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INNOVATIONS IN UV-PROTECTIVE FABRIC COATINGS

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ABSTRACT

This study aimed to test the effectiveness of a ZnO solution mixed with an Anionic Polymer in reducing the amount of UV-C radiation that can penetrate fabric.

The solution was coated onto three types of fabric: silk, cotton, and linen, in both white and black colors. The experiment was conducted in three locations in Nan province: Phaya Phanong Stadium, the Thawangpha Meteorological Department, and the area of Somdet Phra Yupparat Pua Hospital, as well as in the hospital's laboratory.

Using a UV-C radiation meter, the radiation levels under the fabric were measured and compared to the levels measured on the fabric's surface. The results showed that the coating could reduce the amount of UV-C radiation that passed through the fabric, demonstrating the effectiveness of the ZnO and Anionic Polymer solution for UV protection in fabrics.

INTRODUCTION

From the current situation, many human actions have caused a significant increase in the amount of carbon dioxide gas, which in turn has greatly increased greenhouse gases. This has led to a large amount of UV-A, UV-B, and UV-C radiation penetrating the Earth's surface at 75%, 18%, and 0%, respectively. However, if measured, the amount of UV-C radiation that can reach the Earth's surface is as high as 120,000 microwatts/square meter. Excessive exposure to UV-C radiation can cause skin diseases or, in the most severe cases, skin cancer (www.bioderma.co.th).

Thai farmers are highly exposed to UV radiation, not only because their clothes may not fully protect them but also because their workplaces are very open to sunlight, both of which are detrimental to their skin. Many companies have developed UV-protective clothing and products, but these items can be too expensive for farmers to afford. In addition, the process of applying a UV-protective coating to fabric is not yet widespread, and the coating can easily wash off or degrade after being laundered, leading to increased costs.

Therefore, the researchers have developed a formula and three types of fabric coatings to compare their adhesion on three widely used fabrics: silk, cotton, and linen. These coatings can protect against all wavelengths of UV radiation and adhere well to the fabric. This ensures that the UV-protective coating will not wash off or degrade when laundered in a washing machine, helping to reduce the amount of UV-C radiation and allowing for the selection of the most suitable fabric type for specific uses, as well as helping to prevent future skin diseases.

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Objectives

1. To study and discover a compound that can effectively protect against UV radiation and has no harmful effects on human skin.
2. To obtain the best formula for a UV-protective substance.
3. To be able to select the appropriate type and color of fabric for initial UV protection.
4. To produce an innovative UV-protective coating solution.

Scope of Study

The study will be conducted in the open area of Pua Crown Prince Hospital and through controlled laboratory experiments in the hospital's UV incubation chamber.

Hypotheses

1. It is expected that a highly effective fabric coating can be developed that provides UV protection and is safe

for human skin.

2. It is expected that a white fabric, when treated with the UV-C protective coating, will provide better protection against UV-C radiation than a black fabric.
3. It is expected that linen fabric, when coated with the UV-C protective substance, will provide the best protection against UV-C radiation compared to the other three fabric types.

Variables Studied

Independent Variables: The amount of UV radiation that passes through the three types of fabric, and the efficiency of the innovation after being washed in a washing machine.

Dependent Variables: The three types of fabric: black and white cotton, black and white silk, and black and white linen.

Control Variables: The open area of Pua Crown Prince Hospital and the laboratory experiments in the hospital's UV incubation chamber at five specific times: 08:00, 10:00, 12:00, 14:00, and 16:00.

RELATED LITERATURE AND RESEARCH

Effects of UV Radiation on Human Skin and the Depletion of the Ozone Layer.

Ultraviolet (UV) irradiation present in sunlight is an environmental human carcinogen. The toxic effects of UV from natural sunlight and therapeutic artificial lamps are a major concern for human health. The major acute effects of UV irradiation on normal humanskin comprise sunburn inflammation (erythema), tanning, and local or systemic immunosuppression. At the molecular level, UV irradiation causes DNA damage such as cyclobutan pyrimidine dimersand (6-4) photoproducts, which are usually repaired by nucleotide excision repair(NER). Chronic exposure to UV irradiation leads to photoaging, immunosuppression, and ultimately photocarcinogenesis. Photocarcinogenesis involves the accumulation of genetic changes, as well as immune system modulation, and ultimately leads to the development of skin cancers. In the clinic, artificial lamps emitting UVB (280–320 nm) and UVA (320–400 nm) radiation in combination with chemical drugs are used in the therapy of many skin deceaseincluding psoriasisand vitiligo. Although such therapy is beneficial, it is accompanied with undesirable sides effect. Thus, UV radiationis like two sides of the same coin—on one side, it has detrimental effects, and on the other side, it has beneficial effects.(Department of Dermatology, Kansai Medical University, Osaka 570-8507, Japan Department of Immunology, The University of Texas M.D. Anderson Cancer Center, Houston, TX 77030, USA 10 December 2003)

Short-Term Effects of UV radiation on human skin

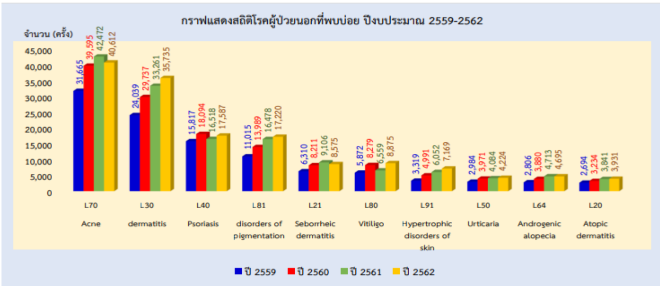
Acute UV irradiation (a single exposure) induces DNA lesions such as pyrimidine dimers and (6-4) photoproducts, which could lead to DNA mutations if they are not repaired. To prevent DNA mutations, cells are equipped with DNA repair mechanisms.

Long-Term Effects of UV Radiation on Human Skin

Long-term and recurrent exposure to sunlight causes the gradual deterioration of cutaneous structure and function. It apparently occurs as a result of cumulative DNA damage resulting from recurrent, acute DNA injury, and from the effects of chronic inflammation. Those actinic damages could ultimately lead to the development of skin cancers, which is a multistep process involving induction of mutations and escape from immune surveillance

Incidence of Dermatological Diseases

สถิติโรคผู้ป่วยนอกที่พบบ่อยปีงบประมาณ 2559-2562 (ครั้ง)



Many of human activities are badly affecting the atmosphere. Ozone depletion is one of those examples . Life is protected from UV rays by stratospheric ozone layer which acts as a shield or sun screen . Approximately 90% ozone is present in stratosphere at the height of 10 to 17 kilometer and is called ozone layer while remaining 10% is present in troposphere . Medium frequency UV radiations (200 nm to 315 nm) are absorbed 97 to 99% by the ozone layer . Ozone (O3) is colourless just like oxygen (O2) but it has very harsh odour. It is very rare as compared to oxygen. It is estimated that out of 10 million air molecules about 2 millions are of O2 and only 3 are of ozone . The process of ozone formation is called as photolysis. When the UV radiations from sun strike the O2 molecules, it causes splitting of O2. Oxygen molecules react with oxygen atoms in the upper atmosphere to form ozone. Stratospheric ozone is measured from the ground in units called "Dobson Unit" (D.U) . Normal ozone concentration is between 300 - 350 D.U . In our present study, we shall discuss how ozone layer depletion is affecting human health and we shall also discuss some recommendations to minimize ozone depletion and its adverse effects on human health.(Anwar, F. , Chaudhry, F. , Nazeer, S. , Zaman, N. and Azam, S. (2016) Causes of Ozone Layer Depletion and Its Effects on Human: Review. Atmospheric and Climate Sciences, 27 January 2016)

Causes of Ozone Layer Depletion

Chlorofluorocarbons

Ozone depletion occurs when the natural balance between the production and destruction of stratospheric ozone is disturbed. Although natural phenomenon can cause ozone depletion but human activities such as CFCs are now accepted as major cause of depletion . All ozone depleting chemicals contain chlorine and bromine . CFCs are highly volatile and non combustible so they are very quickly evaporated and can easily reach in stratosphere where ozone is present here they start depleting ozone molecules. These CFCs have also adverse affects on human health . According to the chemical model for ozone destruction proposed about 20 years ago, the photolysis of Cl2O2 is key to ozone depletion reaction. But now atmospheric researchers studied that the rate of this reaction is not extremely high as it was thought previously so we can no longer say that CFCs are the main cause of ozone depletion .

Unregulated Launches of Rockets

Another major cause of large scale ozone depletion is Rocket launches. It has been studied that unregulated rocket launches can result in much more ozone depletion than CFCs. It is estimated that if rocket launches will be let unregulated then it would cause huge ozone loss by the year 2050 than the CFCs have done .

Global Warming

Global warming also leads to ozone layer depletion. Due to global warming and green house effect most of the heat is trapped in troposphere which is the layer below the stratosphere. As we all know ozone is present in stratosphere so heat don't reaches troposphere and it remain cold as recovery of ozone layer requires maximum sunlight and heat so it leads to depletion of ozone layer .

Nitrogenous Compound

Nitrogenous Compounds emitted by human activities in small amount like NO, N2O and NO2 are considered to be greatly responsible for the depletion of ozone layer.

Substance Capable of Blocking UV Radiation and Safe for Human Skin (ZnO)

Nanoscale ZnO is one of the best choices for ultraviolet (UV) protection, not only because of its antimicrobial properties but also due to its potential application for UV preservation. However, the behavior of nanostructured thin ZnO films and long-term effects of UV-radiation exposure have not been studied yet. In this study, we investigated the UV-protection ability of sol gel-derived thin ZnO films after different exposure times. Scanning electron microscopy, atomic force microscopy, and UV-visible optical spectroscopy were carried out to study the structure and optical properties of the ZnO films as a function of the UV-irradiation time. The results obtained showed that the prepared thin ZnO films were somewhat transparent under the visible wavelength region and protective against UV radiation. The UV-protection factor was 50+ for the prepared samples, indicating that they were excellent UV protectors. The deposited thin ZnO films demonstrated promising antibacterial potential and significant light absorbance in the UV range. The experimental results suggest that the synthesized samples have potential for applications in the health care field. transparent thin ZnO films with high UV light-shielding efficiency were reported in this study using a simple and low-cost method. A highly concentrated pure ZnO sol (2 M) was prepared with In impurities as a suitable candidate to study optical properties against UV irradiation. The effect of UV irradiation on the optical properties of the nanostructured thin ZnO and IZO films was investigated. The obtained results showed that the prepared thin IZO films were somewhat transparent under the visible-wavelength region and were protective against UV radiation. The UPF was 50+ for the prepared samples, showing excellent UV protection. We can postulate that thin IZO film can be used as a UV-blocking material and find application as a UV absorber in cosmetics, packages, textiles, and protective coatings.(National Research Foundation of Korea (NRF) grant funded by the South Korean government (MSIP 2015R1A2A1A15054541), and by the third stage of Brain Korea 21 Plus Project in 2016.)

Substance Capable of Adhering to Fabric Even During Machine Washing

Anionic polymers are a type of chemical substance commonly used to modify the characteristics of water or particulate matter in order to increase viscosity and cohesion. The degree of negative charge depends on the number of acrylamide groups dissolved within acrylic acid. Examples of anionic polymers include Polyacrylamide Acid (PAA), Hydrolyzed Polyacrylamide (HPAM), and Polystyrene Sulfate (PSS). Anionic polyacrylamide flocculants carry negative charges when dissolved in water, leading to the formation of amide groups (NH) or resulting from the aggregation of anionic monomers into an acrylamide polymer.

Physical Characteristics of Anionic polyacrylamide typically appears as a white powder and exhibits positive charge properties.

General Properties and Applications of Polyacrylamides function as agents that facilitate flocculation following the coagulation process. Their flocculant properties enable suspended particles to be adsorbed onto their surfaces due to electrostatic interactions. As suspended solids bind in large quantities to the polymer, they become heavier and settle at the bottom of sedimentation tanks, thus enabling more efficient water treatment.

Due to this capability, anionic polyacrylamide is widely applied across industries, particularly in water purification and wastewater treatment, as it accelerates sedimentation and enhances overall treatment efficiency.

METHODOLOGY

Materials, Equipment, and Special Instruments

Materials

Type of Material	Manufacturer
Paper for collecting substances (Paper)	555 PAPERPLUS
White colored cotton	Curtain & Cotton by Fern Shop
Black colored cotton	Curtain & Cotton by Fern Shop
White colored linen	Happy Fabric
Black colored linen	Happy Fabric
White colored silk	Juliet Rose
Black colored silk	Juliet Rose

Special Instruments

Type of Instrument	Manufacturer
Scissors	RS Online.com
Mixing bottles (6 bottles)	Somdet Phra Yupharat Pua Hospital
Scale	SCIENCE CITY Co., Ltd.
UV-C Meter	Talis Us
UV-C Cleaning Machine	Somdet Phra Yupharat Pua Hospital, by Mr. Wasuanan Thongdee
Ruler	No Brand

Type of Instrument	Manufacturer
Radiation Protection Outfit	Truetronix TECHNOLOGY Co., Ltd.

Chemicals

Chemical	Manufacturer
Zinc Oxide (ZnO)	Ceramics Store by CRU
Anionic Polymer	Future Chem
Sterile Water (HO)	Somdet Phra Yupharat Pua Hospital

Procedures

1. Preparation of Three Types of Fabrics for Testing the Efficiency of UV-C Protective Coatings

1.1 Draw six squares on each fabric using a ruler, each square sized 25 × 25 cm. After marking, cut the fabric along the lines using scissors.

2. Preparation of UV-Protective Substance

2.1 Mix 5% ZnO and 90% water to make a 500 mL solution in three mixing bottles.

2.2 Leave the solution for 2–3 days until it becomes homogeneous.

3. Testing the UV Protection Efficiency of the Coating Substance

3.1 Wear the radiation protection outfit and place the three fabric types inside the UV-C cleaning machine. While irradiating with UV-C, measure the amount of UV-C radiation passing through each fabric using the UV-C meter, ensuring alignment with the UV-C lamp. Record the measured values.

3.2 Immerse the three fabric types in the prepared solution (from 2.2), then irradiate them again with UV-C. Measure and record the UV-C radiation passing through each fabric as described above.

3.3 Take the six types of coated fabrics from step 2.2 and measure UV radiation exposure at three locations: Phaya Pha Nong Sports Field, Meteorological Department (Tha Wang Pha), and Somdet Phra Yupharat Pua Hospital. Measurements will be conducted at four times of the day (morning, noon, evening), aligning the UV-C meter with sunlight passing through the fabric. Record the results.

4. Enhancing Fabric Adhesion Efficiency of UV-C Protective Coating

4.1 Take two of the remaining bottles of solution from step 2.1. Mix 0.1% anionic polymer into bottle 1 and 0.5% anionic polymer into bottle 2, based on a total solution volume of 500 mL. Stir until homogeneous.

4.2 Leave the solutions for 2–3 days until uniform.

5. Testing the UV-C Protection Efficiency of the Coating After Polymer Enhancement and Washing

5.1 Immerse all three fabric types in the solution from bottle 1 (4.2) and conduct tests as described in step 3.

5.2 Immerse all three fabric types in the solution from bottle 2 (4.2) and conduct tests as described in step 3.
5.3 Wash the fabrics coated with solutions from bottles 1 and 2, then retest their efficiency as described in step 3.

FINDINGS

1. Testing the UV Protection Efficiency of UV-Coating Substance

The UV-C transmission test on uncoated fabrics showed that fabrics coated with the UV-protective substance completely blocked UV-C radiation. After washing the coated fabrics and retesting, UV-C transmission was detected but remained minimal.

2. Experimental Results

Table.1 UV-C Transmission through Uncoated Cotton Fabric (Laboratory)

Color	UV-C on Fabric (J/m²)	UV-C Under Fabric (J/m²)	Temp Under Fabric (°C)	Temp on Fabric (°C)	UV-C Under Fabric (J/m², Washed)	Temp on Fabric (°C)	Temp Under Fabric (°C)
White	7408–8448	224–240	25	25	64–80	25	25
Black	7408–8448	224–240	25	25	64–80	25	25

Table 2. UV-C Transmission through Uncoated Silk Fabric (Laboratory)

Color	UV-C on Fabric (J/m²)	UV-C Under Fabric (J/m²)	Temp Under Fabric (°C)	Temp on Fabric (°C)	UV-C Under Fabric (J/m², Washed)	Temp on Fabric (°C)	Temp Under Fabric (°C)
White	7408–8448	96–128	25	25	144–160	25	25
Black	7408–8448	96–128	25	25	144–160	25	25

Table 3. UV-C Transmission through Uncoated Linen Fabric (Laboratory)

Color	UV-C on Fabric (J/m²)	UV-C Under Fabric (J/m²)	Temp Under Fabric (°C)	Temp on Fabric (°C)	UV-C Under Fabric (J/m², Washed)	Temp on Fabric (°C)	Temp Under Fabric (°C)
White	7408–8448	224–240	25	25	160–288	25	25
Black	7408–8448	224–240	25	25	160–288	25	25

Table 4. UV-C Transmission through ZnO-Coated Cotton Fabric (Laboratory)

Color	UV-C on Fabric (J/m²)	UV-C Under Fabric (J/m²)	Temp Under Fabric (°C)	Temp on Fabric (°C)	UV-C Under Fabric (J/m², Washed)	Temp on Fabric (°C)	Temp Under Fabric (°C)
White	7408–8448	0–16	25	25	0	25	25
Black	7408–8448	0	25	25	0	25	25

Table 5. UV-C Transmission through ZnO-Coated Silk Fabric (Laboratory)

Color	UV-C on Fabric (J/m²)	UV-C Under Fabric (J/m²)	Temp Under Fabric (°C)	Temp on Fabric (°C)	UV-C Under Fabric (J/m², Washed)	Temp on Fabric (°C)	Temp Under Fabric (°C)
White	7408–8448	32–48	25	25	48–64	25	25
Black	7408–8448	32–48	25	25	48–64	25	25

Table 6. UV-C Transmission through ZnO-Coated Linen Fabric (Laboratory)

Color	UV-C on Fabric (J/m²)	UV-C Under Fabric (J/m²)	Temp Under Fabric (°C)	Temp on Fabric (°C)	UV-C Under Fabric (J/m², Washed)	Temp on Fabric (°C)	Temp Under Fabric (°C)
White	7408–8448	48–64	25	25	64–80	25	25
Black	7408–8448	48–64	25	25	64–80	25	25

Table 7. UV-C Transmission through ZnO + 0.1% Polymer Coated Cotton Fabric (Laboratory)

Color	UV-C on Fabric (J/m²)	UV-C Under Fabric (J/m²)	Temp Under Fabric (°C)	Temp on Fabric (°C)	UV-C Under Fabric (J/m², Washed)	Temp on Fabric (°C)	Temp Under Fabric (°C)
White	7408–8448	0–8	25	25	0–8	25	25
Black	7408–8448	0–8	25	25	0–8	25	25

Table 8. UV-C Transmission through ZnO + 0.1% Polymer Coated Silk Fabric (Laboratory)

Color	UV-C on Fabric (J/m²)	UV-C Under Fabric (J/m²)	Temp Under Fabric (°C)	Temp on Fabric (°C)	UV-C Under Fabric (J/m², Washed)	Temp on Fabric (°C)	Temp Under Fabric (°C)
White	7408–8448	16–24	25	25	16–24	25	25
Black	7408–8448	16–24	25	25	16–24	25	25

Table 9. UV-C Transmission through ZnO + 0.1% Polymer Coated Linen Fabric (Laboratory)

Color	UV-C on Fabric (J/m²)	UV-C Under Fabric (J/m²)	Temp Under Fabric (°C)	Temp on Fabric (°C)	UV-C Under Fabric (J/m², Washed)	Temp on Fabric (°C)	Temp Under Fabric (°C)
White	7408–8448	24–32	25	25	24–32	25	25
Black	7408–8448	24–32	25	25	24–32	25	25

Table 10. UV-C Transmission through ZnO + 0.5% Polymer Coated Cotton Fabric (Laboratory)

Color	UV-C on Fabric (J/m²)	UV-C Under Fabric (J/m²)	Temp Under Fabric (°C)	Temp on Fabric (°C)	UV-C Under Fabric (J/m², Washed)	Temp on Fabric (°C)	Temp Under Fabric (°C)
White	7408–8448	0–4	25	25	0–4	25	25
Black	7408–8448	0–4	25	25	0–4	25	25

Table 11. UV-C Transmission through ZnO + 0.5% Polymer Coated Silk Fabric (Laboratory)

Color	UV-C on Fabric (J/m²)	UV-C Under Fabric (J/m²)	Temp Under Fabric (°C)	Temp on Fabric (°C)	UV-C Under Fabric (J/m², Washed)	Temp on Fabric (°C)	Temp Under Fabric (°C)
White	7408–8448	8–16	25	25	8–16	25	25
Black	7408–8448	8–16	25	25	8–16	25	25

Table 12. UV-C Transmission through ZnO + 0.5% Polymer Coated Linen Fabric (Laboratory)

Color	UV-C on Fabric (J/m²)	UV-C Under Fabric (J/m²)	Temp Under Fabric (°C)	Temp on Fabric (°C)	UV-C Under Fabric (J/m², Washed)	Temp on Fabric (°C)	Temp Under Fabric (°C)
White	7408–8448	16–24	25	25	16–24	25	25
Black	7408–8448	16–24	25	25	16–24	25	25

Table 13. UV-C Transmission through Uncoated Cotton Fabric (Prototype Field Test)

Color	UV-C on Fabric (J/m²)	UV-C Under Fabric (J/m²)	Temp Under Fabric (°C)	Temp on Fabric (°C)
White	7380–8410	230–250	26	26
Black	7380–8410	230–250	26	26

Table14. UV-C Transmission through Uncoated Silk Fabric (Prototype Field Test)

Color	UV-C on Fabric (J/m²)	UV-C Under Fabric (J/m²)	Temp Under Fabric (°C)	Temp on Fabric (°C)
White	7380–8410	100–130	26	26
Black	7380–8410	100–130	26	26

Table15. UV-C Transmission through Uncoated Linen Fabric (Prototype Field Test)

Color	UV-C on Fabric (J/m²)	UV-C Under Fabric (J/m²)	Temp Under Fabric (°C)	Temp on Fabric (°C)
White	7380–8410	230–250	26	26
Black	7380–8410	230–250	26	26

Table 16. UV-C Transmission through ZnO-Coated Cotton Fabric (Prototype Field Test)

Color	UV-C on Fabric (J/m²)	UV-C Under Fabric (J/m²)	Temp Under Fabric (°C)	Temp on Fabric (°C)
White	7380–8410	0–15	26	26
Black	7380–8410	0	26	26

Table17. UV-C Transmission through ZnO-Coated Silk Fabric (Prototype Field Test)

Color	UV-C on Fabric (J/m²)	UV-C Under Fabric (J/m²)	Temp Under Fabric (°C)	Temp on Fabric (°C)
White	7380–8410	30–45	26	26
Black	7380–8410	30–45	26	26

Table18. UV-C Transmission through ZnO-Coated Linen Fabric (Prototype Field Test)

Color	UV-C on Fabric (J/m²)	UV-C Under Fabric (J/m²)	Temp Under Fabric (°C)	Temp on Fabric (°C)
White	7380–8410	50–65	26	26
Black	7380–8410	50–65	26	26

Table 19. UV-C Transmission through ZnO + 0.1% Polymer Coated Cotton Fabric (Prototype Field Test)

Color	UV-C on Fabric (J/m²)	UV-C Under Fabric (J/m²)	Temp Under Fabric (°C)	Temp on Fabric (°C)
White	7380–8410	0–7	26	26
Black	7380–8410	0–7	26	26

Table 20. UV-C Transmission through ZnO + 0.1% Polymer Coated Silk Fabric (Prototype Field Test)

Color	UV-C on Fabric (J/m²)	UV-C Under Fabric (J/m²)	Temp Under Fabric (°C)	Temp on Fabric (°C)
White	7380–8410	15–25	26	26
Black	7380–8410	15–25	26	26

Table 21. UV-C Transmission through ZnO + 0.1% Polymer Coated Linen Fabric (Prototype Field Test)

Color	UV-C on Fabric (J/m²)	UV-C Under Fabric (J/m²)	Temp Under Fabric (°C)	Temp on Fabric (°C)
White	7380–8410	25–35	26	26
Black	7380–8410	25–35	26	26

Table 22. UV-C Transmission through ZnO + 0.5% Polymer Coated Cotton Fabric (Prototype Field Test)

Color	UV-C on Fabric (J/m²)	UV-C Under Fabric (J/m²)	Temp Under Fabric (°C)	Temp on Fabric (°C)
White	7380–8410	0–4	26	26
Black	7380–8410	0–4	26	26

Table 23. UV-C Transmission through ZnO + 0.5% Polymer Coated Silk & Linen Fabric (Prototype Field Test)

Fabric	Color	UV-C on Fabric (J/m²)	UV-C Under Fabric (J/m²)	Temp Under Fabric (°C)	Temp on Fabric (°C)
Silk	White	7380–8410	8–16	26	26
Silk	Black	7380–8410	8–16	26	26
Linen	White	7380–8410	16–24	26	26
Linen	Black	7380–8410	16–24	26	26

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

CONCLUSION

From the experimental results, it was observed that white cotton fabric can reduce the temperature beneath the fabric compared to the surface, whereas black cotton fabric exhibited higher temperatures beneath the fabric than on the surface. According to Boltzmann's theory, which states that ET^4 this indicates that more energy is accumulated in the black cotton fabric.Similarly, the results showed that white silk fabric can lower the temperature beneath the fabric relative to the surface, while black silk fabric had a higher temperature underneath than on the surface, confirming that black silk accumulates more energy.The same trend was observed for linen fabric: white linen reduced the temperature beneath the fabric, whereas black linen exhibited higher temperatures underneath, indicating higher energy accumulation in the black linen. When comparing all three fabric types and both colors, it was found that white linen exhibited the lowest temperature beneath the fabric among all samples. Testing the efficiency of the UV-C protective coating showed that the coating could reduce the amount of UV-C radiation passing through all three types of fabric in both colors (white and black). Furthermore, even after washing, the fabrics retained their ability to block UV-C radiation according to the fabric type. The innovative coating formulation used was: 5% ZnO + 0.5% Anionic Polymer + 94.5% Sterile Water.

Application of this innovation demonstrated that white fabrics of various types effectively protected against UV-C radiation and maintained a lower internal temperature compared to the external temperature. Fabrics with finer weaving, such as linen, nylon, and synthetic fabrics, provided better UV-C protection than silk and cotton fabrics.

Acknowledgment

This project consisted of several stages of work, from researching and testing to analyzing the test results and preparing the project as a written report, until the project was successfully completed. Throughout this period, the project team received help and advice on various matters, as well as encouragement from many individuals. The team is aware of and deeply grateful for everyone's kindness. On this occasion, we would like to thank everyone as follows:

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