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Prediction of Natural Radiation (UV) Protection in Industrial Safety Helmets Depending on Color Factor Using Fuzzy Logic

Renk Faktörüne Bağlı Olarak Endüstriyel Güvenlik Baretlerinde Doğal Radyasyon (UV) Korumasının Bulanık Mantık ile Tahmini

Murat KODALOĞLU

ABSTRACT

This article presents the ultraviolet protection factor of helmet colors. UVR exposure dose distributions using helmets as sun protection under various exposure conditions were estimated. Increasing the thermal comfort of safety helmets has become a major concern of helmet designers.

Helmets provide simple and convenient protection against UV rays. Ultraviolet Protection Factor (UPF) is widely used to determine the degree of protection of helmets from UV radiation. A predictive model for the size of helmet colors was derived, saved by general logic programming. While developing the prediction model for UPF, helmet outer shell temperature color components were taken into account throughout the period. The blue color has the greatest impact on the ultraviolet protection factor of helmets. This study provides recommendations for engineering helmets with adequate ultraviolet protection. The results show good agreement between actual and predicted values.

Keywords: Helmet, Radiation, Color, Fuzzy Logic, Safety

ÖZET

Bu makale, baret renklerinin ultraviyole koruma faktörü üzerindeki etkilerini sunmaktadır. Baretlerin çeşitli maruz kalma koşullarında güneşten korunma etkinliğini UVR maruziyet dozlarını dağılımları tahmin edilmiştir. İş güvenliği baretlerinin termal konforunu artırmak baret tasarımcılarının en büyük ilgi alanlarından biri haline gelmiştir.

Baretler UV ışınlarına karşı basit ve kullanışlı bir koruma sağlar. Baretlerin UV radyasyonundan korunma derecesini belirlemek için Ultraviyole Koruma Faktörü (UPF) yaygın olarak kullanılır. Baret renklerinin etkisini tanımlamak için bulanık mantık programlamayla belirlenen tahmine dayalı bir model türetildi. UPF için tahmin modeli geliştirilirken süre, baret dış kabuk sıcaklığı renk bileşenleri dikkate alınmıştır. Mavi renk, baretlerin ultraviyole koruma faktörü üzerinde en büyük etkiye sahiptir. Bu çalışma, yeterli ultraviyole korumasına sahip baretlerin mühendisliğine yönelik tavsiyeler sunulmuştur. Sonuçlar deneysel ve tahmin edilen değerler arasında çok iyi bir uyum olduğunu göstermektedir.

Anahtar Kelimeler: Baret, Radyasyon, Renk, Bulanık Mantık, Güvenlik

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I. INTRODUCTION

Ventilation holes in the helmet can increase comfort [1]. However, they should not be used in applications where ventilation is not required [2].

Extreme heat and extreme cold are among the biggest complaints of helmet users [3,4]. Workers do not wear helmets because they are uncomfortable [5]. Helmets reduce airflow, which increases heat-related stress [6,7]. Helmets are important factors, especially in hot climates, so helmet comfort has become important [8,9]. UPF values have been studied in heat transfer in helmets.

Abeysekera et al. measured the heat flux of safety helmets [10,11]. Hsu et al. used the temperature under the helmet shell [12]. Davis et al. measured the physiological responses of workers in a hot environment [13]. Reischl, Coleman et al., Roszkowski, Spaul et al. investigated the heat transfer of helmets [14,15]. Breckemidge et al., Mecheels et al., become dependent on evaporation in hot environments [16,17]. Li et al. ABS outer shells under ultraviolet exposure, hot weather and humid-heat conditions The measured helmets were able to meet engineering tolerances under outdoor, ultraviolet and hot weather conditions and competitive mechanical performance to their intact helmets were investigated by thermal characterizations under humid-heat for 800 hours [18]. Ueno et al. investigated the effects on heat dissipation in industrial safety helmets [19]. Totla et al. ABS material was analyzed for various analyses such as thermal analysis with the help of ANSYS Workbench software. Thermal analysis was performed to examine the insulation properties of the material and the temperature gradient. The coconut shell helmet outer layer showed good insulation properties [20-22].

In this study, a new approach that examines the relationship between the ultraviolet protection factor by considering the helmet colors with fuzzy logic, unlike the literature, is presented. A predictive model based on fuzzy logic programming was derived to define the effect of helmet colors according to existing practices in the literature. While developing the predictive model for UPF, time, helmet outer shell temperature color components were taken into account. Our study compared the UPF of helmets with the same structure in yellow, blue and white colors. The best explanation of the relationship between colors has been proposed to choose paints by developing helmets for UVR transmission and UV protection [23-26].

II. METHODS

In order to help helmet makers with optimum thermal comfort, measurements were performed based on helmet colors. The modeling method presented in this article clearly demonstrates the dependence between the parameters characterizing the helmet color. Figure 1 shows the measurement made with a thermal camera.

Figure 1: Measurement made with thermal camera

For yellow, blue, white helmets, the helmets were exposed to sunlight between 12:00-13:00 on May 3, 2024, and the outer shell temperatures and UPF values of the helmets were determined with the Flır E40 thermal camera to determine how they changed according to their colors.

In the study, the GBellMF method is a type of membership functions used in the input and output sets, thus the trapezoidal shape, which is a geometric shape, is obtained. Our input membership functions for yellow, blue and white helmets were chosen in the range of time twelve and outer shell temperature four feet [27-42]. Our output function, UPF, is determined in the sixteen range. It was created with a hundred and twenty rule base in order to understand the effect of the relationship between the determined membership functions on the result. Figure 2 shows the helmet colors used in the study.

Figure 2: Helmet colors used in the study

The sun's radiation penetrating the helmet shell surface is assumed to be equal. To assist helmet makers with optimum UPF, a prediction model for UPF was developed through fuzzy logic based on helmet colors. The method of modeling UPF presented in this article clearly reveals the dependence between the parameters characterizing helmet color. We want to show that the fuzzy logic method is a useful method for estimating UPF for helmet designers.

III. DISCUSSION

We believe that it is impossible to consider all types of paint, so we concentrated our research on selected colors yellow, blue, white. Therefore, although the UPF was influenced by the chemical structure of the dye molecules, the hue was determined by the color parameters characterizing the helmet color in the visible spectrum range.

A. Fuzzy Logic Method Applied to White Helmet

Figure 3 shows the UPF change for a white helmet. Although white helmets have much lower protection against UV rays, white helmets have some advantages in terms of comfort and reduce heat compared to other colors. Temperature: 37 °C, 38.5 °C, 39.5 °C and 41 °C these levels are important to consider thermal comfort. For this reason, helmet material selection and design should have important insulation properties for UPF. It has been observed that UPF values are between 12.3 and 29.6 in white .

Figure 3: UPF change for white colored helmet

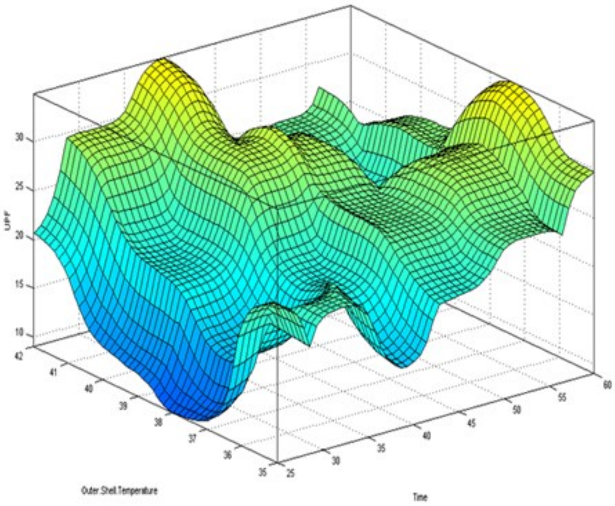


Figure 4: Variation between outer shell temperature and upf for white colored helmet

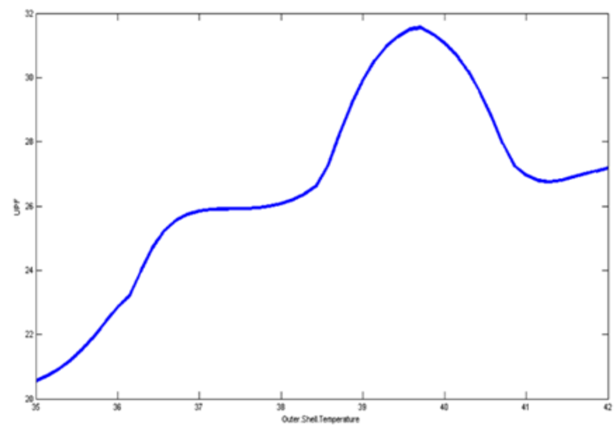


Figure 4 shows the change graph between Outer Shell temperature and UPF for a white helmet. Effect on UPF: 35 to 38 provides low protection, 39 to 41 provides very good protection, 41 to 42 provides good protection. Helmet rated UPF values were found to be "good" in white.

B. Fuzzy Logic Method Applied to Yellow Helmet

Figure 5: UPF change for yellow helmet

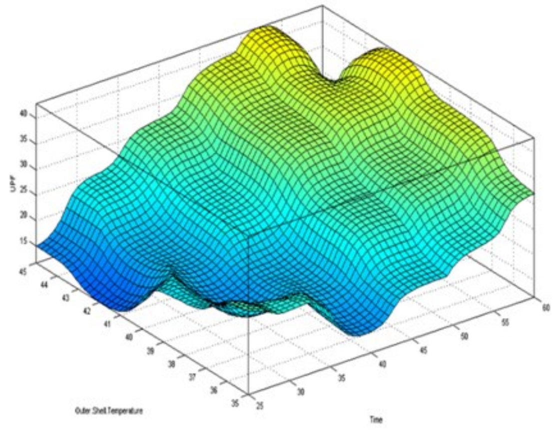


Figure 5 shows the UPF change for the yellow helmet. Yellow helmets react like additives; They increase UV protection because they absorb UV radiation. Temperature: 37 °C, 39 °C, 40 °C and 43 °C these levels are important to consider thermal comfort. For this reason, helmet material selection and design should have important insulation properties for UPF. It has been observed that UPF values are between 15.9 and 35.6 in yellow.

Figure 6: Variation between outer shell temperature and upf for yellow helmet

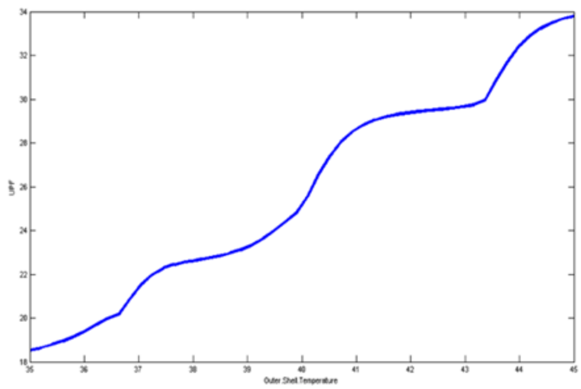


Figure 6 shows the variation between Outer Shell temperature and UPF for the yellow helmet. Effect on UPF: 35 - 41 - low protection, 42 - 43 good protection, 44 - 45 - very good protection. Helmet rated UPF values are "good" in yellow.

C. Fuzzy Logic Method Applied to Blue Colored Helmet

Figure 7: UPF change for blue helmet

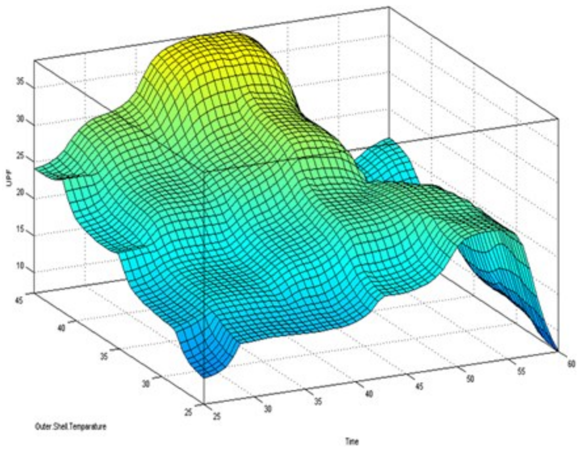


Figure 7 shows the UPF change for the blue helmet. Blue colored helmets react like additives; They provide the highest UV protection because they perfectly absorb UV radiation. Temperature: 30 °C, 35 °C and 40 °C these levels are important to consider thermal comfort. For this reason, helmet material selection and design should have important insulation properties for UPF. It has been observed that UPF values are between 16.3 and 39.4 in blue.

Figure 8: Variation between outer shell temperature and upf for blue colored helmet

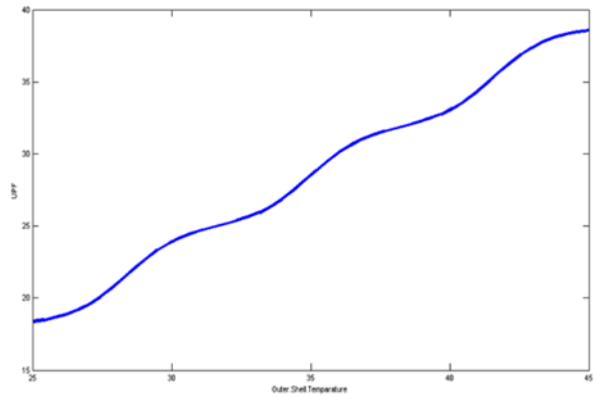
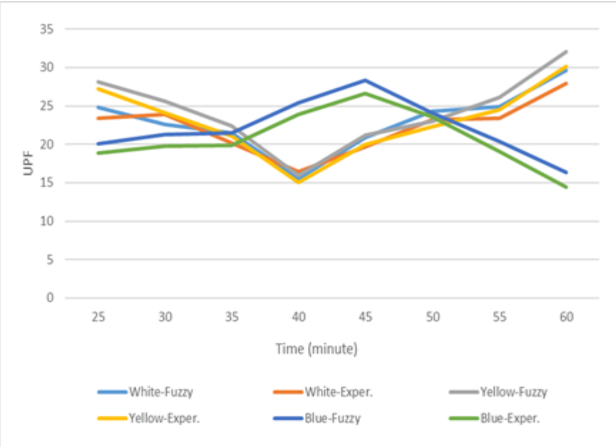


Figure 8 shows the variation between Outer Shell temperature and UPF for the blue helmet. Effect on UPF: 25

to 35 provides low protection, 35 to 40 provides good protection, 40 to 45 provides very good protection. Helmet rated UPF values were found to be "excellent" in blue.

Fuzzy logic and experimental results are given in Experimental values of UPF deviate from predicted ones by an average of 6%; This makes our proposed model satisfactory for the development of helmet structures with the desired UV protection. Fuzzy logic and experiment results are given in Figure 9 for 35 0 C and in Figure 10 for 40 0 C.

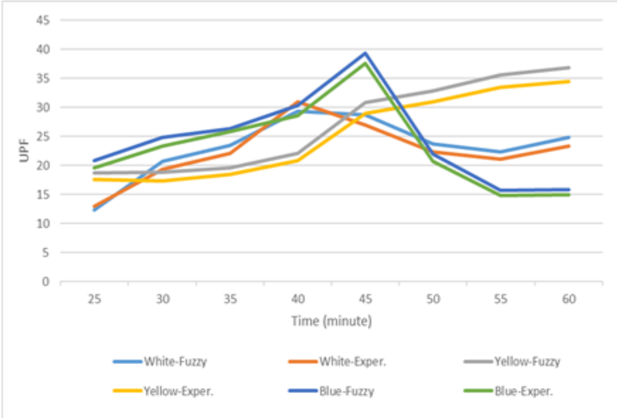
Figure 9: Fuzzy logic and experimental results for 35 ^{0}C are given



Helmet rated UPF values were found to be "good" on light colors and "fairly good" on yellow and blue colors. It has been observed that with the application of UV absorber material in white helmets, the light-coloured UPF increased from "good" to "fairly good", thus the protection category of the light-coloured helmet passed from "good" to "fairly good" category. In the yellow and blue color, the rated UPF increased from "good" to "excellent", a decrease in the permeability of UV rays and an increase in the UPF value of the sample were observed.

Yellow and blue colored helmets provide better protection than light colored ones. It has been observed that the protective properties of helmets against UV rays increase with paint.

Figure 10: Fuzzy logic and experimental results for 40 ^{0}C are given



IV. CONCLUSION

It's clear that color has a big impact on UV protection. Helmets of the same construction but different colors have very different UV protection. Yellow and blue colored helmets offer excellent UV protection; White colored helmets have low UV protection and are not suitable to protect us against UV radiation. But on the other hand, to protect the body against IR radiation, helmets in light pastel colors are suitable. Yellow and blue colored helmets collect a lot of heat and give an unpleasant feeling when wearing them. It is necessary to improve insulation against solar heat, change the surface of the helmet shell and increase thermal protection. It is very important for the helmet manufacturer to both meet the demands and develop a helmet that has good UV protection as well as good protection against heat accumulation.

As a result of the study conducted to see the effect of color on UV transmittance; It has been observed that the protective properties of helmets against UV rays increase and their permeability decreases with the paint. Yellow and blue color helmets have better protection than light colours. With this study, the idea that we should wear light-coloured clothes, especially in summer, has changed somewhat. If you want to be protected from harmful UV rays, helmets painted in yellow and blue colors should be preferred. The fact that yellow and blue colors also increase body temperature has revealed the fact that it would be more appropriate to use light-colored helmets with UV absorbing material.

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REFERENCES

[1] F. M. Shuaeib, "Motorcycle helmets: Part I," *Biomechanics and computational*, 2002.

[2] U. Reischl, "Fire fighter helmet ventilation analysis," *Am Ind Hyg Assoc J* ,47 (8) , 546-551, 1986.

[3] G. T. Egglestone, "Venting of a ballistic helmet in an attempt to reduce thermal loading," *DSTO Aeronautical and maritime research laboratory, Melbourne Victoria*, Australlia, 1999.

[4] H. Mebumder, "Determination of clothing comfort properties with the sweating thermal manikin' in," *Proceedings of The Fifth International Conferenceon Environmental Ergonomics Maastricht, TN0 Institute for Perception, Soesterberg, The Netherlands*, PP 4Ml, 1992.

[5] D. A. John, "Ergonomics evaluation of modified industrial helmets for use in tropical environments," *Ergonomics,* 9: 1317-1329, 1988.

[6] A. Gilchrist, and N.J. Mills, "Modeling of the imp a ct response of motorcycle helmets," *International journal of impact engineering,* 15, 201-218, 1994.

[7] V. Kostopolous, and Y.P. Markopolous, "Finite element analysis of impact damage response of composite motorcycle safety helmet," *Composites*, 33: 99-107, 2003.

[8] X. Liu, and H. Holmer, "Evaporative heat transfer characteristics of industrial safety helmets," *Applied ergonomics*, 26: 135-140, 1995.

[9] Y. Masso, and N.J. Moreu, "Impact compression of polystyrene foam pyramids," *International journal of impact engineering,* 28:653-676, 2003.

[10] J. D. A. Abeysekera, and H. Shahnavaz," Adaptation to discomfort in personal protective devices: an example with safety helmets," *Ergonomics,* 33: 137-145, 1990.

[11] J.D.A. Abeysekera, I. Holmer, and C. Dupois, "Heat transfer characteristics of industrial safety helmets," *Towards human work: Solutions to pratical problems in occupational health and safety, London*, pp: 297-303, 1991.

[12] Y. L. Hsu, "Improving thermal properties of industrial safety helmets," *Int. J. Ergonomic*, 26: 109-117, 2000.

[13] G. A. Davis, "Effect of ventilated safety helmets in a hot environment," *Industrial ergonomics*, 27: 321-329, 2001.

[14] A. E. Coleman, and A. K. Mortagy, "Ambient head temperature and football helmet design," *Med Sci Sports,* 5 (3), 204-208, 1973.

[15] W. Roszkowski, "Guidelines for modernisation of safety helmets," *Ochrony pracy*, 30, 75-86,1980.

[16] J. R. Breckenridge, and R. E. Goldman, "Effect of clothing on bodily resistance against meteorological stimuli' in Tromp," *Progress in Human Biometeorology Sweits, Amsterdam*, pp 194-208, 1977.

[17] J. Mecheels, "Thermophysiologische eigenschaften von kleidungssystemen," , 57, 1029-1030, 1976.

[18] J. Li, X. Feng, Z. Shen, Z. Zhang, S. Xiao, Z. He, and Z. Hu, "Mechanical and thermal properties of aged helmet outer shells made of acrylonitrile-butadiene-styrene," *Materiale Plastice*, 61(1), 2024.

[19] S., Ueno, and S. I. Sawada, "Effects of ventilation openings in industrial safety helmets on evaporative

heat dissipation," *Journal of occupational health*, 61(2), 157-164, 2019.

[20] S. K. Totla, and A. M. Pillai, "Analysis of helmet with coconut shell as the outer layer," *Materials Today: Proceedings,* 32, 365-373, 2020.

[21] K. Dimitrovski, "Evaluation of the structure of monofilament pet woven fabrics and their uv protection properties," *Textile Research Journal,* 80(11), 1027–1037, 2010.

[22] D. Christopher, "Design of appropriate demining personal protection equipment for head and face," *Final report: catimac competition submission, University of Guelph*. 2005.

[23] 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.

[24] 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.

[25] 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.

[26] 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.

[27] 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.

[28] 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.

[29] F. Akarslan, "Dokuma kumaşların kuruma hızı değerlerinin bulanık mantık metodu ile belirlenmesi," T*ekstil Teknolojileri Elektronik Dergisi* vol. 1 no. 2, 15-23, 2007.

[30] 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.

[31] 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.

[32] 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).

[33] 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.

[34] 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.

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

[36] 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.

[37] 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.

[38] 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.

[39] 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.

[40] 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.

[41] M. Kodaloğlu, "Natural radiation sourced heat stress: thermal comfort depending on color factor ın safety reflector vests." *Karaelmas Journal of Occupational Health and Safety* 8.2: 95-103, 2024.

[42] M. Kodaloğlu, F. A. Kodaloğlu, and A. İ. Kodaloğlu. "Problems faced ın export by the ginner role, cost analysis and assessments ın terms of occupational safety." *International Journal of Engineering and Innovative Research* 4.1: 23-32, 2021.