RADIOMETRIC PROPERTIES OF SEPIOLITE MINERALS FROM QUARRIES IN CENTRAL ANATOLIA OF TURKEY

by

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Sepiolite is a naturally occurring clay mineral of sedimentary origin and is a magnesium hydrosilicate. Sepiolite has been widely used as an additive raw material in ceramics and cement industry, pharmaceutical, cleaning-detergent, paper, paint, cosmetic agriculture, fertilizer, *etc*. In this study, the natural radioactivity levels, radon emanation coefficients and radon exhalation rates of 30 sepiolite samples collected from open three sepiolite quarries (Beylikova, Polath and Sivrihisar) in Central Anatolia region of Turkey were determined by using a gamma-ray spectrometry with an HPGe detector. The average absorbed gamma dose rates directly measured in Beylikova, Polath and Sivrihisar open three sepiolite quarries located in Central Anatolia region of Turkey were found as 59, 65, and 64 nGyh^{-1}, respectively. The average activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in 30 sepiolite samples collected from those quarries were found as 38.6, 12.4, and 67.4 Bqkg^{-1}, respectively. The average emanation coefficient and exhalation rate of radon of sepiolite samples were determined as 22 % and 0.065 Bqkg^{-1}h^{-1}, respectively. Also, radiological parameters (outdoor absorbed gamma dose rate, annual effective dose rate, external and internal index) were estimated to evaluate the use of sepiolite samples as additive raw materials in the building sector.

Key words: sepiolite, natural radioactivity, outdoor absorbed gamma dose rate, radon emanation coefficient, radon mass exhalation rate, gamma-ray spectrometry

INTRODUCTION

The external and internal exposure of humans to ionizing radiation (α-, β-, γ-rays, *etc*.) from natural radioactive sources is a continuing and inescapable feature of life on earth [1]. There are two natural radioactive sources: cosmogenic radionuclides and primordial radionuclides. Cosmogenic radionuclides (^{3}H, ^{7}Be, ^{14}C, ^{22}Na, *etc*.) are produced as a result of the interactions of cosmic-ray particles in the atmosphere [1]. Primordial or terrestrial radionuclides are originated in the earth's crust and are present everywhere in the environment [1]. The external exposure is caused by the gamma-ray emitted from terrestrial radionuclides in the ^{238}U and ^{232}Th radioactive series, and ^{40}K.

The internal exposure arises from the intake of these radionuclides by inhalation and ingestion. Inhalation exposure is mainly caused by alpha and beta radiation from the radon (^{222}Rn) and its short-lived decay products [2].

Sepiolite belonging to the sepiolite-palygorskite group is a natural fibrous clay mineral which is formed of sheets of tetrahedral and octahedral oxides [3]. There are roughly two different types of sepiolite enrichment in nature. The first type of sepiolite formation is *meerschaum* and another important sepiolite formation is sedimentary sepiolite, also called *industrial sepiolite* or *layered sepiolite* [4]. Due to its sorptive (absorption/adsorption), rheological and catalytic properties depending on physicochemical, sepiolite have been widely used in industrial applications such as adhesives, agricultural carries, animal feed bondants, industrial floor absorbents, paint and coatings, drilling fluids, paper, pharmaceuticals, polishes, suspension fertilizers, and raw materials in ceramics and cement industry [5]. The important deposits of sepiolite occur in USA, China, Senegal, Spain, Ukraine, and Turkey [5]. Most production occurs in four countries (Spain, China, Turkey, and USA). The world's major commercial sepiolite deposit is located at Vicalvaro near Madrid [5]. In Turkey, meerschaum and layered sepiolite is produced near Eskisehir in Central Anatolia [4]. The meerschaum exists as lumps in Neogene aged conglomerates, and has been known as the only kind of commercially valuable sepiolite [4].

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Recently, sepiolite minerals have been studied extensively because it is a very important group of minerals with a huge number of industrial applications [6-11]. However, according to our literature research, there is no study about the radionuclide contents of sepiolite samples until now. The aim of this study is to complete the missing information about the radiometric properties of sepiolite. For this aim, in this study (1) the absorbed dose rates in outdoor air at a height of one meter above the ground in sepiolite open quarry of Beylikova, Polath and Sivrihisar were measured using a dose rate meter with Geiger-Muller tube, (2) the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K naturally occurring in sepiolite samples from those quarries were measured using a gamma-ray spectrometry with a high purity germanium (HPGe) detector, (3) radon emanation coefficients and radon exhalation rates of sepiolite samples were determined by indirect method and (4) absorbed gamma dose rate and the corresponding annual effective radiation dose, external (activity concentration index) and internal index (alpha index) were estimated to radiologically assess the use of sepiolite samples as building raw materials in the construction sector.

MATERIAL AND METHOD

Sampling and sample preparation for measurements

A total of 30 sepiolite samples were collected randomly from Beylikova (Eskisehir), Polath (Ankara), and Sivrihisar (Eskisehir) sepiolite open quarries located in Central Anatolia of Turkey, as shown in fig. 1. The outdoor gamma dose rate of each quarry

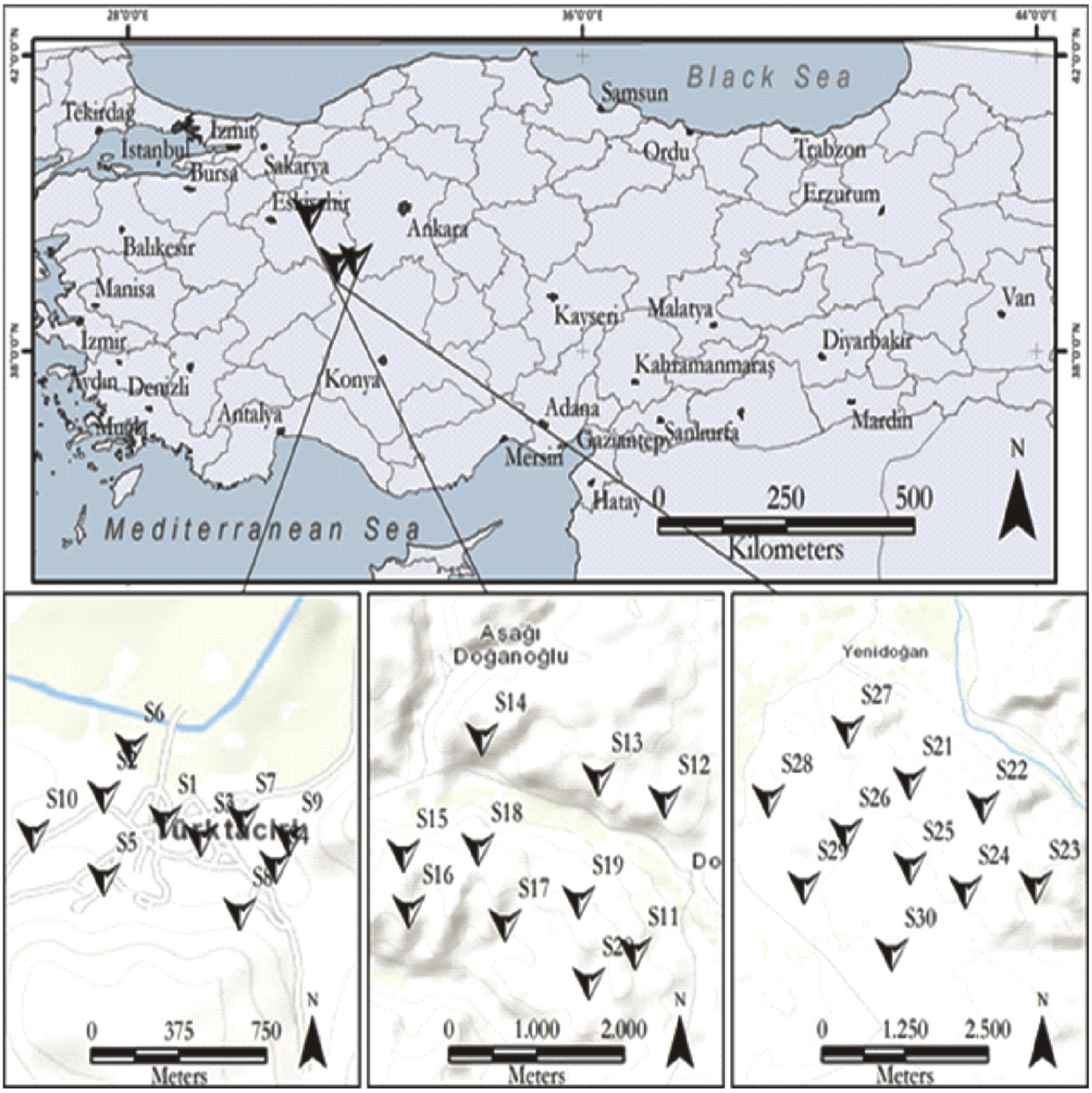

Figure 1. Map showing locations of measured samples

was measured three times at the point where the samples were collected. The outdoor gamma dose rate of each point was given as the average of these three measurements. The samples were coded according to the location of the sampling point.

The samples were crushed, pulverized and dried in a temperature-controlled furnace at 110 °C to remove moisture before being transferred to a sample container (5   6 cm). Sample containers were weighted, hermetically sealed and allowed to stand for at least one month to provide short-term equilibrium between ^{226}Ra and its short-lived decay products [2].

Radiometric measurements

The outdoor absorbed gamma dose rates in the air at a height of 1 m above the ground in sepiolite quarries were measured using dose rate meter (NEB.211L) that was produced at Cekmece Nuclear Research Centre in Istanbul. It has a Geiger Muller detector and provides a dose rate measurement range of 5 μRh^{-1} to 150 mRh^{-1}.

The activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in the sepiolite samples were measured using a gamma-ray spectrometer with a high-resolution coaxial p-type vertical HPGe detector (GEM50P4-83). The detector resolution is 1.9 keV at full-width half maximum of the 1332.5 keV gamma-ray photopeak from ^{60}Co. Peak to Compton ratio of the detector is 66:1 and has a relative efficiency of 50 %. Each sepiolite sample was placed on the top of the detector and counted for 86400 seconds. Background measurements were taken under the same conditions of sample measurements and subtracted in order to get net counts for the sample. The efficiency calibration of the HPGe detector was carried out using reference materials RGU-1 (U-ore), RGTh-1 (Th-ore) and RGK-1 (K2SO4) supplies by International Atomic Energy Authority [12]. The counting time for each sample was adjusted to obtain the gamma-ray spectrum with good statistics. The activity concentration of ^{226}Ra was measured using the 351.9 keV gamma-ray photopeak from ^{214}Pb and the 1764.5 keV gamma-ray photopeak from ^{214}Bi. The activity concentration of ^{232}Th was measured using the 911.2 keV gamma-ray photopeak from ^{228}Ac and the 583.2 keV gamma-ray photopeak from ^{208}Tl. The activity concentration of ^{40}K was measured directly by its own gamma-ray photopeak at 1460.8 keV.

RESULTS AND DISCUSSION

Absorbed gamma dose rates

The outdoor absorbed gamma dose rate measured (*DRM*) in Beylikova, Polath, and Sivrihisar quarry includes the cosmic ray and terrestrial components of the gamma radiation. The values of the DRM are presented in tab. 1. The DRM values of Beylikova, Polath and Sivrihisar varied from 56 to 129 nGyh^{-1} with an average of 88   25 nGyh^{-1}, 47 to 150 nGyh^{-1} with an average of 94   34 nGyh^{-1} and 52 to 159 nGyh^{-1} with an average of 93   36 nGyh^{-1}, respectively. Comparison of the average DRM values with terrestrial outdoor absorbed dose rates obtained by direct measurements in the literature is given in tab. 2. It can be seen from tab. 2 that the average DRM values are found to be in good agreement with the values given in the literature, except for Artvin.

Table 1. The outdoor absorbed gamma dose rate of sepiolite quarries

Quarry	Sample code	DRM [nGyh^{-1}]
Beylikova	S1	119
	S2	129
	S3	96
	S4	113
	S5	71
	S6	86
	S7	66
	S8	75
	S9	67
	S10	56
	Average	88
	SD	25
	Min	56
	Max	129
Polath	S11	128
	S12	120
	S13	114
	S14	94
	S15	62
	S16	150
	S17	91
	S18	68
	S19	62
	S20	47
	Average	94
	SD	34
	Min	47
	Max	150
Sivrihisar	S21	139
	S22	122
	S23	76
	S24	90
	S25	75
	S26	64
	S27	52
	S28	87
	S29	64
	S30	159
	Average	93
	SD	36
	Min	52
	Max	159

Table 2. Comparison of the average outdoor absorbed gamma dose rate value with those reported for different regions of Turkey and other countries

Country	Absorbed dose rate in air [nGyh^{-1}]	Reference
Malaysia	92	[1]
China	62	[1]
Poland	45	[1]
Bulgaria	70	[1]
Romania	59	[1]
Greece	56	[1]
Albania	71	[1]
Turkey (Canakkale)	55	[13]
Turkey (Artvin)	175	[14]
Turkey (Adana)	65	[15]
Turkey (Yalova)	80	[16]
Turkey (Cankiri)	84	[17]
Beylikova	88	This study
Polath	94	This study
Sivrihisar	93	This study

Table 3. Activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K measured in sepiolite samples

Sample code	Activity concentration [Bqkg^{-1}]		
	^{226}Ra	^{232}Th	^{40}K
S1	23.9 2.4	8.7 1.2	107.6 4.7
S2	18.6 2.2	10.8 1.4	108.6 4.4
S3	25.5 2.4	9.7 2.0	112.0 4.5
S4	23.1 2.3	10.0 1.2	111.2 4.7
S5	22.1 2.3	8.9 1.3	115.3 4.6
S6	15.0 2.1	9.5 1.3	117.9 4.6
S7	18.8 2.1	9.8 1.2	57.2 3.4
S8	14.7 2.0	9.7 1.0	111.2 4.4
S9	17.4 2.1	9.3 1.0	128.3 5.0
S10	14.3 2.0	8.7 1.0	113.4 4.6
S11	40.0 3.9	16.1 1.2	69.9 3.4
S12	41.6 3.4	10.4 1.1	16.9 1.6
S13	42.8 3.7	15.2 1.2	53.5 2.7
S14	39.4 3.8	16.3 1.2	72.3 3.3
S15	39.7 3.3	11.4 1.4	63.1 3.0
S16	42.2 3.7	16.1 1.2	71.4 3.1
S17	42.6 3.4	11.3 1.4	16.1 1.0
S18	37.8 3.4	12.0 1.6	20.1 1.2
S19	51.1 4.5	15.4 1.1	64.5 ± 3.0
S20	42.7 4.0	13.7 1.1	35.6 ± 2.2
S21	42.9 3.5	11.1 1.3	45.6 ± 3.1
S22	38.8 3.5	10.9 1.2	42.0 3.5
S23	40.1 3.5	10.8 1.5	41.1 3.5
S24	39.6 3.5	10.4 1.4	41.8 3.5
S25	39.9 3.6	12.6 1.5	42.8 3.6
S26	39.0 3.5	10.6 1.3	38.7 2.8
S27	40.4 3.5	10.6 1.5	38.9 2.6
S28	38.3 3.4	10.5 1.5	39.9 2.7
S29	71.3 4.2	11.5 1.5	57.5 3.8
S30	155.9 5.7	40.1 3.3	66.9 3.5
Average	38.6	12.4	67.4
SD	25.6	5.7	34.3
Min	14.3	8.7	16.1
Max	155.9	40.1	128.3

Activity concentration of radionuclide

The activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K together with the statistical uncertainty (1), average, standard deviation (SD), minimum and maximum values in the sepiolite samples are given in tab. 3. The average activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K are 38.6 25.6, 12.4 5.7 and 67.4 34.3, respectively. The lowest ^{226}Ra and ^{232}Th activity concentrations were measured in the sepiolite sample codded of S10 from Beylikova, whereas the lowest ^{40}K activity concentration was measured in the sepiolite sample codded of S17 from Beylikova. The highest ^{226}Ra and ^{232}Th activity concentrations were measured in the sepiolite sample codded of S30 from Sivrihisar, whereas the highest ^{40}K activity concentration was measured in the sepiolite sample codded of S9 from Polath. The activity concentration of ^{226}Ra is approximately 21% higher than the worldwide soil average value of 32 Bqkg^{-1}, while the activity concentrations of ^{232}Th and ^{40}K are significantly lower than the worldwide soil average values of 45 and 412 Bqkg^{-1}, respectively [18].

Radon emanation coefficients and its mass exhalation rate

The ^{222}Rn and its decay products (^{218}Po, ^{214}Po, ^{214}Pb, and ^{214}Bi) are the most important sources of human exposure to natural sources of ionising radiation [2]. Therefore, knowledge of the ^{222}Rn emanation coefficient and ^{222}Rn mass exhalation rate of building materials is essential to assess the individual contribution of each material to the total indoor radon exposure. A fraction of the ^{222}Rn, which is produced from the decay of ^{226}Ra in the solid grains, escapes into the pore spaces among solid grains [19]. The emanation coefficient (EC) is the ratio of the amount of ^{222}Rn that enters pore spaces over the total amount of produced radon [20]. The EC is a dimensionless parameter and represented as either a fraction or a percentage [20]. The measurement of the EC was carried out by using the gamma-ray spectrometry. This measurement method is a non-destructive and indirect method. In this method, each sepiolite sample kept for at least one month to provide short-term equilibrium was counted until a good statistics. In the gamma-ray spectrum obtained, the net count rate of the 351.9 keV gamma-ray photopeak from ^{214}Pb and the 1764.5 keV gamma-ray photopeak from ^{214}Bi was determined. The cover of each sample container was then opened to allow the escape of radon gas and each sample was counted in the same counting time. The net count rate of the same gamma-ray photopeaks was determined and the radon EC was calculated using the following formula [20]

$$\mathrm{EC} = \frac{CR_{\mathrm{eq}} - CR_0}{CR_{\mathrm{eq}}} \tag{1}$$

where CR_{eq} is the average of the net count rate of the 351.9 keV gamma-ray photopeak and the 1764.5 keV gamma-ray photopeak in the equilibrium condition, and CR_0 is the average net count rate corresponding to CR_{eq} in the initial condition [20]. The radon EC values calculated for the sepiolite samples are given in the second column of tab. 4. The radon EC values varied from 1 to 54 % with an average value of 22 %. The highest EC value was calculated for the sepiolite sample codded of S3 from Beylikova, while the lowest EC value was calculated for the sepiolite sample codded of S22 from Sivrihisar. The average radon emanation coefficient of the sepiolite samples was compared with those obtained for different raw building materials as given in tab. 5. As can be seen from tab. 5, the radon emanation coefficient of sepiolite is higher than those obtained for different raw building materials, except for tuff samples.

Radon mass exhalation rate (MEXR) is important for the assessment of radiation hazards from various solid by-products. The MEXR (in $\mathrm{Bqkg^{-1}h^{-1}}$) is defined as the amount of activity of releasing radon per unit mass per unit time and calculated as follows [20]

$$\mathrm{MEXR} = \lambda_{\mathrm{Rn}} A_{\mathrm{Ra}} EC \tag{2}$$

where λ_{Rn} is the decay constant of radon ($7.6 \cdot 10^{-3}\ \mathrm{h^{-1}}$), A_{Ra} is the activity concentration of ^{226}Ra in the sepiolite samples (in $\mathrm{Bqkg^{-1}}$) and EC is the radon emanating the power of the samples given in eq. (1). The radon MEXR values calculated for the sepiolite samples are given in the last column of tab. 4. The radon MEXR values varied from 0.003 to 0.620 $\mathrm{Bqkg^{-1}h^{-1}}$ with an average value of 0.065 $\mathrm{Bqkg^{-1}h^{-1}}$. The highest MEXR value was calculated for the sepiolite sample codded of S30 from Sivrihisar, while the lowest MEXR value was calculated for the sepiolite sample codded of S22 from Sivrihisar.

The Pearson correlation coefficient matrix of the radiometric parameters of the sepiolite samples is presented in tab. 6. Significant positive correlation coefficients ($p < 0.01$; higher than 0.5) were obtained for the following parameters: Ra *vs*. Th (0.91), MEXR (0.85); ^{232}Th *vs*. MEXR (0.90); ^{40}K *vs*. EC (0.70) and EC *vs*. MEXR (0.54).

Table 4. Radon emanation coefficient and radon mass exhalation rate of sepiolite samples

Sample code	Radon EC [%]	Radon MEXR [$\mathrm{Bqkg^{-1}h^{-1}}$]
S1	30	0.054
S2	21	0.029
S3	54	0.105
S4	48	0.084
S5	50	0.084
S6	28	0.032
S7	37	0.053
S8	31	0.034
S9	51	0.068
S10	15	0.017
S11	4	0.013
S12	2	0.007
S13	13	0.043
S14	34	0.102
S15	13	0.039
S16	22	0.070
S17	10	0.031
S18	8	0.022
S19	19	0.074
S20	10	0.034
S21	6	0.019
S22	1	0.003
S23	10	0.032
S24	29	0.087
S25	7	0.021
S26	3	0.007
S27	4	0.013
S28	10	0.029
S29	24	0.130
S30	52	0.620
Average	22	0.065
SD	17	0.110
Min	1	0.003
Max	54	0.620

Table 5. Comparison of the average emanation coefficient of sepiolite sample with those reported for different raw materials

Building raw material	EC [%]	Reference
Fly ash	10	[20]
Zeolite	4	[21]
Mica	10	[21]
Gypsum	13	[22]
Sandstone	2	[22]
Clay	12	[22]
Zircon flours	3.4	[23]
Zircon sand	0.8	[23]
Tuff	24	[24]
Sepiolite	22	This study

Radiological assessment

The external terrestrial absorbed gamma dose rate (*DRE* in $\mathrm{nGyh^{-1}}$) in outdoor air at 1 m height from the ground in each sampling locations was estimated using the following formula [18]

$$DRE = 0.462 A_{\mathrm{Ra}} + 0.604 A_{\mathrm{Th}} + 0.0417 A_{\mathrm{K}} \tag{3}$$

where A_{Ra}, A_{Th}, and A_{K} are the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K (in $\mathrm{Bqkg^{-1}}$), respectively. The DRE values are given in the second column of tab. 7.

Table 6. Pearson correlation coefficient matrix of the radiometric parameters of soil sample

	^{226}Ra	^{232}Th	^{40}K	EC	MEXR
^{226}Ra	1				
^{232}Th	0.91	1			
^{40}K	–0.36	–0.13	1		
EC	0.06	0.20	0.70	1	
MEXR	0.85	0.89	0.11	0.54	1
Bold value indicates significant correlation at p 0.01					

Table 7. Outdoor absorbed gamma dose rate, annual effective dose, activity concentration index and alpha index 0.21

Sample code	*DRE* [nGyh^{-1}]	*AED* [μSv]	ACI	*AI*
S1	21	26	0.16	0.12
S2	20	24	0.15	0.09
S3	22	27	0.17	0.13
S4	21	26	0.16	0.12
S5	20	25	0.16	0.11
S6	18	22	0.14	0.07
S7	17	21	0.13	0.09
S8	17	21	0.13	0.07
S9	19	23	0.15	0.09
S10	17	20	0.13	0.07
S11	31	38	0.24	0.20
S12	26	32	0.20	0.21
S13	31	38	0.24	0.21
S14	31	38	0.24	0.20
S15	28	34	0.21	0.20
S16	32	40	0.24	0.21
S17	27	33	0.20	0.21
S18	26	31	0.19	0.19
S19	36	44	0.27	0.26
S20	29	36	0.22	0.21
S21	28	35	0.21	0.21
S22	26	32	0.20	0.19
S23	27	33	0.20	0.20
S24	26	32	0.20	0.20
S25	28	34	0.21	0.20
S26	26	32	0.20	0.19
S27	27	33	0.20	0.20
S28	26	32	0.19	0.19
S29	42	52	0.31	0.36
S30	99	122	0.74	0.78
Average	28	35	0.21	0.19
SD	15	18	0.11	0.13
Min	17	20	0.13	0.07
Max	99	122	0.74	0.78

The *DRE* values varied from 17 to 99 nGy h^{-1} with an average of 28 nGyh^{-1}. The average value of DRE is approximately 2 times lower than the world average outdoor absorbed gamma dose rate of 59 nGyh^{-1} [18].

The annual effective dose rate (*AED* in μSvy^{-1}) due to external exposure was estimated from outdoor external gamma radiation dose rate taking into account the conversion factor for adults (0.7 SvGy^{-1}) and the outdoor occupancy (0.2) implying that 20 % of the time is spent outdoors as follows [25]

$$AED \quad DRE \quad 0.7 \; 8766 \; 0.2 \; 10^{\;3} \tag{4}$$

where DRE is the outdoor gamma absorbed gamma dose rate given in eq. (3). The AED values are given in the third column of tab. 7. The AED values varied from 20 to 122 Svy^{-1} with an average of 35 Svy^{-1} which is 2 times lower than the world average of 70 Svy^{-1} [18].

The activity concentration index (ACI) or external index, used as a scanning tool for practical monitoring purposes, was proposed by the European Commission [26]. ACI is estimated to assess the excess gamma radiation originating from building materials as follows [26]

$$\text{ACI} \quad \frac{A_{\text{Ra}}}{300} \quad \frac{A_{\text{Th}}}{200} \quad \frac{A_{\text{K}}}{3000} \tag{5}$$

where A_{Ra}, A_{Th}, and A_{K} are the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in the sepiolite samples, respectively. For building bulk materials, ACI 1 corresponds to an annual effective dose of 1 mSv, while ACI 0.5 corresponds to an annual effective dose of 0.3 mSv [26]. For superficial and other building materials with restricted use, ACI 6 corresponds to an annual effective dose of 1 mSv, while ACI 2 corresponds to an annual effective dose of 0.3 mSv [26]. The ACI values are given in the fourth columns of tab. 7. The ACI values varied from 0.1 to 0.7 with an average of 0.2 which is significantly lower than the recommended upper limits.

The alpha index (AI) or internal index has been used to assess the excess alpha radiation due to inhalation of radon escaped from construction materials. The AI is estimated using the formula [27]

$$\text{AI} \quad \frac{A_{\text{Ra}}}{200} \tag{6}$$

where A_{Ra} is the activity concentration of ^{226}Ra. For bulk and building materials with restricted use, AI 1 corresponds to A_{Ra} 200 Bqkg^{-1} measured in building materials. When A_{Ra} > 200 Bqkg^{-1}, the radon exhalation from building material could cause an indoor radon concentration greater than 200 Bqm^{-3} [28]. The AI values are given in the last column of tab. 7. The AI values varied from 0.1 to 0.8 with an average of 0.2. All values of the AI are below the criterion of 1.

CONCLUSION

This study presents significant information related to radiometric properties of sepiolite samples collected from Beylikova, Polath and Sivrihisar quarries. Therefore, the results obtained in this study can be used as guide information for the use and transportation of the building materials including sepiolite minerals. Radiological assessment reveals that the use of sepiolite samples in any industrial applications (medicine, cleaning-detergent, paper, paint, cosmetic agriculture, fertilizer, *etc*.) and in the construction sectors (ceramic and cement) as direct or additive raw materials does not pose any health hazards.

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AUTHORS' CONTRIBUTIONS

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РАДИОМЕТРИЈСКА СВОЈСТВА СЕПИОЛИТНИХ МИНЕРАЛА ИЗ КАМЕНОЛОМА У ЦЕНТРАЛНОЈ АНАДОЛИЈИ У ТУРСКОЈ

Сепиолит, магнезијум хидросиликат, природни глинени минерал, широко се користи као адитивна сировина у индустрији керамике и цемента, фармацеутској индустрији, детерџентима за чишћење, папиру, бојама, пољопривреди козметичке намене, ђубривима, итд. У овом истраживању утврђени су природни нивои радиоактивности, коефицијенти еманације радона и јачине ексхалације радона из 30 узорака сепиолита прикупљених из три отворена каменолома сепиолита (Бејликова, Полатли и Сиврихисар) у региону Централне Анадолије у Турској помоћу гама спектрометрије HPGe детектором. Просечне јачине апсорбованих гама доза, директно измерених у отворена три каменолома сепиолита, у Бејликови, Полатлију и Сиврихисару, који се налазе у региону Централне Анадолије у Турској, износиле су 59, 65 и 64 $nGyh^{-1}$, респективно. Просечне концентрације активности ^{225}Ra, ^{232}Th и ^{40}K у 30 узорака сепиолита сакупљених из тих каменолома износиле су 38,6, 12,4 и 67,4 $Bqkg^{-1}$, респективно. Просечан коефицијент еманације и јачина ексхалације радона узорака сепиолита одређени су као 22 %, односно 0,065 $Bqkg^{-1}h^{-1}$, респективно. Такође су процењени радиолошки параметри (јачина дозе апсорпције гама зрачења на отвореном, годишња јачина ефективне дозе, спољашњи и унутрашњи индекс) ради употребе узорака сепиолита као адитивних сировина у грађевинском сектору.

Кључне речи: сейиолиш, йриродна радиоакшивносш, јачина дозе айсорйције гама зрачења на ошвореном, коефицијенш еманације радона, јачина масене ексхалације радона, сйекшромешрија гама зрачења