The concentrations of natural radionuclides in 6 different volcanic tuff stones which commonly use as building and decoration material around Cappadocia region, Turkey were determined using gamma ray spectroscopy with an HPGe detector and the chemical name and formula of stones were determined by X-ray diffraction powder for the indoor absorbed gamma dose rate in air (D_a), external radiation equivalent activity (Ra_eq), internal hazard index (H_i), external hazard index (H_e), alpha and gamma index associated with the natural radionuclide are calculated to assess the radiation hazard of the natural radioactivity in the different of volcanic tuff stones.

SAMPLE PREPARATION and MEASUREMENT TECHNIQUES

Preparation of stone samples with Marinelis Beakers

CAPPADOCIA REGION

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

Cambridge 5-85 Multi Channel Analyzer with Model 8874 KADCI

Gamma spectroscopic measurements were performed using a coaxial HPGe detector having a 16% relative efficiency. A detection system containing a Cambridge Model 202 Amplifier and a Cambridge 5-85 Multi Channel Analyzer with Model 8874 KADCI 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 flats. The overall detector resolution (FWHM) of 1.9 keV was obtained for the 1332 keV gamma line of 51Cr. Energy calibration and relative efficiency calibration of the gamma spectrometer were carried out using 133Ba, 137Cs, 133Ba, 131I, 140Ba, 137Cs and 137Cs calibration sources in 1000 ml Marinelis 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.

RESULTS

The indoor absorbed gamma dose rate (D_a) in air was evaluated using data and formulas provided by the UNSCEAR (1999) Report (Fig. 4). Dimensions of the room are 4 m x 5 m x 2.8 m. The thickness of tiles on all walls and density of the structures are 3 cm and 2600 kg m^-3, respectively. These coefficients correspond to 0.12 μSv h^-1 per Bq kg^-1 for 238Ra, 0.14 μSv h^-1 per Bq kg^-1 for 232Th and 0.0096 μSv h^-1 per Bq kg^-1 for 40K (UNSCEAR, 1999; Turhan, 2012). D_a(μSv h^-1) = 0.12C_{Ra} + 0.14C_{Th} + 0.0096C_{K}.

Where C_{Ra}, C_{Th} and C_{K} were the activity concentrations of Ra, Th and K (Beq kg^-1), respectively.

Annual external (gamma) index (H_{ex}) due to emitted gamma ray of each samples are given by following equation:

H_{ex} = (C_{Ra} + C_{Th} + C_{K}) / 4810 \times 10^{-1} (1)

And the internal exposure to 226Ra and its radioactive progeny is controlled by the internal hazard index which is given by:

H_i = C_{Ra} / 370 + C_{Th} / 259 + C_{K} / 4810 \times 10^{-1} (2)

The alpha index was calculated by using the following equation,

L_a = 209Ra / 206Pb

Table 1. αRa, 226Th and 232Th activity concentrations of samples as Bq kg^-1

Table 2. Calculated absorbed dose rates (D_a), indoor annual effective dose (H_{ex}), external radiation equivalent activity (Ra_eq), internal hazard indices (H_i), External hazard indices (H_e), Alpha and gamma indexes for all samples