A Study on Recycling of Dye Effluent with Disperse and Reactive Dyes on Polyester Cotton Blend

By

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Introduction

I. INTRODUCTION

The advent of man made fibers has revolutionised textile production all over the world and has been providing supplementary source of raw materials for clothing. The beginning of blending fiber was started in India, when polyester staple was introduced as a fiber that blended well with fine cotton fiber there by reducing the consumption of the latter Parikh and Patel (1980).

Cotton is the most versatile and widely used textile fiber possessing ideal properties as good absorbency, durability and low cost but it lacks elasticity, lustre and wrinkle resistance. The polyester fiber has many superior properties such as high strength, Crease resistance, lustre, flexibility, durable press, easy washability but it lacks moisture absorption and air permeability. Because of this reason polyester fibers are blended with cotton fibers. As a result of the introduction of blends, our market today is flooded with varieties of polyester cotton material of different proportions. These blended fibers become much more attractive with judicious combination of colours.

Colour plays an important role in making the fabric attractive to the consumers. It can do a great deal to enhance the appearance and also effects ones personality. The colour of a textile fabric is the first property, which is noticed and frequently is the first factor governing the fabric choice than pattern structure, weight and fiber content.

Colour is applied to textile material in the form of dyestuffs by two basic processes, dyeing and printing. A dye is a colourant that penetrates the actual fiber and appears to become part of it. Dye is the name given to the chemicals by which a comparatively permanent colour is impaired to certain bodies of which the most important are the textile fibers. Mathur and Aggrwal (1980) states that, dyes are soluble coloured compounds which produce permanent colour.

Dyeing is a complex specialised science which deals the art of coloring textiles in such a manner that the colour may be fast to washing, rubbing, sunlight and others to which the textiles are subjected.

Various developments have taken place in the field of dyeing polyester, cellulosic fiber blends. The two blend components generally require different classes of dyes. While cotton fibers have a special affinity for reactive dyes, Lyle (1982) by virtue of their ease of application, brilliancy of shades and good fastness properties, opines Shah (1987). Polyester fiber have no affinity at all for these dyes. Similarly polyester is dyed with disperse dyes have no affinity for the cellulosic. Then the blend is generally dyed with two classes of dyes by using double bath procedures , Mehra (1981).

Water is one of the most important solute used in the textile industry. Doshi and Pillai opine that the quality of water used for wet processing of t extiles assumes considerable importance from the point of quality of textile processes.

The industry is the major offender for creating water pollution. Pollution is any degree of contamination of air, water or land which is likely to produce a significant adverse health effect to a significant number of persons in a foreseeable period of time ,opines Barbour (1983).

Water pollution comes from three major sources namely Sewage, Industrial Waste and Agricultural waste, Hari and Rajeswari (1985). The available sources of water supply are fast getting polluted with the industrial wastes, says Haraprasad (1980). Industrial wastes are commonly more concentrated and require extensive treatment as compared to municipal wastes.

Noguchi et al. (1974) and Maharajan (1985) feels that, discharge of dye effluent from textile industries contains large quantities of suspended solids, intermediate products, finer products, co-products and by products. The composition and amount of pollutants discharged into the water are likely to create nuisance and are not suitable for all functions and purposes, stress World Health Organisation (1972).

Pai (1980) and Sandoz (1979) Warn that, the waste water should be free from sludge deposits, unnatural colours, oil films and toxic substances before it can be discharged into the receiving stream. Industrial wastes need to be neutralised before they are discharged into water streams. The effluent treatments are essential to produce water of a standard satisfactory quality to discharge with sewage system or into a river, East (1971).

Because of the short supply of industrial water as well as increasing pollution, it has been earnestly desired to incorporate waste water treating processes. Treating waste water has been directed to the reuse of some parts of the waste by employing a recycling system or by using a so called advanced waste water treatment system, Hiroaki Ida (1983).

The increasing scarcity of water and energy and waste water treatment and the limitations imposed on waste water disposal by changing environmental regulations dictate a need for water recycling in the textile industry, Good man (1980) Water reuse however is some thing else it is the use of the same water more than once, Sidney (1978).

Thus there is a great need for an effective management and recycling dye effluent in textile industries. Hence the investigator made an attempt in this study with the following objectives.

1. To assess the pollution - load of the dyeing effluent.
2. To compare the samples dyed in process water and effluent treated water.
3. To confirm the quality of sample dyed in process water and effluent treated water by testing their physical qualities and
4. Suggestions for improvement.

It is hoped that this study will throw some light on the possibility of recycling the dye effluent on economise the use of water, which is becoming a scarce commodity these days.

Review of Literature

II. REVIEW OF LITERATURE

The literature pertaining to this study is dealt with under the following headings.

1. Definition of Blends
2. Need and importance of blending polyester cotton
3. Dyes suitable for polyester cotton
4. Disperse dyes - classification and application
5. Reactive dyes - classification and application
6. Water - its classification and uses
7. Sources of polluted water and its properties
8. Treatment of waste effluent.

1. Definition of Blends:

Blending of fibers is a old textile art, known practiced for years. In recent years there has been much emphasis placed on "Fabric Blends and on Combination Fabrics". Both terms apply to the manner in which different fabrics may be used to form a fabric.

Subramanian (1973) is of the opinion that, the term blend is used to denote textile materials produced by intimate mixing of more than one by one type of staple fiber.

Blending is a process designed to produce a thorough and intermixing of fibers Wingate (1984) opines that, it is possible to blend two or more different fibers at the spinning stage provided they are of the appropriate length. The resulting yarns are termed blended yarns.

Dantyagi (1974) states, blended fabrics are made up of yarns in which two or more different kinds of fibers are spun together.

According to Barve (1969), placing together two or more yarns of different materials (as cotton and wool) in an intimate mixture so that the ultimate value of the fabric can be enhanced by the joint and positive qualities of both or the components of the blend.

2. Need and importance of blending polyester cotton:

Blend is an intimate mixture of staple fibers of different composition, length, diameter or color, spun together into a yarn ,(Hollen, (1973). Miller (1968) feels that,the terms mixture and blend is similar in general meaning. But in the present content mixture refers to the use of two or more different fibers in a fabric, each fiber being spun a separate yarn, that is the fabric is composed of a mixture of yarns made from different fibers.

The major objectives of blending as outlined by Lyle (1976) and Goswami et al., (1977) are

- Produce better performance
- achieve aesthetic qualities
- obtain cross dyed effects
- obtain usual or desired texture, hand or feel and appearance
- Improve properties for spinning, weaving, dyeing, printing and finishing
- Achieve economic savings

The overall objective is to mix together fibers with different characteristics to produce yarn qualities that cannot be obtained by using one type of fiber alone.

According to Salhotra (1983), the major objective of blending two or more fibers is to produce a yarn or fabric which improved functional properties which a single type of fiber can not achieve this properties like crease recovery, drape and elongation. To achieve a particular end use, some fabric properties may have to be gained by blending even at the expense or some other property on the whole, good blending aims at combining the most desirable proportion of different fiber in the fabric, says Taylor (1985).

Chatterji and Nakerni (1975) are of the opinion that, blended fabrics are being used widely in the country and their popularity is increasing day by day because of their high wear life, crease retention and ease in washing.

Smith (1982) summarises as, in an attempt to improve the consumer acceptance of polyester in apparel the Dupont Company developed techniques for blending polyester and cotton in the same yarn. Eighty per cent polyester and twenty per cent cotton give improved comfort and better dyeability while maintaining the wrinkle resistance and dimensional stability of hundred per cent polyester.

According to Cheetham (1966) blends of polyester and cellulosic fibers are well suited, because of their high tensile strength to processing by continuous methods. Large quantities of these blends are processed. Because of their excellent tensile strength, and chemical resistance, piece good containing polyester and cellulosic fibers are particularly suitable for processing.

3. Dyes Suitable for polyester cotton:

The dyeing of polyester cotton blended material needs special attention on account of their dissimilar characteristics. The dyeing of polyester cotton blends involve dyeing of both fiber components either separately or simultaneously. For dyeing celluloses various classes of dyestuffs such as direct, vat, azoics, solubølised vat and sulphur are available, whereas for dyeing of polyester the use of disperse dyes is aziomatic Achwal and Maharajan (1985).

In exhaust dyeing of polyester cotton blends, disperse dyes are used for polyester and reactive dyes for cotton owing to the latter's brilliancy and fastness properties. The optimum dyeing conditions for reactive dyes are quite different from those for disperse dyes opines Ashuthosh (1988).

Maharajan (1985) and Rengarajan (1988) are of the opinion that the reactive dyes being cheaper than vat dyes, are used in combination with disperse dyes for dyeing deep shades. Reactive dyes (Ramazole) should be chosen with extreme care regarding their light fastness. These provide a range of shades, unattainable by other class of dyes. In the case of cellulose normally most dyeing involves alkaline conditions on atmospheric pressure. Dyeing of polyester is done, however in slightly acidic at high temperature or with the aid of carriers at atmospheric pressure.

4. Disperse dyes - Classification and application:

The society of dyes and colorists defines a disperse dye as a substantially water soluble dye having substantivity for one or more hydrophobic fiber.

Disperse dye is the main class of non ionic dyes developed in the early 1920's as the first type of dye for the newly introduced secondary cellulose acetate they have become increasingly important since the introduction of the new synthetic fiber in the last 3 decades. These dyes have very low water solubility varying with the molecular structure. They are infact, used in water as fine dispersions containing a dispersing agent, Agnihotri, (1988).

All disperse dyes sensitive to temperature variations. The sensitivity is greater or less depending on the particular brand but it is always quite pronounced, Choudhury,(1984).

According to Cowan (1962) these disperse dyes offer good fastness to washing, sunlight, but the presence of gases containing on acid reducing agent like coal gas fumes cause fading of certain blue and lavenders.

Classification:

According to Verma (1984) and Connel (1982), disperse dyes are single homogenous dyestuffs having different chemical nature. This includes three brands are:

1. High diffusion dyestuffs
2. Medium diffusion dyestuffs
3. Low diffusion dyestuffs

1. High diffusion dyestuffs:

High diffusion dyestuffs has low molecular weight around 300°C and the low sublimation and the dye exhaustion starts at around 85°C, when 130°C is reached, total exhaustion of this colour takes place. It has good dispersion and migration fastness. This is generally known as 'E' brand.

2. M.D.D.'s:

In MDD's the molecular weight is around 450°C and has medium sublimation. The exhaustion starts around 95°C and it needs 130°C in order to complete the total exhaustion. This brand is generally known as 'SE' brand.

3. LDD's:

Low energy dye stuffs have high molecular weights around 600°C. They need more energy for diffusion and it has high sublimation. The dye exhaustion starts only around 105°C and needs 30 - 45 minutes. This is generally known as 'SE' brand.

Application:

Disperse dyes are not soluble in water but are applied in the form of dispersions with the help of dispersing agents. Different dyes have different rates which are difficult to control. Dyes which diffuse earlier can cause unlevelness and the dyes which diffuse slowly take much time for exhaustion. There are three factors which determine the uniformity of dyestuff dispersion.

- Rate of absorption
- Rate of diffusion and
- Rate of disorption

The combined action of the three volumes is expressed by the migrating power, which is essential for practical assessment of the performance of disperse dye Sivaramakrishnan, (1981).

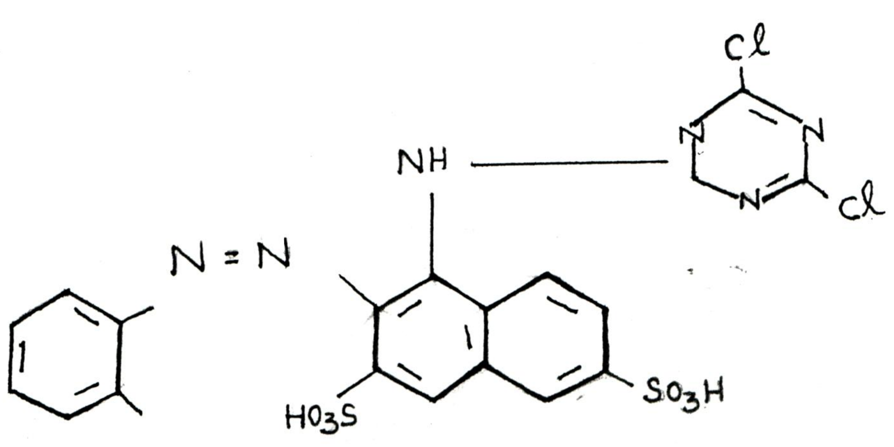
2. Reactive dyes - Classification and application:

Reactive means what the term implies the dyes react chemically with cotton, linen, wool, silk, rayon, nylon and acrylic to produce bright colors. Reactive dyes have very good colour fastness to laundering and dry cleaning. They have good colour fastness to crocking, rubbing off and they are resistant to gas fading. An entire spectrum of colors are available in this class of dyes and they can be used for dyeing and printing Lyle,(1976).

Reactive dyes are of outstanding importance for colouring, cellulosic fibers Srivastava,(1974).

Varghese et al., (1988) states that, the first dicholoro-triazine reactive dyes structured by ICI for cellulose fibers.

Structure of reactive dyes:



Classification:

According to Trotman (1970) reactive dyes are of three types:

1. Cold reactive dyes (Procion)
2. Ramazol dyes
3. Hot brand dyes

1. Cold reactive dyes:

These dyes are dyed on cotton fabrics at room temperature.

2. Ramazol dyes:

These are dyes which contain vinyl sulphone group as a reactive group in their structure. They cannot be dyed at room temperature and they need to be dyed only at 60-65°C.

3. Hot brand dyes:

These dyes need to be dyed at 60-65°C certain dyes are dyed at 80-85°C. These are called hot exhaustic (HE) dyes.

Application:

According to Bell (1988) the dyeing mechanism for fiber reactive dyes may involve, absorption, diffusion, migration, exhaustion and fixation.

Absorption:

Absorption To the fiber surface is that state where the dyestuff loses mobility in the dyebath.

Diffusion:

Diffusion Is when the dyestuff moves into the fibre surface through capillary action.

Migration:

Migration occurs when equilibrium is reached between the dyestuff in solution and the dyestuff in the fiber.

Exhaustion:

Exhaustion takes place when the electrolyte is introduced and equilibrium shifts from dye in the both to dye in the fiber.

Fixation:

Fixation occurs with the addition of alkali and covalent bonds are formed.

Exhaustion and fixation phases may occur simultaneously, depending on the selected dyeing procedures or fiber reactive dye chemistry.

6. Water, its classification and uses:

Water:

According to Jaganathan (1979) water is defined as, water that is free from pathogenic agents, free from harmful chemical substances, pleasant to the taste and useable for domestic purposes. Man is the most important member of the eco system consisting of air, water, land and living and non-living elements expresses Roy,(1980). Water is one of the important and most precious of natural resources used by us Kumar,(1985). It is an essential raw material in almost all chemical oriented industries Ganu,(1982).

According to Pramod Singh (1988) water for human consumption must be free from organisms and concentration of chemical substances that may be hazardous to health. Absense of turbidity, colour, disagreeable taste are of outmost importance in public supplies of drinking water.

Classification of water:

According to Pramod Singh (1985), water for practical purpose can be classified as clean, polluted and contaminated in the following order:

1. A clean water is one which is free from all contamination and safe for human consumption.
2. A contaminated water is poisonous which may carry infections by the addition of human or animal waste.
3. A polluted water is one which is impaired of physical qualities directly or indirectly through addition of substances causing turbidity, colour, odour and taste.

According to Manivasakam (1985), water can be classified according to mineral constituents as "Hard or soft" depending on the concentration of calcium and magnesium ions. When these ions are present in high concentration, the capacity of the water to lather with soap is reduced and such waters are termed as "Hard water". A soft water is one which produces lather easily with the soap.

Uses:

According to Sewell (1975) uses of water can be divided into four broad categories:

1. Direct physical use by man and his domesticated purpose
2. Direct use in industry and agriculture as a factor in production.
3. Psychological use as part of our esthetic and cultural environment.
4. Ecological use as a vital component in the earth's life support system.

Nordell (1956) point out that the water used for many manufacturing plant, mill, institution or municipality to take care of present and future needs.

7. Sources of polluted water and its properties:

Water is never 'pure' in a chemical sense. It contains various kinds of impurities such as dust particles, dissolved gases, dissolved minerals, microscopic plants and animals, suspended impurities and bacteria. These are the natural impurities derived from the atmosphere, catchment area and soil, Jaganathan (1979).

1. Biological oxygen demand (BOD):

It is measure of the strength of organic matter in terms of its ability to depute oxygen in water. Generally the standard test consists in measuring the oxygen depletion at 20°C for 5 days.

2. Chemical oxygen demand (COD):

It is a measure of oxygen consumed to oxidise organic matter by boiling pottassium dichromate and concentrated sulphuricacid for two hours. COD is taken as indicative of the total amount of carbonacious organic matter present in water but it indicates a part of organic matter oxidised.

3. Permanganate value (PV):

It is a chemical oxidation using acid pottassium permanganate solution for four hours at 27°C.

4. Dissolved oxygen (DO):

It is of great use to assess survivability of life, particularly of fish which require atleast 5 mg/1 Do while the maximum dissolved oxygen in water is only 9.1 mg/1 at 20°C.

Aswani (1989) defines pollution is the discharge of material, residue and energy into the environment while some of these residues are unconverted raw materials some are unrecovered products and some are by products. Pollution is a sign of inefficiency in industrial production and it can be considered as money that is going up the chimney-down the sewer and out of plant in waste truck Bajpai, (1990).

According to Mark (1977) principal sources of water pollution are:

1.	Point sources:	Power plants - heated water
		Industries - organics, chemicals, colours
		Municipalities - domestic and industrial waste
2.	Diffuse sources	Agricultural - fertilisers, pesticides, land drainage, organics, micro-organisms
	Urban storm run off	Industrial and residential dust, dirt and litter.

Textile industry is one of the largest industry in India and it contributes a considerable amount for water pollution P.M. Jhala, (1981). Textile wastes containing high percentages of organic solids, highly coloured spent dye and kier liquors acids, starch wastes and other chemical compounds pollute the streams.

Noguchi *et al.*, (1974) opine, the discharge of dye effluent containing relatively large amounts of suspended solids, sulfiels, high biochemical oxygen demand value into water courses which is less suitable for highest uses and for human consumption.

The quantity of dye used depends on the characteristics of the fiber, the colour and the desired finish, synthetic textiles require the use of special carriers to achieve satisfactory penetration of dye into the fiber. These carriers are very strong and present a major source of pollution says Environmental Protection Agency, (1978).

Vakil (1984) feels that, pollution of water is probably a more acute problem in developing nations like India than air pollution. India is poised for a significant and rapid industrial growth and in future the pollution load will increase manifold unless proper care is taken states Roy, (1980).

Properties of polluted water:

Varshney (1983) stresses that the physical and chemical properties of water can be estimated by standard method. According to Sastry, P.S. (1983) important water quality characteristics are explained as follows:

8. Treatment of Waste effluent:

The effluent treatments are essential to produce water of a standard satisfactory quality to discharge into sewage system or into a river view East, (1971).

According to Sharma (1988), the treatment of effluent water to control pollution are as follows:

1. Primary treatment:

Removal of suspended solids using alum and poly-electrolyte.

2. Secondary treatment:

This process carried out by using bleaching powder or chlorine to disinfect the effluent before discharging.

3. Tertiary treatment:

In this reverse osmosis or electrodialysis employed.

According to Dix (1981), the aim of industrial waste treatment is to seperate the suspended solids and dissolved substances from the liquid fraction.

The importance of waste water treatment is to remove or collect the contaminating factors found unwaste water this involves not only the purification and reuse of water but also the effective utilisation of the collected views Uejima,(1973).

Experimental Procedure

III EXPERIMENTAL PROCEDURE

The procedure adopted for the study is given under the following headings:

A. Selection of fabric, dyes, colour and shades

B. Equipment used for dyeing

C. Selection of dyeing method

D. Procedure for dyeing the fabric

 1. Dyeing polyester part with disperse dyes
 2. Dyeing cotton part with reactive dyes

E. Collection of dye effluent

F. Laboratory treatment

 1. Before treatment
 2. After treatment

G. Evaluation

 1. Visual inspection
 2. Laboratory tests.

A. Selection of fabric, dyes, colour and shade:

(a) Fabric :

According to Tripathy and Murthy (1986), polyester cotton blend fabrics occupied a unique place in the field of textiles, because of its wearing properties like durability, excellent crease resistance, drape and good drip dry characteristics. It is ideal for the climatic conditions of India. Moreover, it is economical, light weight and luxurious. It is less expensive than cotton. Blends of polyester cotton have gained wide acceptance because of its aesthetic and functional properties.

A market survey conducted by the investigator revealed that, polyester cotton blend of 80/20 per cent combination was preferred by more than 80 per cent of the consumers for apparel purposes. Therefore, the investigator selected polyester cotton blend material of 80/20 per cent combination for the study. Twelve metres of polyester cotton blend material were used for dyeing with the selected dyes. One metre of the same material was kept aside as original for laboratory testing purposes. The details of the selected material is given in (Appendix I.).

(b) Dyes:

The type of dyestuff used for dyeing , any particular fabric depends on the nature of the fabric and the fastness qualities required in the finished goods (Birell, 1959). The criteria for dyestuff selection would include its shade, dyeing rate, degree of. exhaustion and water solubility. The two most important factors to be considered are the dyeing rate and exhaustion, which in turn are controlled by time, temperature, salt, liquor ratio, dye bath volume, dye concentration and the inherent compatibility of the dyestuff and fiber type.

Maharajan (1985) and Rangarajan (1988) are of the opinion that, the reactive dyes being cheaper than other dyes and are used in combination with disperse dyes for dyeing deeper shades. They provide a range of shades, unattainable by other class of dyes.

Mittal (1983) points out that, disperse dyes produce full range of shades, show good utilisation and colour value as well as exceptionally good fastness properties when properly applied on polyester components.

Hence the commercially available main classes of dyestuffs namely disperse and reactive were chosen to dye the selected fabric.

c. Colour:

The colour selected for the study included yellow (ERGFL), yellow brown (S_2RFL), Blue (BGF), and navy blue (S_2GL) shades in both disperse and reactive dyes in view of its aesthetic value and its technical advantage as to its fastness to prolonged wear and tear.

d. Shade:

The shades of the dyeing is expressed as a percentage of dye to the weight of fabric, opines Kulkarni et al., (1986). According to Shah et al (1988), depth standard is related to the amount of colour consumed, method of application and type of substrate. The general preference to categorise colour substrates are light and dark in the field of colouration. Therefore, the investigator selected 0.5 per cent as it is the minimum depth and 2.0 per cent concentration as it is the maximum depth for the dyestuff for the various concentrations of colours.

B. Equipment used for dyeing:

According to Chitrangada Krishna (1977), the following equipments may be used for dyeing processes.

1. Beam dyeing machine
2. Hand jigger machine
3. Cylinderical beakers
4. Thermometer
5. Small beakers to mix dyes
6. Dyes and chemicals
7. Glass measures
8. Plastic spoons
9. Heater

C. Selection of dyeing method:

The dyeing of polyester cotton blended material needs special attention on account of their dissimilar characteristics. The dyeing of polyester cotton blend involves dyeing of both fiber components separately by different classes of dyes.

Hence the investigator selected double bath method involving first dyeing the polyester part with disperse dye in high temperature beaker dyeing method and then dyeing the cotton part with reactive dye by Jigger method in cold and hot conditions.

D. Procedure for dyeing the fabric:

The pretreated material was cut into 16 pieces. The first eight pieces were dyed in disperse dye using process water, and the remaining eight pieces were dyed in effluent treated water. As a second step the first eight pieces were again dyed in process water but with reactive dyes. Then the remaining eight pieces were dyed in reactive dyes using effluent treated water.

The first set of eight pieces were named as PY, PYB, PB, PNB, PY_1, PYB_1, PB_1 and PNB_1. These samples were dyed in 0.5 and 2.0 per cent yellow, yellow brown, blue and navy blue of disperse dyes using process water in high temperature beaker dyeing method. Again the same samples were

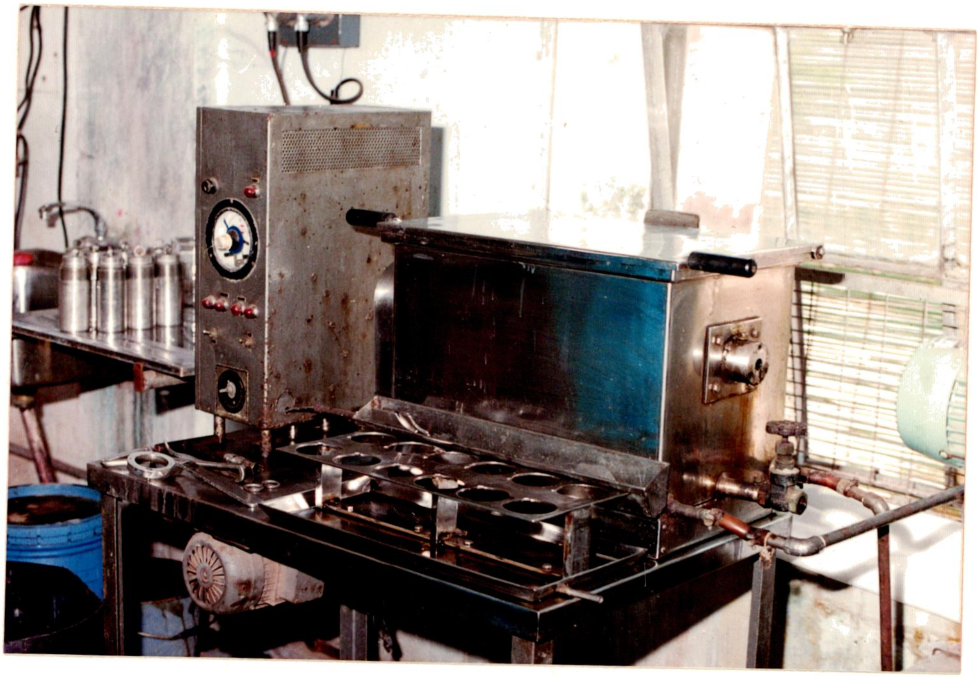


PLATE I. HIGH TEMPERATURE BEAKER DYEING MACHINE dyed in 0.5 and 2.0 percent yellow, yellow brown, blue and navy blue in reactive dyes using process water by hand jigger machine.

The preparation of the dye bath and procedure for dyeing are given in Appendix II.

The second set of eight samples were named as EY, EYB, EB, ENB, EY_1, EYB_1, EB_1 and ENB_1. The first four samples EY, EYB, EB and ENB, the remaining four samples EY_1, EYB_1, EB_1 and ENB_1 were dyed in 0.5 and 2.0 per cent of same shades of disperse and reactive dyes by using effluent treated water.

The preparation of the dye bath and procedure for dyeing are given in Appendix III.

1. Dyeing polyester part with disperse dyes:

The required amount of disperse dye was weighed according to the weight of the fabric. The dye stuff and little quantity of stock solution were taken in one of the cylindrical beaker of the beam dyeing machine (Plate I) and this was made into a paste. Then the stock solution was added to dilute the solution upto 300 cc. Similarly eight beakers were filled with stock solution. The weighed samples were rolled up and placed inside the prepared stock solution of the cylindrical beakers.

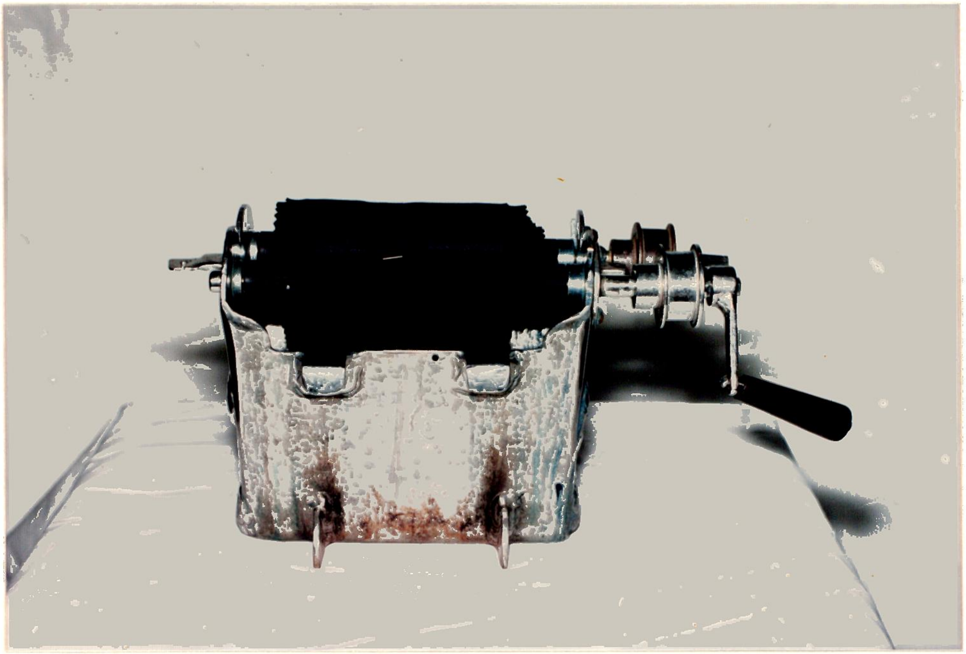


PLATE II.   HAND JIGGER MACHINE

The loaded beakers were placed inside the stand and tightened the lid of each beaker in order to avoid leakage of dye solution. The inner part of the beam was filled with glycerine and the machine was operated.

When the glycerine bath reached 90°C temperature, loaded beakers were placed inside the machine. Then the temperature was set up to 136°C. The samples were dyed for half an hour after reaching the temperature 136°C. After dyeing, the temperature was brought down to 90°C. Then the samples were removed from the beakers, washed, rinsed throughly and dried well.

2. Dyeing cotton part with reactive dyes by hand jigger method:

The hand jigger machine (Plate II) is a simple efficient machine in which dyestuff can be applied on materials of varying weight, length and width. Shenai (1973), Peter (1975) commits that, in the jigger, cloth is kept moving back and forth throughout, till the desired shade is obtained. In jigger dyeing, material runs evenly without over-lapping of selvedge. This is an important advantage of jigger dyeing. Rinsing and after treatment can also be done conveniently in the jigger. To dye the cotton part of the blend, the sample already dyed with disperse dyes were dyed in jigger dyeing method.

The dyed material was wound on the hand jigger machine and the prepared dye solution was poured in the hand jigger machine, and the machine was operated for 10 minutes. The dye solution was removed from the jigger and the sodium chloride was added to develop the colour and the solution was stirred thoroughly, then poured back into the jigger and dyeing was continued for 15 minutes. To fix the colour soda-ash was added to the dye bath and dyeing was continued for 30 minutes. Then the material was washed in hot soapy water and rinsed thoroughly in cold water, and then dried well. The method was suggested by United Bleachers Limited.

The samples were to be dyed using the respective dyeing methods, conditions and concentrations are given in the following Table:

TABLE I

S. No.	Sample	Dye	Colour	Condition	Concentration in percentage
1.	PY	Disperse & reactive	Yellow	Hot & Cold	0.5
2.	PYB	-do-	Yellow brown	-do-	0.5
3.	PB	-do-	Blue	Hot & Hot	0.5
4.	PNB	-do-	Navy blue	Hot & Cold	0.5
5.	EY	-do-	Yellow	-do-	0.5
6.	EYB	-do-	Yellow brown	-do-	0.5
7.	EB	-do-	Blue	Hot & Hot	0.5
8.	ENB	-do-	Navy blue	Hot & Cold	0.5
9.	PY_1	-do-	Yellow	-do-	2.0
10.	PYB_1	-do-	Yellow brown	-do-	2.0
11.	PB_1	-do-	Blue	Hot & Hot	2.0
12.	PNB_1	-do-	Navy blue	Hot & Cold	2.0
13.	EY_1	-do-	Yellow	-do-	2.0
14.	EYB_1	-do-	Yellow brown	-do-	2.0
15.	EB_1	-do-	Blue	Hot & Hot	2.0
16.	ENB_1	-do-	Navy blue	Hot & Cold	2.0

PY = 0.5% Yellow shade
PYB = 0.5% Yellow brown shade
PB = 0.5% Blue shade
PNB = 0.5% Navy Blue shade
EY = 0.5% Yellow shade
EYB = 0.5% Yellow brown
EB = 0.5% Blue shade
ENB = 0.5% Navy Blue shade

PY_1 = 2.0% Yellow shade
PYB_1 = 2.0% Yellow brown shade
PB_1 = 2.0% Blue shade
PNB_1 = 2.0% Navy Blue shade
EY_1 = 2.0% Yellow shade
EYB_1 = 2.0% Yellow Brown shade
EB_1 = 2.0% Blue shade
ENB_1 = 2.0% Navy Blue shade

E. Collection of Dye Effluent:

The United Bleachers Limited, Mettupalayam, Coimbatore is one of the leading bleaching and dyeing units in Coimbatore District. About 32 lakhs litres of water is totally used up by the unit per day. The dyeing section alone consumes about ten lakhs litres daily. The total effluent that is treated is 20 lakhs litre per day.

The investigator collected about 19 litres of untreated effluent in plastic containers. This total effluent was used up for various treatments and dyeing purposes.

F. Laboratory Experiments:

1. Before Treatment:

To find out the pollution potential of an effluent the following general parameters were found.

a. Potentia Hydrogenii (PH):

PH is the measure of the intensity of acidity or alkalinity and measures the concentration of hydrogen ions in water. The PH is an important factor in water chemistry since it enters into processes such as coagulation, disinfection, softening and erosion control. The PH determination is important because excessive acidity or alkalinity is injurious to biological acidity.

The normal acidity or alkalinity depends upon excess H^+ or OH^- ions over the other and measured in gram equivalents of acid and alkali. If free H^+ ions are more than OH^- ions the water is acidic. If free OH^- ions more than H^+ ions, the water is alkaline, says Trivedy and Goel (1984). For accurate measurement of PH, electrometric methods are used employing the hydrogen ion sensitive electrodes.

The description of the PH meter is given in the Appendix IV.

b.Chemical Oxygen Demand (COD):

The chemical oxygen demand is a measure of the oxygen which is equivalent of the organic matter content of a sample i.e. susceptible to oxidation by strong chemical oxidants. COD is also called as dichromate value. In other words the oxygen taken up by a waste sample from potassium dichromate after refluxing for two hours with concentrated sulphuric acid is known as chemical oxygen demand.

Description:

Reflux apparatus consisting of 500ml of 250ml Erlen Meyer Flask with ground glass 24/40 neck and 300 mm condenser and a hot plate having sufficient power to produce atleast 1.4 w/cm^2 of heating surface.

Reagents:

1. Standard potassium dichromate solution
2. Sulphuric acid
3. Ferrion indicator
4. Ferrous ammonium sulphate (0.25 N)
5. Mercuric sulphate
6. Silver sulphate

The procedure for preparing the reagents and the formula for calculating the chemical oxygen demand are given in Appendix V.

c. **Biochemical oxygen demand (BOD):**

BOD is the measure of degradable or organic material present in a water sample. It is defined as the amount of oxygen required by the micro-organisms in stabilising the bio-logically degradable organic matter under aerobic conditions, Trivedy and Goel, (1984).

The method involve, measuring the difference of the oxygen concentration between the sample and after incubating it for five days at 20°C.

Reagents:

1. BOD bottles (350 ml)
2. BOD incubator - 1
3. Phosphate buffer
4. Magnesium sulphate
5. Calcium chloride
6. Ferric chloride
7. Sodium sulphate solution 0.025 N
8. Seeding

The procedure for preparing the reagents and the formula for calculating the BOD are given in Appendix VI.

d. Total Suspended Solids (TSS):

The suspended matter is determined by filtering the sample, drying the residue and determining its weight by substracting the initial weight from the final weight of the Gooch crucible. This gives the weight in mg. of the suspended matter, Indian Standard Institute, (1967).

It is one of the valuable parameter in judging the pollution potential of an effluent.

The preparation of Gooch crucible and calculations are given in the Appendix VII.

e. Total Dissolved Solids:

Dissolved solids denotes mainly the various kinds of minerals present in the water. Dissolved solids do not contain any gas, colloids etc. Concentration of dissolved solids is an important parameter in water quality standards.

Total dissolved solids are determined as the residue left after evaporation of the filtered sample and determining its weight by substracting the initial weight of the dish from final weight of the dish. This gives the weight in mgs of the dissolved solids.

The procedure and formula for calculations are given in the Appendix VIII.

2. After Treatment:

Pilot Study:

During the effluent treatment, there was coagulation only with alum, whereas there was no such precipitation with lime and ferrous sulphate. Hence from the pilot study the investigator selected only alum for effluent treatment.

a. Coagulant used for treatment:

1. Alum:

According to environmental protection agency (1978), when alum is added to waste effluent it reacts with available alkalinity and phosphate to form aluminium salts. The combination of alum with alkalinity or phosphate are competing, reactions that are PH dependent.

Alum is the most commonly and successfully used coagulant on a large scale, says Choudhury (1984). It is an off-white crystal form which when dissolved in water produces acidic conditions (100 gms of alum dissolved in 1 litre of water, states Mckay (1981).

Narayana Rao and Datta (1987) opine that, the optimum range of PH for alum treatment is 6.5 to 8. Alum has been used for the reduction of turbidity and BOD in water treatment.

2. Ferrous sulphate:

It is a chemical coagulant which when added to dye effluent reacts with alkalinity and phosphate forms an insoluble iron salts, state, Pandit and Mayadea (1985).

3. Lime:

Lime is a chemical coagulant which when added to the waste effluent forms calcium salts. Being a hydroxide it should form flocs and the suspended solids would adhere to them and settle down.

B. Treatment Method:

The suitable and the required concentration of coagulant for the treatment of dye effluent was found out by pilot study.

For alum treatment, the dye effluent was taken in five different 1000 ml measuring jars and the PH was adjusted to 7.36 using hydrochloric acid. By adding 200,400,600,800 and 1000 ppm coagulant in each jar, approximate range of coagulant was found out.

For lime treatment, first the dye effluent was taken in three different 1000 ml measuring jars and the PH was adjusted to 7.36 using hydrochloric acid, by adding 100, 300 and 500 ppm coagulant in each jar, the approximate range of coagulant was found out.

For ferrous sulphate treatment, first the dye effluent was taken in four different 1000 ml. measuring jars, and the

PH was adjusted to 7.37 by using hydrochloric acid. By adding 200,400,600 and 800 ppm coagulant in each jar the approximate range of coagulant was found out.

The values for PH of effluent treated with coagulants are given in Appendix IX.

G. Evaluation:

The samples dyed in disperse dyes and reactive dyes using the process water and effluent treated water were evaluated by the following ways :

1. Visual inspection
2. Laboratory test
    - a. Fabric thickness test
    - b. Fabric weight test
    - c. Bursting strength test
    - d. Abrasion resistance
    - e. Wettability and absorbency test
        - i. Drop test
        - ii. Sinking test
    - f. Colour fastness test
        - i. Sunlight
        - ii. Wet and dry crocking
        - iii. Wet and dry pressing
        - iv. Washing test
    - g. Spectro-analysis

1. Visual Inspection:

In order to evaluate the dyed samples 20 judges of textiles and clothing, and family and community science department of Avinashilingam Deemed University, Coimbatore were selected, as they have enough knowledge on textiles. A rating scale was prepared as shown in Appendix X. The dyed samples were displayed for easy evaluation. The prepared rating scale was given to the selected judges and they were requested to evaluate the samples. The data was collected, consolidated and the result is presented under the chapter "Results and Discussion".

2. Laboratory tests:

The original and dyed materials were tested by taking the sample pieces from the same relative proportions of all the materials for their respective laboratory tests.

a. Fabric thickness test:

According to the ASTM Standards (1983), the thickness of a textile material is the distance between two parallel surfaces while exerting a specified pressure on the material .

According to Booth (1970), thickness of a textile material is the distance between the two parallel surface, while exerting

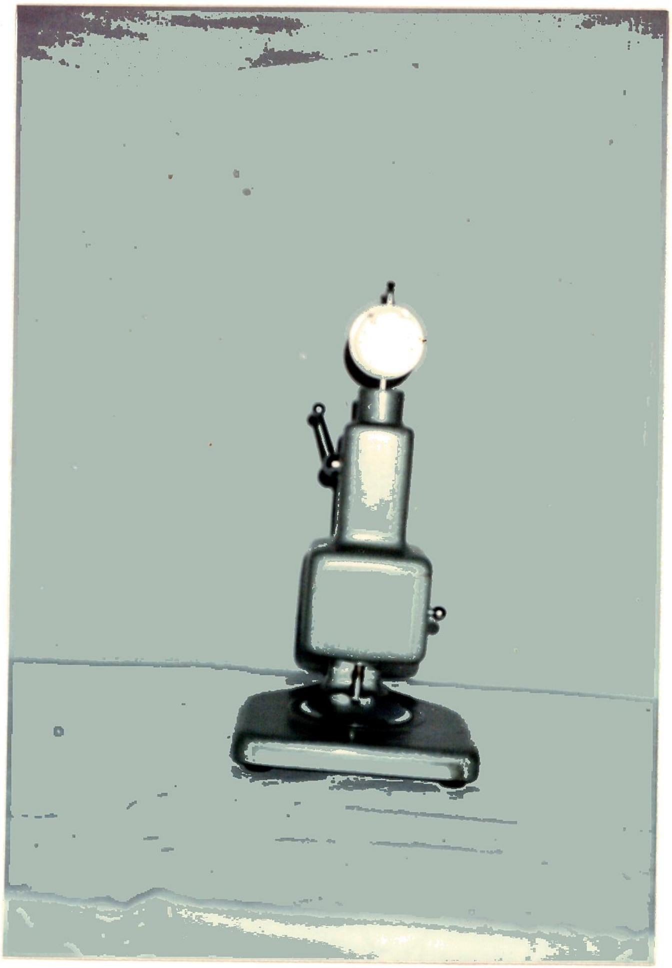


PLATE III.   THICKNESS TESTER

a specified pressure on the material. Skinkle (1972) feels that, fabric thickness test is used to find its density in connection with such property as air permeability, water permeability and thermal conductivity.

The Hungarian Thickness Tester (Plate III) was used to determine the thickness of the original and the dyed materials.

The thickness tester had a broad anvil, upon which a pressure foot is pressed by spring. The dial indicated the thickness of the material in thousands of an inch between the anvil and the pressure foot. Each division on the dial read 0.01 mm. The sample was placed on the anvil without tension or creases and the pressure foot was lowered on to the sample by relaxing the raising level very slowly and allowed to rest upon the sample for two seconds at 2 kgs pressure. The dial reading was recorded. Five readings were taken from different parts of the same material and the mean value was calculated. Similarly mean value of five readings from the original and samples dyed in process water and effluent treated water were calculated and thus the fabric thickness of the samples were recorded.

b. Fabric Weight Test:

Skinkle (1972) says that, the weight of a fabric can be described in two ways, either as the 'weight per unit area' or 'weight per unit length'. Booth (1974) points out that, the

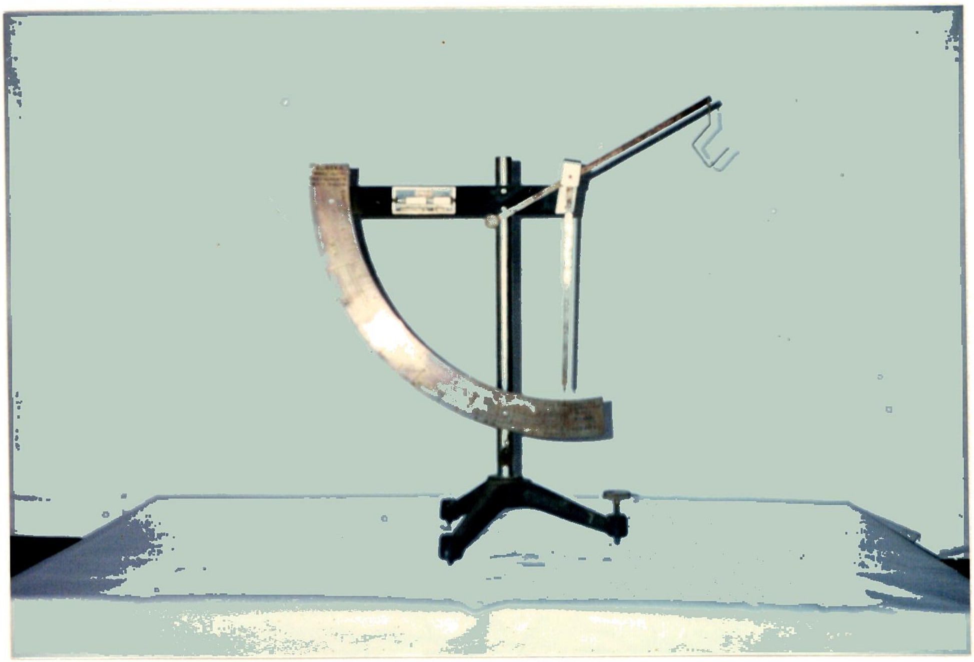


PLATE IV. CLOTH QUARDRANT BALANCE

former is self explanatory, but the later requires a little explanation because the weight of unit length of fabric will obviously be affected by its width.

The Eureka model cloth quardrant balance (Plate IV) was used for this test. A template was used to cut the samples, and the sample was suspended on the hook of the balance and the reading was recorded.

The same procedure was repeated for all the samples and mean value was calculated. The mean value of the samples from the original was calculated separately. This was found in ounces per square yard and the same was converted into grams per square metre.

c. Bursting Strength Test:

Bureau of Indian Standards and Booth (1968) point out that, it is some times desirable to test a fabric by applying the load multidirectionally instead of one single direction as in the case of warp or weft way strip tests. The reasons for this preference may be due to the difficulties associated with other methods of test or perhaps because the material in use may be stressed in many directions simultaneously.

PLATE V. BURSTING STRENGTH TESTER

The Eureka Bursting strength Tester (Plate V) was used to determine the bursting strength of the samples. The internal diametre of the clamp ring was 3 cm. The dial was caliberated in kgs/cm^2. The samples were cut into 10 cm by 10 cm width. The sample was clamped over a rubber diaphragm and hydrostatic pressure was applied until the sample was broken and the readings were recorded in kgs/cm^2. The same procedure was repeated for all samples dyed in process water and effluent treated water and the mean value was calculated. Similarly the mean value of the samples from the original was calculated and thus the bursting strength of the samples were obtained.

d. Abrasion Resistance:

Booth (1968) says that, abrasion is just one aspect of wear and is the rubbing away of the component fibers and yarns of the fabric.

Lyle (1982) illustrates Abrasion resistance as the ability of a fiber to withstand rubbing in use and care and is conducted to find out the amount of rubbing, the fiber can withstand in its life, which in turn will show the resistance of the fabric to rubbing.

The Eureka Marlindale Abrasion Resistance tester (Plate VI) was used to determine the fabric resistance to friction.

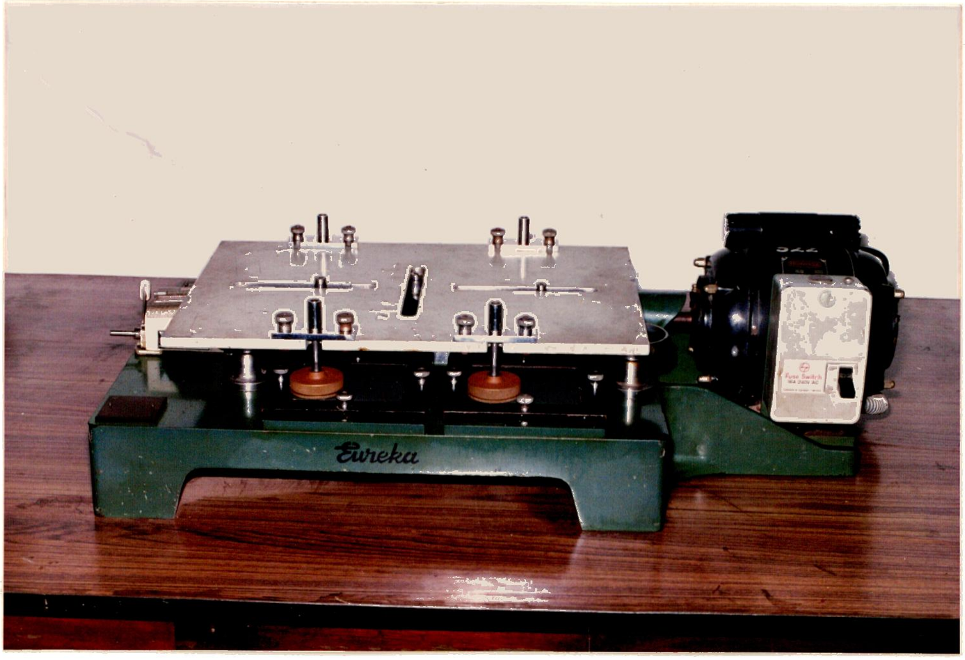


PLATE VI. ABRASION RESISTANCE TESTER

The silicon carborandum C-400 was used as an abradant. The samples were cut from different parts by using the template. The initial weight of each sample was taken accurately to 0.0001gm. The sample was mounted on the sample holder and a multi directional movement was given to rub against the abrasive paper. The number of rubs abrading the sample was determined by the appearance of the hole or the rupture of the sample. Ten rubs were found to be sufficient and each sample was given ten rubs. After abrasion its final weight was taken accurately. The loss of weight of the sample was calculated.

The same procedure was repeated for all the samples dyed using process water and effluent treated water and the mean value was calculated. Each time a fresh abradant was used. Similarly the mean value from the original and dyed samples were calculated and thus the loss of weight of each sample was recorded separately.

e. Wettability and Absorbency Test:

i. Drop Test:

The ability of a fiber to take up moisture is determined as absorbency, remark, Chambers and Moulton (1969). It is the time taken in seconds for a drop of water to sink into the fabric. Fabrics that take more than 200 seconds to absorb water are

PLATE VII.   DROP TEST

considered as unwettable. The test conducted therefore is known as 'Drop test'.

A burette filled with distilled water was clamped to a stand (Plate VII). The sample was mounted in an embroidery frame and was placed at the base of the stand. The height between the sample and burette was kept constant. The nozzle of the burette was opened to allow a drop of water to fall on the sample. The stop watch was started simultaneously and it was stopped when the drop of water fully sank into the material. The time taken for this was noted. The same procedure was repeated for five samples of the same material and the mean value was calculated for all the samples dyed using process water and effluent treated water. Similarly the mean value of the five samples from the original was calculated and thus the drop test for each material was recorded separately.

ii. Sinking Test:

Booth (1968) describes sinking time as the single test which helps to measure the wettability of a fabric.

The samples were cut into 5 cm x 5 cm squares from the original and the dyed materials. A 1000 ml beaker was taken and filled with distilled water. Few drops of wetting agent was added to it. The sample was dropped on the surface of the water from a standard height and the time required for the sample to sink was noted.

The stop watch was started, when the fabric struck surface of water and stopped. When the last corner sank below the water surface. The time taken was noted. The same procedure was repeated for five samples of the same material and the mean value was calculated for all the samples dyed, using process water and effluent treated water. Similarly, the mean value of the five samples from original was calculated and then the sinking time of each material was recorded separately.

f. Colour fastness test:

The American Association textile chemists and colourists (AATCC) established standard terminology for rating colour fastness properties of fabric to different test methods and also for evaluating colour staining and transfer in fabrics. The colour fastness is the ability of fabrics to retain their original colour or to resist transfer of colour (Wingate, 1970).

i. Sunlight:

As per Wingate's (1976) instruction 4 x 4 inches fabric was taken and 2 inches of fabric was exposed to sunlight for 24 hours. The same procedure is repeated for all samples of process water and effluent treated water.

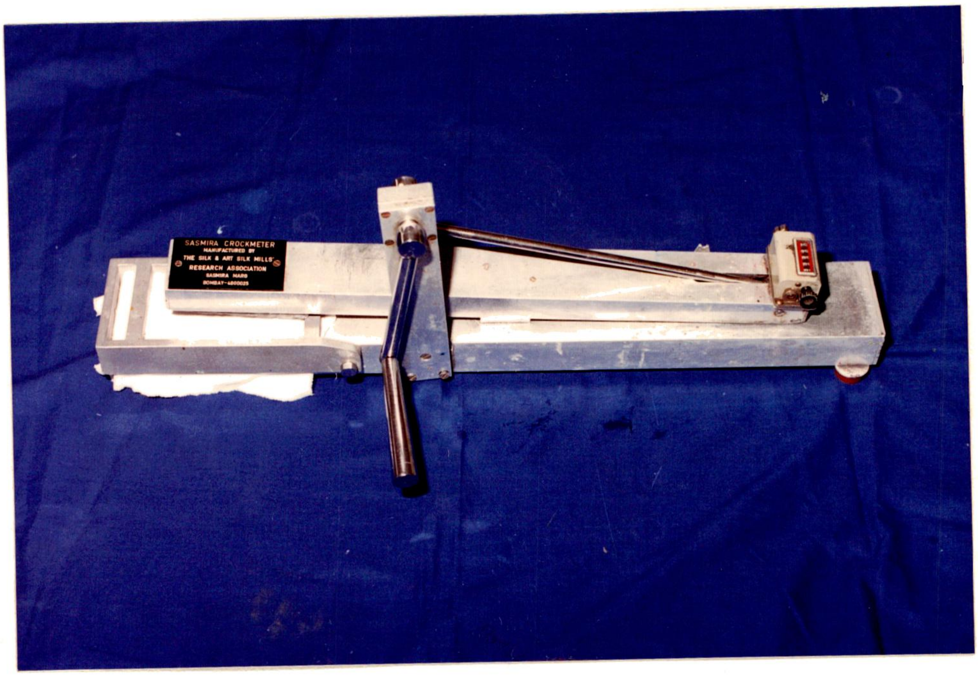


PLATE VIII. CROCK METER

The colour fastness to sunlight was evaluated using AATCC Gray scale, (Appendix XI).

ii. Wet and dry crocking:

According to Wingate and Mohler (1970), crocking is defined the colour transfer from one colour textile material to any other by rubbing.

Sasmira crock meter (Plate VIII) was used for ascertaining the fastness of dyed samples. It consisted of two metal blocks. The base block was stationary where the upper block had an arrangement to move to and fro on the base by means of a rotating handle. There was a finger knob attached to the upper movable block to hold the material with a ring. The number of rubs to be given was standardised / fixed. Each sample was given ten rubs. A white material was rubbed to and fro against the dyed sample along a track of 10 cms with a pressure of 900 gms. on the finger. The colour transfer from the dyed sample to the white material was assessed with AATCC Gray scale and the geometric scale for staining. The same procedure was repeated for the process water samples and samples dyed using effluent treated water.

For wet crocking, a damp white material was used and the same procedure was repeated. Thus the colour fastness of each dyed sample to dry and wet crocking was observed.

iii. Wet and Dry Pressing:

The National Bureau of standards gives a test to determine colour fastness to dry and wet pressing. A hot iron was used to ascertain the fastness of the samples dyed in process water and effluent treated water to wet and dry pressing. Test samples were cut into 5 cm x 10 cm squares. They were kept in between a white material, both in dry and wet condition and then pressed with a heavy hot iron for 5 seconds at a temperature of 425°F and 10 seconds at 350 °F respectively. The same procedure was repeated for the process water samples and samples dyed using effluent treated water.

The colour transfer from the dyed samples were assessed using AATCC Gray scale. Thus the colour fastness of each dyed material to wet and dry pressing was carefully observed.

iv. Washing Test:

A piece of each dyed sample was placed in between a white material and pinned along the three sides and numbered.

3 gms of disodium tetra chloride (DTC) per litre and 1.5 gms soda ash per litre were mixed in distilled water. Boiled beaker machine was used for washing. The prepared solution was poured in the beakers. Each sample of the process water

and effluent treated water were put into the beakers and closed. These beakers were placed into the machine and the temperature was adjusted to 60°C. After reaching the temperature allow the samples to wash for half an hour and remove them, rinsed thoroughly in cold water and dried.

The colour fastness to washing was evaluated using spectro analysis on a computer.

g. Spectro Analysis:

Methods used for assessment off colour fastness using Gray Scale are subjective, depend upon the viewing conditions and do not give any quantitative idea of the changes after treatment.

A simplified method of assessment of colour fastness with respect to changes in colour of the test samples has been developed to overcome these limitations by measuring the reflectance values of the samples before and after treatment with different chemical reagents. Fastness ratings have been given by standardising the Gray Scale based on DE, L and Lb using UELAB colour difference equation.

In using the Gray scale, the character of change, whether in hue, depth, brightness or any combination of these is not related. The overall difference or contrast between the original and the treated sample forms the basis for evaluation. If it is desired to record the character of change in colour, appropriate qualitative terms have to be added. Thus the fastness ratings may be same but there is either loss in depth or change in tone or change in brightness as the case may be.

A simplified procedure for evaluation of the fastness tests results in terms of percentage strength value, colour difference and total changes quantitatively in terms of redder/greener and yellower/bluer, directly by measuring the reflectance values of the original and treated samples with the help of a computer colour control system. The rating is consistent, not subjective and does not depend on the viewing conditions of the observer.

Analysis of Gray Scale:

In the present study, taking the Gray Scale as the standard, an attempt has been made to understand the rating scale by expressing quantitatively the present strength at all the levels as compared to the original standard.

The Gray scale has been analysed by determining the reflectance value of the original and those at the rating level ranging from +2 to -2.

Values of Strength:

PTRIS - Per cent based on pseudo tristimulus values

DE - Colour difference using CIE - 1976 colour difference equation.

La* Lb* - Samples.

Thus with the help of a computer control system it wculd be possible to get a reliable and quantitative assessment of colour fastness with respect to change in colour and with the help of a flow chart even in the absence of a gray scale.

Results and Discussion

IV RESULTS AND DISCUSSION

The results of the study are discussed under the following headings :

A General parameters

B. Visual inspection

C. Laboratory tests

1. Fabric thickness
2. Fabric weight
3. Bursting strength
4. Abrasion resistance
5. Wettability and absorbency tests
   a. Drop test
   b. Sinking test
6. Colour fastness tests
   a. Sunlight
   b. Dry and wet crocking
   c. Dry and wet pressing
7. Colour fastness to washing - Spectro-Analysis
8. Strength test - Spectro-Analysis.

A. General Parameters:

The general parameters for the dye effluent before and after treatment is given in Table II.

TABLE - II

GENERAL PARAMETERS FOR DYE EFFLUENTS

S.No.	General parameters	Concentrations		Tolerance Limit
		Before Treatment	After Treatment	
1.	Potentia Hydrogenii (PH)	12.73	7.5	5.5-9.0
2.	Biochemical oxygen demand (BOD) (mg/l)	240.0	25.5	30.0
3.	Chemical oxygen demand (COD)(mg/l)	1,260.0	228.6	250.0
4.	Total suspended solids (TSS) (mg/l)	420.0	84.4	100.0
5.	Total dissolved solids (TDS) (mg/l)	5,222.0	1,702.3	2,100.0

The above table shows the general parameter values of before and after treatment. It was found that after alum treatment the values for each general parameter had decreased within the tolerance limits.

B. VISUAL INSPECTION :

TABLE - III

EVALUATION OF DYED SAMPLES

S.No.	Sample	EVENNESS IN DYEING		BRILLIANCY OF COLOUR			TEXTURE		LUSTRE			GENERAL APPEARANCE		
		Even %	Uneven %	V.Bright %	Bright %	Dull %	Smooth %	Coarse %	High %	Medium %	Low %	Good %	Fair %	Poor %
1.	PY	100	-	15	85	-	100	-	100	-	-	100	-	-
2.	PY_1	100	-	20	80	-	100	-	100	-	-	100	-	-
3.	PYb	100	-	-	100	-	100	-	100	-	-	100	-	-
4.	PYb_1	100	-	-	100	-	100	-	100	-	-	100	-	-
5.	PB	100	-	-	100	-	100	-	100	-	-	100	-	-
6.	PB_1	100	-	-	100	-	100	-	100	-	-	100	-	-
7.	PNB	100	-	-	100	-	100	-	100	-	-	100	-	-
8.	PNB_1	-	100	-	20	80	100	-	70	30	-	-	80	20
9.	EY	100	-	-	100	-	20	80	-	100	-	-	85	15
10.	EY_1	100	-	-	100	-	30	70	-	100	-	-	85	15
11.	EYb	100	-	-	-	100	-	100	-	100	-	-	-	100
12.	EYb_1	100	-	-	100	-	30	70	-	80	20	-	70	30
13.	EB	100	-	-	100	-	100	-	-	100	-	100	-	-
14.	EB_1	100	-	-	100	-	100	-	-	100	-	100	-	-
15.	ENB	100	-	-	-	100	20	80	-	80	20	-	80	20
16.	ENB^1	-	100	-	-	100	20	80	-	70	30	-	60	40

From the Table III it was clear that except PNB_1 and ENB_1, all other samples were rated as even by 100 per cent, of the judges.

As regards brilliancy of colour, among the process water samples, PY and PNB_1, PY_1 were rated as bright by 85 and 80 per cent of the judges respectively. The samples PYb, PYb_1, PB, PB_1 and PNB were rated as bright by 100 per cent of the judges. Among the effluent treated samples EY, EY_1, EYB_1, EB and EB_1 were rated as bright by 100 per cent of the judges. The samples EYB, ENB and ENB_1 were rated as dull by 100 per cent of the judges.

With respect to the texture all the samples dyed using process water were rated as smooth by 100 per cent of the judges. Among the effluent treated water only EB and EB_1 were rated as smooth by 100 per cent of the judges. The samples EYB, EY, ENB, ENB_1, EY_1 and EYB_1 were rated as coarse by more than 70 per cent of the judges.

Considering the lustre except the sample PNB_1, all other samples dyed using process water were rated as high by 100 per cent of the judges. Among the effluent treated water samples, EY, EY_1, EB and EB_1 were rated as medium by 100 per cent of the judges where as samples EYB, ENB and ENB_1 were rated as medium by 80 and 70 per cent of the judges respectively.

Regarding the general appearance, samples dyed using process water, only the sample PNB_1, was rated as fair by 80 percent of the judges, where as all other samples were rated as good by 100 per cent of the judges. Among the effluent treated samples EB and EB_1 were rated as good by 100 per cent of the judges. The samples EY, EY_1, ENB, EYb_1 and ENB_1 were rated as fair by more than 80 percent of the judges respectively.

Based on the above it is clearly understood that the samples dyed using effluent treated water excelled equally with samples dyed using process water.

1. Fabric Thickness:

The fabric thickness of the original and dyed samples using process water and effluent treated water is presented in Table IV.

TABLE - IV

FABRIC THICKNESS OF ORIGINAL AND DYED SAMPLES

S.No.	Sample	Mean value x0.01mm	Gain over original	Percentage gain over original
1.	Original	0.163		
2.	PY	0.166	0.003	1.840
3.	PY_1	0.167	0.004	2.454
4.	PYb	0.167	0.004	2.454
5.	PYb_1	0.170	0.007	4.294
6.	PB	0.167	0.004	2.454
7.	PB_1	0.166	0.003	1.840
8.	PNB	0.168	0.005	3.067
9.	PNB_1	0.168	0.005	3.067
10.	EY	0.171	0.008	4.908
11.	EY_1	0.170	0.007	4.294
12.	EYb	0.170	0.007	4.294
13.	EYb_1	0.177	0.014	8.588
14.	EB	0.173	0.010	6.134
15.	EB_1	0.170	0.007	4.294
16.	ENB	0.176	0.013	7.975
17.	ENB_1	0.177	0.014	8.588

Statistical Analysis of Fabric Thickness

S.No.	Sample	Mean ± S.D.	Difference Mean ± S.D.	Groups Compared	't' value
1.	Original	0.163 ± 0.004	0.003 ± 0.004	O Vs PY	0.95 NS
2.	PY	0.166 ± 0.005	0.003 ± 0.005	PY Vs EY	1.58 NS
3.	PY_1	0.167 ± 0.002	0.004 ± 0.002	O Vs PY_1	2.11 NS
				PY_1 Vs EY_1	1.58 NS
4.	PYB	0.167 ± 0.004	0.004 ± 0.004	O Vs PYB	1.58 NS
				PYB Vs EYB	0.95 NS
5.	PYB_1	0.170 ± 0.003	0.007 ± 0.003	O Vs PYB_1	2.21 NS
				PYB_1 Vs EYB_1	2.77 *
6.	PB	0.167 ± 0.004	0.004 ± 0.004	O Vs PB	1.58 NS
				PB Vs EB	2.37 *
7.	PB_1	0.166 ± 0.005	0.003 ± 0.005	O Vs PB_1	0.95 NS
				PB_1 Vs EB_1	1.26 NS
8.	PNB	0.168 ± 0.007	0.005 ± 0.007	O Vs PNB	1.58 NS
				PNB Vs ENB	2.11 NS
9.	PNB_1	0.168 ± 0.006	0.005 ± 0.006	O Vs PNB_1	1.58 NS
				PNB_1 Vs ENB_1	2.85 *
10.	EY	0.171 ± 0.005	0.008 ± 0.005	O Vs EY	2.53 *
11.	EY_1	0.170 ± 0.004	0.007 ± 0.004	O Vs EY_1	2.77 *
12.	EYB	0.170 ± 0.006	0.007 ± 0.006	O Vs EYB	2.21 NS
13.	EYB_1	0.177 ± 0.004	0.014 ± 0.004	O Vs EYB_1	5.53 **
14.	EB	0.173 ± 0.004	0.010 ± 0.004	O Vs EB	3.95 **
15.	EB_1	0.170 ± 0.005	0.007 ± 0.005	O Vs EB_1	2.21 NS
16.	ENB	0.176 ± 0.004	0.013 ± 0.004	O Vs ENB	5.14 **
17.	ENB_1	0.177 ± 0.002	0.014 ± 0.002	O Vs ENB_1	7.38 **

* - Significant at 5% level
** - Significant at 1% level
NS - Not Significant

Table IV shows the thickness of the original and dyed samples in process water and effluent treated water. The greater the mean value the more is the thickness of the sample.

It is clearly evident that all the dyed samples showed higher mean values than that of the original sample. Among the dyed samples, effluent treated water samples showed highest mean values than the samples dyed using process water.

On analysing statistically the following facts are seen:

1. There was highly significant difference between the original and the dyed samples using process water and effluent treated water.

2. There was no significant difference between the samples dyed in both 0.5 and 2.0 per cent shades using process water and effluent treated water.

2. Fabric Weight:

The fabric weight of original and dyed samples using process water and effluent treated water is presented in Table V.

TABLE - V

FABRIC WEIGHT OF ORIGINAL AND DYED SAMPLES

S. No.	Sample	Mean value (gms/sq)	Gain over original (gms/sq)	Percentage gain over original
1.	Original	2.54		
2.	PY	2.65	0.11	4.331
3.	PY_1	2.65	0.11	4.331
4.	PYb	2.66	0.12	4.724
5.	PYb_1	2.66	0.12	4.724
6.	PB	2.75	0.21	8.268
7.	PB_1	2.71	0.17	6.693
8.	PNB	2.70	0.16	6.299
9.	PNB_1	2.76	0.22	8.661
10.	EY	2.75	0.21	8.268
11.	EY_1	2.74	0.20	7.874
12.	EYb	2.76	0.22	8.661
13.	EYb_1	2.75	0.21	8.268
14.	EB	2.63	0.09	3.543
15.	EB_1	2.68	0.14	5.512
16.	ENB	2.68	0.14	5.512
17.	ENB_1	2.67	0.13	5.118

Statistical Analysis of Fabric Weight

S.No.	Sample	Mean ± S.D.	Difference Mean ± S.D.	Groups Compared	t value
1.	Original	2.54 ± 0.049	0.11 ± 0.049	O Vs PY	3.47 *
2.	PY	2.65 ± 0.050	0.11 ± 0.050	PY Vs EY	1.82 NS
3.	PY_1	2.65 ± 0.047	0.11 ± 0.050	O Vs PY_1	3.62 **
				PY_1 Vs EY_1	1.26 NS
4.	PYB	2.66 ± 0.089	0.12 ± 0.089	O Vs PYB	2.71 *
				PYB Vs EYB	2.08 NS
5.	PYB_1	2.66 ± 0.040	0.12 ± 0.040	O Vs PYB_1	4.74 **
				PYB_1 Vs EYB_1	2.09 NS
6.	PB	2.75 ± 0.050	0.21 ± 0.050	O Vs PB	6.64 **
				PB Vs EB	4.61 **
7.	PB_1	2.71 ± 0.040	0.17 ± 0.040	O Vs PB_1	6.72 **
				PB_1 Vs EB_1	0.69 NS
8.	PNB	2.70 ± 0.079	0.16 ± 0.079	O Vs PNB	3.61 **
				PNB Vs ENB	0.07 NS
9.	PNB_1	2.76 ± 0.060	0.22 ± 0.060	O Vs PNB_1	6.96 **
				PNB_1 Vs ENB_1	1.87 NS
10.	EY	2.75 ± 0.112	0.21 ± 0.112	O Vs EY	3.82 **
11.	EY_1	2.74 ± 0.152	0.20 ± 0.152	O Vs EY_1	2.80 *
12.	EYB	2.76 ± 0.060	0.22 ± 0.060	O Vs EYB	6.32 **
13.	EYB_1	2.75 ± 0.087	0.21 ± 0.087	O Vs EYB_1	4.61 **
14.	EB	2.63 ± 0.030	0.09 ± 0.030	O Vs EB	3.56 **
15.	EB_1	2.68 ± 0.087	0.14 ± 0.087	O Vs EB_1	3.12 NS
16.	ENB	2.68 ± 0.087	0.14 ± 0.087	O Vs ENB	3.12 NS
17.	ENB_1	2.67 ± 0.097	0.13 ± 0.097	O Vs ENB_1	2.70 *

* - Significant at 5% level
** - Significant at 1% level
NS - Not Significant

Table V shows that, weight of the original and dyed samples in process water and effluent treated water. The greater the mean value, the more is the weight of the sample. It is clearly evident that all the dyed samples showed higher mean values than the original samples.

A maximum gain was observed in the samples PNB_1 and EYb when compared to other samples. The statistical analysis proved the following facts:

1. There was highly significant difference between the original and the dyed samples using process water and effluent treated water.

2. There was no significant difference between the samples dyed in both 0.5 and 2.0 per cent shades using process water and effluent treated water, but significant difference was found between the samples dyed in 0.5 per cent using process and effluent treated water.

3. Bursting Strength:

The bursting strength of original and dyed samples using process water and effluent treated water is presented in Table VI.

TABLE - VI

BURSTING STRENGTH OF ORIGINAL AND DYED SAMPLES

S. No.	Sample	Mean value (lb/sq.inch)	Loss over original	Percentage loss over original
1.	Original	9.50		
2.	PY	8.78	0.72	7.578
3.	PY_1	8.98	0.52	5.474
4.	PYb	8.94	0.56	5.894
5.	PYb_1	8.94	0.56	5.894
6.	PB	8.90	0.60	6.316
7.	PB_1	8.72	0.78	8.211
8.	PNB	8.78	0.72	7.578
9.	PNB_1	8.78	0.72	7.578
10.	EY	9.02	0.48	5.053
11.	EY_1	9.04	0.46	7.158
12.	EYb	9.04	0.46	7.158
13.	EYb_1	9.02	0.48	5.053
14.	EB	9.04	0.46	4.842
15.	EB_1	9.24	0.26	2.737
16.	ENB	9.04	0.46	4.842
17.	ENB_1	9.02	0.48	5.053

Statistical Analysis of Bursting Strength

S.No.	Sample	Mean ± S.D.	Difference Mean ± S.D.	Groups Compared			't' value
1.	Original	9.50 ± 0.223	0.72 ± 0.223	O	Vs	PY	5.06 **
2.	PY	8.78 ± 0.228	0.72 ± 0.228	PY	Vs	EY	1.14 NS
3.	PY_1	8.98 ± 0.130	0.52 ± 0.130	O	Vs	PY_1	5.29 **
				PY_1	Vs	EY_1	0.33 NS
4.	PYB	8.94 ± 0.089	0.56 ± 0.089	O	Vs	PYB	5.24 **
				PYB	Vs	EYB	0.29 NS
5.	PYB_1	8.94 ± 0.456	0.56 ± 0.456	O	Vs	PYB_1	2.47 **
				PYB_1	Vs	EYB_1	0.29 NS
6.	PB	8.90 ± 0.234	0.60 ± 0.234	O	Vs	PB	4.14 **
				PB	Vs	EB	0.68 NS
7.	PB_1	8.72 ± 0.192	0.78 ± 0.192	O	Vs	PB_1	5.87 **
				PB_1	Vs	EB_1	0.30 NS
8.	PNB	8.78 ± 0.443	0.72 ± 0.443	O	Vs	PNB	3.24 *
				PNB	Vs	ENB	0.30 NS
9.	PNB_1	8.78 ± 0.178	0.72 ± 0.178	O	Vs	PNB_1	5.64 **
				PNB_1	Vs	ENB_1	1.45 NS
10.	EY	9.02 ± 0.408	0.48 ± 0.408	O	Vs	EY	2.31 *
11.	EY_1	9.04 ± 0.384	0.46 ± 0.384	O	Vs	EY_1	2.32 *
12.	EYB	9.04 ± 0.397	0.46 ± 0.397	O	Vs	EYB	2.27 NS
13.	EYB_1	9.02 ± 0.408	0.46 ± 0.408	O	Vs	EYB_1	2.31 *
14.	EB	9.04 ± 0.397	0.46 ± 0.397	O	Vs	EB	2.26 NS
15.	EB_1	9.24 ± 0.167	0.26 ± 0.167	O	Vs	EB_1	2.09 NS
16.	ENB	9.04 ± 0.397	0.46 ± 0.397	O	Vs	ENB	2.25 NS
17.	ENB_1	9.02 ± 0.432	0.48 ± 0.432	O	Vs	ENB_1	2.21 NS

* - Significant at 5% level
** - Significant at 1% level
NS - Not Significant

The above Table VI illustrates the bursting strength of the original and dyed samples in process water and effluent treated water. From Table VI it is clearly evident that, all the dyed samples showed lesser mean values than the original sample. Among the dyed samples, process water used for dyeing showed lesser values than the samples dyed using effluent treated water.

The statistical analysis proved the following facts:

1. There was significant difference between original and samples dyed in process water as well as effluent treated water.

2. There was no significant difference between the samples dyed in process water and effluent treated water.

4. Abrasion Resistance:

The abrasion resistance of the original and dyed samples using process water and effluent treated water are shown in Table VII.

TABLE - VII

ABRASION RESISTANCE OF ORIGINAL AND DYED SAMPLES

S.No.	Sample	Mean value (gms)	Gain over original	Percentage gain over original
1.	Original	0.0008		
2.	PY	0.0012	0.0004	50.0
3.	PY_1	0.0023	0.0015	187.5
4.	PYb	0.0016	0.0008	100.0
5.	PYb_1	0.0014	0.0006	75.0
6.	PB	0.0012	0.0004	50.0
7.	PB_1	0.0011	0.0003	37.5
8.	PNB	0.0016	0.0008	100.0
9.	PNB_1	0.0013	0.0005	62.5
10.	EY	0.0011	0.0003	37.5
11.	EY_1	0.0016	0.0008	100.5
12.	EYb	0.0012	0.0004	50.0
13.	EYb_1	0.0011	0.0003	37.5
14.	EB	0.0018	0.0010	125.0
15.	EB_1	0.0018	0.0010	125.0
16.	ENB	0.0016	0.0008	100.0
17.	ENB_1	0.0012	0.0004	50.0

Statistical Analysis of Abrasion Resistance

S.No.	Sample	Mean ± S.D.	Difference Mean ± S.D.	Groups Compared	't' value
1.	Original	0.0008 ± 0.0005	0.0004 ± 0.0005	O Vs PY	1.58 NS
2.	PY	0.0012 ± 0.0006	0.0004 ± 0.0006	PY Vs EY	0.39 NS
3.	PY_1	0.0023 ± 0.0018	0.0015 ± 0.0018	O Vs PY_1	1.82 NS
				PY_1 Vs EY_1	0.73 NS
4.	PYB	0.0016 ± 0.0015	0.0008 ± 0.0015	O Vs PYB	1.27 NS
				PYB Vs EYB	0.63 NS
5.	PYB_1	0.0014 ± 0.0007	0.0006 ± 0.0007	O Vs PYB_1	1.89 NS
				PYB_1 Vs EYB_1	1.19 NS
6.	PB	0.0012 ± 0.0006	0.0004 ± 0.0006	O Vs PB	1.58 NS
				PB Vs EB	1.19 NS
7.	PB_1	0.0011 ± 0.0014	0.0003 ± 0.0014	O Vs PB_1	0.47 NS
				PB_1 Vs EB_1	1.11 NS
8.	PNB	0.0016 ± 0.0015	0.0008 ± 0.0015	O Vs PNB	1.26 NS
				PNB Vs ENB	1.69 NS
9.	PNB_1	0.0013 ± 0.0007	0.0005 ± 0.0007	O Vs PNB_1	1.58 NS
				PNB_1 Vs ENB_1	0.26 NS
10.	EY	0.0011 ± 0.0004	0.0003 ± 0.0004	O Vs EY	1.58 NS
11.	EY_1	0.0016 ± 0.0010	0.0008 ± 0.0010	O Vs EY_1	1.81 NS
12.	EYB	0.0012 ± 0.0006	0.0004 ± 0.0006	O Vs EYE	1.58 NS
13.	EYB_1	0.0011 ± 0.0001	0.0003 ± 0.0001	O Vs EYE_1	1.58 NS
14.	EB	0.0018 ± 0.0011	0.0010 ± 0.0011	O Vs EB	1.98 NS
15.	EB_1	0.0018 ± 0.0011	0.0010 ± 0.0011	O Vs EB_1	1.98 NS
16.	ENB	0.0016 ± 0.0010	0.0008 ± 0.0010	O Vs ENB	1.81 NS
17.	ENB_1	0.0012 ± 0.0007	0.0004 ± 0.0007	O Vs ENB_1	1.05 NS

* - Significant at 5% level
** - Significant at 1% level
NS - Not Significant

Table VII shows the weight of the dyed samples and the original sample after undergoing abrasion it determines the abrasion resistance of the fabric. The greater the loss of weight, the lesser is the resistance.

From the Table VII it is clearly evident that, among the dyed samples only PY_1 showed a noticeable higher mean values than the original.

The statistical analysis showed that:

1. No significant differences was seen between the original and dyed samples using process water and effluent treated water.

2. There was no significant difference between the samples dyed using process water and effluent treated water.

5. Wettability and absorbency tests:

a. Drop Test:

The drop test value of original and dyed samples using process water and effluent treated water are presented in Table VIII.

TABLE - VIII

DROP TEST OF ORIGINAL AND DYED SAMPLES

S.No.	Sample	Mean value (Seconds)	Loss over original	Percentage loss over original
1.	Original	40.0		
2.	PY	25.0	15.0	37.5
3.	PY_1	26.2	13.8	34.5
4.	PYb	24.8	15.2	38.0
5.	PYb_1	25.8	14.2	35.5
6.	PB	26.8	13.2	33.0
7.	PB_1	28.0	12.0	30.0
8.	PNB	25.4	14.6	36.5
9.	PNB_1	25.8	14.2	35.5
10	EY	23.8	16.2	40.5
11.	EY_1	24.2	15.8	39.5
12.	EYb	24.4	15.6	39.0
13.	EYb_1	25.4	14.6	36.5
14.	EB	23.4	16.6	41.5
15.	EB_1	27.6	12.4	31.0
16.	ENB	24.8	15.2	38.0
17.	ENB_1	25.2	14.8	37.0

Statistical Analysis of drop test

S.No.	Sample	Mean ± S.D.	Difference Mean ± S.D.	Groups Compared	t value
1.	Original	40.0 ± 3.162	15.0 ± 3.162	O Vs PY	8.66 **
2.	PY	25.0 ± 2.236	15.0 ± 2.236	PY Vs EY	0.77 NS
3.	PY_1	26.2 ± 2.588	13.8 ± 2.588	O Vs PY_1	7.55 **
				PY_1 Vs EY_1	0.46 NS
4.	PYB	24.8 ± 0.836	15.2 ± 0.836	O Vs PYB	8.49 **
				PYB Vs EYB	0.44 NS
5.	PYB_1	25.8 ± 1.483	14.2 ± 1.483	O Vs PYB_1	7.93 **
				PYB_1 Vs EYB_1	0.33 NS
6.	PB	26.8 ± 2.387	13.2 ± 2.389	O Vs PB	7.37 **
				PB Vs EB	0.41 NS
7.	PB_1	28.0 ± 2.345	12.0 ± 2.345	O Vs PB_1	6.70 **
				PB_1 Vs EB_1	0.22 NS
8.	PNB	25.4 ± 1.673	14.6 ± 1.673	O Vs PNB	8.16 **
				PNB Vs ENB	0.60 NS
9.	PNB_1	25.8 ± 2.280	14.2 ± 2.280	O Vs PNB_1	7.93 **
				PNB_1 Vs ENB_1	0.39 NS
10.	EY	23.8 ± 2.683	16.2 ± 2.683	O Vs EY	8.74 **
11.	EY_1	24.2 ± 1.303	15.8 ± 1.303	O Vs EY_1	8.83 **
12.	EYB	24.4 ± 2.607	15.6 ± 2.607	O Vs EYB	8.51 **
13.	EYB_1	25.4 ± 2.302	14.6 ± 2.302	O Vs EYB_1	8.33 **
14.	EB	23.4 ± 1.140	16.6 ± 1.140	O Vs EB	9.28 **
15.	EB_1	27.6 ± 3.647	12.4 ± 3.647	O Vs EB_1	6.34 **
16.	ENB	24.8 ± 1.483	15.2 ± 1.483	O Vs ENB	9.73 **
17.	ENB_1	25.2 ± 2.387	14.8 ± 2.387	O Vs ENB_1	8.36 **

* - Significant at 5% level
** - Significant at 1% level
NS - Not Significant

The above table illustrates the drop test of the original and dyed samples in process water and effluent treated water.

The lower the mean value the quicker is the absorbency of the sample. From Table VIII it was clearly evident that, all the dyed samples showed lesser mean values than the original sample.

The statistical analysis states the following facts:

1. There was significant difference between original and samples dyed in process water as well as effluent treated water.

2. There was no significant difference between the samples dyed in process water and effluent treated water.

b. Sinking Test:

The sinking time of original and dyed samples using process water and effluent treated water are presented in Table IX.

TABLE - IX

SINKING TIME OF ORIGINAL AND DYED SAMPLES

S.No.	Sample	Mean Value (seconds)	Loss over original	Percentage loss over original
1.	Original	63.6		
2.	PY	30.0	33.6	52.830
3.	PY_1	31.4	32.2	50.628
4.	PYb	32.0	31.6	49.685
5.	PYb_1	32.2	31.4	49.371
6.	PB	32.0	31.6	49.685
7.	PB_1	32.4	31.2	49.056
8.	PNB	32.0	31.6	49.685
9.	PNB_1	32.0	31.6	49.685
10.	EY	32.0	31.6	49.685
11.	EY_1	33.0	30.6	48.113
12.	EY_b	32.4	31.2	49.056
13.	EYb_1	32.6	31.0	48.742
14.	EB	33.0	30.6	48.113
15.	EB_1	33.8	29.8	46.855
16.	ENB	32.8	30.8	48.427
17.	ENB_1	33.2	30.4	47.798

Statistical Analysis of Sinking test

S.No.	Sample	Mean ± S.D.	Difference Mean ± S.D.	Groups Compared	t value
1.	Original	63.6 ± 1.817	33.6 ± 1.817	O Vs PY	31.19 **
2.	PY	30.0 ± 1.581	33.6 ± 1.581	PY Vs EY	2.58 *
3.	PY_1	31.4 ± 1.817	32.2 ± 1.817	O Vs PY_1	28.03 **
				PY_1 Vs EY_1	0.53 NS
4.	PYB	32.0 ± 1.581	31.6 ± 1.581	O Vs PYB	29.33 **
				PYB Vs EYB	0.39 NS
5.	PYB_1	32.2 ± 1.924	31.4 ± 1.924	O Vs PYB_1	26.70 **
				PYB_1 Vs EYB_1	0.40 NS
6.	PB	32.0 ± 1.581	31.6 ± 1.581	O Vs PB	29.28 **
				PB Vs EB	1.29 NS
7.	PB_1	32.4 ± 2.074	31.2 ± 2.074	O Vs PB_1	25.30 **
				PB_1 Vs EB_1	1.28 NS
8.	PNB	32.0 ± 1.225	31.6 ± 1.225	O Vs PNB	32.25 **
				PNB Vs ENB	0.78 NS
9.	PNB_1	32.0 ± 1.871	31.6 ± 1.871	O Vs PNB_1	27.51 **
				PNB_1 Vs ENB_1	1.08 NS
10.	EY	32.0 ± 0.707	31.6 ± 0.707	O Vs EY	26.28 **
11.	EY_1	33.0 ± 1.581	30.6 ± 1.581	O Vs EY_1	28.41 **
12.	EYB	32.4 ± 1.673	31.2 ± 1.673	O Vs EYB	16.17 **
13.	EYB_1	32.6 ± 1.140	31.0 ± 1.140	O Vs EYB_1	32.31 **
14.	EB	33.0 ± 0.707	30.6 ± 0.707	O Vs EB	25.45 **
15.	EB_1	33.8 ± 1.304	29.8 ± 1.304	O Vs EB_1	29.80 **
16.	ENB	32.8 ± 1.924	30.8 ± 1.924	O Vs ENB	26.03 **
17.	ENB_1	33.2 ± 1.643	30.4 ± 1.643	O Vs ENB_1	27.75 **

* - Significant at 5% level
** - Significant at 1% level
NS - Not Significant

The Table IX illustrates the sinking time of the original and dyed samples in process water and effluent treated water.

The lesser the mean value the more is the wettability of the samples. From the table it was clearly evident that, there was marked difference between the dyed samples when compared to their respective originals.

The statistical analysis states the following facts:

1. There was significant difference between original and samples dyed in process water as well as effluent treated water.

2. There was no significant difference between the samples dyed in process water and effluent treated water.

6. Colour fastness test :

The details of the colour fastness tests of the dyed samples are given in Table X.

TABLE - X

EVALUATION OF COLOUR FASTNESS OF DYED SAMPLES

S. No.	Sample	Colour fastness to Sunlight	Colour fastness to crocking		Colour fastness to pressing	
		Colour change	Dry staining	Wet staining	Dry staining	Wet staining
1.	PY	5	5	5	5	5
2.	PY_1	5	5	5	5	5
3.	PYb	4	5	5	5	5
4.	PYb_1	5	5	5	5	5
5.	PB	5	4	4	4	4
6.	PB_1	5	4	3	3	3
7.	PNB	4	5	5	5	5
8.	PNB_1	5	5	5	5	5
9.	EY	4	5	5	5	5
10.	EY_1	5	5	5	5	5
11.	EYb	4	5	5	5	5
12.	EYb_1	5	5	5	5	5
13.	EB	5	4	4	4	4
14.	EB_1	4	4	3	3	3
15.	ENB	5	5	5	5	5
16.	ENB_1	5	5	5	5	5

Table X shows the colour fastness tests for sunlight, dry and wet crocking, dry and wet pressing values of dyed samples using process water and effluent treated water.

The above table states that, in the sunlight test almost all the samples revealed good colour fastness property.

Regarding crocking, all the samples exhibited good fastness in the dry condition. In the wet crocking test, two samples, namely PB_1 and EB_1 dyed in 2.0 percent blue shade using both process and effluent treated water showed medium colour fastness property.

In the pressing test, except EB, PB, EB_1 and PB_1, all other samples dyed using process water and effluent treated water showed good colour fastness to wet and dry pressing.

7. Colour fastness to washing - spectro-analysis

The colour fastness to washing by spectro-analysis values of the original and dyed samples using process water and effluent treated water are shown in data I.

AATCC Gray Scale

DATA - I

	III/Obs	Value
TC WF SC	1	
TC WF PRO YEL .5%	1	3
TC WF EFF YEL .5%	1	4-5
TC WF PRO YEL 2%	1	4
TC WF EFF YEL 2%	1	4-5
TC WF PRO YB .5%	1	4-5
TC WF EFF YB .5%	1	4-5
TC WF PRO YB 2%	1	5
TC WF EFF YB 2%	1	3-4
TCWF PRO BBGF .5%	1	4-5
TCWF EFF BBGF .5%	1	4
TCWF PRO BBGF 2%	1	3
TCWF EFF BBGF 2%	1	3
TC WF PRO NVB .5%	1	5
TC WF EFF NVB .5%	1	4
TC WF PRO NVB 2%	1	5
TC WF EFF NVB 2%	1	4-5

*** INDICATES FACTORS OUT OF RANGE

The dyed samples using process water and effluent treated water exhibited almost equal values from 3-5 range. Hence this test infers that all the dyed samples revealed good colour fastness to washing property.

8. Strength test - spectro-analysis

The strength test by spectro-analysis values of the original and dyed samples using process water and effluent treated water are shown in Data II to IX.

DATA - II (A)

02 - APR - 92 15:50:16
PASS/FAIL
Large Area/Spec Incl d/0
1) D65 /10 deg

CIELAB

	III/Obs	L*	a*	b*	C*	h
TC PRO YEL .5%	1	66.94	8.31	38.62	39.50	77.86
TC EFF YEL .5%	1	66.39	9.06	40.16	41.17	77.29

	DL*	Da*	Db*	DE	
Tolerances	2.00	2.00	2.00	2.00	
	-2.00	-2.00	-2.00	0.00	
TC EFF YEL .5%	-0.55	0.75	1.54	1.80	PASS

DATA - II (B)

STRENGTH

02.Apr.92 15:55:58
Large Area/Spec Incl d/0
1) D65 /10 deg
2) A /10 deg
3) CWF /10 deg

CIELAB

Spec %R : 0.000
Int %R : 0.000

	WI	%R	K/S	Batch Strength (%) As Is	Batch Strength (%) Adjusted
TC PRO YEL .5%	420	11.07	3.5736		
TC EFF YEL .5%	420	10.45	3.8373	107.38	100.00

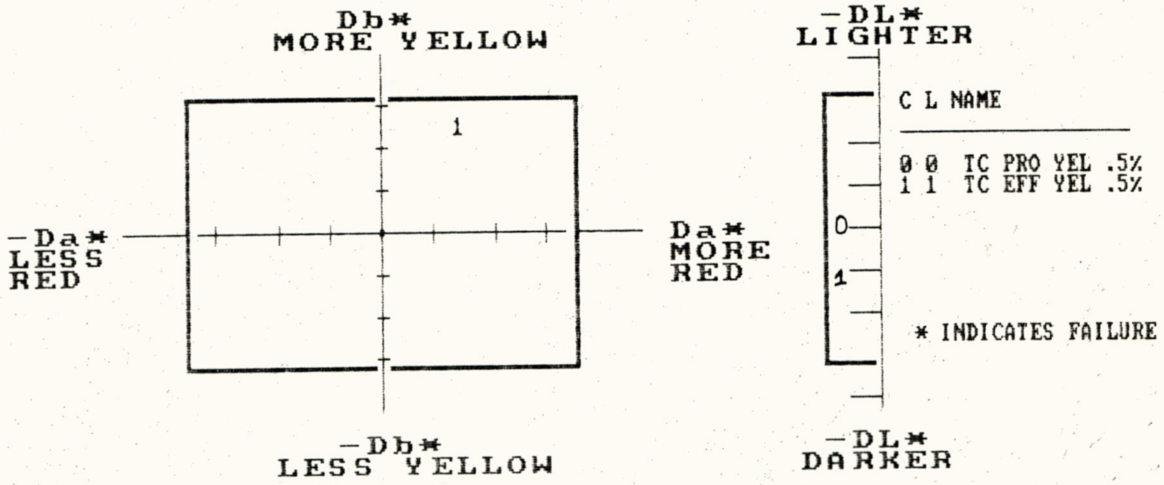
	III/Obs	DE*	DL*	Da*	Db*	DC*	DH*
'As Is'	1	1.80	-0.55	0.75	1.54	1.67	-0.40
Color	2	1.91	-0.42	0.54	1.78	1.86	0.01
Difference	3	1.90	-0.40	0.52	1.78	1.83	-0.30
'Adjusted'	1	1.32	0.31	0.46	1.20	1.27	-0.20
Color	2	1.47	0.41	0.30	1.37	1.40	0.12
Difference	3	1.51	0.45	0.33	1.41	1.43	-0.16

DATA II(C)

D65 /10 DEG

PASS/FAIL

CIELAB L*a*b*



1 DIV = 0.625

Data II shows the comparision between the samples PY and EY, dyed in 0.5 per cent yellow shade, using process water and effluent treated water respectively.

The "pass" value indicates that the sample EY dyed in 0.5 per cent yellow shade using effluent treated water is much similar to sample PY dyed in process water. Since the values fall within the tolerance limits, the computer analysis categories the compared samples as "pass".

It gives the tolerance limits in the form of graphical representation. The square indicates the tolerance limit and the '1' sign within the square gave the highly correlated value of the compared samples PY and EY.

The strength of the sample PY is kept as '100' and the batch was matched to it. Accordingly it shows the value of 107.38 which falls within the tolerance limits.

DATA - III (A)

PASS/FAIL

02.Apr.92 16:06:07
Large Area/Spec Incl d/0
1) D65 /10 deg

CIELAB

	III/Obs	L*	a*	b*	C*	h
TC PRO YEL 2%	1	60.75	20.35	51.45	55.33	68.42
TC EFF YEL 2%	1	59.58	20.41	49.98	53.99	67.79

	DL*	Da*	Db*	DE	
Tolerances	2.00	2.00	2.00	2.00	
	-2.00	-2.00	-2.00	0.00	
TC EFF YEL 2%	-1.16	0.06	-1.47	1.88	PASS

DATA - III (B)

STRENGTH

02.Apr.92 16:10:58
Large Area/Spec Incl d/0
1) D65 /10 deg
2) A /10 deg
3) CWF /10 deg

CIELAB

Spec %R : 0.000

Int %R : 0.000

	WI	%R	K/S	Batch Strength(%) As Is	Batch Strength(%) Adjusted
TC PRO YEL 2%	440	5.50	8.1138		
TC EFF YEL 2%	440	5.46	8.1881	100.92	100.00

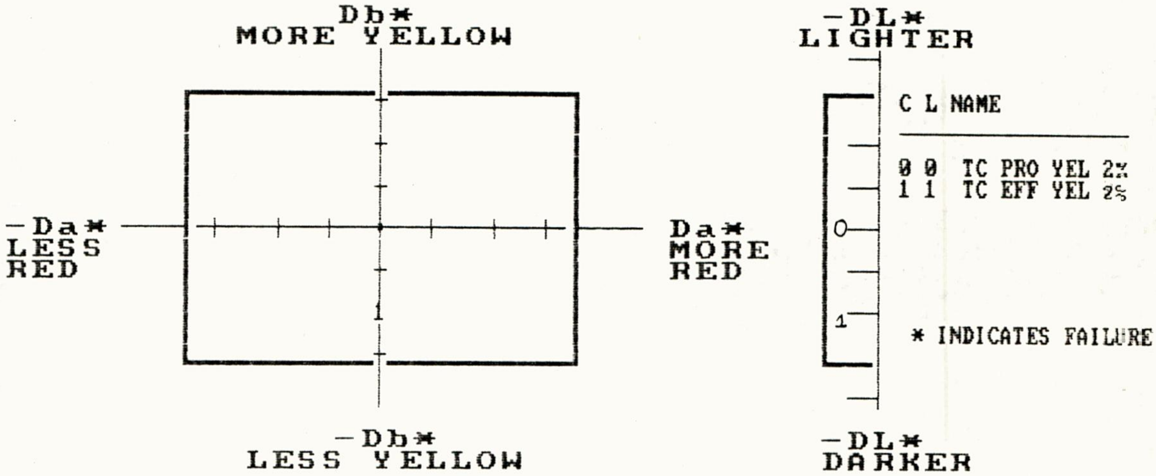
	Ill /Obs	DE*	DL*	Da*	Db*	DC*	DH*
'As Is'	1	1.88	-1.16	0.06	-1.47	-1.34	-0.60
Color	2	1.87	-1.21	-0.06	-1.42	-1.34	-0.47
Difference	3	2.05	-1.22	0.14	-1.64	-1.57	-0.51
'Adjusted'	1	1.82	-1.05	0.02	-1.48	-1.37	-0.57
Color	2	1.82	-1.10	-0.09	-1.44	-1.38	-0.45
Difference	3	1.99	-1.10	0.11	-1.65	-1.58	-0.48

DATA III-C

D65 /10 DEG

PASS/FAIL

CIELAB L*a*b*



1 DIV = 0.625

Data III shows the comparision between the samples PY_1 and EY_1 dyed in 20 per cent yellow shade using process water and effluent treated water respectively.

The "pass" value indicates that the sample EY_1 dyed in 2.0 per cent yellow shade using effluent treated water is much similar to sample PY_1 dyed in process water. Since the values fall within the tolerance limits, the computer analysis categories the compared samples as "pass".

It gives the tolerance limits in the form of a graphical representation. The square indicates the tolerance limit and the '1' sign within the square gives the highly correlated value of the compared samples PY_1 and EY_1.

The strength of the sample PY_1 is kept as '100' and the batch was matched to it. Accordingly it shows the value of 100.92 which falls within the tolerance limits.

DATA - IV (A)

02.Apr.92 16:16:58

PASS/FAIL

Large Area/Spec Incl d/0

1) D65 / 10 deg

CIELAB

	III/Obs	L*	a*	b*	C*	h
TC PRO YB .5%	1	58.99	22.29	33.10	39.91	56.04
TC EFF YB .5%	1	58.52	18.51	31.62	36.64	59.65

	DL*	Da*	Db*	DE	
Tolerances	2.00	2.00	2.00	2.00	
	-2.00	-2.00	-2.00	0.00	
TC EFF YB .5%	-0.47	-3.78	-1.48	4.08	FAIL

DATA - IV (B)

02.Apr.92 16:21:24

STRENGTH

Large Area/Spec Incl d/0

1) D65 /10 deg

2) A /10 deg

3) CWF /10 deg

CIELAB

Spec %R : 0.000

Int %R : 0.000

	WI	%R	K/S	Batch Strength(%) As Is	Adjusted
TC PRO YB .5%	450	10.50	3.8146		
TC EFF YB .5%	450	10.61	3.7646	98.69	100.00

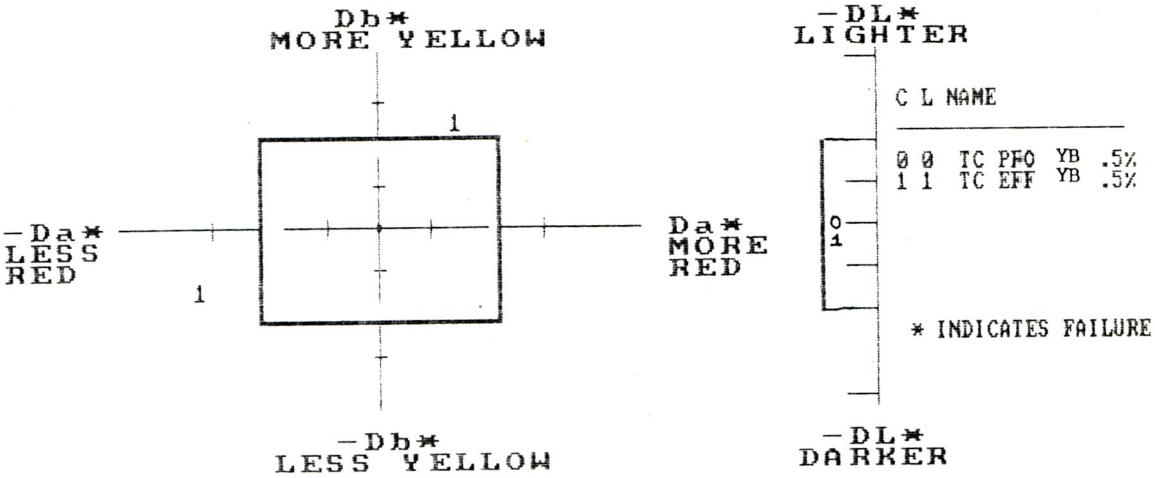
	III/Obs	DE*	DL*	Da*	Db*	DC*	DH*
'As Is'	1	4.08	-0.47	-3.78	-1.48	-3.26	2.41
Color	2	4.18	-0.95	-3.24	-2.46	-3.75	1.59
Difference	3	3.44	-0.74	-2.80	-1.86	-2.72	1.97
'Adjusted'	1	4.05	-0.64	-3.73	-1.44	-3.21	2.39
Color	2	4.17	-1.13	-3.20	-2.42	-3.69	1.57
Difference	3	3.44	-0.91	-2.77	-1.82	-2.68	1.95

DATA IV(C)

D65 /10 DEG

PASS/FAIL

CIELAB L*a*b*



1 DIV = 1.181

Data IV shows the comparision between sample YB and EYB dyed in 0.5 per cent yellow brown shade using process water and effluent treated water respectively.

The 'Fail' values indicate that the sample EYB dyed in 0.5 per cent yellow brown using effluent treated water much darker than the sample PYB dyed in process water. The value 'Fail' indicate that the sample EYB is much below the tolerance limit.

The graphical representation of the tolerance limits, shows the '1' sign in the outer square and thus gives the drastic correlation of compared sample PYB and EYB.

The sample EYB dyed in 0.5 per cent yellow brown shade using effluent treated water was found to be darker, more yellow and less saturated when compared to the sample PYB dyed in 0.5 per cent yellow brown shading using effluent treated water.

The strength of the sample PYB was kept as '100' and the batch was matched to it. Accordingly the strength of the sample EYB was found to be as low as 98.69 per cent.

DATA - V (A)

02.Apr.92 16:26:04

PASS/FAIL

Large Area/Spec Incl d/0

1) D65 /10 deg

CIELAB

	III/Obs	L*	a*	b*	C*	h
TC PRO YB 2%	1	49.73	30.88	36.03	47.45	49.40
TC EFF YB 2%	1	49.85	29.65	34.96	45.84	49.70

	DL*	Da*	Db*	DE	
Tolerances	2.00	2.00	2.00	2.00	
	-2.00	-2.00	-2.00	0.00	
TC EFF YB 2%	0.12	-1.23	-1.07	1.64	PASS

DATA - V (B)

02.Apr.92 16:30:41

STRENGTH

Large Area/Spec Incl d/0

1) D65 /10 deg

2) A /10 deg

3) CWF /10 deg

CIELAB

Spec %R : 0.000

Int %R : 0.000

	WI	%R	K/S	Batch Strength(%) As Is	Batch Strength(%) Adjusted
TC PRO YB 2%	460	5.33	8.4116		
TC EFF YB 2%	460	5.61	7.9380	94.37	100.00

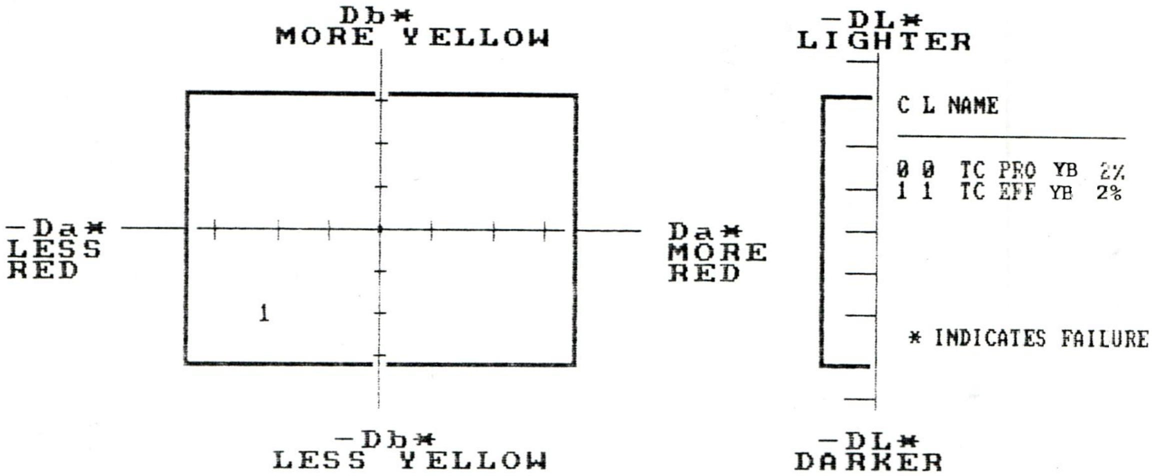
	III/Obs	DE*	DL*	Da*	Db*	DC*	DH*
'As Is'	1	1.64	0.12	-1.23	-1.07	-1.61	0.24
Color	2	1.78	-0.07	-1.09	-1.41	-1.78	0.07
Difference	3	1.46	0.05	-0.86	-1.18	-1.44	0.20
'Adjusted'	1	1.67	-0.66	-1.09	-1.07	-1.53	0.13
Color	2	1.89	-0.83	-0.97	-1.39	-1.70	-0.01
Difference	3	1.62	-0.75	-0.75	-1.22	-1.43	0.09

DATA V-C

PASS/FAIL

D65 /10 DEG

CIELAB L*a*b*



1 DIV = 0.625

Data V shows the comparision between the samples PYB_1 and EYB_1 dyed in 2.0 per cent yellow brown shade using process water and effluent treated water respectively.

The "pass" value indicates that the sample EYB_1 dyed in 2.0 per cent yellow brown shade using effluent treated water is much similar to sample PYB_1 dyed in process water. Since the values fall within the tolerance limits, the computer analysis categories the compared samples as "Pass".

It gives the tolerance limits in the form of a graphical representation. The square indicates the tolerance limit and the '1' sign within the square gives the highly correlated value of the compared samples PYB_1 and EYB_1.

The strength of the sample PYB_1 is kept as '100' and the batch was matched to it. Accordingly it shows the value of 94.37 which falls within the tolerance limits.

DATA - VI (A)

02.Apr.92 16:39:38

PASS/FAIL

Large Area/Spec Incl d/0

1) D65 /10 deg

CIELAB

	III/Obs	L*	a*	b*	C*	h
TC PRO BBGF .5%	1	55.45	-11.45	-22.39	25.15	242.90
TC EFF BBGF .5%	1	53.55	-10.95	-22.21	24.77	243.75

	DL*	Da*	Db*	DE	
Tolerances	2.00	2.00	2.00	2.00	
	-2.00	-2.00	-2.00	0.00	
TC EFF BBGF .5%					
	-1.90	0.50	0.18	1.97	PASS

DATA VI (B)

02.Apr.92 16:42:35

STRENGTH

Large Area/Spec Incl d/0

1) D65 /10 deg

2) A /10 deg

3) CWF /10 deg

CIELAB

Spec %R : 0.000

Int %R : 0.000

	WI	%R	K/S	Batch Strength(%) As Is	Adjusted
TC PRO BBGF .5%	660	11.53	3.3959		
TC EFF BBGF .5%	660	11.01	3.5966	105.91	100.00

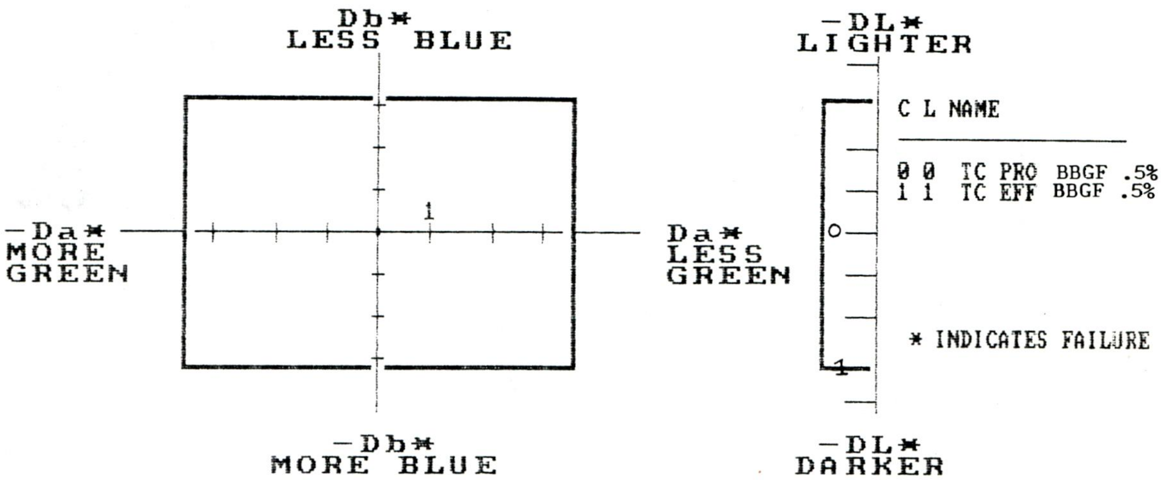
	III/Obs	DE*	DL*	Da*	Db*	DC*	DH*
'As Is'	1	1.97	-1.90	0.50	0.18	-0.38	0.37
Color	2	1.99	-1.83	0.73	0.25	-0.60	0.48
Difference	3	1.95	-1.89	0.40	0.26	-0.36	0.31
'Adjusted'	1	1.21	-1.08	0.46	0.31	-0.49	0.26
Color	2	1.32	-1.00	0.76	0.41	-0.76	0.42
Difference	3	1.19	-1.05	0.36	0.42	-0.51	0.22

DATA VI-C

D65 /10 DEG

PASS/FAIL

CIELAB L*a*b*



1 DIV = 0.625

Data VI shows the comparision between the samples PB and EB dyed in 0.5 per cent. Blue shade using process water and effluent treated water respectively.

The 'pass' value indicates that the sample EB dyed in 0.5 per cent yellow shade using effluent treated water is much similar to sample PB dyed in process water. Since the value fall within the tolerance limits, the computer analysis categories the compared samples as 'pass'.

It gives the tolerance limits in the form of a graphical representation. The square indicates the tolerance limit and the '1' sign within the square gives the highly correlated value of the compared samples PB and EB.

The strength of the sample PB is kept as '100' and the batch was matched to it. Accordingly it shows the value of 105.91 which falls within the tolerance limits.

DATA - VII (A)

02.Apr.92 16:46:16

PASS/FAIL

Large Area/Spec Incl d/0

1) D65 /10 deg

CIELAB

	III/Obs	L*	a*	b*	C*	h
TC PRO BBGF 2%	1	43.23	-7.00	-27.80	28.67	255.86
TC EFF BBGF 2%	1	43.37	-5.91	-29.00	29.59	258.48

	DL*	Da*	Db*	DE	
Tolerances	2.00	2.00	2.00	2.00	
	-2.00	-2.00	-2.00	0.00	
TC EFF BBGF 2%	0.14	1.10	-1.20	1.63	PASS

DATA - VII (B)

02.Apr.92 16:49:56

STRENGTH

Large Area/Spec Incl d/0

1) D65 /10 deg

2) A /10 deg

3) CWF /10 deg

CIELAB

Spec %R : 0.000

Int %R : 0.000

				Batch Strength (%)	
	WI	%R	K/S	As Is	Adjusted
TC PRO BBGF 2%	650	6.76	6.4259		
TC EFF BBGF 2%	650	6.89	6.2865	97.83	100.00

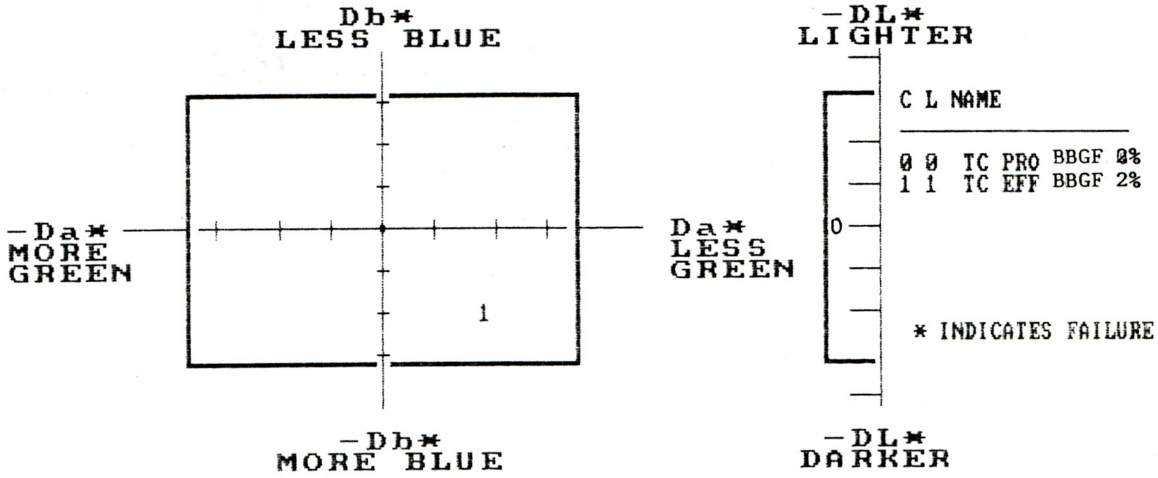
	Ill/Obs	DE*	DL*	Da*	Db*	DC*	DH*
'As Is'	1	1.63	0.14	1.10	-1.20	0.93	1.33
Color	2	1.40	0.12	0.73	-1.20	0.79	1.15
Difference	3	1.52	0.12	0.88	-1.23	1.10	1.04
'Adjusted'	1	1.68	-0.17	1.16	-1.21	0.92	1.39
Color	2	1.43	-0.19	0.76	-1.20	0.78	1.19
Difference	3	1.56	-0.19	0.93	-1.24	1.10	1.08

DATA VII(C)

D65 /10 DEG

PASS/FAIL

CIELAB L*a*b*



1 DIV = 0.625

Data VII shows the comparision between the samples PB_1 and EB_1, dyed in 2.0 per cent blue shade using process water and effluent treated water respectively.

The 'pass' value indicates that the sample EB_1 dyed in 2.0 per cent blue shade using effluent treated water is much similar to sample PB_1 dyed in process water. Since the values fall within the tolerance limits, the computer analysis categories the compared samples as "pass".

It gives the tolerance limits in the form of a graphical representation. The square indicates the tolerance limit and the '1' sign within the square gives the highly correlated value of the compared samples PB_1 and EB_1.

The strength of the sample PB_1 is kept as '100' and the batch was matched to it. Accordingly it shows the value of 97.83 which falls within the tolerance limits.

DATA - VIII (A)

02.Apr.92 16:54:53

PASS/FAIL

Large Area/Spec Incl d/0

1) D65 /10 deg

CIELAB

	III/Obs	L*	a*	b*	C*	h
TC PRO NVB .5%	1	44.11	-1.65	-20.06	20.13	265.31
TC EFF NVB .5%	1	45.74	-1.99	-19.35	19.46	264.14

	DL*	Da*	Db*	DE	
Tolerances	2.00	2.00	2.00	2.00	
	-2.00	-2.00	-2.00	0.00	
TC EFF NVB .5%	1.64	-0.34	0.70	1.81	PASS

DATA - VIII (B)

02.Apr.92 16:59:02
Large Area/Spec Incl d/0

STRENGTH

1) D65 /10 deg

2) A /10 deg

3) CWF /10 deg

CIELAB

Spec %R : 0.000

Int %R : 0.000

				Batch Strength (%)	
	WI	%R	K/S	As Is	Adjusted
TC PRO NVB .5%	600	9.77	4.1641		
TC EFF NVB .5%	600	10.74	3.7099	89.09	100.00

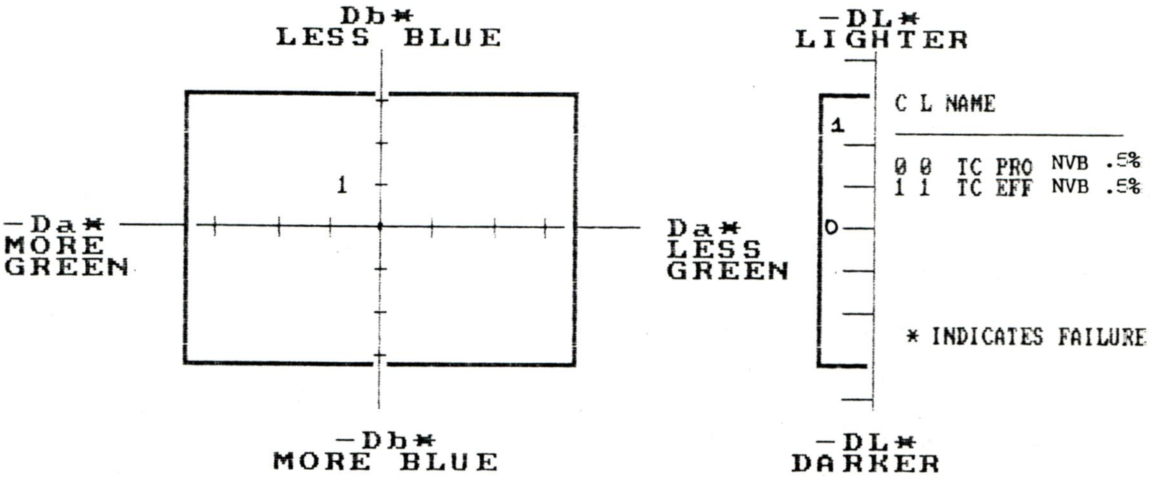
	III/Obs	DE*	DL*	Da*	Db*	DC*	DH*
'As Is'	1	1.81	1.64	-0.34	0.70	-0.67	-0.40
Color	2	1.83	1.68	0.06	0.73	-0.72	-0.13
Difference	3	1.84	1.65	-0.28	0.76	-0.74	-0.33
'Adjusted'	1	0.71	-0.08	-0.22	0.67	-0.65	-0.28
Color	2	0.71	-0.03	0.11	0.70	-0.70	-0.07
Difference	3	0.75	-0.07	-0.19	0.73	-0.71	-0.23

DATA VIII(C)

D65 /10 DEG

PASS/FAIL

CIELAB L*a*b*



1 DIV = 0.625

Data VIII shows the comparision between the samples PNB and ENB dyed in 0.5 per cent navy blue shade using process water and effluent treated water.

The 'pass' value indicates that the sample ENB dyed in 0.5 per cent navy blue shade using effluent treated water is much similar to sample PNB dyed in process water. Since the values fall within the tolerance limits, the computer analysis categories the compared samples as 'pass'.

It gives the tolerance limits in the form of a graphical representation. The square indicates the tolerance limit and the '1' sign within the square gives the highly correlated value of the compared samples PNB and ENB.

The strength of the sample PNB is kept as '100' and the batch was matched to it. Accordingly it shows the value of 89.09 which falls within the tolerance limits.

DATA - IX (A)

02.Apr.92 17:07:01

PASS/FAIL

Large Area/Spec Incl d/0

1) D65 /10 deg

CIELAB

	III/Obs	L*	a*	b*	C*	h
TC PRO NVB 2%	1	35.00	1.75	-17.67	17.76	275.65
TC EFF NVB 2%	1	35.47	1.21	-17.66	17.70	273.93

	DL*	Da*	Db*	DE	
Tolerances	2.00	2.00	2.00	2.00	
	-2.00	-2.00	-2.00	0.00	
TC EFF NVB 2%	0.47	-0.54	0.01	0.71	PASS

DATA - IX (B)

02.Apr.92 17:10:22

STRENGTH

Large Area/Spec Incl d/0

1) D65 /10 deg

2) A /10 deg

3) CWF /10 deg

CIELAB

Spec %R : 0.000

Int %R : 0.000

	WI	%R	K/S	Batch Strength (%) As Is	Batch Strength (%) Adjusted
TC PRO NVB 2%	590	6.52	6.6995		
TC EFF NVB 2%	590	6.66	6.5435	97.67	100.00

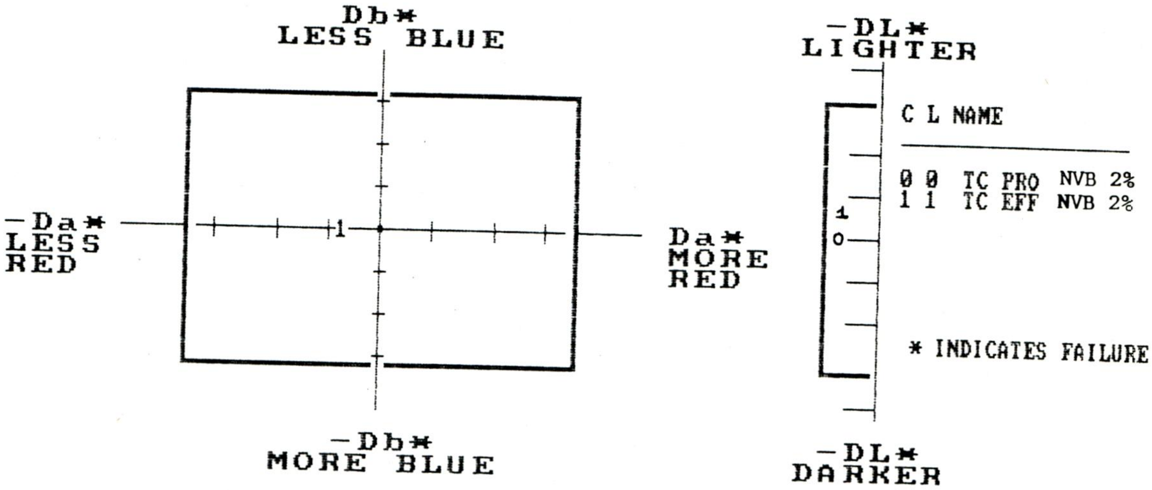
	III/Obs	DE*	DL*	Da*	Db*	DC*	DH*
'As Is'	1	0.71	0.47	-0.54	0.01	-0.06	-0.53
Color	2	0.74	0.41	-0.60	-0.12	0.19	-0.59
Difference	3	0.60	0.45	-0.40	-0.00	-0.02	-0.40
'Adjusted'	1	0.54	0.13	-0.52	0.05	-0.10	-0.52
Color	2	0.60	0.07	-0.59	-0.08	0.15	-0.58
Difference	3	0.41	0.12	-0.39	0.04	-0.06	-0.38

DATA IX(C)

PASS/FAIL

D65 /10 DEG

CIELAB L*a*b*



1 DIV = 0.625

Data (IX) shows the comparision between the samples PNB_1 and ENB_1 dyed in 2.0 per cent navy blue shade using process water and effluent treated water respectively.

The 'pass' value indicates that the sample ENB_1 dyed in 2.0 per cent navy blue shade using effluent treated water is much similar to sample PNB_1 dyed in process water. Since the values fall within the tolerance limits, the computer analysis categories the compared samples as 'pass'.

It gives the tolerance limits in the form of a graphical representation. The square indicates the tolerance limit and the '1' sign within the square gives the highly correlated value of the compared samples PNB_1 and ENB_1.

The strength of the sample PNB_1 is kept as '100' and the batch was matched to it. Accordingly it shows the value of 97.67 which falls within the tolerance limits.

Summary and Conclusion

V. SUMMARY AND CONCLUSION

The study was conducted with the following objectives.

1. To assess the pollution - load of the dye effluent.
2. To compare the samples dyed in process water and effluent treated and
3. To confirm the quality of samples dyed in process water and effluent treated by testing their physical qualities.

Nineteen litres of dye effluent taken and it was treated with alum. The treated effluent was used for dyeing.

Twelve metres of 80/20 percent polyester cotton material was used and one metre was kept aside as original for laboratory testing purposes. Commercially available main classes of dyes namely disperse for polyester part and reactive for cotton part was selected to dye the fabric.

Yellow, yellow brown, blue and navy blue of 0.5 and 2.0 percent shades were selected. High temperature beaker dyeing method for polyester part and jigger dyeing method for cotton part were followed for dyeing the polyester cotton blend material.

The pretreated material was cut into 16 pieces.

The first eight pieces were dyed in disperse dye using process water and the remaining eight pieces were dyed in effluent treated water. As a second step, the first eight pieces were again dyed in process water but with reactive dyes. Then the remaining eight pieces were dyed in reactive dyes using effluent treated water. These samples were dyed using the respective dyeing methods, conditions and concentrations as given in Table - I.

TABLE I

S. No.	Sample	Dye	Colour	Condition	Concentration in percentage
1.	PY	Disperse & reactive	Yellow	Hot & Cold	0.5
2.	PYB	-do-	Yellow brown	-do-	0.5
3.	PB	-do-	Blue	Hot & Hot	0.5
4.	PNB	-do-	Navy blue	Hot & Cold	0.5
5.	EY	-do-	Yellow	-do-	0.5
6.	EYB	-do-	Yellow brown	-do-	0.5
7.	EB	-do-	Blue	Hot & Hot	0.5
8.	ENB	-do-	Navy Blue	Hot & Cold	0.5
9.	PY_1	-do-	Yellow	-do-	2.0
10.	PYB_1	-do-	Yellow brown	-do-	2.0
11.	PB_1	-do-	Blue	Hot & Hot	2.0
12.	PNB_1	-do-	Navy blue	Hot & Cold	2.0
13.	EY_1	-do-	Yellow	-do-	2.0
14.	EYB_1	-do-	Yellow brown	-do-	2.0
15.	EB_1	-do-	Blue	Hot & Hot	2.0
16.	ENB_1	-do-	Navy blue	Hot & Cold	2.0

Findings of the study:

The study revealed that dye effluents after alum treatments showed decreased values with in the tolerance limits for general parameters like potentia hydrogenic, biochemical oxygen demand, chemical oxygen demand, total dissolved solids and total suspended solids.

The dyed samples were evaluated by:

A. Visual Inspection

B. Laboratory tests

A. Visual Inspection:

It is clearly understood that the samples dyed using effluent treated water excelled equally with samples dyed using process water.

B. Laboratory tests:

Fabric Thickness :

The test of significance proved that there was significant difference between the original and dyed samples but there was no significant difference between the process and effluent treated water samples.

Fabric Weight:

The statistical analysis proved that there was significant difference between the original and dyed samples using process water and effluent treated water. But no significant difference was found between the dyed samples except the samples dyed in 0.5 per cent using process and effluent treated water.

Bursting strength:

Significant difference was found between the original and dyed samples but there was no significant difference between the dyed samples.

Abrasion Resistance:

The test of significance proved that, there was no significant difference between the original and dyed samples and also between the samples dyed using process and effluent treated water.

Wettability and Absorbency:

The wettability and absorbency tests revealed the fact that, there was significant difference between the original and the dyed samples. But no significant difference was found between the samples dyed using process and effluent treated water.

Colour fastness:

On evaluation of colour fastness of the dyed samples it could be concluded that all the dyed samples showed good colour fastness property in the sunlight.

Regarding crocking, all the samples exhibited good fastness against dry crocking. In wet crocking except PB_1 and EB_1 dyed in 2.0 percent blue shade using both process and effluent treated water, all other samples showed good fastness property.

In the pressing test, except EB, PB, EB_1 and PB_1, all other samples dyed using process and effluent treated water showed good colour fastness to wet and dry conditions.

The colour fastness to washing by spectro - analysis infers that all the dyed samples revealed good colour fastness to washing property.

Strength:

Strength by spectro-analysis infers that, the samples which are dyed in process water are kept as '100' and the batch was matched to it. Accordingly the samples which are dyed in effluent treated water fall within the tolerance limits.

CONCLUSION

From the present study it can be concluded that the samples dyed in effluent treated water excelled equally with samples dyed in process water in all aspects namely fabric thickness, fabric weight, bursting strength, abrasion resistance, wettability and absorbency and colour fastness. It was heartening to know that the samples dyed in effluent treated water did not match the standards those dyed in process water only with regard to the washing test for colour fastness.

The study therefore throws light on the advantages of processing effluent water namely preventing water wastage and pollution. So we can suggest that effluent treatment could be adopted in dyeing units as a conservative measure thereby producing good quality products with minimal consumption of water.

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Appendix

APPENDIX - I

Details of selected material:

80/20 percent polyester cotton blend

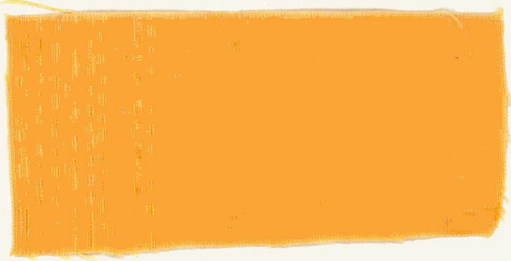
Width - 91 cm

Weave - Plain

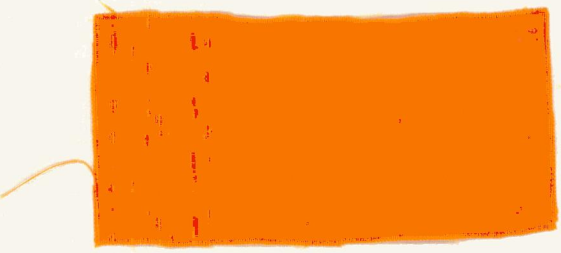
Cost - Rs. 35.00/metre

DYED SAMPLES

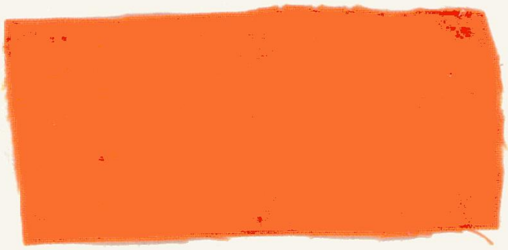
Process



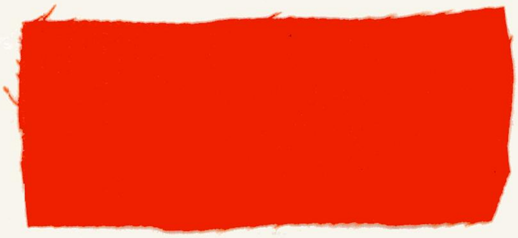
yellow ERGFL 0.5% Shade



yellow ERGFL 2.0% Shade

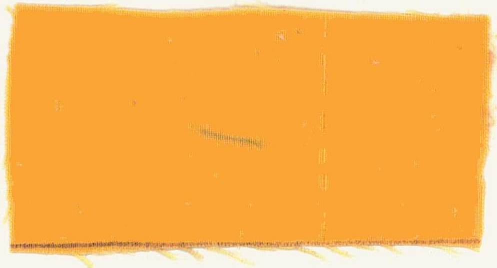


YB S_2RFL 0.5% Shade

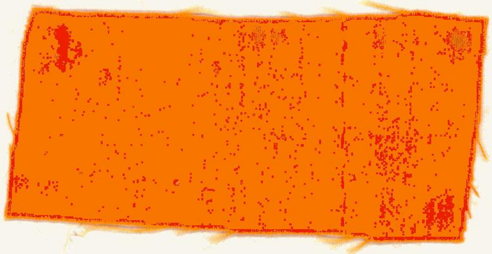


YB S_2RFL 2.0% Shade

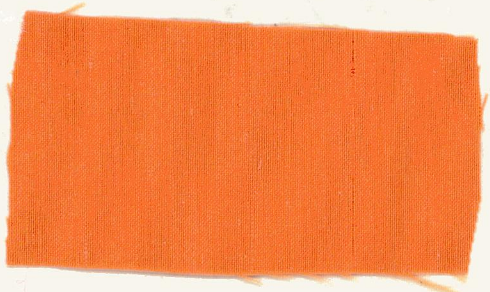
Effluent treated



yellow ERGFL 0.5% Shade



yellow ERGFL 2.0% Shade

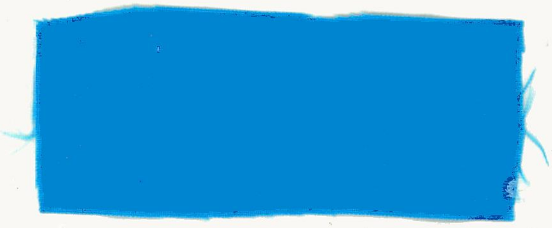


YB S_2RFL 0.5% Shade

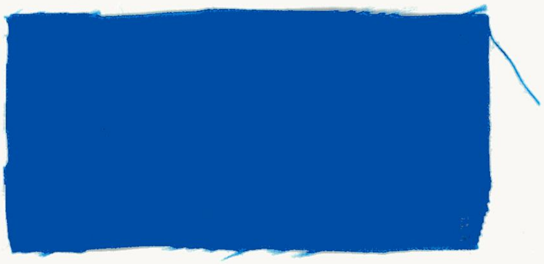
YB S_2RFL 2.0% Shade

DYED SAMPLES

Process



Blue BGF 0.5% Shade

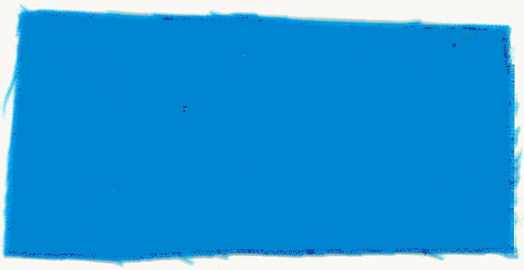


Blue BGF 2.0% Shade

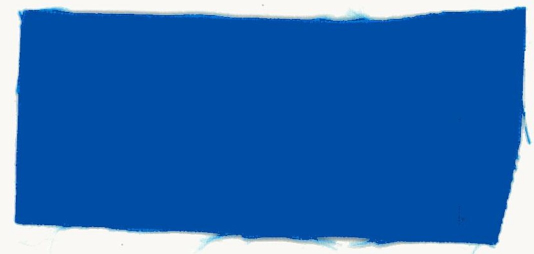
Navy S_2GL 0.5% Shade

Navy S_2GL 2.0% Shade

Effluent treated



Blue BGF 0.5% Shade



Blue BGF 2.0% Shade

Navy S_2GL 0.5% Shade

Navy S_2GL 2.0% Shade

APPENDIX II

LIST OF CALCULATIONS USED FOR DOUBLE BATH DYEING IN BEAM

Name of the dye	Wt. of the Material (gm)	Amount of disperse dye (mg)
Yellow ERGFL		
0.5	10.51	52.3
2.0	10.52	210.2
Yellow brown (S_2 RFL)		
0.5	10.87	54.5
2.0	10.14	201.1
Blue BGF		
0.5	10.18	50.5
2.0	10.21	202.3
Navy Blue S_2 GL		
0.5	10.28	51.4
2.0	10.56	210.4

APPENDIX III

LIST OF CALCULATIONS USED FOR DOUBLE BATH DYEING IN JIGGER

Name of the dye	Wt. of the material (gm)	Amount of reactive taken (mg)	Salt (gm)	Soda (gm)	Caustic (gm)
Yellow ERGFL					
0.5	50	227	10	2.5	-
2.0	50	498	15	3.75	-
Yellow brown S_2RFL					
0.5	50	223	10	2.5	-
2.0	50	543	15	3.75	-
Blue BGF					
0.5	100	240	12.5	2.5	0.45
2.0	100	1200	25	4	9.0
Navy Blue S_2GL					
0.5	50	227	10	2.5	-
2.0	50	900	15	3.75	-

Procedure for disperse dyeing:

1. Weighing the material

The pretreated fabric is cut into strips of 36 Cms long and 10 cm wide approximately. The samples were weighed using an electronic balance.

2. Weighing the dye-stuff:

The amount of dyestuff needed is based on the weight of the material and the percentage of shade.

3. Preparation of the stock solution

A mixture of product CD (dispersing agent) 0.5 gms per litre of water, sodium acetate (buffer) 0.5 gm. per litre of water and Acetic acid (PH maintain 4-5) 2 cc per litre of water were used to prepare stock solution.

Procedure for double bath dyeing

Beam dyeing machine has been used to dye the material. The required amount of disperse dye was weighed according to the weight of the fabric. The dyestuff and few cc of stock solution were taken in beakers and made into a paste. Then the stock solution added and made into 300 cc of dilute solution. The weighed samples rolled up and placed inside the beakers.

The loaded beakers were placed in a stand and tighten the lids of each beakers in order to avoid any leakage of dye-solution. The inner part of the machine was filled with glycerine. When the glycerine bath reached the temperature 90°C it was stopped and beakers were loaded into the machine. Then the temperature set up to 136°C. After reaching the temperature the samples were dyed for half an hour. After dyeing the temperature was brought down to 90°C. Then the samples were removed from the beakers. Washed, rinsed, and dried thoroughly. In this method the polyester part of the combination got dyed. To dye the cotton part a separate dye bath had to be prepared and the dyeing was carried out in a jigger.

Procedure for jigger dyeing:

The hand jigger machine has been used to dye the material. The hand jigger machine was washed thoroughly. One end of the sample was pinned to one of the rollers of the jigger. With the help of the handle, the jigger was rotated and the sample wound around the roller. A little amount of water was added and the jigger was rotated to wet the sample. The water was removed and the jigger was ready to use.

The prepared dye solution was poured and the jigger was rotated for 10 minutes at room temperature. The dye solution from the jigger was taken in a beaker. To this, half of the salt from the required amount was added, mixed thoroughly and this solution was poured back into the jigger. It was operated for 10 minutes. Then the remaining salt was added and the machine was operated for 10 more minutes.

Half of the soda ash from the required amount of the solution was poured into the jigger and operated at one end. Then the remaining solution was poured into the jigger. It was operated for 30 minutes. The material was removed from the jigger and rinsed well. Then the material was boiled in soap solution for three minutes and rinsed thoroughly in cold water, dried and pressed well.

* (For hot condition along with soda ash, caustic soda is added).

APPENDIX IV

Description of PH meter:

PH meter employs 2 electrodes, an indicator glass electrode and a calomel reference electrode, while other may have combined glass and reference electrodes, operated by battery. PH scale ranges from 0 to 14 with 5.5 as neutral, below 5.5 being acidic and above 5.5 as alkaline.

APPENDIX V

Procedure for Chemical oxygen demand (COD):

In a 500 ml reflexing flask, 20 ml of sample was taken, one gram of mercuric sulphate. 3-4 glass beads and 10 ml of potassium dichromate solution (0.25 N) were added. A pinch of silver sulphate was added to the content in the flask and mixed thoroughly. While mixing to dissolve the mercuric sulphate, 30 ml of sulphuric acid was added slowly. A flask was attached to the condenser and distilled water was allowed to flow to cool down the condenser. This was to reflux the mixture for two hours and then it was disconnected. The mixture was diluted by adding 100 ml distilled water. This was titrated against excess potassium dichromate with Ferrous Ammonium sulphate using ferroin indicator. As a result the first sharp colour changes from blue green to reddish brown. The reading was noted. Like wise same procedure was followed and noted down the reading for blank also. To get concordant values same procedure was repeated.

Procedure for preparing the Reagent and the Formula for calculating the chemical oxygen Demand (COD):

Preparation of Reagents:

1. Standard potassium dichromate solution(0.25N):

Dissolved 12.259 gm. of potassium dichromate in distilled water and diluted in to 1000 ml.

2. Sulphuric Acid:

Added 25g silver sulphate in 2.5 litres of concentrated sulphuric acid.

3. Ferroin indicator:

Dissolved 1.48 mg, 1.10 phenanthroline monohydrate and 695 mg ferrous sulphate in distilled water and diluted it to 100 ml.

4. Ferrous Ammonium Sulphate Titrant (0.25N):

Dissolved 98 gm Ferrous Ammonium sulphate in distilled water and added 20 ml. of concentrated sulphuric acid and diluted it to 1000 ml.

Standardisation of Ferrous Ammonium Sulphate:

Diluted 10 ml. standard potassium dichromate to 100ml added 30 ml. concentrated sulphuric acid and titrated it with Ferrous Ammonium sulphate using Ferroin indicator.

5. Mercuric Sulphate
6. Silver sulphate

Formula for calculating COD:

$$\text{COD mg/l} = \frac{(A-B) \times N \times 8000}{\text{ml. of sample}}$$

Where

A = Volume of Ferrous Ammonium sulphate used for the blank

B = Volume of Ferrous Ammonium sulphate used for the sample.

C = Normality of Ferrous Ammonium sulphate.

APPENDIX - VI

Procedure for Biochemical oxygen demand (BOD):

In one litre water, 1 ml. of each reagent was added and mixed thoroughly. Neutralise the required amount of sample using sulphuric acid to PH around 7.0 since dissolved oxygen in the sample was likely to be exhausted. It was necessary to prepare a suitable dilution of the sample to the expected BOD range (table given in Appendix). Required dilution were prepared in a large glass through and filled in two sets of BOD bottles. One set of sample was kept in the incubator at 20°C for five days and the other set of the sample was used to determine the dissolved oxygen count immediately. The same procedure was repeated to get concordant values.

Preparation of dilutions for various ranges of (BOD) in the dye effluent:

Range of BOD mg/l O_2	Dilution (%)	Sample volume in 1 litre of mixture
0-6	No Dilution	1,000
4 - 12	50	500
10 - 30	20	200
20 - 60	10	100
40 - 120	5	50
100 - 300	2	20
200 - 600	1	10
400 - 1200	0.5	5
1000 - 3000	0.2	2
2000 - 6000	0.1	1
Above 6000	0.05	0.5

Procedure for preparing the reagents and the formula for calculating the Biochemical oxygen demand (BOD):

Preparation of Reagents:

1. Phosphate Buffer:

Dissolved 8.5 g potassium biphosphate, 21.75g Dipotassium hydrogen phosphate, 33.4 g Disodium hydrogen phosphate and 1.7 g Ammonium chloride Adjusted PH to 7.2.

2. Magnesium sulphate:

Dissolved 82.5 g magnesium sulphate in distilled water and diluted it to 1 litre solution.

3. Calcium chloride:

Dissolved 27.5 g of anhydrous calcium chloride in distilled water and prepared 1 litre of solution.

4. Ferric chloride:

Dissolved 0.25 g Ferric chloride in distilled water and prepared 1 litre of solution.

5. Sodium sulphite solution (0.025N):

Dissolved 1.575g sodium sulphite in distilled water and diluted it to 1000 ml. solution.

Formula used for calculating BOD:

$$\text{BOD mg/l} = \frac{(D_1 - D_2) - (B_1 - B_2)}{P}$$

Where,

D_1 = Dissolved oxygen content in diluted sample immediately

D_2 = Dissolved oxygen content in diluted sample after 5 days, incubation at 20°C

B_1 = Dissolved oxygen of seed control before incubation

B_2 = Dissolved oxygen of seed control after incubation

P = Decimal volumetric fraction of sample used.

APPENDIX - VII

Procedure for total suspended solids (TSS):

Required volume of the sample was filtered through the crucible by applying suction. The filteration was carried out at a lower vaccum than that was used in the preparation of the mat. The content was washed with distilled water to remove the soluble salts. Care was taken to prevent loss of fine asbestos particles. Finally the crucible was dried in an oven at 105°C. The increase in weight of the crucible was noted. This gives the value of the total suspended solids. The same procedure was repeated to get concordant values.

Formula used for calculating the total suspended solids (TSS):

$$\text{TSS mg/l} = \frac{1000 \times W}{V}$$

where

W = Weight in mg. of the dissolved matter

V = Volume of sample taken in ml.

APPENDIX - VIII

Procedure for total Dissolved solids (TDS):

Required volume of sample was filtered through a filter paper and this was evaporated in a China dish on a water bath. The residue was dried in an oven at 105°C. The increase in weight of the dish was noted. This gives the value of the dissolved solids. The same procedure was repeated to get concordant values.

Formula used for calculating the total dissolved solids (TDS):

$$\text{TDS mg/l} = \frac{A - B \times 1000}{V}$$

Where,

A = Final weight of the dish in mg.

B = Initial weight of the dish in mg.

V = Volume of sample taken in ml.

APPENDIX - IX

COAGULANT TREATMENT WITH DYE EFFLUENT

Coagulants used	Dosage in ppm	Observation	Non ionic polyelectrolyte in ppm.	Settling time in hrs.	Sludge in ml.	Final PH
1. Alum	200	No Coagulation	-	-	-	-
	400	Slight flocs are developed	-	-	-	-
	600	Coagulation occurs,but slow settling	3	4	20	-
	800	Coagulation occurs with rapid settling	3	1	15	6.03
	1000	Coagulation disturbed, discrete particles occurs, but no settling	-	-	-	-
2. Lime	100	Very slight coagulation	-	5	20	11.5
	300	No coagulation	-	-	-	-
	500	No coagulation	-	-	-	-
3. Ferrous Sulphate	200	Very slight coagulation builds up turbidity	-	-	-	4.5
	400	Very slight coagulation builds up turbidity	-	-	-	-
	600	Very slight coagulation builds up turbidity	-	-	-	-
	800	Colladal solution	-	-	-	-

APPENDIX - X

EVALUATION OF DYED SAMPLES

S.No.	EVENNESS IN DYEING		BRILLIENCY OF COLOUR			TEXTURE		LUSTRE			GENERAL APPEARANCE		
	Even	Uneven	V.Bright	Bright	Dull	Smooth	Rough	High	Medium	Low	Good	Fair	Poor

APPENDIX - XI

GRAY SCALE USED TO EVALUATE THE DYED MATERIALS

The dyed materials were rated using the AATCC (American Association of textile colourists and chemists) gray scale to measure the extent of colour change and staining. The gray ratings envisaged the following standards for colour fastness to disperse and reactive dyes applied on polyester cotton blend material under selected conditions:

Nomenclature	Used for Colour change
5	No change (Excellent)
4	Slight change (good)
3	Noticeably changed (fair)
2	Considerably changed (poor)
1	Much changed (very poor)

Nomenclature	Used for staining
5	No staining
4	Slightly stained
3	Noticeably stained
2	Considerably stained
1	Heavily stained

APPENDIX - XII

Key to Spectro-Analysis:

Delta L	(DL)	:	Lighter or darker
Delta a	(Da)	:	Yellower or greener
Delta b	(Db)	:	Blue or redder
Delta E	(DE)	:	Total colour difference
Delta C	(DC)	:	Chrome
Delta H	(DH)	:	Hue
Tolerance limits		:	Negative values indicate darker values
		:	Positive values indicate lighter values

Here the tolerance limit given was +2 to -2.

1.	D - 65	:	Day light (Ultra violet light) 10°
2.	A	:	Artificial light
3.	CWF	:	Cool white fluorescent
4.	CIELAB	:	International standards

APPENDIX - XIII

Formula used for statistical analysis of the data obtained in this study:

Statistical Analysis of the results obtained in the laboratory tests was done according to the method recommended by Gupta (1986) as follows:

't' tests were conducted whenever necessary to check if the results were significant using the formula.

$$t = \frac{\overline{x_1} - \overline{x_2}}{S} \times \sqrt{\frac{n_1 n_2}{n_1 + n_2}}$$

where

$\overline{x_1}$ = mean of the first sample

$\overline{x_2}$ = mean of the second sample

S = combined standard deviation

n_1 = Number of observations of the first sample

n_2 = Number of observations of the second sample

$$S = \sqrt{\frac{(n_1 - 1)\ S_1^2 + (n_2 - 1)\ S_2^2}{n_1 + n_2 - 2}}$$