Reactive Phenylbenzimidazole UV Absorbers and Their Application to Cellulose Textiles

Lubomír Kubáč,[1] Jiří Akrman,[1] Ladislav Burgert,[2] Drahomír Dvorský,[3] Pavel Grüner[3]

[1]*VUOS Research Institute of Organic Syntheses, 53354 Rybitví 296, Czech Republic*
[2]*Institute of Polymeric Materials, University of Pardubice, Nám.Cs. Legií 565, 53210 Pardubice, Czech Republic*
[3]*inoTEX, Štefánikova 1208 544 01 Dvůr Králové n.L. Czech Republic*

Received 15 February 2008; accepted 18 November 2008
DOI 10.1002/app.29739

ABSTRACT: New types of reactive UV absorbers for applications to cellulose textiles have been prepared. These substances are condensation products of sulfobenzimidazolaniline, cyanuric chloride, and aminophenyl-(2-sulfethoxy)-sulfone. They were applied to bleached, unbleached, as well as dyed cellulose textiles with the aim to increase the protection effect of these textiles against UV radiation. All the tested textiles showed a marked increase in the UV protection factor (UPF). The effects of the UV absorbers tested neither interfere with the function of fluorescent brighteners (FBs) nor affect the hue of the used dyestuffs. They exhibit synergistic effect in the protection effectiveness against UV radiation: the UV absorbers used together with dyestuffs and FBs have a higher UPF factor than is the sum of UPF contributions of the individual components. © 2009 Wiley Periodicals, Inc. J Appl Polym Sci 112: 3605–3612, 2009

Key words: sun protection; UV absorbers; phenylbenzimidazoles; cellulose; cotton

INTRODUCTION

Sun radiation, especially its UV segment, belongs among the most harmful external factors that damage human health. It is known that wearing of common textiles provides insufficient protection against its effects. Especially, summer clothing made of cotton represents an unsatisfactory protection.[1,2] Dermatological studies have proved that skin must be protected against both UVB and UVA radiation, i.e., against the whole UV radiation wavelength range of 290–400 nm present in sun spectrum.[3]

The UV absorbers that are not attached to the textile by a covalent bond are washed out from the treated textile during laundering; hence, their effect is not permanent. In addition, many UV absorbers reduce the bleaching effect of common fluorescent brighteners (FBs), because their efficiency in UV area reaches up to the region of efficiency of FBs.

For these reasons, it is necessary to use broadband UV absorbers that do not stretch into the absorption band of FBs and that are bound to the treated textile by a covalent bond. In the case of cellulose textiles, it is appropriate to apply the systems that are commonly used for reactive dyestuffs based on cyanuric chloride (CNC) (Fig. 1).

An effective UVB absorber is the condensation product of CNC and (4-aminophenyl)-(2-sulfethoxy)-sulfone (PAFSES), which effectively absorbs in the region about 300 nm. In addition, this combination brings two reactive systems into the molecule and more effective covalent bond with fiber. A number of UV absorbers active for UVA radiation have been tested. Previous paper[4] describes condensation products with 2-hydroxy-phenylbenzotriazole chromophore, which is an exceptionally efficient UV filter. However, laundering of treated textiles in domestic surfactants can cause undesirable graying and yellowing. Washing of cellulose textiles takes place in alkaline medium at pH > 9. Under these conditions, the 2-hydroxyphenyl-benzotriazole chromophore can partially be converted into phenoxide, which is yellow. Whiteness of washed textile cannot be achieved by means of FBs, since benzotriazole chromophores also block the activity of FBs.

Suitable UVA chromophore for reactive UV absorber must be insensitive to pH change and it is necessary to absorb radiation in the wavelength range of 320–360 nm (the UVA II region). The appropriate chromophore is, e.g., 2-phenylbenzimidazole-5-sulfonic acid, which is used as a UVA II filter in sunscreens. It is produced by condensing benzoic acid with 1,2-phenylenediamine in the medium of concentrated sulfuric acid. The condensation is accompanied by sulfonation (Fig. 2).[5]

Laboratory experiments showed that analogous reaction proceeds under the same conditions and

---

Correspondence to: J. Akrman (jiri.akrman@vuos.com).

Contract grant sponsor: Czech Ministry of Industry and Trade; contract grant number: ČR FT-TA/035.

Journal of Applied Polymer Science, Vol. 112, 3605–3612 (2009)

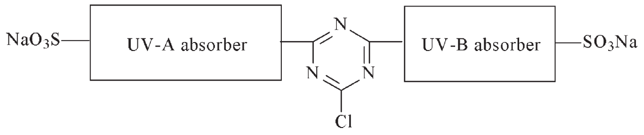


Figure 1 Schematic arrangement of reactive UV absorber.

with the same yield (65%) also with 4-aminobenzoic acid and 3-aminobenzoic acid. The obtained intermediates, 4-aminophenyl-1*H*-benzimidazole-5-sulfonic acid (Fig. 3, Formula I) and 3-aminophenyl-1*H*-benzimidazole-5-sulfonic acid, contain water-solubilising sulfonic group as well as amino group; the latter can be used for the condensation reaction with CNC and with PAFSES to give a new reactive UV absorber (Fig. 3, Formula II).

Cotton textiles have their own degree of transmission for UV radiation. This transmission is further decreased by application of the reactive UV absorber to cotton. Also other substances present on the textile, such as FBs and dyestuffs, decrease the overall transmission. FBs, by their nature, are UV absorbers too.

The aim of this work is to investigate transmission of textiles treated with reactive UV absorber in combination with optical brightener. More details are brought out in a Czech patent.[6]

EXPERIMENTAL

Materials and chemicals

All synthesis was done with catalogue chemicals delivered by Sigma-Aldrich.

Tests with FB were done with Blankophor BA fl. from CIBA, according Color Index Fluorescent Brightener 113 (FB 113).

Dyeing of cotton was performed using a bi-functional type of reactive dye Sumifix Supra Blue BRF (C. I. Reactive Blue 221), from Sumitomo Chemicals (Tokyo, Japan).

Application tests were done with commercial accessible cotton fabrics. Their descriptions are done in paragraph, which describes actual tests.

Preparation of reactive phenylbenzimidazole UV Absorber I

The condensation of 109 g 1,2-phenylenediamine (1.0 mol, purity 99%) with 138 g 4-aminobenzoic acid (1.0 mol) was carried out in 360 mL of 96% sulfuric acid at the temperature of 165°C (Fig. 4). The reaction mixture was stirred at this temperature for a period of 7 h, whereupon it was cooled, diluted with 1 L of water, and the formed suspension was stirred for another 3 h. The precipitated solid was collected by suction, washed with diluted sulfuric acid, and then with water. The filter cake was dried to give 205 g 4-aminophenyl-1*H*-benzimidazole-5-sulfonic acid (yield 71%). The product was characterized by UV/VIS spectroscopy.

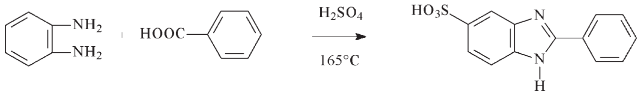


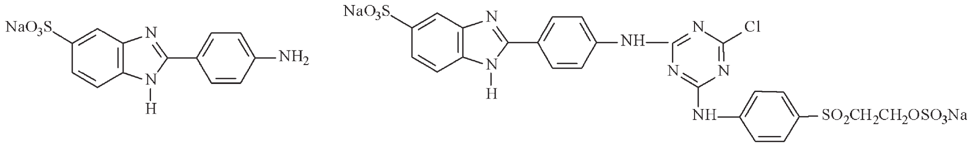
Figure 2 Synthesis of phenylbenzimidazole chromophore.

Preparation of condensate cyanuric chloride/PAFSES

A suspension of 186 g CNC (1.0 mol, purity 99%) was prepared in a mixture of 600 g of crushed ice and 1 200 mL of water. This mixture, at the temperature of 0–5°C was treated with 2.0 L aqueous solution of PAFSES with the concentration of 0.5 mol L^{-1} (Fig. 5). Throughout the reaction, the pH value was maintained at 1.7–3.5 by addition of sodium carbonate water solution (1.25 mol L^{-1}). The total reaction time was 8 h at the temperature of 0–25°C. After finished condensation, the pH value of the suspension was adjusted at 5.0–6.0 by addition of sodium carbonate water solution (1.25 mol L^{-1}).

Preparation of reactive phenylbenzimidazole UV absorber

The suspension of 1.0 mol condensate CNC/PAFSES was stirred at the temperature of 25–35°C and treated with 1 L of aqueous solution of sodium 4-aminophenyl-1*H*-benzimidazole-5-sulfonate (1 mol L^{-1}), whereupon the reaction mixture was stirred at the temperature of 50–70°C and pH value 6.5–7.5 for a period of 6 h. Then, the reaction mixture was stirred at the temperature of 60–70°C for another 6 h. Insoluble parts were filtered out. It was obtained 10 L of aqueous solution of reactive phenylbenzimidazole UV absorber (Fig. 6) with the concentration of 7.2%. The product was characterized by UV/VIS spectroscopy.



Formula I

Formula II

Figure 3 Chemical structures of phenylbenzimidazole intermediate and reactive UV absorber.

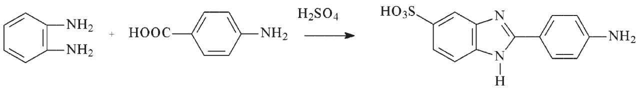


Figure 4 Preparation of 4-aminophenyl-1*H*-benzimidazole-5-sulfonic acid.

By the same procedure was prepared UV Absorber II (Fig. 7) from 3-aminobenzoic acid in the first reaction step and UV Absorber III (Fig. 8) from (3-aminophenyl)-(2-sulfethoxy)-sulfone (MAFSES) in the second reaction step.

Application of phenylbenzimidazole UV absorber to cellulose material

Three cellulose materials for testing of reactive UV absorbers were selected. An optically brightened (with FB 113) cotton knitted fabric with the bulk surface density of 130 g m^{-2}, a foil of regenerated cellulose (cellophane foil) of 0.15 mm thickness, and a bleached cotton batiste fabric with the bulk surface density of 120 g m^{-2}.

An amount of 5 g was weighed from each material. At first, they were washed in hot water with added nonionic surface-active agent (0.1%). Then, they were immersed in 75-mL bath containing 0.10 g tested UV absorber at the temperature of 50–70°C for a period of 20 min, whereupon 3.75 g sodium chloride and (after a while) 1.5 g anhydrous sodium carbonate were added into the bath. Then, the materials were washed with water by standard route. The exhausted bath, rinsing water, and washing bath were combined, and the content of the UV absorber was determined spectrophotometrically. The degree of fixation (i.e., the ratio of the amount of UV absorber fixed to the cellulose to that present in the starting bath) was calculated.

The dry treated materials were compared with untreated materials.

Application of fluorescent brightening agent

A foil (2 g) of regenerated cellulose (cellophane) of 0.15 mm thickness was treated in a 60-mL bath containing 0.2% (related to the weight of cellophane) of FB 113 (Fig. 9) and 0.33 g sodium chloride at the temperature of 40°C for a period of 20 min, whereupon the foil was rinsed with water and dried.

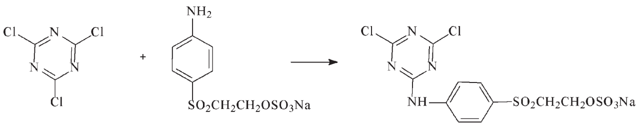


Figure 5 The first condensation—preparation of condensation product of cyanuric chloride with PAFSES.

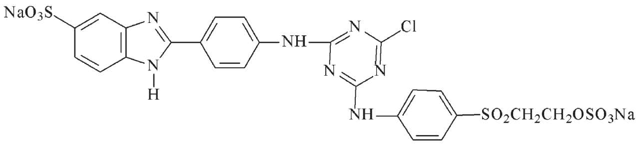


Figure 6 Chemical structure of UV Absorber I.

Determination of ultraviolet protection factor of textiles *in vitro*

The fabric's transmission of UV radiation was measured by the spectrophotometer Varian Cary Solascreen 50. A spectrophotometer was equipped with the extension, fabric protection factor, which enabled the measurement of diffusion-transmission spectra. The measuring was done in the wavelength range of 290–400 nm using the steps of 5 nm. This device was equipped with the extension fabric protection factor, which enabled the measurement of diffusion-transmission spectra. The samples of fabrics which exhibited fluorescence were measured with attached Schott UG 11 filter, which is supplied among the accessories of the spectrophotometer. The ultraviolet protection factor (UPF) was calculated according to the Australian standard[5] using the values of spectral distribution of sun radiation in Southern Europe.[4,7] The protection factor UPF was calculated from the eq. (1):

$$\mathrm{UPF} = \frac{\int_{280\,\mathrm{nm}}^{400\,\mathrm{nm}} S_\lambda \cdot E_\lambda \cdot d\lambda}{\int_{280\,\mathrm{nm}}^{400\,\mathrm{nm}} S_\lambda \cdot E_\lambda \cdot T_\lambda \cdot d\lambda} \tag{1}$$

where,

S_λ is spectral representation of energy of sun radiation,

E_λ is spectral erythemal effectiveness of UV radiation,

T_λ is spectral transmission of measured material at wavelength λ (in nm).

The UPF values give information about the degree of protection against UV radiation. As per the standard norms, the values above 50 are mentioned as 50+ as they may not offer substantially more protection than those with a UPF of 50. In this article, the measured UPF values are mentioned as such to demonstrate the influence of various parameters and their synergy.

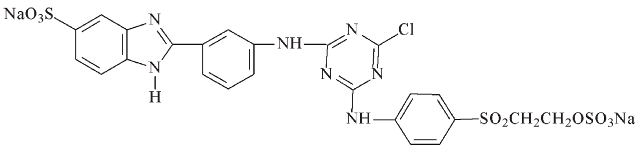


Figure 7 Chemical structure of UV Absorber II.

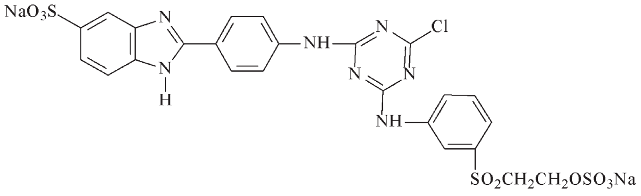


Figure 8 Chemical structure of UV Absorber III.

Application of fluorescent brightener and phenylbenzimidazole reactive UV absorber on cellulose textile

There was used cotton knitted fabric with the bulk surface density of 160 g m^{-2} in amount of 5 kg. This fabric was treated in a commercial-size apparatus using a bath contained 2% (relative to mass of textile) UV Absorber I in the ratio 1 : 15 by common dyeing process. The fabric was treated 10 min at bath temperature of 60°C and then 50 g L^{-1} sodium sulfate was added into the bath, and after another 15 min, 5 g L^{-1} sodium carbonate and 0.7 g L^{-1} sodium hydroxide were added. The bath was kept at the temperature of 60°C for additional 35 min, whereupon the material was washed with water by standard route.

A part of the material was treated at the same condition in a bath containing 0.125% (relative to the mass of textile) of C.I. Fluorescent Brightener 113 for a period of 20 min. After this operation, the knitted fabric samples were evaluated spectrophotometrically and their UPF factors were measured. The degree of whiteness was also estimated using a spectrophotometer Minolta CM 2002 with Treepoint QTEX program.

Wash- and light-fastness of cotton textiles treated with phenylbenzimidazole reactive UV absorbers

Cotton textile treated by UV Absorber I was used for determination of laundering and light fastness. Light fastness was done by the exposition to UV radiation in an ATLAS-SUNTEST instrument with the maximum proportion of UV component and the temperature of the black panel thermometer being maximum at 45°C. The samples were irradiated up to the fastness degree of 6 according to the standard blue scale. The laundering fastness at the temperature of 60°C was determined according to standard EN 20105-C03. The values of UPF factor represent the measure of stability.

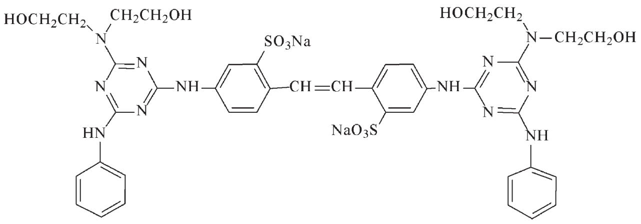


Figure 9 C.I. Fluorescent Brightener 113 (FB 113).

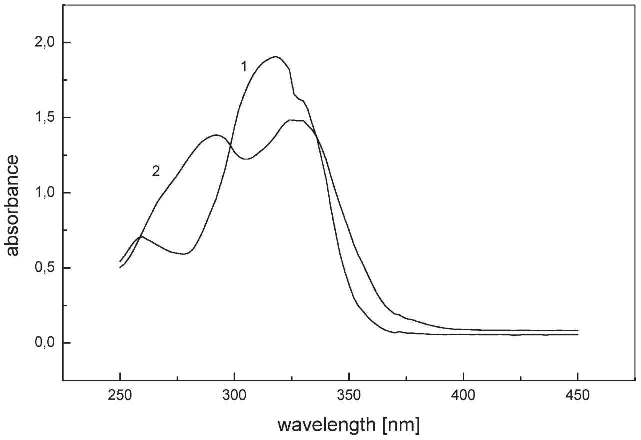


Figure 10 UV/VIS spectrum of aqueous solution of intermediate and UV Absorber I. (1) Sodium 4-aminophenyl-1*H*-benzimidazole-5-sulfonate, concentration 25 mg/L, 1-cm cell. (2) UV Absorber I, concentration 25 mg/L, 1 cm cell.

One-bath process of dyeing and treatment with UV absorber (Pad Batch)

Cotton twill suitable for working clothes with the bulk surface density of 202 g m^{-2} was treated by standard dyeing process—Pad Batch. It was done on a laboratory foulard Mathis using a working bath containing 2 g/L C.I. Reactive Blue 221, 2 g/L UV Absorber I, and 5 g/L NaOH. After passing through the foulard, the textile material was rolled up on a roller lap and covered with PE foil. The roller lap

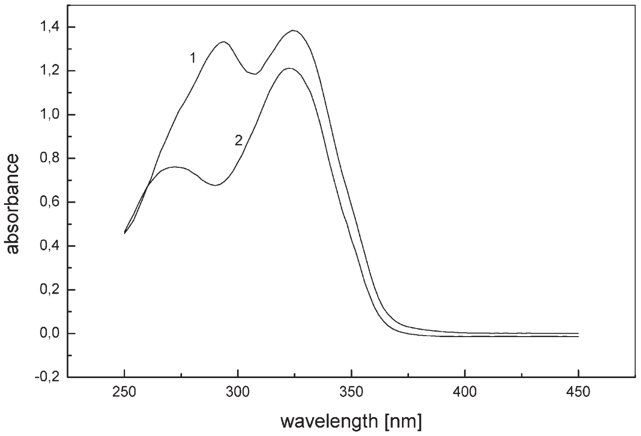


Figure 11 Comparison of UV/VIS spectra of aqueous solutions of UV Absorbers I and III; concentration 25 mg L^{-1}, 1-cm cell; (1) UV Absorber I and (2) UV Absorber III.

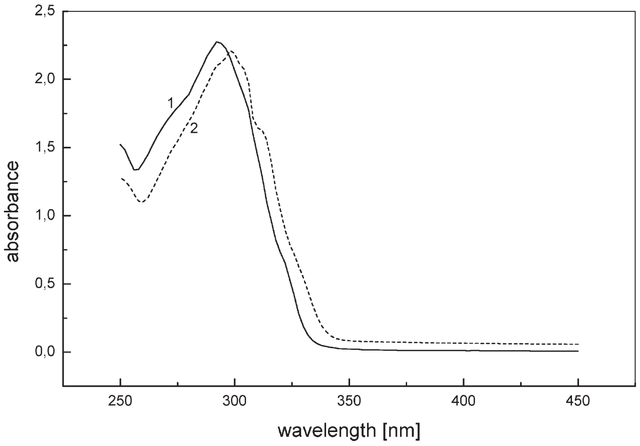


Figure 12 UV/VIS spectra of UV Absorber II. (1) Aqueous solution, 25 mg L^{-1}, 1-cm cell, absorbance maximum at 292 nm. (2) Dyeing on cellophane, 0.35%, absorbance maximum at 298 nm.

was continuously rotated at the temperature of 25°C for a period of 12 h, whereupon the material was washed in a washing apparatus with seven working compartments with the water temperature ranging from 20 to 90°C. After passing through the continuous washing apparatus, the fabric was dried on a drying frame at the temperature of 120°C. Thank to the described procedure, it was obtained the textile fabric pretreated against UV radiation and at the same time dyed to pale blue color in one step.

RESULTS AND DISCUSSION

Characterization of reactive UV absorbers

The chosen UV absorber chromophore, sodium 4-aminophenyl-1*H*-benzimidazole-5-sulfonate, has appropriate absorption spectra. Its aqueous solution absorbs UV radiation in the wavelength range of 300–340 nm. After reaction of this chromophore with the CNC/PAFSES condensate was obtained reactive UV Absorber I, which exhibits a UV absorption spectrum over the whole UVB radiation getting through atmosphere and over the majority of UVA radiation. This spectrum has two absorption maxima at the wavelength of 292 and 326 nm (Fig. 10).

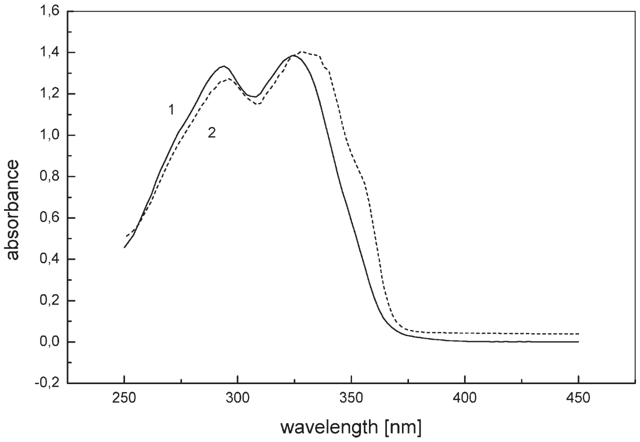


Figure 13 UV/VIS spectra of UV Absorber I. (1) Aqueous solution, 25 mg L^{-1}, 1-cm cell, absorbance maxima 294 and 324 nm. (2) Dyeing on cellophane, 0.15%, absorbance maxima 295 and 331 nm.

TABLE I
Appearance of Treated Textile Materials

UV protection preparation	Fixation (%)	Bleached batiste fabric appearance	Brightened knitted fabric appearance
UV Absorber I	91	White	Brightly white
UV Absorber II	85	White	Brightly white
UV Absorber III	62	White	Brightly white

The absorption band at the wavelength of 290 nm is mainly due to the moiety formed by the CNC/PAFSES condensate, which can be deduced from the fact that UV Absorber III, whose synthesis uses the CNC/MAFSES (3-aminophenyl isomer) condensate instead of the CNC/PAFSES (4-aminophenyl isomer) condensate, exhibits a spectrum with decreased absorption about the wavelength of 290 nm (Fig. 11).

On the other hand, the absorption in the wavelength region about 330 nm is due to the phenylbenzimidazole moiety. If its structure is varied by using the isomeric 3-aminophenyl-1*H*-benzimidazole-5-sulfonic acid (UV Absorber II), the impact on the ability to filter off the UV radiation is extensive (Fig. 12). UV Absorber II is only effective in the wavelength region of 290–320 nm (UVB region).

The best absorption properties from the three synthesized UV absorbers was proved by UV Absorber I. This preparation is able to filter off the radiation in the wavelength range of 290–360 nm, i.e., the most harmful radiation component for human skin.

Laboratory tests of UV absorbers on cotton fabrics

The application of reactive UV absorbers to cellulose is connected with chemical reaction between absorber and cellulose, and the spectrum of attached absorber is different from that of the absorber in solution. The spectrum of UV Absorber I have been extended by about 7 nm after bonding on cellulose. This is possible to observe in Figure 13, where is compared its spectrum of aqueous solution and spectrum of treated cellophane foil. Cellophane foil was chosen because of its similar behavior to cellulose textiles, but it is completely transparent and it proves no side impact on UV/VIS spectra due to light scattering. The observed spectra shift is favorable, since it increases the effectiveness in the sense

TABLE II
Ultraviolet Protection Factor of Cellulose Material Before and After Treatment

UV protection preparation	Bleached batiste fabric		Brightened knitted fabric		Cellophane foil	
	Original UPF	Final UPF	Original UPF	Final UPF	Original UPF	Final UPF
UV Absorber I	3	36	3	41	1	58
UV Absorber II	3	19	3	22	1	20
UV Absorber III	3	15	3	17	1	15

of reaching a higher protection factor of the treated textile material.

The effectiveness of phenylbenzimidazole UV absorbers bonding on cellulose materials was tested on a batiste fabric, cellophane foil, and knitted fabric containing FB. The uptake of UV absorbers from the bath and fixation on the fabric are high, particularly in the case of UV Absorber I (Tables I and II). That mean that the all tested UV absorbers make good reaction bond with cellulose material and this bond is stable. None of the three UV absorbers affected the appearance of the batiste fabric after the treatment. The brightly white appearance of brightened knitted fabric remained the same. It was observed that the phenylbenzimidazole UV absorbers do not interfere with the effect of FBs.

The effectiveness of reactive UV absorbers was measured on batiste fabric and knitted fabric, the cellophane foil was added for comparison. Textile materials possess low protection factors, UPF = 3. The treatment increased the protection factors to the values of 15–40. The most effective is UV Absorber I, whose high UPF value results from its high fixation degree on fiber as well as from favorable shape of its absorption spectrum.

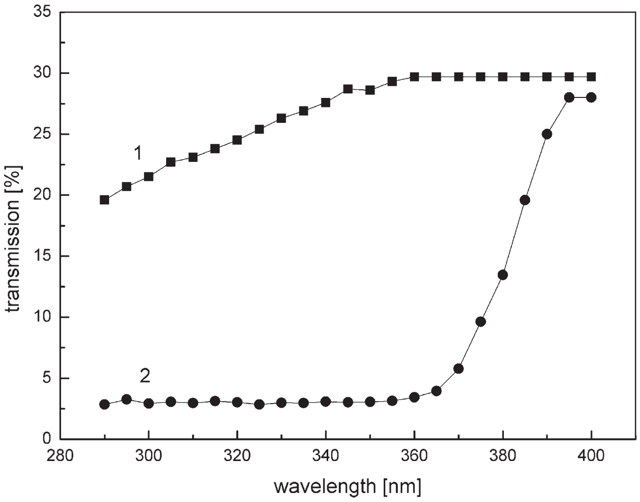


Figure 14 Diffusion-transmission spectra of batiste fabric. (1) Original fabric, UPF = 3. (2) Fabric treated with 2% UV Absorber I, UPF = 36.

The changes of protection ability of treatment textile are possible to observe by comparison of the spectra of the fabric before and after treatment. There is presented it in Figure 14, a comparison of the original batiste fabric (UPF = 3) and the batiste fabric treated with UV Absorber I (UPF = 36). The original fabric exhibits a transmission about 25%, and the treated fabric shows a distinct lowered transmission in the wavelength region of 290–370 nm, which is the main reason of the UV protection factor increase.

UV absorbers mixture with fluorescent brightener or reactive dyes

A further increase in the protection factor would be attained if the fabric was more densely woven and if the absorber extended its effect more into the wavelength region above 370 nm. This part of the radiation could be covered by FBs, which absorb in the wavelength region of 370–400 nm. Optimal situation is obtained if the UV absorber and FB complement each other in their effects.

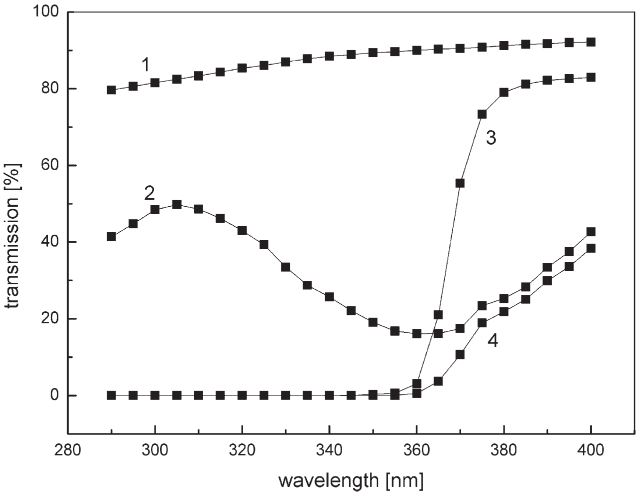


Figure 15 Synergistic effect of UV Absorber I and fluorescent brightener. (1) Cellophane, UPF = 1.2. (2) Cellophane treated with 0.2% C.I. Fluorescent Brightener 113, UPF = 2.2. (3) Cellophane treated with 2% UV Absorber I, UPF = 51. (4) Cellophane treated with 2% UV Absorber I and 0.2% C.I. Fluorescent Brightener 113, UPF = 163.

TABLE III
Whiteness of Untreated and Brightened Fabrics After Treatment with UV Absorber I

UV Absorber I (%)		0	0.07	0.14	0.28	0.42
Whiteness degree Berger	Original	66.82	67.98	67.92	67.35	65.52
	FB	100.99	102.88	102.90	100.95	93.66
Whiteness degree CIE	Original	67.26	68.85	68.80	68.15	66.23
	FB	101.11	102.65	102.75	100.98	94.17

The coexistence of UV Absorber I and FB 113 are well-seen in the case of cellophane foil. Cellophane transmits UV radiation very well, and its protection factor is negligible (UPF = 1.2). The cellophane treated with 0.2% of the aforementioned FB exhibits a lower transmission with the minimum at the wavelengths of 355–375 nm (UPF = 2.2). On the other hand, the cellophane treated with 2% UV Absorber I has the transmission of radiation in the wavelength range of 290–355 nm completely blocked (UPF = 51). The highest value of UPF, 163, is achieved if the foil is treated with UV Absorber I as well as with FB 113 (Fig. 15).

UV Absorber I was tested in laboratory from the standpoint of its effect upon the effectiveness of FB, using bleached cotton knitted fabric, which was treated with UV Absorber I of various concentrations (from 0.07% to 0.42%). Besides that, this fabric was pretreated with 0.125% FB 113 and then treated with UV Absorber I. All the samples were tested for their whiteness degree (Table III). It was proved that the UV absorber does not affect the whiteness of fabric.

The combination of UV Absorber I and FB 113 has positive impact on treated fabric, as it is demonstrated in Table IV. The untreated knitted fabric exhibits the value of UPF = 15. The UPF value increased to 30 after treatment with FB 113 and to 102 after treatment with UV Absorber I (0.14% relative to the mass of knitted fabric). The combination of both treatments gives value of UPF 328. These results indicate a very strong synergistic effect of the combination of treatment with reactive UV Absorber I with the treatment with FB 113. At the same time it was shown that the tested UV absorber has an only negligible negative influence on brightening effect of tested FB, measured by the whiteness degree of the knitted fabric.

TABLE IV
Effect of C.I. Fluorescent Brightener 113 and UV Absorber I on UPF and Whiteness Degree

Knitted fabric treated	UPF	Whiteness degree
Original	15	65.70
Original after brightening with FB	30	102.88
After treatment with UV Absorber I	102	64.20
After treatment with UV Absorber I and brightening with FB	328	100.95

The reactive UV absorber was applied to cotton twill by two techniques used in commercial practice for dyeing with reactive dyestuffs—exhaust method and Pad-Batch. The cotton twill treated with reactive UV Absorber I can be used for manufacturing of working protection clothing. In both aforementioned cases, we determined the effect of concentration of UV absorber upon the UPF value. Table V shows that the concentration as low as 0.028% UV Absorber I (relative to mass of textile material) increases the UPF value of the textile material to a sufficient level.

The durability of UV protection effect is key factor from the point of view of practical use such treated cotton textiles. Fastness of the effects to repeated laundering was determined at the temperature of 60°C using a standard detergent. The light fastness was determined by irradiation in a Suntest apparatus for a period of 300 h. Tests were done with a fabric treated by 0.14% UV Absorber I. The results are presented in Table VI. The experiment proved a high permanency of the photo-protection treatment. A mild decrease in UPF after 10 laundering cycles can be ascribed to mechanical changes of the textile material rather than to a decrease in the concentration of UV absorber in it.

TABLE V
Effectiveness of UV Absorber I on Cotton Twill; Application by Exhaust Process and by Pad-Batch

UV Absorber I (%)	0	0.028	0.056	0.112	0.224	0.336
Exhaust process, UPF	17	56	75	114	127	184
Pad-Batch, UPF	17	41	57	68	102	110

TABLE VI
UPF Values of Textile Treated with UV Absorber I After Exposition to Light and Laundering

Original UPF	UPF after treatment	UPF after exposition to light	UPF after 5 laundering cycles	UPF after 10 laundering cycles
7	95	92	91	85

TABLE VII
Effect of One-Bath Application of Reactive Dyestuff and UV Absorber I on UPF

Original UPF	UPF after treatment with UV Absorber I	UPF after dyeing with C.I. Reactive Blue 221	UPF after application of UV Absorber I + C.I. Reactive Blue 221
17	119	55	315

Reactive UV absorbers resemble reactive dyestuffs, which evokes the question whether they both could be applied together from a single bath. The respective experiment testing the possibility of one-bath dyeing plus treatment with UV Absorber I gave very good results. Table VII presents the effect of individual treatments upon the UPF value. Both UV Absorber I and reactive dyestuff, if applied separately, increase the protection factor of textile material. However, if they are applied together in a mixture, the resulting protection factor is unusually high. The results unambiguously indicate a synergistic effect in the one-bath way of application.

CONCLUSIONS

The tested reactive UV absorbers exhibit high effectiveness in improving protection properties of cellulose textiles against UV radiation. The proposed UV Absorber I can be applied by the take-up process identical with that used for common reactive dyestuffs. In this procedure, more than 90% of the UV absorber is fixed to the textile by chemical (covalent) bond. The UV absorber can be applied together with reactive dyes by a one-bath procedure, and this way of application even exhibits additional synergistic effect.

The UV absorbers tested do not affect the effectiveness of FBs; on the contrary, they exhibit a synergistic effect in the combination with FB.

The result of treatment is permanent and washfast. Application of common powder detergents for laundering even increases the UPF value as a result of synergistic action of FB present in the powder and UV absorber.

The reactive phenylbenzimidazole UV absorbers are also light-fast. The tested textile materials did not show any decrease in photo-protective properties after their exposition to UV radiation.

On the whole, it can be stated that the suggested system of protection against solar UV radiation is effective and of long-term stability.

The research was conducted in cooperation with the University of Pardubice and it is included in a PhD Thesis.

References

1. Wolf, R.; Kaul, B. L. Plastic, Additives, in Ullmann's Encyclopaedia of Industrial Chemistry, 6th ed.; Wiley-VCH Verlag GmbH & Co. KgaA: Weinheim, Germany, 1998, Electronics Release, DVD.
2. Gugumus, F. In Plastic Additive Handbook, 5th ed.; Hanser Publ: Munich, 2001.
3. Schaefer, H.; Moyal, D.; Fourtanier, A. J Dermatol Sci 2000, 23, 62.
4. Akrman, J.; Přikryl, J. J Appl Polym Sci 2008, 108, 334.
5. Heywang, U.; Stein, I.; Fechtel, U.; Casutt, M.; Faller, G.; Hartner, H. U.S. Pat. 5,473,079 (1995).
6. Akrman, J.; Kubáč, L.; Dvorský, D.; Grüner, P. Czech Pat. 298,042 (2007).
7. Standards Association of Australia, Standard AS/NZS 4399. Sun Protective Clothing: Evaluation and Classification; Australian/New Zealand. Homebush: Australia, 1996.