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Natural Radiation Sourced Heat Stress: Thermal Comfort Depending On Color Factor In Safety Reflector Vests

Doğal Radyasyon Kaynaklı Isı Stresi: Reflektörlü Güvenlik Yeleklerinde Renk Faktörüne Bağlı Termal Konfor

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ABSTRACT

Research has shown that personal protective clothing is not used by employees due to personal reasons such as lack of working comfort and heat stress. Solar (UV) radiation creates a heat effect on people working outdoors. Agricultural and construction workers are exposed to solar radiation and are known to be at high risk of heat stress, especially in arid climates. It is important for the person to individually evaluate the ambient temperature as hot or cold for the ergonomic conditions of the employee. In this study, for increasing safety and comfort expectations, heat changes in reflector vests based on colors of heating due to natural radiation were estimated with thermal camera measurements, and gained heat values of vests with different fabric thicknesses were estimated using fuzzy logic modeling over time, and the effects of natural radiation on human health were examined.

Keywords: Natural Radiation, Heat Stress, Protective Clothing, Reflector Vest, Human Health.

ÖZET

Yapılan araştırmalar kişisel koruyucu giysilerin çalışanlar tarafından çalışma konforu eksikliği ve ısı stresi gibi kişisel sebeplerle kullanılmadığı tespit edilmiştir. Güneş (UV) radyasyonu, açık havada çalışan kişiler üzerinde ısı etkisi oluşturmaktadır. Güneş radyasyonuna maruz kalan tarım ve inşaat işçileridir ve bunlar özellikle kurak iklimlerde yüksek ısı stresi riskine sahip oldukları bilinmektedir. Kişinin ortam sıcaklığını bireysel olarak sıcak veya soğuk şeklinde değerlendirmesi çalışanın ergonomik şartları açısından önemlidir. Bu çalışmada, artan güvenlik ve konfor beklentilerine yönelik, doğal radyasyondan kaynaklı ısınmanın renklere bağlı olarak reflektörlü yeleklerdeki termal kamera ölçümleri ile ısı değişimleri ve farklı kumaş kalınlıklarındaki yeleklerin zamana bağlı olarak bulanık mantık modellemesi ile kazanılmış ısı değerleri tahminlenmiş ayrıca doğal radyasyonun insan sağlığına etkileri incelenmiştir.

Anahtar Kelimeler: Doğal Radyasyon, Isı Stresi, Koruyucu Giysi, Reflektörlü Yelek, İnsan Sağlığı.

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I. INTRODUCTION

Personal protective equipment is not used enough because employees prefer work comfort to safety. Solar heat radiation imposes a significant heat load on workers. Requiring employees to wear protective clothing may also be counterproductive in such environments because physiologically, the human body is a metabolic heat-producing system, which maintains a balance between heat loss and heat gain. The manufacturing material and garment design of the reflective vest can affect thermal balance by increasing or decreasing heat. The radiant shielding performance of fabrics is related to the chemical structure of the fabric material and its physical thickness. Textile materials generally protect against infrared radiation, the greater the thickness of the fabric, the better.

Safety vests are preferred for security and awareness purposes, produced using phosphorescent type fabric, with strips on the front and back that reflect light even in low-light conditions, and can be worn over sleeveless and wide work clothes. These vests, which have reflective parts within the scope of work clothes that are required by law to be worn as determined by legal regulations and legislation regarding occupational safety, are used for occupational safety and to ensure easy identification of personnel.

We can also call the reflector tapes on safety vests that can reflect light as life-saving tapes. Because conspicuousness is of vital importance in the production field, which is full of many dangers. Polyester fabric is mostly used in the production of safety vests. Polyester fabrics have a breathable fabric structure that is not heavy, dries quickly when wet, can be used without the need for ironing. In this way, employee comfort is prioritized, work performance is not reduced, and frequent use is aimed. In today's market, vest colors are prioritized in the color and size standards determined for work safety vests, and products made of phosphorescent fabric with orange, yellow or red colors, which allow easy distinction from the surrounding environment during the day, are preferred. The front and back of the vests have stripes that reflect light in the night environment. It is as wide, thin and comfortable as possible because it is worn over a dress with business attire.

In today's manufacturing environment, where there is fast flow and intense material movements, wearing conspicuous clothing provides a significant advantage in terms of precautions against accidents such as crushing, collision, conflict, etc. for personnel working with human-controlled moving vehicles. For this reason, while some businesses are taking precautions on personnel visibility, they are also implementing practices to increase the visibility of vehicles that pose a risk of collision, especially with eye-catching colors and lighting such as red and yellow. In this context, occupational safety vests are the general name for vests that must be worn in order to attract attention and increase visibility, especially in work areas or jobs that require precautions, such as construction sites and manufacturing environments [1].

Employees can work productively under working conditions where they feel comfortable. Poor working conditions; inappropriate physical conditions of the working environment, such as insufficient ventilation, heating and the like, cause negative ergonomic environment conditions.

The advantage of a work safety vest in night work and facilities with low light is thus considered a necessity within the scope of work safety as a specification rather than a choice[2-5]. Another issue is that a person who gets physically tired while doing work experiences mental fatigue after a while, causing attention deficit and coordination problems. This lack of attention makes it increasingly difficult due to mental fatigue to detect objects such as people, which can be easily separated from the surrounding colors and background, or objects that are moving and/or dangerous and at risk of impact. In this case, even if adequate lighting conditions are met, encountering objects that use colors such as yellow, red or orange, which can perceptually create feelings of attention in the mind, provides results that can increase awareness even in a tired mind.

Sun et al., radiant protection of textile structures is affected by the thickness and materials of the fabrics [6]. Holmér, the structure of protective clothing prevents the heat exchange of sweat [7]. Nunneley, developed computer models that predict work, clothing, and environmental response to a combination of heat stress factors [8]. Potter, clothing designed for safety has shown that heat stress caused by work and the environment imposes a heat load and that thermal comfort is necessary to increase safe working time [9]. Glitz and Seibel, they stated that heat stress caused by protective clothing reduces working time, therefore convective heat loss should be increased [10]. Talukdar et al., thermal properties of fabrics, environmental conditions and protective performance of fabrics were examined [11]. Reischl, he developed a heat radiation point for protective clothing and a prototype vest for workers exposed to solar radiation, and found that it reduced heat gain by 30% [12]. Feiyu et al., they found that the layer structure of the clothing affects the heat transfer effect [13]. Neves, to analyze the thermal conductivity effect of fabric properties, they determined the effects of multilayer clothing on heat transfer [14]. Song and Reischl, they estimated the thermal protection and physiological load provided by clothing with different layers [15, 16]

In the literature review, there are many studies on the evaluation of heat stress and thermal comfort measurements in textile protective clothing. However, unlike the literature, we have not found a study that directly addresses the field of testing a thermal camera using two different colored reflective safety vests and detecting heat gain on the inner surface of the vest by fuzzy logic modeling of the fabric thickness over time.

II. METHODS

Measurement methods measure only one of many parameters related to heat transfer. The low IR transmittance of the vest does not mean that it has high reflectivity. The vest may also cause an extra temperature increase by transmitting heat to the body due to high IR absorption and emissivity [5].

For yellow and orange vests, the vests were exposed to sunlight between 12:00 and 14:00 on November 9, 2023, and it was determined how the outer surface temperatures of the vests changed according to their colors with the FLIR E40 thermal camera. Figure 1 shows the reflective vest colors used in the study.

The fuzzy logic tables created in this study were described using the MATLAB program and the resulting data were examined[17-22]. The Mamdani method allows us to define expertise in a more intuitive, more human-like way . At the same time, fuzzy logic is rule-based to produce an information output. These rules consist of propositions such as "If… Then… (If…Then…)".In the study, the type of membership functions used in the input sets is the gbellmf method, and the type of membership functions used in the output sets is the trimmf method, thus the trapezoid shape, which is a geometric shape, is obtained [23-30]. Our input membership functions, Time (min), were chosen to be three, thickness of fabric (mm) was chosen to be six, and our output membership functions, input heat gain (°C), were chosen to be sixteen feet. It was created with a hundred and thirty rule base in order to understand the effect of the relationship between the determined membership functions on the result.

Figure 1: Color colors used in the study

Reflective vest fabric properties are given in Table 1.

Table 1: Vest fabric features

Fiber	100% Poliester (PES)
Thread	75/72 Denye
Weight	120 ±5 gr/m2
Most	1500 ±20 mm
Burst Strength	>1000 kPa (kN/m2)

It is assumed that the sun's rays penetrating the vest surface are equal. In order to assist vest manufacturers with optimum thermal comfort, measurements were made based on vest colors. The method of modeling thermal comfort presented in this article clearly reveals the dependence between the parameters characterizing vest color.

III. DISCUSSION

Since there is no need to consider all color types, we focused on the selected yellow and orange colors. Therefore, although the thermal change is affected by the chemical structure of the color molecules, the color tone is determined by the color parameters that characterize the vest color in the visible spectrum range.

Figure 2: Yellow vest preliminary temperature measurement

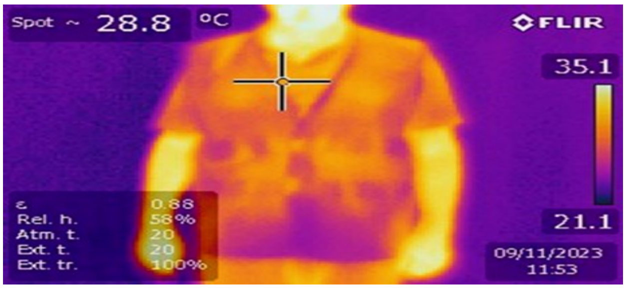
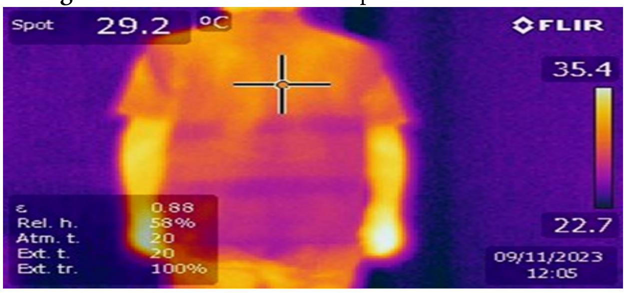


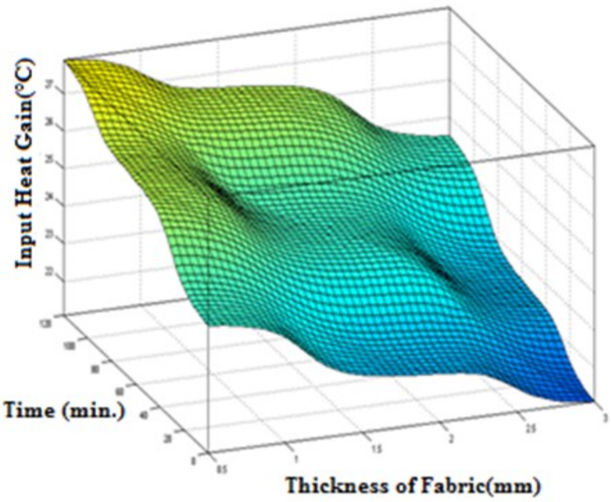
Figure 3: Yellow vest back temperature measurement



A. Thermal Camera Measurement Applied To The Yellow Vest

Measurement values for the yellow vest are given in Figures 2-3. Yellow colored vests provide very good protection against sunlight and reduce heat. External surface front temperature: 28.8 °C, 29.2 °C measured from the rear side on the worker. These levels are important to con-

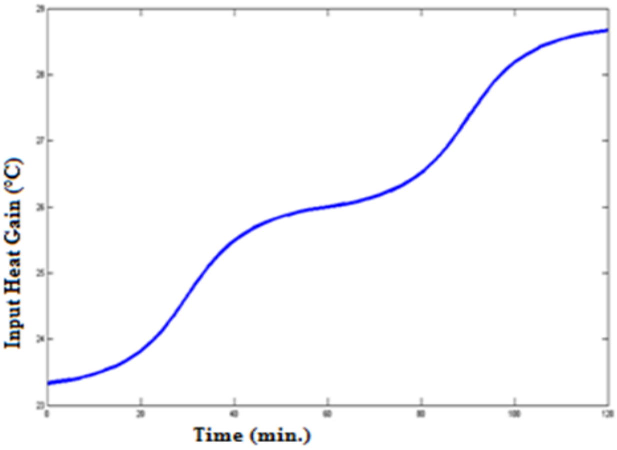
Figure 4: Vest inner surface temperature change graph depending on time and fabric thickness



sider for thermal comfort. Figure 4 shows the acquired temperature change graph entering the inner surface of the vest depending on time and fabric thickness.

When the connection graph between fabric thickness and time is examined, it is seen that the temperature value entering the vest decreases with the increase of fabric thickness, and with the increase in the acquired temperature

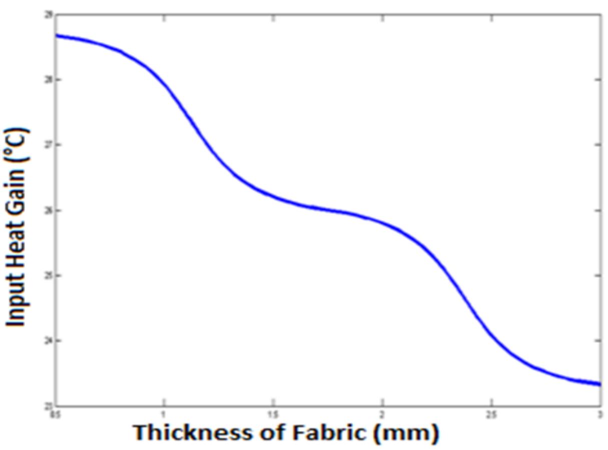
Figure 5: Vest internal temperature change over time



entering the vest depending on time, the value of the acquired temperature value reaches 28.8 °C. Figure 5 shows the temperature change inside the vest depending on time.

In the 0-20 minutes, the temperature rises to 23.3-23.80 °C, in the 20-40 minutes, it rises to 23.3-25.4 °C, in

Figure 6: Vest internal temperature change depending on fabric thickness



the 40-60 minutes, it rises to 25.5-26 °C, and in the 100-120 minutes, the maximum level is 28.80 °C. It is seen that it has increased to C levels. It is seen that the acquired temperature change increases with time.

For 0.5-1 mm fabric thickness, the temperature drops to 28.8-28 °C, for 1-1.5 mm, it drops to 28-26.4 °C, for 2-2.5 mm it drops to 25.7-24 °C, for 2.5-3 mm it is the minimum level. It is seen that it dropped to 23.23 °C levels.

Figure 7: Orange vest front temperature measurement

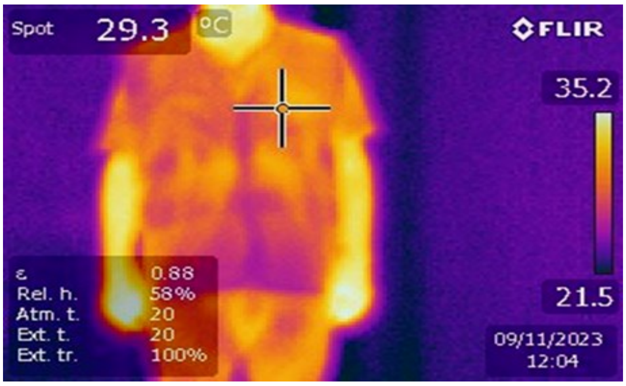
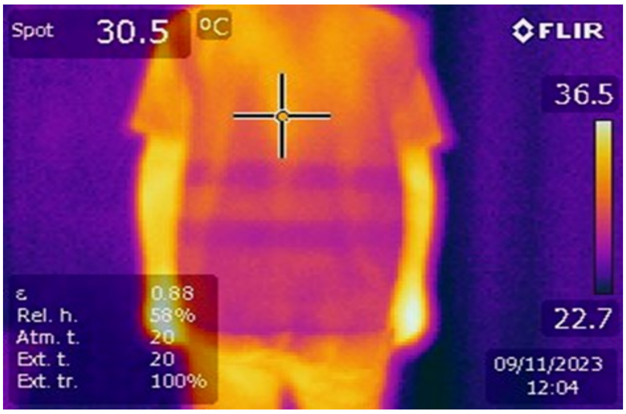


Figure 8: Orange vest back temperature measurement

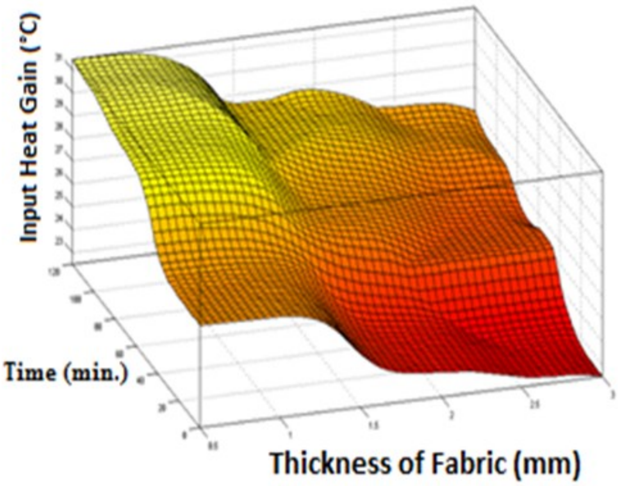


It is seen that the acquired temperature change decreases depending on the fabric thickness.

B. Applied Thermal Camera Measurement for Orange Colored Vest

Measurement values for the orange vest are given in Figures 7-8. It appears that orange vests have a lower level of protection against sunlight. External surface front tem-

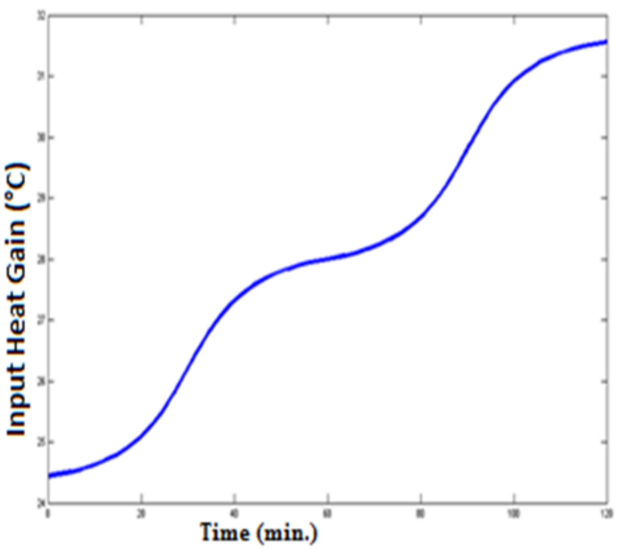
Figure 9: Vest ınner surface temperature change graph depending on time and fabric thickness



perature: 29.3 °C, 30.5 °C measured from the rear side on the worker. These levels are important to consider for thermal comfort. Figure 9 shows the temperature change graph entering the inner surface of the vest depending on time and fabric thickness.

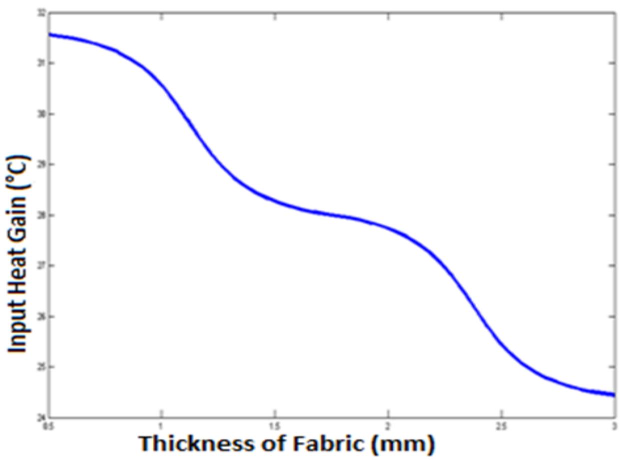
When the connection graph between fabric thickness and time is examined, it is seen that the temperature entering the vest decreases with the increase of fabric thickness, and with the increase in the acquired temperature entering the vest depending on time, the temperature reaches 31.6 °

Figure 10: Vest acquired ınternal temperature change over time



C. Figure 10 shows the temperature change inside the vest depending on time.

Figure 11: Vest internal temperature change depending on fabric thickness



The temperature rises to 24.6-25 °C in the 0-20 minutes, 25-27.4 °C in the 20-40 minutes, 27.4-27.8 °C in the 40-60 minutes, and reaches the maximum level of 31.6 °C in the 100-120 minutes. It seems to come out. It is seen that the acquired temperature change increases with time.

Between 0.5-1 mm fabric thickness, the temperature drops to 31.6-30.8 °C. Between 1-1.5 mm, the temperature drops to 30.8-28.4 C. For 2-2.5 mm, it drops to 27.7-25.1 °C. 2.5 It is seen that it drops to 24.3 °C, which is the minimum level of -3 mm. It is seen that the acquired temperature change decreases depending on the fabric thickness.

IV. NATURAL RADIATION SOURCED (UV) EFFECT ON HUMAN HEALTH

Initial effects of solar radiation (UV) include sunburn, tanning, hyperplasia, immunosuppression, vitamin D synthesis, and photoonycholysis. Sunburn inflammation is the first and most well-known immediate skin response to ultraviolet rays. Absorption of sunlight by DNA and proteins leads to molecular and cellular destruction. One effect of UV is skin discoloration [31]

Another effect of UV is abnormal proliferation of cells. When the inflammation threshold stimulated by ultraviolet rays increases, it causes thickening in the stratum corneum, epidermis and dermis layers of the skin. Especially in those with fair skin and white spots on their skin, the protective layer of the skin thickens after a single UVB dose. This thickening protects the skin from sunburn 10-20 times. "Hyperplasia is the result of increased DNA, RNA and protein synthesis, as well as increased epidermal and, to a lesser extent, cell proliferation activity, following exposure to acute UV. This thickening provides more protection against tanning in light-skinned people".

UV rays also disrupt the functions of keratinocyte cells and affect their effects on LH cells. They negatively affect its regulatory properties. Uroconic acid, which absorbs UV, plays an important role in immunosuppression. The positive effect of UV radiation on human health is the synthesis of vitamin D3. UVB rays convert moderate amounts of epidermal dehydrocholesterol into provitamin D3. Provitamin D3 multiplies within days and enters the circulation with plasma vitamin D binding protein [32].

V. CONCLUSION

Today, as a result of increasing industrial applications, variations of work accidents have also increased. For this reason, the use of equipment called Personal Protective clothing by field workers is of vital importance. By providing visibility, protective clothing protects against most potential accidents and reduces the impact of impact in the event of an accident. The development of a reflector vest is recommended for use by agricultural and construction workers exposed to high heat stress in environments exposed to sunlight. One of the simplest precautions is to try to be exposed to the sun as little as possible in the middle of the day, when the sun's rays are more direct. If we are exposed to these harmful sun rays (UV radiation), even if unintentionally, by wearing clothes that cover the body, we should try to minimize the damage by taking the necessary precautions. The outer surface front temperature for the yellow colored vest was: 28.8 °C, measured from the back side on the worker at 29.2 °C, and the outer surface front temperature for the orange colored vest was: 29.3 °C, measured from the back side on the worker: 30.5 °C. measured.

In the textile industry, especially in order for protective clothing manufacturers to benefit from fabric development studies, it is necessary to take into account the heat transfer, weight, comfort, and safety parameters of the developed fabrics. Other issues that should be taken into account in the design of protective clothing are environmental damages and energy costs during production and use. In addition, during the management of the radiation component of heat transfer in the body-clothing-environment system, it is important to consider the combined heat and mass transfer mechanisms that occur by transmission, transportation and evaporation, as well as the transfer of sweat in vapor and liquid form, which are other heat transfer mechanisms, as a whole, in terms of determining the real-life performance of products.

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REFERENCES

[1] E. Evren, “Otomotiv sektöründe saha çalışanlarının dijital dönüşüm kapsamında güvenlik yeleği ve baretlerinin yapay sinir ağı yöntemi ile algılanması,” Master's thesis, Sakarya Üniversitesi, 2020.

[2] G. K. Günaydın, A. S. Soydan, A. Yavaş, O. Avinç, M. Demirtaş, and S. Palamutçu, “Comparıson of some physical properties of woven fabric types produced usıng naturally colored organic cotton,” “Emırel”. Proceedıng & Abstract Book, 161, (2019).

[3] G. K. Günaydin, O. Avinc, S. Palamutcu, A. Yavas, and A. S. Soydan, “Naturally colored organic cotton and naturally colored cotton fiber production,” *Organic Cotton: Is it a Sustainable Solution*, 81-99, 2019.

[4] Ö. Aydın, and G. K. Günaydın, “Elektromanyetik kalkanlama amaçli koruyucu tekstiller,” In 1st International Fashion And Textile Design Symposium Proceedings Special Edition-I ,76-85, 2012.

[5] S. Yelkovan, E. K. Çeven, and G. K. Günaydın, “Tekstil ürünlerinde solar geçirgenlik,” In International Conference on Frontiers in Academic Research, 1, 351-361, 2023.

[6] G. Sun, H. S. and X. S. Zhang, “Radiant protective and transport properties of fabrics used by wildland firefighters,” *Textile Research Journal*, vol. 70, no. 7, 567-573, 2000.

[7] I. Holmér, “Protective clothing and heat stress,” *Ergonomics*, vol. 38 no.1, 166-182, 1995.

[8] S. A. Nunneley, “Heat stress in protective clothing: interactions among physical and physiological factors,” *Scandinavian journal of work, environment & health*, 52-57. (1989).

[9] A. W. Potter, “Ebola response: modeling the risk of heat stress from personal protective clothing,” *PLOS One*, vol. 10 no. 11, 2015.

[10] K. J. Glitz and U. Seibel, “Reducing heat stress under thermal insulation in protective clothing: microclimate cooling by a ‘physiological’method,” *Ergonomics*, vol. 58 no. 8, 1461-1469, 2015.

[11] P. Talukdar, A., Das and R. Alagirusamy, “Heat and mass transfer through thermal protective clothing–A review,” *International Journal of Thermal Sciences*, 106, 32-56, 2016.

[12] U. Reischl, “Prototype Heat Attenuation Vest,” In Third International Conference on Occupational Safety and Health, 2010.

[13] C. Feiyu, F. U. Ming, and Yayun, L. I. “Heat and moisture transfer model of heated clothing for human thermal response calculation,” *Journal of Tsinghua University (Science and Technology)*, 63(6), 900-909. (2023).

[14] S. F. Neves, “Effects of clothing and fibres properties on the heat and mass transport, for different body heat/sweat releases,” *Applied Thermal Engineering*, 117, 109-121, 2017.

[15] G. Song, “Thermal protective performance of protective clothing used for low radiant heat protection,” *Textile Research Journal*, vol. 81 no.3, 311-323, 2011.

[16] U. Reischl, “heat transfer dynamics in clothing exposed to ınfrared radiation,” In Advances in Ergonomics Modeling and Usability Evaluation, pp. 600-610, 2010.

[17] M. Kodaloğlu, and F. A. Kodaloğlu, “Prediction of the ultraviolet protection provided by woven fabric construction using fuzzy logic,” *Süleyman Demirel University Faculty of Arts and Science Journal of Science*, vol. 19 no. 1, 40-52, 2024.

[18] F. A. Kodaloğlu, and M. Kodaloğlu, “Determining the drying rates of fabrics with different knit structures by fuzzy logic method,” *International Journal of Computational and Experimental Science and Engineering*, vol. 9, 191-196, 2023.

[19] F. Akarslan, “Dokuma kumaşların kuruma hızı değerlerinin bulanık mantık metodu ile belirlenmesi,” *Tekstil Teknolojileri Elektronik Dergisi* vol. 1 no. 2, 15-23, 2007.

[20] F. Akarslan Kodaloğlu, “Fuzzy modeling applied to

a microwave dryer: Cotton weaving fabric drying process," *Uluslararası Teknolojik Bilimler Dergisi* vol. 15, no.1, 19-26, 2023.

[21] F. Akarslan Kodaloğlu, and M. Kodaloğlu, "Fuzzy logic control (flc) for a yarn conditioning system," *International Journal of Engineering and Innovative Research* vol. 3, 170-179, 2023.

[22] F. Akarslan Kodaloğlu, A. Elbir, and M. E. Şahin, "Wool drying process ın heat-pump-assisted dryer by fuzzy logic modelling," *Thermal Science* vol. 27, 2023).

[23] M. Kodaloğlu, and F. Akarslan Kodaloğlu, "Evaluation of noise on ring spinning machines," *Mühendislik Bilimleri ve Tasarım Dergisi* vol. 11, no. 2, 768-775, 2023.

[24] M. Kodaloğlu, and F. Akarslan Kodaloğlu, "Evaluation of thermal comfort in terms of occupational safety in weavıng facilities by fuzzy logic," *International Journal of 3D Printing Technologies and Digital Industry* vol. 6, no. 2, 273-279, 2022.

[25] M. Kodaloğlu and F. Akarslan Kodaloğlu, "Wearable technologies: wearable sensor and detectıon of motion sensor data using fuzzy logic", Yekarum, c. 9, sy. 1, ss. 1–19, 2024

[26] M. Kodaloğlu and F. Akarslan Kodaloğlu, "Thermal comfort effect of natural radiation: color factor ın ındustrial safety helmets, human health", *Uluborlu Mesleki Bilimler Dergisi*, vol. 7, no. 2, 20-33, 2024.

[27] M. Kodaloğlu and F. Akarslan Kodaloğlu, "Environmentally friendly recycled leather reinforced composite: thermal and acoustic properties", *Teknik Bilimler Dergisi*, vol. 14, no. 2, 32-37, 2024.

[28] M. Kodaloğlu, "The effect of thermal conditions on occupational accidents frequency in textile sector", *International Journal of Engineering and Innovative Research*, 6(1), 40-47, 2024.

[29] M. Kodaloğlu, "Effluent decolorization for sustainable textile: wastewater treatment, environmental risk and human healt", *Uluslararası Sürdürülebilir Mühendislik ve Teknoloji Dergisi*, 8(1), 1-7, 2024.

[30] M. Kodaloğlu, "Sustainability through textiles recycling: yarn reuse, environmental and human health impact", *International Journal of Engineering and Innovative Research*, 6(2), 98-105, 2024.

[31] E. Gökoğlan, M. Ekinci, E. Özgenç, İ. Ö. Derya, and M. Aşıkoğlu, "Radyasyon ve insan sağlığı üzerindeki etkileri," *Anatolian Clinic the Journal of Medical Sciences*, vol. 25, no. 3, 289-294, 2020.

[32] B. Mutlu, O. Şen, H. Toros, and İ. Maslak, "Ultraviole Radyasyonun İnsan Sağlığı Üzerine Etkileri. Ultraviole radyasyonun insan sağlığı üzerine etkileri," III. Atmosfer Bilimleri Sempozyumu, İTÜ, İstanbul. ISBN.975-561-236-X. 2003.