NATURAL RADIOACTIVITY OF VOLCANIC TUFF STONES WITH DIFFERENT COLORS USED AS COMMONLY BUILDING MATERIALS

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Abstract

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 diffactometer for powder. Indoor absorbed gamma dose rate in air (D_{in}), radium equivalent activities (Ra_{eq}), external hazard index (H_{ex}), internal hazard index (H_{in}), 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

CAPADOCIA REGION

Preparation of stone samples with Marinelli Beakers

The stone samples were pulverized, dried, homogenized and sieved through 2 mm mesh. The meshed samples were transferred to Marinelli 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 (Mollah et al., 1987)

Canberra S-85 Multi Channel Analyzer with Model 8087 4K ADC

Gamma spectroscopic measurements were performed using a coaxial HPGe detector having a 16% relative efficiency. A detection system containing a Canberra Model 202 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.

Material	Stone Colors	Stone Compound Name	Ra-226 (Bq/kg)	Th-232 (Bq/kg)	K-40 (Bq/kg)	Cs-137 (Bq/kg)
T1	Yellow	Albite high	64,5 ±1,6	96,0 ±2,3	1033,0 ±29,0	<1,1
		Tridymite				
T2	Dark Gray	Labradorite	42,4 ±0,8	38,8 ±3,6	747,4 ±18,6	<0,2
T3	Light Gray	Andesine	50,0 ±0,8	61,6 ±0,9	813,0 ±21,0	<0,3
		Tridymite				
T4	Light Beige	Albite intermediate	97,2 ±3,0	96,0 ±2,2	1036,0 ±31,5	<0,4
		Tridymite				
T5	Red	Andesine	32,2 ±0,6	42,0 ±0,7	447,0 ±11,7	<0,3
T6	Gray	Hatrurite	17,8 ±0,7	17,4 ±1,0	228,9 ±8,2	<0,5
		Gypsum				
Mean Value			50,7	58,6	717,6	

Table 1. ^{226}Ra, ^{232}Th and ^{40}K activity concentrations of samples as Bq kg^{-1}

Sample code	Stone Colors	Stone Compound Name	D_{in} (nGy/h)	E_{in} (mSv)	Ra_{eq}(Bq/kg)	H_{in}	H_{ex}	Gamma Index	Alpha Index
T1	Yellow	Albite high	31,1	0,15	281,3	0,9	0,8	1,0	0,3
		Tridymite							
T2	Dark Gray	Labradorite	17,6	0,09	155,4	0,5	0,4	0,6	0,2
T3	Light Gray	Andesine	22,4	0,11	200,7	0,6	0,5	0,8	0,3
		Tridymite							
T4	Light Beige	Albite intermediate	35,1	0,17	314,3	1,1	0,9	1,2	0,5
		Tridymite							
T5	Red	Andesine	14,1	0,07	126,7	0,4	0,3	0,5	0,2
T6	Gray	Hatrurite	6,8	0,03	60,3	0,2	0,2	0,2	0,1
		Gypsum							
Mean Value			21,18	0,1	379,6	0,6	0,5	0,7	0,3

Table 2. Calculated absorbed dose rates (D_{in}),indoor annual effective doses (E_{in}), Radium equivalent activity (Ra_{eq}), Internal hazard indexes (H_{in}), External hazard indexes (H_{ex}), Alpha and gamma index for all samples

CALCULATIONS

The indoor absorbed gamma dose rate (D_{in}) in air was evaluated using data and formulae provided by the EC Report (EC,1999) 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 nGy h^{-1} per Bq kg^{-1} for ^{226}Ra, 0,14 nGy h^{-1} per Bq kg^{-1} for ^{232}Th and 0.0096 nGy h^{-1} per Bq kg^{-1} for ^{40}K (EC,1999, Turhan 2012).

$$D_{in}(nGy\,h^{-1}) = 0.12C_{Ra} + 0{,}14\,C_{Th} + 0.0096\,C_K$$

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

The indoor annual effective dose equivalent (E_{in}) was calculated as follows;

$$E_{in}\,(mSv) = D_{in}\,(nGy\,h^{-1}) \times F_c\,(Sv\,Gy^{-1}) \times T_E\,(hy^{-1}) \times 10^{-6}$$

Where D_{in} is the indoor absorbed gamma dose rate, F_C is the conversion factor of 0,7 Sv Gy^{-1} from indoor absorbed gamma dose in air to effective dose received by adults (UNSCEAR, 2000) and T_E is annual exposure time of 7000 h y^{-1}, implying that 80% of time is spent indoors.

Radium equivalent activity (Ra_{eq}) is used to assess the hazards associated with materials that contain ^{226}Ra, ^{232}Th and ^{40}K in Bq kg^{-1}. This definition is based on the assumption that 1 Bq kg^{-1} of ^{226}Ra, 0.7 Bq kg^{-1} of ^{232}Th and 13 Bq kg^{-1} of ^{40}K produce the same gamma dose rate.The Ra_{eq} of the sample in (Bq kg^{-1}) can be determined using the following equation (UNSCEAR 1982; Huda Al-Sulaiti et al.2011):

$$Ra_{eq} = C_{Ra} + 1.43 \times C_{Th} + 0.077 \times C_K$$

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

$$H_{ex} = C_U / 370 + C_{Th} / 259 + C_K / 4810 \leq 1$$

(4)

And the internal exposure to ^{222}Rn and its radioactive progeny is controlled by the internal hazard index which is given by

$$H_{in} = C_U / 185 + C_{Th} / 259 + C_K / 4810 \leq 1$$

Gamma Index

In order to assess whether the safety requirements for building materials are being fulfilled, a gamma index proposed by the European Commission (EC,1999) was used. It is defined as,

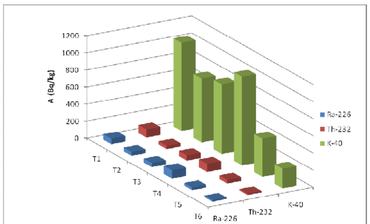
$$I_\gamma = \frac{C_{Ra}}{300} + \frac{C_{Th}}{200} + \frac{C_K}{3000}$$

ALPHA INDEX

The alpha index was calculated by using the following equation,

$$I_\alpha = \frac{C_{Ra}}{200}$$

RESULTS



3D spectrum for Ra,Th and K activity

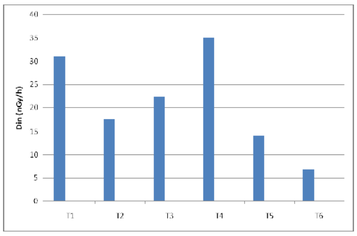


Fig 2. Indoor Absorbed Gamma Dose Rate due to The Natural Radioactivity for All Samples

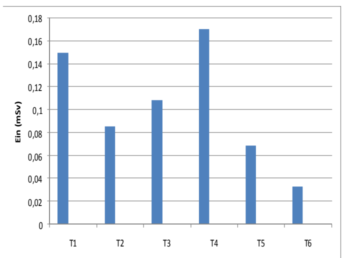


Fig 3. Indoor Annual Effective Dose Equivalent for All Samples

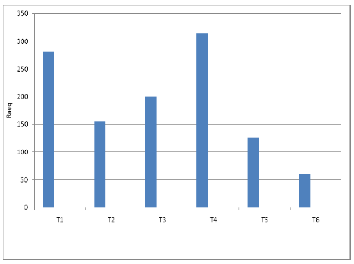


Fig 4. Radium equivalent activity (Ra_{eq}) of the samples

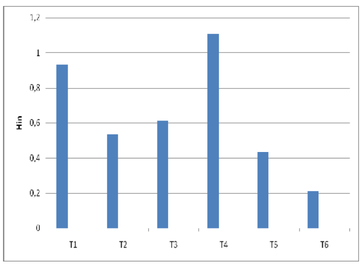


Fig 5. Internal hazard index of the samples

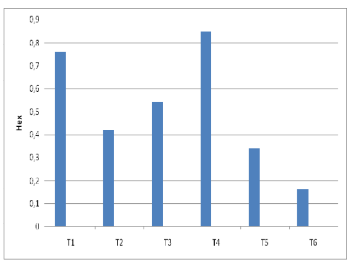


Fig 6. External hazard index of the samples