A STUDY ON RECYCLING OF DYE EFFLUENT WITH REACTIVE DYE ON COTTON

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CHAPTER I

INTRODUCTION

INTRODUCTION

The very desire that a single unit of production should be able to meet the entire demand of the population for a specific type of product has given rise to the untiring efforts of mankind to evolve a genesis of mass production with the use of technical know-how and advanced mechanisation. The concept of mass-production, although with considerable rationalisation, envisages a package application of raw material (natural or man-made) and labour (manual or mechanical),leading to excessive discharge of effluents during the complex processes involved in the manufacture. The adverse effects of concentration of such effluents are hazardous to all living creatures nearby.

Industrial pollution is thus a great problem in advanced countries and in developing nations like India aswell. It requires immediate attention of all governments and world bodies to formulate and enforce certain regulatory measures to check it out. Pollution is highly detrimental to the whole biosphere if left unchecked or unregulated. Pollution is the direct or indirect alteration of the physical, thermal, biological or radio-active properties of any part of the environment in such a way as to create hazards to health, safety or welfare of any living species (Allaby,M. 1979).

The industry is a greater offender of course, much greater than the agricultural sector, earning somany occupational hazards to labourers and pollution problem to the environment, especially in air and water. For the purpose of this, our study is confined to the water pollution caused by the use of dyes and chemicals in the textile industry.

It is therefore the need of the hour, that a study was evolved to assess the extent of damage that the textile industry would cause to humanity and also to initiate measures to safeguard our limited water resources from excessive pollution. An International awareness is being felt for some decades to take all possible regulatory steps to check industrial pollution. Special ordinance have been enacted in this respect. In terms of chemistry steps are afoot to preserve the oxygen-content of the whole environment. Several recycling processes of industrial wastes are devised and much emphasis is given to purification (including desalination treatments) of water and protection of the natural environment from various pollutants. More and more conservation techniquesare attempted and education about a pollution-free state is unfailingly imparted to all the public.

In the textile industry, the feasibility of reusing the treated water should be given a serious thought in a combined effort in order to minimise fresh water consumption and also to mitigate the problem of water shortages thereby exercising a control over the water pollution to a certain extent. The following suggestions are noteworthy in tackling the water pollution as a whole, viz..

(a) **A complete assessment of industrial wastes**

Studies may be conducted of all processes by collecting data relating to the rate of concentration of pollutants at source in each stage;

(b) **Evolution of new processes**

Manufacturing processes may be modified suitably so as to give the same quality of product, by effectively minimising the pollutant load in a particular process; and,

(c) **Effective treatment of effluents**

Suitable effluent treatment plants may be designed and installed, taking into consideration the product mix, fluctuation in pollution-load and projected pollution-load through continuous R & D with a view to time-bound expansion of the industry.

Thus there is a great need for an effective management of industrial wastes which cause pollution in air, water, noise and in the whole environment.

In the light of the above, the main objectives of this study are,

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. To study the reuse of dye effluent in the dyeing unit in the textile mills.

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

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

A. Water, its Classification and its Uses

B. Sources of Water Pollution

C. Properties of Polluted Water

D. Pollution and Industrial Effluents

E. Pollution and Legislation

F. Dyes and Their Classification

G. Properties of Selected Dye-Reactive Dye, its Structure and Classification

H. Cotton and its Properties.

WATER, ITS CLASSIFICATION AND ITS USES

Water is a liquid of hydrogen and oxygen molecules. It is never pure in nature. Gases including oxygen, carbon dioxide and nitrogen are dissolved in between the water molecules. Salts such as nitrates, chlorides and carbonates, also become part of the liquid solution. Solids, dust and sand are carried as suspended solids. Other chemicals give water, colour and taste. Ions may cause a chemically alkaline or acid reaction (Sewell 1975).

Carpenter et al (1947) opines that regular and plentiful supply of clean water is essential for the survival and health of all living organisms. According to Kumar (1983) it is one of the most important and most precious of natural resources used by us.

TYPES OF WATER - CLASSIFICATION

Pramod Singh (1985) states that water for human consumption must be free from organisms and concentration of chemical substances that may be hazardous to health. Absence of turbidity, colour, disagreeable taste are of utmost importance in public supplies of drinking water. Water for practical purposes 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 polluted water is one which may carry infection by the addition of human or animal wastes or which has been rendered wholesome by poisonous chemical compounds.

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

SOURCES OF WATER POLLUTION

Pollution is any degree of contamination of air or land which is likely to produce a significant adverse health effect to a number of persons in a forceable period of time (Barbour 1983).

Kale (1986) defines pollution as contamination of natural resources. Pollution can happen naturally as a result of decaying plant life and impurities washed from soil. But most pollution is man-made and comes from the community and industry, around the river banks (NRA, 1990).

Water is said to be polluted when it changes its quality directly or indirectly as a result of discharge of various toxic chemical pollutants so that it becomes less suitable for drinking and agricultural purposes (Kumar 1983).

Hari and Rajeswari (1985) define sources of water pollution as

1. Sewage
2. Industrial waste and,
3. Agricultural waste.

Hara Prasad (1980) elucidates the following information that, the available sources of water supply are fast getting polluted with the industrial wastes, which contain different water-borne germs, organic matter, oils, detergents, radio-active substances and sewage on account of the unrestrained urbanisation and industrialisation.

PROPERTIES OF POLLUTED WATER

The physical and chemical properties of water can be estimated by standard methods. Important water characteristics are

1. BOD

The Biochemical Oxygen Demand is the amount of oxygen which is needed to oxidise the organic material by micro-organisms, anaerobically and the test period is five days.

2. COD

The Chemical Oxygen Demand is a measure of oxygen consumed to oxidise organic matter by boiling potassium dichromate and concentrated sulphuric acid for two hours. COD is taken as indicative of the total amount of carbonaceous organic matter present in water but it indicates a part of organic matter oxidised.

3. Permanganate Value (PV)

PV is a chemical oxidation using acid potassium permanganate solutions for four hours.

4. Dissolved Oxygen (DO)

It is of great use to assess survivability of life, particularly of fish which require atleast 5mg/litre Dissolved Oxygen. While the maximum dissolved oxygen in water is only 9.1mg/litre at $20^{o}C$ (Varshney 1983).

POLLUTION AND INDUSTRIAL EFFLUENTS

The reduction in the environmental quality is caused by the disposal of residue from the industry. Industrial effluents are actually more serious. They may include organic material and inorganic compounds like sulphuric acid, arsenic and cyanide, which are difficult to remove and highly poisonous. Industry is responsible for more than twice as much pollution as in domestic sewage (Vakil 1984).

Sampath Kumaran (1972) feels that water is getting polluted by chemical, biological and other toxic agents.

According to the WHO, industrial wastes usually contain traces or large quantities of raw materials, intermediate products, final products, co-products, by products and processing chemicals used. The composition and amount of pollutants discharged into the water are likely to create nuisances and are not suitable for all functions and purposes.

Water Pollution occurs due to the presence of dissolved inorganic materials such as free chlorine, ammonium, hydrogen sulphide and organic materials such as proteins, fats, carbohydrates and other substances found in industrial water and physical factors such as turbidity, colour, temperature of effluent, associated radioactivity etc. (Mahajan, 1985).

Dix (1981) opines that the addition of industrial waste effluents and sludge containing organic matter and many inorganic salts and metals to water which change its natural qualities. Industrial effluents are produced with a wide range of potential pollutants.

Vakil feels that pollution of water is probably a more acute problem in developing countries 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 (Roy 1980).

For effective water pollution control, it is essential to have a system of adequate collection, treatment and disposal of community wastes. A sound system of water pollution control results in the preservation of the aquatic organisms; lower waste treatment costs. (Haraprasad 1980).

Textile industry water effluents must meet the requirements for biochemical oxygen demand, chemical oxygen demand, potentia hydrogenii, total dissolved solids, total suspended solids, heavy metals, colour, toxic non-degradable chemicals, solvents, temperature, oil and grease and turbidity (Benisek 1979).

The waste water should be free from sludge deposits, unnatural colour, oil films and toxic substances before it can be discharged into the receiving stream. It should have pH of 5.5 to 9. The dissolved oxygen in the receiving water should be at least 5 parts per million (ppm).

The waste waters discharged from industries vary widely in their characteristics and volume depending on the type and size of the industry, raw materials handled, products manufactured, process, patterns followed, location, nature of water supply etc. The pollutants present in waste water also vary widely from industry to industry. (Dutta 1983).

POLLUTION AND LEGISLATION

Water quality is assessed from a network of monitoring sites at significant points in the river system. The water samples taken are analysed for a range of determinants in order to assess compliance with quality stands (EPA Water Quality Criteria 1972).

The main determinants used to assess river quality are Biological Oxygen Demand (BOD mg/litre), Dissolved Oxygen percentage Saturation (DO %) and Ammoniacal Nitrogen (Amm.mg/litre). Biological and the general health of river should also be considered in assessing the quality.

According to Manivasakam 1987 Pollution Control Act is being in force and each state has a Pollution Control Board for implementing pollution control measures, to monitor the quality of water and air and to protect the environment from pollution. Each State Pollution Control Board has fixed tolerance limits for effluents to be discharged. These tolerance limits are almost the same as those prescribed by Bureau of Indian Standards.

In developing countries, assessment of water sources both surface flows and ground water supplies, is essential for development of irrigation, industrial and domestic needs (Ramakrishna 1978).

DYES AND THEIR CLASSIFICATION

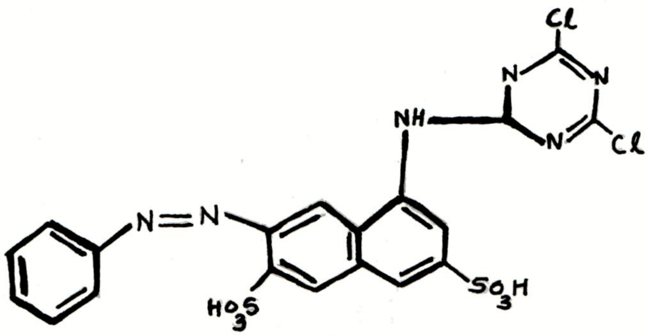
Dye is the name given to the chemicals by which a comparitively permanent colour is imparted to certain bodies of which the most important are the textile fibres. (Mathur and Agarwal 1980). American Home Economics Association (1967) states that dyes are soluble coloured compounds which produce permanent colours.

Dyeing in its simplest form consists of immersion of the textile fabric in a solution of dyestuff (Miller 1970). The dyeing

The term reactive normally refers to a dye applicable to cotton because the technical importance of reactive dyes is essentially for cotton (Venkataraman 1972). Reactive dyes are of outstanding importance for colouring cellulosic fibres. (Srivastava, 1974).

Varghese-et-al (1988) states that the first dichlorotriazine reactive dyes introduced by ICI for cellulosic fibres.

STRUCTURE OF REACTIVE DYES



CLASSIFICATION OF REACTIVE DYES (Trotman 1970)

Reactive dyes are of three types

1. Cold Reactive Dyes (Procion)
2. Remazol Dyes.
3. Hot Brand Dyes.

1. Cold Reactive Dyes

These dyes are dyed on cotton fabrics at room temperature.

2. Remazol 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 Exhauste (HE) Dyes.

COTTON AND ITS PROPERTIES

Of all the textile materials handled in the power laundry, those made of cotton fibres are encountered most frequently (Johnson 1927). It has been proved that India was the first country to manufacture cotton (Dantyagi 1974).

According to Taylor (1985) all cotton fibres exhibit good moisture absorption, good wet and dry tensile strength and resistance to abrasion, and that they withstand frequent laundering at a high temperature.

Mercerised cotton is cotton treated with a concentrated solution of caustic soda with the application of tension. There is a marked increase in weight and tensile strength and a greater affinity for dyestuffs is developed. Mercerised cotton is much more absorptive than ordinary untreated material (Johnson - 1927).

Cotton is thus found to be a natural cellulose fibre which is cheap, strong and hard wearing. It has the useful property of being stronger when wet than dry. It remains hardy to all washing. (WilliamsD.A.R.1974). Cotton is far stronger than wool. (Johnson 1927).

CHAPTER III

EXPERIMENTAL PROCEDURE

EXPERIMENTAL PROCEDURE

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

A. Selection of Fabric, Dyes, Colour and Shade.

B. Equipment used for Dyeing

C. Selection of Dyeing Method

D. Procedure for Dyeing the Fabric

E. Collection of Dye Effluent

F. Laboratory Experiments

  1. Before Treatment

  2. After Treatment

G. Evaluation

  1. Visual Inspection

  2. Laboratory Tests

  a. Fabric Weight Test

  b. Fabric Thickness Test

  c. Bursting Strength Test

  d. Abrasion Resistance Test

  e. Wettability and Absorbency Tests

    i. Drop Test

    ii. Sinking Test

  f. Colour Fastness Test

    i. Wet and Dry Crocking

    ii. Wet and Dry Pressing

    iii. Washing Test

  g. Spectro Analysis

A. SELECTION OF FABRIC, DYE, COLOUR AND SHADE

FABRIC

Cotton has occupied a unique place in the field of textiles, because of its wide range of uses in domestic and industrial applications. It is ideally suited for tropical conditions.

According to Taylor (1985) all cotton fibres exhibit absorption, good wet and dry tensile strength and resistance to abrasion and they withstand frequent laundering at high temperature. Cotton fibres have the highest wear resistance of all textile fibres in common use. Moisture increases the strength of cotton and a greater affinity for dyestuffs Oerke (1957).

Owing to the remarkable properties of cotton, the investigator selected cotton material for the study. Ten metres of cotton material was 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.

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, Birrell (1959). The criteria for dyestuff selection would include its shade, dyeing rate, degree of exhaustion and water solubility Shenai (1973). Dolby (1976) suggests that the reactive dyes offer more benefits to the dyers. Reactive dyes can be dyed by simple methods. Hence reactive dye was selected to dye the selected fabric.

COLOUR

Bright colour with excellent wash fastness are available by means of reactive dyes and the cost is decreasing. So they are gaining popularity, Joseph (1972).

The dyestuffs Procion and Remazol are effectively applied on cotton fabrics. Hence the investigator selected Procion orange M_2R and Remazol NAV. blue RN.

SHADE

The shades of the dyeing is expressed as a percentage of dye to the weight of fabric opines Kullkarni-et-al (1978). 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, medium and dark in the field of colouration. Therefore the investigator selected

0.5 percent and 4 percent shades. It may be noted that the depth of shades in terms of light and dark is based on the visual perception.

B. EQUIPMENT USED FOR DYEING

According to Chitrangada Krishna (1977) the following equipments are used for dyeing purposes :

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

C. SELECTION OF DYEING METHOD

The hand jigger machine is a simple efficient machine in which dyestuffs can be applied on materials of varying weight and length (Shenai 1973). Peter (1975) commits that in the jigger, the material is kept moving back and forth throughout till the desired shade is obtained. In jigger dyeing, material runs evenly without

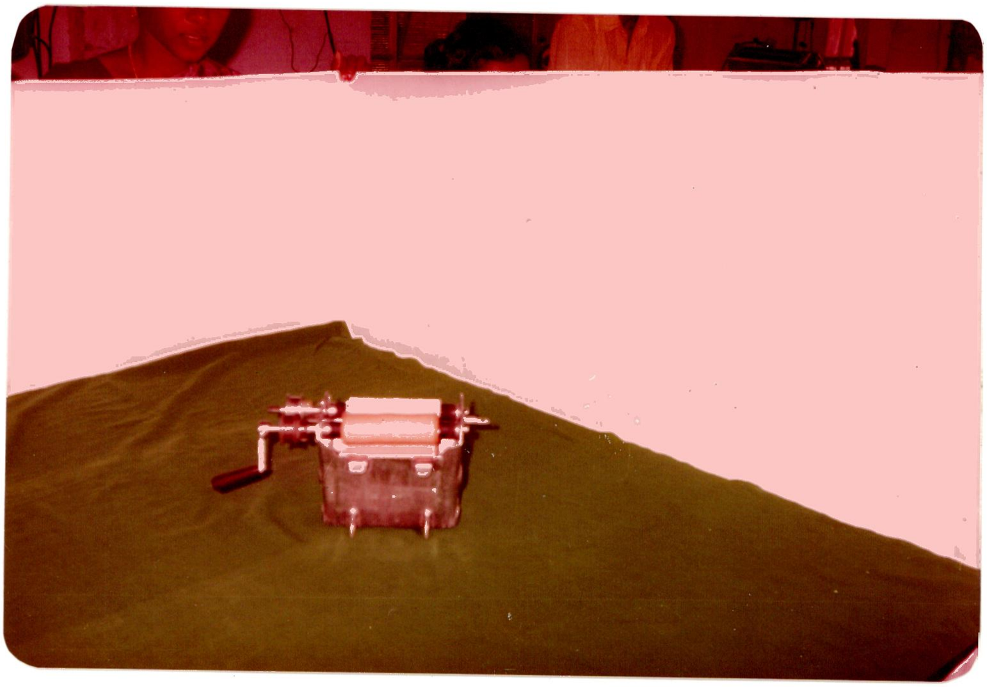


PLATE I. HAND JIGGER MACHINE

overlapping of selvedge. This is an important advantage of jigger dyeing. Therefore hand jigger method was selected for dyeing the cotton material. (Plate I)

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

D. PROCEDURE FOR DYEING THE FABRIC

Dyeing with process water

The desized material was cut into eight pieces. A set of four pieces were named as PO_1, PO_2, PB_1 and PB_2. The samples PO_1 and PO_2 were dyed in 0.5 and 4 percent Procion orange shade using process water in cold condition. Samples PB_1 and PB_2 were dyed in 0.5 and 4 percent Remazol blue shade using process water in hot condition. The preparation of the dye bath and procedure for dyeing are given in Appendix II.

DYEING WITH EFFLUENT TREATED WATER

The second set of four pieces were named as EO_1 EO_2, EB_1 and EB_2. The samples EO_1 and EO_2 were dyed in 0.5 and 4 percent Procion orange shade using effluent treated water in cold condition. Samples EB_1 and EB_2 were dyed in Remazol blue shade of 0.5 and 4 percent concentrations, using effluent treated water in hot condition. The preparation of dye bath and procedure for dyeing are given in Appendix II

These samples were to be dyed using the respective dyeing methods, conditions and concentrations as given in the following Table.

TABLE - I

S.No.	Sample Name	Colour	Condition	Concentration In Percentage
1.	PO_1	Orange	Cold	0.5
2.	PO_2	Orange	Cold	4.0
3.	PB_1	Blue	Hot	0.5
4.	PB_2	Blue	Hot	4.0
5.	EO_1	Orange	Cold	0.5
6.	EO_2	Orange	Cold	4.0
7.	EB_1	Blue	Hot	0.5
8.	EB_2	Blue	Hot	4.0

PROCESS WATER	EFFLUENT TREATED WATER
PO_1 - 0.5% Orange Shade	EO_1 - 0.5% Orange Shade
PO_2 - 4% Orange Shade	EO_2 - 4% Orange Shade
PB_1 - 0.5% Blue Shade	EB_1 - 0.5% Blue Shade
PB_2 - 4% Blue Shade	EB_2 - 4% 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 ware is totally used up by the unit per day. The dyeing section alone consumer about ten lakhs litres daily. The total effluent that is treated is 20 lakhs litres per day.

The investigator collected about twenty five litres of untreated effluent on ten occasions in plastics containers. This total effluent was used up for various treatments and dyeing purposes.

F. LABORATORY EXPERIMENTS

1. BEFORE TREATMENT

To judge the pollution potential of an effluent, the following general parameters were found :

1. Potentia Hydrogenii (pH)

pH is the measure of intensity of acidity or alkalinity and measures the concentration of hydrogen ions in water. 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 are more than H^+ ions, the water is alkaline, say Trivedy and Goel (1984).

pH is an important factor in water chemistry since it enters in to processes such as coagulation, disinfection, softening and corrosion control. The pH determination is important because excessive acidity or alkalinity is injurious to biological activity.

An essential aspect to use in all the pH meters was to calibrate it with suitable buffers. Ready buffer tablets with known pH value are available. pH meter value with a buffer value was checked. The pH of the effluent was first determined by pH paper and then confirmed by pH meter.

The description of the pH meter is given in the Appendix III.

a. CHEMICAL OXYGEN DEMAND (COD)

American Society for testing and Materials (ASTM) defines COD as the amount of oxygen expressed in mg/1 litre consumed under specific conditions in the oxidation of organic matters and oxidisable inorganic matters, corrected for the influence of chlorides. 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.

It has to be noted that COD is not a measure of carbon content. It is based on the fact that all the carbanaceous organic matter can be oxidised to carbon dioxide and water.

Nearly every organic substance is virtually completely oxidised in this procedure with the exception of certain aromatic compounds such as pyridine, benzene or toluene. The COD value thus given the measure of the total organic content of a waste, whether or not it is a bio-degradable.

PRINCIPLE

The organic matter of the sample is completely oxidised by refluxion with a known excess potassium dichromate solution under acidic conditions. The unreacted dichromate is back titrated with a standard ferrous ammonium sulphate Solution.

REAGENTS

1. 0.25 N Potassium dichromate solution
2. Concentrated sulphuric acid
3. 0.25 N standard ferrous ammonium sulphate solution
   (The solution shall be standarised against standard Potassium dichromate solution)
4. Ferroin indicator
5. Mercuric sulphate
6. Silver sulphate

The procedure for preparing the reagents and formula for calculating the COD are given in the Appendix IV.

b. 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 biologically degradable organic matter under aerobic conditions (Trivedy and Goel 1984).

The method involves measuring the difference of the oxygen concentrations between the samples and then incubating it for five days at 20° c.

REAGENTS

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

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

c. TOTAL SUSPENDED SOLIDS

The undissolved matter present in water is usually referred to as suspended solids. It is one of the valuable parameters in judging the pollution potential of an effluent.

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

MATERIALS REQUIRED

1. Gooch crucible
2. Asbestos powder

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

d. TOTAL DISSOLVED SOLIDS

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

TDS are determined as the residue left after evaporation of the filtered sample and determining its weight by subtracting the initial weight of the disc from final weight of the disc. This gives the weight in mgs of the dissolved solids (Trivedy and Goel, 1984).

MATERIALS REQUIRED

1. Whatman filter paper (No. 30).
2. China dish

The procedure and formula for calculation are given in the Appendix VII.

2. AFTER TREATMENT

PILOT STUDY

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

a. COAGULANT USED FOR TREATMENT

1. ALUM

Alum is the most common 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).

When alum is added to the 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.

2. FERROUS SULPHATE

It is a chemical coagulant which when added to the dye effluent reacts with alkalinity and phosphate forms an insoluble iron salt states 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

For alum treatment, the dye effluent was taken in 5 different 1000 ml measuring jars and the pH was adjusted to around 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 around 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 a dye effluent was taken in four different 1000 ml measuring jars, and the pH was adjusted to around 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 table show values for pH of effluent treated with coagulants is given in Appendix VIII.

G. EVALUATION

The samples dyed in both the process water and effluent treated water were evaluated by the following ways.

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

1. VISUAL INSPECTION

In order to evaluate the dyed samples, 25 judges of Textiles and Clothing and Family and Community Science departments of Avinashilingam Deemed University, Coimbatore were selected as they

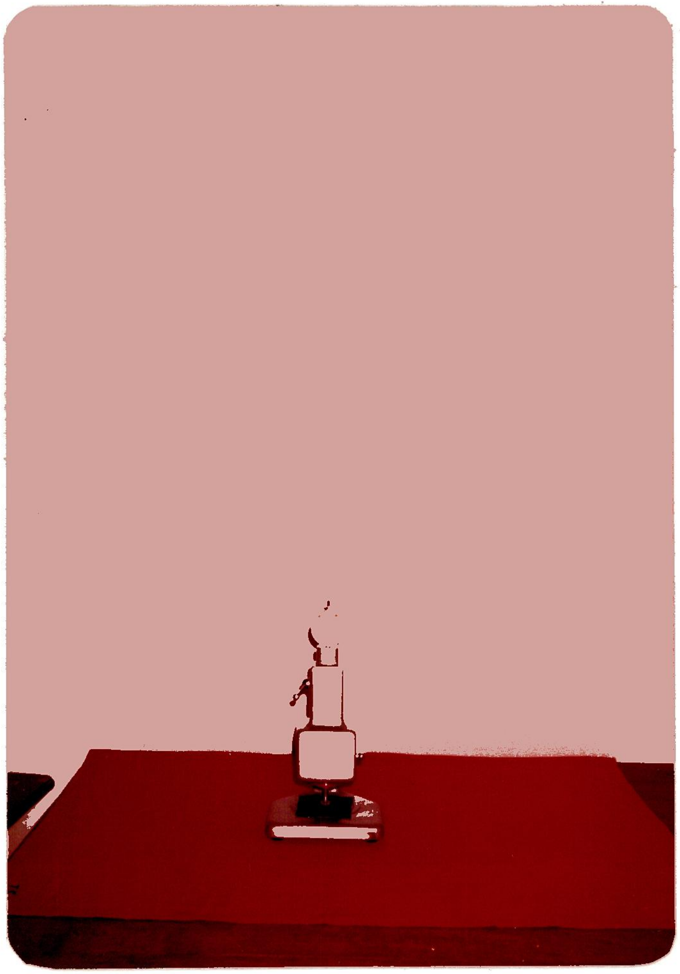


PLATE II. THICKNESS TESTER

have enough knowledge on textiles. A rating scale was prepared as shown in Appendix IX. 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 were collected, consolidated and the result is presented under the chapter "Results and Discussions".

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.

The Hungarian Thickness Tester (Plate II) 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

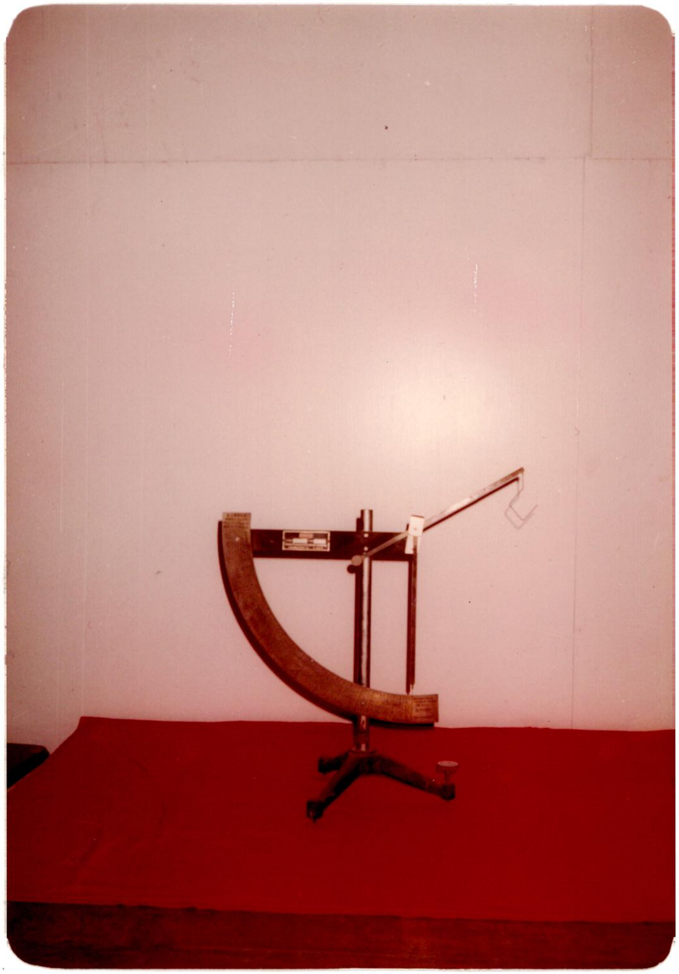


PLATE III. CLOTH QUADRANT BALANCE

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. Ten readings were taken from different parts of the same material and the mean value was calculated. Similarly, mean value of ten 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**

The fabric weight may be determined by measuring the weight per unit area and weight per unit length (Skinkle 1972).

The Eureka Cloth Quadrant Balance (Plate III) was used to determine the fabric weight directly. It has a graduated scale in ounces per square yard. A template was used to cut the sample and the sample was suspended on the hook of the balance and the recording 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 meter.

PLATE IV. BURSTING STRENGTH TESTER

c. BURSTING STRENGTH

Skinkle (1972) stresses that Bursting strength is the force applied to break a fabric, when applied at right angles to the fabric and uniformly distributed over a given area. It is the maximum fluid pressure applied to a circular specimen in distending it to rupture, ISI (1982).

The Eureka Bursting Strength tester (Plate IV) was used to determine the bursting strength of the samples. The internal diameter of the clamp ring was 3 cm. The dial was calibrated in Kgs/cm^2. The samples were cut into 10 cm by 10 cm width. The same was clamped over a rubber diaphragm abd 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 the 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 was obtained.

d. ABRASION RESISTANCE

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

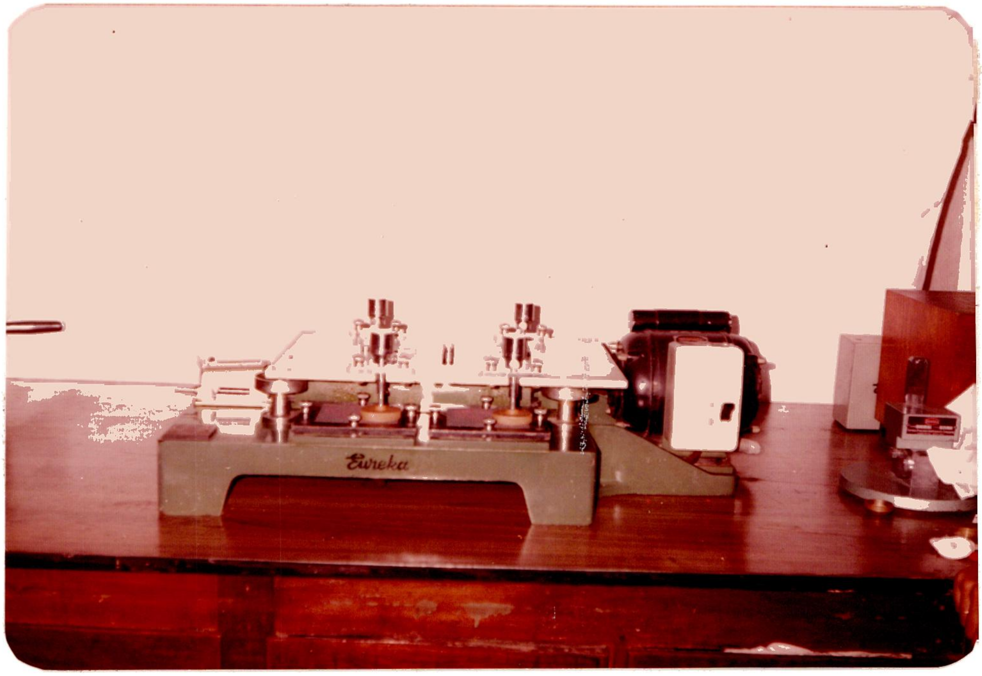


PLATE V. ABRASION RESISTANCE TESTER

The Eureka Marlindale Abrasion Resistance Tester (Plate V) was used to determine the fabric resistance to friction. 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 0.0001 gm. 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 was calculated and thus the loss of weight of each sample was recorded separately.

e. WETTABILITY AND ABSORBENCY TESTS

1. DROP TEST

The ability of a fibre 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 considered as unwettable. The test conducted therefore is known as "Drop test".

A burette filled with distilled water was clamped to a stand securely. 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 ten 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 ten samples from the original, was calculated and thus the drop test for each material was recorded separately.

2. 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 5X5 cm squares from the original and the dyed materials. A 1000 ml beaker was taken and filled with

PLATE VI. SINKING TIME

distilled water. Few drops of wetting agent were 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 the 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 ten 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 ten samples from original was calculated and thus the sinking time of each material was recorded separately. (Plate VI)

f. COLOUR FASTNESS TEST

The American Association of 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. WET AND DRY CROCKING

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

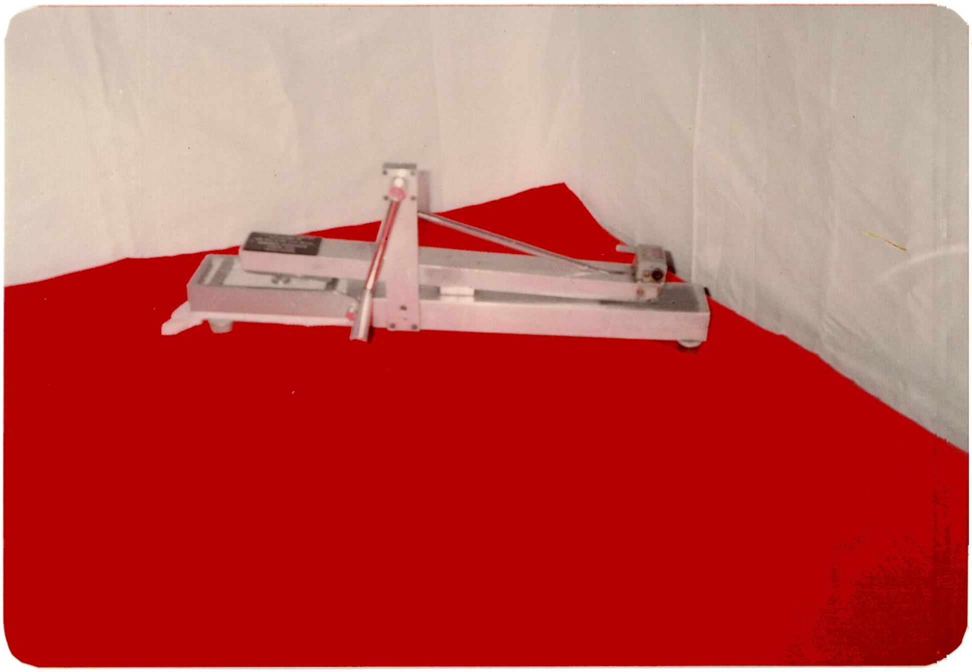


PLATE VII. CROCK METER

Sasmira crockmeter was used for ascertaining the fastness of dyed samples. It consisted of two metal blocks. The base block was stationary while 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 standardized / 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. (Plate VII)

ii. 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 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.

iii. COLOUR FASTNESS TO WASHING

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

3 gms of Lissapol D soap per litre was mixed with distilled water in a trough. The temperature was raised to boil. The samples dyed in process water were put into it. After 3 minutes, the samples were removed, rinsed in cold water and dried. The same procedure was repeated for samples dyed in effluent treated water.

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

g. SPECTRO ANALYSIS

Methods used for assessment of 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, La and Lb using CIELAB 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 he 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 - Percent 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 would 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.

CHAPTER IV

RESULTS AND DISCUSSION

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 Weight
2. Fabric Thickness
3. Bursting Strength
4. Abrasion Resistance
5. Wettability and Absorbency Tests
   a. Drop Test
   b. Sinking Test
6. Evaluation of Colour Fastness
   a. Spectro Analysis - Strength Tests
   b. Spectro Analysis - Washing Tests

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 Hydrogen II (PH)	11.05	6.03	5.5 - 9.0
2.	Biochemical Oxygen Demand (BOD) (mg/l)	105.73	22.70	30.0
3.	Chemical Oxygen Demand (COD) (mg/l)	1560.0	231.6	250.0
4.	Total Suspended Solids (TSS) (mg/l)	191.8	76.0	100.0
5.	Total Dissolved Solids (TDS) (mg/l)	2412.0	1056.8	2100.0

The above table shows the general parameter values 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

The details of the panel ratings include the eveness in dyeing, brilliancy of colour, texture, lustre and general appearance of the dyed materials using process water and effluent treated water. These are given in Table III.

TABLE - III

EVALUATION OF DYED SAMPLES

S.No.	Sample	Eveness in Dyeing		Brilliancy of Colour			Texture		Lustre			General Appearance		
		Even %	Uneven %	V.Bright %	Bright %	Dull %	Smooth %	Coarse %	High %	Med %	Low %	Good	Fair	Poor %
1.	PO_1	100	-	20	80	-	-	100	-	-	100	30	70	-
2.	PO_2	100	-	100	-	-	-	100	-	-	100	100	-	-
3.	PB_1	100	-	-	-	100	-	100	-	-	100	35	65	-
4.	PB_2	100	-	100	-	-	-	100	-	-	100	100	-	-
5.	EO_1	100	-	30	70	-	-	100	-	-	100	30	70	-
6.	EO_2	100	-	100	-	-	-	100	-	-	100	100	-	-
7.	EB_1	100	-	-	-	100	-	100	-	-	100	25	75	-
8.	EB_2	-	100	-	-	100	-	100	-	-	100	-	-	100

PROCESS WATER

PO_1 - 0.5% Orange Shade
PO_2 - 4% Orange Shade
PB_1 - 0.5% Blue Shade
PB_2 - 4% Blue Shade

EFFLUENT TREATED WATER

EO_1 - o.5% Orange Shade
EO_2 - 4% Orange Shade
EB_1 - 0.5% Blue Shade
EB_2 - 4% Blue Shade

From Table III it was clear that except EB_2, all the other samples PO_1, PO_2, PB_1, PB_2, EO_1, EO_2 and EB_1 were rated as "even" by 100 percent of the judges.

As regards brilliancy of colour, PO_2, EO_2 and PB_2 were rated as "very bright" by 100 percent of the judges. The sample PO_1 was rated as "bright" by more than 80 percent of the judges.

With respect to texture, all the samples were rated as "coarse" by 100 percent ofthe judges. Considering the lustre, all the samples were rated as " low" by 100 percent of the judges.

Regarding the general apperance, samples PO_2, PB_2 and EO_2 were rated as "good" by 100 percent of the judges. The samples PO_1, PB_1, EO_1 and EB_1 were rated as "medium" by more than 70 percent of the judges.

Based upon the above, it is clearly understood that except the sample dyed in 4 percent blue shade of effluent treated water, all other samples excelled in all the respects.

C. LABORATORY TESTS

1. FABRIC WEIGHT

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

TABLE - IV

FABRIC WEIGHT OF ORIGINAL AND DYED SAMPLES

S.No.	Sample	Mean Value (gms/sq)	Gain Over Original (gms/sq)	% Gain Over Original
1.	Original	4.42	-	-
2.	PO_1	4.83	0.41	9.276
3.	PO_2	4.65	0.23	5.203
4.	PB_1	4.75	0.33	7.466
5.	PB_2	5.20	0.78	17.647
6.	EO_1	4.96	0.54	12.217
7.	EO_2	4.92	0.50	11.312
8.	EB_1	4.77	0.35	7.918
9.	EB_2	5.08	0.66	14.932

STATISTICAL ANALYSIS OF FABRIC WEIGHT

S.No.	Sample Name	Mean ± S.D.	Difference Mean ± S.D.	Groups Compared	't' Value
1.	Original	4.42 ± 0.207	0.4 ± 0.207	O Vs PO_1	4.309 * *
2.	PO_1	4.83 ± 0.207	0.4 ± 0.207	PO_1 Vs EO_1	1.1206 N.S.
3.	PO_2	4.65 ± 0.207	0.23 ± 0.207	O Vs PO_2 PO_2 Vs EO_2	2.47 * 4.128 * *
4.	PB_1	4.75 ± 0.207	0.28 ± 0.207	O Vs PB_1 PB_1 Vs EB_1	3.016 * 0.250 N.S.
5.	PB_2	5.2 ± 0.220	0.78 ± 0.220	O Vs PB_2 PB_2 Vs EB_2	7.908 * * 0.176 N.S.
6.	EO_1	4.96 ± 0.162	0.54 ± 0.162	O Vs EO_1	7.43 * *
7.	EO_2	4.92 ± 0	0.48 ± 0	O Vs EO_2	0 N.S.
8.	EB_1	4.77 ± 0.214	0.28 ± 0.214	O Vs EB_1	2.917 *
9.	EB_2	5.08 ± 0.193	0.66 ± 0.193	O Vs EB_2	7.625 **

* - Significant At 5% Level

* * - Significant At 1% Level

N.S. - Not Significant

Table IV shows the 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 sample.

A maximum gain was observed in the samples PB_2 and EB_2 when compared to the other samples.

The statistical analysis showed the following facts

1. There was highly significant difference between the original and dyed samples using process water and effluent treated water.
2. There was significant difference between the samples dyed in 4 percent orange shade using process water and effluent treated water, but no significant difference was found between the other samples dyed in process water and effluent treated water.

2. FABRIC THICKNESS

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

TABLE - V

FABRIC THICKNESS OF ORIGINAL AND DYED SAMPLES

S.No.	Sample	Mean Value (X 0.01 mm)	Gain Over Original	% Gain Over Original
1.	Original	5.05	-	-
2.	PO_1	7.50	2.45	48.51
3.	PO_2	7.35	2.30	45.54
4.	PB_1	7.50	2.45	48.51
5.	PB_2	7.60	2.55	50.49
6.	EO_1	7.55	2.50	49.50
7.	EO_2	7.75	2.70	53.46
8.	EB_1	7.45	2.40	47.52
9.	EB_2	7.70	2.60	52.47

PROCESS WATER

PO_1 - 0.5% Orange Shade

PO_2 - 4% Orange Shade

PB_1 - 0.5% Blue Shade

PB_2 - 4% Blue Shade

EFFLUENT TREATED WATER

EO_1 - 0.5% Orange Shade

EO_2 - 4% Orange Shade

EB_1 - 0.5% Blue Shade

EB_2 - 4% Blue Shade

STATISTICAL ANALYSIS OF FABRIC THICKNESS

S.No.	Sample Name	Mean ± S. .	Difference Mean ± S.D.	Groups Compared	't' Value
1.	Original	0.05 ± 0.019	0.25 ± 0.019	O Vs PO_1	2.934 *
2.	PO_1	0.075 ± 0.019	0.025 ± 0.019	PO_1 Vs EO_1	O N.S
				O Vs PO_2	2.699 *
3.	PO_2	0.0735 ± 0.019	0.023 ± 0.019	PO_2 Vs Eo_2	0.583 N.S
				O Vs PB_1	2.934 *
4.	PB_1	0.075 ± 0.019	0.025 ± 0.019	PB_1 Vs EB_1	0.00842 N.S
				O Vs PB_2	3.221 *
5.	PB_2	0.076 ± 0.018	0.026 ± 0.018	PB_2 Vs EB_2	0.119 N.S
6.	EO_1	0.075 ± 0.019	0.025 ± 0.019	O Vs EO_1	2.934 *
7.	EO_2	0.077 ± 0.019	0.027 ± 0.019	O Vs EO_2	3.168 *
8.	EB_1	0.0745 ± 0.018	0.024 ± 0.018	O Vs EB_1	2.97
9.	EB_1	0.077 ± 0.018	0.027 ± 0.018	O Vs EB_2	3.345 **

* - Significant At 5% Level

* * - Significant At 1% Level

N.S - Not Significant

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

From Table V , it was clearly evident that all the dyed samples showed higher mean values than that of the original sample. Among the dyed samples, EO_2 and EB_2 showed the highest mean values.

On analysing statistically, the following facts are seen :

1. The difference between the original and dyed samples using process water and effluent treated water were found to be significant, but there was no significant difference between samples dyed in process water and effluent treated water.

3. **BURSTING STRENGTH**

The bursting strength of original and dyed samples using process water and effluent treated water is given 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	7.88	-	-
2.	PO_1	6.64	- 1.24	15.73
3.	PO_2	7.20	- 0.68	8.62
4.	PB_1	6.64	- 1.24	12.69
5.	PB_2	6.84	- 1.04	13.19
6.	EO_1	6.88	- 1.0	12.69
7.	EO_2	6.64	- 1.24	12.69
8.	EB_1	6.64	- 1.24	12.69
9.	EB_2	6.70	- 1.18	14.97

PROCESS WATER

PO_1 - 0.5% Orange Shade

PO_2 - 4% Orange Shade

PB_1 - 0.5% Blue Shade

PB_2 - 4% Blue Shade

EFFLUENT TREATED WATER

EO_1 - 0.5% Orange Shade

EO_2 - 4% Orange Shade

EB_1 - 0.5% Blue Shade

EB_2 - 4% Blue Shade

STATISTICAL ANALYSIS OF BURSTING STRENGTH

S.No.	Sample Name	Mean ± S.D.	Difference Mean ± S.D.	Groups Compared	't' Value
1.	Original	7.88 ± 0.516	1.24 ± 0.576	O Vs PO_1	3.64 * *
2.	PO_1	6.64 ± 0.576	1.24 ± 0.576	PO_1 Vs EO_1	0.249 N.S.
				O Vs PO_2	1.964 N.S.
3.	PO_2	7.2 ± 0.772	0.68 ± 0.772	PO_2 Vs EO_2	1.432 N.S.
				O Vs PB_1	4.240 * *
4.	PB_1	6.64 ± 0.631	1.2 ± 0.631	PB_1 Vs EB_1	O N.S.
				O Vs PB_2	2.938 *
5.	PB_2	6.84 ± 0.759	1.0 ± 0.759	PB_2 Vs EB_2	0.0359 N.S.
6.	EO_1	6.88 ± 0.771	1.0 ± 0.771	O Vs EO_1	2.892 *
7.	EO_2	6.64 ± 0.759	1.16± 0.759	O Vs EO_2	3.408 * *
8.	EB_1	6.64 ± 0.759	1.2 ± 0.759	O Vs EB_1	3.525 * *
9.	EB_2	6.7 ± 0.759	1.1 ± 0.759	O Vs EB_2	3.231 *

* - Significant At 5% Level

* * - Significant At 1% Level

N.S. - Not Significant

Table VI illustrates the bursting strength of the original and dyed samples in process water and effluent treated water. It is clearly evident that all the dyed samples showed lesser mean values than the original sample. Amongst the dyed samples, sample PO_2 showed the highest mean value.

The statistical analysis states the follwoing facts

1. There was significant difference between original and samples dyed in process water, but no significant difference was found between original and sample dyed in 4 percent orange shade in process water.

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

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 No	Mean Value (gm)	Gain Over Original	Percentage gain Over Original
1.	Original	0.0038		
2.	PWO_1	0.0055	0.0017	44.73
3.	PWO_2	0.0051	0.0013	34.21
4.	PB_1	0.0180	0.0142	0
5.	PB_2	0.0006	0.0032	84.21
6.	EO_1	0.0050	0.0012	31.57
7.	EO_2	0.0140	0.0102	268.42
8.	EB_1	0.0038	0	0
9.	EB_2	0.0028	0.0010	26.315

PROCESS WATER

PO_1 - 0.5% Orange Shade

PO_2 - 4% Orange Shade

PB_1 - 0.5% Blue Shade

PB_2 - 4% Blue Shade

EFFLUENT TREATED WATER

EO_1 - 0.5% Orange Shade

EO_2 - 4% Orange Shade

EB_1 - 0.5% Blue Shade

EB_2 - 4% Blue Shade

STATISTICAL ANALYSIS OF ABRASION RESISTANCE

S.No.	Sample Name	Mean ± S.D.	Difference Mean ± S.D.	Groups Compared	't' Value
1.	Original	0.0051 ± 0.0528	0.00509 ± 0.05280	O Vs PO_1	0.2718 N.S.
2.	PO_1	0.0051 ± 0.0528	0.00509 ± 0.0528	PO_1 Vs EO_1	0.00135 N.S.
				O Vs PO_2	0.4219 N.S.
3.	PO_2	0.010 ± 0.04176	0.042 ± 0.04176	PO_2 Vs EO_2	0.2121 N.S.
				O Vs PB_1	2.242 N.S.
4.	PB_1	0.0178 ± 0.04176	0.42 ± 0.04176	PB_1 Vs EB_1	0.7419 N.S.
				O Vs PB_2	0.03150 N.S.
5.	PB_2	0.00062 ± 0.04176	0.00059 ± 0.04176	PB_2 Vs EB_2	0.21913 N.S.
6.	EO_1	0.00542 ± 0.7465	0.0541 ± 0.7465	O Vs EO_1	0.16174 N.S.
7.	EO_2	o.o143 ± 0.04877	0.0142 ± 0.4877	O Vs EO_2	0.6534 N.S.
8.	EB_1	0.004 ± 0.04176	0.00399 ± 0.04176	O Vs EB_1	0.21311 N.S.
9.	EB_2	0.00526 ± 0.04176	0.0052 ± 0.04176	O Vs EB_2	0.2803 N.S.

* - Significant At 5% Level

* * - Significant At 1% Level

N.S. - Not Significant

Table VII shows the weight of dyed samples and 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 Table VII it is clearly evident that among the dyed samples, only PB_2 showed a lower mean value.

The statistical analysis showed that

1. No significant difference 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 in process water and effluent treated sample.

5. WETTABILITY AND ABSORBENCY TESTS

a. DROP TEST

The Drop test values done on the 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 In Seconds	Loss Over Original	% Loss Over Original
1.	Original	4.0	-	-
2.	PO_1	3.4	0.6	15.0
3.	PO_2	2.8	1.2	30.0
4.	PB_1	3.6	0.4	10.0
5.	PB_2	3.0	1.0	25.5
6.	EO_1	3.2	0.8	20.0
7.	EO_2	3.4	0.6	15.0
8.	EB_1	2.8	1.2	30.0
9.	EB_2	3.0	1.0	25.5

PROCESS WATER

PO_1 - 0.5% Orange Shade

PO_2 - 4% Orange Shade

PB_1 - 0.5% Blue Shade

PB_2 - 4% Blue Shade

EFFLUENT TREATED WATER

EO_1 - 0.5% Orange Shade

EO_2 - 4% Orange Shade

EB_1 - 0.5% Blue Shade

EB_2 - 4% Blue Shade

STATISTICAL ANALYSIS OF DROP TEST

S.No.	Sample Name	Mean ± S.D.	Difference Mean ± S.D.	Compared Groups	't' Value
1.	Original	4 ± 0.683	0.6 ± 0.683	O Vs PO_1	1.959 N.S.
2.	PO_1	3.4 ± 0.683	0.6 ± 0.683	PO_1 Vs EO_1	2.020 N.S.
				O Vs PO_2	5.986 * *
3.	PO_2	2.8 ± 0.447	1.2 ± 0.447	PO_2 Vs EO_2	2.22 N.S.
				O Vs PB_1	8.976 * *
4.	PB_1	3.6 ± 0.596	2.4 ± 0.596	PB_1 Va EB_1	3.43 *
				O Vs PB_2	8.979 * *
5.	PB_2	3 ± 0.745	3 ± 0.745	PB_2 Vs EB_2	0 N.S.
6.	EO_1	3.2 ± 0.730	2.8 ± 0.730	O Vs EO_1	8.553 * *
7.	EO_2	3.4 ± 0.683	2.6 ± 0.683	O Vs EO_2	8.489 * *
8.	EB_1	2.8 ± 0.447	3.2 ± 0.447	O Vs EB_1	15.964 * *
9.	EB_2	3 ± 0.745	3 ± 0.745	O Vs EB_2	8.979 * *

* - Significant At 5% Level

* * - Significant At 1% Level

N.S. - Not Significant

Table VIII shows the results of Drop test done on original and dyed samples. The lower the mean value the quicker is the absorbency of the sample.

From Table VIII , it is clearly evident that all the dyed samples showed a mean value lower than the original. Among the dyed samples PO_2 and EB_1 showed the lowest percentage values when compared to the other samples.

The statistical analysis shows the following facts

1. There was no significant difference between the original and the sample dyed in 0.5 percent orange shade using process water, but there was significant difference between original and the other samples dyed using process water and effluent treated water.

2. There was no significant difference between the samples dyed in process water and effluent treated water, but there was significant difference between the samples dyed in 0.5 percent blue shade using process water and effluent treated water.

b. SINKING TEST

The sinking time of the 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 In Seconds	Loss Over Original	% Loss Over Original
1.	Original	6.0	-	-
2.	PO_1	3.6	2.4	40.0
3.	PO_2	3.4	2.6	43.3
4.	PB_1	3.2	2.8	46.6
5.	PB_2	3.6	2.4	40.0
6.	EO_1	2.6	3.4	56.6
7.	EO_2	2.6	3.4	56.6
8.	EB_1	2.8	3.2	53.3
9.	EB_2	2.8	3.2	53.3

PROCESS WATER

PO_1 - 0.5% Orange Shade

PO_2 - 4% Orange Shade

PB_1 - 0.5% Blue Shade

PB_2 - 4% Blue Shade

EFFLUENT TREATED WATER

EO_1 - 0.5% Orange Shade

EO_2 - 4% Orange Shade

EB_1 - 0.5% Blue Shade

EB_2 - 4% Blue Shade

STATISTICAL ANALYSIS OF SINKING TEST

S.No.	Sample Name	Mean ± S.D.	Difference Mean ± S.D.	Groups Compared	't' Value
1.	Original	6 ± 0.894	2.4 ± 0.894	O Vs PO_1	5.986 * *
2.	PO_1	3.6 ± 0.894	2.4 ± 0.894	PO_1 Vs EO_1	3.626 * *
				O Vs PO_2	6.077 * *
3.	PO_2	3.2 ± 0.954	2.6 ± 0.954	PO_2 Vs EO_2	3.529 * *
				O Vs PB_1	6.319 * *
4.	PB_1	3.6 ± 0.988	2.8 ± 0.988	PB_1 Vs EB_1	2.484 *
				O Vs PB_2	5.986 * *
5.	PB_2	3.6 ± 0.894	2.4 ± 0.894	PB_2 Vs EB_2	2.116 N.S.
6.	EO_1	2.6 ± 0.894	3.4 ± 0.894	O Vs EO_1	8.484 * *
7.	EO_2	2.6 ± 0.894	3.4 ± 0.894	O Vs EO_2	8.484 * *
8.	EB_1	2.8 ± 0.802	3.2 ± 0.802	O Vs EB_1	8.897 * *
9.	EB_2	2.8 ± 0.802	3.2 ± 0.802	O Vs EB_2	8.897 * *

* - Significant At 5% Level

* * - Significant At 1% Level

N.S. - Not Significant

Table IX determines the sinking time of the original and dyed materials. The lesser the mean value, the more is the wettability of the sample. From the table it was clearly evident that there was marked difference between original and dyed sample.

On analysing statistically, it was clearly evident that

1. The difference between the original and dyed samples using process water and effluent treated water was found to be highly significant.

2. There was significant difference between the samples dyed in process water and effluent treated water but there was no significant difference between the samples dyed in 4 percent blue shade using process water and effluent treated water.

TABLE - X

EVALUATION OF COLOUR FASTNESS OF DYED SAMPLES

S.No.	Sample	Colour Fastness To Crocking		Colour Fastness To Pressing	
		Dry	Wet	Dry	Wet
		Staining	Staining	Staining	Staining
1.	PO_1	4	4	5	4
2.	PO_2	3	2	4	4
3.	PB_1	5	4	5	4
4.	PB_2	3	2	3	1
5.	EO_1	4	4	4	4
6.	EO_2	4	2	4	3
7.	EB_1	5	4	4	4
8.	EB_2	2	2	3	2

PROCESS WATER

PO_1 - o.5% Orange Shade

PO_2 - 4% Orange Shade

PB_1 - 0.5% Blue Shade

PB_2 - 4% Blue Shade

EFFLUENT TREATED WATER

EO_1 - o.5% Orange Shade

EO_2 - 4% Orange Shade

EB_1 - 0.5% Blue Shade

EB_2 - 4% Blue Shade

Table X shown the crocking test evaluation of the dyed samples. Accordingly the sample PB , and EB , dyed in 0.5 per cent blue shade showed maximum fastness whereas PO , EO, and EB showed very minimum fastness property.

In the pressing test , except PB and EB , all other samples showed good colour fastness to dry pressing. As regards wet pressing PB and EB exhibited very bad colour fastness when compared to the rest of the samples.

6. COLOUR FASTNESS TEST

a.	Spectro Analysis	-	Strength Tests
b.	Spectro Analysis	-	Washing Tests

KEY TO SPECTRO ANALYSIS

Delta L (DL)	-	Lighter or Darker
Delta a (Da)	-	Yellower or Greener
Delta b (Db)	-	Bluer or Redder
Delta E (DE)	-	Total Colour Difference
Delta C (DC)	-	Chrome
Delta H (DH)	-	Hue
Tolerance limits	-	Negative values indicates darker values
	-	Positive values indicates lighter value

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

1.	D - 65	-	Daylight (Ultra violet light) 10^{o}
2.	A	-	Artificial light
3.	CWF	-	Cool white Fluorescent
4.	CIELAB	-	International standards

PROCESS WATER	EFFLUENT TREATED WATER
PO_1 - PWC 0.5%P. Orange	EO_1 = ETW 0.5% P. Orange
PO_2 - PWC 4% P. Orange	EO_2 - ETW 4% P. Orange
PB_1 - PWC 0.5% Rem Blue	EB_1 - ETW 0.5% Rem Blue
PB_2 - PWC 4% Rem Blue	EB_2 - ETW 4% Rem Blue

DATA - I

PASS / FAIL

08 Apr. 91 11:19:16
Small Area/Spec Incl d/0
1. D65/10 deg

CIELAB

	III/Obs	L*	a*	b*	C*	h
PWC 0.5% P. Orange	1	67.94	47.60	43.91	64.76	42.69
ETW 0.5% P. Orange	1	67.35	46.55	45.45	65.06	44.31

	DL *	Da *	Db *	DE	
Tolerance	2.00	2.00	2.00	2.00	
	-2.00	-2.00	-2.00	0.00	
ETW 0.5% P.Orange	-0.59	-1.04	1.54	1.95	PASS

DATA - I (A)

08.Apr.91 11:23:27

Small 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

		Wl	%R	K/S	Batch Strength(%) As Is	Batch Strength(%) Adjusted
PWC 0.5%	P.ORANGE	500	7.21	5.9755		
ETW 0.5%	P.ORANGE	500	6.86	6.3255	105.86	100.00

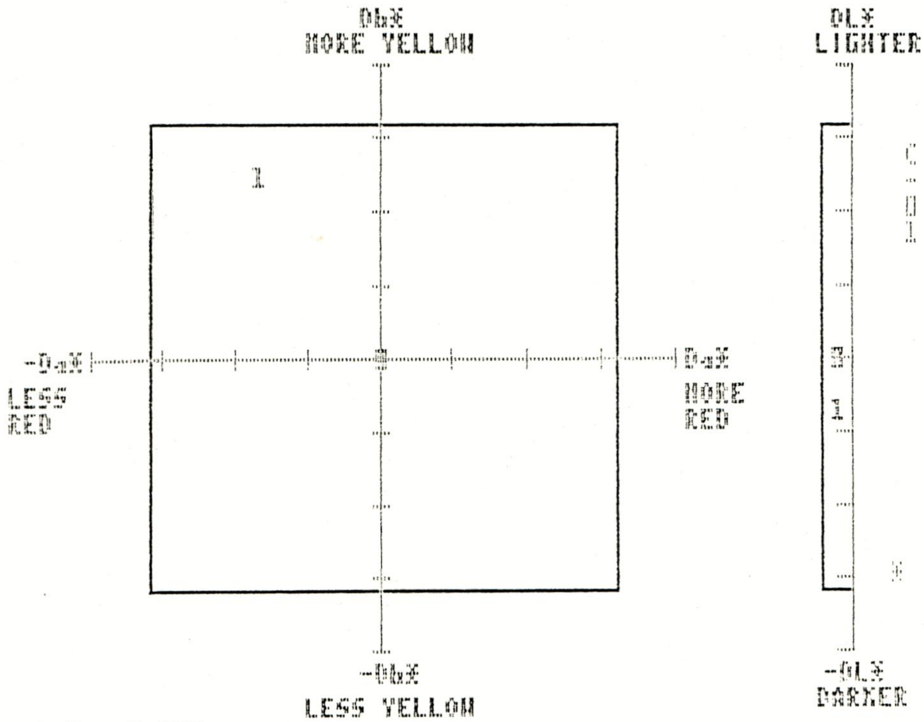
	III/Obs	DE*	DL*	Da*	Db*	DC*	DH*
'As Is'	1	1.95	-0.59	-1.04	1.54	0.30	1.84
Color	2	1.76	-0.68	-0.98	1.29	0.47	1.55
Difference	3	2.02	-0.53	-0.80	1.78	1.06	1.64
'Adjusted'	1	1.69	-0.14	-1.44	0.87	-0.45	1.62
Color	2	1.48	-0.29	-1.36	0.52	-0.38	1.40
Difference	3	1.58	-0.08	-1.14	1.09	0.30	1.55

DATA - I (B)

CIELAB L*a*b*

PASS/FAIL

D65 /10 DEG

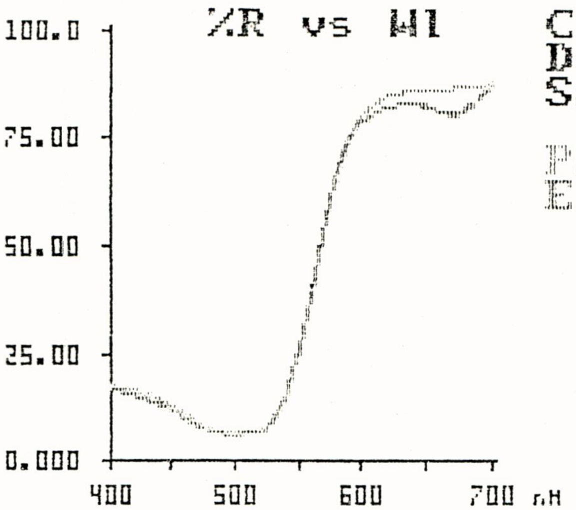


C	L	NAME
0	0	PVC .5% P.ORANGE
1	1	ETH .5% P.ORANGE

* INDICATES FAILURE

1 DIV = 0.625

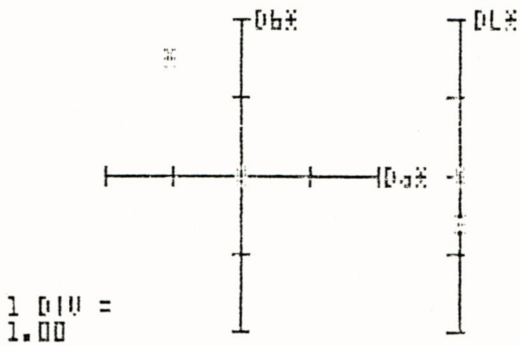
DATA - I (C)



CIELAB
D65 /10 deg
Small Area/Spec Incl

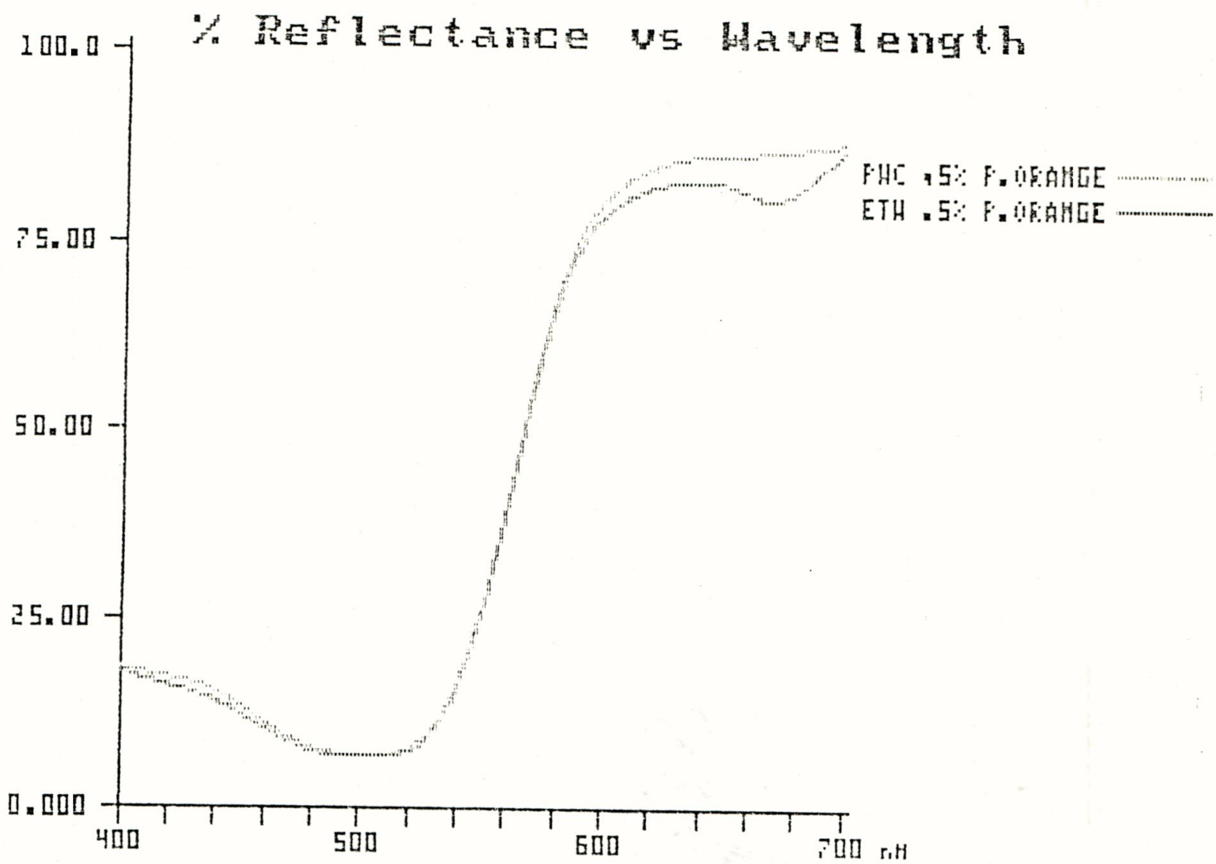
PWC .5% P.ORANGE
ETW .5% P.ORANGE

	Std	Batch
L*	67.94	67.35
a*	47.60	46.55
b*	43.91	45.45
C*	64.76	65.06
h	42.69	44.31
DL*		-0.59
Da*		-1.04
Db*		1.54
DC*		0.30
DH*		1.84
DE*		1.95



Batch Is
0.59 DARKER
1.84 MORE YELLOW
0.30 MORE SATURATED

DATA - I (D)



% Reflectance vs Wavelength
100.0
75.00
50.00
25.00
0.000
400
500
600
700 nm
PHC .5% P.ORANGE
ETH .5% P.ORANGE

Data I shows the comparison between the samples PO_1 and EO_1 dyed in 0.5 percent orange shade, using process water and effluent treated water respectively.

The "pass" value indicates that the sample EO_1 dyed in 0.5 percent orange shade using effluent treated water is much similar to sample PO_1 dyed in process water ; since the values fall within the tolerance limits, the computer analysis categorises 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 PO_1 and EO_1.

The standard (std) indicates the values for the sample PO_1 and 'batch' indicates the values of the sample EO_1.

The strength of the sample PO_1 is kept as '100' and the batch was matched to it. Accordingly it shows the value of 101.75 which falls within the tolerance limits.

A diagrammatic representation of percentage reflectance Vs wavelength was shown for both the compared samples PO_1 and EO_1.

DATA - II

08.Apr.91 11:34:53
Small Area/Spec Incl d/0
1) D65 /10 deg

PASS/FAIL

CIELAB

	III/Obs	L*	a*	b*	C*	h
PWC 4% P.ORANGE	1	55.92	60.22	63.96	87.85	46.73
ETW C4% P.ORANGE	1	55.24	58.86	63.62	86.67	47.23

	DL*	Da*	Db*	DE	
Tolerances	2.00	2.00	2.00	2.00	
	-2.00	-2.00	-2.00	0.00	
ETW C4% P.ORANGE	-0.69	-1.36	-0.34	1.56	PASS

DATA - II (A)

08.Apr.91 11:48:17

Small Area/Spec Incl d/0

1) D65 /10 deg

2) A /10 deg

3) CWF /10 deg

STRENGTH

CIELAB

Spec %R : 0.000

Int %R : 0.000

	Wl	%R	K/S	Batch Strength(%) As Is	Adjusted
PWC 4% P.ORANGE	490	2.20	21.7609		
ETW C4% P.ORANGE	490	2.16	22.1407	101.75	100.00

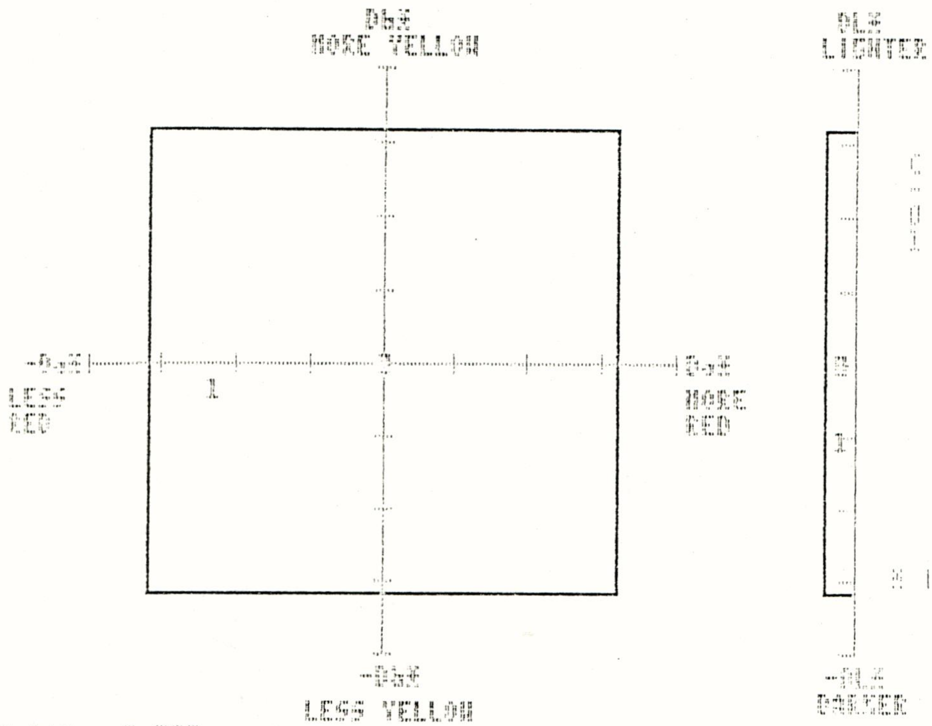
	Ill/Obs	DE*	DL*	Da*	Db*	DC*	DH*
'As Is'	1	1.56	-0.69	-1.36	-0.34	-1.18	0.76
Color	2	1.76	-0.88	-1.34	-0.73	-1.37	0.68
Difference	3	1.26	-0.63	-1.07	-0.17	-0.72	0.81
'Adjusted'	1	1.59	-0.55	-1.43	-0.43	-1.29	0.75
Color	2	1.79	-0.75	-1.40	-0.83	-1.48	0.67
Difference	3	1.26	-0.48	-1.14	-0.24	-0.18	0.83

DATA - II (B)

CIELAB L*a*b*

PASS/FAIL

D65 /10 DEG

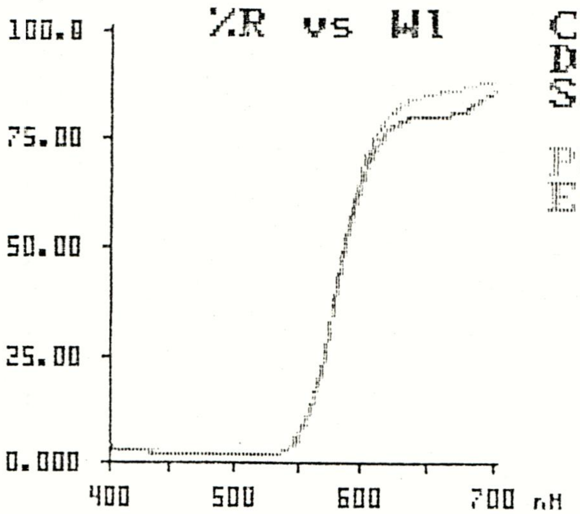


C	L	NAME
0	0	PHC 4% P.ORANGE
1	1	ETH C4% P.ORANGE

X INDICATES FAILURE

1 DIV = 0.625

DATA - II (C)

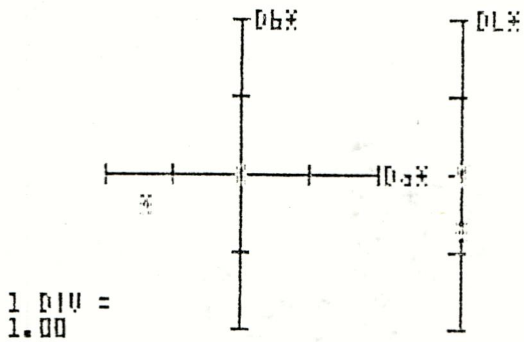


CIELAB
D65 /10 deg
Small Area/Spec Incl

PWC 4% P.ORANGE
EIW C4% P.ORANGE

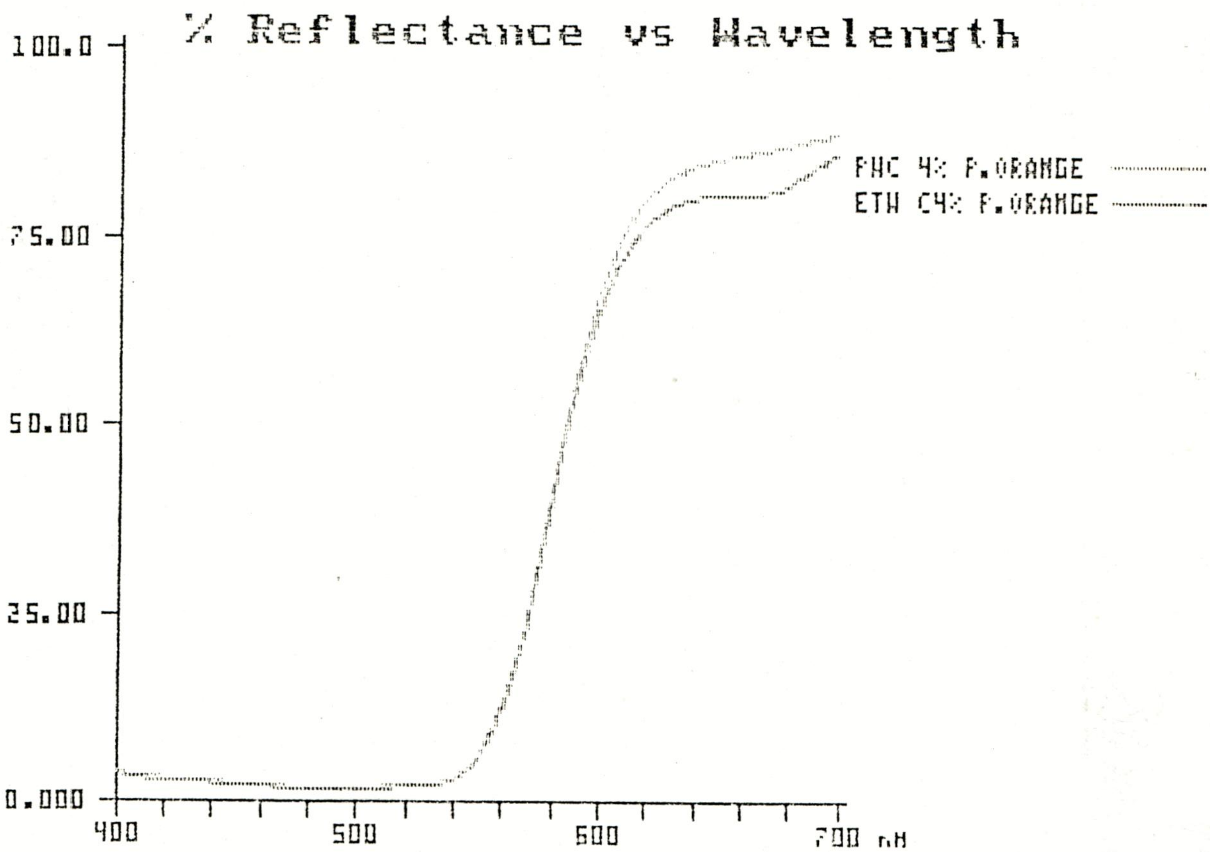
	Std	Batch
L*	55.92	55.24
a*	60.22	58.86
b*	63.96	63.62
C*	87.85	86.67
h	46.73	47.23

DL*	-0.69
Da*	-1.36
Db*	-0.34
DC*	-1.18
DH*	0.76
DE*	1.56



Batch Is
0.69 DARKER
0.76 MORE YELLOW
1.18 LESS SATURATED

DATA - II (D)


% Reflectance vs Wavelength
100.0
75.00
50.00
25.00
0.000
400
500
600
700 nM
PHC 4% P.ORANGE
ETH C4% P.ORANGE

Data II shows the comparison between the samples PO_2 and EO2 dyed in 4 percent orange shade, using process water and effluent treated water respectively.

The "pass" value indicates that the sample EO_2 dyed in 4 percent orange shade using effluent treated water is much similar to the sample PO_2 dyed in process water; since the values fall within the tolerance limits, the computer analysis categorises the compared samples as "pass".

It gives the tolerance limits in the form of graphical represntation. The square indicates the tolerance limit and the '1' sign within the square gives the value of the compared samples PO_2 and EO_2 in correlation.

The standard (std) indicates the value for the sample PO_2 and the 'batch' indicates the values of the sample EO_2.

The sample EO_2 dyed in 4 percent orange shade using effluent treated water was found to be darker, more yellow and less saturated when compared to the sample PO_2 dyed in 4 percent orange shade using process water.

The strength of the sample PO_2 was kept as '100' and the 'batch' was matched to it. Accordingly the strength of the sample EO_2 was found to be 101.75 percent.

The diagrammatic representation of percentage reflectance Vs wavelength was shown for compared samples.

DATA - III

08.Apri.91 11:52:30
Small Area/Spec Incl d/0

PASS/ FAIL
1) D65 /10 deg

CIELAB

	III/Obs	L*	a*	b*	C*	h
PWC0.5% REM BLUE	1	59.82	-3.45	-32.54	32.72	263.95
ETW0.5% REM BLUE	1	56.30	-3.21	-33.55	33.70	264.54

	DL*	Da*	Db*	DE	
Tolerances	2.00	2.00	2.00	2.00	
	-2.00	-2.00	-2.00	0.00	
ETW0.5% REM BLUE	-3.52	0.24	-1.01	3.67	FAIL

DATA - III (A)

08-APR-91 11:57:17
Small Area/Sepc Incl d/0
1) D65 /10 deg
2) A /10 deg
3) CWF /10 deg

Strength

CIELAB
Spec %R : 0.000
Int %R : 0.000

	Wl	%R	K/S	Batch Strength (%) As Is	Batch Strength (%) Adjusted
PWC .5% REM BLUE	600	17.47	1.9488		
ETW .5% REM BLUE	600	14.42	2.5394	**130.30**	100.00

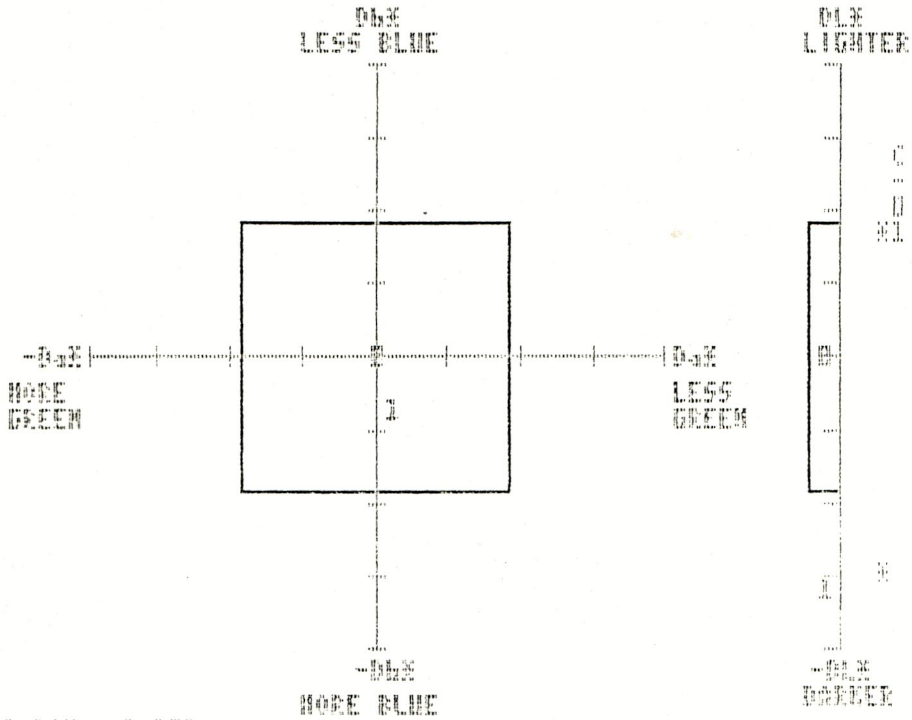
	Ill/Obs	DE*	DL*	Da*	Db*	DC*	DH*
'As Is'	1	**3.67**	-3.52	0.24	-1.01	0.98	0.34
Color	2	**3.87**	-3.66	-0.48	-1.15	1.24	-0.12
Difference	3	**3.88**	-3.64	0.22	-1.34	1.32	0.30
'Adjusted'	1	**0.84**	0.06	-0.46	0.70	-0.65	-0.54
Color	2	**0.87**	0.09	-0.34	0.80	-0.66	-0.56
Difference	3	**0.78**	0.09	-0.37	0.68	-0.65	-0.41

DATA - III (B)

CIELAB L*a*b*

PASS/FAIL

D65 /10 DEG

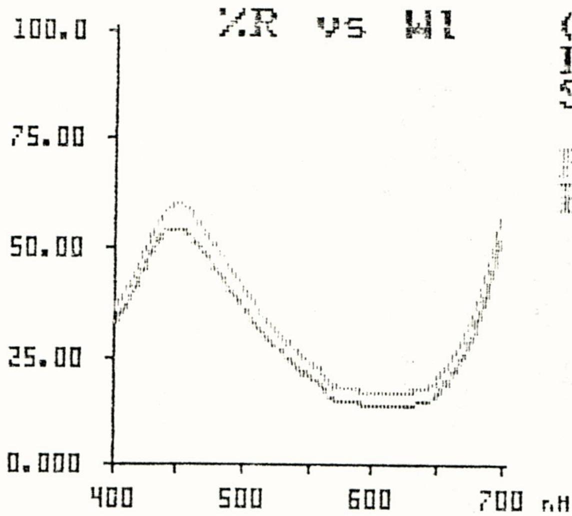


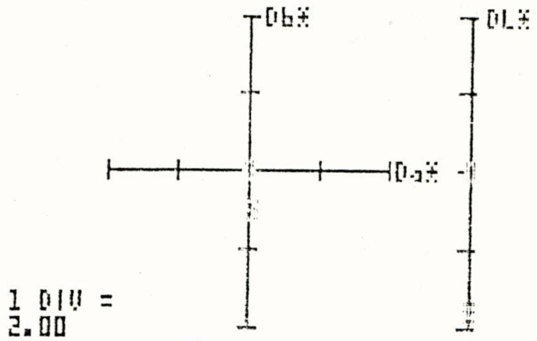
C	L	NAME
0	0	PVC .5% GEN BLUE
*1	1	ETW .5% GEN BLUE

* INDICATES FAILURE

1 DIV = 1.101

DATA - III (C)





CIELAB
D65 /10 deg
Small Area/Spec Incl

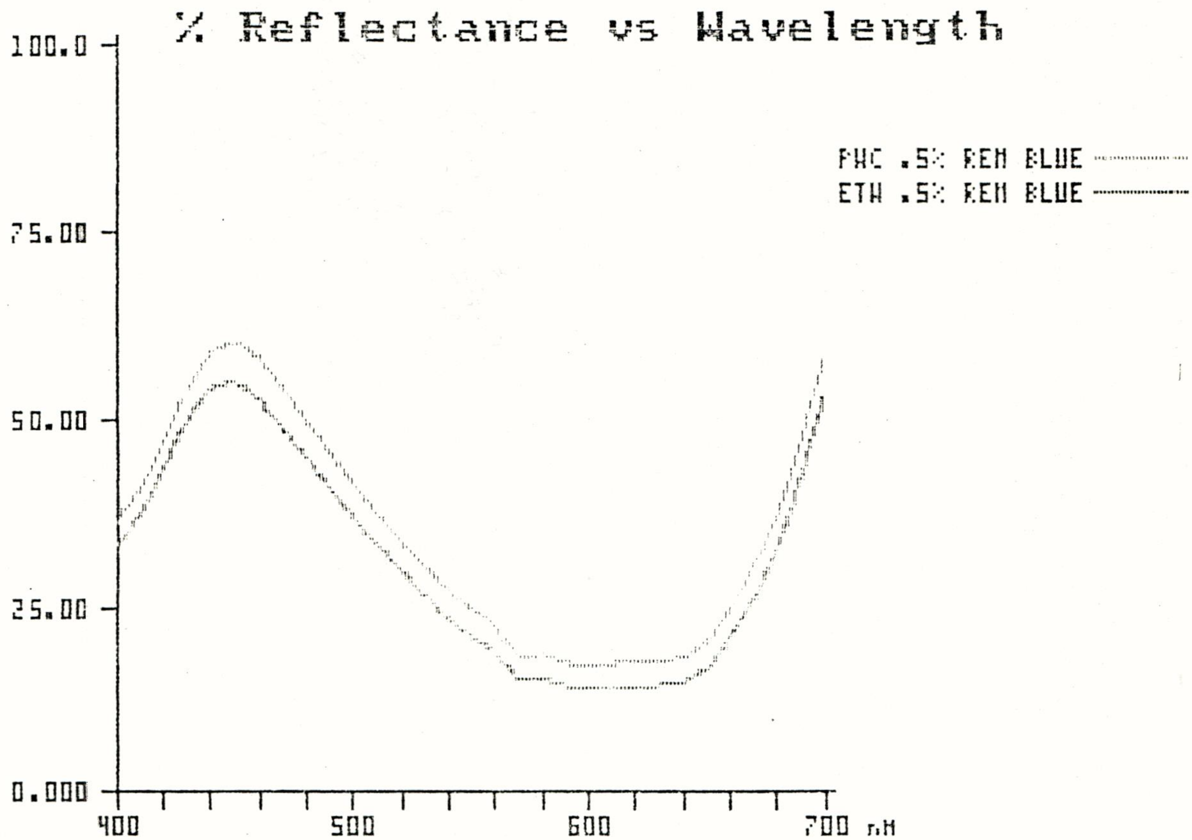
PWC .5% REM BLUE
ETH .5% REM BLUE

	Std	Batch
L*	59.82	56.30
a*	-3.45	-3.21
b*	-32.54	-33.55
C*	32.72	33.70
h	263.95	264.54

DL*	-3.52
Da*	0.24
Db*	-1.01
DC*	0.98
DH*	0.34
DE*	3.67

Batch Is
3.52 DARKER
0.34 MORE RED
0.98 MORE SATURATED

DATA - III (D)


% Reflectance vs Wavelength
100.0
75.00
50.00
25.00
0.000
400
500
600
700 nM
PHC .5% REM BLUE
ETH .5% REM BLUE

Data III shows the comparision betweem samples PB_1 and EB_1 dyed in 0.5 percent blue shade using process water and effluent treated water respectively.

The 'fail' values indicate that the sample EB_1 dyed in 0.5 percent Remazol blue shade using effluent treated water much darker than the sample PB_1 dyed in process water. The value 'fail' indicate that the sample EB_1 is much below the tolerance limit.

The graphical representation of the tolerance limits, shcw the '1' sign in the lower square and thus gives the drastic correlation of compared sample PB_1 and EB_1.

The standard (std) indicates the value of the sample PB_1 and the batch indicates the values of EB_1.

The sample EB_1 dyed in 0.5 percent blue shade using effluent treated water was found to be darker, more red and more saturated when compared to the sample PB_1 dyed in 0.5 percent blue shade using effluent treated water.

The strength of the sample PB_1 was kept as '100' percent and the 'batch' was matched to it. Accordingly the strength of the sample EB_1 was found to be as high as 130.30 percent.

The diagrammatic representation of percentage reflectance Vs wavelength was shown for the compared samples PB_1 and EB_1.

DATA - IV

08-APR-91 12:07:24
Small Area/Spec Incl d/0
1) D65 /10 deg

Pass / Fail

CIELAB

	Ill/Obs	L*	a*	b*	C*	h
PWC 4% REM BLUE	1	27.96	11.49	-41.14	42.71	285.60
ETW 4% REM BLUE	1	32.38	6.98	-38.44	39.07	280.30

	DL*	Da*	Db*	DE	
Tolerances	2.00	2.00	2.00	2.00	
	-2.00	-2.00	-2.00	0.00	
ETW 4% REM BLUE	**4.42**	**-4.51**	**2.70**	**6.87**	**FAIL**

DATA - IV (A)

08-APR-91   12:10:14
Small Area/Sepc Incl   d/0
1) D65   /10 deg
2) A   /10 deg
3) CWF   /10 deg

Strength

CIELAB
Spec %R : 0.000
Int %R : 0.000

	Wl	%R	K/S	Batch Strength (%) As Is	Batch Strength (%) Adjusted
PWC 4% REM BLUE	570	2.53	18.8047		
ETW 4% REM BLUE	570	3.62	12.8121	**68.13**	100.00

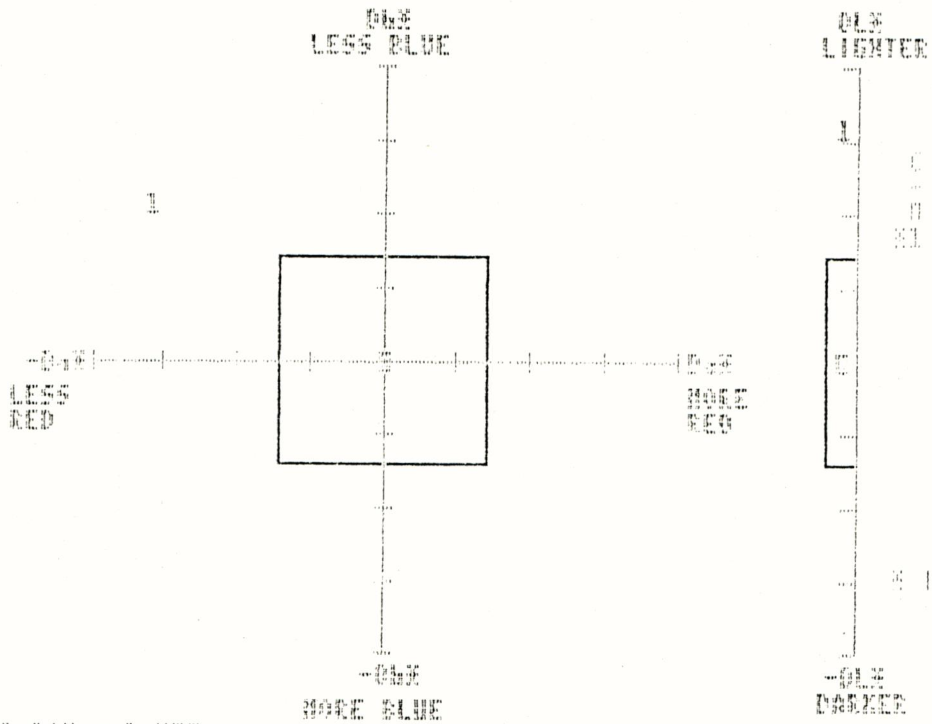
	Ill/Obs	DE*	DL*	Da*	Db*	DC*	DH*
'As Is'	1	**6.87**	4.42	-4.51	2.70	-3.65	-3.78
Color	2	**6.17**	4.50	-3.10	2.86	-2.56	-3.35
Difference	3	**6.45**	4.42	-3.89	2.62	-3.27	-3.36
'Adjusted'	1	**5.47**	-0.46	-3.60	4.09	-4.83	-2.5[illegible]
Color	2	**5.00**	-0.24	-2.20	4.48	-4.28	-2.57
Difference	3	**5.31**	-0.30	-3.13	4.28	-4.79	-2.28

DATA - IV (B)

CIELAB L*a*b*

PASS/FAIL

D65 /10 DEG

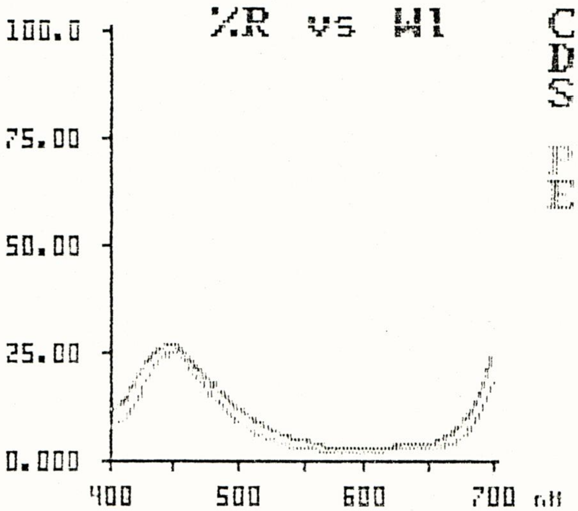


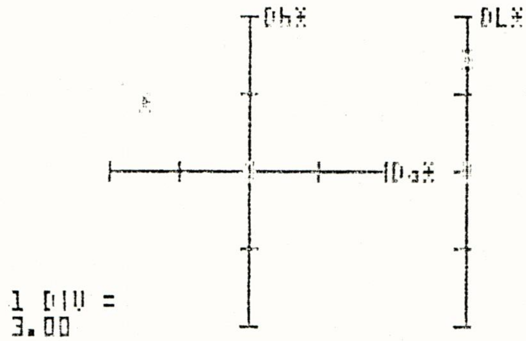
C	I	NAME
0	0	PAC 4% REM BLUE
*1	1	ETH 4% REM BLUE

* INDICATES FAILURE

1 DIV = 1.400

DATA - IV (C)





CIELAB
D65 /10 deg
Small Area/Spec Incl

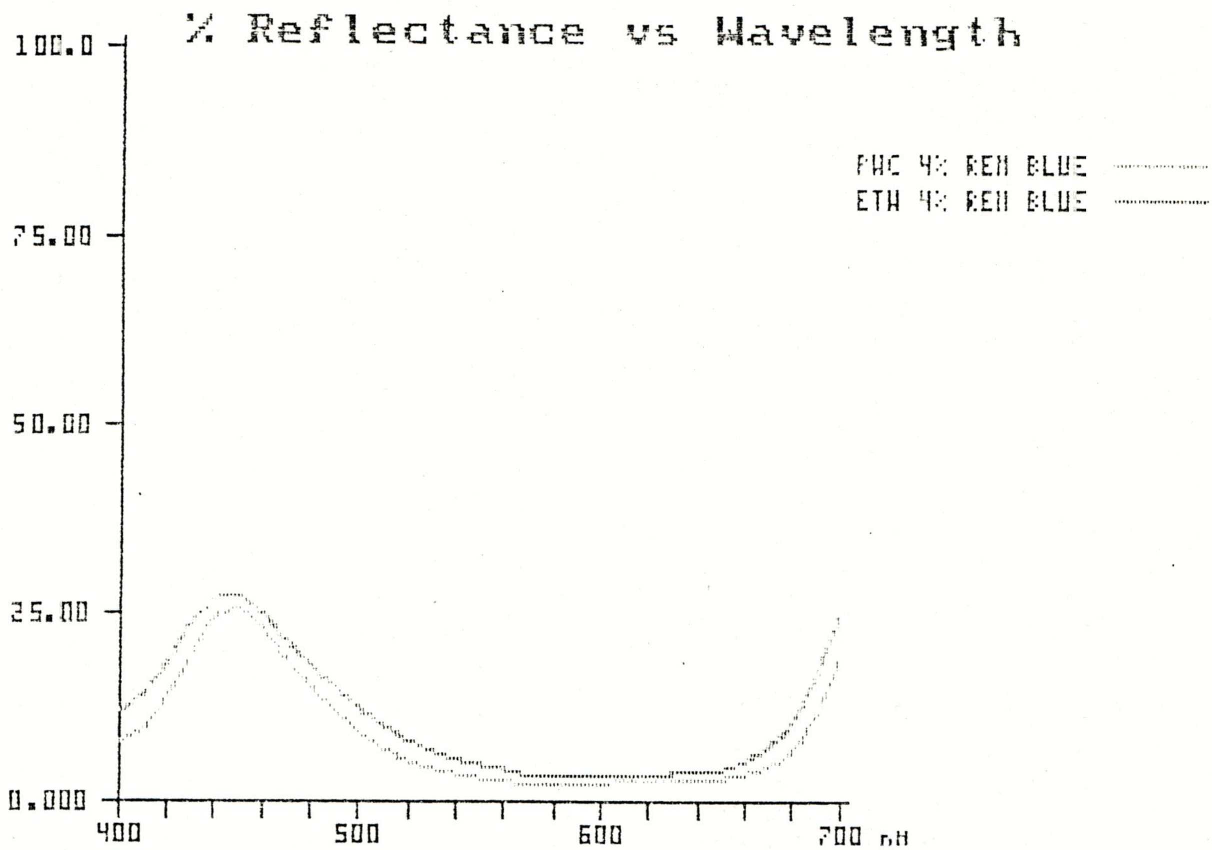
PWC 4% REM BLUE
ETW 4% REM BLUE

	Std	Batch
L*	27.96	32.38
a*	11.49	6.98
b*	-41.14	-38.44
C*	42.71	39.07
h	285.60	280.30

DL*	4.42
Da*	-4.51
Db*	2.70
DC*	-3.65
DH*	-3.78
DE*	6.87

Batch Is
4.42 LIGHTER
-3.78 MORE GREEN
3.65 LESS SATURATED

DATA - IV (D)


% Reflectance vs Wavelength
100.0
75.00
50.00
25.00
0.000
400
500
600
700 nm
PHC 4% REN BLUE
ETH 4% REN BLUE

Data IV shows the comparision between samples PB_2 and EB_2 dyed in 0.5 percent blue shade using process water and effluent treated water respectively.

The 'fail'values indicate that the sample EB_2 dyed in 0.5 percent Remazol blue shade using effluent treated water was not similar to the sample PB_2 dyed in process water. The 'fail' indicates that the sample EB_2 is not within the tolerance limits at all.

The graphical representation of tolerance limit, show that the '1' sign is away from the square and thus exhibits the dinimilarity of the two samples PB_2 and EB_2.

The standard (std) indicates the value of the sample PB_2 and the batch indicates the values of the sample EB_2.

The sample EB_2 dyed in 4 percent blue shade using effluent treated water was found to be lighter, more gren and less saturated when compared to the sample PB_2 dyed using process water.

The strength of the sample PB_2 was kept at 100 percent and the batch was matched to it. Accordingly the strength of the sample EB_2 was found to be as low as 68.13 percent.

The diagrammatic representation of the percentage reflectance Vs wavelength was given.

DATA - V

08-APR-91 12:36:07
Small Area/Spec Incl d/0
1) D65 / 10 deg

AATTCC Gray Scale

	Ill/Obs	Value
WHITE 40s	1	
PWC .5% P. ORANGE	1	3-4
PWC 4% P. ORANGE	1	3-4
PWC 0.5% REM BLUE	1	5
PWC 4% REM BLUE	1	3
ETW 0.5% P. ORANGE	1	2
ETW 4% P. ORANGE	1	1-2
ETW 0.5% REM BLUE	1	2
ETW 4% REM BLUE	1	1-2

*** INDICATES FACTORS OUT OF RANGE

DATA - V(A)

08-APR-91 12:41:26
Small Area/Spec Incl d/o

Strength

Spec %R : 0.000
Int %R : 0.000

White 40s	Wl	%R	K/S	Batch Strength (%)	
	420	84.51	0.0142	As is	Adjusted
PWC 0.5% P. Orange	420	79.20	0.0273	192.36	100.00
PWC 4% P.Orange	420	83.73	0.0158	111.28	100.00
PWC .5% Rem Blue	420	83.70	0.0159	111.78	100.00
PWC 4% Rem Blue	420	83.18	0.0170	119.74	100.00
ETW .5% P.Orange	420	76.44	0.0363	255.57	100.00
ETW 4% P.Orange	420	75.67	0.0391	275.30	100.00
ETW .5% Rem Blue	420	80.56	0.0235	165.12	100.00
ETW 4% Rem Blue	420	73.14	0.0493	347.23	100.00

DATA - V(B)

08-APR-91 12:43:29
Small Area/Sepc Incl d/o
1) D65 / 10 deg

Pass/Fail

CIELAB
WHITE 40s

	DL*	Da*	Db*	DE	
Tolerances	1.00 -1.00	1.00 -1.00	1.00 -1.00	1.00 0.00	
PWC .5% P. ORANGE	**-1.02**	0.80	**1.83**	**2.24**	**FAIL**
PWC 4% P. ORANGE	**-1.05**	**2.58**	0.04	**2.78**	**FAIL**
PWC .5% REM BLUE	-0.37	-0.09	-0.12	0.40	PASS
PWC 4% REM BLUE	1.96	0.23	**-2.24**	**2.99**	**FAIL**
ETW .5% P. ORANGE	**-4.89**	**5.61**	**-1.40**	**7.58**	**FAIL**
ETW 4% P. ORANGE	**-5.67**	**7.54**	-0.72	**9.47**	**FAIL**
ETW .5% REM BLUE	**-4.31**	**3.82**	**-3.52**	**6.75**	**FAIL**
ETW 4% REM BLUE	**-8.63**	0.99	**-5.60**	**10.33**	**FAIL**

Data V shows the spectro analysis of washing test. The dyed samples using process water shows ranges of values as PO_1 = 3 - 4 PO_2 = 3-4, PB_1 = 5, PB_2 = 3, but in comparison the dyed samples using effluent treated water show EO_1 = 2, EO_2 = 1-2, EB_1 = 2 and EB_2 = 1-2. Therefore this test infers that the dye samples using effluent treated water showed very poor colour fastness to washing when compared to samples dyed using process water.

CHAPTER V

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

Textile mills need large quantities of water for different purposes. One such is dyeing. The reuse of water in the dye-industry is therefore of great concern. This study was conducted in order to find out if recycled dye effluent can be put to use in the textile industry.

The study revealed that dye effluents after alum treatments, showed decreased values within the tolerance limits for general parameters like potential hydrogenii, Biochemical Oxygen Demand, Chemical Oxygen Demand, Total Dissolved Soils and Total Suspended Solids.

All but one sample dyed in effluent treated water showed eveness in dyeing during the visual inspection test and this could be attributed to improper dyeing. Samples dyed in 4% dyestuff were uniformly judged to be brilliant while the samples dyed in 0.5% dyestuff were only judged as bright due to lower concentration of dyestudy..

Since 20's mercersied cotton was used, the samples were found to be coarse as rated by the judges.

Except the sample dyed in 4% blue shade ETW, the rest of the dyed samples were judged as good in the General Appearance Test. In the same test, the samples dyed in 0.5% dyestuff were rated as medium.

All the dyed samples except the sample dyed in 4% blue shade, using effluent treated water, were more or less alike in all respects.

Significant difference was found between original and dyed samples. No significant difference was found between original and sample which were dyed in 4% orange shade in process water and also among dyed samples in the bursting strength test.

The abrasion resistance test showed that there was no significant difference between original and dyed samples and also between the compared samples.

There was highly significant difference between original and dyed samples in the test to determine the fabric weight. Among the dyed samples there was no significant difference except between the samples dyed in 4% orange shade.

Regarding fabric thickness there was significant difference between the original and dyed samples but no significant difference among the samples itself.

In the wettability and absorbency tests a drop test revealed no significant difference between original and samples dyed in 0.5% orange shade process water but significant difference between original and other dyed samples. Only, the samples dyed in 0.5% blue shade showed significant difference between those dyed in process water and those in effluent treated water.

Regarding the sinking test, significant difference was seen between original and dyed samples and also between the dyed samples itself though there was no significant difference between samples dyed in 4% blue shade using process water and effluent treated water.

CONCLUSION

To conclude samples dyed in effluent treated water were found to be as good as the samples dyed in process water in all respects such as fabric weight, fabric thickness, abrasion resistance, bursting strength, wettability and absorbency and colour fastness. The samples dyed in effluent treated water did not match the standards of those dyed in process water, only with regard to the washing test for colour fastness.

The study therefore revealed that the dye effluent after undergoing treatment can be utilised in the dyeing units of the textile mills for dyeing purpose thereby effecting pollution control and promoting water conservation and waste recycling.

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APPENDICES

APPENDIX - I

DETAILS OF SELECTED MATERIAL

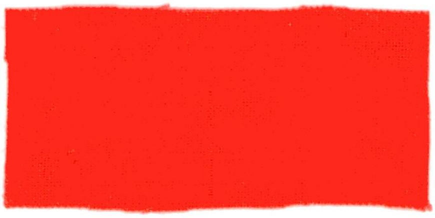
100 Percent Cotton.

Width - 127 Cm.

Weave - Plain weave.

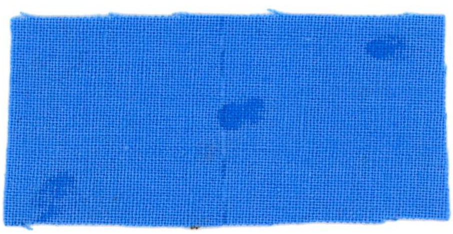
Cost - Rs. 14.00/metre.

PROCESS WATER

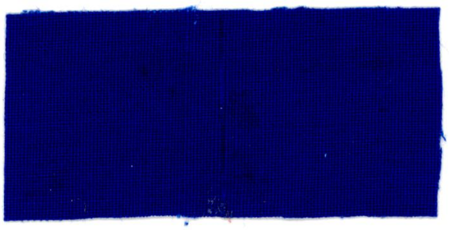


0.5 % PO_1

4 % PO_2

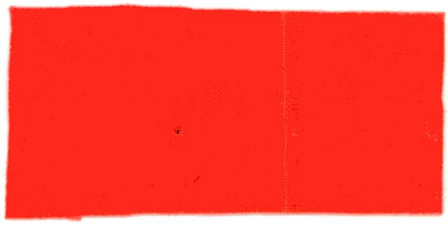


0.5 % PB_1

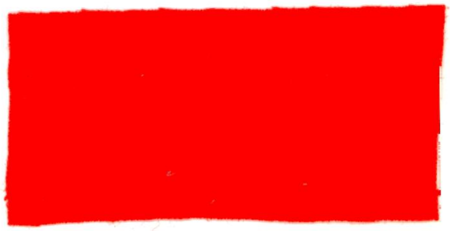


4 % PB_2

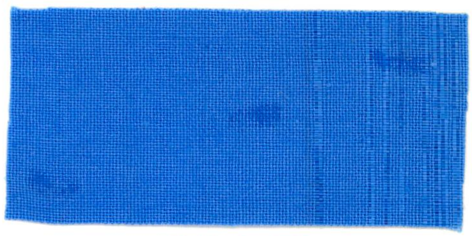
EFFLUENT TREATED WATER



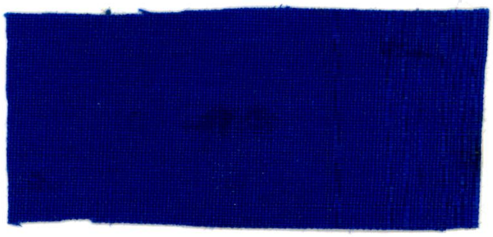
0.5 % EO_1



4 % EO_2



0.5 % EB_1



4 % EB_2

PROCESS WATER

PO_1 0.5% ORANGE SHADE

PO_2 4% ORANGE SHADE

PB_1 0.5% BLUE SHADE

PB_2 4% BLUE SHADE

EFFLUENT TREATED WATER

EO_1 - 0.5% ORANGE SHADE

EO_2 - 4% ORANGE SHADE

EB_1 - 0.5% BLUE SHADE

EB_2 - 4% BLUE SHADE

APPENDIX - II

METHOD OF REACTIVE DYEING

Particulars	Shade : Dye % Gm.	
	0.5 %	4%
1. Weight of the Material	60 gm.	60 gm.
2. Weight of the dye powder		
(Pr. Org. M_2 R)	300 mg.	2.4 gm.
3. Water Bath	240 ml.	300 ml.
4. Salt	18 gm.	30 gm.
5. Soda Ash	4.5 gm.	7.5 gm.
6. Time	1 Hour	1 Hour
7. Material liquor ratio	1:5	1:5
8. Temperature	Room temp.	Room temp.

REMAZOL METHOD

1. Weight of the Material	75 gm.	80 gm.
2. Weight of the dye powder		
(NAV Blue RN)	375 mg.	3.2 gm.
3. Water Bath	375 ml.	400 ml.
4. Salt	18.75 gm.	30 gm.
5. Soda Ash	1.875 gm.	2.5 gm.
6. Caustic	0.56 gm.	0.8 gm.
7. Temperature	60°	60°
8. Time	1 Hour	1 Hour
9. Material liquor ratio	1:5	1:5

PREPARATION OF DYEBATH

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 samples were 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 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 bolied in soap solution for three minutes and rinsed thoroughly in cold water, dried and pressed well.

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

APPENDIX - III

DESCRIPTION OF pH METER

pH meter employs 2 electrodes, an indicator glass electrode, and calomel reference electrode, while others may have combined glass and reference electrodes, operated by battery. pH scale ranges from 0 to 14 with 5.5 as neutral ,below 3.5 being acidic and above 5.5 as alkaline.

APPENDIX - IV

PROCEDURE FOR CHEMICAL OXYGEN DEMAND (COD)

In a 500 ml refluxing flask, 20ml of sample was taken, one gram of mercuric sulphate, 3-4 glass beads anbd 10 ml of potassium dichromate solution (0.25 N) were added. A pinch of silver sulphate was added to the contents in the flask and mixed thoroughly. While mixing to disolve 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 the reading was noted down for blank also. To get concordant values same procedure was repeated.

PROCEDURE FOR PREPARING THE REAGENTS AND THE FORMULA FOR CALCULATING THE CHEMICAL OXYGEN DEMAND (COD)

Preparation of Reagents

1. Standard Potassium dichromate solution (0.25 N)

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

2. Sulphuric acid

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

3. Ferroin Indicator

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

4. Ferrous Ammonium sulphate Titrant (0.25 N)

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

Standardisation of Ferrous Ammonium Sulphate

Diluted 10ml standard Potassium dichromate to 100ml, added 30ml concentrated sulphuric acid and titrated it with Ferrous Ammonium Sulphate using ferroin indicator.

5. Mercuric sulphate

6. Silver sulphate

Formula for calculating COD

$$\text{COD, mg/1} = \frac{(A - B) \times N \times 8000}{\text{ml of sample}}$$

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 - V

PROCEDURE FOR BIOCHEMICAL OXYGEN DEMAND (BOD)

In one litre water, 1ml 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 trough 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 BIOCHEMICAL OXYGEN DEMAND THE DYE EFFLUENT

Range of BOD mg/1 O_2	Dilution (%)	Sample Volume in 1 litre of mixture
0 - 6	No dilution	1000
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 8.5g pottassium bi phosphate, 21.75g Dipotassium hydrogen phosphate, 33.4g Disodium hydrogen phosphate and 1.7g Ammonium chloride. Adjusted pH to 7.2.

2. Magnesium sulphate

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

3. Calcium chloride

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

4. Ferric chloride

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

5. **Sodium sulphite solution (0.025 N)**

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

Formula used for calculating BOD

$$\text{BOD, mg/1} = \frac{(D_1 - D_2) - (B_1 - B_2)}{P}$$

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 - VI

PREPARATION OF ASBESTOS MAT IN THE GOOCH CRUCIBLE FILTRATION METHOD

In a 250ml beaker, 10gms of good quality asbestos with 100ml of distilled water was taken & stirred well. Decanted the supernatant water containing the impurities of asbestos. This process was repeated nearly ten times and then 1000ml of distilled water was added & mixed the contents thoroughly. Only 25ml of asbestos solution was taken in a Gooch crucible & this was dried by applying suction. The crucible was placed in an oven at 105°c.

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 vacuum and that was used in the preparation of the mat. The contents 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 - VII

PROCEDURE FOR TOTAL DISSOLVED SOLIDS (TDS)

Required volume of sample was filtered through a filter paper and this evaporated in a China dish on a water bath. The residue was dried in an oven at $105^{\circ}c$. The increase in weight of the dish was noted. This gives the value of the disolved solids. The same procedure was repeated to get concordant value.

FORMULA USED FOR CALCULATING THE TOTAL DISSOLVED SOLID (TDS)

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

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 - VIII

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	-	-	-	-
2	400	Slight floes 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 - IX

GRAY SCALE USED TO EVALUATE THE DYED MATERIALS

The dyed materials were rated using the 'AATCC' (American Association of Textile colourists and chemical gray scale to measure the extent of colour change and staining. The gray ratings envisaged the following standards for colour fastness to reactive dyes applied on cotton 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 - X

EVALUATION OF DYED SAMPLES

S.No.	Sample	Eveness in Dyeig		Brilliancy in Colour			Texture		Lustre			General Appearance		
		Even	Uneven	V.Bright	Bright	Dull	Smooth	Coarse	High	Med	Low	Good	Fair	Poor
		%	%	%	%	%	%	%	%	%	%	%	%	%

APPENDIX - XI

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 followes :

"t" tests were conducted whenever necessary to check if the results were significant using the formula

$$t = \frac{x_1 - x_2}{s} \text{ X } \frac{n_1 n_2}{n_1 + n_2}$$

Where

x_1 = mean of the final sample

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

$$s = \frac{(x_1 - x_1)^2 + (x_2 - x_2)^2}{n_1 + n_2 - 2}$$