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UV Clothing and Skin Cancer

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A B S T R A C T

Skin cancer incidence in Croatia is steadily incresing in spite of public and govermental permanently measurements. It is clear that will soon become a major public health problem. The primary cause of skin cancer is believed to be a long exposure to solar ultraviolet (UV) radiation. The future designers of UV protective materials should be able to block totally the ultraviolet radiation. The aim of this paper is to present results of measurements concerning UV protecting ability of garments and sun-screening textiles using transmission spectrophotometer Cary 50 Solarscreen (Varian) according to AS/NZS 4399:1996; to show that standard clothing materials are not always adequate to prevent effect of UV radiation to the human skin; and to suggest the possibilities for its improvement for this purpose.

Key words: *UV radiation, skin cancer, UV protective factor, UV clothing*

Introduction

Skin cancer is the most prevalent form of human neoplasia. An rough estimate[1] suggests that about 20.000 new cases of skin cancer will be diagnosed this year alone in Croatia of which 256 will be melanoma cases (see Figure 1.)

Because of highly visible location, skin cancers are more easily diagnosed and treated than other types of cancer. The primary cause of skin cancer is believed to be a long exposure to solar ultraviolet (UV) radiation. There are indications that other parts of solar spectrum (e.g. blue light) might also have effects on skin and vision[2]. In addition to its carcinogenic potential, both A and B UV radiation are also known to be immune suppressive. Skin cancer will soon become a major public health problem. It is, therefore, important to study various UV protective devices, one of which is a proper UV clothing. Textile fabric can reflect, absorb and scatter solar wavelengths (Figure 2.), but in the most cases it does not provide full sun screening properties[3]. For that reason, the future designers of UV protective materials should use both ultraviolet A and ultraviolet B filters to block totally solar UV radiation.

According to the litarature and recent research work on skin cancer of human bodies[1] it is evident that back side for both men and women bodies, and women lower limbs are the most threatened areas of their bodies. Therefore, the aim of this paper is to show and discuss resuts of UV protective factor (UPF) measurement of some common textile materials used for clothing and to suggest the possibilities for its improvement.

Material and Methods

It is well known that cloths provide some UV protection. Since the upper back side and lower limbs are the most threatened areas for skin cancer on human bodies, cotton knitted fabric for T-shirts, linen woven fabric for summer trousers and polyamide panty hoses commonly worn by women were researched in this paper. The fabric structure was changed. The fabrics were dyed, and finished by conventional methods for UV protection using UV absorber Tinofast CEL (Ciba), bi-reactive oxalic acid di-anilide derivative; fluorescence whitening agent (FWA) Uvitex BAM (Ciba), stilben-derivate, and by new developed method using nanoparticles of natural zeolite. Firstly, it is to point out that in major wet processes fabric structure is changed.

There are many methods for measuring fabric UV protection ability, but all of them are based on Ultraviolet protection factor (UPF). For the purpose of UPF cal-

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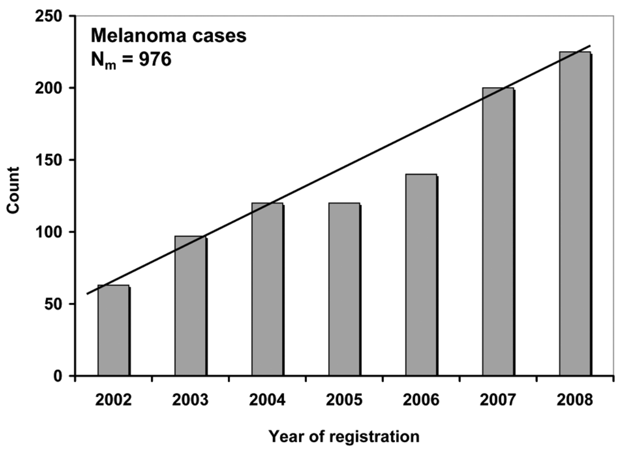

Fig. 1. Melanoma cases in Croatia between 2002 and 2008

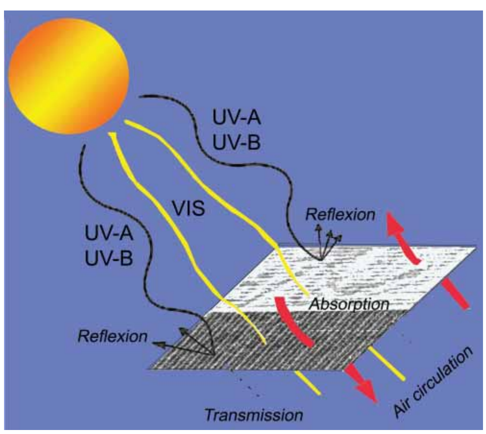

Fig. 2. UV radiation in contact with textile fabric

culation the transmissions of A and B UV-radiation were measured according to AS/NZS 4399:1996 Sun protective clothing – Evaluation and classification on transmission spectrophotometer Cary 50 Solarscreen (Varian). Ultraviolet protection factor (UPF) was calculated according to eq. (1)[4]:

$$UPF = \frac{\sum_{\lambda=280}^{400} E(\lambda)\cdot\varepsilon(\lambda)\cdot\Delta\lambda}{\sum_{\lambda=280}^{400} E(\lambda)\cdot T(\lambda)\cdot\varepsilon(\lambda)\cdot\Delta\lambda} \quad (1)$$

Where:
$E(\lambda)$ = Solar radiation [W m^{-2} nm^{-1}]
$\varepsilon(\lambda)$ = relative erythemal spectral effectiveness
$T(\lambda)$ = spectrum permeability at wavelength λ
$\Delta\lambda$ = measured wavelength interval [nm]

Ultraviolet protection factor, UPF values indicate the ability of fabrics to protect the skin against sun burning. It indicates how much longer a person can stay in the sun with the fabric covering the skin as compared with the uncovered skin to obtain same erythemal response[3–20].

Results

The obtain results according to AS/NZS 4399:1996 are summarized in Tables 1–3 showing mean UPF value, transmission of both A and B UV radiation, UPF rating and UV protection of differently finished cotton knitted fabrics, linen woven fabrics and polyamide panty hoses.

Discussion and Conclusion

UV protection by sing textile materials e.g. garment and clothing, highly depends on large number of factors such are type of fiber, fabric surface, construction, porosity, density, moisture content, type and concentration of applied dye and FWA, in the case of white textiles, and on efficiency of UV-B protective agents, as well as nanoparticles, if applied[3,5–20].

UPF directly depends upon transmission of UV-A and UV-B radiation through fabric. On the other hand, these transmissions depend upon fabric cover factor. In the most of the textile finishing wet processes fabric shrinks, lowering the UV-R transmission, resulting in higher UV protection[8–10]. The results presented in Table 1 for bleached (B), and mercerized (BM) cotton fabric confirms that. Yarn linear mass density has the same influence on UV protection. The increment of yarn linear mass density lowers fabric porosity and transmission of UV radiation, resulting in higher UPF values[8–10]. Relation between cotton yarns of 20 tex and 36 tex in Table 1; as well as relation between polyamide yarns of 20 den and 40 den in Table 2 confirms that. For example, $UPF_{B\ 20\ tex}$ = 6,613 is increasing to $UPF_{B\ 36\ tex}$ = 9,502 as in Table 1; and $UPF_{skin\ color\ 20\ den}$ = 2,114 is increasing to $UPF_{skin\ color\ 40\ den}$ = 4,944 presenting in Table 2.

Textile finishing agents for UV protection can be incorporated into the fiber matrix, or it can be applied to the surface of the fabric[12]. Usually sun protection effect is achieved through the use of UV absorbers[13,14]. Molecules of UV absorbers such as benzotriazole and phenyl benzotriazole, are able to absorb the damaging Solar UV-R range of 290 nm to 360 nm, and convert it into harmless heat energy. For example in Table 1, $UPF_{B\ 20\ tex}$ = 6,613 is increasing to $UPF_{B-UV\ 20\ tex}$ = 176,452; and $UPF_{B\ 36\ tex}$ = 9,502 is increasing to $UPF_{B-UV\ 36\ tex}$ = 1000. It is to point out that using textile material with higher yarn linear mass density and treated with UV absorber results with highest UPF value of 1000. At the same time, UV absorbers can cause changes of fabric (like changes in color), if used in higher concentrations, therefore the alternative methods have to be developed.

Dyes are also selective absorbers. All dyes absorb visible light but some of those also absorb light in the near ultraviolet region. On textiles, dyes often provide tangible UV blocking with the structure of dye molecules playing an important role. Other important factors are including type of dye or pigment, present absorptive groups, depth of dyeing and the uniformity. Additives also influence the UV protection abilities of textile materials[3,12]. According to colour physic principles, darker colors (e.g.

TABLE 1
DENSITY AND UV PROTECTION COMPONENTS FOR TREATED COTTON KNITTED FABRICS (T-SHIRTS)

Yarn linear mass density*	Treatment	Mean UPF	T(λ)UV-A	T(λ)UV-B	UPF rating	UV-R protection
	Raw	18,767	6,946	4,725	10	Non-rateable
	Bleached	6,613	17,773	13,333	5	Non-rateable
	BM	10,259	9,661	9,639	10	Non-rateable
	B-FWA	113,807	0,551	0,807	50+	Excellent
20 tex*	BM-FWA	157,807	0,308	0,673	50+	Excellent
	B-UV	176,452	0,285	0,603	50+	Excellent
	B-Z	16,480	5,783	6,006	15	Good
	B-Z-FWA	404,960	0,114	0,249	50+	Excellent
	Black	86,422	2,275	1,035	50+	Excellent
	Raw	43,286	3,836	1,844	40	Excellent
	Bleached	9,502	13,046	8,376	5	Non-rateable
	BM	26,045	6,657	2,873	25	Very good
	B-FWA	1000,00	0,100	0,100	50+	Excellent
36 tex	BM-FWA	1000,00	0,100	0,100	50+	Excellent
	B-UV	1000,00	0,100	0,100	50+	Excellent
	B-Z	35,778	5,287	2,159	35	Very good
	B-Z-FWA	1000,00	0,100	0,100	50+	Excellent
	Black	404,960	0,114	0,249	50+	Excellent

*tex is unit of linear mass density of fibres and yarn commonly used in the SI unit system, having dimension of ML-1 where M is mass, and L is length. It is the mass in grams per 1000 meters that can be converted to the corresponding standard SI unit kg/m by multiplying its value by a factor of 1E-006.

black, navy blue and dark red) absorb UV-R much more strongly than light pastel colors. The results presented in Tables 2 and 3 proof that. It is evident from Table 2 that ladies panty hoses dyed in lighter shades e.g. beige, skin color, and brown do not give UV protection regardless of yarn linear mass density, while black one gives good protection.

Some direct, reactive and vat dyes are capable of giving a high UPF of 50+. From Table 3 it can be seen that purpur, navy blue and black linen trousers give off excellent protection (UPF>50).

Fluorescence whitening agents (FWAs) (or Optical brightening agents, OBAs) are commonly used for reaching higher whiteness degrees of white textiles in textile finishing processes, as well as in wash cycles. Based on electronically-excited state by energy of ultraviolet radiation the FWA molecules show the phenomenon of fluorescence giving to white textiles high whiteness of out-

TABLE 2
UV PROTECTION WITH LADIES PANTY HOSES

Yarn linear mass density*	Color	Mean UPF	T(λ)UV-A	T(λ)UV-B	UPF rating	UV-R protection
	White	2,226	44,986	43,790	0	Non-rateable
	Beige	2,359	40,960	41,169	0	Non-rateable
20 den*	Skin Color	2,114	41,539	47,265	0	Non-rateable
	Brown	2,735	32,147	36,556	0	Non-rateable
	Black	14,10	19,431	5,305	10	Non-rateable
	White	5,686	20,305	16,462	5	Non-rateable
	Beige	4,216	23,983	22,504	0	Non-rateable
40 den	Skin color	4,944	18,101	20,110	0	Non-rateable
	Brown	8,237	11,337	12,104	5	Non-rateable
	Black	27,319	3,986	3,684	25	Good

*den (Denier) is a unit commonly used in the French unit system. Denier (den, denier) has a dimension of ML-1 where M is mass, and L is length. It is defined as the mass in grams per 9000 meters It can be converted to the corresponding standard SI unit kg/m by multiplying its value by a factor of 1.11E-007.

TABLE 3
UV PROTECTION WITH LINEN TROUSERS

Linen trousers	Mean UPF	T(λ)UV-A	T(λ)UV-B	UPF rating	UV-R protection
Natural	22,974	14,338	2,351	20	Good
White	9,425	13,451	8,974	5	Non-rateable
White (FWA)	160,978	2,201	0,451	50+	Excellent
Navy blue	195,013	1,574	0,331	50+	Excellent
Purpur	96,070	1,400	0,890	50+	Excellent
Black	206,620	0,066	0,466	50+	Excellent
Zeolite	26,045	6,657	2,873	25	Very good
Zeolite + FWA	1000,00	0,100	0,100	50+	Excellent

standing brightness. It is emission process occurring from lowest excited state to the ground state of molecules reemitting the energy at the blue end of the spectrum. Recently it has been shown that FWAs have marked contribution to fabric UV protection[15–17] giving to fabric the capability to absorb UV radiation of partially radiation range, from 300 nm to 380 nm. From Table 1 it is evident that FWAs increase UPF values from $UPF_{B\ 20\ tex}$ = 6,613 to $UPF_{B\text{-}FWA\ 20\ tex}$ = 113,807 for cotton knitted fabrics of yarn linear mass density of 20 tex; and from $UPF_{B\ 36\ tex}$ = 9,502 to $UPF_{B\text{-}FWA\ 36\ tex}$ = 1000 for cotton knitted fabrics density of 20 tex. The UPF values of white linen trousers presented in Table 3 indicate that the excellent UV protection can be achieved by using only FWAs (UPF_{white} = 9,425 to $UPF_{white+FWA}$ = 160,978).

It can be seen that maximum UV protection can be accomplished without UV absorber. It is to point out that FWAs have multifunctional activity by giving the high whiteness, neutralizing the fabric yellowness, giving to the fabric the high luminosity and protecting fabrics against UV radiation.

The presence of inorganic pigments in the fibers also allows better scattering of light from the substrate, thus providing better protection[3,12]. Titanium dioxide (TiO_2), which is used as a delustering agent and other ceramic materials have an absorption capacity in the UV region of 280 nm to 400 nm reflecting visible and infrared rays. Incorporation of TiO_2 in fiber matrix improves the UV blocking capacity of the fiber. Good skin protection thereby can be achieved by the textile itself, if the fabric is sufficiently dense. Introducing the nanoparticles in textile finishing, led to UV protection by coating the surface of textiles and clothing with nano particles of TiO_2 titanium and zinc oxide[21], and nowadays, of natural zeolite clinoptilolite[17–20].

Zeolite nanoparticles applied to textile surface scatter the UV-R resulting in lower UV-A and UV-B transmission[17–20]. From Table 1 it can be seen that zeolite nanoparticles increase UPF values from non-rateable $UPF_{B\ 20\ tex}$ = 6,613 to good one $UPF_{BZ\ 20\ tex}$ = 16,480. The same effect is noticed for linen trousers in Table 3. The UPF values of white linen trousers presented in Table 3 indicate that excellent UV protection can be achieved by using only FWAs (UPF_{white} = 9,425 to $UPF_{white+FWA}$ = 26,045). If natural zeolite is applied with other UV absorbing agents, e.g. FWAs, synergistic effect occurs. From Table 1 it is to be seen that zeolite nanoparticles increase UPF values from $UPF_{BZ\ 20\ tex}$ = 16,480 to $UPF_{BZ\text{-}FWA\ 20\ tex}$ = 404,960 for cotton knitted fabrics of yarn linear mass density of 20 tex. Using higher density of 36 tex with natural zeolite and FWAs the maximum UPF of 1000, indicating that excellent UV protection can be achieved.

The main purpose of this paper was to show that standard clothing is not always the best UV-protected cloth for which requires UPF 50+. Additionally it should be stated that in the summer months when UV index reaches the highest values, UPF should not be only higher than UPF>50, but higher than UPF>150, which in Croatia is not yet generally recognized. For countries with UV index 7–10 as Croatia, Spain, Greece and other Mediteranian countries, the UPF shuold be 15 times higher than UV index[14]. Therefore it is recommended for people who spend eight hours in the open to use UV clothing with UPF between 105 and 150 if they want excellent UV protection.

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ZAŠTITNA ODJEĆA OD UV ZRAČENJA I RAK KOŽE

S A Ž E T A K

Pojava raka kože u Hrvatskoj je u stalnom porastu unatoč javnim i vladinim mjerama, te će uskoro postati i velik javno zdravstveni problem. Vjeruje se da je primarni uzrok raka kože dugo izlaganje sunčevom ultraljubičastom (UV) zračenju. Pretpostavlja se da će se budućnosti novim UV zaštitnim materijalima moći u potpunosti blokirati ultraljubičasto zračenje. Cilj ovog rada je prikazati rezultate mjerenja sposobnosti UV zaštite odjećom i zaštitnim tekstilom prema AS/NZS 4399:1996 određenom na transmisijskom spektrofotometru Cary 50 Solarscreen (Varian). Rezultati su pokazali da odjeća koja se nalazi na tržištu nije uvijek adekvatna za sprječavanje djelovanja UV zračenja na ljudsku kožu, te su predložene mogućnosti za njezino poboljšanje.