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Radioactivity Determination in Soil Gas, Air and Marble Samples in Iscehisar Marble Quarry

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Abstract—This study aims on determining the radioactivity level in the selected marble quarry in Afyonkarahisar (İsçehisar), Turkey with three different methods. Radon gas activity and ^{40}K, ^{238}U and ^{232}Th activities were measured using AB-5R detector by Pylon Electronics and sodium iodide thallium detector respectively. Radon activity in air in the marble quarries was assessed with AlphaGUARD Radon Monitor. The mean radon activity in air and in the soil gas in the region was measured to be in the range of 9.98 Bq/L – 116.39 Bq/L and 9.91 Bq/m3 respectively. Mean specific activity for marble samples taken from the studied quarries was found to be 139.29, 38.40 and 35.28Bq/kg for ^{40}K, ^{238}U and ^{232}Th, respectively. The measured results indicated that the radioactivity level for both the marble quarries and marble itself are safe.

Index Terms—Radioactivity level, Radon, Soil gas, K-40, U-238 and Th-232 activities.

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1 Introduction

THE main source of exposion to ionizing radiation in the environment is the cosmic rays and natural radioactivity [1] with an average effective dose of 2.4 mSvh [2]. The absorbed dose resulting from ^{40}K, ^{238}U and ^{232}Th radionuclides in soil core and building materials are reported in literature [3], [4], [5],[6]. Another source of radiation is Radon. The decay of the naturally occurring ^{238}U series present in soil, rocks, building materials and in underground water generates Radon (^{222}Rn) gas which is radioactive. Typical radon concentration and the radon concentration in a region depends on the composition of the underlying soil and rock formations and on meteorological parameters -typically at outdoors it is low (approximately 10 Bqm-3) - UNSCEAR (2000). However, inhaling microscopic dust particles radiated by daughter nuclides following radon decay may cause damage to the lung cells biologically due to the emission of alpha particles. The health hazards caused by radon inhalation force to emphasize the need defining upper limits for radon concentration in old and new buildings and to construct associated radon maps for each country [2], [7], [8].
This paper reports radon gas measurement to obtain activity of ^{238}U,^{232}Th and ^{40}K in air, in soil and the gamma radiation in marble samples collected from marble quarries in Afyonkarahisar.

2 Material and Method

2.1 Location of the Study Area

All samples have been collected from active marble quarry in the town of Iscehisar which is located in Afyonkarahisar region of Turkey. In Figure 1 the location of the town where the marble quarries are and where samples being collected has been shown.

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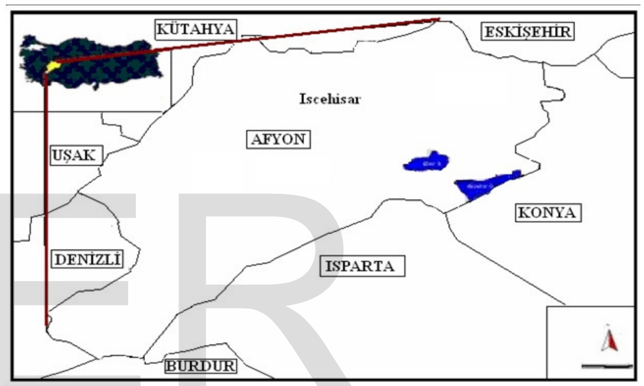

Fig. 1.The location of Iscehisar in Afyonkarahisar where samples were collected

2.2 Sample Collection

2.2.1 The Natural Activity of Marble Samples

All samples were collected from the marble quarry in town of Iscehisar. The collected marble samples were dried at 100℃. The dried samples were placed in a tightly sealed cup with a thick tape around the cup neck to avoid any gas leakage. Then all samples were left for four weeks until they reached an equilibrium between ^{238}U and its progeny [9]. The natural radioactivity of collected marbles were measured by using a NaI(Tl) detector connected to MCA. The measurement was based on recording natural radioactivity quantities of three natural long-live elements of ^{238}U, ^{232}Th and ^{40}K [10], [11]. The photo-peaks related with those radioactive elements were considered at 1760, 2610 and 1461 keV respectively, in the natural γ-ray spectrum. The following relation was used to calculate the activities for the natural radionuclides where N is the counts recorded in the detector after background substraction, ε is the detector efficiency of the specific γ-ray, P is the absolute transition probability of γ-decay, M is the mass of the sample (kg) and t is the counting time.

$$A\left(\frac{Bq}{kg}\right) = \frac{N}{\varepsilon.P.M.t} \quad (1)$$

2.2.2 Radon Activity Measurement in Soil

All samples for the soil gas measurement were collected from eight different points in the marble quarry. At sample collection points, 80 - 100 cm holes at 2-3 cm diameters were opened. Then, soil gas samples were collected with the vacuum soil probe. The collected soil gases were stored in Radon Storage Cell as shown in Figure 2.

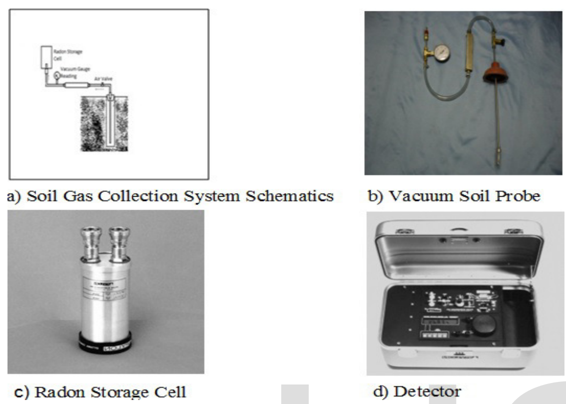

Fig. 2.Soil Gas Collection System.

2.2.2 Radon Activity Measurement in Air

Absorbed dose rates in air were measured 1m above the surface at each quarry using a hand-held survey meter (Canberra-radiagem 2000 model) with a reading range of up to 100 μSvh^{-1}. The absorbed dose rates in air in nGyh^{-1} were calculated from the dose rates in μSvh-1 as measured in the field using the conversion coefficient factor of 0.7 SvGy^{-1} as recommended by UNSCEAR (2000).

3 Results

The measured natural activity of marble samples taken from the quarries ranged from 35.30 - 39.66 Bq/kg for ^{238}U, from 32.16 - 41.53 Bq/kg for ^{232}Th, and from 106.26 - 167.04 Bq/kg for ^{40}K. The obtained results were displayed in Table 1. It can be clearly seen from this table that the highest value obtained for ^{40}K and the lowest value obtained for ^{232}Th from all samples.

Table 1: ^{40}K, ^{238}U and ^{232}Th activities for marble samples taken from quarries

Sample	Activity (Bq/kg)			***D***	***EDR***
	^{40}K	**^{238}U**	**^{232}Th**	$(nGy \cdot h^{-1})$	$(mSv \cdot y^{-1})$
1	106.26	39.66	35.30	44.07	0.054
2	167.04	38.08	32.16	43.98	0.054
3	150.13	37.94	33.11	43.79	0.054
4	116.83	41.06	34.31	44.56	0.055
5	155.78	35.30	41.53	47.89	0.059
Average	**139.29**	**38.40**	**35.28**	**44.86**	**0.055**

The characteristic of the external terrestrial γ-ray [12,2] was obtained by calculating the absorbed dose rate (D) in air at 1 m above the ground:

$$D(nGy \cdot h^{-1}) = 0.462A_{Ra} + 0.604A_{Th} + 0.0417A_K \quad (2)$$

Where; A_{Ra}, A_{Th}, A_K represent the activity of ^{238}U, ^{232}Th and ^{40}K in Bqkg^{-1}. The absorbed dose rate is given in the last column of Table 1 where it can be seen that all the values obtained for marble is less than the global average value of absorbed dose rate of 55 nGyh^{-1} [2]. The annual effective dose rates (EDR) is an important parameter in order to judge the health effects of the absorbed dose. By using the conversion coefficient from the absorbed dose in air to the effective dose (0.7 Sv Gy^{-1}) and the outdoor occupancy factor (0.2) proposed in ref. [12], EDR is:

$$EDR(mSv \cdot y^{-1}) = D(nGy \cdot h^{-1}) \times 8760(h \cdot y^{-1}) \times 0.2 \times 0.7(SvGy^{-1}) \times 10^{-6} \quad (3)$$

The converted results due to the marbles ranged 0.054 to 0.059 mSv.y^{-1}. It is clear that none of the results are higher than the UNSCEAR limit where the average EDR from the terrestrial radionuclids is 0.460 mSv y^{-1} in areas with the normal background radiation [2].

Radon activity in soil gas samples taken from 8 different holes were presented in Table 2. Results indicate increase in radon activity during dry summer months.

Table 2: Radon activity in soil gas samples taken from different holes every other week between April-August

Week	**Radon Activity in Soil Gas** (Bq/l)							
	Hole 1	**Hole 2**	**Hole 3**	**Hole 4**	**Hole 5**	**Hole 6**	**Hole 7**	**Hole 8**
15	66.13	14.77	-	48.63	40.90	40.24	63.01	97.81
18	-	20.01	9.98	30.65	38.30	-	39.69	101.06
20	97.45	26.80	37.36	42.00	51.42	60.22	57.61	107.70
22	108.63	34.38	49.09	64.07	43.95	71.88	68.39	104.02
24	92.27	32.79	43.22	42.38	47.94	55.05	47.36	109.73
25	83.18	30.66	58.42	35.69	33.21	52.62	54.87	102.00
26	96.24	24.11	61.64	47.92	24.10	58.45	43.67	114.60
28	88.78	27.95	53.27	46.12	26.19	52.03	33.07	107.11
30	84.40	22.65	42.03	44.17	27.00	47.63	37.95	111.54
32	79.31	18.87	26.94	43.93	32.08	41.41	34.36	116.39
34	81.94	31.04	33.36	39.09	28.90	38.92	31.85	104.90
Average	**87.83**	**25.82**	**41.53**	**44.06**	**35.82**	**51.85**	**46.53**	**106.99**

The absorbed dose rate (D) in air at 1 m above the ground as shown in Table 3 is calculated to provide a characteristic of the external terrestrial γ-ray [12], [2].

Table 3: Radon activity in air at the related region

Week	Radon activity in air (Bq/m^3)	Week	Radon activity in air (Bq/m^3)
15	5,32	**26**	11,92
18	6,31	**28**	8,68
20	11,36	**30**	9,82
22	13,13	**32**	9,78
24	12,81	**34**	11,93
25	7,95	**Average: 9,91 Bq/m^3**	

4 CONCLUSION AND COMMENT

The current study has provided useful information and a baseline for the future studies on the radioactive elemental concentration in boreholes. Generally, the results revealed specific activity for the three natural occurring radionuclides: K-40, U-238 ve Th-232 activities for marble samples taken from quarries radioactivity levels 139.29, 38.40 and 35.28Bq/kg, respectively are well below the UNSCEAR accepted upper limits.

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