exceed the average world recommended values and do not pose a significant health hazard. The data presented can be used for comparison in future investigations and may be useful for preparing a radiological map of the area. The results may also be used as a reference data for monitoring possible radioactivity pollutions in future.

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