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Wavelength sensitivity of AATCC Blue wool lightfastness standards under light radiation

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ABSTRACT

The fading characteristics of the AATCC Blue Wool L2 and L4 lightfastness standards were examined from the standpoint of wavelength sensitivity. Experiments were carried out by exposing a specimen to a narrow monochromatic band isolated from the dispersed polychromatic light emitted by a Xe lamp source. The wavelength sensitivity characteristics of Blue wool L2 and L4 lightfastness were determined on a radiant energy basis. Both Blue Wool Standards displayed peak maxima at 245 and 294 nm. The results indicated that UVA and UVB had a significant fading effect, whereas visible light caused fading to a small extent. Specific wavelengths caused Blue wool to significantly fade, suggesting that the total irradiated UV energy may not be an appropriate index. In addition, their spectral reflectances did not directly explain these characteristics of the standards.

1. Introduction

Light irradiation is one of the most influential factors in the fading of dyestuffs in addition to temperature, humidity, and air pollutants. Many approaches have been reported to investigate lightfastness [1–8]. Most lightfastness experiments were carried out under accelerated conditions using artificial light sources like carbon and xenon arc lamps instead of direct solar radiation. In these experiments, lightfastness standards such as the AATCC Blue Wool lightfastness standards [9], the Japan Industrial Standard Blue Scales [10] and the British dyed-wool lightfastness standards [11] were used to measure the accumulated light intensity.

The performance of these blue standards has been examined since the 1950s, and some extensive discussions related to the measurement of solar radiation intensity in langleys have been carried out [12–17]. A question arose concerning whether a UV narrow band in the sunlight spectral regions may cause greater fading than the visible light region despite its negligible intensity compared to the total solar energy recorded. It was pointed out that measurement of the active wavelengths was necessary to better understand lightfastness testing results [15]. However, information given about the wavelength dependence of fading has been insufficient for blue standards.

The use of blue wool standards is not limited to dyed fabrics. The standards have also been applied as fading references to evaluate various material deteriorations such as wool yellowing [18], fading of water colors [19], photodamage of human hair [20] and to perform instrumental solar radiation measurements [21,22]. As mentioned above, sets of blue wool standards have been widely used in light dosimetry to qualitatively evaluate light induced damage. However, they have occasionally failed to give a proper prediction of fading characteristics. For instance, Zhang et al. [18] concluded that blue wool standards may not be effective in showing the impact of irradiated light on spectrum-sensitive fabrics. Crews [23] also found the inadequacy of blue wool standards on their sensitivity in the visible light. Some failures of the standards are considered to be due to the lack of knowledge regarding the wavelength sensitivity of blue wool standards.

Ideally, the correlation between fading characteristics generated using artificial and natural sunlight would be expected to be consistent. In certain cases, however, total energies emitted by the lamp and by the sun are not well correlated. This may lead to contradictory data because materials adsorb at their defined wavelengths. Measuring the fading or deterioration resulting from different radiant wavelengths is necessary to better understand photodamage.

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As noted above, most fading experiments were performed under accelerated conditions using polychromatic light sources. However, it is important to understand the photosensitivity of a material to a specific wavelength, because photoreactions generally depend on specific wavelengths that relate to the bonding energy of molecules. Identifying these specific wavelengths is useful when investigating processes that promote material degradation. Therefore, knowing spectral sensitivities is crucial in photodegradation control.

Investigations on the wavelength dependence of a given reaction or a process have been applied to biological systems [24,25], erythema in human skin [26], and polymer materials [27,28]. However, studies related to the fading of dyestuffs and fabrics have been scarce [29–33]. This may be partly due to limitations of instrumental availability and recognition of serious necessity on their fading evaluation.

In this study, the fading characteristics of AATCC Blue Wool lightfastness standards were investigated in terms of radiant energy on exposure to monochromatic light. The sensitivity of the standards to radiant wavelengths with respect to fading was determined. We herein provide some clues and insightful discussion on some contradicting questions pertinent to the assessment of materials that exhibit sensitivity to both visible and ultraviolet radiations such as wool yellowing and bleaching [18], some colorants [19], and natural dyes [23,34,35].

2. Experimental

2.1. Materials

AATCC Blue Wool L2 and L4 lightfastness standards [9] were used in this experiment. As described in the AATCC technical manual [9], these standards were prepared by blending different proportions of wool dyed with the very fugitive Erio Chrome Azurole BA dyestuff (C.I. 43 830) (Fig. 1) and wool dyed with the fast Indigosol Blue AGG dyestuff (C.I. 73 801) (Fig. 2).

These specimens were stored in a refrigerator to prevent preageing of the dye before the usage.

2.2. Exposure to light sources

Samples were irradiated with monochromatic light using a JASCO CRM-FD spectroirradiator (Fig. 3). The spectroirradiator was equipped with a 300 W xenon arc lamp with an ellipse half sphere mirror to collect light emission. Radiation from this source was converted into monochromatic light using a diffraction lattice grating with 1200 lines/mm. The wavelength dispersion was about 2 nm mm^{-1} and the slit was set to 2 mm, resulting in an accuracy of about 4 nm for each irradiation wavelength. The specimens were placed in an appropriate position in a sample holder and exposed to monochromatic radiations interspaced by about 16 nm within the 220–700 nm wavelength range. The light intensity in W m^{-2} nm^{-1} was periodically measured for each wavelength using a photometer. The photometer was an advanced device which consisted of a thermopile detector attached to the spectroirradiator, unlike the previous model used by Katsuda et al. [29,30]. Light exposures were carried out at temperatures and relative humidities ranging from 20 to 25 °C and from 50% to 70%, respectively.

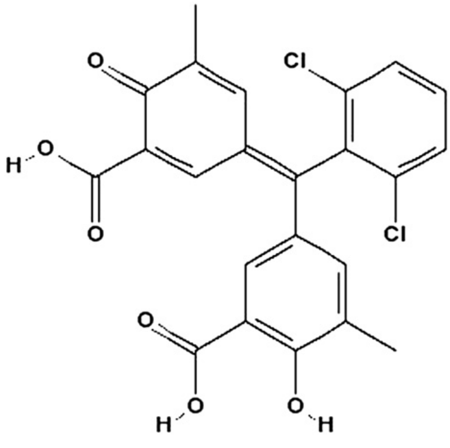

Fig. 1. Chemical structure of Erio Chrome Azurole BA.

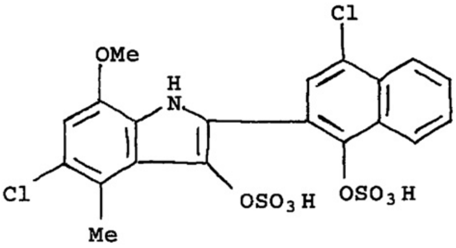

Fig. 2. Chemical structure of Indigosol Blue AGG.

2.3. Evaluation of fading

The specimen color change was measured using a Minolta Model CM-3700d color analyzer with a 4 × 7 mm^2 viewing aperture. The amount of fading was evaluated in terms of color difference and calculated using the following formula proposed by the CIE Committee in 1976 (Equation (1)):

$$\Delta E = \left[(\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2\right]^{1/2} \tag{1}$$

where ΔL^* is the lightness–darkness difference, Δa^* is the redness–greenness difference, and Δb^* is the yellowness–blueness difference.

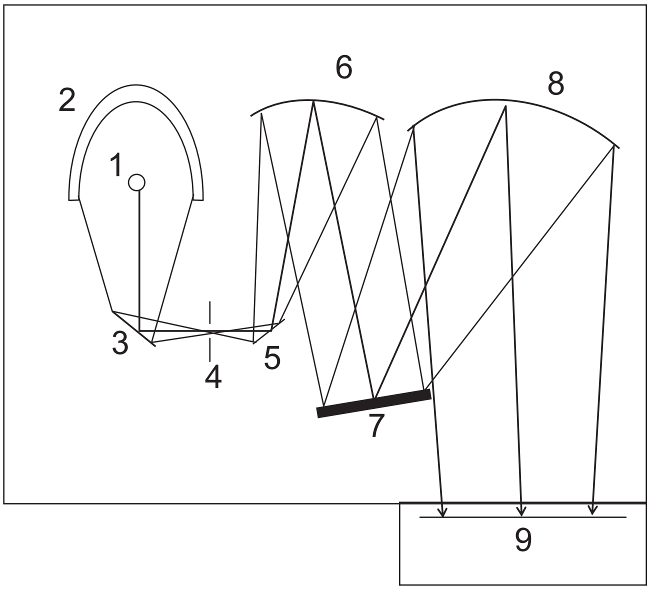

Fig. 3. Schematic diagram of the spectroirradiator: (1) Xenon arc lamp; (2) elliptical sphere mirror; (4) slit; (7) diffraction grating; (9) sample holder. (3), (5), (6), and (8) are mirrors.