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Review Article

Parameters involved in assessment of dry state colour of fabrics from their wet state colour

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One of the parameters that affects the colour appearance of a given material is the moisture content. The wet to dry colour change slows down the process of colour matching because, in present practice, a sample from a dyebath must be dried before it can be assessed. The process would be much more efficient if the colour of the sample when dry could be accurately predicted from the colour of wet sample taken fresh from the dyebath. The dry colour of fabric is affected by parameters such as refractive index of medium and moisture. Studies have been carried out to examine the effect of moisture content on the colour appearance of the dyed textile materials and proposed a geometric model to predict the dry reflectance value from wet materials. The use of refractive index of the embedding medium and the modified Kubelka-Munk equation to predict the dry reflectance value from wet materials have also been studied. In this paper, various parameters that affect the dry colour of fabric, their measurement and various approaches used for the assessment of dry state colour of the fabric from its wet state colour have been reviewed.

Keywords: Kubelka-Munk equation, Reflectance value, Refractive index

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1 Introduction

Colour appearance plays an important role in the production of textile materials. Appearance is a summary of visually perceived attributes. The appearance of an object is the response of a complex interaction of the light incident on the object, the optical characteristics of the object and human perception. It involves all visual phenomena such as colour, gloss, shape, texture, haze, and translucency that characterize the objects.

Colour is associated with light waves specifically their wavelength distributions. These distributions are most often referred to as the spectrophotometric characteristics. Visible wavelengths are those between the violet and red ends of the spectrum, near 400 and 700 nm respectively. The selective absorption of different amounts of the wavelengths within these limits ordinarily determines the colour of objects.

The colour of the object will vary, if any other foreign matter is present in it apart from colouring matter. In the case of textiles, colour of the wet material appears darker than dry material. Several studies have been carried out to assess the dry state colour of the fabric from its wet state.

The objective of the present study is to analyse the effect of moisture, dyeing auxiliaries and refractive indices on the colour of the fabric and various methods involved in the assessment of dry state colour of fabric from its wet state colour.

2 Colour Measurement

Colour of textile material is an important parameter to be presented to the customer. Therefore, the colouration of textiles, its assessment and matching are important phases in production of textile materials. The colour assessment and matching can be done either visually or using instruments such as spectrophotometer. The visual examination of dyed materials can be made by keeping the production

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sample and standard side by side under standardized lighting condition. The human eye and brain have incredible sensitivity to detect even a small colour difference. But the source, illuminating-viewing conditions and surroundings are the parameters, which will have significant impact on the results of visual assessment. Hence, the conditions for the visual colour assessment has to be standardized. To overcome the problems associated with visual colour assessment, instrumental colour measurement and matching are gaining importance in all the industries dealing with the colouration of products. In colour measuring instrument such as spectrophotometer, the colour of an object is measured and represented by spectrophotometric curves, which are plots of fractions of incident light as a function of wavelength throughout the visible spectrum relative to a reference.[1] The typical reference is a white standard that has been calibrated relative to the perfect white reflecting diffuser (100% reflectance at all wavelengths). While colour measuring, in principle the medium of the material is assumed to be the same as the medium of the light and the incident light undergoes absorption, reflection and transmission.[2,3] If the incident light is diffused, there will be either a quantitative change in transmitted and reflected radiations or a change in direction of mass action in the case of reflection. However, the degree of diffusion remains constant.[4,5] But in the case of luminescent material, the absorption and reflection will vary from normal colouring material.[6]

In the textile industry, the most common approach is an adaptation of the theory expressed by Kubelka and Munk in 1931 (ref. 7). This is a two-flux radiation transfer theory that has been developed for optically homogeneous substrates. But the textile material has a definite structure and therefore it cannot be assumed to be a homogeneous layer. Subsequently, Saunderson[8] and Tunstall[9] tried to improve the original Kubelka-Munk model. The theory has also been thoroughly discussed and expanded by Nobbs.[10] Atherton[11] attempted to incorporate collimated beam illumination into the theory. Preston and Tsien[12] proposed a model where the fibre structure is accommodated using the pile of plates approach and the Beer-Lambert law. Some of the authors have also approached to modify the Kubelka-Munk equation. Sokkar *et al.*[13,14] reviewed and expanded the above approach.

In the production process, colour of fabric is assessed either at the end or during the process of dyeing. In both the cases the material has to be completely dried and taken for colour measurement. The colour appearance of a textile material changes with moisture content. Even a small amount of water can dramatically changes the lightness, chroma and hue of the colour.[15]

3 On-line Colour Measurement

In continuous dyeing, the colour assessment is made while processing by reflectance measurement of the fabric at the exit of continuous dyeing range after drying. Keesee and Aspland[16] discussed the causes and magnitudes of colour changes in on-line colour measurement for cotton fabrics dyed with selected reactive and sulphur dyes and finished with a durable press finish. While using on-line colour measurement, it is important that both the temperature and the moisture content on the products are as consistent as possible from side to centre to side and from piece to piece, because the measured colour strongly dependent on both. The colour of the fabric also depends on the amount of water present in it after drying and the chemicals used in finishing process. It has been suggested that the sulphur dyeing on cotton changes the shade quite markedly on ageing.

Wersch [17] discussed about the various parameters involved in on-line colour measurement with respect to machine. The dyeing machine requirements, such as automatic liquor change, constant speed, infrared dryer and uniform drying mechanism, were discussed. The material colour has been analysed at various stages of dyeing and the effect of fabric speed, low residual moisture, high residual moisture, average moisture and temperature on colour and colour difference values studied. He also discussed about on-line liquor pick-up measurement with level correction and control in dyebath. The purpose of on-line pick-up measurement through continuous measurement and logging of the actual liquor consumption rate is to give the production management sufficient confidence to enable it to reduce the amount of excessive liquor formulated without any danger to the production process. He also explained an on-line colorimetry process for measuring the intensity of colour in the wet fabric downstream of the padder. An on-line colorimetry system provides an indication of the distribution of dyestuff over the textile web. Wills[18] discussed the roadblocks in implementing on-line colour monitoring instruments. Compared to laboratory colour measuring systems, on-line systems are more complex and present a wide array of new problems. Inter-instrument agreement, calibration, storing standards, establishing tolerances, linking to remote system and sampling methods are examples of some of the more common problems.

An evaluation is made immediately downstream of the padder, indicating whether the fabric has been uniformly dyed. This is an improvement over conventional systems where such an evaluation is only made at the outlet of the dyeing range. This means that the colorimetry results can be employed for the production control purposes, as has already been confirmed in practice.[19] This system can be further expanded for the implementation of automatic padder control using computer. The data conditioned by a computer for output to the screen and printer are further processed in a computer and then transferred to the padder programmable logic controller (PLC). This PLC then transmits the signals, indicating the necessary pressure changes, to the padder. Line pressure changes in the padder result in a modified colour profile on the fabric and this, in turn, is detected by the colorimeter and fed back to the computer. The relevant tolerances and increments can be preprogrammed into the system as desired.[20]

In continuous dyeing, one of the biggest developments of the last decade has been the automatic measurement and control of moisture or wet pick-up. This type of control is achieved by the use of state-of-the-art non-contact radiation-based moisture measurement device and modern squeeze rolls. Even though this provides a dyer with an opportunity to control, one of the most important parameters in pad dyeing does not facilitate direct measurement of the dye-liquor add-on. Discussion was made about the use of an on-line colorimetry process for measuring the intensity of colour in the wet fabric downstream of a padder. This measurement can be useful in the implementation of automatic control of the nip line pressure for uniformity in colour.[20]

Pleva AF 310 (Germany), a moisture measurement system, is equipped with microwave emission units and detectors opposite to each other, separated by a layer of the fabric to be measured. This unit can be used for monitoring/recording only or, as some companies do, for controlling nip pressure. Since it measures water content, it has no idea about colour. A typical problem of continuous dyeing is tailing due to substantivity of dyes causing change in concentration during fabric run. This instrument cannot detect the dye distribution on the fibre.[21]

4 Effect of Moisture on Colour

It is well known that when light falls on textile material scattering takes place at the surface, which depends on its surface characteristics. In addition to this, light also undergoes diffusion through the material, resulting in absorption and scattering within the material. Finally, the scattered light comes out of the material as diffuse reflection, which depends on the extent of internal scattering that take place.[22, 23] This internal scattering depends on number of dye molecules present and number of other atoms/ molecules present, which may be air, water or chemical compounds.

When dyed textiles are transferred from the dry to wet state, their reflectance properties change; the reflectance reduces[24] (Fig. 1). This drop in reflectance is due to the reduced light scatter, while light absorption remains constant.[25] Frequently this transformation from the dry to the wet state is also accompanied by a shade shift. The drop in reflectance due to moisture depends on the substrate and the reflectance level but not the shade. Allen and Goldfinger[26] found that a decrease in scattering efficiency would provide more opportunity for absorption of light in the sample and thus contribute in its brightness. Dalton *et al.*[15] presented a graphical representation of reflectance changes with varying moisture content and a method of representing all reflectance changes for reactive dyes on wool on a single graph. Moisture measurements and colour readings were taken at approximately 15 min intervals for the first 30 min, then at 20 min intervals for the next 60 min, and finally at 30 min intervals for the next 90 min during drying process. This ensured an

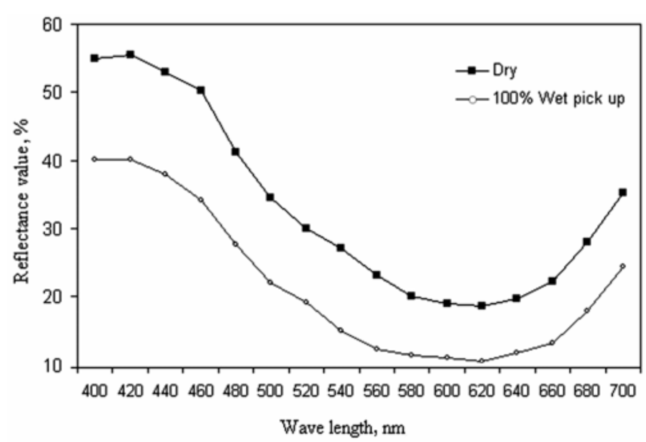

Fig. 1 — Effect of moisture content on reflectance values of fabric dyed with Direct Blue 77

even spread of moisture content readings. A final reading taken 48 h later was used as the dry colour. They concluded that the reflectance change from wet to dry is independent of the colour of the dye used, i.e. wavelength, rather it is related to the dry reflectance at discrete wavelengths. As reflectance changes are the same for dyed and undyed samples, the dye itself can play no part in reflectance changes at different moisture contents. The effect of moisture on fabric colour measurement has also been discussed by Kazmi *et al.*[20] in on-line colour monitoring dyeing process. Lee *et al.*[27] mentioned that the fabric with higher moisture contents appears to be darker in colour than fabric with low moisture contents.

A geometric model was used in the prediction of colour appearance of dry fabrics from their measurement in a wet state.[28] This approach can be applied to on-line colour measurement. The model is based on the basic principles of optics and hence it can accommodate changes of fibre geometry and embedding medium. The potential application of predicting the appearance of dry fabric from their wet state measurement was tested. The results obtained were encouraging for synthetic fibres with low levels of delustrant but when applied to natural or dull synthetic fibres, the model tends to underestimate the reflectance. A study has been carried out by Manian *et al.*[29] with three direct dyes and cotton knitted fabric and the wet and dry colour of these fabrics were analysed. Changes in colour of dyed specimens as they dry was quantified through CIELAB measurements and reflectance spectra.

The effect of moisture on colour of soil and other materials has also been discussed by various authors. A study was carried out to model reflectance changes due to soil moisture in a real field situation using multi resolution airborne spot data. The proposed exponential model was not valid when all soil categories were considered together. However, when fitted to each category, the root mean square error on moisture estimates ranged from 2.0% to 3.5% except for silty soils with crusting problems.[30] Barrett[31] discussed about the overall reduction of reflectance with increasing moisture content in the well drained sandy soils. The colour of the banana pieces was also analysed by Chua *et al.*[32] at various moisture levels and drying temperatures. Moisture effect on visible spectral characteristics of lateritic soils was discussed by Bedidi *et al.*.[33] Bhadra and Bhavanarayana[34] discussed about the estimation of the influence of soil moisture on soil colour. Coleman and Montgomery[35] also discussed about the soil moisture, organic matter, and iron content effects on the spectral characteristics of selected soil. Spectrophotometric measurement of soil colour and its relationship to moisture and organic matter was discussed by Shields *et al.*.[36] A study was carried out to evaluate the surface-soil water content by measuring the reflectance of soil by Skidmore *et al.*.[37]

4.1 Determination of Moisture Content in Fibre

To assess the dry state colour of material, quantification of moisture in the material is necessary. The temperature influences the moisture sorption of cellulose fibres [38] and the chemical as well as physical properties of cellulose also depend on the moisture in the material.[39] Moisture pick-up measurement provides data concerning the water content per unit area of fabric, but it is often found to be the case that uniform moisture levels do not necessarily mean uniform dyeing. Moisture measurement is unable to provide any direct information regarding the actual distribution of dyestuff within the fabric. Determination of moisture content in the material can be done using several methods.

Gregory[40] discussed the mechanism of water vapour diffusion through the fabric and suggested a test for the transfer of moisture. He concluded that the vapour diffusion through fabrics is independent of the rate of passage of air under pressure. Tankard [41] discussed about the determination of water in cellulose by hydration. In this study, the cellulose was allowed to attain equilibrium and then submitted to a gradually increasing pressure. Samples were taken at intervals during the application of pressure, and their composition determined. Using graphical method, the amount of water and other solution in the material was measured. Fourt and Harris[42] analysed the diffusion of water vapour through textiles. They concluded that the resistance towards diffusion of a woven fabric depends on the kind of fibre, the thickness and its tightness of weaving.

Liepins and Kearney[43] discussed the water vapour barriers for aromatic and aliphatic hydrocarbons, nitriles, chlorine-containing compounds and a silane coated paper. A method was described for measuring the water vapour resistance of textiles under variable conditions of relative humidity by Farnworth *et al.*.[44] In this proposed method, the position of the sample in an air gap between a wet and dry surface was varied while keeping all other conditions constant. The resistance was determined by the rate of water loss and the temperature of the water.

5 Effect of Refractive Index on Colour

Coloured objects scatter part of the incident light, but in addition they preferentially absorb certain wavelengths of the mixed radiation. The percentage of the total incident light, which is scattered, depends on the difference in refractive index between coloured objects and surrounding medium.[45, 46]

Devore and Pfund[47] discussed the effect of surrounding refractive index on optical scattering of dielectric powders of uniform particle size and suggested a empirical relationship to determine the particle size for white pigment paints. Garrett and Peters [48] discussed the effect of fibre refractive index on the reflectance of undyed fibres. They measured the refractive index of fibres dyed with various concentrations of dye and concluded that the variation in reflectance with refractive index is small.

The most important reason for a fabric to look darker when wet than in dry is that the ratio of the refractive indices of the scattering particles (fibres) to that of the continuous medium (water or air) has been significantly reduced, which also reduces the scattering efficiency of the system.[49] According to Allen *et al*.[50], if the ratio of the refractive indices of the fibre and the continuous medium is 1, then the sample is black regardless of the other optical properties of the substrate. Also, as the ratio of refractive indices deviates more and more from unity, the sample becomes less and less dark, since the scattering efficiency increases and light is back scattered having had fewer opportunities to be absorbed. Allen *et al*.[51] also discussed the effect of refractive index of the continuous medium on colour. In this study, the light scattering-absorbing substrate used was polyester fabric and the liquid continuous media used was water and 63.7% sucrose solution. The refractive index of continuous medium and textile materials was measured with the Abbe refractometer. A theory was established by them to predict the dry colour of a fabric from its wet colour as a function of the refractive index of the continuous medium.

An approach has been made by Allen and Goldfinger[52] that permit independent determination of all variables, such as coefficient of absorption of the dye, refractive index of the fibre, effect of geometry of the fabric and yarn, and the distribution of the dye within the fibre. The approach is based on 'pile of plates' model. However, unlike the Kubelka method, it leaves open the possibility to consider the geometry of the array constituting the plate. It also permits one to include the effect of the coefficient of absorption of the fibre-dye system, the refractive indices of the fibre, and the distribution of the dye in the fibre on the colour of the textile substrate. Goldfinger *et al*.[53] further discussed the effect of distribution of colourant on the colour of fibres. Based on their discussion, in the wavelength range in which no light is absorbed the distribution of the (ineffective) dye can have no effect and the reflectance ratio between ring dyed material and homogeneously dyed material must be one. If the entire refracted light is absorbed then only that reflected from the fibre surfaces can contribute to the reflectance of the sample and, if there is no change in the refractive index of the ring dyed and homogeneously dyed material, the reflectance ratio for those materials also has to be one. Allen and Goldfinger[54] proposed a new approach to the prediction of the colour of absorbing-scattering substrates such as fabrics by using the optical properties of the fibres and the medium of observation. They also included the refractive index of the fibre and the medium in their model.

Goldfinger *et al*.[55] theoretically assumed that the refractive indices of the dyed and undyed portions of the ring dyed filament to be the same. In refractive index measurement, they did not observe any effect of dye on the refractive index with monochromatic radiation at 436 nm. But they observed the curved light path in the dyed portion, when radiation of 546 nm was used. A gradual change in refractive index with penetration will give the same effect on colour. They observed significant light absorption at 546 nm in the dye-fibre system with the red dye. Lee and Patterson[56] discussed the effect of dye penetration on the resultant colour of polyester fibres using fibre-chop method and analysed the models developed by Garrett and Peters[48] and Allen and Goldfinger [52] with respect to refractive index, diameter of the filaments and the concentration and absorption coefficient of the dye. Manian *et al*.[29] and Tsoutseos and Nobbs [28] also reported that the change in refractive index of fabric is the reason for the change in colour of the fabric in wet condition. Motamedian and Broadbent [57] suggested an optical model to predict the colour depth of an array of filaments, representing textile fabric, with various distributions of dye in either the entire filament assembly or in individual filaments based on the light reflection and refraction in the filament.

5.1 Determination of Refractive Index of Fibre

The refractive index of textile fibres can be determined using several methods, such as double variation method, Becke line method, immersion technique[50], etc. Fox[58] suggested a double variation method for the determination of refractive indices of textile fibres. In this method, the fibre was immersed in a liquid, the refractive index of which is near to that of the fibre. If the indices of the fibre and fluid are the same, the fibre will move to extinction (disappear), indicating a perfect match between fibre and fluid indices. The relative position of the fluid index to the fibre index can be obtained by means of the Becke line. In his further study along with Finch, he suggested a simplified method for determining the refractive indices of fibres which uses as its basis, a photometric match of Becke line intensities emanating from the difference between the maximum and the minimum refractive indices of the fibre and the index of the mounting fluid.[59]

Preston[60] discussed Schroder van der kolk method for rounded cross-section fibres. In this method, the fibre acts as either a positive or a negative cylindrical lens, depending on whether its refractive index is greater or lesser than the surrounding medium. The relation between the density and the refractivity of cellulose fibres with respect to their structure is dealt by Hermans.[61] Heyn[62, 63] proposed central illumination method to measure the refractive index of fibres. In this method, the fibre acts as a lens (concave or convex) with respect to the refractive index difference between liquid medium and fibre. Using microscope the refractive index of the fibre can be measured. Barakat and El-Hennawi[64] used immersion technique and multiple beam fizeau fringes to measure the refractive index of textile fibres.[65,66] Conde *et al*.[67] used refractive near-field (RNF) method to measure the refractive indices of multicore fibres. Zhao *et al*.[68] suggested non-destructive technique for measurement of refractive index of hollow fibres.

6 Assessment of Dry State Colour from its Wet State Colour

The wet to dry colour change slows down the process of colour matching because, in present practice, a sample from a dyebath must be dried before it can be assessed. The process would be much more efficient if the colour of the sample when dry could be accurately predicted from wet sample taken fresh from the dyebath. Several techniques were proposed to predict the dry state colour from wet state colour of textiles.

Prescott and Stearns[69] described method using software for determining the concentration of any dye formula having a fixed ratio of dyes, which will produce the maximum visual effect of an oil stain on opaque fabrics (cotton fabric). An SOB (soil on black) index was also proposed to give the relative visibility of oil on any particular fabric. The small oil spot was measured with the R-cam on a general electric spectrophotometer.[70] The colour difference between the oil stained fabric and the normal fabric was calculated using MacAdam-Friele-Chickering colour difference formula.[71] But the location of the soil in the fabric, influence of illuminating and viewing conditions and the effect of fluorescence on colour have not been investigated in the above study. The effect of pattern has not been studied but it is believed that a pattern would reduce the apparent colour.[72]

Goldfinger *et al*.[49] presented the following empirical equation and experimental results relating the colour of an absorbing-scattering substrate (cellulose triacetate dyed with disperse dye) under two different viewing conditions, that is dry in which case the continuous medium is air and, wet for the sample immersed in water:

$$R_{\mathrm{w}} = R_{\mathrm{d}} \left(\frac{0.12\,(1 - R_{\mathrm{d}})^2}{(0.10 + R_{\mathrm{d}})} - (0.20 + R_d) \right)$$

where R_{w} is the reflectance value in wet state; and R_{d}, the reflectance value in dry state. These measurements have been carried out as exploratory steps in preparation for the development of a general treatment of the light reflectance from an absorbing-scattering sample in which the refractive indices of the scattering particles and the continuous medium appear explicitly. Ratio of the reflectance of the sample immersed in water to that of the dry one plotted against the reflectance of the dry sample (Fig. 2) and the reflectance of the sample immersed in water predicted from equation plotted against the measured values (Fig. 3).

Allen *et al*.[51] compared a plot of $R_{\mathrm{w}} / R_{\mathrm{d}}$ or $(1\text{-}R_{\mathrm{d}}) / (1\text{-}R_{\mathrm{w}})$ against R_{d}. They do, however, cast strong doubt on the validity of the Kubelka-Munk theory to assess the dry reflectance value of wet sample. Allen *et al*.[50] also tried to establish a theory to predict the dry colour of a fabric from its wet colour as a function of the refractive index of the continuous medium. But it was not achieved because of the inadequacy of the

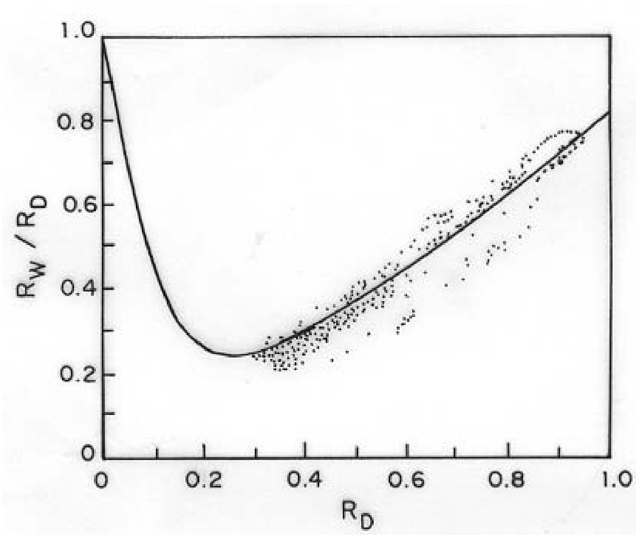

Fig. 2 — Ratio of the reflectance of the sample immersed in water (R_w) to that of the dry one (R_D) plotted against the reflectance of the dry sample

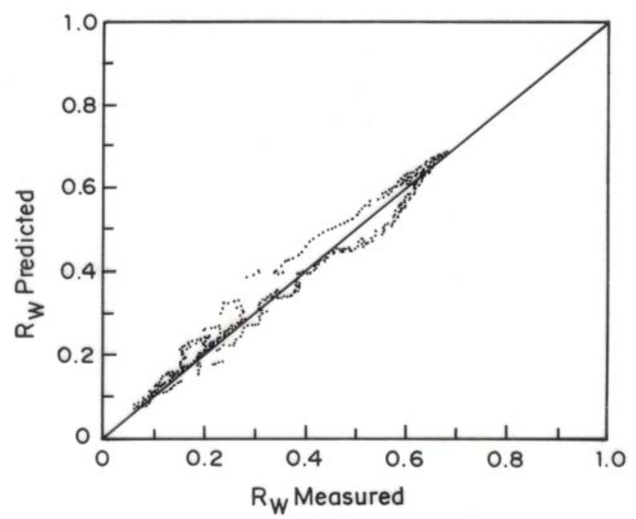

Fig. 3—Reflectance of the sample immersed in water (R_w) predicted from equation plotted against the measured values

following Kubelka-Munk theory at low reflectance values:

$$\frac{S_d}{S_w} = \frac{(m_d^2 - 1)(m_w^2 + 2)}{(m_d^2 + 2)(m_w^2 - 1)}$$

where S is the scattering coefficient; m the ratio of the refractive index of the scattering particles to that of the continuous medium; and subscripts d and w indicate dry and wet condition respectively. However, at high reflectance the prediction is possible. They also have concluded that one will be able to predict the dry colour from the wet colour on the basis of the scattering efficiency of a substrate in the particular medium. Noechel and Stearns[73] analysed the inadequacy of Kubelka-Munk equations.

An empirical equation was developed, relating wet and dry reflectance values for the common textile fibres by Smith.[74] The results of wet and dry colour measurement obtained are furnished. The developed equation varies with fibre type, but independent of colour. In general, it can be fitted to wet and dry reflectance relationship. He also suggested that if the samples in the holder are transparent, an accurate equation could be developed provided that a constant thickness is used. But the refractive index difference across the boundary was not included in the equation. A substrate specific mathematical relationship between moist and dry reflectance was calculated on the basis of several measurement values for cotton and polyacrylonitrile in the form of a double-logarithmized polynomial of fifth order, which makes it relatively simple to convert the measurement values, obtained with moist material to those of dry material.[75] A relationship, as shown below, has been demonstrated between the ΔL^*, ΔE^* values of dyed cotton samples and their %moisture content as it dries after dyeing by Manian *et al.*[29]:

$$\Delta L^* = -11.897 + 12.202\,(X) - 1.85\ln(X) + 9.322\times10^{-2}\,(X)0.5 - 9.942\,(X)^{0.5}$$

$$\Delta E^* = 9.459 + 9.422\,(X) + 1.27\ln(X) + 1.567\times10^{-3}\,(X)^2 + 8.081\,(X)^{0.5}\ln(X)$$

where X is the moisture content, R^2 value of ΔL^* model is 0.9059 and of ΔE^* model is 0.9351.

Jahagirdar *et al.*[24] carried out a study with five different reactive and direct dyes on mercerised cotton fabric and established the following wet-dry reflectance relationship:

$$R_d = 3.03R_w^3 - 4.14\,R_w^2 + 2.57R_w$$

$$\left(\frac{K}{S}\right)_{dry} = \frac{[1 - (3.03\,R_w^3 - 4.14\,R_w^2 + 2.57\,R_w)]^2}{2\,(3.03\,R_w^3 - 4.14\,R_w^2 + 2.57\,R_w)}$$

The numerical relationship between the reflectance of the same coloured substrate in the dry state (in air) and in the wet state (in water) was established, which can be used as an analytical tool to predict the reflectance values of the dry sample from the reflectance values of the same sample when it is in the wet state. This relationship can be fitted to all the samples for which *K*/*S* function is linear and non-linear.

7 Conclusions

A comprehensive review of various findings on assessment of dry state colour of fabrics from their wet state colour is outlined in this paper. The studies show that the moisture present in the fabric not only makes the fabric darker but also affects the lightness value. These factors significantly affect the CIE 1976 LAB colour parameters. Attempts by various researchers have demonstrated the quantitative relationship between the change in lightness value and the colour deviation with moisture content of the fabric. Several authors have also discussed the effect of refractive index and moisture content on wet colour of fabric and the determination of refractive index of the fibre.

The current status on dry colour prediction from wet colour of textile materials stands with respect to the presence of water in the material. In actual situation, so many dyeing auxiliaries other than water are present in the material, which has a role to play in deciding the wet colour of the material. The distribution of water and other agents in the fabric could also affect the wet colour. No attempt has been made so far taking into account the above aspect to predict the dry colour of the material from wet colour under various conditions.

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