Süleyman Demirel Üniversitesi YEKARUM e-DERGİ (Journal of YEKARUM)
Cilt 10, Sayı 2, 150-160, 2025
E - ISNN:1309-9388

Prediction of Radiation Absorption Coefficient in Barite Coated Fabrics Using Fuzzy Logic

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(İlk Geliş Tarihi 28/08/2025 ve Kabul Tarihi 24/11/2025)

(**DOI:** 10,71208/yekarum.1773568)

ABSTRACT :

Today, the use of radiation in basic science, medicine, agriculture, industry, and military purposes has reached enormous scale. Workers in radiation-risk environments must wear special clothing to protect themselves from these rays. Radiation protection is achieved through three basic methods: time, distance, and armor. Because armoring is the most effective of these three methods, workers in these areas must wear armored clothing that effectively absorbs radiation rays. Although lead is a very effective radiation shield, it poses significant risks to human health. Alternative clothing for use in radiation-exposed facilities needs to be considered. Because barite is a heavy material, it shields harmful radiation. This study aims to combine this property of barite with fabric to create protective clothing that absorbs harmful radiation. Using experimental data, a fuzzy logic model was developed to estimate the radiation absorption coefficients of barite-coated fabrics. Using barite percentage and energy level as input variables and the radiation absorption coefficient as output variables, a fuzzy information-based model was developed. It can be concluded that the developed fuzzy intelligent model can be applied as an effective tool to satisfactorily predict the radiation absorption intensity of barite coated fabrics.

Keywords: *Radiation, Fuzzy logic, Barite.*

Barit Kaplanmış Kumaşlarda Radyasyon Soğurma Katsayısının Bulanık Mantık ile Tahmini

ÖZET

Günümüzde radyasyonun temel bilimde, tıpta, tarımda, endüstride ve askeri amaçlarla kullanılışı, çok büyük ve geniş boyutlara ulaşmıştır. Radyasyon açısından riskli ortamlarda çalışanların bu ışınlara karşı korunması için özel kıyafetler giymesi gerekir. Radyasyondan korunma: zaman, uzaklık ve zırh olmak üzere üç temel yolla yapılır. Bu üç yoldan en etkili yol zırhlama olduğu için bu alanlarda çalışanların korunması amacıyla radyasyon ışınlarını iyi soğuran zırh kıyafetleri giymeleri gerekmektedir. Kurşun çok iyi bir radyasyon zırh olmasına karşın insan sağlığına çok büyük zararlar vermektedir. Radyasyon kullanılan merkezlerde giymek için alternatif giysilerin düşünülmesi gereği doğmuştur. Barit ağır bir madde olduğu için zararlı radyasyonu zırhlama özelliği bulunmaktadır. Bu çalışmada baritin bu özelliği kumaş ile birleştirilerek zararlı ışınları absorblayan koruyucu giysi elde etmek amaçlanmıştır. Deneysel veriler kullanılarak bulanık mantık ile barit kaplanmış kumaşların radyasyon soğurma katsayıları tahmin edilebilecek bir model oluşturulmuştur. Giriş değişkenleri olarak barit yüzdesi ve enerji seviyesi

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ile çıkış değişkenleri olarak radyasyon soğurma katsayısı değişkeni kullanılarak, bulanık bilgiye dayalı bir model geliştirilmiştir. Geliştirilen bulanık akıllı modelin, barit kaplama uygulanan kumaşların radyasyon soğurma yoğunluğunu tatmin edici bir şekilde tahmin etmek için etkili bir araç olarak uygulanabileceği sonucuna varılabilir.

Anahtar Kelimeler**:** *Radyasyon, Bulanık mantık, Barit*

1. INTRODUCTION

More than three thousand nuclear facilities worldwide use radiation to meet needs in medicine, scientific research, energy, agriculture, and industry, as well as in medical centers for treatment and diagnostic purposes. Those working in radiation-risk environments wear special protective clothing to minimize radiation risk. Radiation protection is achieved through three basic methods: time, distance, and armor. Because armoring is the most effective of these three methods, workers in these areas must wear armored clothing that effectively absorbs radiation to protect their health.

Ionization is defined as the release of an electron from the nucleus under the influence of radiation and its release. Ultraviolet rays, X-rays, alpha, beta, and gamma rays, neutrons, protons, and other elementary particles produced by nuclear reactions or radioactive decay cause "ionizing radiation." This radiation, which ionizes molecules and disrupts their structure, also causes genetic deterioration and damages biological structures. Radiation that does not ionize electrons within matter by knocking them away from the nucleus is called "non-ionizing radiation." Non-ionizing radiation is divided into two types: UV rays and electromagnetic radiation (radio waves, microwaves, cell phones, FM and TV transmitters, radars, transformers, computers, and current-carrying cables) [1].

Gamma (λ) and X-rays are electromagnetic radiation. These are high-frequency electromagnetic waves, similar to visible light and radio waves. Their wavelengths are very short but their energy is high. They stated that the use of practical and comfortable textile surfaces would be extremely suitable for reducing or controlling the negative effects of the electromagnetic pollution problem faced by modern life. They pointed out that textile materials used in daily life for covering, protection, or fashion concerns would also become protective products against the effects of electromagnetic pollution, creating new markets for the textile sector [2].

Although lead is an excellent radiation shield, it causes significant harm to human health. This has led humanity to seek alternative methods that offer radiation shielding properties and are harmless. Barite has the ability to neutralize gamma rays. Therefore, it is used in all X-ray-related procedures in hospitals. Radiation causes disruptions in tissue and

organ growth or even tissue and organ death. Radiation damage depends on the sensitivity of the irradiated tissues or organs to radiation and the functions these tissues and organs perform in the body. Tissue death results from irreparable damage. If the tissue is not completely destroyed, repair ceases, and cells proliferate rapidly to replace the dead cells. The most significant effects of radiation on tissues and organs are seen in the blood and bone marrow. Furthermore, it causes significant damage to the skin, hair, lungs, digestive system, eyes, urinary tract, bone tissue, and reproductive organs. Animal experiments have shown that exposure to radiation doses accelerates aging and shortens the natural lifespan, and this effect is also true for humans. There is a linear relationship between radiation dose received and lifespan reduction [3].

The development of modern computer science is expanding the range of methods available for solving engineering problems. One of the useful mathematical tools used in computer science is fuzzy set theory, based on fuzzy logic. Fuzzy logic was first proposed by L.A. Zadeh and has been widely used in control applications in recent years, achieving successful results.

In one study, the radiation attenuation coefficient was experimentally determined in concrete produced using different amounts of barite and normal aggregate, with varying w/c ratios and barite percentages. A prediction model was developed using the fuzzy logic method using the experimental data. This developed model provided a high degree of predictability of experimental results, and it was determined that the radiation retention of concrete batches that could not be tested could also be predicted [4].

The shielding capabilities of woven products containing barite at different rates were investigated against ionizing and electromagnetic radiation. It was observed that the mass attenuation coefficient at different energies, radiation shielding effectiveness parameters, and radiation shielding properties increased with increasing barite content, and that the product containing 10% barite was a good shielding material against radiation compared to others [5].

The degree of protection of textile materials against radiation, Ultraviolet Protection Factor (UPF), was derived from a prediction model determined by fuzzy logic programming and the experimental and predicted values were shown to be in very good agreement [6].

This study aims to impregnate barite into fabrics using a coating method and produce fabrics capable of absorbing gamma rays. Protective armor clothing made from barite fabric, produced by infusing barite into the fabric, will be lighter than armor clothing made from lead plates, making it easier to use. Furthermore, because barite fabric has no harmful effects on human health, it is intended to be an alternative to armor clothing made from lead plates. Barite

fabrics were impregnated with barite fabric, and their radiation absorption properties were investigated. Furthermore, using experimental data, the radiation absorption coefficient of barite-applied fabrics was estimated using fuzzy logic. A model based on fuzzy information was developed, using barite percentage and energy level as input variables and radiation absorption as output variables.

2. MATERIALS and METHODS

In this study, 100% cotton knitted fabrics were used. Barite was applied to the fabric using a coating method. Barite, prepared at a micron scale, was mixed using textile coating chemicals at varying ratios until a homogeneous and fluid consistency was achieved. After the fabric to be coated was fixed to a flat surface, a metal coating template was placed over the fabric. The mixture, prepared by adding varying amounts of barite, was then applied to this metal template to ensure even penetration of the barite into the fabric. After the coating process, the fabrics were dried and fixed (Cotton combed fabric; 100% cotton, 230 g/m² interlock knit fabric).

The neutron absorption properties of fabric samples coated with different amounts of barite were measured experimentally. The barite coating ratios were 40%, 50%, 60%, and 70%. A neutron absorption detector located at the Süleyman Demirel University Gamma Spectroscopy Laboratory was used for neutron absorption measurements. The device's neutron measurement is provided by a removable He-3 proportional detector.

When creating a fuzzy model, firstly all input and output variables of the interface functions are designed [7-15]. Membership input and output variables are selected with linguistic terms. The general structure of the fuzzy logic model for determining the radiation absorption coefficients of fabrics is shown in Figure 1[16-20]. In the figure, on the left side, the input parameters for the model, which are the barite ratio and energy level, in the middle, the part where the output value is estimated according to these inputs, the part containing the rules of the model and the part that determines the numerical output value (clarified value) in the light of these rules, and on the right, the part containing the percentages of transmitted radiation, which is the output value of the model, is expressed representatively [21-26].

Fuzzy inference operations were performed using the Mamdani approach. The center of gravity method was used for defuzzification [27-30].

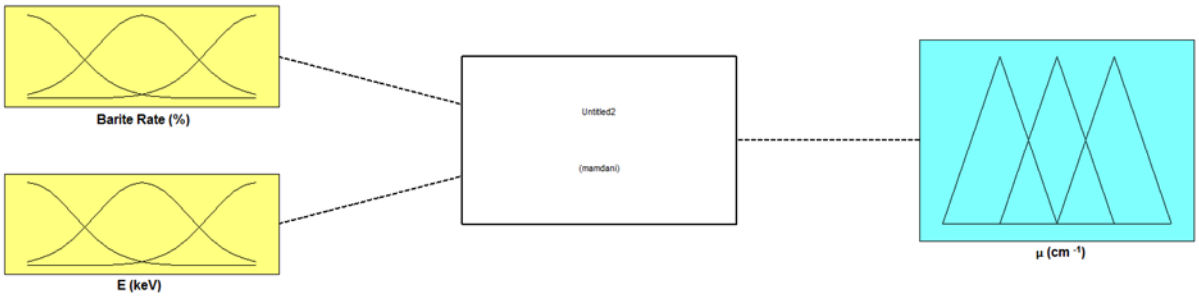

Figure 1. General structure of developed model.

In this study, five membership functions were determined for the input variables barite ratio (%) and three for the energy level when creating the fuzzy model. Seven membership functions were determined for the output variable transmitted radiation percentages. All membership functions, each with a specific numerical value range, were determined for the barite ratio-energy level inputs and transmitted radiation percentage outputs, and were fuzzyized using verbal expressions. The membership functions for the inputs and outputs are shown in Figures 2, 3, and 4.

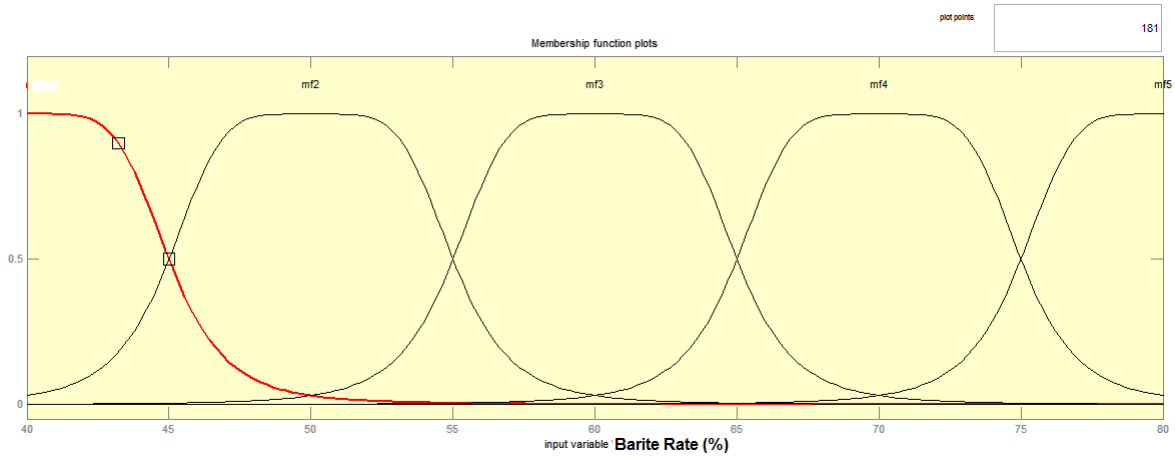

Figure 2. Membership functions of barite rate (%)

For the fuzzification stage, the input variable, Barite percentage, was categorized into five possible linguistic categories.In this study, the input Barite percentage for the developed fuzzy model is determined between 40% and 80%.

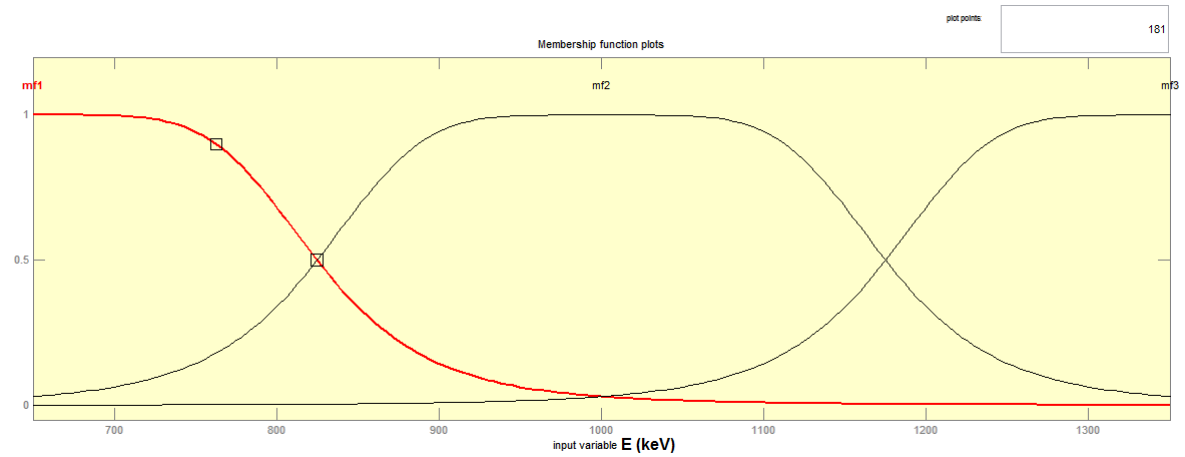

Figure 3. Membership functions of Energy level (keV).

For the fuzzification stage, the input variable energy level was categorized into five possible linguistic levels, and the energy level as input for the developed fuzzy model was determined between 650 and 1350.

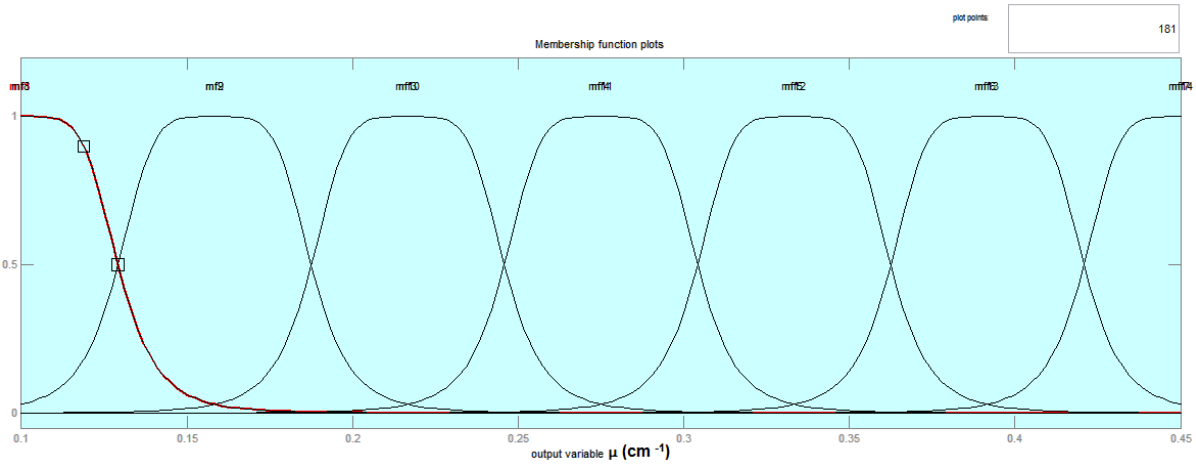

Figure 4. Membership functions of radiation absorption coefficient.

The output was the radiation absorption variable categorized into fourteen possible linguistic variables. The output was the radiation absorption coefficients between 0.1 and 0.45.

3. RESULTS AND DISCUSSION

In this study, the neutron absorption coefficients of combed cotton fabrics coated with varying amounts of barite were measured experimentally. The operation of the fuzzy logic model, developed to estimate the radiation absorption coefficients of barite-coated fabrics using experimental data, is schematized in Figure 5. All 90 rules are evaluated simultaneously to obtain the fuzzy output.

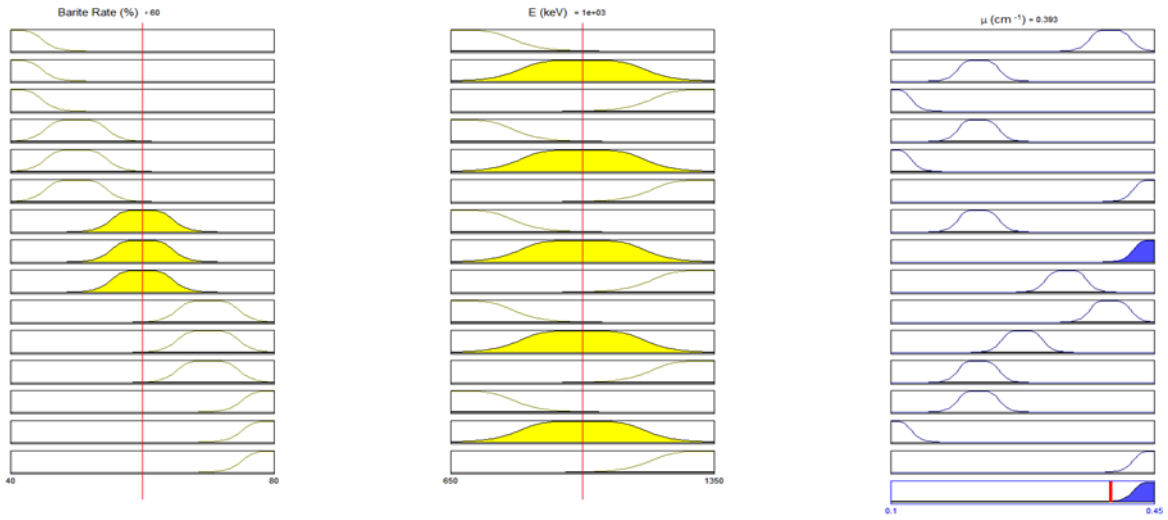

Figure 5. Rule viewer of the fuzzy inferring system.

Essentially, the membership functions of fuzzy set theory are based on knowledge, expert judgment, and experimental conditions. Better results are achieved when applying functions with fewer parameters and a wider range of memberships. In a fuzzy logic model, decision logic is best achieved by mimicking human decision-making processes and making inferences based on information from fuzzy control.

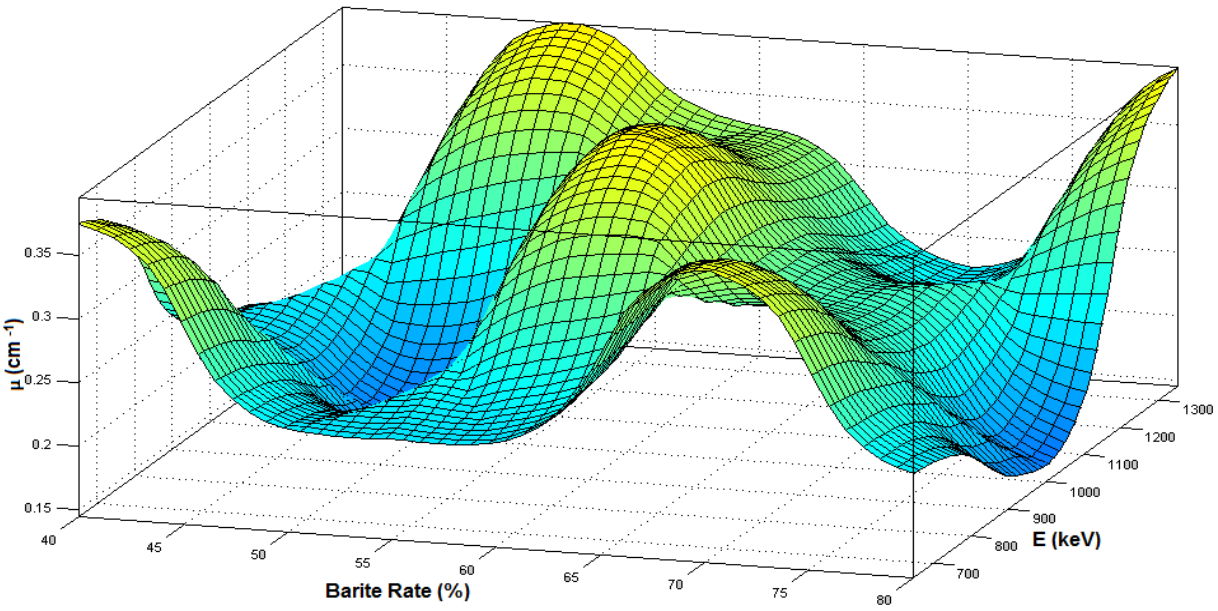

Figure 6. Percentage of radiation passed through fabric as a function of barite rate (%) and energy level (keV)

In this study, the barite percentage and energy level were defined as input parameters for radiation absorption of barite-coated fabric, and the radiation absorption coefficient was determined as the output parameter. The developed model was evaluated and estimated using the fuzzy logic model. The model results were then compared with experimental results. A fuzzy system is a tool used to model the radiation absorption intensity of barite-impregnated fabrics. After the model was developed, it was estimated using the MATLAB fuzzy rule viewer. Therefore, it can be confidently concluded that the developed fuzzy model can help select the relevant process parameters to achieve the desired results. In the absence of such a model, numerous tests must be conducted to achieve the desired result. Insufficient data can lead to inaccurate predictions. In multivariable processes, creating a fuzzy system with a large number of input parameters becomes complex and difficult to manage.

4. CONCLUSION

Protective armor clothing made from barite fabric, produced by infusing barite into the fabric, is lighter than armor clothing made from lead plates, making it easier to use. Furthermore, barite fabric has no harmful effects on human health, making it an alternative to armor clothing made from lead plates. The radiation absorption properties of the resulting barite fabrics were investigated. Furthermore, using experimental data, the radiation absorption coefficient of barite-applied fabrics was estimated using fuzzy logic. In this study, a fuzzy information-based model was developed, with barite percentage and energy level as input variables and the radiation absorption variable as output variables. The results demonstrate that the fuzzy prediction model is accurate. Therefore, it can be concluded that the developed fuzzy intelligent model can be applied as an effective tool to satisfactorily estimate the radiation absorption intensity of barite-impregnated fabrics.

This study determined a significant relationship between the radiation absorption coefficients and the barite content of coated fabrics containing different barite content. Increasing the barite content positively affected radiation absorption coefficients. Experimental results were compared with the developed fuzzy logic model, and the model's reliability was tested. The comparison determined that the developed model was highly predictable for experimental results and could also predict situations where experiments could not be performed using the developed model. An examination of the results revealed that, compared

to the sharp boundaries of classical logic, fuzzy logic smooths out these sharp transitions in classical logic, thus yielding results more compatible with human thought and judgment.

Çıkar Çatışması Beyanı

Yazarlar arasında çıkar çatışması yoktur.

Araştırma ve Yayın Etiği Beyanı

Çalışma, araştırma ve yayın etiğine uygundur.

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