AN EVALUATION OF THE EFFECT OF DETERGENT, WASH TEMPERATURE AND DRYING ON THE COLOURFASTNESS OF INDIGO AND AZO DYED COTTON FABRICS

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By

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This work is dedicated to............

my son Thapelo Lenka ....

and my husband Pesa Lenka

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CHAPTER 1

INTRODUCTION

1.1 Introductory remarks

Colour is an important factor when buying clothes. Textile items that exhibit significant change of colour after home laundering consistently rank as undesirable in consumer opinion surveys. Marketing research shows that unsatisfactory fading performance is significantly important to consumers, regardless of which consumer age groupings are surveyed. (Ankeny *et al.* 2001:19). In recent years consumers experienced poor colourfastness to laundering, particularly cotton goods dyed with reactive dyes (Aspland 2000:206).

According to Ankeny *et al.* (2001:19) textile industries have vested interest in dye durability. Dye suppliers and chemical companies that manufacture resins, catalysts, binders, print pastes, softeners and other auxiliaries that are applied to textile materials, are concerned about the retention of colour.

Indigo has been a popularly used dye for thousands of years. In fact, it is thought that this ancient dye was the first naturally occurring blue colourant discovered by primitive man in his search to expand his limited spectrum of natural, earth-tone shades. Of all the natural dyes that man has used to add colour to his environment, indigo has the richest history (Travis and Edelstein 1990:18).

Dyes are classified into three groups according to how they are applied to the fabric; vat dyes, mordant dyes and direct dyes (White 1989:3). Indigo is an example of a vat dye and was originally obtained from the fermentation of the woad plant. Today, indigo used in commercial dyeing of denim yarn no longer is of natural origin. Synthetic indigo has replaced the natural dye worldwide. However, compared to the fastness standards exhibited by modern vat dyes, indigo is completely inferior: the dye has poor crock fastness, poor light fastness, poor wash fastness, poor fastness to chlorine bleach and poor fastness to atmospheric contaminants (Intersectional 1989:25). Authors pointed out that if it were not for the persistence of the denim fashion, indigo would hardly be produced or used at all. It is, however, the poor fastness of indigo that is responsible for the attractive blue colour that develops after repeated laundering of denim fabrics. In view of the unrelenting popularity of denim and the long history of the use of indigo in dyeing denim yarn, it is surprising that the application of indigo to cellulosic fibre still remains largely an art, not a science (Intersectional 1989:25). Azo dyestuff, on the other hand, allows the manufacturer to have red, yellow, brown and other colours. Compared to indigo dye, azo dyestuff offers good colourfastness to washing, light, chlorine and peroxide bleaches but poor resistance to crocking (Wang 1999:47).

The importance of cleansing to consumers has been demonstrated by the use of detergent with good characteristics such as soil removal and dispersion properties (Emsley 1998:22). Researchers intensively investigated the effects of detergent ingredients over a number of years. The effectiveness of unbuilt and built liquid detergents of varying formulations in cleaning a standard soiled fabric in soft water was evaluated (Brown, Cameron and Meyer 1993:145). The effectiveness of non-phosphate and phosphate containing powder detergents of varying formulations in cleaning a standard soiled fabric in soft water was also evaluated (Brown, Cameron and Meyer 1993:145).

Laundry detergents that are used worldwide are classified as heavy-duty products suitable for heavily soiled fabrics and light-duty products, developed primarily for hand washing and light soiled clothing (Cameron and Brown 1995:86). Detergents for household and institutional use contain several substances such as surfactants, builders, bleaching agents and auxiliary agents (Jakobi and Lohr 1987:41; Schlager 1994:248; Longman, 1975:2; Davidsohn and Milwidsky, 1972:1; Aspland 2000:206).

Surfactants are the active ingredients of a detergent (Schlager 1994:247). Their main function is to make calcium and magnesium less available so that they do not interfere with the surfactant action. The most common builders used in laundry powders are carbonates, phosphates and zeolites. These chemicals increase the efficiency of the surfactants as well as holding minerals in hard water in solution preventing them from precipitating out. It should be noted, however, that bleaches do not clean, but make fabrics whiter. Bleaches function by oxidizing colouring matter into colourless compounds (Brown *et al.* 1993:145).

Webb and Obendorf (1987:640) discovered that phosphate built powder detergent with anionic surfactant removes oily and particulate soil from yarn surface more than the carbonate built powdered detergent with non-ionic surfactants. Zhou and Crews (1998:19) claimed that laundering fabrics with detergent containing optical brightening agents might improve the sun blocking properties over the course of repeated washing and wearing. Umber, Brown, Cameron, Meyer, Powell and Sisco (1992:151) found that the addition of a builder improved the cleaning efficiency of a surfactant.

1.2 Problem statement

Basotho women use seshoeshoe to make their traditional dress. Seshoeshoe is a cotton fabric brightly coloured in blue, red, brown or yellow with a white pattern printed on it. The typical white pattern is printed on it with a discharge printing process. Basotho women are often dissatisfied with colour loss that they experience from this cotton cloth. Several factors may affect colour loss in seshoeshoe cotton fabric. Basotho women wash seshoeshoe with detergent, use different water temperatures for the washing process and often dry these clothes for several hours in full sunlight. If the most harmful factor or factors could be determined, it might be possible to recommend a better laundry procedure. According to Jakobi and Lohr (1987:397) the criteria for investigating colour change require between twenty-five and fifty wash cycles.

Several researchers (Brown, Cameron, Meyer and Umber 1991:215, Tinsley, Byne and Fritz 1991) suspected that a number of factors such as wash cycles, detergent type, water temperature, drying methods and fabric finish might be the cause of colourfastness problems.

Saito, Minemura, Nanashima and Kashiwagi (1988:450) concluded from their investigation that environmental factors controlling the colour fading of dyes are light, oxygen, water and heat. In their investigation they discovered that light is the most common cause of colour fading. Perenich and Epps (1986:25) found that the amount of chlorine in water used for laundering influences colour change. In a study conducted by Williams and Horridge (1996:156) it was discovered that laundry pre-treatment on soiled, naturally coloured cotton altered the colours of the fabrics. Research conducted by Carver and Wylie (1980:96) revealed that an increase in the exposure of fabric samples to laundry treatment and environmental factors cause more discolouration and yellowing.

Although research reports that detergent type, water temperature and drying methods may have an effect on colourfastness, no information is available on the effect of detergent, wash temperature and drying on the colourfastness of indigo and azo dyed cotton fabric used by the Basotho in their traditional dress. Apart from the role detergents play in colourfastness, it is suspected that different brands of detergent and the type of dye might react differently on fabrics (Ohura, Katayama and Takagishi, 1991:242; Swaine, 1993:4).

Based on the above it is evident that there is a need to determine the effect of different factors on the colourfastness of indigo and azo dyed cotton fabrics used by the Basotho in their traditional dress. Findings from this research would be valuable to both industry and the Basotho nation at large.

1.3 Research objectives

The broad aim of the research was to evaluate the effect of detergent, wash temperature and drying method on the colourfastness of indigo and azo dyed cotton fabrics known to Basotho women as seshoeshoe. The evaluation of the results could be determined by the repeated laundering of indigo and azo dyed seshoeshoe cotton fabric using detergent A and detergent B and water without detergent (control) in up to fifty wash cycles.

1.3.1 Specific Objectives

- To determine the effect of laundry wash cycles on the colour loss of indigo and azo dyed cotton fabrics.
- To determine the effect of different detergents on the colour loss of indigo and azo dyed cotton fabrics.
- To compare indigo and azo dyed fabrics for colour loss.

- To determine the effect of drying indoors and outdoors in full sunlight on colour loss of indigo and azo dyed cotton cloth.
- To compare the effect of different water temperatures on the colour loss of indigo and azo dyed cotton fabric.
- To determine the staining of cotton, polyester, acetate, nylon, wool and viscose rayon washed with the experimental cloth.
- To determine the amount of crocking that takes place in the dry and wet state of indigo and azo dyed cotton cloth.

1.4 Variables

1.4.1 Independent Variables

The independent variables were the detergent type, number of wash cycles, dyestuff, colour of the experimental fabrics, wash temperature and drying used in this study.

1.4.2 Dependent Variables

The dependent variable is the colourfastness of azo and indigo dyed cotton fabrics.

1.5 Hypotheses

The null hypotheses were:

$H1_0$: The number of wash cycles will cause no difference in the colour loss of azo and indigo dyed cotton fabrics.

$H2_0$: The detergent will not cause colour loss on indigo and azo dyed cotton.

$H3_0$: There will be no difference in colour loss between azo and indigo dyed cotton fabric.

$H4_0$: Drying outdoors in full sunlight and indoors will cause no difference in the colour loss of azo and indigo dyed cotton fabrics.

$H5_0$: Different wash temperatures will cause no difference in the colour loss of indigo and azo dyed cotton fabrics.

$H6_0$: There will be no staining of cotton, polyester, nylon, wool, acetate and viscose rayon washed with the azo and indigo dyed cotton fabrics.

$H7_0$: Crocking of indigo and azo will not take place in the wet or dry state.

1.6 Conceptual framework

1.6.1 Flow chart of the experimental procedure

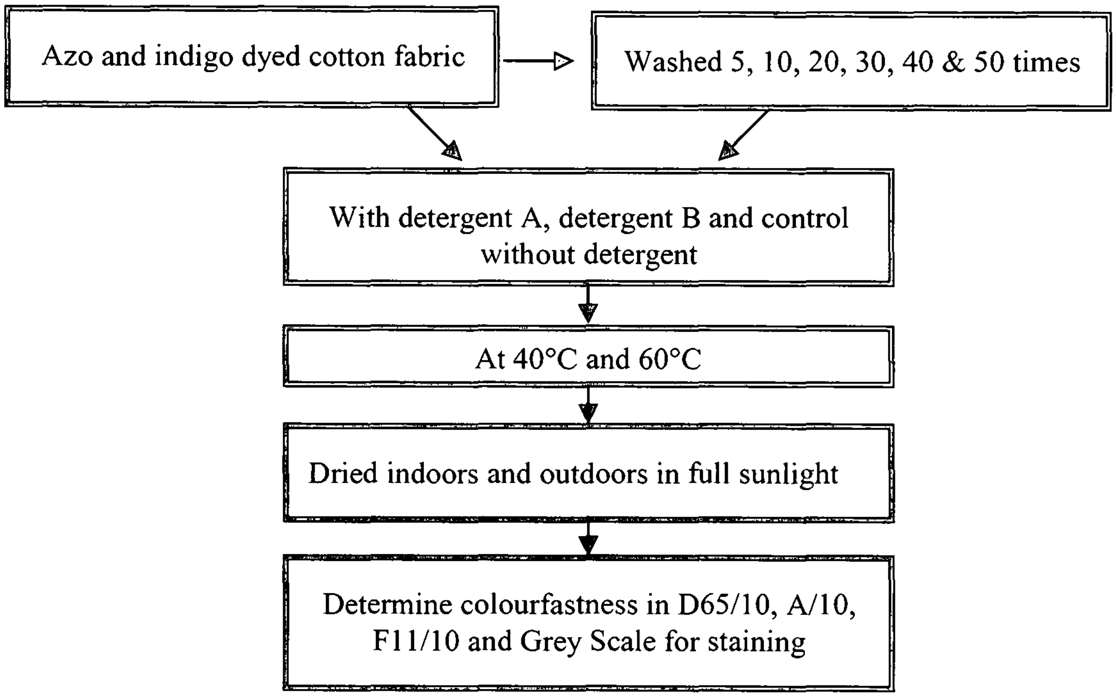


Figure 1.1 Flow chart of the experimental procedure

The flow chart shows that the influence of the detergent, wash temperature, number of wash cycles and drying method on the colourfastness of azo and indigo dyed cotton fabric was investigated in this study.

1.6.2 Key Terms

1.6.2.1 Azo dyes

Dyes that produce colour as a result of a chemical reaction in the fibre between a diazonium salt and a naphthol compound (Joseph 1986:324).

1.6.2.2 Bleaching

Bleaching means the inducing of any change towards a lighter shade in the colour of an object. Bleaching removes stains that are not removed by ordinary washing processes but are amenable to bleaching (Kay 1995:40).

1.6.2.3 Colourfastness

The resistance of a textile fibre to change in any of its colour characteristics. A transfer of its colourants to adjacent material as a result of exposure to laundering treatment, sunlight, rubbing, perspiration and atmospheric pollution (White 1989:2 and Mehta 1984:28).

1.6.2.4 Crocking

The transfer of colourants from the surface of a coloured yarn or fabric to another surface or to an adjacent area of the same fabric principally by rubbing (AATCC 1990:196).

1.6.2.5 Detergent

A chemical compound formulated to remove soil or other material from textiles (Kay 1995:28.

1.6.2.6 Dyes

Coloured organic compounds used to impart colour to fabrics (Kadolph, Langford, Hollen and Saddler 1993:18).

1.6.2.7 Indigo

A blue dye that was obtained from the plant genus *Indigofera* (fermentation of a woad plant) (Travis 1990:18).

1.6.2.8 Re-deposition

Soil re-deposition may be defined as the deposition during the wash process of that soil which, having been removed from fabrics and sometimes dispersed into small particles is deposited back on to the same or accompanying fabrics (Bevan 1980:69).

1.6.2.9 Nonanoyloxybenzene Sulfonate (NOBS)

NOBS is an activated oxygen bleach that has a significant advantage over stain removal and whitening power (McLean 1999:42; Moe 2000:79 and Wang 1999:46).

1.6.2.10 SES (∝-Sulphonate)

Fatty Acid Esters are important anionic surfactants that are distinguished for their stability (Kay 1995:34).

1.6.2.11 FES (Alkyl Ether Sulfates)

FES are anionic surfactants that exhibit unique characteristic, including low sensitivity to water hardness, high solubility and storage stability at low temperature in liquid formulation (Jakobi and Lohr 1987:54).

1.6.2.12 OBAs (Optical Brightening Agents)

Optical brightening agents are common additives to home laundering detergent formulations that enhance whiteness of textiles by ultraviolet excitation and re-emission in the visible blue range of the electromagnetic spectrum (Zhou and Crews 1998:19).

1.6.2.13 PCAs (Poly Carbolic Acids)

The poly carbolic acid catalyst combined with an inorganic or an organic catalyst imparts durable-press properties in cotton fabric (Schramm and Rinderer 2000:50).

1.6.2.14 1,2,3,4- Butane-Tetra Carboxylic Acid (BTCA) or Citric Acid (CA)

These are examples of PCAs that offer an alternative to the formaldehyde-emitting N-methylol compounds such as dimethylol-dihydroxyethyleneurea (DMDHEU) as cross-linking agent (Schramm and Rinderer 2000:50).

1.7 Research Plan

The main objective of the study is to evaluate the effect of detergent, wash temperature and drying method on the colourfastness of indigo and azo dyed cotton fabrics. The relevance and relationship of detergent, wash temperature and drying outdoors and indoors are discussed in Chapter 1. In an effort to explore the study, a literature review was conducted (Chapter 2) to find insight in the factors that affect colourfastness. Detergent ingredients and their functions as well as their influence on cotton properties are discussed in Chapter 2. This is followed by the structure of cotton fibre and the type of finishes that are applied to cotton.

The experimental procedure (Chapter 3) describes the type of detergent, fabric, laundering equipment used as well as the method used to assess colour on staining, crocking and laundering. The results and a discussion of the results are presented in Chapter 4. The effects of the detergent, wash temperature and drying on azo and indigo dyed cotton fabrics are described in terms of data obtained on colour loss. In Chapter 5, conclusions are drawn and recommendations are based on the findings obtained in the study.

CHAPTER 2

LITERATURE REVIEW

Cotton is the most important apparel fibre. It provides a set of properties that leads to acceptable fabric performance to textile end users. Cotton has a pleasing appearance, comfort, easy care, moderate cost and durability that makes it ideal for warm-weather clothing, active sportswear, work clothes, upholstery, draperies, area rugs, towelling and bedding (Smith and Block 1982:76). Considerable research has been conducted on the effect of detergent on the colourfastness of dyed/printed cotton fabric (McLean 1999:42). It has been reported by most researchers that a number of factors such as wash cycles, detergent type, water temperature drying method as well as fabric finish have an effect on textile degradation during laundering (Carver and Wylie 1980:97; Perenich and Epps 1986:28; Jakobi and Lohr 1987:103).

Chapter 2 is a review of related literature. It gives an insight into household detergents and their effect on the colourfastness of dyed cotton fabrics. In it detergent ingredients and the role they play in textile fabrics are discussed. The structure of the cotton fibre and its relation to fabric properties, basic finishing processes, the application of colour as well as the evaluation of colourfastness on indigo and azoic dyed cotton fabrics are also considered.

2.1 Detergents

The word detergent means something that cleans, and detergents work with water to make something clean (Moore 1970:2). Kay (1995:28) defines detergent as any material which exerts a cleaning action. In Kay's opinion water alone or solvents such as perchlorethylene are also detergents. They are found in the form of tablets, powders, liquids and flakes for all kinds of washing.

Detergents have evolved in the past few decades due to changes in consumer needs and the introduction of new technology (McLean 1999:42). Consumers' search for better performing products combined with new technology has led to the emergence of detergents with good characteristics including soil removal, low sensitivity to water hardness and dispersion properties. Detergents should have a soil anti-re-deposition capability, high solubility, wetting power, neutral odour, low intrinsic colour, storage handling characteristics, minimal toxicity to humans, favourable environmental behaviour, assured raw material supply, and should be economical (Emsley 1998:22).

Detergents fall into two main categories. Soap, the earliest manufactured detergent, includes household soaps, toilet soaps, soap powders, flakes, and special hard soaps as well as powders for use in industry. The second category is that of soapless detergents, manufactured in the form of washing powders and liquids for clothes, dishes and other household articles (Moore 1970:2).

According to Bloomfield (2000:1) soap is derived from fats or oils and consists of positively charged sodium ions and negatively charged molecular chains. Each negative ion's charge is located at one end, where its non-polar hydrocarbon chain ends in a polar carboxyl group. When soap is added to water, its sodium ions dissolve, and the negatively charged chains form micelle. The chains also coat the surface of water molecules, reducing their surface tension and allowing them to penetrate fabrics (Bloomfield 2000:1).

Soap works poorly in hard water (Schlager 1994:247 and Bloomfield 2000:1). The positively charged calcium, magnesium and iron ions in hard water bind to the negatively charged end, interfering with micelle formation. Detergents, however, can handle hard water. They have synthetic polar groups such as sulphonate or ethoxy sulphate attached to their hydrocarbon chains. Bloomfield (2000:1) added that even though synthetic groups carry a negative charge, they are only weakly attracted to the ions in water and therefore continue to clean well by dislodging and dispersing dirt particles.

2.1.1 Soapy Detergents

Moore (1970:8) stated that fats and oils used in soap-making are described chemically as triglycerides, that is, they consist of one molecule of glycerol, combined with three molecules of fatty acids. The aim in saponification (the chemical name for soap-making) is to break down the triglyceride oil with an alkali. The glycerol is freed and the alkali combines with the released fatty acid. The resulting molecule has a carboxyl head group (hydrophilic part) and a long hydrocarbon tail (hydrophobic part) (Schlager 1994:247).

Moore (1970:8) added that one example of a hard soap would be sodium palmitate, where the head of the molecule consists of sodium carboxylate (COONa), while the tail consists of a chain of fifteen carbon atoms, with thirty-one hydrogen atoms linked around it. Soft soaps have potassium instead of sodium in the head group, and they are made of liquid oils, which have a different mixture of molecular tails.

2.1.2 Soapless Detergents

The majority of soapless detergents are anionic, like soap. The tail of their molecules consists of a long hydrocarbon chain, but the head is sulphonate instead of carboxyl. Most of the anionic sulphonate is made of sulphonating alkylbenzene, a hydrocarbon with a benzene ring. The presence of benzene makes sulphonation easier (Moore 1970:8).

Detergents that are currently used worldwide are classified into groups such as heavy-duty or all-purpose detergents, speciality detergents, and laundry aids (Jakobi and Lohr 1987:103). Lloyd and Adams (1989:80) contended that detergent powder remains the dominant product in Europe and Africa. Lloyd and Adams added that consumers have a choice between light-duty powders specially formulated for the care of coloured and delicate fabrics and general-duty powders with built-in softeners and antistatic action. It provides high-cleaning efficiency and utilises sophisticated blends of polymers to prevent soil re-deposition and fabric incrustation. It should be noted, however, that in developing countries like Lesotho, the choice of detergent is limited.

Lloyd and Adams (1989:80) stated that advances in the way that powders are manufactured have led to powders that are more concentrated, so that a lower-volume dosage can still provide the same concentration of active ingredients in the wash. Brown *et al.* (1993:146) stated that laundry powders continue to make up the bulk of sales in detergents accounting for 60% of the market. Even in the year 2003 detergents available to consumers are mainly powders.

Liquid detergent has been a popular product in the United States and Australia for many years (Jakobi and Lohr 1987:10; Lloyd and Adams 1989:80). In Europe however, the current restriction on the performance of liquid products is the instability of bleaches, but in wash cycles up to 50°C liquids provide an excellent general cleaning and good removal of oily and proteinaceous soils. It has been noted that several companies in the United States and Europe offer laundry products in sachets. These eliminate the need to measure the dose of product, reduce dustiness and spillage and by the separation of components offer the possibility of very effective delivery of a range of technical benefits, including improved cleaning, softening and static control (Lloyd and Adams 1989:80).

2.2 Active detergent ingredients

Textile articles during their use become soiled and most will be subjected to some form of washing process - either a hand-wash for delicate ones such as wool and silk, or a laundering, in a typical domestic washing machine for cottons, synthetics, and blends of it. During this laundering process the article comes into contact with a sophisticated "cocktail of chemicals," introduced via the detergent. A typical European domestic powder detergent will contain anionic and non-ionic surfactants, builders (to remove calcium and magnesium ions), bleaching agents (usually an inorganic source of hydrogen peroxide), pH-control agents, enzymes, optical brighteners, sequestrants, and perfumes (Phillips and Scotney 2002:50; Schlager 1994:248; Longman 1975:2; Davidsohn and Milwidsky 1972:1).

2.2.1 Surfactants

The most common combination of ingredients found in laundry products is that of surface-active agents ("surfactants") (Lloyd and Adams 1989:77; Emsley 1998:22 and Schlager 1994:247). Surfactants constitute the most important group of detergent components, and are present in all types of detergents. They are water-soluble surface-active agents comprising of hydrophobic portions (usually a long alkyl chain) attached to hydrophilic or solubility-enhancing functional groups. Examples of the surfactants mostly used include anionic, nonionic, cationic and amphoteric surfactants (Kay 1995:33 and Kiwi Web 2000).

2.2.1.1 Anionic surfactants

This is the largest class of detergents in which detergency is vested in the anion, which has to be neutralised with an alkaline or basic material before the full detergency is developed (Dilks and Domiano 2000:2 and Davidsohn and Milwidsky 1972:13). Detergent cleans because each molecule consists of a hydrogen chain and a carboxylic group (fatty acids). The carboxylate end of the detergent molecule is hydrophilic (attracted to water) while the hydrocarbon end of the molecule is hydrophobic (repelled by water) and attracted to the oil and grease in dirt. The hydrophobic end of a detergent molecule attaches itself to dirt and the hydrophilic end attaches itself to water. The dirt attached to the carboxylate end of the molecule is chemically dragged away from the clothes being cleaned and lands into the wash water (Schlager 1994:247).

Anionic surfactants are the most common agents in detergents designed for laundry (Dilks and Domiano 2000:2; Kay 1995:34 and Jakobi and Lohr 1987:47). They include Alkylbenzenesulphonates (LAS) that have excellent foaming characteristics, and are of great importance to its use in detergents. Despite its high solubility, LAS is sensitive to water hardness. The detergency power of LAS diminishes as the hardness of water increases. The second class of surfactants is Alkanesulfonates (SAS). Sodium Alkanesulfonates are compounds that nearly resemble LAS in detergency properties, therefore they can be substituted for LAS in most formulations.

The third group is the ∝-Olefinsulfonates (AOS), which has an advantage of showing little sensitivity to water hardness. Fourth are the Alkyl sulfates (FAS), also known as fatty alcohol sulfonates. They are known for easy care of fabrics and as components of auxiliaries. Fifth are ∝-Sulphonate Fatty Acid Esters (SES), which are important anionic surfactants. Apart from their good performance characteristics, they are distinguished by their stability, since the presence of the neighbouring sulfonate group reduces any tendency towards hydrolysis of the ester function. Lastly are Alkyl Ether Sulfates (FES). These exhibit unique characteristics, including low sensitivity to water hardness, high solubility, and storage stability at low temperature in liquid formulation (Jakobi and Lohr 1987:54).

2.2.1.2 Nonionic surfactants

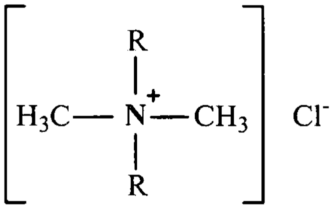
Nonionic surfactants do not ionise and are therefore extremely stable under any conditions likely to be encountered in laundry processing, making them good wetting and emulsifying agents and useful for stain removal processes (Dilks and Domiano 2000:2 and Kay 1995:37). Jakobi and Lohr (1987:56) stated that an important advantage of nonionic surfactants that are based on poly (alkylene glycol) ethers as compared to ionic compounds', is that a proper relationship can be achieved easily between the hydrophobic and hydrophilic portions of the nonionic surfactants. For example the hydrophilic portion of the molecule can be extended gradually by the stepwise addition of the ethylene oxide group. This leads to the stepwise increase in hydration and corresponding successive increase in solubility.

Nonionic surfactants display very high detergency performance, even at relatively low concentrations. They function as foam boosters, adding desired stability to the foam produced by detergents prone to heavy foaming (Dilks and Domiano 2000:2-3).

2.2.1.3 Cationic surfactants

These are compounds in which the important members are essentially ammonium salts with organic groups substituted for hydrogen atoms. The materials are cation active (ionise or dissociate), they do not hydrolyse and can be used effectively in hard water

(Dilks and Domiano 2000:2 and Kay 1995:36). The most common (indicated by the formula) are:



$$\left[H_3C-\overset{R}{\underset{R}{N^+}}-CH_3 \right] Cl^-$$

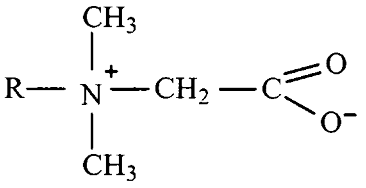
Dialkyldimethylammonium chlorites (Jakobi and Lohr 1987:42)

Cationic surfactants display a behaviour opposite to that of anionic surfactants as regards charge relationships on solids. Since the molecule bears a positive charge, their absorption reduces the negative potential of solids present in aqueous solution, thereby reducing mutual repulsion, including that between soil and fibres. The use of high surfactant concentrations therefore causes a charge reversal. Solid particles become positively charged, resulting in repulsion. Soil removal can be achieved if adequate amounts of cationic surfactants are present and if their alkyl chains are longer than those of comparable anionic surfactants (Jakobi and Lohr 1987:60).

Dilks and Domiano (2000:2) noted that cationic surfactants are employed in laundry and cleansing agents for the purpose of achieving special effects such as application in fabric softeners, antistatic agents and microbicides. Reactions between anionic and cationic surfactants produce neutral salts with low water solubility. Nonionic surfactants are more tolerant of the cationic surfactants. A mixture of the two is used in speciality detergents intended to have a fabric softening effect (Kay 1995:37).

2.2.1.4 Amphoteric surfactants

These are compounds of the alkylbetaine or alkylsulfobetaine type, which possesses both anionic and cationic groups in the same molecule, even in aqueous solution, the formula for which, is:



Betaines (Jakobi and Lohr 1987:42)

They have excellent detergent properties, but are rarely employed in specialty detergents because of economical reasons (Jakobi and Lohr 1987:63).

2.2.2 Builders

In addition to surfactants, modern detergents contain several other ingredients. Among the most significant are builders (Schlager 1994:248). The category of builders is comprised of several types of material including specific alkaline substances such as sodium carbonate, potassium carbonate and sodium silicate, complex agents like sodium diphosphate, sodium triphosphate or nitrilotriacetic acid (NTA) and ion exchangers, such as water-soluble poly carboxylic acids and insoluble zeolite (Jakobi and Lohr 1987:63).

Sodium carbonates soften water and provide high alkalinity by precipitation of calcium and magnesium carbonates when the pH of the solution is less than nine. Sodium bicarbonate will neutralise any free caustic alkalinity (Dilks and Domiano 2000:3).

Schlager (1994:248) and Umber *et al.* (1992:151) outline the main functions of builders as follows:

- Holding minerals from hard water in solution preventing them from precipitating out.
- Emulsify grease and oils into tiny globules that can be washed away.
- Builders have a good soil anti-redeposition capability.
- They prevent incrustation on textiles.
- Builders buffer the wash solution pH to maintain alkalinity.
- Some builders like sodium silicate inhibit corrosion and help assure that the detergent will not damage the washing machine as well.

- It contributes to the chemical balance of wash water, making sure that it conduces to effective washing.

2.2.3 Bleaching agents

The term bleach can be taken in the widest sense to include the inducing of any change toward a lighter shade in the colour of an object. Physically this implies an increase in the reflectance of visible light at the expense of absorption (Jakobi and Lohr 1987:77). Until the late 1980s, the only effective laundry bleach available to consumers was chlorine bleach (McLean 1999:42 and Moe 2000:79). Chlorine bleach is still utilized today as a separate additive product, but there are limitations. According to Moe (2000:79) and McLean (1999:42) chlorine bleach provides high levels of whitening and disinfectant properties. It also imparts fading on many coloured fabrics that restricts its practical use to white items only.

A second type of bleach used is oxygen bleach or colour-safe bleach. This class of bleach delivers hydrogen peroxide to the wash (McLean 1999:42 and Moe 2000:79). Hydrogen peroxide offers colourfastness, fabric safety and ease of use. Recent research indicates that even oxygen bleach causes colourloss as a result of alkaline hydrolysis of dye-fibre bonds, oxidative fading of the dye chromophore by peroxides and also cellulose degradation (Sugane *et al.* 2001:223).Wang (1999:46) stated that there are two types of oxygen bleach used in detergents, namely non-activated and activated. Activated and non-activated detergents use sodium perborate or sodium per carbonate as the oxygen bleach source.

Activated oxygen bleach containing detergents convert hydrogen peroxide to a bleach species known as nonanoyloxybenzene sulfonate (NOBS), a hydrophobic activator (McLean 1999:42; Moe 2000:79 and Wang 1999:46). Activated oxygen bleach delivers significant improvements across a wide range in stain removal as well as overall whitening. Aspland (2000:206) claimed that the inclusion of perborate may be the reason for the colourloss that consumers experience with cotton goods.

NOBS/peroxide bleach system achieves a significant advantage over chlorine bleach by striking a balance between stain removal and whitening power, while allowing other detergent components such as brighteners and enzymes to function as intended. Dye fading profiles are vastly improved for NOBS/peroxide vs. chlorine bleach and, when considering the impact of chlorine in tap water and certain dye transfer situations, NOBS/peroxide is actually better for fabric colour care than detergents containing no bleach at all (Moe 2000:81 and Thiry 2000:20).

McLean (1999:42) noted that NOBS is not used in Europe because of the incompatibility with the rubber hoses of European washing machines. It is estimated that over 70% of domestic washing in Europe is carried out at 50°C or lower, although it is not uncommon for some coloured cotton items to be laundered at 60°C. In the United States washing at temperatures below 35°C (and at much higher liquor ratios than used in Europe) is quite common.

According to McLean (1999:42) the trend to lower washing temperatures has developed because of energy-saving considerations and the increased use of coloured articles (with their associated finishes), particularly for leisure and sportswear articles. Since hydrogen peroxide is most effective for stain removal at temperatures in excess of 70°C, a bleach activator needs to be used to wash efficiently at lower temperatures.

The activator most commonly used in Europe is tetraacetylethylenediamine (TAED) (Figure. 2.1). It reacts with hydrogen peroxide, generated from sodium perborate tetrahydrate, to form peracetic acid, the effective low temperature bleach.

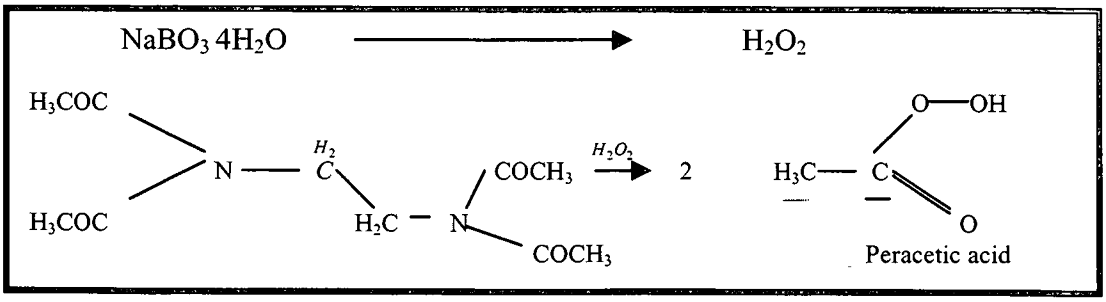
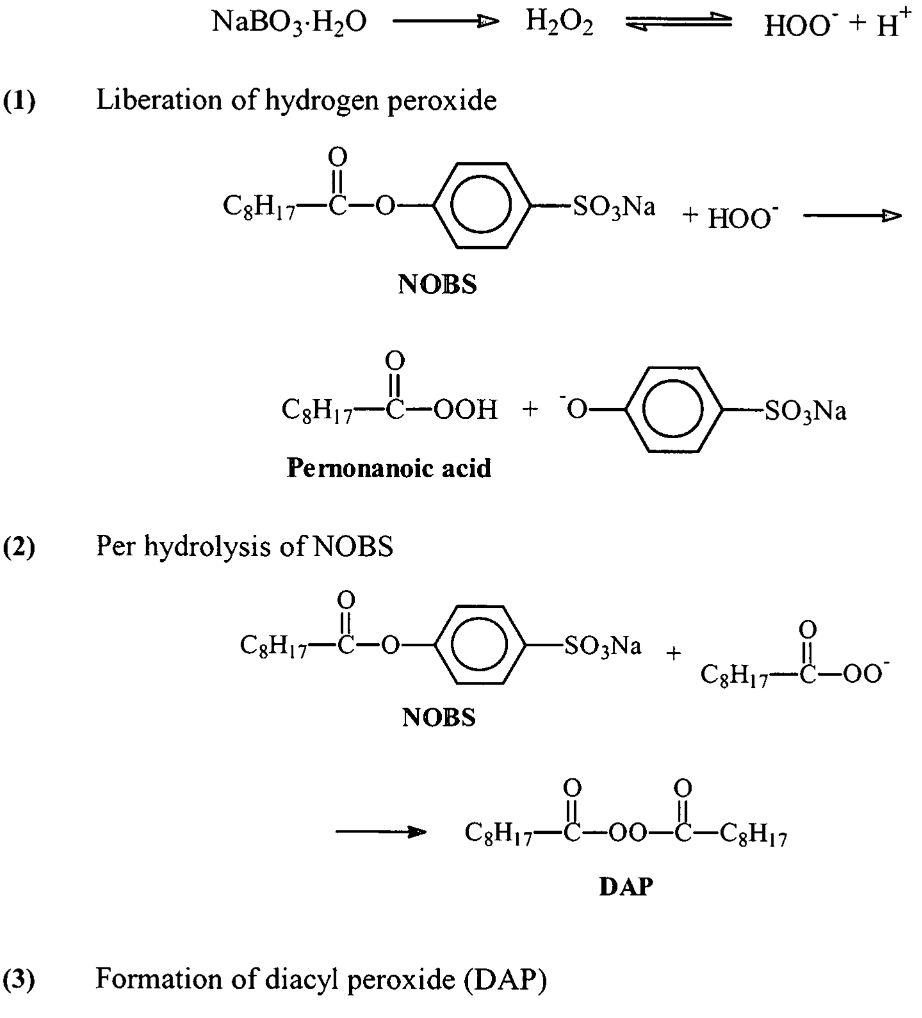


Figure 2.1 TAED bleach activation reaction (Phillips and Scotney 2002:50)

A NOBS bleach system is composed of perborate monohydrate (PBI) and NOBS (Figure 2.2). The function of PBI is to liberate hydrogen peroxide into the wash, which when ionised in the alkaline wash, reacts with NOBS to form pernonanoic acid, a low temperature bleaching agent (Wang 1999:46). Pernonanoic acid provides diacyl peroxide (DAP) that is a second active bleaching agent that is effective in stain removal.



$$NaBO_3{\cdot}H_2O \longrightarrow H_2O_2 \rightleftharpoons HOO^- + H^+$$

(1) Liberation of hydrogen peroxide

(2) Per hydrolysis of NOBS

(3) Formation of diacyl peroxide (DAP)

Figure 2.2 NOBS bleach system (Wang 1999:46)

2.2.4 Auxiliary agents

Surfactants, builders and bleaches are the major components of modern detergents. However, auxiliary agents are also introduced in small amounts to accomplish a specific purpose. These include enzymes, soil anti-redeposition agents, foam regulators, corrosion inhibitors, fluorescent whitening agents, fragrance, dyes and fillers (Jakobi and Lohr 1987:87).

2.2.4.1 Enzymes

Enzymes that are commonly used in detergents, include proteolytic enzyme amylases, proteases and lipases (Kiwi Web 2000). Protein stains derived from sources such as milk, blood, egg yolk and grass are resistant to removal from fibres by simple detergents, particularly after the stain has dried. However, proteolytic (protein cleaving) enzymes are usually capable of eliminating such soils without difficulty during the course of washing (Dilks and Domiano 2000:1). Amylase-containing detergents have been introduced in the markets to take advantage of carbohydrate-containing soils while lipases are used for the removal of fat-containing soils (Jakobi and Lohr 1987:90). Cellulase is used to inhibit the greying of washed fabrics (as a result of soil redeposits) with inorganic builders, especially with zeolite (Meine, Poethkow and Upadek 1998:317)

The use of enzymes in the textile industry is becoming increasingly popular because of mid-temperature and pH conditions that are required and their capability for replacing harsh organic/inorganic chemicals. Typical temperatures of processing during enzymatic treatment are about 40-50°C, which offer a significant decrease in energy consumption compared with normal processing (Yachmenev, Blanchard and Lambert 1999:47). The application of enzymes for the treatment of cotton in industry helps in:

- Desizing. Removal of starch size with amylases.
- Scouring. Dissolution/dispersion of waxes, protein, pectins and natural fats from the surface of cotton fibres with amylase, lipase, cellulase or pectinase solutions.
- Bleach. Cleanup removal of residual hydrogen peroxide with catalase.
- Bio-polishing. Improvement of the appearance of cotton fabrics by the removal of fuzz-fibre and pills from the surface with cellulase.
- Bio-Staining. Stone-washing of denim fabrics to produce an aged appearance with cellulase (Yachmenev *et al.* 1999:47, Traore and Buschle-Diller 1999:51).

2.2.4.2 *Soil anti-redeposition agents*

The principal characteristic expected of a detergent is to remove soil from textile fibres during the washing process (Breen, Durnam and Obendorf 1984:198). Removed soil is normally dispersed, and if less than optimal detergent formulation is employed, some or all of it may at some point return to the fibres. This is termed wash liquor showing insufficient soil anti-re-deposition capability (Jakobi and Lohr 1987:90). Cellulase acts as an anti-redeposition agent in the detergent (Meine *et al.* 1998:317).

2.2.4.3 *Foam regulators*

In the days of soap detergents, foam was understood as an important measure of washing power. With modern detergents based on synthetic surfactants, foam has lost virtually all its former significance. Most consumers still expect their detergents to produce voluminous foam, preferably comprised of the smallest possible bubbles. The reason seems to be largely psychological (foam provides evidence of detergent activity and it hides the soil). Automatic washing machines do not tolerate this foam, thus foam regulators are necessary to prevent excessive foaming (Kiwi Web 2000).

2.2.4.4 *Corrosion inhibitors*

Washing machines currently on the market are constructed with drums and laundry tubs of corrosion-resistant stainless steel or with enamelled finish that is inert to alkaline wash liquors (Jakobi and Lohr 1987:95). According to Dilks and Domiano (2000:3) silicates are combinations of sodium oxide and silicon dioxide. Silicates contain wetting and emulsifying properties. In the presence of acidic materials, their pH is maintained until exhaustion, for this reason silicates are known for having good buffering action. They are also very effective in inhibiting stainless steel and aluminium corrosion.

2.2.4.5 *Fluorescent Whitening Agents (FWAs)*

Fluorescent whitening agents are colourless compounds applied to textile material to improve the appearance of the final product. They absorb ultraviolet radiation from sunlight and convert part of the energy into blue-to-violet visible radiation. White textile materials to which they have been applied, appear whiter and brighter because the additional blue light radiated from the textile surfaces neutralizes the effect of the yellowness of the material and increases the total amount of visible radiation coming from it (Burdett 1986:42). Aspland (2000:204) described them as fluorescent brightening agents rather than whitening agents.

Fluorescent whitening agents are common additives to home laundering detergent formulations where they enhance the whiteness of textiles by ultraviolet excitation and re-emission in the visible blue range of the electromagnetic spectrum. The yellowish cast of freshly washed and bleached laundry is a result of partial absorption of the blue radiation reaching it, resulting in reflected light that is deficient in the blue region of its spectrum. The radiation emitted by whitening agents makes up for this deficiency, so that the laundry becomes brighter and whiter (Zhou and Crews 1998:19).

Zhou and Crews (1998:19) found that laundering fabrics with detergent containing OBA (Optical brightening agent) might improve the sun-blocking properties of a fabric or at least maintain a fabric's initial level of sun-blocking properties over the course of repeated washings and wearing. In their experiment Zhou and Crews (1998:19) used eight types of lightweight woven and knitted cotton fabrics commonly used for summer clothing. Fabric samples were laundered up to twenty times in AATCC 1993 Standard Reference Detergent containing OBA and dried according to AATCC guidelines for Standardization of Home Laundering Test Conditions.

Transmission percentage and Ultraviolet Protecting Factor (UPF) values were measured, using a Cary ultraviolet-visible spectrophotometer, with an ultraviolet light source and an integrated sphere attachment to collect all the diffusely scattered light transmitted through a fabric. Results demonstrated that OBAs used in laundering improved the ultraviolet radiation (UVR) blocking ability of cotton fabrics and cotton blend fabrics. The implication of the results is that the UPF rating of cotton blends can be maintained and be enhanced by the repeated laundering of garments in a detergent containing OBA (Zhou and Crews 1998:19).

2.2.4.6 Fragrances

The role of fragrances in a detergent is to mask unpleasant odour arising from the wash liquor during washing. They are also intended to confer a fresh, pleasant odour on the laundry itself (Jakobi and Lohr 1987:101).

2.2.4.7 Dyes

Prior to the 1950s, powdered detergents were more or less, white consistent with the colour of their components, but currently the idea of introducing colouring agents has become quite common. The preferred colours for powdered detergents are blue, pink and green. In selecting colouring agents one should bear in mind that the agents have good storage stability with respect to other detergent components and light as well as having no effect on textile fibres (Jakobi and Lohr 1987:101).

2.2.4.8 Fillers

Fillers for powdered detergents are organic salts, especially sodium sulphate. Their purpose is to confer flowability, good flushing properties, high solubility, no caking of powder, even under high humid conditions, as well as having no dusting (Jakobi and Lohr 1987:101).

2.3 Detergency

Detergency is not the main focus of this study, but the increasing use of cellulosic fibres and the application of a variety of chemical finishes to fabrics have accentuated the problem of soiling and soil removal. A brief discussion on detergency is therefore necessary for the consumer to understand the process of soil removal from fabrics. The soiling of textiles depends on the chemical nature of the fibre, the constructional characteristics of fibre, yarn, fabric chemical treatments and the conditions under which the fabric is used. Deposited soil arises from the most diverse activities such as particulate soil, organic soils and stains (Bevan 1980:69).

Bevan (1980:69) noted that the particulate soiling of textiles takes place by contact with soiled surfaces, by a filtration mechanism or the electrostatic attraction of particles from air. Fatty material excreted by the body is usually in an emulsified state on the skin surface, emulsion formation allows the sebum to wet the surface of the fabric and penetrates into the structure. The amount of penetration is increased by mechanical actions, which occur as fabric rubs against the skin, and by capillary forces, which promote the wicking of soil through the fibre bundles in the yarns.

Soil re-deposition may be defined as deposition during the wash process of that soil which, having been removed from fabrics and sometimes dispersed into small particles, is deposited back on to the same or accompanying fabrics. This may be a result of insufficient detergent being present to suspend the soil completely, resulting in the greying of white fibres and loss of brightness of coloured fabrics (Bevan 1980:69).

According to Cox (1986:559) and Kissa (1981:508) soil removal involves the diffusion of water and detergent to the soil-fibre interface and mechanical dislodgement and transport of soils. Cox (1986:559) further noted the three principal mechanisms for removing soil from a hard surface (Figure 2.3). Detergency employs surfactants to achieve soil removal. Mechanical processes use some sort of physical means and chemical processes involve the use of solvents.

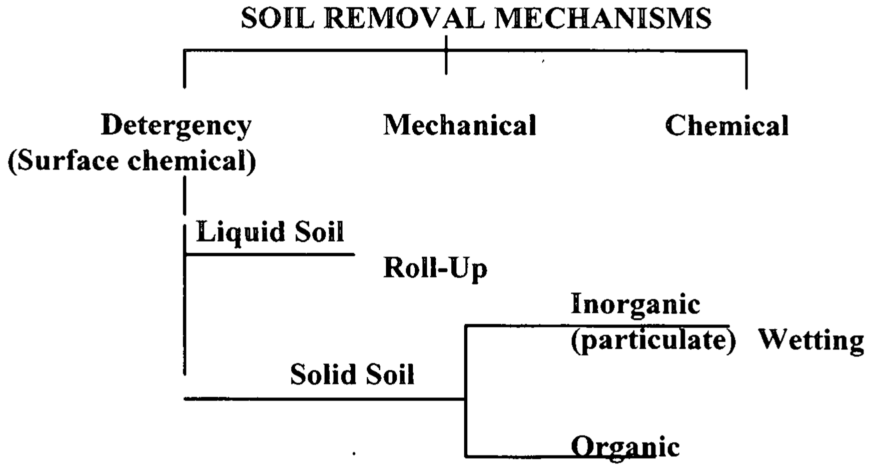


Figure 2.3 Major mechanisms involved in the removal of soils from a hard surface (Cox 1986:559)

Soil removal is achieved through detergency because it offers a more cost-effective and versatile approach. Most detergency processes rely on the mechanical action and chemical solvation of soil to aid in soil removal, for example the addition of caustic soda to saponify and solubilize natural oils and fats. Different detergency mechanisms can be classified according to the type of soil removed. Liquid soils generally are removed through a roll-up mechanism. Solid inorganic soils are removed via a wetting mechanism, which lowers adhesion between the soil and substrate (Cox 1986:560 and Kissa 1981:509).

The diffusion of surfactants into soil has been suggested as a possible mechanism by which surfactants remove solid, organic soils. The penetration of surfactants into the soil causes it to swell and soften. Liquefaction allows soil to be removed more easily through some mechanical process and permits soil removal via emulsification. This examines the effect of surfactant structure and surfactants type on its ability to penetrate and remove solid, organic soils (Cox 1986:560).

Research findings on detergency have been employed by a number of researchers. The effect of laundering white hospital uniforms with phosphate built and carbonate built detergent was compared to dry-cleaning (Mohamed 1982:65). A measurement of the whiteness was taken after the hospital staff worn garments made from polyester/cotton fabrics. Results showed that dry-cleaning caused greying due to the accumulation of re-deposited soils. Re-deposition increased with laundering. There seemed to be more loss of whiteness in using phosphate built detergent than in carbonate built detergent.

The use of detergent with carbonate and zeolite builders led to the increased greying of fabrics, while built anionic detergents seem to be the most effective particular soil removal agents (Webb and Obendorf 1987:640). Cameron and Brown (1995:85) in their study of the cleaning effectiveness of forty-two laundry detergents built with high phosphate concentrations found these to be more effective than detergents built with other compounds.

Another effect of poor detergency is the incrustation of fibres. Incrustation is caused by deposits of insoluble compounds on a fabric surface because of reactions between hard water components and carbonates, phosphates or silicates in detergents. It should be noted that incrustation increases with a decrease in wash temperature and it could negatively influence fabric handle, absorbency as well as mechanical stability (Webb and Obendorf 1987:640).

A detergency study conducted by Webb and Obendorf (1987:640) showed that an anionic surfactant phosphate built powdered detergent removed oily and particulate soil from yarn surfaces more than the carbonate built powdered detergent with nonionic surfactants. In their experiment Webb and Obendorf (1987:640) subjected soiled facial swatches of blue polyester/cotton fabrics to a twelve minutes wash and two minutes rinse cycle. The appearance of soiled fabrics was measured using a Hunter lab colour difference meter with ultraviolet. The implication of the study was that the effectiveness of particulate soil removal was related to the surfactant/builder system, with the phosphate built anionic powdered detergent being the most effective.

In his study Sainio (1996:83) found that most residues were anionic tensides. One of the washing powders used contained a very high amount of silicates, which resulted in a large amount of silica residues on the fabric after washing. The concentrated or micro washing powders tested left the least residues.

Tinsley, Byrne and Fritz (1991:223) washed towels at two different temperatures using micro and conventional detergent. After washing, the towels were line-dried and tumble-dried respectively. A panel of judges who evaluated the fabric handle concluded that the detergent containing sodium carbonate caused a harsh handle in towels. This harsh feel could be a result of deposition of calcium carbonate on the fabric.

In another study by Brown *et al.* (1993:145) on commercial laundry detergents, the effectiveness of twenty-three detergents containing active ingredients were evaluated (11 non-phosphate and 12 phosphate). Samples of polyester/cotton fabrics soiled with clay, lampblack and black iron oxide as well as lanolin dissolved in carbon tetrachloride and a salt solution to resemble human perspiration, were laundered in a Launder-Ometer for fifteen minutes at 30°C and 50°C, respectively.

Whiteness indices of the samples were determined as a measure of how clean they were. A higher whiteness index equals a cleaner sample. Whiteness indices were measured using a Spectrogard Computer Colour and calculated according to ASTM E313. Results demonstrated that the detergent with higher phosphate concentration gives whiter results, but samples washed in hot (50^0C) water were significantly whiter than those washed in warm water (Brown *et al.* 1993:147).

2.4 Cotton

Cotton, when picked, is about ninety-four percent cellulose and it is ninety-nine percent cellulose in finished fabrics. Like all cellulose fibres, cotton contains carbon, hydrogen and oxygen with reactive hydroxyl (OH) groups, which react with moisture, dyes and finishes (Kadolph *et al.* 1993:42). Information on the structure of cotton is necessary in order to understand the chemical changes that a cotton fibre undergoes when exposed to a multiple laundry treatments. A discussion on cotton properties will enhance the consumers' acceptance of cotton fabric. The main disadvantage of cotton is its tendency to wrinkle, colour change and wash down issues. Therefore information on functional finishes applied will help the consumer as well as the manufacturer to resolve these problems.

2.4.1 Structure of cotton fibre

Cotton fibre is made up of a cuticle, a primary wall, a secondary wall and lumen (Figure 2.4). The cuticle is a wax-like film covering the primary wall. The inert nature of the wax protects the rest of the fibre against chemical and other degrading agents during consumer use. Most of the cuticle is, however, removed during processing (Hatch 1993:164; Kadolph *et al.* 1993:41; Herbert, 1993:695 and Joseph 1986:67).

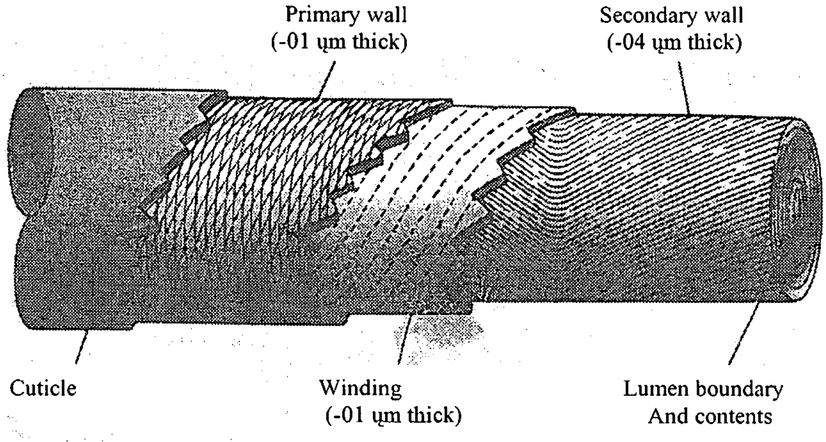


Figure 2.4 Sub-microscopical structure of cotton fibre (Hatch 1993:165)

Beneath the primary wall lies the secondary cell wall, which forms the bulk of the fibre (Hatch 1993:164). Cellulose layers that are deposited during the day and night are composed of fibril bundles of cellulose chains arranged in spiral form. The reverse spiral is a result of the different directions, which are deposited during day and night. These spirals reverse directions at some points causing the fibre to twist. They are important in the development of convolutions of the fibre (Tortora 1978:39). They are also considered the weak points of the fibre. The lumen is the central canal through which the nourishment travels during growth. When the fibre matures, it collapses inwardly (Figure 2.5), resulting in a twisted-ribbon or kidney-shaped cross-section (Bhat, Dharmadhikari, Wani and Kulkarni1990:242 and Kadolph *et al.* 1993:39).

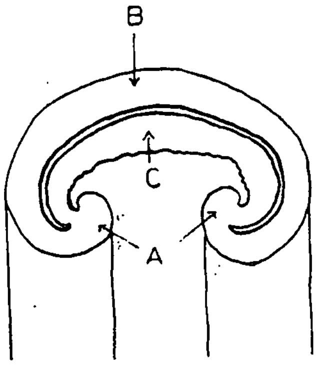


Figure 2.5 Cross-section of cotton fibre showing three regions (A.B.C) (Bhat *et al.* 1990:242)

Dried cotton fibre collapses into a bean-shaped cross section and the different regions A, B and C show different reactivities. Region A is the most compact and therefore has less reactivity with little loosening of the fibrillar structure. The fibrillar layer in region C is the most susceptible to chemical reactions. When treatment time increases the more the fibrillar layers are removed (Goynes, Carra and Berni 1984:243) one after the other, hence the fibrils are separated from each other. This is probably due to the swelling, which causes the splitting up and peeling off of the fibrillar layers (Bhat *et al.* 1990:243).

Cotton, like other vegetable fibres, consists mainly of cellulose, which is classified chemically as a carbohydrate and has the formula ($C_6H_{10}O_5$) (Lyle 1976:93). It is a high molecular-weight polymer, the basic unit of which is cellobiose, the repeat unit of cellulose (Figure 2.6). Cellulose is a linear chain in which oxygen atoms are packed together in parallel rows within the fibrils of the fibre, allowing cellulose to be insoluble in water. The regions in which the cellulose chains are packed are mostly crystalline. Hydrogen bonding between the adjacent polymer chains in the crystalline area draws the molecules closer to each other and increases the strength, stiffness and rigidity of the fibre (Smith and Block 1982:73).

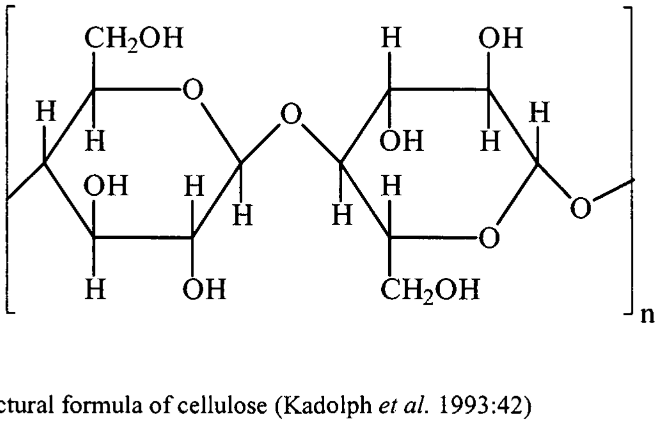


Figure 2.6 Structural formula of cellulose (Kadolph *et al.* 1993:42)

Hydrogen bonding plays an important role in the cotton's moisture absorption. The reason that cotton rank among the most absorbent fibres is that the oxygen atom in water is attracted to the hydroxyl groups in the cellulose therefore, contributing to the high moisture regain of cotton (Rowland and Howley 1988:96; Lyle 1976:93; Labarthe 1975:19 and Smith and Block, 1982:74).

2.4.2 Properties of cotton

Cotton is an important textile material (Lee and Dardis 1991:97). Cotton fabrics are common in all tropical countries. Cotton has an advantage over synthetic materials in its ability to absorb moisture, soft hand, good heat and electrical conductivity. Cotton fabric has consumer acceptance because of its soft pleasant lustre, drape, and texture. The only disadvantage of cotton is its low resiliency, which results in a cloth that wrinkles badly (Bhat *et al.* 1990:240).

During wear, cotton is subjected to a number of stresses such as flexing, rubbing and abrasion, as well as severe sunlight, environmental gases, microbial growth and perspiration. Any changes in the structure of a cotton fibre may result in significant changes in its original properties. The fibres absorb moisture and feel good against the skin in high humidity. Moisture passes freely through cotton fabric, thus aiding evaporation and cooling. All cotton fabrics shrink unless they have been given a durable-press finish or a shrinkage-resistant finish (Bhat *et al.* 1990:240 and Eckhardt and Rohwer 2000:21).

Cotton fibre is susceptible to water-borne soiling due to its highly hydrophilic nature. It also absorbs large quantities of oil, which can fill the lumen and lie between the numerous internal layers. Solid dirt particles become lodged in the convolusions of the fibre. However, cotton fibre readily releases oily and particulate soil in laundry solutions and dry-cleaning solvents (Breen *et al.* 1984:198).

Because of the hydroxyl group in the cellulose, cotton has a high attraction for water. As water enters the fibre, cotton swells and its cross-section becomes more rounded. The high affinity for moisture and the ability to swell when wet, allows cotton to absorb moisture. This means that in hot weather perspiration from the body will be absorbed

(Smith and Block 1982:75). Burdett (1986:39) stated that cotton can be washed with strong detergents and requires no special care during washing and drying. White cotton can be washed in hot water. Coloured cotton retains its colour better if washed in warm water. Cotton is highly resistant to most organic solvents, including those used in normal care and stain removal. Fungi, such as mildew and bacteria damage cotton fibres.

2.4.3 Finishing of cotton

Pre-treatment prepares the textile material for subsequent processing such as dyeing, printing and finishing. This can be successful if interfering substances are removed and the resultant material is uniformly absorbent and hydrophilic (Goynes *et al.* 1984:243). Cotton from different locations differs with regard to impurities such as hemicellulose, proteins, pectin, fats and waxes, husks coloured pigment and inorganic substances. These inorganic substances, salts and oxides of alkaline earth metals such as Ca and Mg and heavy metals such as Fe, Mn, Cu, and Zn can occur in very different quantities, therefore pre-treatment of cotton is necessary in order to reduce damage by these heavy metals (Karl and Freyberg 2000:24).

Finishing applications are a key element in resolving colour change and wash-down issues (Farias 2000:23). Prior to chemical modification with various agents, cotton fabric is routinely desized, scoured and bleached. Scouring imparts the required wettability by removing the natural waxes and the sizing agent applied to facilitate fabric construction. Bleaching renders the fabric white so that it can be dyed true to colour. Swelling pre-treatments are also used to improve dyeability, softness and dimensional stability. Such treatments also enhance textile performance both before and after cross-linking to impart durable press properties (Bertoniere and King 1989:114).

2.4.3.1 Bleaching

Bleaching is an essential preliminary finish on raw cotton to gain a pure white before dyeing and printing.

It should be clear that bleaching will not remove the bulk of inorganic and organic soiling but bleaching completes the purification of the fibre by ensuring that seed and husks are fully broken down and removed. The main function of bleaching is the removal of stains, which are not removed by ordinary washing processes but are amenable to bleaching. The common laundry bleaches are oxidising agents and their action is due to the fact that many coloured substances become colourless or soluble in water, or both, on oxidation. The whitening effect that bleaching may have upon the fabrics should be looked upon as a subsidiary function to improve the first-class colour already obtained by good washing (Kay 1995:40 and Wynne 1997:234).

Two types of bleaches, which can be used in the washing, are sodium hypochlorite (NaOCl) and hydrogen peroxide (H_2O_2). Hydrogen peroxide is the most commonly used bleach for cotton. It is not only used for textile pre-treatment, it is also included in laundry detergents in solid form as sodium perborate and is increasingly replacing chlorine–based bleaching processes. H_2O_2 is easier to use than NaOCl and does not produce any toxic by-products that are damaging to the environment (Dannacher and Schlenker 1996:24).

The bleaching process involves that the cloth is saturated with the bleaching agent; the temperature is raised to that recommended for the particular fibre or blend and held for the time needed to complete the bleaching action and the cloth is thoroughly washed and dried. The bleaching agent temperature, and the time must be carefully controlled to avoid damage to the fibre, or severe losses in strength may occur (Smith and Block 1982:277).

According to Kay (1995:43) bleach can become a useful addition to the washing process if the following rules are followed:

- Never bleach at a temperature higher than 60^0C.
- Never use bleach of an unknown concentration.
- Never add concentrated bleach direct into a washing machine.

- Always use a dilute stock solution, made up of required concentration.
- Always measure out bleach, whether concentrated or diluted; never guess quantities.
- When adding bleach to a washing machine always ensure that the cage is rotating in the right direction.

2.4.3.2 Mercerisation

One of the major treatments cotton undergoes during processing is mercerisation. This is a process of subjecting cellulosic material to a concentrated aqueous solution of a strong base to produce great swelling with resultant changes in fine structure, dimensions, morphology and mechanical properties (Aboul-Fadl *et al.* 1985:461).

According to Aboul-Fadl *et al.* 1985:461 mercerisation involves placing fabrics or yarn in a cold bath of 18-27% sodium hydroxide for a minute or less. After the fabric or yarn is rinsed several times it is treated in a cold acid bath to neutralise any remaining alkali. The fabric must be held under tension during the process to prevent shrinkage and develop lustre. Mercerised fibres are more cylindrically shaped and have a rounder lumen than unmercerised fibres.

The fine structure of mercerised fibres is composed of smaller crystalline areas, which tend to be stronger because each fibre's polymers are arranged to share pulling forces more equally. These crystalline areas are more lustrous due to the rounded cross-sectional shape and decreased fibre twisting. They are more absorbent and have greater affinity for dyestuff due to the expanded fibre structure. Mercerisation is often applied in conjunction with durable-press finish to help fabrics maintain strength and abrasion resistance, which are considerably reduced by durable-press finishing (Aboul-Fadl, Zeronian and Kamal, Kim and Elison 1985:461).

The objectives of mercerisation are to increase lustre, tensile strength, dimensional stability and increases uniformity in the dyeing of the fibre, softness and improves the fabric's affinity for dyes and water-borne finishes (Kadolph *et al.* 1993:289). Bertoniere and King (1989:114) further noted that swelling pre-treatments include caustic mercerisation and liquid ammonia treatment. In both cases the swelling agent penetrates the fibre and disrupts the hydrogen-bonding network. Liquid ammonia treatments used on cotton fabrics result in similar changes in fabric properties as obtained in mercerisation. It produces a moderate degree of swelling and an improved resistance to abrasion and shrinkage during washing.

One of cotton's biggest disadvantages is its tendency to wrinkle. A variety of durable-press finishes emerged over the years to improve the quality of cotton, but all of them influenced other properties to some extent.

According to Schramm and Rinderer (2000:50) cotton fabric is modified by means of poly carbolic acids (PCAs) in combination with an inorganic or an organic catalyst to impart durable-press properties. PCAs such as 1, 2, 3, 4- butane-tetra carboxylic acid (BTCA) or citric acid (CA) offer an alternative to the formaldehyde-emitting N-methylol compounds such as dimethylol-dihydroxyethyleneurea (DMDHEU) as cross-linking agent.

Schramm and Rinderer (2000:50) added that when applying a proper catalyst (sodium hypophosphite monohydrate, SHP), an esterification reaction takes place between the cellulosic material and the PCA. BTC has been examined as a formaldehyde-free durable-press agent. This compound combines with the properties of both the cross-linking agent and the phosphorus-containing catalyst. If the curing process is carried out properly, the ester linkage formed will be resistant to multiple alkaline launderings.

Cross-linking of cellulose molecules renders wrinkle resistance, smooth drying and crease retention properties in cotton fabrics (Wei and Yang 2000:53). Textile industries use formaldehyde-base DMDHEU for durable-press finishes. Wei and Yang (2000:53) reported that DMDHEU are efficient and cost effective, but the health risks associated with formaldehyde emission have caused a worldwide concern leading to more research on formaldehyde-free cross-linking agents.

Cellulose fibres do not have natural cross-links. The molecular chains are held together by weak hydrogen bonds. Bonds are formed in the presence of moisture to hold the fibre in a bent position, forming a wrinkle. Wrinkle recovery is therefore dependent on cross-links that hold adjacent molecule chains together and pull them back into position after the fibre is bent (Wei and Yang 2000:53).

Welch (1988:480) and Yang (1993:420) discovered that 1, 2, 3, 4-butanetetracarboxylic acid (BTCA) imparts high levels of wrinkle resistance to cotton fabrics. Welch reported that mono and disodium phosphate and disodium tartrate were about equally effective cross-linking catalysts and were more effective than the monosodium salt of cyclopentanetetracarboxylic acid formed by adding sodium carbonate to tetracarboxylic acid. Wei, Yang and Jiang (1999:34) added that as a formaldehyde free durable-press finish agent for cotton fabrics, BTCA meets many of the requirements for satisfactory performance such as level of reactivity, durable-press performance, durability to laundering, fabric strength retention and fabric softness, reagent volatility as well as absence of odour.

Morris and Harper (1994:34) compared the resistance to laundry abrasion of BTCA and DMDHEU. Abrasion resistance was evaluated by observing damage to collars and hemmed edges during repeated washing (up to 50 wash cycles). Results showed that fabrics treated with BTCA resisted abrasive damage during laundering better than DMDHEU treated fabrics.

Even though BTCA meets the requirements for satisfactory performance, its high cost may be prohibitive for commercial use. This led to further research with citric acid (CA), an inexpensive tri-carboxylic acid. In the study carried out by Andrews (1990:63), it was discovered that the cost of BTCA could be cut by using BTCA in a mixture with citric acid as an extender. Andrews noted that blending BTCA with citric acid would allow the use of citric acid in high-level durable-press finish. Citric acid could also be used with certain inorganic salts of phosphorus-containing acid to produce cotton fabrics of acceptable smooth drying properties without appreciable loss of fabric whiteness.

In another study by Reinhardt and Graves (1996:28) it was concluded that cotton fabrics dyed after being treated with a durable-press finish are more colourfast than those dyed conventionally. Even though traditionally cotton was dyed before finishing, it was discovered that untreated cotton has poor wrinkle resistance and dimensional stability. A process was, however, developed of cross-linked reactions, before dyeing whereby additives such as quaternary ammonium salt were added before the dyeing process.

Fabrics were then dyed in various colours, after the durable-press treatment. Colourfastness tests were carried out using a Launder-Ometer at 49°C and a 0.2% detergent solution. Grey Scales were used to evaluate colour change. Results indicated that 93.4% to 98.0% of the colour was retained. It was therefore concluded that dyeable durable-press cotton fabrics could be produced with high levels of colourfastness (Reinhardt and Graves 1996:28).

2.5 Application of colour

Colour is a visual sensation. It results from the reflectance of visible light rays that strike the retina of the eye and stimulate cells in the nerves of the eye. When all the visible light rays are reflected, an object appears white. If none of the rays is reflected, it appears black. When one or more rays are reflected, the viewer senses the colour produced by the specific reflected ray or combination of rays (Davis 1996:147).

Burdett (1986:39) stated that colour is one of the most important features of a textile material. While many physical, chemical and mechanical properties are important in textile design, style and fashion dictate a major role for colour. In general, the process of dyeing or printing may impart colour. Dyeing is the application of colour in a uniform manner to all parts of textile material such as loose fibre, yarn and fabric so that samples taken at random are alike in all respects.

Dyeing is a chemical process and is subjected to all the laws that govern chemical processes, that is in general any dyeing process is affected by changes in time and temperature, and by additions to dyebath of various chemicals such as acids, alkalis and salts. To obtain a satisfactory dyeing, all such changes and additions must be controlled carefully, and details will be dictated by the type of fibre to be dyed, the dyes that are used and the equipment in which the dyeing operation is to be carried out (Burdett 1986:39; Warwicker 1980:50). Burdett (1986:39) further noted that textile material must be coloured uniformly before its colour is assessed. The colour must be satisfactory to customers and agreed with the dyehouse. The fastness properties of the dye material or those characteristics that make the dye material retain its colour without changing, must be appropriate to the end-use of the product. The properties together with the shade of colour will strongly influence the type of dye to be used and the method of application.

Before the nineteenth century the only dyes available were those derived from natural products such as fruits, flowers, roots, minerals or agricultural products. This situation was completely changed in the nineteenth century by the introduction of synthetic organic dyestuffs, which dominated the dyeing industry. Synthetic dyestuffs are composed of carbon-containing molecules whose structural features cause them to absorb particular wavelengths of light while reflecting or transmitting others. It is this selective absorption that results in the coloured appearance (Warwicker 1980:50).

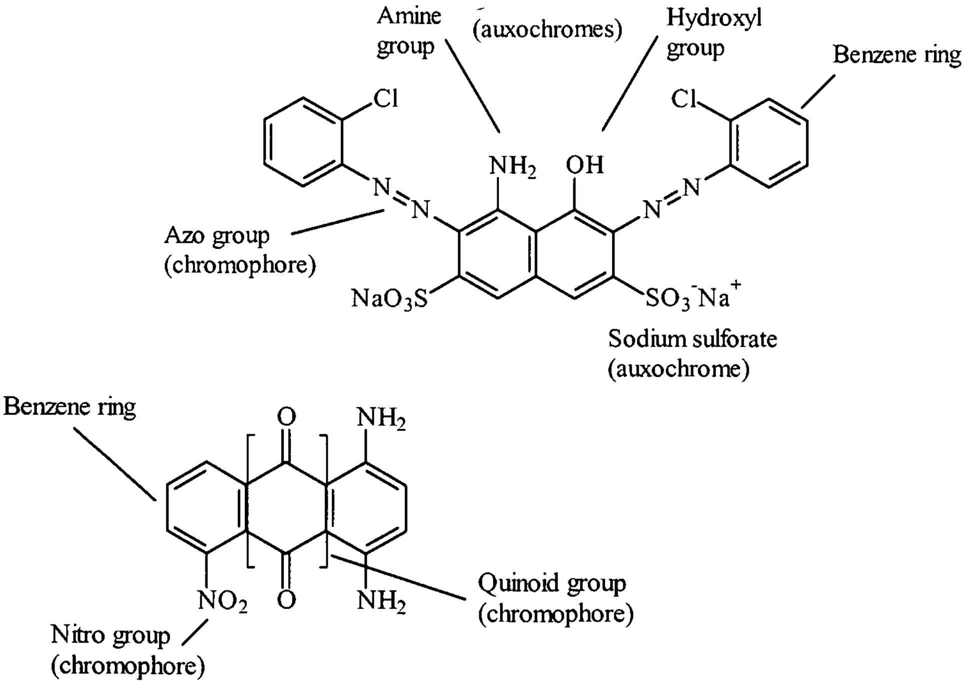


Figure 2.7 Chemical structure of dye molecules (Hatch 1993:432)

Warwicker (1980:50) further noted that the most important structural feature is a system of conjugated double bonds between some of the carbon atoms which form the framework of the dye molecule. The length of this system determines the hue of the dyestuff.

Chromophores are made up of organic molecular arrangements such as an azo group, the thio group, the nitroso group, and the anthraquinoid group. To produce colour visible to the human eye, the dyestuff must have at least two chromophore groups. To obtain deep and intense colours, the number of chromophores is increased and strong ones replace weak chromophore systems. Although chromophores confer colour on the material, the intensity or brightness of the colour depends on the presence of one or more substances called auxochromes (Kadolph *et al.* 1993:329 and Hatch, 1993:431).

Dyes usually diffuse into the interior of a fibre from a water solution and are retained in the amorphous area within fibres. Hatch (1993:432) noted that the auxochromes make the dye more soluble to water by allowing forces of attraction to form between the dye and fibre polymers, thus assisting in the even uptake of dye and also improving the colourfastness of the dyed textiles. Lewis and Lei (1989:23), Kearney and Maki (1994:24) and Aspland (1992a:31 and 1992b:37) indicated that dyes are retained within the fibre by hydrogen bonding, ionic bonding or mechanical entrapment. Dyes react with fibre polymers to form covalent bonds, which are not easily broken by laundering processes (Hatch, 1993:432).

A free movement of dye in the capillary network of a fabric is a significant problem. Uncontrolled dye migration causes faded areas in the fabric, resulting in an uneven depth of shades on the fabric surface. When a fabric is immersed in pad liquor, its capillary network swells, allowing free movement of dye. Dye is transported to the surface of the fabric by the water movement in the capillary network and is deposited. As water evaporates from the fabric, the capillary diameter shrinks to the size of the dye particles, thus ceasing migration. Migration occurs when the capillary network is not able to trap the smaller dye particles during the early stage of migration. Antimigrants and gel structure formation are two techniques that are used to control dye migration (Lewis 2000:26).

Dyes should be permanently fixed on the fibres so that they do not migrate onto the skin. A better dye penetration improves the colourfastness, such as to washing, crocking, perspiration, light, dry-cleaning and saliva (Yang, , Brown, and Casey 2002:55). The saliva fastness is required for babies wear because babies usually suck on their clothing but do not perspire (Sewekow 1996:22).

Dyes can be applied to textiles in various stages of manufacture. Natural fibres can be coloured as fibres (loose-stock dyeing), sliver form (top dyeing), in yarn form, or as a fabric (piece dyeing). They may even be coloured after the final end-use product has been made (Storey, 1978:9 and Stuart and Robinson 1982:20).

The process of dyeing consists of presenting the dye to the material in some suitable way, often by immersing the material in an aqueous dyebath or by padding and then creating the conditions which enable the dye to penetrate the fibre. After penetration the dye molecules have to be fixed so that they cannot be removed under normal conditions of laundering and cleaning. This fixation of dye can be by a bonding force such as hydrogen bonds, electrovalent attraction, or chemical bonds between dye and fibre molecule, by deposition in the fibre so that the dye is not removed again or by combination with an insoluble substance inside the fibre. The dyeing process is completed by washing away of excess or unfixed dye and unwanted chemicals developed or used during the dyeing operation, and by drying the fabric under appropriate conditions (Warwicker 1980:50 Fu and Viraraghavan 2001:36).

2.5.1 Fibre dyeing

Textile may be dyed in the fibre state. When colour is added at this point, the process is known as top dyeing or stock dyeing. Loose (usually staple) fibres are immersed in a dye bath, dyeing takes place, and the fibres are dried. This is a relatively expensive method because it takes longer to dye the fibres than to dye a comparable quality of yarn or fabric, and because the cost of reopening fibres after dyeing is higher. But it does achieve a higher degree of dye penetration into the fibre, and the fibres tend to take up the dye evenly (Yang and Li 2000:38).

Stock-dyed fibres are most often used in tweed or heather effect materials in which delicate shadings of colour are produced by combining fibres of various colours. Fibres for worsted fabrics are sometimes made into sliver before they are dyed. This variation of fibre dyeing is known as top dyeing. By dyeing the fibres after they have been combed, the manufacturer avoids the wasteful step of colouring the short fibres that would be removed in the combing process (Joseph 1986:333).

2.5.2 Yarn dyeing

Colour can be added to the yarn before they are made into fabrics. Usually yarns are dyed to one solid colour, but in a variant of the technique called space dyeing, yarns may be dyed in such a way that colour-and-white or multicoloured effects are formed along the length of yarn. Yarns may be dyed in skeins, in packages, or in beams. Special dyeing equipment is required for each of these processes. In skein dyeing, large loosely wound skeins of yarn are placed in a vat for dyeing. Package dyeing utilises a number of perforated tubes into which the yarn is wound. The dye is circulated around and through the tubes to assure that the yarns have maximum contact with the dyestuff. Beam dyeing is a variation of package dyeing, which uses a large cylinder onto which a set of warp yarn is wound (Owen 2000:18).

2.5.3 Piece dyeing

Fabrics that are to be a solid colour are usually piece dyed. In piece dyeing, the finished fabric is passed through a dye bath in which the fabric absorbs the dyestuff. A number of different methods are used for piece dyeing, each of which has some slight differences in the way in which the fabric is handled. Some fabrics are dyed in open, flat widths. Because knit cloth must be carefully handled during dyeing to prevent stretching most are dyed by union dyeing. (Anton 2000:26).

Among the different methods that are used in piece dyeing union dyeing may be used. This is mostly used where a cloth contains two or more different fibres and special care must be taken to achieve the same colour in both fibres. In union dyeing two different dyes may be used in one bath. Cross dyeing is used for stripes or checked patterns. The fabric is dyed in different baths, one dye being compatible with one fibre and the other dye having an affinity for the other fibre. Beck dyeing, is another procedure whereby the cloth is twisted to form a rope. The rope is passed over sets of reels through the dye bath and out again in a continuous loop form allowing thousands of meters of cloth to be treated at one time. The process in jig dyeing is similar to beck dyeing except that the cloth is dyed in open width (Smith and Block 1982:344).

2.5.4 Product dyeing

It is possible to make the end-use textile product and then dye it. In such cases, the dyeing technique commonly used is pad dyeing. Apparel manufacturers do not consider this method practical for general use, but it is used for some speciality items like couture apparel and it is frequently used for home furnishings such as towels, bedspreads and similar items (Owen 2000:18 and Anton 2000:26).

2.6 Types of dyes

The consumer wishes to pay the lowest price commensurate with the best performance, while the producer wishes to provide the best performance commensurate with the lowest cost. The attempt to satisfy consumer desires while maintaining manufacturers' needs for reasonable profits has led to the large number of available dyes. In the textile industry, dyes are classified by both chemical type and method of utilization. (Smith and Block 1982:338).

Types of dyes that are discussed in this section are mainly suitable for cellulosic fibres.

2.6.1 Direct dyes

Direct dyes were mainly developed for use with cotton, but they are applicable to many other cellulosic fibres. The dyes are soluble in water and have an affinity for cellulosic fibres; hence they can be used directly. Cellulosic fibres can directly be dyed from an aqueous dyebath solution, the dissolved dye molecules readily penetrate the water-filled channels within the fibres and are attracted on to the hydroxyl groups of the cellulose molecule by hydrogen bonding. The addition of salts to the dyebath encourages the tendency of the dye molecule to be taken up to the hydroxyl groups on the cellulose fibre molecules and by careful control of salt additions and temperature, the dyebath can exhaust the dye (Warwicker 1980:52 and Hauser 2000:44).

Direct dyestuffs exhibit good fastness to light and crocking and resist perspiration and are resistant to dry-cleaning solvents and atmospheric fumes. However, since they are water-soluble, colourfastness to washing may be poor. Laundry processes tend to dissolve some of the dye and remove it from the fabric (Joseph 1986:323).

The problem of poor wash-fastness of cellulose fibres dyed with direct dyes can be improved by after-treatment of dye products with fixatives (Larney and van Aardt 1994:69; Bhattacharyya, Doshi, Sahasrabudhe and Mistry 1990:24-37; Burdett 1986:39-46 and Etters 1989:19-22). These methods include diazotisation, treatment with metallic salts like copper sulphate and the use of cationic agents as well as formaldehyde and other cross-linking agents. After-treatments with fixatives are aimed at increasing the size of the direct dye molecule located within the polymer system of the fibre, thereby making it less soluble in water and more fast to wet processes (Larney and van Aardt 1994:69).

2.6.2 Reactive dyes

Reactive dyes have the basic structure of acid, direct or mordant dyes but in addition have a reactive group capable of covalent bond formation within the fibre (Larney and van Aardt 1994:69 and (Needles 1981:35). The reactive groups react with –OH group in cellulose polymers (Hauser 2000:45). Lyle (1976:299), Larney and van Aardt (1994:69), and Burdett (1986:42) reported that of all the dyes employed for dyeing cellulose fibres, reactive dyes show the greatest growth potential, due to their almost unrestricted shade range coupled with their excellent wet-fastness properties.

The covalent bond formed between the reactive group of the dye and the hydroxyl group in cellulose is very strong and is not easily broken by heat, light or water during the washing process. Reactive dyes have small, highly soluble molecular structures and low substantivity, but the problem can be overcome by the addition of electrolytes to assist exhaustion of the dye onto the fibre (Lewis and Lei 1989:23; Kearney and Maki 1994:24; Aspland 1992a and 1992b:35-40).

Aspland (2000:205) mentioned that bleach activators in domestic laundry products may cause poor colourfastness to laundering for cotton goods dyed with reactive dyes.

Fabrics dyed after cationic pre-treatment showed comparable or superior wet fastness and colourfastness properties when compared to conventional dyeing and could be sold as first-quality fabric (Hauser 2000:46). In his studies Hauser concluded that the use of cationic reactant rather than a cationic polymer allows for more complete penetration of the dye into the fibre, avoiding colourfastness problems presented when using polymeric cationic pre-treatment.

In another study by Cardamone and Turner (2000:49) on cationic application for union dyeing wool/cotton blends, results demonstrated that wool/cotton blend pre-treated with biguanide for union dyeing have poor colourfastness to laundering and wet crocking. Cardamone and Turner (2000:49) discovered that treating wool/cotton-blended fabrics with a cationic fixative improves colour stability to laundering, but lowers colourfastness to crocking. Fabrics treated with resins, choline chloride and dyed with neutral metallised dyes give excellent colourfastness, but moderate to good wet crocking, thus overcoming biguanide limitations.

2.6.3 Mordant dyes

Warwicker (1980:52) stated that in mordant dyeing cellulosic fibres have to be treated with one of various types of chemicals which, after reaction within the fibre, deposits an insoluble material that can combine with a dye to fix it within the fibre. In many cases the mordants are prepared by soaking the cotton in acid or basic products which form the insoluble compounds within the fibre by hydrolysis. Metal salts are used, particularly aluminium, chromium and iron salts. The mordanted cellulose fibres are put into a dyebath containing acid or basic dyes. These dyes have little or no substantivity to the cellulose. Therefore, the mordant is essential for fixing them to the cellulose molecules of the fibre.

2.6.4 Azoic dyes

Naphthol dyes are made from two components. The azoic diazo components (Figure 2.8) are primarily stabilized diazonium compounds and the azoic coupling components (Figure 2.9) are mostly naphthols. During dyeing these two azoic components react with each other to form water insoluble azo dyes. Since significant dye remains on the fibre surface after the dyeing process, the other major issue with azoic dyes is their poor crock-fastness. Azoic dyes have good wet-fastness so they are often applied to outdoor textiles (Wang 1999:47 and Oakes 2000:47).

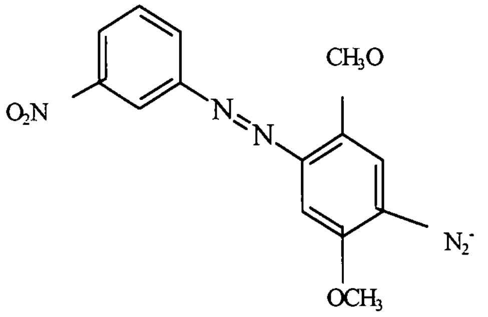


Figure 2.8 Azo Diazo Component (Wang 1999:47)

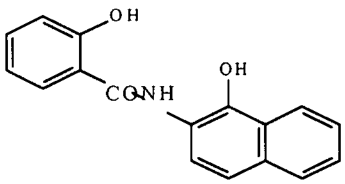
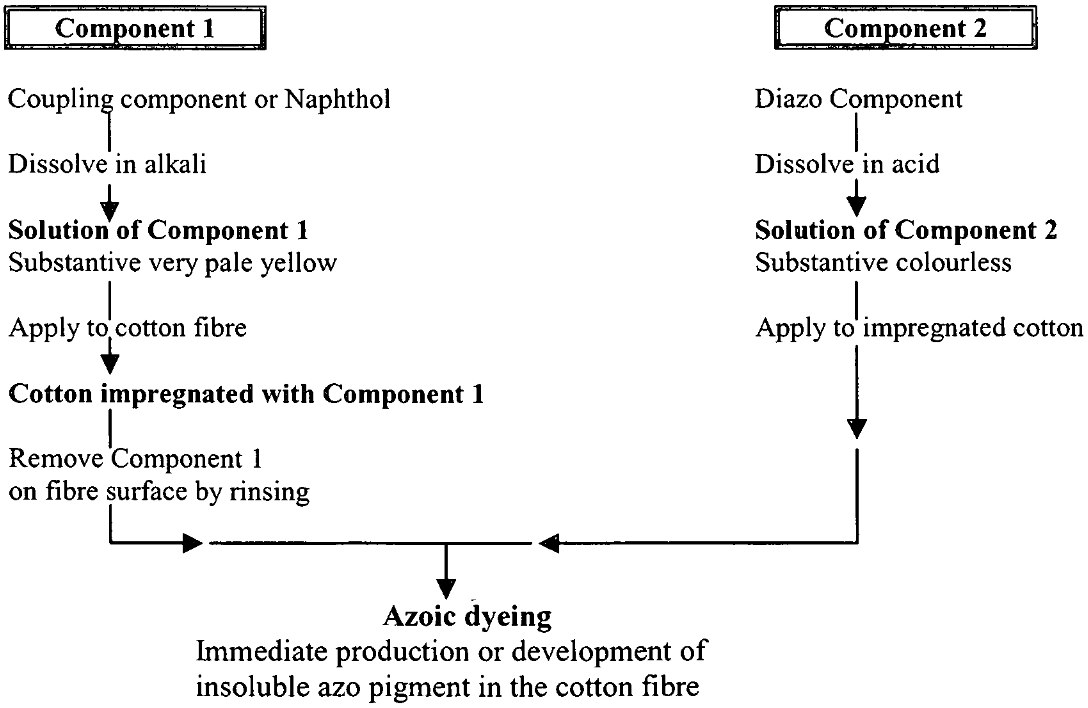


Figure 2.9 Azoic Coupling Component (Wang 1999:48)

Azoic dyes are produced within the textile fibre by application of diazo and coupling components, which are then caused to react with each other (Table 2.1). The colour produced depends on the particular combination of the two components and the depth of colour depends on the amount of insoluble colorant produced inside the fibre. The brightness of colour and fastness to light, washing, as well as wet and dry crocking depends on as little dye as possible being left on the fibre surface and on the dye within the fibre being present as large particles.

Table 2.1: Representation of azoic dyeing (Burdett 1986:43)



Component 1

Coupling component or Naphthol

Dissolve in alkali

Solution of Component 1
Substantive very pale yellow

Apply to cotton fibre

Cotton impregnated with Component 1

Remove Component 1
on fibre surface by rinsing

Component 2

Diazo Component

Dissolve in acid

Solution of Component 2
Substantive colourless

Apply to impregnated cotton

Azoic dyeing
Immediate production or development of
insoluble azo pigment in the cotton fibre

While azoic dyes generally show good washfastness, they tend to loose colour in the presence of oxygen bleach (Wang 1999:47). In his study on the colourfastness of azoic dyes to activated oxygen bleach Wang discovered that bleach sensitivity is largely related to the molecular structure of both diazo components and naphthol coupling components of azoic dyes. Wang (1999:47) determined colourfastness by placing 17 g of detergent into a testing cup and pouring 200 ml of 55°C tap water into the cup. The mixture was stirred for 30 seconds to dissolve the detergent.

A fabric sample (50 cm x 50 cm) was placed into the test cup for 20 minutes. The sample was rinsed in warm water and air-dried overnight. The colour change was measured using Delta E (ΔE) (CIELab) as an indication of the colour change by comparing it with the original dyed fabric. This method was employed to measure the colour change caused by the chemical interaction between dyes and bleach. Since the agitation action was minimal during testing, colour change caused by rubbing was limited. The colour change caused by bleaching was larger than multi-cycle home laundering because of the high detergent concentration and high temperature used in the testing (Wang 1999:48).

2.6.5 Vat dyes and sulphur dyes

The general problem with vat and sulphur dyes for cellulosics is in the preparation of a suitable dyebath because these dyes are insoluble in water. The dyes have to be converted in alkaline solution to form soluble compounds, which can be dyed on to cotton in a similar manner to direct dyeing. It should be noted that the dyebath does not have a colour similar to that of the final dyed fibres due to an oxidation process which converts the dye back to its original coloured and insoluble form. An example is natural indigo, which is pale yellow in its water-soluble form; the blue colour is restored when the dyed goods are exposed to air (Warwicker 1980:53).

If properly applied, vat dyes have excellent fastness to washing and light which makes them very suitable for such items as curtains and upholstery. Unfortunately some yellow and orange vat dyes, although light-fast, cause fabrics to weaken during exposure to sunlight and their use for curtaining is avoided (Warwicker 1980:53).

Although sulphur dyes have a limited colour range they are useful for dyeing items such as working clothes, corduroys and overalls because they are cheaper than vat dyes and if carefully chosen give good fastness to washing and light (Warwicker 1980:53).

Vat dyes are water in soluble, but can be dissolved in alkaline solution where a chemical modification (reduction) renders vat dye suitable for application in the form of a leuco compound. At this stage a colour change usually takes place. Once within the fibre, a chemical reaction opposite to that of reduction namely oxidation regenerates the dye to its original colour. Thus the application of a vat dye entails reduction (Table 2.2) and dissolution of the dye, dyeing by use of leuco compound and regeneration of the dye inside the fibre by oxidation (Burdett 1986:41).

Table 2.2: Regeneration of a vat dye inside the fibre by oxidation (Burdett 1986:42)

Vat dye Insoluble Non-substantive	**e.g.** Indigo
↓	
Dissolve in alkali	
↓	
Vat acid Non-substantive	
↓	
Reduce	
↓	
Leuco vat dye Alkali-soluble Substantive	Indigo at this stage will have a clear yellow to greenish-yellow appearance
↓	
Absorption of Leuco compound By cotton	
↓	
Cotton dye with Leuco compound Alkali-soluble Inside fibre	
↓	
Oxidize	
↓	
Cotton dye with vat dye Insoluble Inside fibre	Indigo-dyed cotton can be various shades of blue

In a vat-dyeing process, the dye is applied to the fabric in a vat-soluble form and is subsequently allowed to undergo chemical reaction to an insoluble form.

2.6.5.1 Indigo dyes

Indigo is an example of a vat dye and was originally obtained from the plant *genus Indigofera*, and was cultivated in India, Java, the Philippines, China, Japan and Central America (MacFoy 2003:13; Pfeifer 1997:40; Fox and Pierce 1990:14; Intersectional 1989:25; White 1989:4; Conway and Tessin 1991:13 and Travis and Edelstein 1990:18).

The dye was extracted from the leaf, which contained no more than 0.8% of useful product (Travis and Edelstein 1990:18). Fermentation gave indoxyl, which became oxidized in the air to indigo. This was obtained by precipitation and filtration as a paste and cut into cakes. As the demand for indigo increased especially in the United States where indigo became the base of the dark blue and gray of the Union and Confederate armies chemical studies on synthetic indigo became necessary (Travis and Edelstein 1990:18 and Reidies, Jensen and Guisti 1992:26).

Of all the natural dyes that man has used to add colour to his environment, indigo has the richest history. Indigo was one of the most important agricultural crops in India. Indigo is still honoured, especially in the East, for traditional styles of dress and for its aesthetic value (Fox and Pierce 1990:13). Indigo has also been greatly valued since antiquity by the Chinese. The Egyptians dyed mummy clothes with a blue dye having all the properties of indigo. Since the nineteenth century indigo used in the commercial dyeing of denim yarn no longer is of natural origin. Much progress has been made in vat dye synthesis during the past hundred years (Intersectional 1989:25).

Indigo is applied in the reduced and soluble form, which on exposure to air is reoxidized to the insoluble blue dye (Hauser and Merritt 2000:33-35). Fox and Pierce (1990:15) noted that indigo can be dyed cold on cotton. This saves energy costs. It is developed by air, which is still free; therefore costs of chemical oxidants do not rise. Indigo has the advantage of building up on tone from pale to heavy depths by simple dipping and the air oxidation process.

Travis and Edelstein (1990:19) determined the structure of indigo by using the method of anthranilic acid made from the phthalic acid and phthalimide condensed with chloroacetic acid and alkali to give a salt of *N*-phenylglycine-*O*-carboxylic acid (Figure 2.10). This was then converted to indoxyl, which was oxidized to indigo.

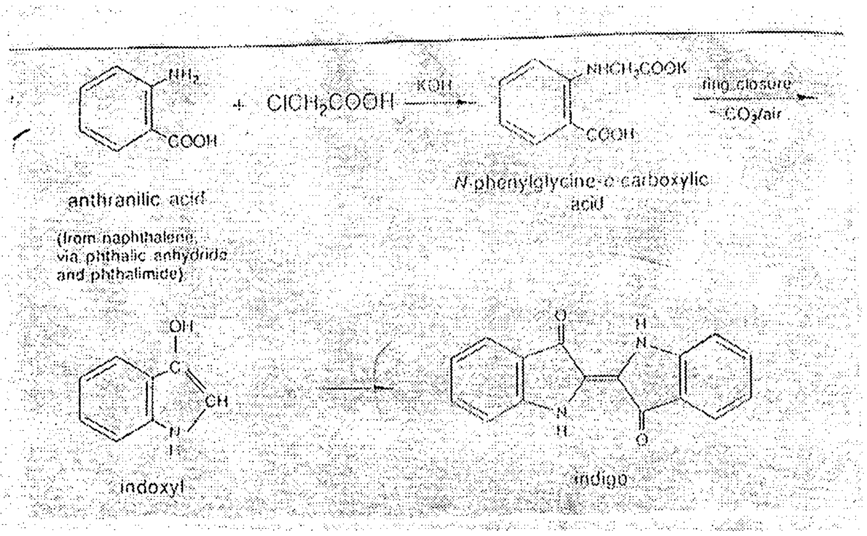


Figure 2.10 Process for synthetic indigo manufacture starting from naphthalene (Travis and Edelstein 1990:19)

In spite of the fact that indigo dyed cotton shows a significant loss in depth by exposure to light, weather, wear and repeat washing, the resulting material retains a rich, pleasing and beautiful blue colour to the end of the life of the most vigorously used garment. This durability of tone is a prime factor distinguishing indigo dyed cottons. It shows good resistance to hypochlorite, peroxides and other bleaching agencies. No matter how pale the colour may become in use, the freshly laundered garment retains a clear and clean tone, which is always preferred to the off-tone fades obtained from many other dyes. Faded denims hold out an inexplicable aesthetic appeal to millions of wearers who appreciate the natural look contrast to the artificiality which is so easy to find in so many things at the present day (Fox and Pierce 1990:13).

When compared to the fastness standard exhibited by modern vat dyes, indigo is completely inferior: the dye has poor :, crockfastness, and fastness to chlorine bleach and poor fastness to atmospheric contaminants. If it were not for the persistence of the denim fashion, indigo would hardly be produced or used at all (Intersectional 1989:25).

Funnell (2001) indicated that indigo dye washes down progressively until a certain point. The wash down is part of the product and performs similarly to what one would expect when purchasing denim jeans. Indigo dyes progressively fade when subjected to extensive sunlight, and the presence and use of washing powders that contain perborates, chlorine as well as optical brightening agents, will aggravate the fading. Funnell added that a noticeable characteristic of German print is the feel, as the cloth is treated with starch finish that gives it a very stiff handle. This starch finish washes out to leave the fabric with a lovely soft handle. The fabric also has a very distinctive smell and taste, recognized and demanded by the regular traditional users of "German Print" or seshoeshoe (Funnell 2001).

2.7 Printing

Most fabrics require some form of decoration to make them attractive. Decoration can take many forms, but the most common involve the use of colour (Burtonshaw 1983:39). In general, the process of printing or dyeing may impart colour. Printing is the application of colour in discrete areas forming patterns of various complexities and is mainly carried out on fabrics (Burdett 1986:39 and Tabba and Hauser 2000:30). Fabrics are coloured or decorated during a fabric-forming process from coloured yarns such as coloured wovens or knits after the base fabric has been formed, sometimes by a combination of dyeing and printing or through finishing operations, whereby other finishes add decorations to the fabric (Burtonshaw 1983:39).

2.7.1 Printing methods

Originally textile printing was a handcraft operation and its roots are extremely ancient. It originated in the Far East and the methods were based on the use of carved wooden blocks with a raised pattern area or stencils. Output was low and production labourintensive. Designs were crude due to limitations imposed by the methods used, and pattern sizes were generally small and ill-fitting between repeats. However, attempts were made in the early nineteenth century to mechanise the process of printing (Burtonshaw 1983:41 and Burdett 1984:44).

2.7.1.1 Discharge printing

Another approach for applying a colour pattern is discharge printing. The fabric is dyed in piece form and then printed with a chemical that will destroy the colour in certain areas. Sometimes the base colour is removed and another colour printed in its place (Wynne 1997:265 and Burtonshaw 1983:41).

Discharge prints are characterised by a dark background that is the same depth of shade on the face and the back and usually by widely spaced motifs. On white discharge fabrics the white motifs appear on both the face and the back. On colour discharge fabrics the area where the motif occurs is usually filled with vibrant colours and the motif area on the fabric back is nearly white (Smith and Block 1982:347).

In discharge printing the fabric is first dyed. A discharge print that contains sodium sulfoxylate formaldehyde is printed onto the fabric with rollers. Sulfoxylate formaldehyde is a chemical that is capable of reducing the dye in the fabric causing the dye to lose its ability to absorb and reflect light so that the fabric is not coloured in the areas where the paste comes into contact with the dye. Production of discharge prints is often expensive because the fabric has to be dyed before printing and the delicate process must be very carefully and precisely controlled. It is important that proper procedures be followed because improper discharge procedures may result in poor colour removal, poor shades as well as weakening and destruction of fabric in the pattern area (Joseph 1986:345 and Hatch 1993:448).

The German Print or seshoeshoe is a vat dyed (indigo) cloth or red, green or brown/azo/dyed cloth with white motifs formed by discharge printing (Funnell 2001)

2.7.1.2 Transfer printing

This is the latest method of printing fabrics by transferring designs to fabric from a special pre-printed paper by a simple heat process using modified garment presses. The dye used has to be capable of vaporising under the heat conditions and has a high affinity for the fibre being coloured. The basic technique was quickly adapted to printing rolls of paper for application to lengths of fabric by employing rotary paper printing machines and continuously rotary calendars running at elevated temperatures. The process is suitable for the printing of circular knitted fabrics (Burtonshaw 1983:45).

Burtonshaw (1983:45) further noted that the sophistication of paper printing with its fine line enabled new design concepts to be employed for textile fabrics. Large blotch effects, realistic textures and lifelike flowers could be produced, giving rise to many new dramatic styles. Prints are clean and bright because of the absence of post-print processing, but they lack penetration on all but light to medium-weight fabrics. Fabrics are therefore confined to dress weights with some application for men's suiting and workwear.

2.7.1.3 Roller printing

The prints produced by roller machines are distinguished by their delicacy of design, fine lines and good fit. Regular geometric patterns such as dots, stripes and small motifs tend to be small to medium sized and fairly closely spaced to avoid large blotch areas unless printed on white grounds. The increasing demand led to the development of computer-controlled methods. In this the design is scanned electronically and converted into electrical signals, which are stored in a computer. The signals are then fed to a mechanical diamond stylus, which produces indented dots in a continuous spiral round the copper cylinder, thereby producing rollers of exceptional quality (Burtonshaw 1983:45).

The most common roller machine consists of a large hollow metal pressure cylinder around which the printing rollers are arranged. Printing rollers are individually driven and can be adjusted to ensure the correct register of pattern. The printing roller is fed with colour from a colour box by a second brush-like roller. A sharp stainless steel blade scrapes the roller surface before printing leaving the colour in the engraved areas where it can be transferred to the fabric as roller and fabric pass in contact with each other. The fabric to be printed is fed on to the pressure cylinder on top of an endless rubber printing blanket to which it is stuck for control of movement during printing. In the process the fabric is printed by rollers that apply colour and design. After leaving the cylinder the cloth is dried through a hot air dryer and then fed over steam-heated cylinders (Wynne 1997:259)

2.8 Health hazards

In Germany reports appeared in journals and on television about the supposed harmful potential of clothing to human health (Sewekow 1996:21). Examples of reported cases included skin irritations from easy-care treated fabrics containing an excess of formaldehyde, and risks from carcinogenic dyes or those which can break down into carcinogenic arylamines by enzymatic reduction. Sewekow noted that some of the criticisms and accusations that were directed to conventional textiles were:

- Sensitising (allergic effects) from azo dyes, formaldehyde, optical brighteners and softeners.
- Poisonous and/or toxic residues of pesticides and preserving agents on cotton and wool.
- Synthetic dyes.
- 'Cancer induced by azo dyes, monomer residues in manmade fibers, formaldehyde, and halogenated carriers.'
- Use of pesticides in cotton farming such as DDT, lindane and hexachlorocyclohexane.
- Use of artificial fertilizers in cotton farming.
- Preservation agents in cotton and wool such as pentachlorophenol.
- High energy and water consumption during processing.
- Effluent pollution through dyeing and finishing, including dyes, preparation, phosphate (sizing), bleach, heavy metals and complexing agents; as well as
- Insufficient protection of workforce from dust and noise during processing.

These harmful potentials lead to the uncertainty and doubtfulness of consumers and textile producers about the safety of garments from the health point of view (Sewekow 1996:21)

2.9 Colourfastness

It is a fundamental requirement that dyed textiles should withstand the conditions encountered during processes following dyeing and during their subsequent useful life. When a dyed textile is subjected to particular conditions such as light, washing or bleaching, several things may occur. As far as the colour of the material is concerned, there may be an alteration of depth, hue, or brightness. During washing adjacent white material may acquire new colour due to the transfer of the dye from the original dyed material (Burdett 1986:43 and Warwicker 1980:50).

Colourfastness is the property of a dye or print to retain its depth and shade throughout the wear-life of a product (Mehta 1984:26). Colourfastness is the resistance of a material to change in any of its colour characteristics. The transfer of its colourants to adjacent materials, as a result of the exposure of the material to any environment that might be encountered during the processing, testing, storage or use of the material (AATCC 1990:17 and Rheinhardt and Graves 1996:30).

Consumers' demand for fabrics with excellent fastness properties are of great importance to apparel manufacturers. Therefore there is a need for apparel manufacturers' to test their fabrics for various colourfastness properties in order to avoid customer complaints of poor colourfastness (Griffin and Neal 1992:173). Proper testing of material will facilitate communication between fabric suppliers and manufacturers, should any fabric need improvement in colourfastness (Mehta 1984:26; Burdett 1984:44 and Bevan 1980:69).

In evaluating the colourfastness of fabrics, industries and researchers use the Grey Scale method. This scale consists of nine pairs of standard grey chips, each pair representing a difference in colour or contrast corresponding to a numerical fastness rating. The results of colourfastness tests are rated by visually comparing the difference in colour represented by the scale (Merkel 1991:252).

Part of the original fabric and the tested specimen of it are placed side by side in the same plane and oriented in the same direction. The Grey Scale is placed nearby in the same plane. The visual difference between the original and the tested fabric is compared with the differences represented by the Grey Scale. The difference in the colour change and the amount of colour transfer are given a numerical value ranging from 5 to 1. Class 5 indicates no change in the original colour (shade) and no colour transfer. Class 1 indicates a noticeable change in colour or heavy colour transfer (Mehta 1984:26; Angliss 1991:19).

2.9.1 Colourfastness to crocking

Crocking is a transfer of colourant from a surface of a coloured fabric to an adjacent area of the same fabric or to another surface principally by a rubbing action (AATCC 1990:196). A variety of small mechanical forces disturb fibres during production, use and care of fabrics and can lead to a reduced life of garment. (Annis *et al.* 2001:71) Friction during use can cause the dye to rub off when it does not properly penetrate the fibre but remains on the surface. This causes the fading or removal of colour on fabrics (Smith and Block 1982:338).

Tabba and Hauser (2000:31) conducted a study on crocking. In their study the printed pieces were washed for a specific number of times with detergent in a hot home washing cycle using a Kenmore washing machine. The washed samples were compared to the washed samples in each set by using the AATCC Grey Scale for colour change under D65 illuminant. Testing demonstrated that as the number of wash cycles increased for the printed unwashed samples, the crockfastness improved, thus confirming the loss of printed colour. Also the printed treated samples maintained their crockfastness ratings, thus confirming constant colour after washing.

In another study by Larney and van Aardt (1994:70) the performance of selected dyes in home dyeing of cotton were tested for various colourfastness properties. All the dyed test specimens were tested for colourfastness to light, washing, rubbing and perspiration. Colour changes were evaluated according to SABS method 268, while SABS method 269 was used to evaluate staining in the case of washing and perspiration.

Colour change during washing, crocking and perspiration was assessed using the standard Grey Scale. Blue wool lightfastness standards were used to assess colour change due to exposure to light. Results showed that all dyes stained cotton during washing. It is recommended that home-dyed cotton fabrics should not be washed together with other cotton fabrics. Dry rubbing presented negligible problems, while wet rubbing showed more colour transfer in the case of all dyes.

2.9 2 Colourfastness to laundering

Some dyes may be chemically bound to the fibre with which they are used (Smith and Block 1982:338). The dyes that are not chemically bound may be leached from the fibre by soaps or detergents during laundering, or by dry-cleaning solvents. Removal of any dye causes the colour to fade. Strong bleaches may also cause chemical changes that affect dyes, and cause them to lose their colour during laundering. For example a pair of red socks that is accidentally laundered with white goods may turn the entire wash load pink (Williams and Horridge 1996:137; Breen *et al.* 1984:199, Mohamed 1982:65).

Dye loss can occur as a result of alkaline hydrolysis of dye-fibre bands, oxidative fading of the dye chromophone by peroxides and as a result of cellulose degradation (Sugane *et al.* 2001:223).

Breen, Durnam and Obendorf (1984:199) used four different wash temperatures (4, 27, 38 and 49°C) and three different detergents and ran their laundering cycles in a Launder-Ometer. The specimens washed at 27, 38 and 49°C were rinsed twice for five minutes each at 21°C, while specimens washed at 4°C were rinsed at 4°C. After laundering fabric specimens were air-dried at 21°C. After specimens were analysed using backscattered electron images and energy dispersive x-ray analysis results showed that with increased temperatures, more oleic acid was removed from the fabric for all three detergents.

Research conducted by Williams and Horridge (1996:137) on the effect of selected laundering and dry-cleaning pre-treatment on the colours of naturally coloured cotton three different colours (green, brown and white) were laundered and dry-cleaned for 15 cycles. Instrument colour readings were taken on the Mac Beth 1500 Colour Measurements system sphere optical sensor. A panel of judges also evaluated the samples, using Grey Scale measurements. Results showed that when coloured cotton samples were placed in a detergent presoak solution, colour immediately bled into the water.

In the study by Perenich and Epps (1986:25) 100% cotton samples were laundered with detergent alone while some samples were laundered with detergent and chlorine in different laundering temperatures. Colour change was evaluated using a AATCC Grey Scales. It was concluded from the panel of judges that the chlorine and detergent combination was associated with less colour change than detergent alone. That is, the effects of detergent alone were higher. Temperature also affected the fastness of several dyes.

2.9.3 Colourfastness to light

Lightfast colours are those that do not change under exposure to sunlight or artificial light source. Light can be defined as a form of energy. When dyes absorb energy, they may be altered in their chemical makeup. That is, the auxochromes are removed, or chemical bonds within the dye may be broken. These chemical changes affect the hue, value and saturation of the dye and eventually the colourants may lose their ability to produce colour (Smith and Block 1982:337; Carver and Wylie 1980:96).

Research conducted by Carver and Wylie (1980:96) on whiteness as affected by laundry treatments and environmental factors reveal that an increase in exposure of the fabric samples to laundry treatment, light and oxygen caused more discolouration and yellowing, therefore a greater loss in the effectiveness of the OBA. In their investigation Carver and Wylie used polyester/cotton fabrics with a durable-press finish and OBA incorporated into the fibre.

Carver and Wylie (1980:97) subjected fabric samples to forty wash cycles with OBA containing detergent used for each wash load at 40°C and 60°C respectively. Drying treatment used included tumble-drying, one-hour line drying and four hours line drying. Results showed that samples washed at 40°C resulted in less de-colouration. Increase in the number of wash cycles resulted in more pronounced colour change. Four-hour-line dried samples were lower in fluorescence, samples washed at 60°C were lower in fluorescence, while samples washed at 40°C and tumble-dried were whiter than the line-dried samples.

In research conducted by Saito *et al.* (1988:450) on the colour fading behaviour of anthraquinone dyes due to environmental conditions, white pieces of cotton were treated with a dye solution containing ethanol. The solution was placed in a covered optical quarts cell and irradiated by ultraviolet light from a mercury lamp for a period of 240 minutes. For weathering, test samples were exposed to outdoor sunlight in summer for 66 days to measure the light fastness of the dyes according to JIS-L-0841.

For the fadometer method, each piece of dyed cloth was placed in a stoppered test tube filled exclusively with oxygen or nitrogen with either very high or low humidity. For colour characterisation, the extent of colour fading is expressed by the fastness grade using JIS and colour difference (ΔE) between the original and faded samples. Results showed that the fading of cotton is related to the ability of each dye to oxidise.

CHAPTER 3

EXPERIMENTAL PROCEDURE

This chapter describes the empirical study. The main objective of the study was to evaluate the effects of detergent, wash temperature and drying on the colourfastness of indigo and azo dyed cotton fabric that is used by women in Lesotho as a traditional dress. The procedures followed were described in terms of detergents, fabric and laundering colourfastness assessment.

3.1 Detergents

Two types of anionic detergent A and B (purchased from a local supermarket) were used in this study. Table 3.3 shows the active ingredients as indicated by the manufacturer in the selected household detergents.

Table 3.3: Active ingredients in the selected household detergents

Detergent	Ingredients	Functions
A	**Cationic surfactants**	**Wetting and soil remover**
	Polycarboxilate	**Anti-redeposition agent**
	Silicates	**Corrosion inhibitor**
	Soda ash	**Water softener**
	Anionic surfactants	**Wetting agent and soil remover**
	Phosphates	**Water softener, soil suspending agent and alkalinity source.**
B	**Silicones**	**Antifoam**
	Phosphonates	**Sequestering agent**
	Zeolites	**Water softener**
	Sulphonated co-polymer	**Flow aid**
	Silicates	**Corrosion inhibitor**
	Anionic surfactants	**Agent for stain release**
	Nonionic surfactants	**Wetting agent**
	Soda ash	**Water softener**
	Phosphates	**Water softener, soil suspending agent and alkalinity source.**

3.2 Experimental fabrics

Two metre pieces of blue indigo (Lot CY03 6936) and red azo (Lot CY03 4171) dyed cotton test fabrics were obtained from the Da Gama Textile Company Ltd. The manufacturer kindly supplied the pieces that were removed from the manufacturing process before the discharge printing process which would provide the typical German print cloth (seshoeshoe) that is used by the Basotho women for their traditional dress. It was essential to have unprinted cloth to be able to determine colour loss in the experimental process.

Fabric samples were cut to 5 cm x 10 cm rectangles according to the AATCC test method 61-1975 and raw edges over-locked to avoid fraying during the laundering process. The multifibre test fabrics style was 10A (DW). Lot number 8889 fibre sequence spun diacetate, bleached cotton, spun polyamide (type 66), spun polyester (type 554), spun polyacrylic (type 75) and worsted wool (standard adjacent test fabric per ISO/AATCC/WW requirements) of the same size were attached to the experimental fabrics to determine staining.

3.3 Laundering

Laundering tests were carried out using a Launder-Ometer (Atlas Electric Devices Co.). Washing tests were performed for 45 minutes at 40°C and 60°C. Samples were washed individually in 200 ml of wash solution with 0.2% detergent solution according to the IIA test in AATCC Test Method 61-1975 for Colourfastness to Washing, Domestic, and Commercial laundering. Fabrics were subjected to 0 to 10 Launder-Ometer cycles (the equivalent of 0 to 50 home wash cycles), of laundering in six treatments:

- With detergent B at 40°C
- With detergent B at 60°C
- With detergent A at 40°C
- With detergent A at 60°C
- Control without detergent at 40°C
- Control without detergent at 60°C

After washing samples were rinsed in cold water and allowed to dry for four hours in open air and sunlight respectively between 10:00 and 15:00. This method was used to represent realistic conditions that are employed by most people in the Southern African region. In an effort to compare the effects of sunlight on colourfastness, other samples were dried indoors on household drying frames at room temperature.

3.4 Assessment of Colourfastness

3.4.1 Laundering

Colourfastness to laundering at 40°C and 60°C were measured in daylight (D65/10), UV-light (Woolworth's Storelight F11/10), and Tungsten (A/10), using a Spectrogard Computer Colour System. Indigo and azo dyed cotton fabrics were washed with detergent A and B and line dried after each cycle. In order to assess the effect of wash cycles, the treatment process was repeated. After each cycle pre-determined samples of the experimental fabric was removed (Table 3.4) for assessment of colour.

3.4.2 Staining

In assessing the colourfastness of the experimental fabrics to laundering, tests for colour change as well as staining are important (Merkel 1991:252). White strips of multifibre fabrics; cotton, polyester, nylon, wool, acetate and viscose rayon were used during laundering treatment to indicate their possible staining due to colour loss of experimental fabrics and were assessed by means of a Grey Scale.

The Grey Scale for assessing staining (including half values) approved and issued in collaboration with the Society of Dyers and Colourists recommended for use with ISO 105, A03: 1987; BS 1006, A03: 1990 and SDC standard method was used for the measurement of colour change in the experimental fabrics after exposure to laundry treatment.

A piece of stained fabric was placed next to the Grey Scale and the tested stained piece was visually compared with the difference represented by the Grey Scale. A higher whiteness index (a 5 indicated no staining and a 1 excessive staining) was given if there was no difference in colour between the tested sample and the rating of five on the Grey Scale.

3.4.3 Crocking

The AATCC crock meter model CM5, manufactured by the Atlas electronic devices Co. USA) was used to determine crocking in the wet and dry state. Wet and dry experimental fabrics of 5 x 13 cm were rubbed against a dry, white cotton cloth. According to the AATCC method 8-1988 the testing procedure required the rubbing of a piece of crocking cloth, back and forth, 10 times in 10 seconds, over a 100 mm section of the specimen. Crocking was done after every washed cycle up to cycle five. It was not necessary to continue thereafter, since the results remained similar after cycle three.

3.5 Statistical analysis

Statistical analysis was carried out using a factorial layout to determine the effect of factor types, detergent, fabric dye and number of wash cycles (1, 5 10, 20, 30, 40, 50) on the colourfastness of experimental fabrics. The Analysis of Variance (ANOVA) procedure was used to analyse colourfastness measurements. A regression approach was used to investigate the changes in the measurements due to the frequency of washing. Tables and figures in Chapter 4 illustrate significant differences in the effect of selected detergents on dyed cotton fabrics.

CHAPTER 4

RESULTS AND DISCUSSION

Colour loss experienced in the laundering and wear of the Seshoeshoe cotton fabric is the concern of consumers and the motivation for the study. The study was done to evaluate the effect of detergent, wash temperature and drying on the colourfastness of indigo and azo dyed cotton fabrics. The results of colour loss to washing, light, crocking and staining are graphically presented in this chapter.

Different factors that influence colour loss in the home laundering process such as detergent type, number of wash cycles and fabric dye were identified.

Research has shown that detergents contain several substances that have specific functions in the washing process (McLean 1999:42; Moe 2000:79). To evaluate the effect of detergent on the colourfastness, azo dyed cotton fabrics and indigo dyed cotton fabrics were washed fifty times at 40°C and 60°C in the Launder-Ometer, using detergents A and B, as well as water without detergent as control. Samples of azo and indigo dyed cotton fabrics were subjected to multiple wash treatments and measurements of colour loss were expressed by Delta E value.

A description of colour loss as affected by detergent, wash temperature and drying will be given. The pass/fail value used in industry to indicate the acceptability of colour change will also be presented. This value is used in industry and cannot be used as a quality measurement in colour loss during laundering.

4.1 Colour loss of azo dyed cotton according to the pass/fail method employed by industry

Table 4.1 represents an overview of the total effect of wash treatments on azo and indigo dyed cotton as expressed by the pass/fail method employed by industry. This method is widely used by industries to assess the colour quality from one colour batch to another.

Table 4.1 Summary of total colourfastness results expressed by the pass/fail method

Dye of fabric	Number of samples	Detergent	Factor combination	Un-acceptable Response	Total Response
Azo Indigo	8	Water w/out detergent (C)	C Azo C Indigo	8/8 3/8	11/16
Azo Indigo	8	Detergent B	B Azo B Indigo	8/8 8/8	16/16
Azo Indigo	8	Detergent A	A Azo A Indigo	8/8 8/8	16/16

The following are depicted in Table 4.1:

- The average percentage of samples rejected on the standard set for colour loss due to water without detergent after fifty wash cycles is eleven out of sixteen (69%).
- The average percentage of samples rejected on the standard set for colour loss due to detergent B after fifty wash cycles is sixteen out of sixteen (100%).
- The average percent of samples rejected on the standard set for colour loss due to detergent A after fifty wash cycles is sixteen out of sixteen (100%).

It is indicated in Table 4.1 that both azo and indigo dyed cotton washed with detergent B and A had a failure rate of sixteen out of sixteen, while azo and indigo washed with water without detergent have a failure rate of eleven out of sixteen. This indicates a higher colour loss due to detergent use. Although this pass/fail method is used in industry as a colour batch quality control measure in this project, it merely indicates that visible colour change has taken place.

4.2 Colour loss of azo dyed cotton washed at 60°C and dried indoors

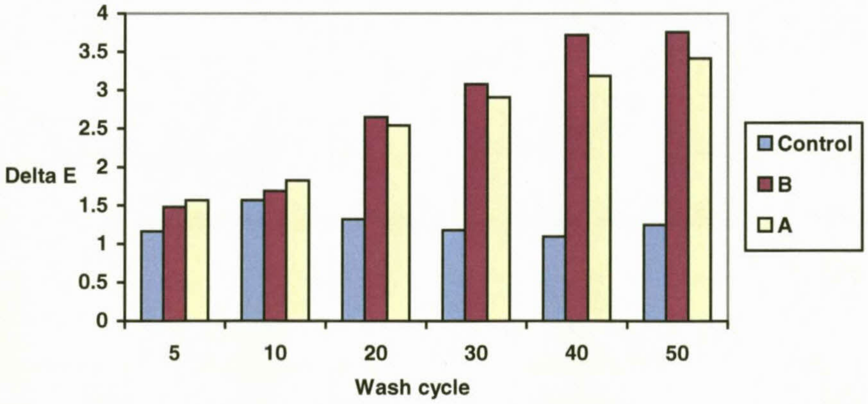


Figure 4.1 Colour loss of azo dyed cotton fabric washed at 60°C observed under D65/10 daylight

Figure 4.1 shows azo dyed cotton fabric washed fifty times with detergent B, detergent A and with water without detergent at 60°C. The results determined under D65/10 daylight conditions show an increase in colour loss with the use of detergent B and detergent A, while little colour difference is noticed between the fifth and the fiftieth cycles with water without detergent. It is worth noting that with the use of detergent regardless of the brand, colour loss increases noticeably throughout all cycles. Detergent B shows a higher increase than detergent A from cycle thirty to cycle fifty. It is evident from Figure 4.1 that detergents do cause colour loss, but the amount of loss will depend on the type of detergent.

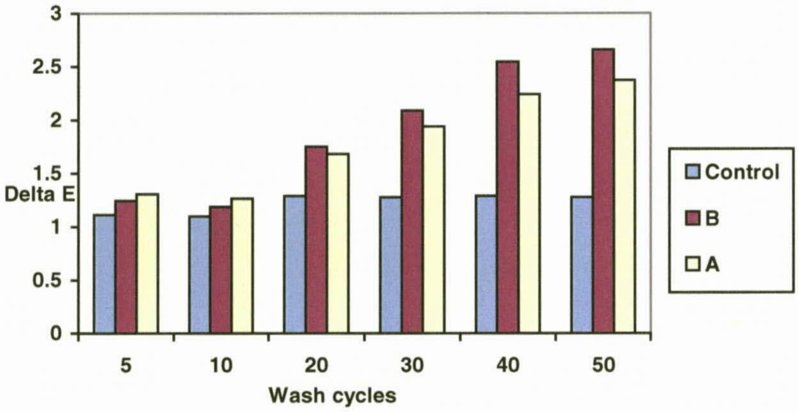


Figure 4.2 Colour loss of azo dyed cotton fabric washed at 60°C and dried indoors observed under tungsten light A/10

The results from Figure 4.2 shows samples of azo dyed cotton fabrics washed fifty times at 60°C with detergent B, detergent A and with water without detergent measured under tungsten light (A/10). The results from Figure 4.2 show a constant colour loss from cycle twenty to cycle fifty in samples washed with water without detergent. Samples of azo dyed cotton fabric washed with detergent B seem to have lost almost the same amount of colour in the fifth and tenth cycle, but a gradual increase of colour loss is noticed after cycle ten. Detergent A shows an upward slope of colour loss from cycle twenty and the remaining cycles.

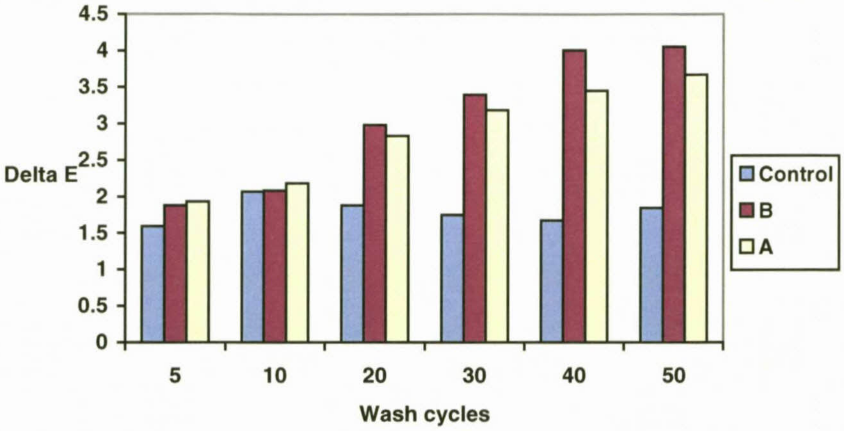


Figure 4.3 Colour loss of azo dyed cotton fabric washed at 60°C and dried indoors observed under UV light F11/10

It is clear from Figure 4.3 that no major difference in colour loss between samples washed with detergent and those washed without detergent could be noticed in the first five to ten wash cycles, but after the tenth cycle the difference more obvious. Samples washed with detergent B appear to have caused more colour loss than samples washed with water without detergent after the tenth cycle. Detergent A has higher values for colour loss than values indicated by water without detergent.

However, UV light (F11/10) shows more severe loss of colour than D65/10 and A/10. This shows that colour loss is more visible under UV light than daylight and even more pronounced than under tungsten light. It can be concluded from Figures 4.1, 4.2, and 4.3 that there is a correlation ($P \leq 0.05$) between the number of wash cycles and colour loss of azo dyed cotton fabric, colour loss increases as the number of wash cycles increase. These results correspond with findings by Carver and Wylie (1980:97) that increase in the number of wash cycles resulted in more pronounced colour change

Table 4.2 shows the results according to the analysis of variance (ANOVA) for the number of wash cycles, the colour of the cotton fabric used and the type of detergent used.

Table 4.2: Analysis of Variance for azo dyed cotton fabrics

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
X (cycles)	1	179.84	179.84	221.65	0.000000	1.000000
A (brand)	2	48.46148	24.23074	29.86	0.000000*	1.000000
S	50	40.56821	0.8113641			
Total (Adjusted)	53	270.2446				
Total	54					

Term significant at alpha = 0.05

Table 4.2 indicates that the influence of cycles (X) is significant ($P \leq 0.05$) and there is a significant difference between the brand of detergents and water without detergent ($P \leq 0.05$).

4.3 Colour loss of indigo dyed cotton fabric washed at 60°C and dried indoors

Samples of indigo dyed cotton fabric were washed fifty times with detergent B, water without detergent and detergent A. The treatment process was conducted for forty-five minutes at 60°C and samples dried indoors.

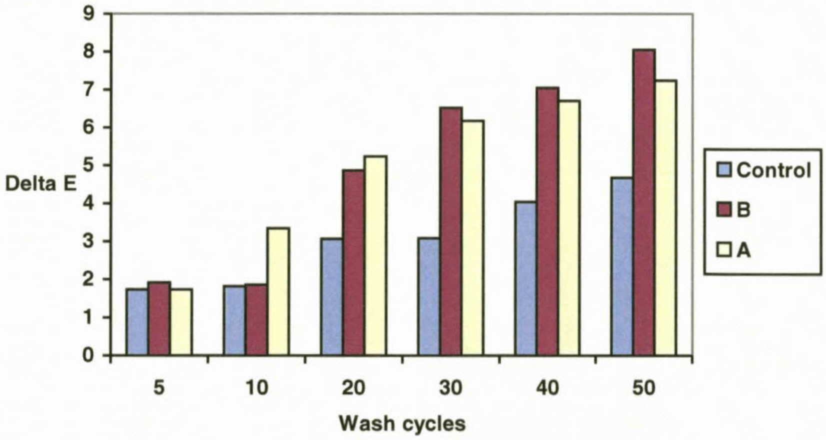


Figure 4.4 Colour loss of indigo dyed cotton fabric washed at 60°C and dried indoors observed under D65/10 daylight

Figure 4.4 shows the colour loss of indigo dyed cotton fabric washed with detergent B, detergent A and with water without detergent at 60°C and with the results observed under daylight D65/10. The results show an increase in colour loss from the tenth to the fiftieth wash cycles for both detergent B and A, as well as in water without detergent. Though it is evident that colour loss in water without detergent is much less than the colour loss with detergent, the difference between water with detergent and water without detergent becomes more pronounced as the number of wash cycles increase. These results confirm previous research indicating that indigo has poor wash fastness (Intersectional 1989:25).

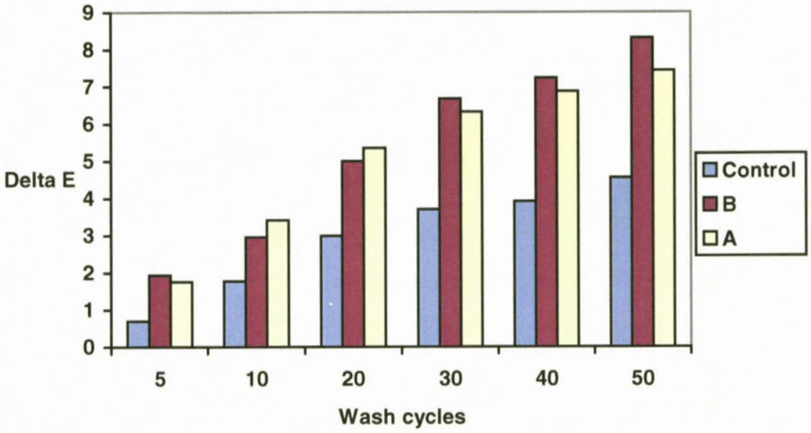


Figure 4.5 Colour loss of indigo dyed cotton fabric washed at 60°C and dried indoors observed under UV light

Figure 4.5 clearly shows that there was a gradual loss of total colour as the number of wash cycles increased. Figure 4.5 shows a significant ($P \leq 0.05$) loss of colour in samples washed with water without detergent in the tenth cycle and a gradual upward slope of colour loss thereafter up to cycle fifty. Measurements associated with the number of wash cycles and the type of detergent used show an upward slope with colour loss in samples washed with detergent B and detergent A.

Even though there seems to be a difference in an increase of colour loss between samples washed with detergents B and A, the colour loss caused by detergent A appears to have lower values than detergent B. As with azo dyed cotton, colour loss determined under UV light seems more than in daylight conditions.

Table 4.3 Analysis of variance for indigo dyed cotton fabrics

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
X (cycles)	1	179.84	179.84	221.65	0.000000	1.000000
A (brand)	2	48.46148	24.23074	29.86	0.000000*	1.000000
S	50	40.56821	0.8113641			
Total (Adjusted)	53	270.2446				
Total	54					

Term significant at alpha = 0.05

Table 4.3 indicates that the number of wash cycles and the type of detergent is highly significant ($P \leq 0.05$). Delta E increased as the number of wash cycles increased.

4.4 Colour loss of azo and indigo dyed cotton fabric washed at 40°C with detergent B, detergent A and with water without detergent

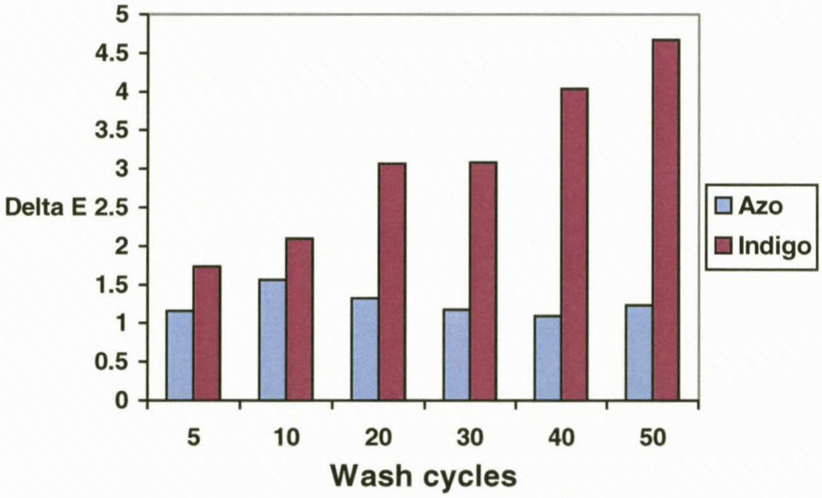


Figure 4.6 Colour loss of azo and indigo dyed cotton fabric washed in water without detergent at 40°C observed under D65/10 daylight

Figure 4.6 indicates the difference in colour loss observed in azo and indigo dyed cotton fabrics. It is evident from Figure 4.6 that the colour loss of azo dyed cotton does not differ very much throughout all cycles. It is interesting to note a downward slope from cycle twenty. The results indicate a slight difference of colour loss of indigo between the fifth and the tenth cycles, while the colour loss remains constant at cycle twenty and cycle thirty and a prominent increase thereafter. These results prove that indigo dyed cotton fabric looses more colour than azo dyed cotton fabric. These results are in congruence with the expected as cited in the literature that indigo washes down progressively until a certain point (Intersectional, 1989 and Funnel, 2001). Figure 4.6 indicates that the end point for colour loss is not reached after fifty wash cycles, there is no indication of a slowdown in colour loss visible.

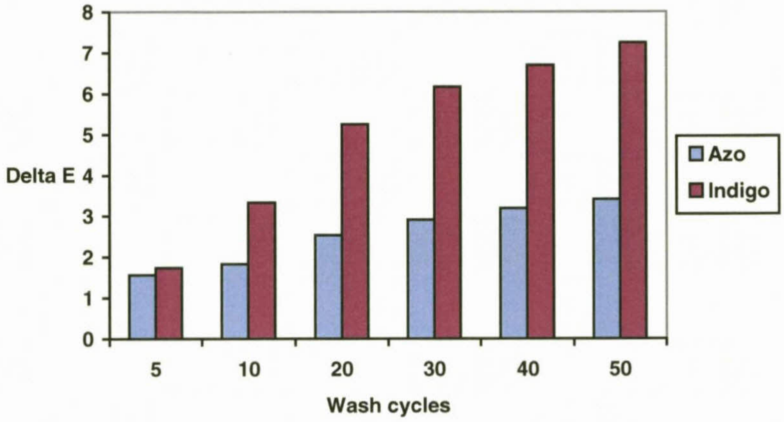


Figure 4.7 Colour loss of azo and indigo dyed cotton fabric washed with detergent A at 40°C observed under D65/10 daylight

The difference in the colour loss of indigo and azo dyed cotton fabric washed with detergent A up to the fiftieth cycle and dried indoors is illustrated in Figure 4.7. The differences in colour were determined in D65/10 daylight. It is observed from Figure 4.7 that indigo dyed cotton lost almost the same amount of colour as azo dyed cotton in cycle five.

A remarkable amount of colour loss in indigo compared to the azo dyed cotton is noticed from the tenth to the fiftieth cycle. These results do not only confirm the washing down of indigo dye when exposed to laundry treatments, but it also links the rise in colour loss of indigo dye to the increase in the number of wash cycles, indicating the poor wash-fastness of indigo dyed cotton fabric. In comparison azo dyed cotton fabric appears to be loosing less colour throughout all cycles than indigo.

The poor wash-fastness of indigo dyed cotton fibre appears to be a major problem. This finding corresponds with observations reported from previous research. Intersectional (1989:25) Reidies *et al.* (1992:26) and Etters (1995:17) indicated that indigo has poor wash-fastness when compared to fastness standards exhibited by modern vat dyes.

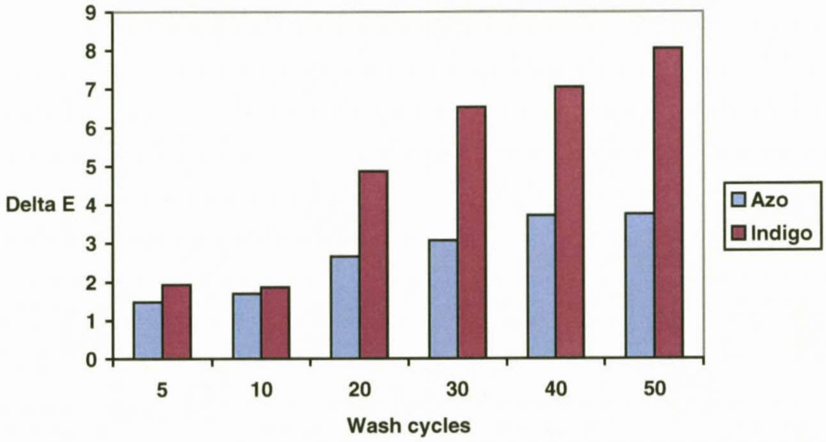


Figure 4.8 Colour loss of azo and indigo dyed cotton fabric washed with detergent B at 40°C observed under D65/10 daylight

Figure 4.8 shows that the colour loss of indigo and azo dyed cotton fabric washed with detergent B at 40°C does not differ much in cycle five and ten, but a remarkable difference is seen thereafter. With detergent B indigo dyed cotton appears to have lost more colour than azo dyed fabric from cycle twenty up to cycle fifty. This does not differ from the results indicated in Figure 4.7, where detergent A was used. It is interesting to note that fabrics washed without detergent in Figure 4.6 show lower values in colour loss. It is therefore evident to conclude that detergent does have a negative effect on colour loss.

These results are in line with William and Horridge (1996:137), who found that when coloured cotton samples were placed in a detergent pre-soak solution, colour immediately bled into the water. Another contributing factor could be that detergents do contain several ingredients that have specific functions in the washing process but a negative influence on colour (Webb and Obendorf 1987:640; Schlager 1994:248 and Aspland 2000:205).

4.5 Colour loss of azo and indigo dyed cotton fabric washed at 40°C and dried indoors

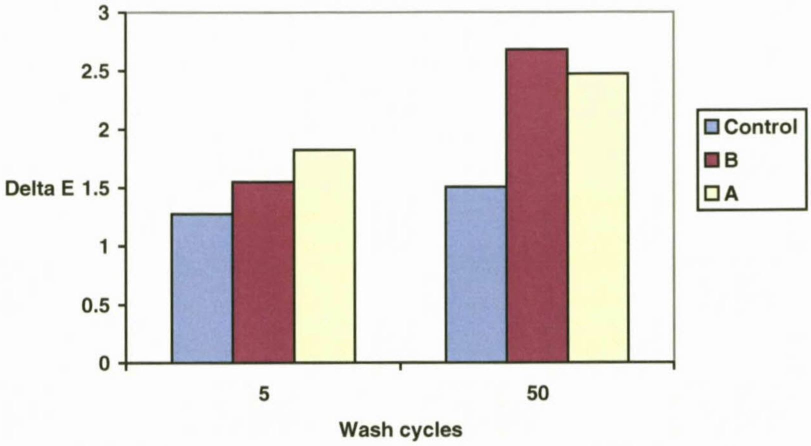


Figure 4.9 Colour loss of azo dyed cotton fabric washed at 40°C dried indoors observed under D65/10 daylight

Data in Figure 4.9 illustrate colour loss observed in D65/10 daylight of azo dyed cotton fabric washed fifty times at 40°C with detergent B and detergent A, as well as water without detergent and dried indoors. The results from Figure 4.9 clearly demonstrate that under daylight conditions, azo dyed cotton fabric washed with detergent A seemed to have lost more colour after the fifth cycle than azo treated with detergent B and with water without detergent. There seems to be an increase of colour loss after the fiftieth wash cycle of azo dyed cotton fabric washed with detergent B than those washed with detergent A. Detergent A and B after cycle fifty show more increase in colour loss than azo washed with water without detergent. These results do not differ from the finding of Perenich and Epps (1986:25) that detergents do cause colour change.

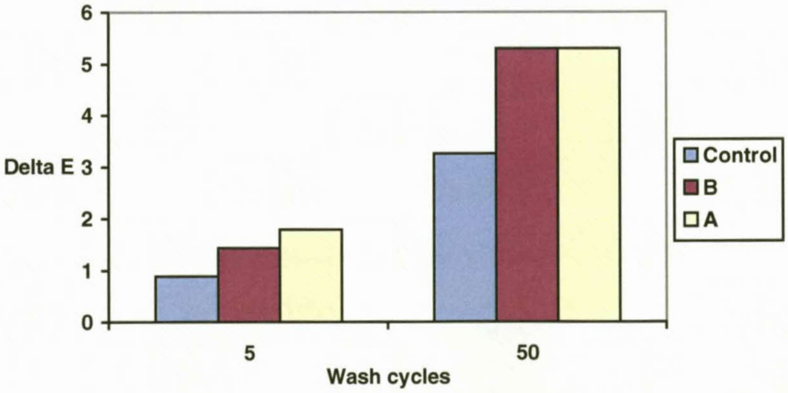


Figure 4.10 Colour loss of indigo dyed cotton fabric washed at 40°C dried indoors observed under D65/10 daylight

Figure 4.10 shows the difference in colour loss of indigo dyed cotton samples washed at 40°C using detergents B and A as well as water without detergent. The results from Figure 4.10 clearly indicate that the colour loss of indigo cotton fabric dried indoors observed under daylight shows a significant difference in colour loss between samples washed with water without detergent and samples washed with detergent A. It is also clear that there is no significant difference between samples washed with detergent A and B in the fifth cycle. The colour loss of both fabrics is more pronounced in cycle fifty with more colour loss with the use of detergent A and B.

No dye is totally colourfast (White 1989:1). Indigo and azo dyed cotton persistently loose colour regardless of the brand of the detergent, even when washed with water without detergent. This proves that both dyes are not colourfast, even when washed at a lower temperature.

4.6 Colour loss of azo and indigo dyed cotton fabric washed with detergent B, detergent A and with water without detergent at 40°C and dried outdoors

The experiment was designed to study the effect of sunlight on the colourfastness of azo and indigo dyed cotton fabrics. In an effort to evaluate the effect of sunlight samples on indigo and azo dyed fabrics, cotton were washed with detergent B, detergent A and with water without detergent. Some samples were dried indoors while others were dried outdoors in an extensive sunlight for four hours between 10:00 and 15:00. Colour loss of the experimental fabrics was observed under D65/10 daylight

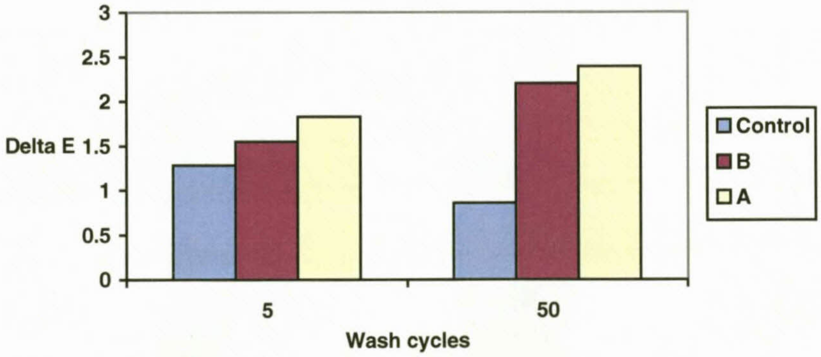


Figure 4.11 Colour loss of azo dyed cotton fabric washed at 40°C, dried outdoors and observed under D65/10 daylight

Data in Figure 4.11 indicate that the azo dyed fabric washed with water without detergent when examined under daylight appears to have lost slightly less colour than azo dyed cotton fabric washed with detergent B and A in the fifth cycle. Values of colour loss of azo dyed cotton washed with detergent A and detergent B are slightly higher than that washed with water without detergent in the fifth cycle. However, an increase in the colour loss of azo dyed cotton washed with detergents B and detergent A was noticed after the fiftieth cycle. There was more colour loss with the use of detergent A and B.

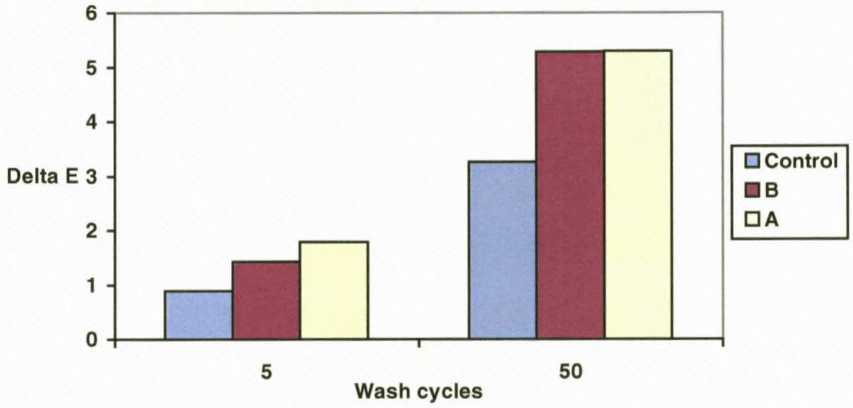


Figure 4.12 Colour loss of indigo dyed cotton fabric washed at 40°C, dried outdoors and observed under D65/10 daylight

Figure 4.12 gives the results of indigo dyed cotton samples washed with detergent B, detergent A and with water without detergent dried outdoors in extensive sunlight for four hours. It is obvious from Figure 4.12 that the amount of colour loss of indigo dyed cotton appears to be slightly higher in samples washed with detergent A after the fifth cycle. The colour loss of indigo dyed cotton washed with water without detergent indicates lower values than that washed with detergent B and detergent A after the fifth cycle.

4.7 Colour loss of azo and indigo dyed cotton fabric washed with detergent B, detergent A and with water without detergent at 40°C and dried outdoors and indoors observed under D65/10 daylight

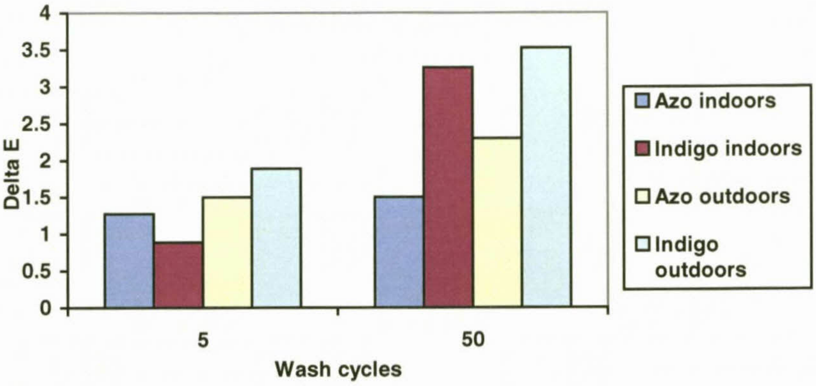


Figure 4.13 Colour loss of indigo and azo dyed cotton fabric washed with water without detergent and dried outdoors and indoors observed under D65/10 daylight

The results in Figure 4.13 show that the colour loss of azo dyed cotton fabrics dried indoors appear to be slightly lower than azo dyed cotton fabric dried outdoors after both cycle five and fifty. Indigo dyed cotton dried outdoors lost much more colour than indigo cotton dried indoors after cycle five. It is evident from Figure 4.13 that there is an increase in colour loss of both fabrics dried outdoors.

The underlying cause indicated by results in Figure 4.13 could be that the increase in colour loss that appears after cycle fifty is due to the prolonged drying of samples in extensive sunlight. These results correspond with findings by Saito *et al.* (1988:450), who discovered that the fading of cotton is related to the ability of each dye to oxidise after exposing samples to outdoor sunlight in summer for 66 days. Sugane and co-workers (2001:223) also indicate that oxidation causes colour loss.

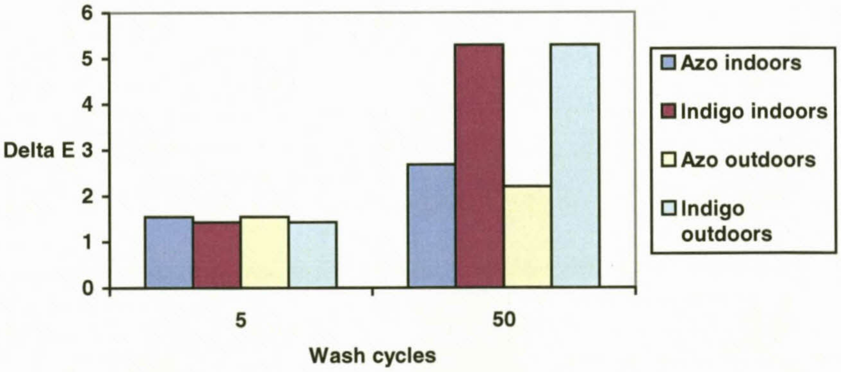


Figure 4.14 Colour loss of indigo and azo dyed cotton fabric washed with detergent B and dried outdoors and indoors observed under D65/10 daylight

The results displayed in Figure 4.14 show that in the presence of detergent B both azo and indigo dyed cotton lost more colour when dried outdoors than when dried indoors after fifth and fiftieth cycles.

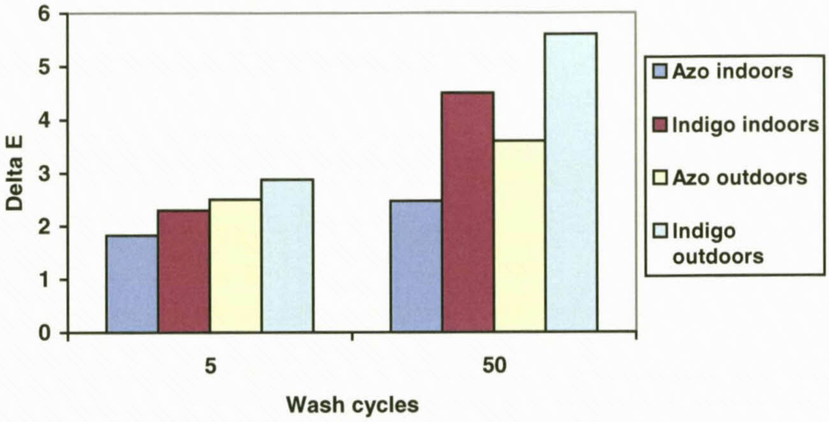


Figure 4.15 Colour loss of indigo and azo dyed cotton fabric washed with detergent A and dried outdoors and indoors observed under D65/10 daylight

The results in Figure 4.15 show that azo dyed cotton dried indoors lost less colour than azo dyed cotton dried outdoors after both cycle five and fifty. Indigo dyed cotton subjected to detergent A show the same results as azo dyed cotton after cycles five and fifty. Cycle fifty displays higher values in colour loss when compared with cycle five. Samples washed with detergent and dried outdoors show the most colour loss, which indicate that sunlight is a factor that causes colour loss.

4.8 Colour loss of azo and indigo dyed cotton fabric washed with detergent B, detergent A and with water without detergent at 40°C and 60°C observed under D65/10 daylight

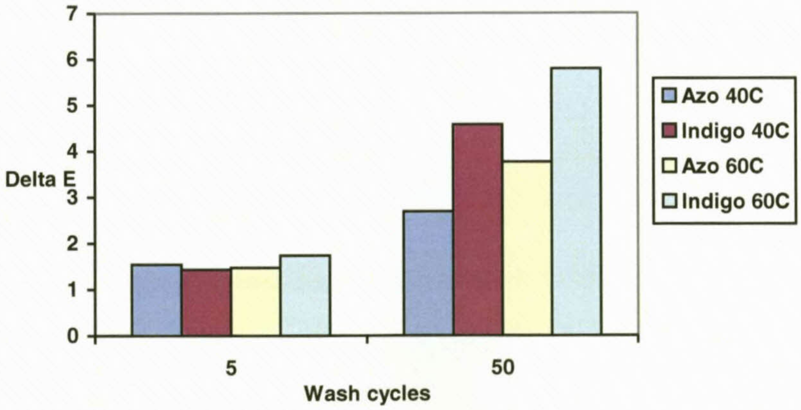


Figure 4.16 Colour loss of azo and indigo dyed cotton fabrics washed with detergent B at 40°C and 60°C observed under D65/10 daylight

It is evident from Figure 4.16 that the colour loss of both experimental fabrics appears to be the same after cycle five, regardless of the difference in temperature. Data in Figure 4.16 shows that after cycle fifty azo dyed cotton lost remarkably more colour at 60°C than at 40°C. It is also obvious from Figure 4.16 that more colour of indigo dyed cotton is lost at 60°C than at 40°C after the fiftieth cycle with the use of detergent B. Conclusions can be drawn from Figure 4.16 that high temperature has a negative effect on colour loss. This is in line with the finding of Perenich and Epps (1986:28) that temperature affects the colourfastness of several dyes. Carver and Wylie (1980:97) showed that samples washed at 40°C resulted in less de-colouration than samples washed at 60°C.

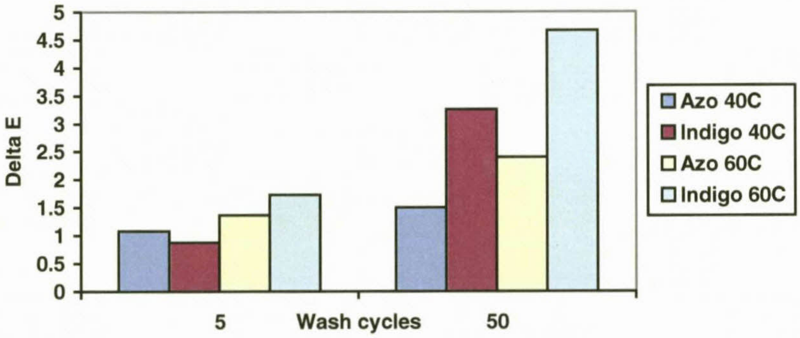


Figure 4.17 Colour loss of indigo and azo dyed cotton washed with water without detergent at 40°C and 60°C observed under D65/10 daylight

It is established in Figure 4.17 that azo dyed cotton washed with water without detergent appears to have lost more colour at 60ºC than at 40ºC after the fifth cycle. There seems to be an increase of colour loss of both azo-dyed cotton washed at 60°C and 40°C in cycle fifty. Indigo dyed cotton lost more colour at 60°C than at 40°C after both cycle five and fifty. The prominent difference in colour loss between azo at 40°C and 60°C but even a bigger colour loss between indigo at 40°C and 60°C without the presence of a detergent emphasises the fact that the higher temperature causes a bigger colour loss. It also proves that indigo is more sensitive to temperature in colour loss than azo.

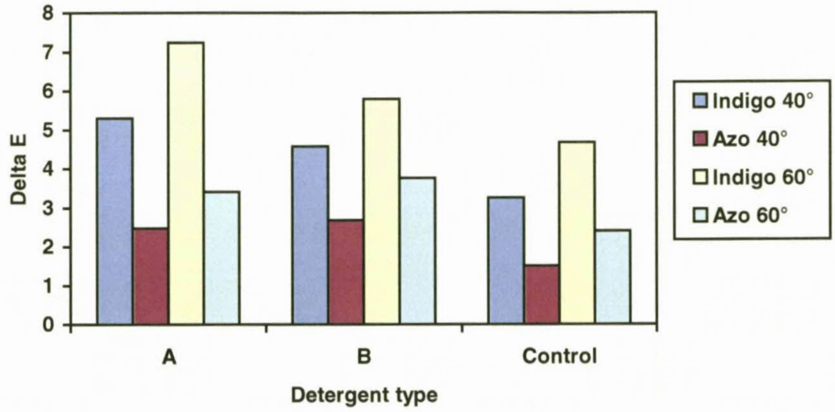


Figure 4.18 Colour loss of indigo and azo dyed cotton fabric washed with detergent A and detergent B and water without detergent at 40°C and 60°C observed under D65/10 daylight after fiftieth wash cycle

Figure 4.18 indicates, among other things, that azo dyed cotton washed with detergent A at 40°C lost less colour than azo at 60°C after cycle fifty. Indigo shows a bigger increase in colour loss from 40°C to 60°C. Figure 4.18 also points out that colour loss from indigo dyed fabric with the use of detergent A is much more prominent than colour loss with the use of detergent B, especially at the higher temperature. No difference between the azo dyed fabrics with the two detergents could be detected. These results indicate that detergent A contains ingredients that are more detrimental to indigo dye than azo dye.

Indigo and azo dyed cotton persistently lost colour, even with water without detergent, with indigo loosing more colour than azo dyed cotton at both temperatures. These results do not only prove that indigo dyed cotton is more sensitive to high temperatures than azo dyed cotton fabric but they also confirm the results of other researchers (Intersectional 1989:25) that when compared to the fastness standards exhibited by modern vat dyes, indigo has poor wash-fastness.

4.9 Staining of azo and indigo dyed cotton washed with detergent B, water without detergent and detergent A on multi-fibre fabrics during laundering measured by the the Grey Scale

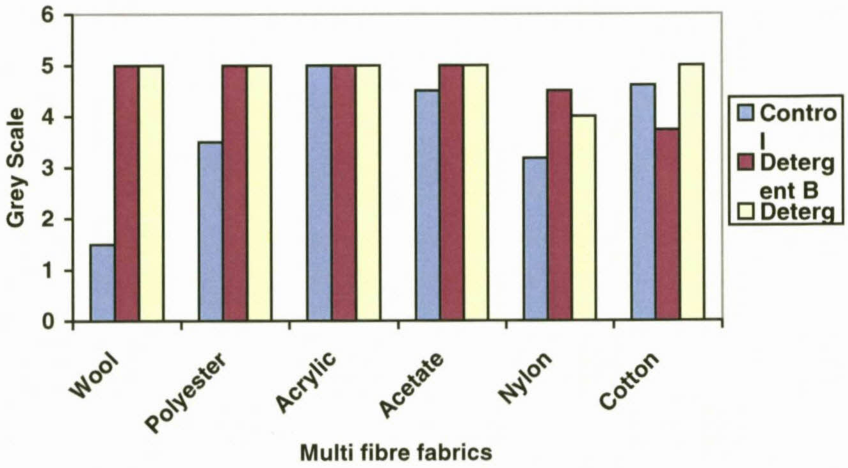


Figure 4.19 Staining of indigo dyed cotton on multifibre fabrics washed with water without detergent, detergent B and A measured by Grey Scale

Figure 4.19 shows the staining of indigo dyed cotton on multifibre fabrics subjected to detergent A, detergent B and water without detergent measured on a grey scale of one to five where a rating of five represents no difference in colour between the original material and the tested piece. The results in Figure 4.19 show a noticeable transfer of the indigo dyestuff washed with water without detergent to wool, polyester, and nylon with acetate and cotton getting closer to five, while none of the indigo dyestuff is transferred to acrylic. Indigo dye seems to have no effect on wool, polyester, acrylic, and acetate washed with detergent B, but there seems to be a noticeable amount of staining on nylon and cotton.

Detergent A on the other hand, appears to have an effect on nylon and no effect on the rest of the fibres. More staining is observed without the use of detergent. This proves that the anti-re-deposition ingredients of detergent do play an important role in the prevention of grey staining in the laundry process. Previous research (Breen, Durham and Obendorf 1984:198) on the ingredients of a detergents emphasises the importance of the role of anti-redeposition agents in the prevention of re-deposition and grey staining of the white laundry process. Meine and et.al (1998:317) claim that re-deposition is a problem with zeolite containing detergents. Detergent B does contain zeolite but shows only more staining on cotton and nylon.

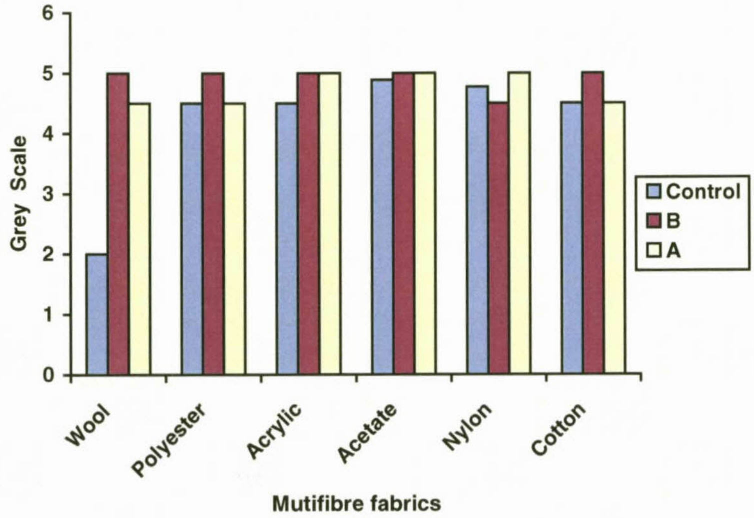


Figure 4.20 Staining of azo dyed cotton on multifibre fabrics washed with water without detergent, detergent B and A measured by a Grey Scale

Azo dyestuff seemed to have been transferred to wool, which shows lower values than the rest of the multifibre fabrics washed with water without detergent. Staining was also observed on polyester, acrylic and cotton. None of the azo dye washed with detergent B and A was transferred to wool, polyester, acetate, acrylic, nylon and cotton. In the laundering process with detergent A some staining was observed on cotton, wool and polyester.

Cotton is an absorbent fibre (Bhat *et al.*, 1990:240). Wool has a higher regain value. This explains why these two fibres easily get stained in laundering with a non-colourfast fabric. These results confirm the findings of Larney and van Aardt (1994:70) that dyes stain cotton during washing. The staining of polyester, and to a lesser extent, nylon, confirms the claim that polyester and nylon are the colour scavengers of the synthetic fibre range (Smith and Block 1982). Acrylic and acetate are not easily stained or soiled and that explains why they seem to be unaffected by the dyestuff.

4.10 Dry and wet crocking displayed by indigo and azo dyed cotton washed with detergent B, water without detergent and detergent A measured by a Grey Scale

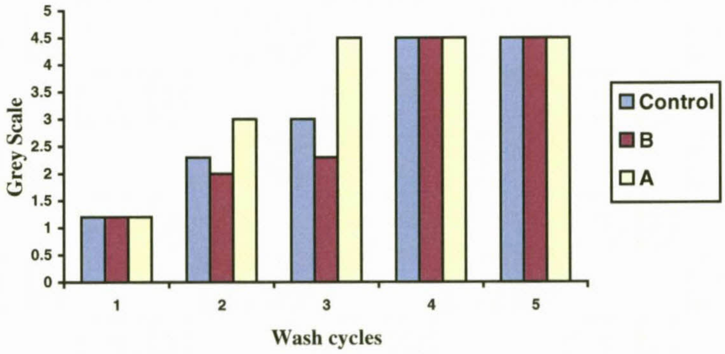


Figure 4.21 Crocking in the wet state of azo dyed cotton washed with detergent B, detergent A and water without detergent measured by a Grey-Scale

Results in Figure 4.21 indicate a severe amount of colour transferred during crocking of azo dyed cotton washed with detergent A, detergent B and water without detergent observed using a Grey Scale after the first cycle. There is an increase of values up to 2.5 and 3 after the second and third cycles respectively of azo washed with water without detergent, indicating that less colour crocked off. Cycle four and five show no obvious crocking.

Fabrics washed with detergent B show a transfer of colour after cycle two and three and no colour transfer thereafter, while fabrics washed with detergent A displays a transfer of colour in cycle two and none after the remaining cycles. The fact that colour loss through crocking takes place only after the first number of wash cycles, confirms that crocking is a result of rubbing off of dye molecules which did not properly penetrate the fibre and stayed on the surface (Smith and Block 1982:338). These results are to be expected, as some azo dye remains on the surface of the fibre during the dyeing process and crocks off easily according to Wang (1999:45) and Oakes (2000:47).

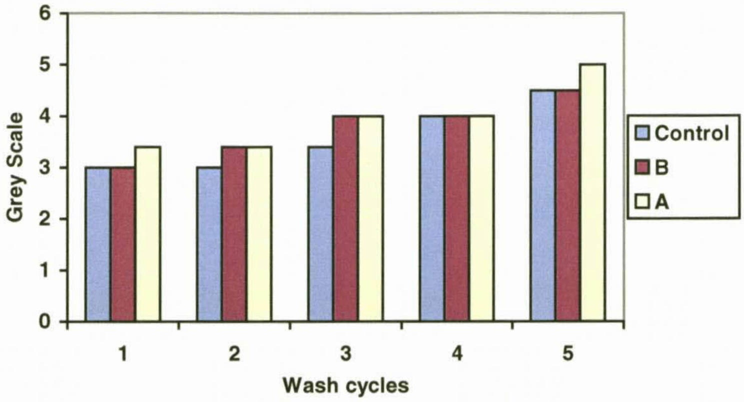


Figure 4.22 Crocking in the dry state of azo dyed cotton washed with detergent B, detergent A and water without detergent measured by a Grey-Scale

The results in Figure 4.22 show that the colour transfer of azo dyed cotton in the dry state is not as severe as the colour transfer in the wet state (Figure 4.21). Fabrics washed with detergent A, detergent B and water without detergent, display almost the same amount of colour transfer with figures ranging from three to three point five in cycle one and two, showing an increase in values of between four and five after the remaining cycles.

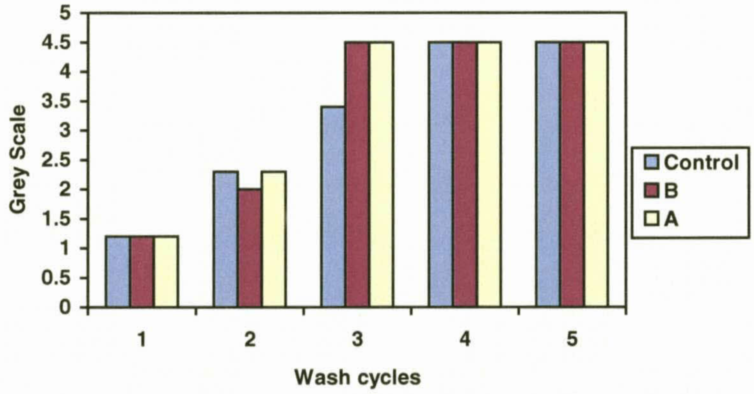


Figure 4.23 Crocking in the wet state of indigo dyed cotton washed with detergent B, detergent A and water without detergent measured by a Grey-Scale

The results in Figure 4.23 show that indigo dyed cotton washed with detergent B, detergent A and water without detergent has a tremendous transfer of colour to the adjacent fabric after the first and second cycles, showing less colour transfer after the remaining cycles. These results confirm previous research which indicate that indigo dye has poor crock fastness (Intersectional, 1989:29).

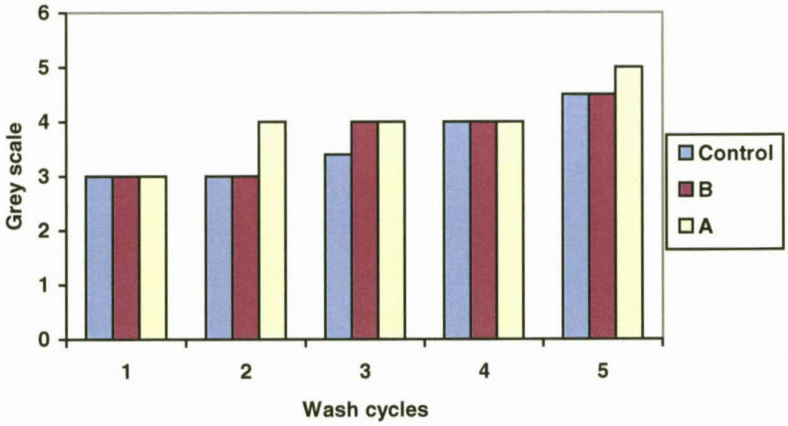


Figure 4.24 Crocking in the dry state of indigo dyed cotton washed with detergent B, detergent A and water without detergent measured by a Grey Scale

Crocking in the dry state of indigo dyed cotton in Figure 4.24 shows less transfer of colour than crocking in the wet state after cycle one of fabrics washed with detergent B, detergent A and water without detergent (Figure 4.25). Contrary to the other forms of colour loss it seems that crocking that takes place is influenced more by the wet than dry state of the fabric than by any other factor such as the kind of dye and the use of detergent.

Results in Figure 4.24 confirm the findings of Larney and van Aardt (1994:70) that wet rubbing transferred more colour than dry rubbing in the case of all dyes. In the study by Tabba and Hauser, (2000:31) it was found that as the number of wash cycles increased for the printed washed samples, the crockfastness improved, thus confirming the loss of printed colour: in the first wash cycles as a result of the rubbing off of dye molecules which did not penetrate the fibres but remained on the surface.

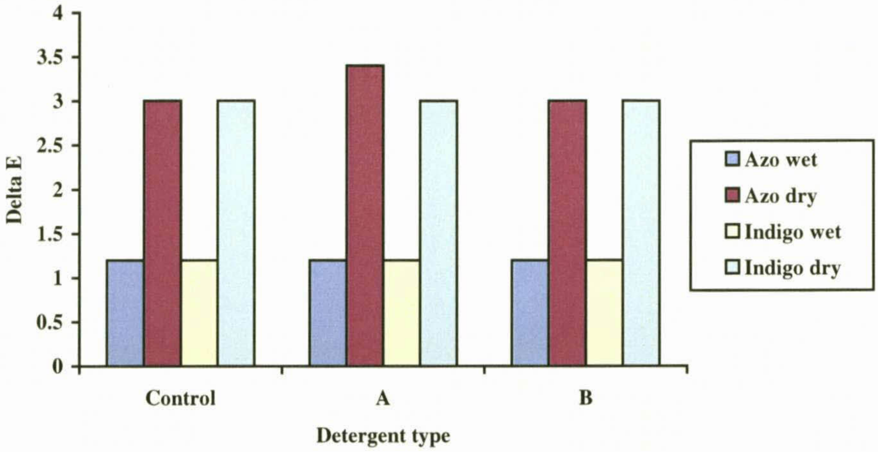


Figure 4.25 Crocking in the wet and dry state of indigo and azo dyed cotton fabric washed with detergent A, detergent B and water without detergent measured by a Grey Scale

Figure 4.25 shows that azo dyed cotton fabric resulted in more staining in the wet state than in the dry state when treated with water without detergent; detergent A and detergent B.

The graph also reflects that indigo dyed cotton fabric has more staining in the wet state than in the dry state when treated with water without detergent; detergent A and detergent B.

Azo and indigo dyed cotton fabrics show the same results of staining.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

The broad aim of this study was to determine to what extent the different factors detergent, wash cycles, temperature and drying method are responsible for the colour loss of azo and indigo dyed cotton fabric. The main goal was to be able to suggest laundering practices to minimise colour loss and improve the level of satisfaction of the Basotho women with the colour quality of the seshoeshoe cotton fabric used for the traditional Basotho dress.

The conclusions reached are based only on the effect of selected detergents, wash temperature and selected drying methods employed.

The first objective formulated for this study was to determine the effect of laundry wash cycles on colour loss of indigo and azo dyed cotton fabrics. The null hypothesis was:

Hl_o: There will be no difference in the influence of laundry wash cycles on colour loss of indigo and azo dyed cotton fabrics after fifty wash cycles.

This hypothesis is rejected, as results showed that there was a significant difference in colour loss with increasing number of wash cycles. This study revealed that there was a significant correlation between the number of wash cycles and loss of colour. As the number of wash cycles increased, colour loss of both azo and indigo dyed cotton fabrics increased.

The second objective formulated for this study was to determine the effect of laundry detergent on colour loss of indigo and azo dyed cotton fabrics. The null hypothesis was:

$H2_{0:}$ There will be no difference in the influence of laundry detergents on colour loss of indigo and azo dyed cotton fabrics after fifty wash cycles.

This hypothesis is rejected, as results showed that there was significant difference in colour loss between the detergents used and the control. Indigo and azo dyed cotton persistently lost colour with the use of detergent B and A throughout all cycles.

The third objective was to compare indigo and azo dyed cotton fabrics for colour loss after repeated laundering. The null hypothesis was:

H3o: There will be no difference in colour loss of azo, and indigo dyed cotton fabrics after repeated laundering.

The hypothesis is rejected, as results showed that there was a significant difference in colour loss between azo and indigo dyed cotton fabrics. Under the standard conditions of laundering employed it was evident that indigo dye lost a tremendous amount of colour throughout all the fifty cycles more than azo dyed cotton fabric did. In general it appeared that indigo lost much more colour than azo regardless of the type of detergent, wash temperature and the method of drying.

Literature review confirms that indigo is completely inferior in terms of colourfastness. When consumer concerns arise about indigo dye fabrics, the best defence against consumer complaints would be consumer education about implementing the best possible laundering practices of the fabric. It is important that technologists within the textile community should improve the process that they use in indigo dyed items in order to stay in the leading edge of technology and thereby maintaining the competitive advantage.

Even though azo dyed cotton fabrics exhibit good colourfastness standards when compared to indigo dyed fabrics, there are possible health problems associated with the use of azo dyes. Some consumers may not wish to use azo dyed cotton apparel. Under these circumstances, the consumer would be best advised to use indigo dyed apparel. Research to test the azo dyed cotton for health hazards should be done, especially while azo dyed fabric is widely used by women in Lesotho.

The fourth objective was to determine the effect of drying method on colour loss. The null hypothesis was:

$H4_0$: There will be no difference in colour loss between azo and indigo dyed cotton fabric dried indoors and outdoors.

This hypothesis is rejected on the basis that data reveals that there is a noticeable difference in colour loss between indigo and azo dyed cotton fabrics dried indoors and outdoors. Results show that there is more colour loss of indigo and azo dyed cotton fabrics that are dried outdoors than those dried indoors. Based on the results consumers can be advised on the best method of drying seshoeshoe. In order to prolong the original colour of the seshoeshoe it is important for consumers to dry in the shade rather than drying it in full sunlight

The fifth objective of the study was to compare the effect of wash temperature on colour loss of indigo and azo dyed cotton fabrics. The null hypothesis was:

$H5_0$: There will be no difference in the effect of wash temperature on colour loss of indigo and azo dyed cotton fabrics.

The hypothesis is rejected. It is evident from the data that higher temperature (60°C) causes more colour loss than lower temperature (40°C) with and without the use of detergent. Colour loss appeared to be less severe at 40°C than at 60°C of both experimental fabrics.

The sixth objective was to determine the staining of cotton, polyester, acetate, nylon, wool and viscose rayon. The null hypothesis was:

$H6_0$: There will be no staining of multifibre cloth from azo and indigo dyed cotton fabric.

The hypothesis was rejected on the basis that results showed staining on cotton, wool, and polyester and, to some extent nylon. In the control fabric there was a noticeable colour transfer of azo dye onto wool, polyester and nylon during washing. It is therefore recommended that the mentioned fibres should not be washed together with azo and indigo dyed fabrics. Without the presence of detergent, separate washing of the azo and indigo dyed cotton can be recommended.

The seventh objective was to determine the amount of crocking that took place. The null hypothesis was:

$H7_0$: Crocking will not take place from azo and indigo dyed cotton fabric.

The hypothesis is rejected on the basis that there was a noticeable amount of colour transfer in both the wet and dry crocking state that was seen from cycle one up to cycle three. It is therefore the responsibility of the researchers, manufacturers and dealers to make their consumers aware of the rubbing off of colour, especially in the first to third use of the seshoeshoe in the dry and wet state.

5.2 Recommendations

A comparison of the extent of colour loss of dyes in the experimental cotton fabrics showed that a certain relationship does exist and colour loss increased as the number of wash cycles increased. However, there is no particular connection between colour loss rates of the two types of detergent, indicating that detergent ingredients in both brands have mainly the same effect on cotton fabrics.

The literature also indicates that cotton fabrics dyed after being treated with durable-press finish are more colourfast than those dyed conventionally. Research to investigate the possible benefits of durable press and other finishes on the colourfastness of azo and indigo dyed cotton might benefit both the consumer and manufacturers.

As reported in the literature review, there are some health hazards associated with azo dyed fabric; some authors believe that azoic dyes are carcinogenic. In future a study could be carried out to determine the occurrence of cancer among Basotho women as this fabric is very often used by Basotho women.

It is evident from the study that detergents affect the colour loss of indigo dyed cotton more than that of azo dyed cotton fabric, but taking into consideration the role of detergent in laundering it is impossible to wash without detergent.

Based on the results, Basotho women who use indigo and azo dyed cotton fabric could be advised among other things to consider the following hints:

- Do not use excessive quantities of detergent.
- The drying of azo and indigo dyed fabrics should be done outside under the shade or indoors.
- Use low water temperature (less than 40°C) when washing.
- Separate the washing of indigo and azo dyed fabric from other fabrics during the laundering process.

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SUMMARY

An experimental study was carried out to evaluate the effect of detergent, wash temperature and drying on the colourfastness of indigo and azo dyed cotton fabric. After repeated laundering treatments (50 wash cycles) at wash water temperature of 40°C and 60°C, samples were laundered in a Launder-Ometer for 45 minutes in 200 ml of wash solution with 0,3g detergent, and line dried both indoors and outdoors in open air and extensive sunlight between 10:00 and 15:00. Colour loss was measured in daylight (D65/10), UV-light (Woolworths Storelight F11/10) and Tungsten (A/10), using spectraflash.

Treated indigo and azo dyed cotton fabrics were subjected to colourfastness tests for washing, crocking, light and staining.

In a colour transfer test where multifibre test strips were used, wool, polyester and nylon were the fibre types most severely affected by water without detergent (control) none of the dyes in both fabrics were transferred to fibres treated with the two brands of detergent.

A correlation of the data by dye used shows that:

- Colour loss increase with the number of wash cycles.
- Indigo dyed cotton loose more colour than azo dyed cotton
- Sunlight causes more colour loss
- More colour loss is experienced at 60°C wash temperature
- Detergents cause more colour loss than water without detergent
- More staining to other fabrics take place without a detergent
- More crocking takes place in the wet than the dry state.

OPSOMMING

Die doel van die eksperimentele studie was om die wasfaktore wat kleurverlies van aso en indigo gekleurde katoenstof veroorsaak te ondersoek. Die aso en indigo gekleurde katoestof is 50 keer by onderskeidelik 40°C en 60°C gewas. Die wasaksie is in 'n Launder-Ometer uitgevoer. Elke wassiklus was 45 minute lank en elke houer het 200ml wasvloeistof met 0,3 g detergent A of B asook water sonder 'n detergent bevat. Die monsters is daarna vir 4 ure onderskeidelik binneshuis en in direkte sonlig tussen 10:00 en 15:00 gedroog. Kleurverlies is gemeet in daglig (D65/10), UV-lig (Woolworths F11/10) en Wolfram (A/10) ligstoestande met die spectraflash apparaat. Monsters is van 5, 10, 15, 20, 30, 40 en 50 siklusse onttrek vir toetsing. Kleurafvrywing is m.b.v. die Crockmeter in die nat en droë toestand bepaal. Kleuroordraging na katoen, asetaat, rayon, nylon, poliëster en akriel is deur grysskaal metings bepaal na die eerste aantal wassiklusse.

Korrelasie van die data het aangetoon dat:

- kleurverlies toeneem met die toename in aantal wassiklusse
- indigo gekleurde katoen meer kleur verloor as aso gekleurde katoen
- sonlig meer kleurverlies veroosaak
- meer kleur verlies waargeneem word by 60°C as by 40°C
- detergente meer kleurverlies veroorsaak as water sonder detergent
- meer kleur na ander vesels oorgedra word sonder die teenwoordigheid van 'n detergent (herneerlegging)
- meer kleurafvrywing in die nat toestand plaasvind

KEY TERMS

Azo
Colour loss
Crockfastness
Detergent
Dyes
Indigo
Laundering
Lightfastness
Staining

ADDENDUM A

CIEab colour difference results

M&S89 Colour Difference

dataMASTER V2.0
25.03.102 13:55

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm

Batch: **!BLUE C611**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:40 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	3.30	-1.93	1.65	-2.10	thinner brighter bluer(greener)
A/10	FAIL ELCH	3.65	-2.20	2.76	-0.94	thinner brighter greener(yellower)
F11/10	FAIL ELCH	3.05	-1.48	2.20	-1.50	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm

Batch: **!BLUE C612**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:41 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	3.22	-1.61	1.83	-2.10	thinner brighter bluer(greener)
A/10	FAIL ELCH	3.58	-1.98	2.82	-0.99	thinner brighter greener(yellower)
F11/10	FAIL ELCH	3.06	-1.26	2.34	-1.50	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm

Batch: **!BLUE C613**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:41 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	3.53	-2.03	1.71	-2.34	thinner brighter bluer(greener)
A/10	FAIL ELCH	3.89	-2.29	2.93	-1.15	thinner brighter greener(yellower)
F11/10	FAIL ELCH	3.29	-1.58	2.32	-1.72	thinner brighter bluer(greener)

M&S89 Colour Difference

dataMASTER V2.0
25.03.102 13:55

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE C617**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:45 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	2.77	-1.79	1.27	-1.68	thinner brighter bluer(greener)
A/10	FAIL ECH	3.10	-2.03	2.25	-0.64	thinner brighter greener(yellower)
F11/10	FAIL ELCH	2.51	-1.37	1.77	-1.13	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE C618**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:46 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	3.42	-1.95	1.80	-2.17	thinner brighter bluer(greener)
A/10	FAIL ELCH	3.80	-2.25	2.90	-0.98	thinner brighter greener(yellower)
F11/10	FAIL ELCH	3.18	-1.49	2.36	-1.53	thinner brighter bluer(greener)

M&S89 Colour Difference

dataMASTER V2.0
25.03.102 13:53

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm

Batch: **!BLUE S517**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:38 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	5.08	-0.99	3.86	-3.15	thinner brighter bluer(greener)
A/10	FAIL ELCH	5.40	-1.72	4.81	-1.76	thinner brighter greener(yellower)
F11/10	FAIL ELCH	5.14	-0.62	4.56	-2.30	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm

Batch: **!BLUE S518**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:38 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	5.50	-1.37	4.09	-3.41	thinner brighter bluer(greener)
A/10	FAIL ELCH	5.89	-2.07	5.19	-1.86	thinner brighter greener(yellower)
F11/10	FAIL ELCH	5.51	-0.90	4.83	-2.49	thinner brighter bluer(greener)

M&S89 Colour Difference

dataMASTER V2.0
25.03.102 13:53

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE S511**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 20/03/102 at 07:32 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	5.90	-1.13	4.50	-3.65	thinner brighter bluer(greener)
A/10	FAIL ELCH	6.25	-1.93	5.57	-2.07	thinner brighter greener(yellower)
F11/10	FAIL ELCH	5.96	-0.70	5.28	-2.69	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE S512**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 20/03/102 at 07:34 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	5.01	-1.22	3.74	-3.09	thinner brighter bluer(greener)
A/10	FAIL ELCH	5.37	-1.88	4.75	-1.67	thinner brighter greener(yellower)
F11/10	FAIL ELCH	5.05	-0.75	4.46	-2.23	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE S513**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 20/03/102 at 07:34 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	5.15	-0.89	4.08	-3.00	thinner brighter bluer(greener)
A/10	FAIL ELCH	5.47	-1.68	4.96	-1.58	thinner brighter greener(yellower)
F11/10	FAIL ELC	5.24	-0.47	4.77	-2.13	thinner brighter bluer(greener)

M&S89 Colour Difference

dataMASTER V2.0
25.03.102 13:51

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE O417**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:06 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	5.82	-0.98	4.41	-3.66	thinner brighter bluer(greener)
A/10	FAIL ELCH	6.13	-1.80	5.46	-2.15	thinner brighter greener(yellower)
F11/10	FAIL ELCH	5.90	-0.61	5.19	-2.75	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE O418**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:06 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	4.98	-1.31	3.72	-3.03	thinner brighter bluer(greener)
A/10	FAIL ELCH	5.37	-1.98	4.73	-1.59	thinner brighter greener(yellower)
F11/10	FAIL ELCH	4.99	-0.85	4.41	-2.19	thinner brighter bluer(greener)

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Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE O414**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:04 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	5.72	-1.33	4.19	-3.67	thinner brighter bluer(greener)
A/10	FAIL ELCH	6.09	-2.02	5.34	-2.12	thinner brighter greener(yellower)
F11/10	FAIL ELCH	5.77	-0.84	5.01	-2.74	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE O415**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:05 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	4.22	-1.17	3.17	-2.52	thinner brighter bluer(greener)
A/10	FAIL ELCH	4.59	-1.81	4.03	-1.26	thinner brighter greener(yellower)
F11/10	FAIL ELCH	4.23	-0.77	3.76	-1.78	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE O416**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:05 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	5.30	-1.39	3.66	-3.57	thinner brighter bluer(greener)
A/10	FAIL ELCH	5.65	-1.97	4.85	-2.13	thinner brighter greener(yellower)
F11/10	FAIL ELCH	5.32	-0.91	4.48	-2.72	thinner brighter bluer(greener)

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Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE O411**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:03 pm

Formula: *Illuminant*	**MS89** *Decision*	**1.2** DE:	**0.6** DH:	**0.8** 'DC:'	**0.8** 'DL:'	*Batch is*
D65/10	FAIL ELCH	5.58	-1.36	4.04	-3.61	thinner brighter bluer(greener)
A/10	FAIL ELCH	5.96	-2.03	5.20	-2.08	thinner brighter greener(yellower)
F11/10	FAIL ELCH	5.61	-0.88	4.84	-2.70	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE O412**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:03 pm

Formula: *Illuminant*	**MS89** *Decision*	**1.2** DE:	**0.6** DH:	**0.8** 'DC:'	**0.8** 'DL:'	*Batch is*
D65/10	FAIL ELCH	5.53	-1.25	4.09	-3.50	thinner brighter bluer(greener)
A/10	FAIL ELCH	5.88	-1.94	5.19	-1.99	thinner brighter greener(yellower)
F11/10	FAIL ELCH	5.58	-0.76	4.87	-2.60	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE O413**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:04 pm

Formula: *Illuminant*	**MS89** *Decision*	**1.2** DE:	**0.6** DH:	**0.8** 'DC:'	**0.8** 'DL:'	*Batch is*
D65/10	FAIL ELCH	5.24	-1.22	3.91	-3.26	thinner brighter bluer(greener)
A/10	FAIL ELCH	5.61	-1.93	4.95	-1.80	thinner brighter greener(yellower)
F11/10	FAIL ELCH	5.29	-0.76	4.65	-2.39	thinner brighter bluer(greener)

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Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm

Batch: **!BLUE O317**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:01 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	7.63	-1.29	5.49	-5.14	thinner brighter bluer(greener)
A/10	FAIL ELCH	7.99	-2.09	6.93	-3.37	thinner brighter greener(yellower)
F11/10	FAIL ELCH	7.77	-0.82	6.57	-4.06	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm

Batch: **!BLUE O318**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:01 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	7.07	-1.46	4.96	-4.82	thinner brighter bluer(greener)
A/10	FAIL ELCH	7.43	-2.17	6.39	-3.10	thinner brighter greener(yellower)
F11/10	FAIL ELCH	7.12	-0.99	5.95	-3.80	thinner brighter bluer(greener)

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Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE O314**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 06:59 pm

Formula: *Illuminant*	**MS89** *Decision*	**1.2** DE:	**0.6** DH:	**0.8** 'DC:'	**0.8** 'DL:'	*Batch is*
D65/10	FAIL ELCH	7.30	-1.50	5.15	-4.96	thinner brighter bluer(greener)
A/10	FAIL ELCH	7.68	-2.28	6.60	-3.18	thinner brighter greener(yellower)
F11/10	FAIL ELCH	7.35	-1.07	6.14	-3.90	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE O315**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:00 pm

Formula: *Illuminant*	**MS89** *Decision*	**1.2** DE:	**0.6** DH:	**0.8** 'DC:'	**0.8** 'DL:'	*Batch is*
D65/10	FAIL ELCH	7.07	-1.30	5.03	-4.80	thinner brighter bluer(greener)
A/10	FAIL ELCH	7.40	-2.04	6.40	-3.11	thinner brighter greener(yellower)
F11/10	FAIL ELCH	7.17	-0.83	6.04	-3.77	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE O316**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:00 pm

Formula: *Illuminant*	**MS89** *Decision*	**1.2** DE:	**0.6** DH:	**0.8** 'DC:'	**0.8** 'DL:'	*Batch is*
D65/10	FAIL ELCH	7.02	-1.46	4.95	-4.76	thinner brighter bluer(greener)
A/10	FAIL ELCH	7.38	-2.19	6.36	-3.04	thinner brighter greener(yellower)
F11/10	FAIL ELCH	7.08	-0.99	5.93	-3.73	thinner brighter bluer(greener)

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Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm

Batch: **!BLUE O311**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 06:58 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	6.82	-1.55	4.80	-4.59	thinner brighter bluer(greener)
A/10	FAIL ELCH	7.21	-2.28	6.21	-2.87	thinner brighter greener(yellower)
F11/10	FAIL ELCH	6.84	-1.10	5.73	-3.57	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm

Batch: **!BLUE O312**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 06:59 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	7.11	-1.09	5.28	-4.63	thinner brighter bluer(greener)
A/10	FAIL ELCH	7.42	-1.95	6.54	-2.91	thinner brighter greener(yellower)
F11/10	FAIL ELCH	7.22	-0.68	6.24	-3.58	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm

Batch: **!BLUE O313**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 06:59 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	7.14	-1.67	4.88	-4.94	thinner brighter bluer(greener)
A/10	FAIL ELCH	7.53	-2.34	6.40	-3.19	thinner brighter greener(yellower)
F11/10	FAIL ELCH	7.18	-1.15	5.92	-3.90	thinner brighter bluer(greener)

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Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm

Batch: **!BLUE S217**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 06:53 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	6.96	-1.22	5.08	-4.60	thinner brighter bluer(greener)
A/10	FAIL ELCH	7.29	-2.04	6.37	-2.90	thinner brighter greener(yellower)
F11/10	FAIL ELCH	7.03	-0.82	6.00	-3.57	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm

Batch: **!BLUE S218**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 06:53 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	6.92	-1.47	4.84	-4.72	thinner brighter bluer(greener)
A/10	FAIL ELCH	7.28	-2.17	6.25	-3.03	thinner brighter greener(yellower)
F11/10	FAIL ELCH	6.97	-0.99	5.83	-3.70	thinner brighter bluer(greener)

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andard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE S214**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 06:51 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	7.59	-1.61	5.17	-5.33	thinner brighter bluer(greener)
A/10	FAIL ELCH	7.99	-2.29	6.76	-3.58	thinner brighter greener(yellower)
F11/10	FAIL ELCH	7.69	-1.10	6.28	-4.29	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE S215**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 06:52 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	6.42	-0.94	5.00	-3.92	thinner brighter bluer(greener)
A/10	FAIL ELCH	6.73	-1.84	6.06	-2.28	thinner brighter greener(yellower)
F11/10	FAIL ELC	6.52	-0.56	5.81	-2.92	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE S216**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 06:52 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	6.48	-0.89	5.06	-3.95	thinner brighter bluer(greener)
A/10	FAIL ELCH	6.78	-1.80	6.11	-2.31	thinner brighter greener(yellower)
F11/10	FAIL ELC	6.60	-0.49	5.89	-2.94	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE S211**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 06:49 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	6.91	-1.52	4.89	-4.64	thinner brighter bluer(greener)
A/10	FAIL ELCH	7.28	-2.24	6.29	-2.91	thinner brighter greener(yellower)
F11/10	FAIL ELCH	6.93	-1.05	5.83	-3.61	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE S212**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 06:50 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	7.08	-0.90	5.46	-4.42	thinner brighter bluer(greener)
A/10	FAIL ELCH	7.37	-1.83	6.61	-2.70	thinner brighter greener(yellower)
F11/10	FAIL ELC	7.21	-0.52	6.36	-3.36	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%. 400..700nm,d=10. 18/03/102 at 08:26 pm
Batch: **!BLUE S213**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%. 400..700nm,d=10, 20/03/102 at 06:51 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	6.94	-1.50	4.81	-4.77	thinner brighter bluer(greener)
A/10	FAIL ELCH	7.30	-2.19	6.25	-3.08	thinner brighter greener(yellower)
F11/10	FAIL ELCH	6.99	-1.03	5.80	-3.76	thinner brighter bluer(greener)

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Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED S207**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 05:59 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	2.54	-2.00	1.27	-0.92	thinner brighter redder(bluer)
A/10	FAIL ELCH	1.81	-1.10	1.19	-0.80	thinner brighter redder(bluer)
F11/10	FAIL ELCH	2.93	-2.13	1.69	-1.09	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED S208**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 06:00 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	1.82	-1.36	1.09	-0.55	thinner brighter redder(bluer)
A/10	FAIL ECH	1.28	-0.61	1.00	-0.50	thinner brighter redder(bluer)
F11/10	FAIL ECH	2.21	-1.44	1.52	-0.71	thinner brighter redder(bluer)

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Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED S204**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 05:57 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	2.01	-1.37	1.22	-0.84	thinner brighter redder(bluer)
A/10	FAIL ECH	1.46	-0.60	1.12	-0.72	thinner brighter redder(bluer)
F11/10	FAIL ELCH	2.47	-1.46	1.75	-0.94	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED S205**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 05:58 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELH	2.36	-1.97	0.63	-1.14	thinner brighter redder(bluer)
A/10	FAIL ELH	1.55	-1.08	0.57	-0.95	thinner brighter redder(bluer)
F11/10	FAIL ELCH	2.74	-2.07	1.29	-1.25	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED S206**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 05:58 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	2.75	-2.41	0.91	-0.97	thinner brighter redder(bluer)
A/10	FAIL ELCH	1.82	-1.38	0.82	-0.85	thinner brighter redder(bluer)
F11/10	FAIL ELCH	3.12	-2.59	1.28	-1.18	thinner brighter redder(bluer)

M&S89 Colour Difference

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Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED S201**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 05:56 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	1.99	-1.65	0.90	-0.67	thinner brighter redder(bluer)
A/10	FAIL EH	1.30	-0.83	0.80	-0.60	thinner brighter redder(bluer)
F11/10	FAIL ELCH	2.35	-1.74	1.34	-0.83	thinner brighter redder(bluer)

tandard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

atch: **!RED S202**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 05:56 pm

ormula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
lluminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
65/10	FAIL ECH	1.73	-1.18	1.21	-0.40	thinner brighter redder(bluer)
/10	FAIL EC	1.27	-0.44	1.14	-0.37	thinner brighter redder(bluer)
F11/10	FAIL ECH	2.15	-1.27	1.64	-0.58	thinner brighter redder(bluer)

tandard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

tch: **!RED S203**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 05:56 pm

ormula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
5/10	FAIL ELH	2.40	-2.08	0.31	-1.17	thinner brighter redder(bluer)
A/10	FAIL ELH	1.55	-1.17	0.31	-0.96	thinner brighter redder(bluer)
1/10	FAIL ELCH	2.74	-2.22	0.90	-1.33	thinner brighter redder(bluer)

M&S89 Colour Difference

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Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED O307**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 05:54 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	2.14	-1.40	1.48	-0.64	thinner brighter redder(bluer)
A/10	FAIL ECH	1.63	-0.62	1.39	-0.58	thinner brighter redder(bluer)
F11/10	FAIL ECH	2.56	-1.47	1.94	-0.80	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED O308**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 05:54 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	2.59	-1.96	1.41	-0.94	thinner brighter redder(bluer)
A/10	FAIL ELCH	1.88	-1.05	1.33	-0.82	thinner brighter redder(bluer)
F11/10	FAIL ELCH	2.99	-2.09	1.83	-1.11	thinner brighter redder(bluer)

M&S89 Colour Difference

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Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED O304**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 20/03/102 at 05:52 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	2.54	-1.82	1.61	-0.74	thinner brighter redder(bluer)
A/10	FAIL ECH	1.91	-0.93	1.53	-0.67	thinner brighter redder(bluer)
F11/10	FAIL ELCH	2.95	-1.92	2.04	-0.94	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED O305**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 20/03/102 at 05:53 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	2.15	-1.34	1.62	-0.48	thinner brighter redder(bluer)
A/10	FAIL EC	1.73	-0.59	1.56	-0.45	thinner brighter redder(bluer)
F11/10	FAIL ECH	2.56	-1.44	2.01	-0.67	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED O306**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 20/03/102 at 05:53 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	2.62	-2.08	1.38	-0.79	thinner brighter redder(bluer)
A/10	FAIL ECH	1.88	-1.15	1.30	-0.71	thinner brighter redder(bluer)
F11/10	FAIL ELCH	2.99	-2.23	1.72	-1.01	thinner brighter redder(bluer)

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Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED O301**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 05:50 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	2.04	-1.32	1.49	-0.47	thinner brighter redder(bluer)
A/10	FAIL EC	1.60	-0.58	1.43	-0.44	thinner brighter redder(bluer)
F11/10	FAIL ECH	2.44	-1.42	1.87	-0.67	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED O302**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 05:51 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	2.46	-1.95	1.31	-0.74	thinner brighter redder(bluer)
A/10	FAIL ECH	1.74	-1.04	1.23	-0.67	thinner brighter redder(bluer)
F11/10	FAIL ELCH	2.84	-2.07	1.70	-0.95	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED O303**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 05:51 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	2.54	-1.69	1.76	-0.70	thinner brighter redder(bluer)
A/10	FAIL ECH	2.00	-0.85	1.69	-0.63	thinner brighter redder(bluer)
F11/10	FAIL ELCH	2.95	-1.81	2.15	-0.91	thinner brighter redder(bluer)

M&S89 Colour Difference

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Standard: **ISTD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 18/03/102 at 08:26 pm

Batch: **IBLUE C117**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 20/03/102 at 06:46 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
msTL84-10	FAIL ELCH	4.88	-2.36	3.03	-3.01	thinner brighter bluer(greener)
msD65-10	FAIL ELCH	5.19	-2.93	2.22	-3.66	thinner brighter bluer(greener)
msA-10	FAIL ELCH	5.52	-3.04	4.04	-2.22	thinner brighter greener(yellower)

Standard: **ISTD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 18/03/102 at 08:26 pm

Batch: **IBLUE C118**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 20/03/102 at 06:47 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
msTL84-10	FAIL ELCH	5.20	-2.50	3.15	-3.29	thinner brighter bluer(greener)
msD65-10	FAIL ELCH	5.52	-3.08	2.31	-3.95	thinner brighter bluer(greener)
msA-10	FAIL ELCH	5.86	-3.19	4.24	-2.48	thinner brighter greener(yellower)

M&S89 Colour Difference

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Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%.
400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE C114**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%.
400..700nm,d=10, 20/03/102 at 06:42 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
msTL84-10	FAIL ELCH	5.31	-2.71	3.12	-3.34	thinner brighter bluer(greener)
msD65-10	FAIL ELCH	5.69	-3.37	2.24	-4.01	thinner brighter bluer(greener)
msA-10	FAIL ELCH	6.00	-3.38	4.29	-2.49	thinner brighter greener(yellower)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°. Specular Included. Large Aperture, UV 100%.
400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE C115**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%.
400..700nm,d=10, 20/03/102 at 06:43 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
msTL84-10	FAIL ELCH	5.31	-2.48	3.22	-3.41	thinner brighter bluer(greener)
msD65-10	FAIL ELCH	5.62	-3.05	2.38	-4.07	thinner brighter bluer(greener)
msA-10	FAIL ELCH	5.96	-3.17	4.32	-2.60	thinner brighter greener(yellower)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°. Specular Included. Large Aperture. UV 100%.
400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE C116**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included. Large Aperture. UV 100%.
400..700nm,d=10, 20/03/102 at 06:46 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
msTL84-10	FAIL ELCH	5.41	-2.70	2.94	-3.66	thinner brighter bluer(greener)
msD65-10	FAIL ELCH	5.78	-3.35	2.06	-4.24	thinner brighter bluer(greener)
msA-10	FAIL ELCH	6.05	-3.33	4.18	-2.85	thinner brighter greener(yellower)

M&S89 Colour Difference

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Standard: **ISTD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **IBLUE C111**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 06:40 pm

ormula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
luminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
msTL84-10	FAIL ELCH	4.05	-2.08	2.49	-2.43	thinner brighter bluer(greener)
sD65-10	FAIL ELCH	4.34	-2.58	1.78	-3.01	thinner brighter bluer(greener)
sA-10	FAIL ELCH	4.66	-2.72	3.37	-1.72	thinner brighter greener(yellower)

andard: **ISTD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
tch: **IBLUE C112**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 06:40 pm

rmula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
sTL84-10	FAIL ELCH	4.15	-2.14	2.56	-2.47	thinner brighter bluer(greener)
D65-10	FAIL ELCH	4.45	-2.65	1.83	-3.07	thinner brighter bluer(greener)
msA-10	FAIL ELCH	4.77	-2.80	3.45	-1.75	thinner brighter greener(yellower)

Standard: **ISTD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm.
tch: **IBLUE C113**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 06:41 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
TL84-10	FAIL ELCH	4.82	-2.47	2.94	-2.92	thinner brighter bluer(greener)
nsD65-10	FAIL ELCH	5.18	-3.08	2.13	-3.57	thinner brighter bluer(greener)
-10	FAIL ELCH	5.50	-3.16	3.98	-2.10	thinner brighter greener(yellower)

M&S89 Colour Difference

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Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED O607**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 08:00 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	2.73	-2.14	1.50	-0.79	thinner brighter redder(bluer)
A/10	FAIL ECH	2.00	-1.22	1.42	-0.72	thinner brighter redder(bluer)
F11/10	FAIL ELCH	3.10	-2.25	1.87	-1.00	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED O608**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 08:01 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	2.37	-1.56	1.68	-0.60	thinner brighter redder(bluer)
A/10	FAIL ECH	1.86	-0.76	1.60	-0.55	thinner brighter redder(bluer)
F11/10	FAIL ECH	2.81	-1.62	2.16	-0.78	thinner brighter redder(bluer)

M&S89 Colour Difference

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Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED O604**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:59 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	2.53	-1.60	1.86	-0.60	thinner brighter redder(bluer)
A/10	FAIL ECH	2.06	-0.81	1.81	-0.55	thinner brighter redder(bluer)
F11/10	FAIL ELCH	2.94	-1.71	2.25	-0.80	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED O605**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:59 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	2.27	-1.47	1.66	-0.49	thinner brighter redder(bluer)
A/10	FAIL ECH	1.79	-0.67	1.60	-0.47	thinner brighter redder(bluer)
F11/10	FAIL ECH	2.71	-1.56	2.11	-0.69	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED O606**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 08:00 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	2.69	-2.09	1.53	-0.73	thinner brighter redder(bluer)
A/10	FAIL ECH	1.99	-1.19	1.45	-0.67	thinner brighter redder(bluer)
F11/10	FAIL ELCH	3.07	-2.19	1.93	-0.95	thinner brighter redder(bluer)

M&S89 Colour Difference

dataMASTER V2.0
25.03.102 13:47

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED O601**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:57 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	2.78	-2.20	1.50	-0.80	thinner brighter redder(bluer)
A/10	FAIL ECH	2.06	-1.29	1.44	-0.72	thinner brighter redder(bluer)
F11/10	FAIL ELCH	3.11	-2.34	1.79	-1.02	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED O602**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:58 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	2.13	-1.38	1.51	-0.58	thinner brighter redder(bluer)
A/10	FAIL EC	1.63	-0.59	1.42	-0.53	thinner brighter redder(bluer)
F11/10	FAIL ECH	2.60	-1.46	2.02	-0.75	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED O603**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:58 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	2.30	-1.33	1.81	-0.47	thinner brighter redder(bluer)
A/10	FAIL EC	1.90	-0.58	1.76	-0.45	thinner brighter redder(bluer)
F11/10	FAIL ECH	2.71	-1.41	2.21	-0.67	thinner brighter redder(bluer)

M&S89 Colour Difference

dataMASTER V2.0
25.03.102 13:18

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 18/03/102 at 08:26 pm

Batch: **!BLUE S817**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 25/03/102 at 06:07 pm

Formula: **MS89**

Illuminant	*Decision*	**1.2** DE:	**0.6** DH:	**0.8** 'DC:'	**0.8** 'DL:'	*Batch is*
D65/10	FAIL EC	1.32	0.08	1.24	-0.43	thinner brighter
A/10	FAIL EC	1.38	-0.37	1.33	-0.05	brighter greener(yellower)
F11/10	FAIL EC	1.36	0.06	1.34	-0.20	thinner brighter

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 18/03/102 at 08:26 pm

Batch: **!BLUE S818**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 25/03/102 at 06:08 pm

Formula: **MS89**

Illuminant	*Decision*	**1.2** DE:	**0.6** DH:	**0.8** 'DC:'	**0.8** 'DL:'	*Batch is*
D65/10	FAIL ELC	2.21	0.59	1.92	-0.91	thinner brighter redder(yellower)
A/10	FAIL EC	2.03	-0.02	1.99	-0.41	thinner brighter
F11/10	FAIL EC	2.24	0.48	2.11	-0.59	thinner brighter redder(yellower)

M&S89 Colour Difference

dataMASTER V2.0
25.03.102 13:18

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE S814**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 25/03/102 at 06:06 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	1.51	1.22	0.86	0.20	fuller brighter redder(yellower)
A/10	FAIL H	1.03	0.75	0.69	0.19	fuller brighter bluer(redder)
F11/10	FAIL ECH	1.35	0.99	0.90	0.18	fuller brighter redder(yellower)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE S815**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 25/03/102 at 06:06 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL EC	1.81	0.43	1.63	-0.65	thinner brighter redder(yellower)
A/10	FAIL EC	1.70	-0.12	1.68	-0.21	thinner brighter greener(yellower)
F11/10	FAIL EC	1.86	0.38	1.78	-0.37	thinner brighter redder(yellower)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE S816**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 25/03/102 at 06:07 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	1.31	0.63	1.14	-0.16	thinner brighter redder(yellower)
A/10	FAIL C	1.08	0.16	1.07	0.05	brighter bluer(redder)
F11/10	FAIL EC	1.32	0.54	1.21	-0.03	brighter redder(yellower)

M&S89 Colour Difference

dataMASTER V2.0
25.03.102 13:18

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE S811**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 25/03/102 at 06:04 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELH	1.61	-1.10	0.19	-1.17	thinner brighter bluer(greener)
A/10	FAIL ECH	1.75	-1.16	1.17	-0.59	thinner brighter greener(yellower)
F11/10	FAIL ELH	1.45	-0.80	0.80	-0.92	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE S812**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 25/03/102 at 06:05 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
luminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	1.52	1.03	1.10	-0.13	thinner brighter redder(yellower)
/10	FAIL C	1.08	0.53	0.94	0.02	brighter bluer(redder)
11/10	FAIL ECH	1.41	0.81	1.15	-0.04	brighter redder(yellower)

tandard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
atch: **!BLUE S813**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 25/03/102 at 06:05 pm

ormula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
uminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
65/10	FAIL ECH	1.82	1.09	1.40	-0.41	thinner brighter redder(yellower)
/10	FAIL EC	1.39	0.55	1.26	-0.16	thinner brighter bluer(redder)
11/10	FAIL ECH	1.73	0.85	1.49	-0.24	thinner brighter redder(yellower)

M&S89 Colour Difference

dataMASTER V2.0
25.03.102 13:39

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED O907**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 08:12 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL EC	1.70	-0.43	1.65	-0.03	brighter redder(bluer)
A/10	FAIL EC	1.70	-0.01	1.70	-0.05	brighter
F11/10	FAIL EC	2.00	-0.44	1.95	-0.15	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED O908**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 08:13 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	1.99	-0.99	1.69	-0.35	thinner brighter redder(bluer)
A/10	FAIL EC	1.76	-0.43	1.67	-0.33	thinner brighter redder(bluer)
F11/10	FAIL ECH	2.29	-1.03	1.99	-0.50	thinner brighter redder(bluer)

M&S89 Colour Difference

data**MASTER** V2.0
25.03.102 13:39

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED O904**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 08:09 pm

Formula: *Illuminant*	**MS89** *Decision*	**1.2** DE:	**0.6** DH:	**0.8** 'DC:'	**0.8** 'DL:'	*Batch is*
D65/10	FAIL ECH	1.85	-0.86	1.61	-0.30	thinner brighter redder(bluer)
A/10	FAIL EC	1.66	-0.32	1.60	-0.29	thinner brighter redder(bluer)
F11/10	FAIL ECH	2.17	-0.87	1.94	-0.44	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED O905**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 08:10 pm

Formula: *Illuminant*	**MS89** *Decision*	**1.2** DE:	**0.6** DH:	**0.8** 'DC:'	**0.8** 'DL:'	*Batch is*
D65/10	FAIL ECH	1.70	-0.64	1.56	-0.16	thinner brighter redder(bluer)
A/10	FAIL EC	1.59	-0.17	1.57	-0.17	thinner brighter redder(bluer)
F11/10	FAIL ECH	2.05	-0.67	1.91	-0.30	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED O906**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 08:11 pm

Formula: *Illuminant*	**MS89** *Decision*	**1.2** DE:	**0.6** DH:	**0.8** 'DC:'	**0.8** 'DL:'	*Batch is*
D65/10	FAIL ECH	1.84	-0.94	1.56	-0.30	thinner brighter redder(bluer)
A/10	FAIL EC	1.62	-0.40	1.54	-0.29	thinner brighter redder(bluer)
F11/10	FAIL ECH	2.15	-0.95	1.87	-0.44	thinner brighter redder(bluer)

M&S89 Colour Difference

dataMASTER V2.0
25.03.102 13:39

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED O901**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 08:07 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL EC	1.67	-0.13	1.66	-0.01	brighter redder(bluer)
A/10	FAIL EC	1.72	0.22	1.70	-0.03	brighter yellower(greener)
F11/10	FAIL EC	2.04	-0.13	2.03	-0.12	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED O902**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 08:08 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	1.87	-0.89	1.62	-0.30	thinner brighter redder(bluer)
A/10	FAIL EC	1.67	-0.35	1.61	-0.29	thinner brighter redder(bluer)
F11/10	FAIL ECH	2.19	-0.93	1.93	-0.45	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED O903**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 08:09 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	1.98	-0.91	1.74	-0.28	thinner brighter redder(bluer)
A/10	FAIL EC	1.79	-0.36	1.73	-0.28	thinner brighter redder(bluer)
F11/10	FAIL ECH	2.30	-0.94	2.05	-0.44	thinner brighter redder(bluer)

M&S89 Colour Difference

dataMASTER V2.0
25.03.102 13:36

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED S807**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 08:18 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL EC	1.57	-0.43	1.51	-0.09	brighter redder(bluer)
A/10	FAIL EC	1.53	-0.00	1.53	-0.10	brighter
F11/10	FAIL EC	1.90	-0.46	1.83	-0.21	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED S808**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 08:18 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL EC	1.46	-0.37	1.41	0.00	brighter redder(bluer)
A/10	FAIL EC	1.45	0.03	1.45	-0.02	brighter
F11/10	FAIL EC	1.77	-0.40	1.72	-0.11	thinner brighter redder(bluer)

M&S89 Colour Difference

dataMASTER V2.0
25.03.102 13:36

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED S804**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 08:16 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL EC	1.63	-0.03	1.63	0.02	brighter
A/10	FAIL EC	1.71	0.30	1.68	0.00	brighter yellower(greener)
F11/10	FAIL EC	1.96	-0.03	1.95	-0.07	brighter

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED S805**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 08:17 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL EC	1.62	-0.53	1.53	-0.06	brighter redder(bluer)
A/10	FAIL EC	1.57	-0.09	1.56	-0.08	brighter
F11/10	FAIL EC	1.93	-0.55	1.83	-0.19	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED S806**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 08:17 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	1.63	-1.02	1.23	-0.34	thinner brighter redder(bluer)
A/10	FAIL EC	1.30	-0.44	1.18	-0.32	thinner brighter redder(bluer)
F11/10	FAIL ECH	1.98	-1.06	1.60	-0.48	thinner brighter redder(bluer)

M&S89 Colour Difference

dataMASTER V2.0
25.03.102 13:36

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED S801**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 20/03/102 at 08:14 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL EC	1.75	-0.55	1.64	-0.27	thinner brighter redder(bluer)
A/10	FAIL EC	1.65	-0.10	1.63	-0.26	thinner brighter redder(bluer)
F11/10	FAIL EC	2.10	-0.58	1.97	-0.40	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED S802**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 20/03/102 at 08:14 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL EC	1.29	-0.54	1.17	-0.02	brighter redder(bluer)
A/10	FAIL EC	1.21	-0.14	1.20	-0.04	brighter redder(bluer)
F11/10	FAIL EC	1.56	-0.54	1.46	-0.13	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED S803**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 20/03/102 at 08:15 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL EC	1.44	-0.48	1.36	-0.11	thinner brighter redder(bluer)
A/10	FAIL EC	1.36	-0.04	1.35	-0.12	thinner brighter
F11/10	FAIL EC	1.78	-0.49	1.70	-0.23	thinner brighter redder(bluer)

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Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED S507**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:56 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	2.95	-2.32	1.56	-0.94	thinner brighter redder(bluer)
A/10	FAIL ELCH	2.14	-1.31	1.47	-0.84	thinner brighter redder(bluer)
F11/10	FAIL ELCH	3.37	-2.47	1.97	-1.16	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED S508**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:56 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	2.26	-1.49	1.63	-0.44	thinner brighter redder(bluer)
A/10	FAIL ECH	1.77	-0.67	1.58	-0.42	thinner brighter redder(bluer)
F11/10	FAIL ECH	2.69	-1.59	2.07	-0.66	thinner brighter redder(bluer)

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Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED S504**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:54 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	2.69	-2.21	1.20	-0.95	thinner brighter redder(bluer)
A/10	FAIL ELCH	1.86	-1.24	1.10	-0.84	thinner brighter redder(bluer)
F11/10	FAIL ELCH	3.09	-2.33	1.67	-1.13	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED S505**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:55 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	2.87	-2.32	1.42	-0.93	thinner brighter redder(bluer)
A/10	FAIL ELCH	2.05	-1.32	1.33	-0.83	thinner brighter redder(bluer)
F11/10	FAIL ELCH	3.27	-2.47	1.81	-1.15	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED S506**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:55 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	2.85	-2.31	1.44	-0.85	thinner brighter redder(bluer)
A/10	FAIL ECH	2.03	-1.31	1.35	-0.77	thinner brighter redder(bluer)
F11/10	FAIL ELCH	3.23	-2.46	1.79	-1.08	thinner brighter redder(bluer)

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Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED S501**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:53 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	2.64	-2.03	1.53	-0.71	thinner brighter redder(bluer)
A/10	FAIL ECH	1.95	-1.12	1.45	-0.65	thinner brighter redder(bluer)
F11/10	FAIL ELCH	3.02	-2.15	1.90	-0.93	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED S502**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:53 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	3.01	-2.55	1.27	-0.99	thinner brighter redder(bluer)
A/10	FAIL ELCH	2.15	-1.56	1.19	-0.87	thinner brighter redder(bluer)
F11/10	FAIL ELCH	3.36	-2.70	1.61	-1.20	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED S503**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:53 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ECH	2.20	-1.53	1.53	-0.40	thinner brighter redder(bluer)
/10	FAIL ECH	1.68	-0.71	1.48	-0.39	thinner brighter redder(bluer)
F11/10	FAIL ECH	2.61	-1.64	1.93	-0.63	thinner brighter redder(bluer)

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Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED C407**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:51 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL EC	1.46	-0.12	1.44	-0.18	thinner brighter redder(bluer)
A/10	FAIL EC	1.44	0.31	1.40	-0.17	thinner brighter yellower(greener)
F11/10	FAIL EC	1.94	-0.13	1.92	-0.27	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture. UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED C408**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:51 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL EC	1.27	-0.11	1.26	-0.08	brighter redder(bluer)
A/10	FAIL EC	1.27	0.32	1.22	-0.09	brighter yellower(greener)
F11/10	FAIL EC	1.78	-0.10	1.76	-0.18	thinner brighter redder(bluer)

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Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED C404**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:49 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL EC	1.36	-0.17	1.34	-0.21	thinner brighter redder(bluer)
A/10	FAIL EC	1.32	0.30	1.27	-0.20	thinner brighter yellower(greener)
F11/10	FAIL EC	1.90	-0.20	1.87	-0.31	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED C405**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:50 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL EC	1.61	0.40	1.56	0.10	fuller brighter yellower(greener)
A/10	FAIL ECH	1.73	0.71	1.58	0.09	brighter yellower(greener)
F11/10	FAIL EC	2.11	0.41	2.07	0.03	brighter yellower(greener)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED C406**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:50 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL EC	1.43	0.38	1.38	0.11	fuller brighter yellower(greener)
A/10	FAIL ECH	1.55	0.67	1.39	0.10	brighter yellower(greener)
F11/10	FAIL EC	1.90	0.41	1.86	0.05	brighter yellower(greener)

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Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED C401**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:48 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL C	1.19	-0.01	1.19	0.01	brighter
A/10	FAIL EC	1.23	0.40	1.17	-0.00	brighter yellower(greener)
F11/10	FAIL EC	1.69	0.01	1.69	-0.07	brighter

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED C402**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:48 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
luminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL EC	1.84	-0.11	1.81	-0.31	thinner brighter redder(bluer)
A/10	FAIL EC	1.81	0.30	1.76	-0.29	thinner brighter yellower(greener)
11/10	FAIL EC	2.37	-0.14	2.33	-0.41	thinner brighter redder(bluer)

tandard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

atch: **!RED C403**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:49 pm

ormula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
uminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
65/10	FAIL EC	1.47	0.37	1.42	0.13	fuller brighter yellower(greener)
/10	FAIL ECH	1.60	0.69	1.44	0.12	fuller brighter yellower(greener)
11/10	FAIL EC	1.95	0.40	1.91	0.07	brighter yellower(greener)

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Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED C707**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 08:05 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL C	1.11	0.36	1.04	0.17	fuller brighter yellower(greener)
A/10	FAIL EC	1.23	0.54	1.09	0.16	fuller brighter yellower(greener)
F11/10	FAIL EC	1.39	0.39	1.33	0.14	fuller brighter yellower(greener)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm
Batch: **!RED C708**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 08:05 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL EC	1.25	0.46	1.15	0.16	fuller brighter yellower(greener)
A/10	FAIL ECH	1.36	0.62	1.20	0.15	fuller brighter yellower(greener)
F11/10	FAIL EC	1.58	0.49	1.50	0.12	fuller brighter yellower(greener)

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Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED C704**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 20/03/102 at 08:03 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL C	1.00	0.26	0.96	0.16	fuller brighter yellower(greener)
A/10	FAIL C	1.12	0.47	1.01	0.16	fuller brighter yellower(greener)
F11/10	FAIL EC	1.25	0.30	1.21	0.13	fuller brighter yellower(greener)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED C705**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 20/03/102 at 08:04 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL EC	1.36	-0.13	1.35	-0.12	thinner brighter redder(bluer)
A/10	FAIL EC	1.37	0.15	1.35	-0.12	thinner brighter yellower(greener)
F11/10	FAIL EC	1.69	-0.13	1.68	-0.20	thinner brighter redder(bluer)

Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED C706**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%,
400..700nm,d=10, 20/03/102 at 08:04 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL EC	1.36	-0.09	1.35	-0.11	thinner brighter
A/10	FAIL EC	1.37	0.23	1.34	-0.12	thinner brighter yellower(greener)
F11/10	FAIL EC	1.71	-0.10	1.70	-0.20	thinner brighter redder(bluer)

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Standard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED C701**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 08:02 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL EC	1.26	-0.47	1.14	-0.23	thinner brighter redder(bluer)
A/10	FAIL C	1.13	-0.09	1.11	-0.22	thinner brighter
11/10	FAIL EC	1.62	-0.46	1.52	-0.32	thinner brighter redder(bluer)

andard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

Batch: **!RED C702**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 08:02 pm

rmula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
minant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
65/10	FAIL EC	1.34	-0.17	1.32	-0.12	thinner brighter redder(bluer)
10	FAIL EC	1.33	0.16	1.31	-0.12	thinner brighter yellower(greener)
1/10	FAIL EC	1.69	-0.17	1.67	-0.20	thinner brighter redder(bluer)

ndard: **!STD RED (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:25 pm

ch: **!RED C703**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 08:03 pm

mula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
inant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
/10	FAIL EC	1.54	-0.17	1.52	-0.18	thinner brighter redder(bluer)
	FAIL EC	1.52	0.19	1.49	-0.18	thinner brighter yellower(greener)
1/10	FAIL EC	1.96	-0.19	1.93	-0.28	thinner brighter redder(bluer)

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Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE C614**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:42 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	3.12	-2.03	1.44	-1.88	thinner brighter bluer(greener)
A/10	FAIL ECH	3.48	-2.28	2.52	-0.74	thinner brighter greener(yellower)
F11/10	FAIL ELCH	2.83	-1.58	1.97	-1.28	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE C615**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:43 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	3.00	-1.67	1.79	-1.73	thinner brighter bluer(greener)
A/10	FAIL ECH	3.40	-2.04	2.64	-0.64	thinner brighter greener(yellower)
F11/10	FAIL ELCH	2.79	-1.27	2.21	-1.13	thinner brighter bluer(greener)

Standard: **!STD BLUE (18/03/02)**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 18/03/102 at 08:26 pm
Batch: **!BLUE C616**
Spectraflash SF600, Serial Nr 1, d/8°, Specular Included, Large Aperture, UV 100%, 400..700nm,d=10, 20/03/102 at 07:44 pm

Formula:	**MS89**	**1.2**	**0.6**	**0.8**	**0.8**	
Illuminant	*Decision*	DE:	DH:	'DC:'	'DL:'	*Batch is*
D65/10	FAIL ELCH	3.72	-2.27	1.80	-2.34	thinner brighter bluer(greener)
A/10	FAIL ELCH	4.11	-2.53	3.05	-1.06	thinner brighter greener(yellower)
F11/10	FAIL ELCH	3.41	-1.74	2.42	-1.67	thinner brighter bluer(greener)

ADDENDUM B

Statistical analysis of colourloss of azo and indigo dyed cotton washed at 60°C and dried indoors.