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Optical Properties and Natural Radioactivity Levels of Turkish Natural Glass Obsidian

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Abstract: Obsidian is a naturally occurring volcanic glass formed as an igneous rock. It is a kind of alumino-silicate glass containing iron impurities and some tiny particles (particle-dispersed glasses). It can be found in black, gray, brown, blue, and green colors in nature. In recent work, the obsidian specimens in black and brown colors were collected from Sarıkamış which is a small town in Kars province located at the north-east part of Turkey. The obtained specimens were then cut and polished to obtain two parallel surfaces to perform optical measurements. The optical absorption spectra of the samples were collected under ambient environment. The natural radioactivity levels of the specimens were also measured using a gamma spectrometer whıch uses a NaI(Tl) scintillation detector for the determination of the radioactivity.

Keywords: Obsidian, NaI(Tl) detector, Natural radioactivity

Introduction

The total radiation dose, which all living beings exposed to everyday, is mainly due to the natural radioactivity. There are two main sources of natural radioactivity. These are primordial sources (^{238}U, ^{235}U, ^{232}Th, ^{40}K, ^{87}Rb, and ^{187}Re), which are always available from the beginning of the Earth because of their long lifetimes, and cosmic rays. Therefore, all the natural geographical formations around us can be considered as a source of natural radioactivity (UNSCEAR, 2000, Tzortzis et al., 2003).

The obsidian, one of these formations, is a volcanic glass formed as an igneous rock. It is a kind of alumino-silicate glass containing iron impurities and some tiny particles (particle-dispersed glasses). It is formed when felsic lava extruded from a volcano cools so rapidly which does not allow atoms to re-arrange themselves into a crystalline structure. It is a non-crystalline amorphous material and doesn’t have long range order. It can be found in black, gray, brown, blue, and green colors in nature (Chataigner et al., 2014).

In this work, the optical properties and the natural radioactivity levels of obsidian specimens in black and brown colors, which were collected from Sarıkamış, were investigated.

Method

All obsidian specimens were collected from Sarıkamış, which is a small county of Kars province located at the eastern part of Anatolia. The Sarıkamış district stands between 40^{o} 18’ north latitude and 42^{o} 31’ east longitude and an average of 2225 m above sea level. The obsidian samples were collected from near the Mescitli village, which is 14 kilometers away from the Sarıkamış town center.

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The obtained samples were cut and polished using a Microcut model cutting and polishing machine to obtain two parallel surfaces to perform optical absorption measurements. The optical absorption characteristics of the samples were determined using a Perkin Elmer Lambda 25 UV-Vis spectrophotometer in the 300–1100 nm wavelength range.

The collected samples were crushed, homogenized, sieved through a 1 mm mesh sieve, weighed and transferred into an airtight cylindrical plastic container with 65 mm diameter and 50 mm height. Then, each were sealed and stored for about 40 days before counting to achieve equilibrium for ^{238}U and ^{232}Th with their respective progeny. The radioactivity analysis of naturally occurring radionuclides (^{226}Ra, ^{232}Th, and ^{40}K) were performed on obsidian samples using gamma spectrometry system with NaI(Tl) detector which shielded by 5 cm thick lead on all sides to avoid the natural gamma radiation contribution.

The obtained gamma ray spectra were analyzed using a PC based multichannel analyzer (MCA) system and Maestro software. The energy calibration and relative efficiency calibration of the gamma spectrometry system were carried out using a standard reference material (IAEA-375). Each sample was acquired for 100.000 seconds to obtain good statistics in the evaluation of gamma peaks.

Results and Discussion

The optical absorption spectra of brown and black obsidian samples were measured in the 200–1100 nm wavelength range under ambient conditions and the results are given in Figure 1. The samples with different colors were prepared in 1.2 mm thicknesses using a cutting and polishing machine to perform optical absorption measurements. The rapid increase of the absorption below 400 nm seen in the absorption spectrum of the black obsidian can be easily assigned to the forbidden gap of the sample. However, although some absorption characters appear in the absorption spectrum of the brown obsidian, no clear rapid absorption due to the forbidden band gap of the sample was observed.

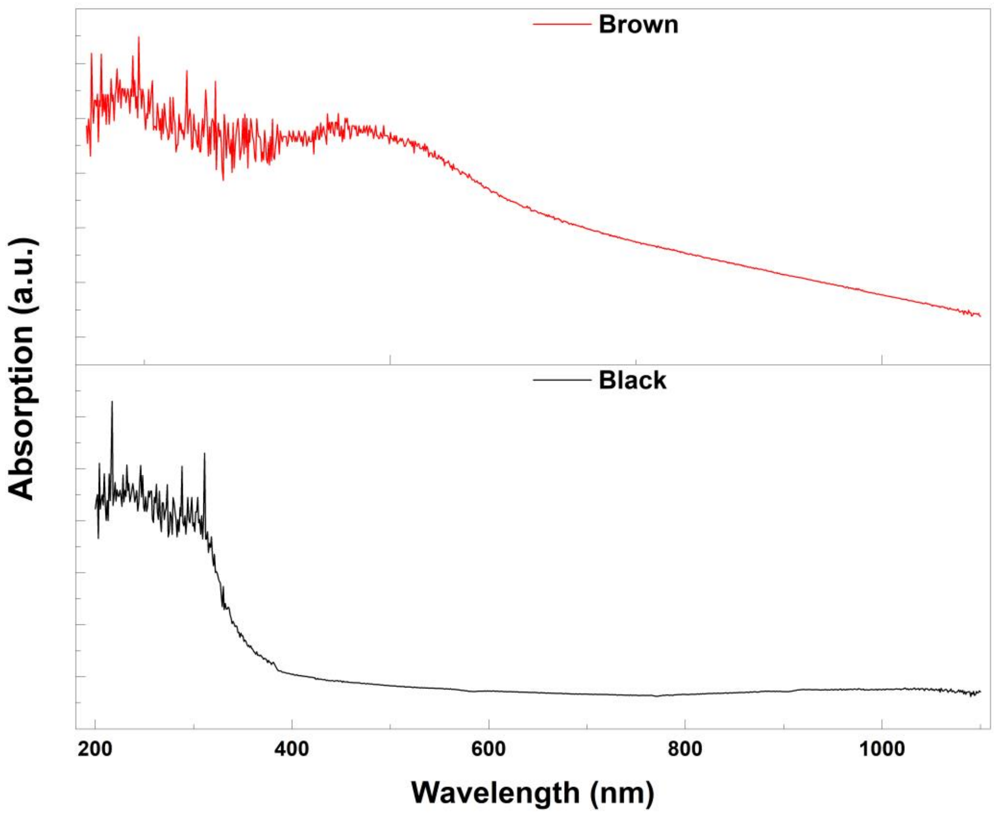

Figure 1. Absorption spectra of obsidian samples with different colors

The activity concentrations of ^{238}U (^{226}Ra) and ^{232}Th were determined from 1764.5 keV gamma peak of ^{214}Bi and 2614 keV gamma peak of ^{208}Tl, respectively. The activity of ^{40}K was directly measured using its own 1460.8 keV gamma peak.

The activity concentrations of the natural radionuclides in the each samples were calculated through the following formula (El-Farrash et al., 2012)

$$A = \frac{C}{\varepsilon_\gamma P_\gamma T_m m_S} \qquad (1)$$

where *A* is the activity of the radionuclides in Bq kg^{-1}, *C* is the net count (background subtracted) under the γ-ray peak, ε_γ is full energy peak efficiency of detector at particular γ-ray energy, P_γ is the γ-ray emission probability per decay, T_m is the counting time in second and m_S is the weight of the sample in g. The results obtained from equation 1 were corrected for gamma ray self-attenuation effects to obtain accurate values for the activity concentrations. The self-attenuation correction factor (F) for given energy *E*, were estimated from the equation 2 (Bilgici Cengiz G., 2018).

$$F = \frac{1 - e^{-\mu_s d_s}}{\mu_s d_s} \times \frac{\mu_r d_r}{1 - e^{-\mu_r d_r}} \qquad (2)$$

where μ_r and μ_s are attenuation coefficient of reference and sample respectively; and d_r and d_s are heights of reference and sample, respectively.

The attenuation coefficient values of reference and samples were determined with the help of XCOM software package which uses chemical parameters of a mixture.

In black obsidian, the activity concentrations of ^{238}U (^{236}Ra), ^{232}Th and ^{40}K were found to be 0.0812 ± 0.015, 0.0802 ± 0.022, and 1.528 ± 0.076 Bqg-1, respectively. The activity concentrations of ^{238}U, ^{232}Th and ^{40}K were found to be 0.0735 ± 0.016, 0.0755 ± 0.023 and 1.767 ± 0.080 Bqg^{-1} in brown obsidian, respectively. It was observed that the activity concentrations of ^{40}K are quite higher than both ^{226}Ra and ^{232}Th in two samples.

The results showed that the activity values of ^{238}U (^{226}Ra) and ^{232}Th radionuclides are approximately same in two samples, while the activity value of ^{40}K in brown obsidian is about %15 higher than that of black obsidian. This difference may be related to the chemical composition of obsidian samples. Because Brown obsidian is more reach in terms of K_2O content than black obsidian (Çolak and Aygün., 2011).

Table 1 shows the comparison of the radioactivity concentrations of above-mentioned radionuclides in obsidian samples with the values reported by Chiozzi et al., 2000.

Table 1. The comparision of the activity concentrations of ^{238}U (^{226}Ra), ^{232}Th, and ^{40}K in the obsidian samples with the values reported in the literature

References	Location of sample	Type of sample	Activity concentrations (Bqg^{-1})		
			^{238}U	^{232}Th	^{40}K
Present Study	Sarıkamış, Turkey	Black Obsidian	0.0812±0.015	0,0802±0.022	1.528±0.076
		Brown Obsidian	0,0735±0,016	0,0755±0,016	1,767±0.080
. Chiozzi et al., 2000	Italy	Obsidian	0.183±0.002	0.219± 0.004	1.379±0.017
		Obsidian	0.167±0.002	0.193± 0.003	1.368±0.015
		Obsidian	0.175±0.002	0.197±0.004	1.314±0.016

As shown in Table 1, the activity concentration values of ^{238}U (^{226}Ra) and ^{232}Th measured in this study for obsidian samples are quite lower than those of the reported in Italian obsidian. However, the obtained activity concentrations for ^{40}K are slightly higher than the values reported by (Chiozzi et al., 2000).

Conclusion

The optical absorption properties and the natural radioactivity levels of the black and the brown obsidians collected from the north east part of Anatolia/Turkey has been studied. It is found that the natural radioactivity level of the of ^{40}K radionuclide in brown obsidian is about %15 higher than that of black obsidian, while the activity values of ^{238}U (^{226}Ra) and ^{232}Th radionuclides are quite same in two samples. Additionally, those values were also compared with the literature and was found to be almost same for the ^{238}U (^{226}Ra) and ^{232}Th radionuclides and slightly higher for ^{40}K than the values given in the literature.

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