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Radiation shielding properties of barite coated terry-cotton fabric

Serpil Emikonel [a], Roya Boodaghi Malidarre [b], M.I. Sayyed [c,d], Iskender Akkurt [e], Nina Tuncel [f]

[a] Usak University, Usak, Turkey
[b] Institute of Physics and Technology, Ural Federal University, Ekaterinburg, Russia
[c] Department of Physics, Faculty of Science, Isra University, Amman, Jordan
[d] Renewable Energy and Environmental Technology Center, University of Tabuk, Tabuk, 47913, Saudi Arabia
[e] Suleyman Demirel University, Isparta, Turkey
[f] Akdeniz University, Antalya, Turkey

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ABSTRACT

With the rapid development of technology, the radiation started to be used in many different fields and thus radiation protection becomes important. The use of radiation in basic science, industry, military purposes and medical applications has reached enormous dimensions. The protection of radiation, which has such a wide range of uses, has become inevitable. Dresses used by radiation workers are important against possible radiation damage. In this study, the linear attenuation coefficients have been measured to investigate the radiation shielding properties of terry-cotton fabric coated by barite in the rate of 0%, 40%, 50% and 60%. The measurements were performed using a NaI (Tl) detector at 511, 835 and 1275 keV gamma ray energies. It was found that the barite is an important materials and when it is used to coat fabric lead to improve radiation shielding properties.

1. Introduction

In the modern world, the utilization of radiation in various forms has caused health problems due to radiation hazardous effects. Besides this hazardous effect, radiation should be used as it is a one of the most important generic technology and it is used many different fields. Therefore radiation protection becomes an important issue in many applications (He, 2020; Liu et al., 2014). There are three main ways for radiation protection namely time, distance and shielding. The most effective of these methods is shielding. It is aimed to reduce radiation by placing a protective material between the radiation source and the human. The lead and lead based materials are conventionally used for years as it is a high-density material, and therefore it is very effective for radiation shielding. On the other hand, as it has some negative effect to human and environment (Wani et al., 2015), scientists have been focused to develop alternative materials to lead based materials (Akkas et al., 2015; Akkurt et al., 2010; Altunsoy et al., 2020a; Buyuk et al., 2015; Gezmişoğlu et al., 2020; Jawad et al., 2019; Kaur & Sharma, 2019; Kilinçarslan & Türker Şimşek, 2020; Piotrowski et al., 2015; Reda & El-Daly, 2020; Sariyer, 2020; Sariyer & Küçer, 2020; Tekin et al., 2018; Wen et al., 2019). This is especially vital for radiation workers as they should wear clothes to be protected from radiation. In our knowledge there is only few research were done about radiation shielding properties of fabric (Akarslan et al., 2014; Emikönel, 2015; İskender et al., 2015) even there are some works were done for different purposes in different types textile (Hu et al., 2019; Li et al., 2019; Lu et al., 2019; Sun et al., 2019). For this reason, the fabric must be investigated for possibility of using it as shielding material and also the way of developing its shielding capability. In those works different types of fabric (polyster) and also different types of technique (image processing method) were used to obtained radiation shielding properties.

In this study, barite is used as coating material. Tericoton fabric was covered with barite in different proportions, and the change in barite amount and linear absorption coefficients were analyzed, and at what rates it was determined by statistical analyzes. The advantage to be added to the fabric here is that the barite mine can absorb gamma rays by using the gamma rays retaining feature.

In the present study, the radiation shielding properties of four different types of terry-cotton fabric (TCF) were measured at gamma rays energies of 511, 835, and 1275 keV. Those of fabric were coated by using barite which was done for firat time according to our knowledge. Thus this will be important work and will be valuable for the academic

E-mail address: serpil.emikonel@usak.edu.tr (S. Emikonel).

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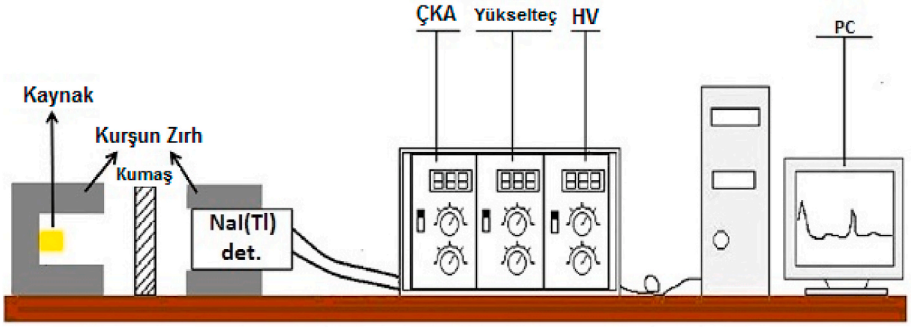


Fig. 1. Schematic view of the gamma spectroscopy system.

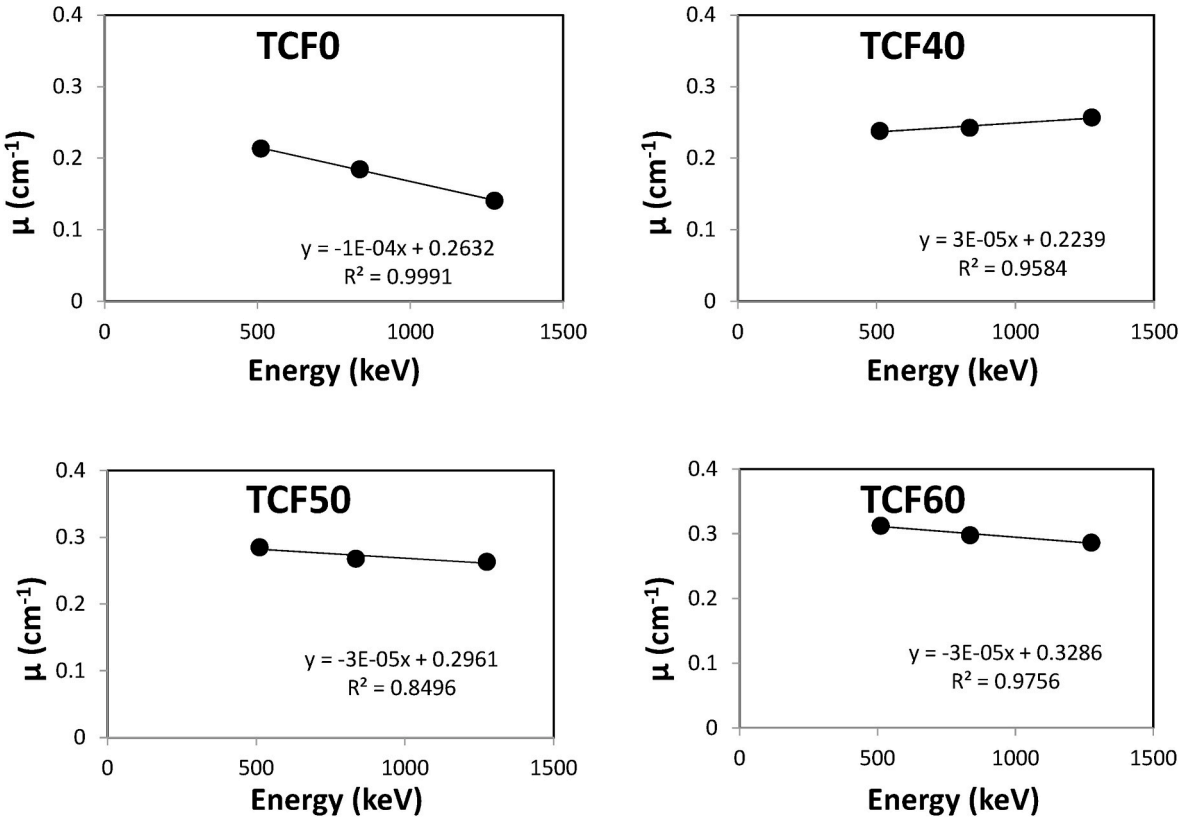


Fig. 2. The measured linear attenuation coefficients as a function of gamma rays for all types of terry-cotton fabric.

literature and also for industrial sector.

2. Materials and methods

The linear attenuation coefficients of terry-cotton fabric (TCF) have been obtained to investigate radiation shielding properties. The terry-cotton fabric is prepared on a micron scale and in order to develop its shielding properties it was coated by barite. The barite is the barium sulphate ($BaSO_4$), which is known as the most common mineral of the barium element. Some properties of barite is given in. The barite does not dissolve in water and cold acid, may melt slightly in boiling sulfuric acid. The reason why tericoton fabric is preferred in this study is that it is widely used as apron and shirting. Tericoton fabric; polyerster/viscose blend, 172 gr/m2, weft-density 38 strand/cm, warp/density 110 strand/cm, weft-yarn count 60 Nm, warp-yarn count 100 Nm, plain woven fabric. Barite was applied to the fabric by coating method. In this study, coating process was carried out with the knife method. Barite prepared with micron scale was prepared by mixing Tubicoat textile coating chemical obtained from CHT Kimya A.Ş. After the fabric to be covered is fixed on a flat surface, the silk (template) stretched to a metal frame is placed on the fabric to be covered. The mixture, which was prepared by adding Barite in different proportions, was plastered over this metal frame to allow barite to penetrate the fabric equally. After the coating process was carried out, the fabrics were dried and fixed (Wulfhorst, 1998).

The fabric was coated by using barite in different rate into the mixtures prepared for use in the application of the coating method. Four different rate of 0% (before coating), 40%, 50%, 60% barite used in coating processes and tagged as TCF0, TCF40, TCF50, TCF60 for fabric respectively. More details about those processes is detailed in elsewhere (Akarslan et al., 2014; Emikönel, 2015; İskender et al., 2015). Prepared fabrics were used to measure the linear attenuation coefficients. The

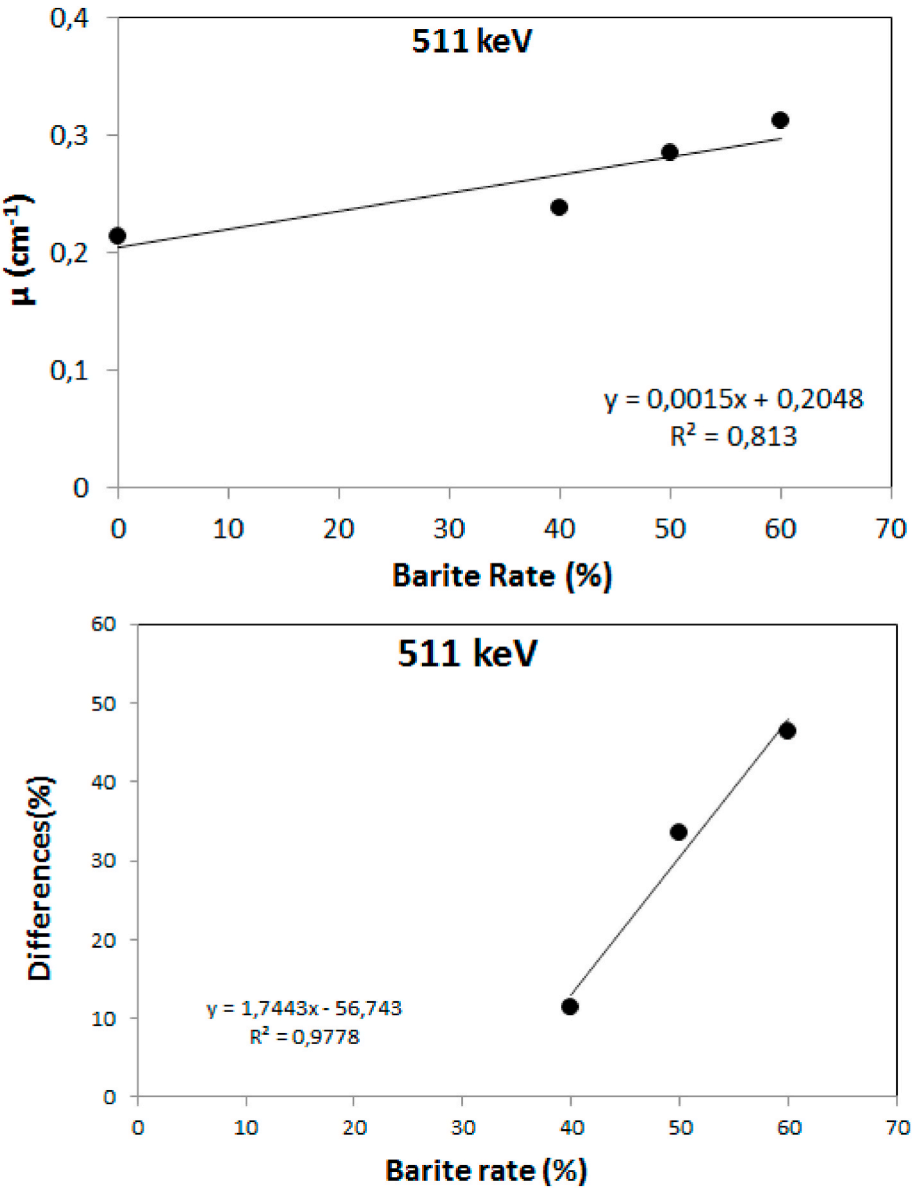


Fig. 3. The measured linear attenuation coefficients (for 511 keV) as a function of barite rate in fabric (upper) and differences of barite rate(lower).

measurements were performed using gamma spectrometer contains NaI (Tl) detector and counting system (Akkurt et al., 2015, 2020; Gunoglu & Arda, 2014) and shown in Fig. 1. In this measurements ^{54}Mn (emits 835 keV) and ^{22}Na (emits 511, 1275 keV) sources were used.

Here the detector is powered by the high voltage source (HV). The amplifier strengthens the pulses from the detector and allows shaping by making a suitable energy separation. The signal output from the amplifier is digitalized by coming to the Multichannel Analyser (MCA), each corresponding to an energy value. Depending on the amplitude of each signal, it is thrown into the memory channel. Information that is converted into a numerical form is observed on the screen as a spectrum.

The linear attenuation coefficients is calculated using number of counts recorded in NaI(Tl) detector with (N) and without (No) fabric material between detector and source and also thickness (x) of material. It is formulated as given in ref (Akkurt et al., 2010):

$$N = N_0 e^{-\mu x} \tag{1}$$

With the linear attenuation coefficients, there is also other parameter called mean free path (*mfp, cm*) and it is defined as the average penetration length into materials and it is given using equation (2) (Akkurt et al., 2010):

$$mfp = \frac{1}{\mu} \tag{2}$$

The half-value-layer (HVL) is an also important parameter for this purposes and it is defined as the thickness of materials to stop half (%50) of gamma rays. It is given by equation (3) (Akkurt et al., 2010):

$$HVL = \frac{Ln(2)}{\mu} \tag{3}$$

The tenth-value-layer (TVL) is defined as the thickness of material to stop 10% of radiation in materials. This parameter is obtained using equation (4) (Akkurt et al., 2010):

$$TVL = \frac{Ln(10)}{\mu} \tag{4}$$

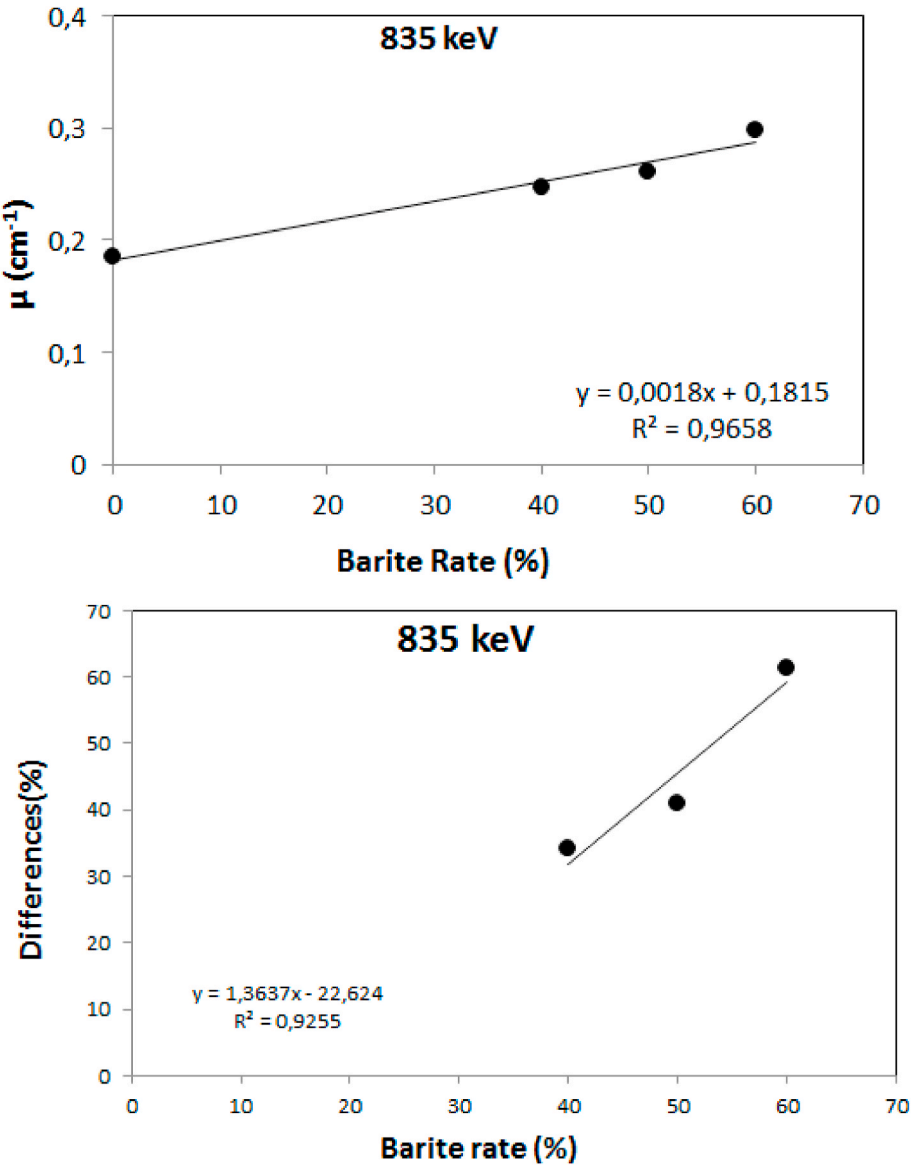


Fig. 4. The measured linear attenuation coefficients (for 835 keV) as a function of barite rate in fabric (upper) and differences of barite rate(lower).

3. Results and discussions

The linear attenuation coefficients have been measured in order to see gamma ray shielding properties of teri-cotton fabric and also to see the effect of barite rate in coating processes. The linear attenuation coefficients for four different types of farbric have been measured at 511, 835 and 1275 keV. In Fig. 2 obtained results are displayed as a function of gamma ray energies. It can be seen from those figures that the linear attenuation coefficients decreased with the increasing gamma ray energies. It is also clearly seeen from this figure that the correlation between the linear attenuation coefficients and gamma ray energies are good as R^2 is higher than %95 for TC0, TC40 and TC60 type fabric and its is 84% for the case of TC50 type. In order to see the effect of barite coating on fabric in terms of radiation shielding the obtained results were also displayed as a function of barite rate. Those are displayed in Fig. 3-Fig. 5 for 511, 835 and 1275 keV gamma rays respectively. In each of those figures the linear attenuation coefficients have been displayed as a function of barite rate in fabric (upper figures) and differences in percent of the linear attenuation coefficients related to barite rate in fabric (lower figures). It can be seen from all those figures that the linear attenuation coefficients increased linearly with the increasing barite rate in fabric. It is also clearly seen from those figure (lowers) that the increasing barite rate in fabric casue large increasing in terms of the linear attenuation coefficients (see Fig. 4).

The differences parameter have been obtained using formulation given in equation (6):

$$Differences\ (\%) = \left(\frac{TC - TC0}{TC0}\right) x100 \tag{6}$$

Here TC is the coated linear attenuation coefficients values and TC0 before coated values of linear attenuation.

This can also be seen in Fig. 6 where the differences displayed as a function of gamma ray energies for 3 different barite rate (40%,50%,60%). It is clearly seen from this figure that the large differences has been obtained for both high energy and also high rate. The correlation between the linear attenuation coefficients and barite rate on the fabric can also be seen from those figures. The value of R^2 is higher than %95 for 835 and 1275 keV and it is 81% for the case of gamma ray

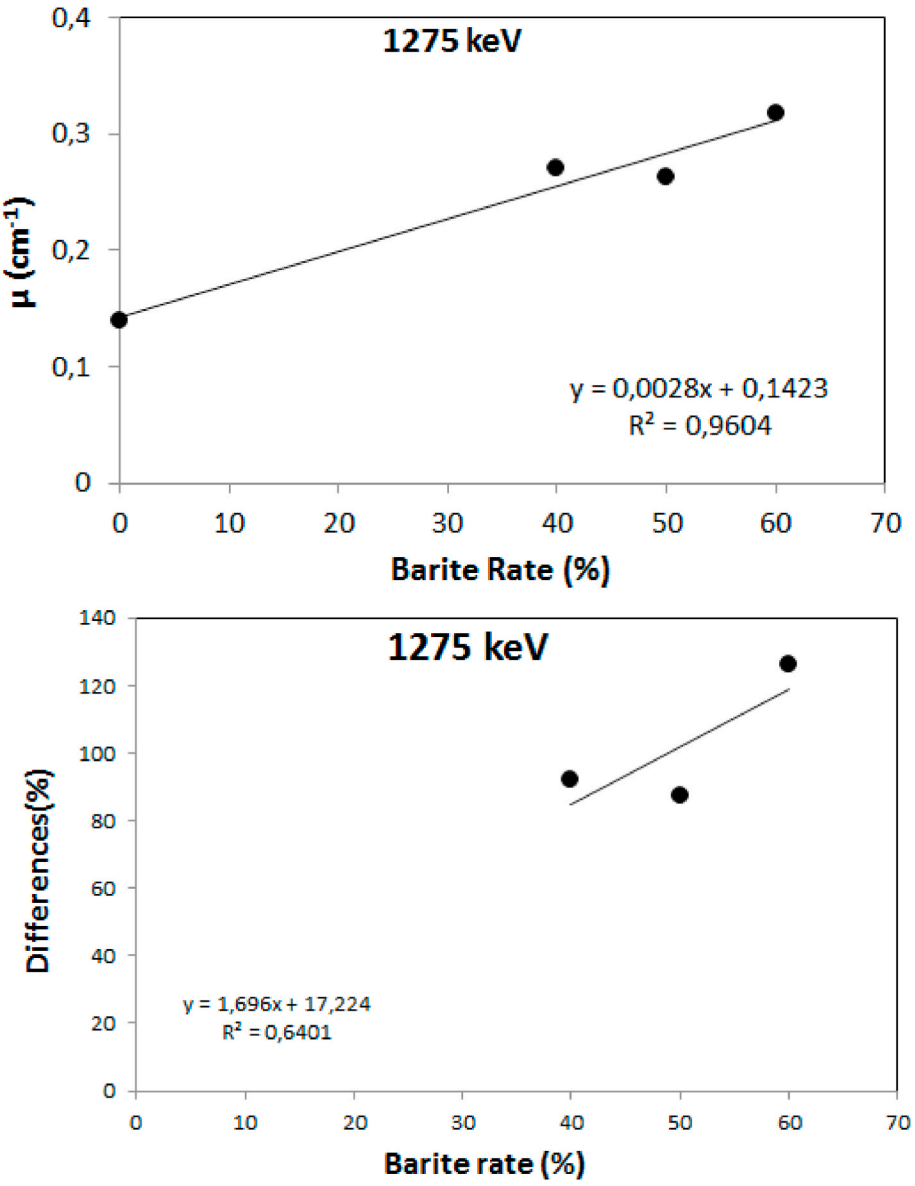


Fig. 5. The measured linear attenuation coefficients (for 1275 keV) as a function of barite rate in fabric (upper) and differences of barite rate(lower).

energy of 511 keV.

The mean free path of fabric as a function of gamma ray energy for four types is displayed in Fig. 7 where it is clearly seen that the mfp increased with the increasing gamma ray energy. In order to see the effect of barite rate more clearly on mean free path, it is plotted as a function of barite and displayed in Fig. 8. It is can be seen more clearly in this figure that the mean free path decreased with the increasing barite rate in fabric. This is another indication of how important of barite coating on fabric in terms of radiation shielding. Another important parameter is the HVL and TVL are also another important parameters in radiation physics and thus they were obtained and displayed in Figs. 9 and 10 respectively as 3D plot as a function of both gamma ray energy and barite rate. It can be seen from those figures that the both HVL and TVL value are higher for low barite rate and high gamma ray energies.

Even there are many different previous data in radiation field (Akkurt, 2007; Akkurt, 2009; Akkurt, Malidarre, & Kavas, 2021; Akkurt, Malidarre, Kartal, & Gunoglu, 2021; Albıdhanı et al., 2019; Altunsoy et al., 2020b; Aygun & Aygün, 2023; Boodaghi Malidarre et al., 2021; Celen et al., 2023; Fatih Kuluöztürk, 2023; Karpuz, 2023; Kurtulus et al., 2021; MALIDARRE et al., 2021; Oruncak, 2023; Zarkooshi et al., 2021; İskender AKKURT, 2015; Akkurt and El-Khayatt; Şen Baykal et al., 2021; Şengül, 2023), in our knowledge there is no similar previous results (at least at same energies), those of results are very important data for literature and in this field.

4. Conclusions

Considering the literature, it is determined that the barite mine has the feature of absorbing radiation. Taking advantage of this feature of barite, it is aimed to increase the radiation absorption property by considering a new alternative because it is both unhealthy and difficult to use since the protective clothing obtained using lead plates contain heavy metal and it is difficult to use.

The linear attenuation coefficients were obtained in order to investigate radiation shielding properties of terry-cotton fabric and also to see the effect of barite rate in coated on fabric. From the present study it can be concluded that:

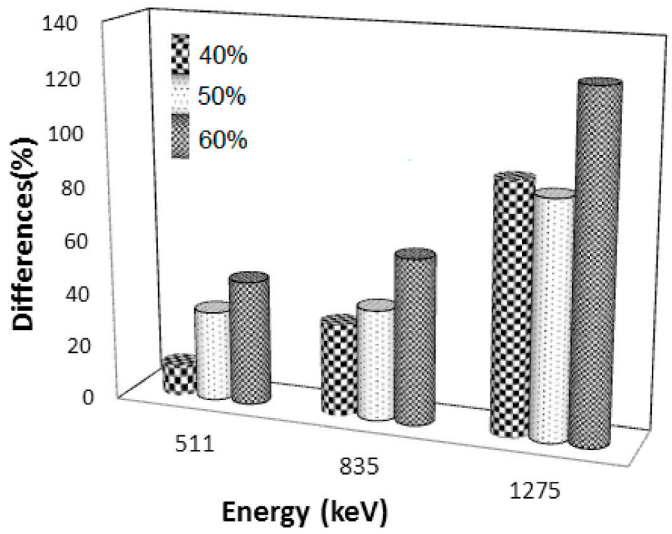


Fig. 6. The differences of measured linear attenuation coefficients for all energies.

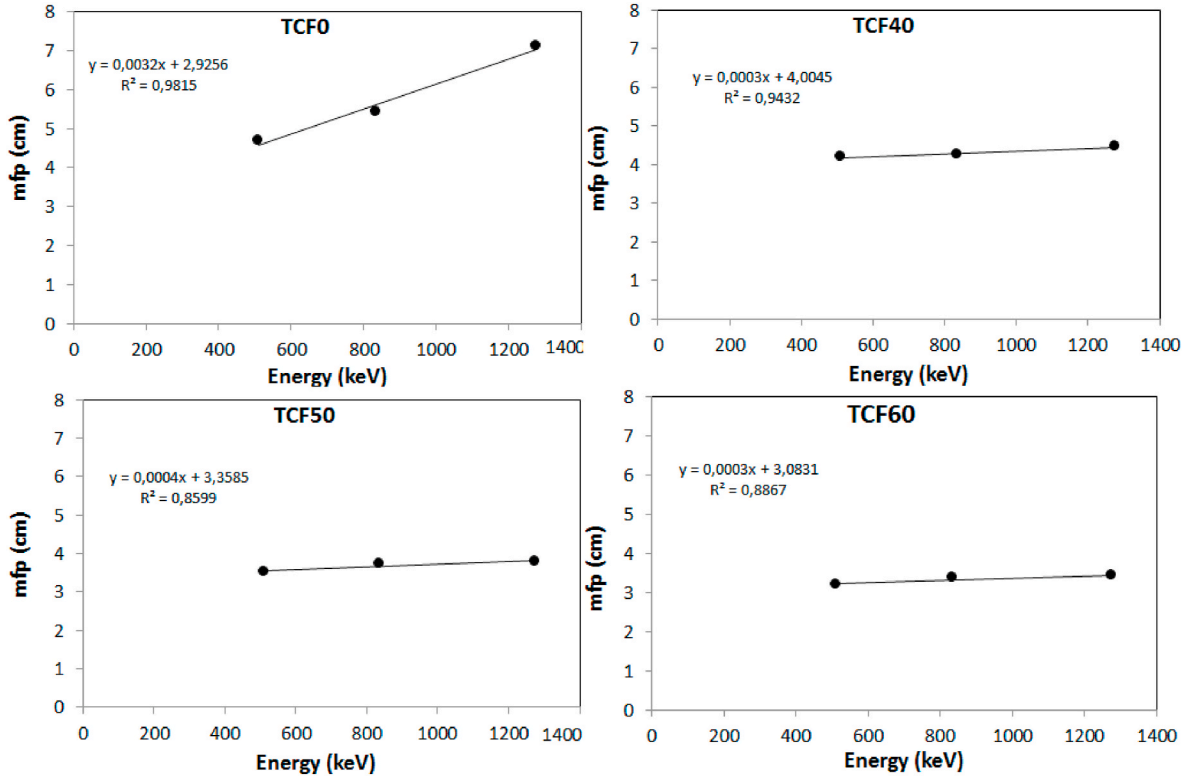


Fig. 7. The mean free path as a function of gamma ray energies for all types of fabric.

- It was found that barite coating on fabric is an effective way to improve radiation shielding properties.
- Coating fabric with barite improves mfp, HVL and TVL values to the extent that lower thicknesses.
- It is can be seen more clearly in this work that the mean free path decreased with the increasing barite rate in fabric. This is another indication of how important of barite coating on fabric in terms of radiation shielding.
- It can be clearly concluded from this work that the high rate of barite is more effective on the radiation shielding properties of fabric.
- The coating barite on fabric is more effective on the radiation shielding properties of fabric for high energy gamma rays.

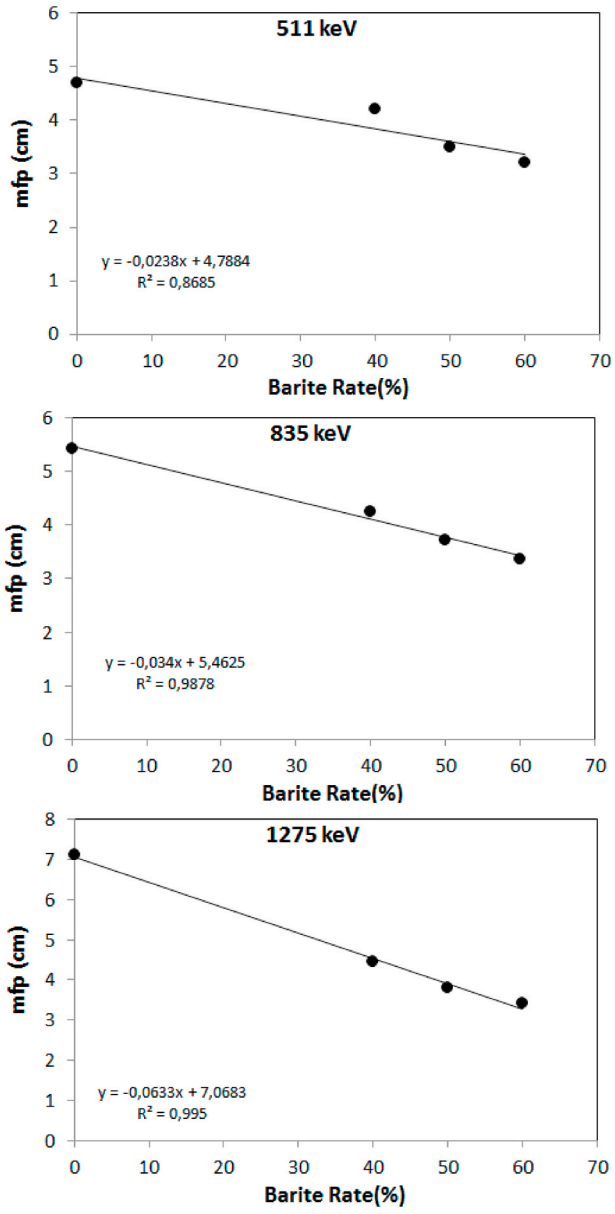


Fig. 8. The mean free path as a function of barite rate in fabric for 511,835 and 1275 keV energy gamma rays.

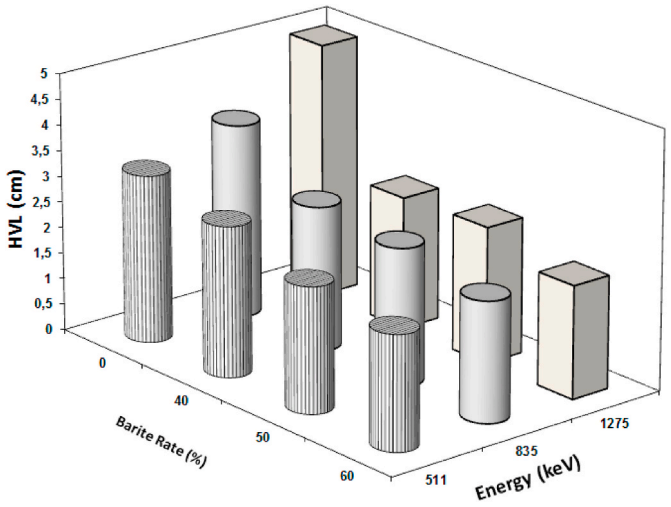


Fig. 9. The measured HVL as a function of gamma ray energies and barite rate in fabric.

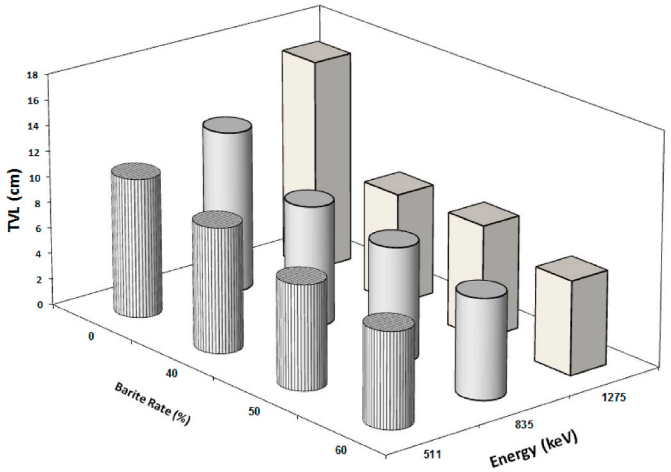


Fig. 10. The measured TVL as a function of gamma ray energies and barite rate in fabric.

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