Light Fastness Evaluation: A Review

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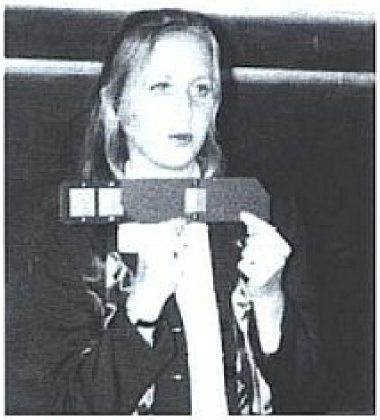

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Introduction

Light fastness is a measure of the stability of a coloured material to light. It may also be considered as the resistance of coloured material to fading. The lifetime of many coloured products needs to be evaluated from several points of view, including the lightfastness. A colorant, such as a dye, may exhibit different properties under different conditions. The binder or substrate can have a marked effect on the performance of a colorant. The lightfastness of coloured materials has a significant influence on the commercial acceptability of the material. From the standpoint of the consumer, it is not acceptable for coloured products to fade during their lifetime. For example, the fading of a pair of curtains, whilst they were hanging in a window, would be unacceptable and would cause major problems for the retailer. Similarly, one does not expect the colour of an automobile to fade during its lifetime. By measuring the light fastness of a coloured product, a measure of quality assurance can be provided to consumers.

The fading of a coloured material is caused by the photochemical degradation of the coloured molecule, by various sources of radiation [1] under a range of environmental conditions (including humidity, the pH, microenvironment and matrix). Most commonly, it is the far visible and the ultra violet part of the electromagnetic spectrum that induces this breakdown that takes place via a free radical mechanism [2]. Such breakdown may be enhanced by additives and by the polymeric binder.

All products exposed to light, whether it is natural daylight or artificial lighting, will eventually fade. In media containing more than one dye or pigment, one dye may act as a photosensitiser, which in turn will accelerate the breakdown of the other colorant [3]. Another effect that is sometimes observed is the breakdown of the substrate or of an additive by a similar mechanism [4].

Assessment of lightfastness

The testing of lightfastness requires the assessment of the colour change of a sample relative to a set of standards following irradiation under controlled conditions. The BS, CEN and ISO test methods involve the use of:

1. The blue wool scale
2. The grey scale for assessing change in colour
3. Fadeometers fitted with a defined light source.
4. BSI, CEN and ISO standard test methods.

The first blue wool scale was developed in Germany by the DEK in 1914. This became the basis of the internationally accepted, blue wool scale adopted by the Society of Dyers and Colourists in 1934. At present, this set of standards comprises the ISO Blue Wool Scale. The scale consists of a series of eight woollen samples each dyed with a specific dye, to a certain level. The dyed wool samples are designed to fade in a controlled way on exposure to light. The most commonly used BS test is carried out using a xenon arc lamp. This point will be discussed later.

In 1945, the American Association of Textile Chemists and Colorists developed their own scale. This approach utilised two dyestuffs, one fast and one fugitive that are dyed onto loose stock. The dyed stock is subsequently blended in different proportions, spun and woven into cloth. This results in a set of fabrics that give a range of fading rates on exposure. The two dyes used were CI Mordant Blue 1, a fugitive dye, and CI Solubilised Vat Blue 8, a fast dye. This system is currently in use and was originally designed for use with a carbon arc lamp. However, American test methods commonly currently use xenon arc.

A set of pigment printed lightfastness standards has recently been developed by the Society of Dyers and Colourists [5]. This step in development was necessary because some of the dyes used to produce the blue wool standards are no longer available. In addition, questions were being asked of the suitability of the blue wool scale for the vast range of fastness evaluations being carried out. The reduced availability of the dyes arose partly because they are either an environmental hazard to produce, or they became obsolete. Other applications for low value light fast dyes are very limited. Production therefore became non-viable.

The lightfastness standard formulations are printed onto polyethylene coated board. The pigment printed standard rated at four units fades at a similar rate as the blue wool standard of four units, under ISO 105:BO2 conditions. The pigment printed lightfastness standards are designed to follow a geometric rate of fading. This development is a vast improvement on the current Blue Wool Scale which, in places, shows quite marked deviation from a geometric progression of two units [6,7] Another problem arises when the wool standards are exposed to certain conditions. The wool substrate yellows [7]. This may lead to difficulties in assessing the change in colour on fading, particularly for instrumental assessment. The pigment printed standards eliminate this problem through the inertness of the components of the print to the events that occur during fading of the chromophore.

The Grey Scale, which is used to assess fading consists of 9 squares showing an increasing contrast. A grey scale value of five shows no contrast. Conversely, a reading of one shows a high contrast. The scale is divided initially into five sections, but sub-divisions are also allowed, as defined by an international standard [8]. When carrying out assessments, the sample must be masked off using either a standard black mask or, a grey mask of a similar colour to Munsell N5 grey. The sample and the grey scale must be viewed in a light cabinet in the correct viewing plane using standard D65 illumination at 600 lux or more. The samples are inclined at an angle of 45¡ therefore they are viewed by the eye perpendicularly. All the surrounding areas, including the room, should be painted a neutral grey. The room should be illuminated to a value that is just below 600 lux.

Accelerated test methods were devised because, the use of natural sunlight was found to be too time consuming. In addition, any climatic variation could have a dramatic effect on the degree of fading (up to two grades).

When carrying out accelerated lightfastness testing, there are a number of variables that must be monitored:[9]

1. The spectral distribution of the light source.
2. The intensity of the light source.
3. The distance of light source from samples.
4. The sample temperature/black panel temperature.
5. The ambient temperature/dry bulb temperature.
6. The relative humidity
7. Details related to sample preparation.
8. The duration of the test.

Under the ISO 105 light fastness test methods, the ambient temperature is not controlled. Varying any of the conditions specified above will lead to inaccuracies in analysis of results, as the standard conditions will not have been employed.

Several different types of fadeometers have been developed [10]. Although the design may vary, there are predominantly two types. These are the xenon arc lamp and the carbon arc lamp. The xenon arc lamp [11] is the artificial light source described in some British Standards test methods. The enclosed carbon arc lamp [12] is described in the American Association of Textile Chemists and Colorists test methods. The xenon arc gives a very similar spectral distribution to that of natural daylight. The carbon arc source gives a much higher intensity in the ultra violet part of the electromagnetic spectrum than is provided by the xenon arc. It is the belief of the AATCC that ultraviolet light has the most marked effect on fading. Early work was carried out using a mercury lamp. A British Standard does exist for this approach [13]. However, this approach is not used in general practice. There is a standard geometry specified for illumination of the sample and the spectral distribution is maintained by the use of a set of borosilicate glass filters. Samples are arranged equidistant around the light source and are rotated throughout irradiation. The sample holder may either be fixed in its position, or may rotate through 180°, after each revolution around the light source. This rotation will cause variation in the humidity and temperature for the exposed surfaces. Thus, when the sample is facing away from the light it will have a higher relative humidity and a lower temperature. Alternation of light and dark periods, as opposed to continuous exposure to light causes an increase in the rate of fading for coloured hydrophilic fibres [9]. This is because the sample cools during the dark period allowing absorption of moisture, (ie conditions of high humidity), which in turn promotes fading [9].

The British Standard BS EN ISO 105:B02-Colour Fastness to Artificial Light specifies the assessment of fading using an accelerated test method. In this case, the artificial light source is a xenon arc lamp. The conditions of temperature and relative humidity are specified. The standard describes four slightly different methods of assessment. In each case, the sample or samples are mounted on a white card, that must be free from optical brightening agents along with the appropriate blue wool standards. The card is then placed in a holder in the fadeometer and the samples faded until a contrast of grey scale 4 is achieved by the sample. This sample is then compared with the blue wool standards. The sample is said to have the lightfastness that corresponds to the blue wool scale sample with the same degree of fading.

Of the four specified procedures, methods one and two have an element of absolute character. Procedures three and four are more comparative. Procedures three and four are more likely to be used for quality control assessment.

Future developments

- BS 1006 UK TP is now published. This standard specifies the preparation of the pigment printed lightfastness standards. It is anticipated that the printed standards will be launched in 1999 as the replacement, in the UK, for the blue wool standards.
- The current pigment printed scale will be developed for values below one unit and above eight units.
- Measurements of the kinetics of change in colour/ light fastness will be carried out using colorimetric techniques. The possible replacement of the grey scale, once appropriate equations have been devised will be considered.
- The development of scales that are appropriate for use by other industries, in accordance with their current practices, will be undertaken. This work will be targeted towards the needs of the paint industry, moulded plastic industry and the automotive industries.

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Acknowledgement

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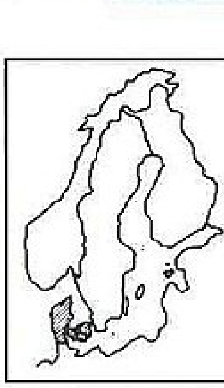

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