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Determination of Transmission Factors and γ-Ray Linear Attenuation Coefficients of Some Construction Materials Mixed with Ulexite and Borax

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ABSTRACT

In the study, transmission factors *(T)* and linear attenuation coefficients (μ) of some construction materials (briquette, sand, marble, paint, adobe, soil, and lime) mixed with ulexite and borax are measured with energy dispersive X-ray fluorescence spectrometer for 59.5 keV energy by using a Si(Li) detector. Ulexite and borax were added to the samples at a rate of 25, 50, and 75 percent. Results are presented and discussed in this paper. Measurements made on these construction materials with technological importance will create new use areas..

Keywords: **C**onstruction material, Radiation isolation, EDXRFS.

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Introduction

The research on shielding materials is essential to protect human beings from the harmful effects of various ionizing radiations. The most proper materials for shielding according to the radiation energy are specified based on their radiation shielding capacities. In this sense, the most used material is lead because of its properties [1]. It is also necessary to find new materials such as lead. Zayed et al. investigate the effect of boric acid on the physical, mechanical, microstructural, and radiation-shielding properties of serpentine concrete. The results of they showed that the addition of boric acid hindered the hydration of cement[2]. Zahran et al. have studied the attenuation characteristics of some semiconductor compounds at different photon energies [3]. They have estimated interaction parameters in the range of 0.015-15 MeV. Abbasi et al.[4] have discussed the great potential of mesoporous silica nanoparticles for application in cancer immunotherapy. The electronic, atomic, and absorption ability of the composite are analyzed from the irradiation intensity after the X-rays pass through the samples by Anugrah et al. [5]. They have compared the linear attenuation coefficients of different composite gelatin with those of breast phantom. As a result of the study, they obtained a new composite with excellent characteristics for breast phantom. Kumar et al. [6] did experimental studies on the measurement of the mass attenuation coefficient of zirconium and some compounds of zirconium in the range of 17.919–18.664 keV. In a distinct study, Akça et al. [7] investigated the change according to the different voltages of linear attenuation coefficients for some semiconductors by using EDXRFS and Am-241 point source. Saleh et al. have determined the natural radioactivity of different cement raw materials in Yemen[8]. Tyagi et al. [9] did a review on the usage of alternate materials, emphasizing hazardous industrial byproducts, as constituents of radiation shielding concrete. They have expected that the exposition of these research gaps will be helpful in the area of alternate materials in radiation shielding concrete. Akça and Erzeneoğlu [10] have measured the mass attenuation coefficients for compounds of biomedically important elements by using the transmission method. They have obtained shielding parameters from these results. The relative difference between the experimental and theoretical values is given in the article. Böke [11] has computed coherent, incoherent scattering, photoelectric cross sections, and linear attenuation coefficients for liver, kidney, muscle, and fat. Akça et al. [12] have measured shielding parameters for various materials. It was shown that maximum interaction with gamma rays for lime and minimum interaction for polyvinyl chloride. Madej et al. [13] have presented a study on the performance of shielding refractory concretes. Linear attenuation coefficients are determined twice, firstly after casting and drying of concretes, and secondly after sintering. Eke C. [14] has calculated radiation protection coefficients of beach sand samples from Antalya in the energy range of 80–1332 keV by using gamma-ray spectrometry. Erzeneoğlu et al. [15] have measured the mass attenuation coefficients of ternary semiconductors that are InSe and InSe having different holmium concentrations. Samson et al. [16] have made Rhizophora spp. particleboard phantoms using SPI-based adhesives, modified with sodium hydroxide and itaconic acid poly amidoamine-epichlorohydrin (0, 5, 10, and 15 wt%) by using an X-ray computed tomography imaging system. Koirala et al. [17] have researched the total cross-section of electrons, atoms, and molecules in iron oxides to select the best shielding material for iron oxides in the energy range of 0–10 MeV. Cinan and Yılmaz [18] have obtained the calibration curve by using Rayleigh to Compton scattering ratio. They showed that this curve can be used for qualitative analysis of compounds within a certain range of effective atomic numbers. Kurudirek et al. [19] have determined the chemical compositions of materials. Also, they have investigated some building materials and their admixtures with TSW in terms of radiation shielding parameters by using X-rays at 22.1, 25 keV, and γ-rays at 88 keV photon energies. Gökmen [20] investigated neutron and gamma-ray shielding properties of Inconel 718 reinforced B_4C (0-25 wt%) using PSD software.

Theoretical Basis

The transmission of a beam of monochromatic gamma photons on absorbing material is given by the Lambert-Beer law:

$$I = I_0 e^{-\mu t} \tag{1}$$

where I_0 is the incident photon intensity and I is the reduced photon intensity after passing through the material of thickness t, the linear attenuation coefficient $\mu(cm^{-1})$ and $(^{I}/_{I_0})$ the transmission factor T.

Experimental Basis

The experimental setup used is given in Figure. 1. In this study, we used a point source of Am-241 of intensity 100 mCi which emits 59.5 keV gamma rays. The source is placed in lead blocks to collimate the rays. We used a Si(Li) detector having a diameter of 3,91 mm and an active area of 12 mm^2 and a resolution of 160 eV at 5,9 keV. Measurements were taken under the same experimental conditions for 600 s. The spectra are recorded in a 4096-channel analyzer. In the experiment, the source, sample, and detector were positioned on the same plane. Ulexite and borax have been added to building materials (briquette, sand, marble, paint, adobe, soil, and lime) in different proportions (0%, 25%, 50%, and 75%) and have been mixed at 20 min by the mixer. Samples have a diameter of 13 mm and are compressed into pellets. The typical spectra for Adobe are shown in Figure 2. Experimental errors are attributed to the deviation from the average value in intensities (<0.9%), sample thickness (<0.5%), the mass of the sample (<0.8%), and systematic errors (<1%).

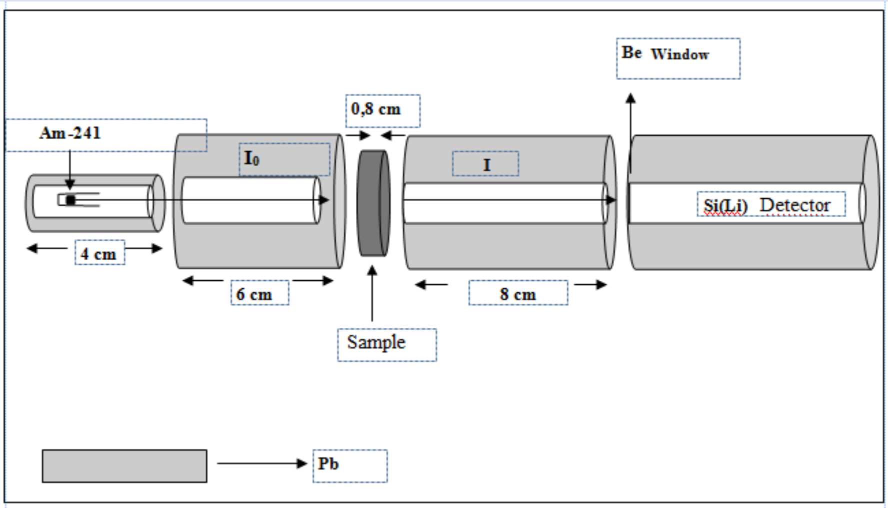

Figure 1. The experimental setup).

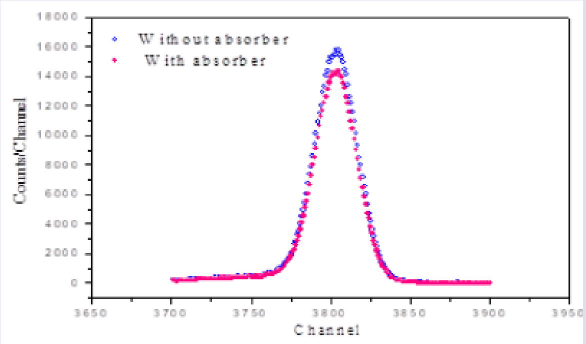

Figure 2. Representative spectrum for Adobe.

Results and Discussion

Borax (Na2B4O7) is widely used in the industry. Some usage areas are glass, agriculture, ceramics, fire retardants, metallurgy, construction, anti-freeze, and adhesive. In Turkey, ulexite (Na2O.2CaO.5B2O3.16H2O) is commonly found in Bigadiç/Balıkesir. Some usage areas of ulexite are glass, ceramics, heat and sound insulation, and fertilizer. It is important to find new uses for boron since Turkey has the highest boron reserves in the world. On the other hand, it is also important to minimize the damage effects of radiation. Radiation has caused diseases such as cancer have affected the quality of life. In this study, we aimed to use different materials for radiation shielding. At the same time, we are researching new uses for future mine boron. T and μ values of construction materials mixed with ulexite and borax are given in Table 1-2. Experimental results are also graphically given in Figures 3-17. As seen in Figure 3, the transmission factors of pure construction materials increase for soil, marble, lime, adobe, paint, briquette, and sand, respectively. When the transmission factors increase, the linear attenuation coefficients decrease, i.e. the absorption decreases. Maximum absorption was obtained for soil and minimum for sand. The experimental linear attenuation coefficient results have been fitted as in Figures 3-17. There are some minor deviations here which may be due to beam collimation and preparation of samples such as mixture. As shown in Figures 4-17, the concentration of ulexite and borax changes the μ values of construction materials. This is a clear result. In Figures 4, 5, 6, 8, 9, 11, 13, 14, 15, and 16, the linear attenuation coefficients decrease with increased ulexite and borax concentration. In other words, when the concentration of ulexite and borax increases, linear attenuation coefficients decrease. In Figures 7, 10, 12, and 17, there is still a decrease with increased ulexite and borax, but the form of change is different from others. On the other hand, When the results with ulexite and borax in Table 1-2 are compared, it is seen that there is no significant difference. Average linear attenuation coefficients for borax are slightly larger than for ulexite. As far as we know, there are no experimental results reported in the literature for these samples, ratios, and energy. Therefore, we could not compare the experimental results with other experimental results.

Table 1. T and μ values of construction materials mixed with Ulexite

Sample	T	μ (cm-1)
Briquette	0.231	5.940
Briquette + %25 Ulexite	0.277	4.072
Briquette + %50 Ulexite	0.315	3.554
Briquette + %75 Ulexite	0.250	2.798
Sand	0.266	5.151
Sand + %25 Ulexite	0.295	4.987
Sand + %50 Ulexite	0.261	3.532
Sand + %75 Ulexite	0.130	5.032
Marble	0.097	10.442
Marble + %25 Ulexite	0.601	2.232
Marble + %50 Ulexite	0.631	0.574
Marble + %75 Ulexite	0.150	3.911
Paint	0.194	5.865
Paint + %25 Ulexite	0.301	10.976
Paint + %50 Ulexite	0.274	9.938
Paint + %75 Ulexite	0.063	7.164
Adobe	0.129	6.457
Adobe + %25 Ulexite	0.305	2.933
Adobe + %50 Ulexite	0.334	2.411
Adobe + %75 Ulexite	0.205	3.104
Soil	0.070	9.517
Soil + %25 Ulexite	0.188	7.337
Soil + %50 Ulexite	0.153	5.901
Soil + %75 Ulexite	0.084	6.425
Lime	0.113	2.202
Lime + %25 Ulexite	0.265	3.287
Lime + %50 Ulexite	0.291	3.396
Lime + %75 Ulexite	0.361	2.487

Table 2. T and μ values of construction materials mixed with borax

Sample	*T*	μ (cm-1)
Briquette	0.231	5.940
Briquette + %25 Borax	0.071	7.061
Briquette + %50 Borax	0.083	5.482
Briquette + %75 Borax	0.087	4.980
Sand	0.266	5.151
Sand + %25 Borax	0.144	6.164
Sand + %50 Borax	0.109	5.620
Sand + %75 Borax	0.587	1.301
Marble	0.097	10.442
Marble+ %25 Borax	0.073	9.905
Marble + %50 Borax	0.068	8.507
Marble + %75 Borax	0.086	5.118
Paint	0.194	5.865
Paint+ %25 Borax	0.322	3.432
Paint + %50 Borax	0.364	2.512
Paint + %75 Borax	0.374	1.754
Adobe	0.129	6.457
Adobe + %25 Borax	0.194	6.135
Adobe + %50 Borax	0.185	5.177
Adobe + %75 Borax	0.077	5.288
Soil	0.070	9.517
Soil + %25 Borax	0.252	4.675
Soil + %50 Borax	0.344	3.495
Soil + %75 Borax	0.318	2.464
Lime	0.113	2.202
Lime + %25 Borax	0.198	5.706
Lime + %50 Borax	0.068	6.012
Lime + %75 Borax	0.215	3.170

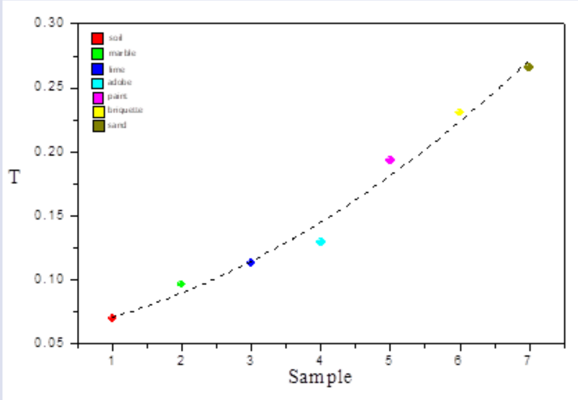

Figure 3. Transmission factors versus sample

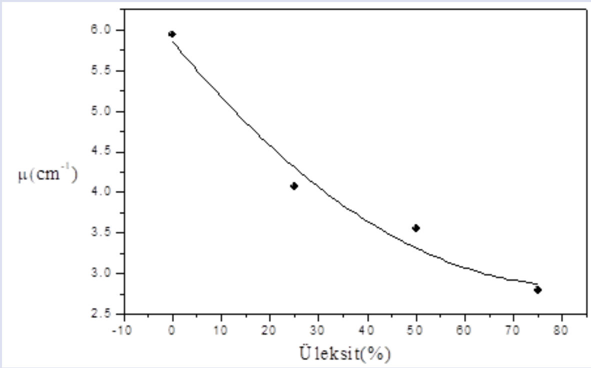

Figure 4. Linear attenuation coefficients versus percent of ulexite for briquette.

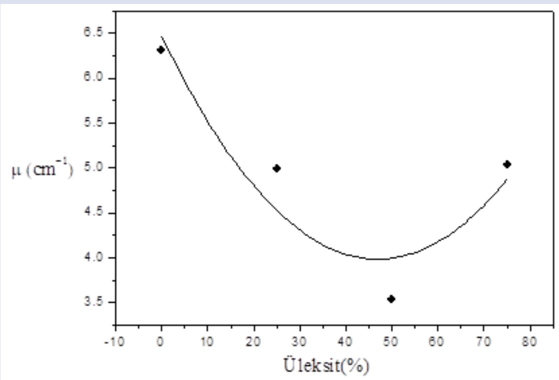

Figure 5. Linear attenuation coefficients versus percent of ulexite for sand.

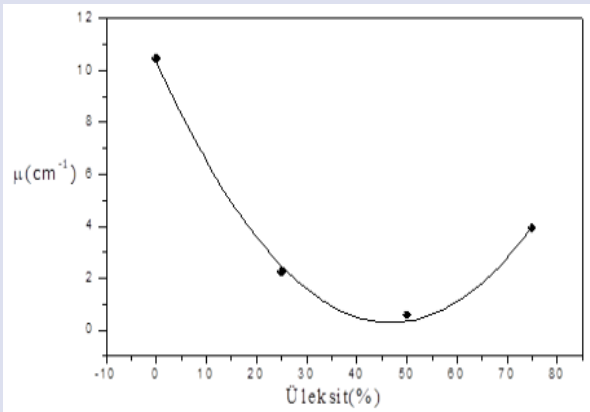

Figure 6. Linear attenuation coefficients versus percent of ulexite for marble.

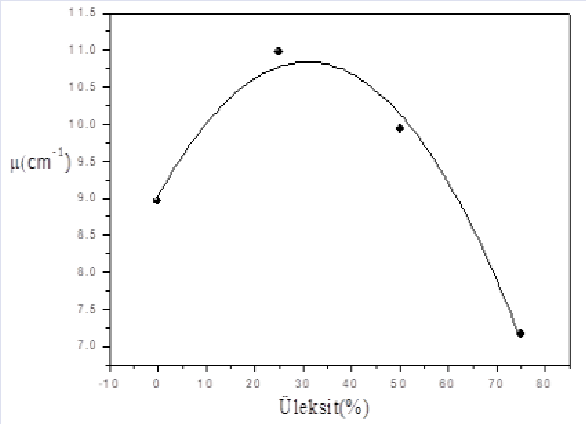

Figure 7. Linear attenuation coefficients versus percent of ulexite for paint.

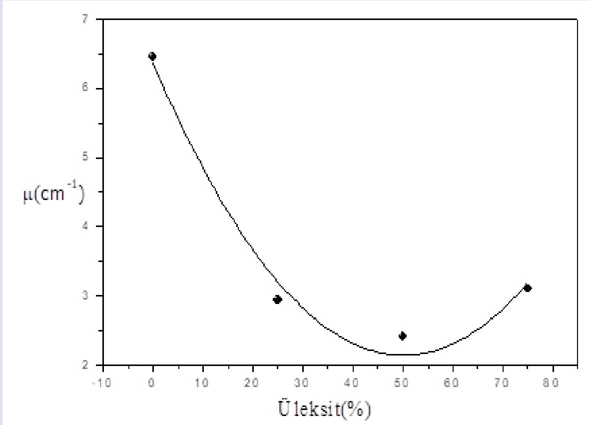

Figure 8. Linear attenuation coefficients versus percent of ulexite for Adobe.

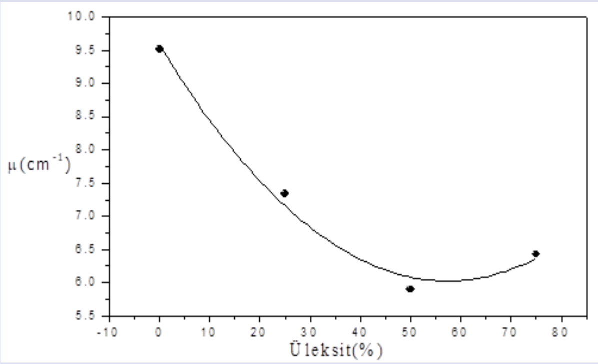

Figure 9. Linear attenuation coefficients versus percent of ulexite for soil

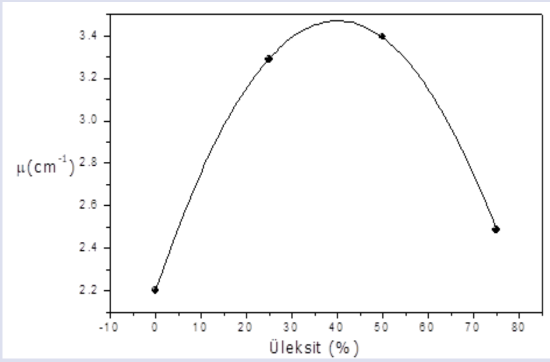

Figure 10. Linear attenuation coefficients versus percent of ulexite for lime.

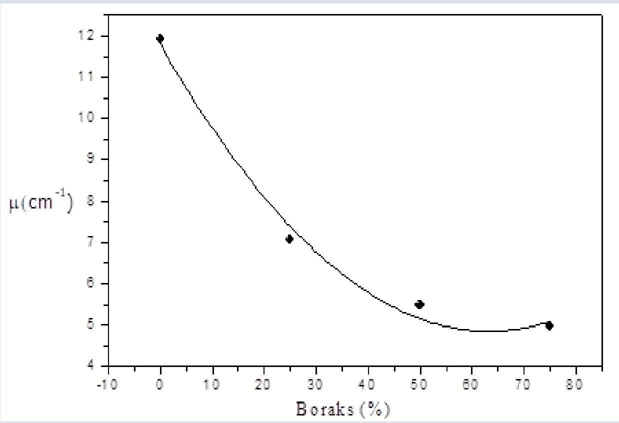

Figure 11. Linear attenuation coefficients versus percent of borax for Briquette.

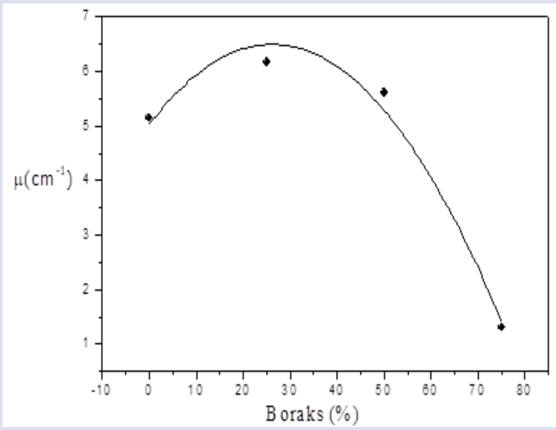

Figure 12. Linear attenuation coefficients versus percent of borax for sand.

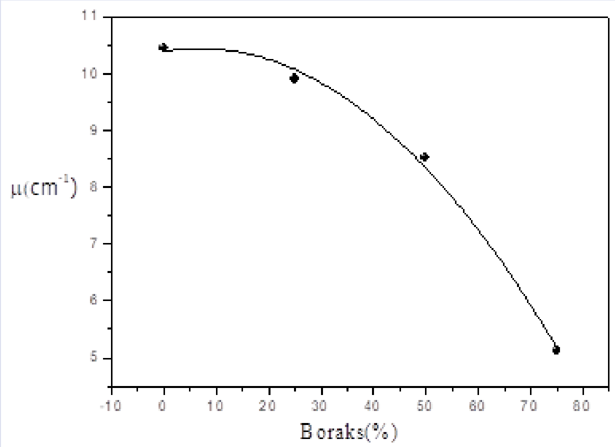

Figure 13. Linear attenuation coefficients versus percent of borax for Marble.

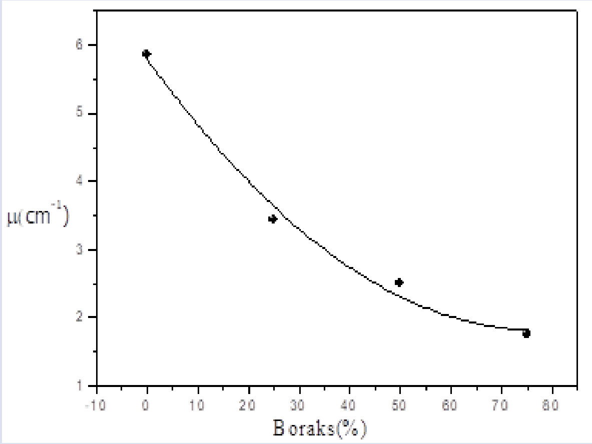

Figure 14. Linear attenuation coefficients versus percent of borax for paint

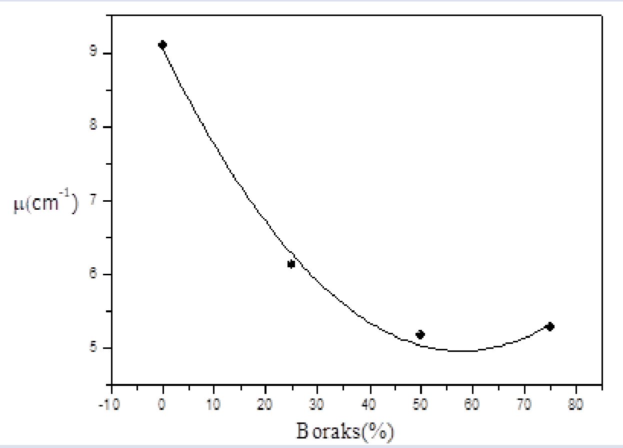

Figure 15. Linear attenuation coefficients versus percent of borax for Adobe.

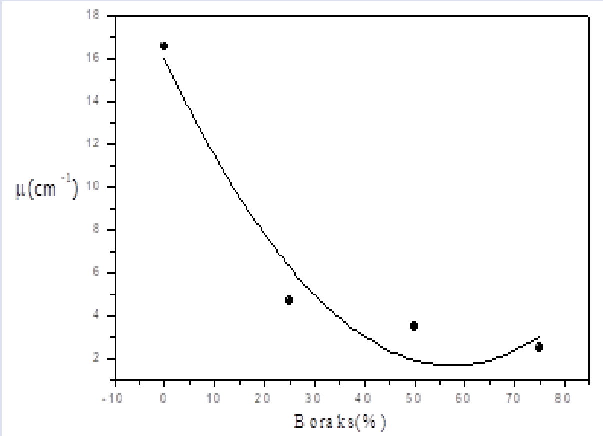

Figure 16. Linear attenuation coefficients versus percent of borax for soil.

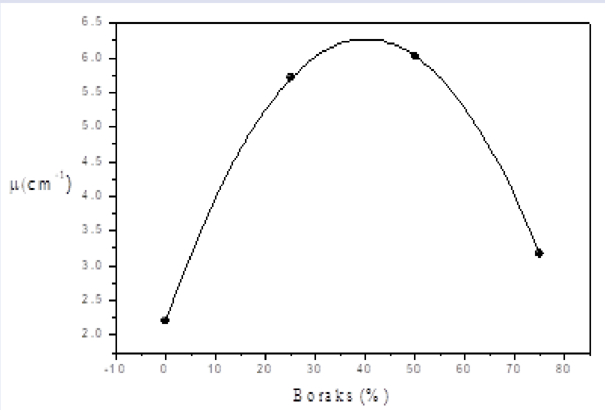

Figure 17.Linear attenuation coefficients versus percent of borax for lime

CONCLUSİON

In this study, we have tested to be used as a shield against gamma radiation of some construction materials mixed with two boron compounds. These construction materials and boron compounds have numerous uses in our lives. The transmission factors and linear attenuation coefficients of these samples were measured and compared to each other. In general, linear attenuation coefficients is decreasing with increasing ratio of ulexite and borax. It was also observed that the transmission factors of sand are higher than the other. We can say that qualitative and quantitative analyzes of the construction materials should be made and the shielding parameters should be measured for a more accurate interpretation of the results. Also, various energies and construction materials can be tried for different usage areas of boron.

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Conflicts of interest

There are no conflicts of interest in this work.

Authors's Contributions

S. Erzeneoğlu: Writing, review, editing, investigation, supervision, project, administration, conceptualization, methodology, **B. Akça:** Writing, review, editing, investigation, data curation, original draft, conceptualization, methodology, **H. Uyanık:** Writing, review, editing, investigation, data curation, conceptualization.

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