# CHAPTER – III
# METHODOLOGY

The present study entitled **"Impact of Bioscouring Pretreatment on the Quality of Cotton and Polyester/Cotton Blended Fabrics"** was conducted in the following manner. A glimpse of which is depicted by means of schematic layout in **Tables: 11, 12, 13 & 14.**

## 3.1 MATERIALS

3.1.1 **Fabrics:** 100% grey Cotton and 61:39 Polyester / Cotton blended fabrics were selected in the present study. These fabrics were procured from – M/s Praffulchandra M. Shah, Dadar, Mumbai. The specifications are as follows: **(Table: 5)**

| Sl. No | Fabric type | Weave | Fabric count (Ends X Picks) | Yarn Count (Ne) (Warp X Weft) | GSM of the fabric ($g/m^2$) |
|---|---|---|---|---|---|
| 1 | 100% Grey Cotton woven fabric | Plain | 93 X 83 | $34^s$ X $43^s$ | 122.02 ≈ 122 |
| 2 | 61:39 Grey Polyester / Cotton woven blended fabric | Plain | 66 X 54 | $28^s$ X $31^s$ | 103.02 ≈ 103 |

**3.1.2 Chemicals & Auxiliaries:** During conventional preparatory process, the following Analar grade chemicals were used: **(Table: 6)**

| Sl. No. | Chemical & auxiliaries |
|---|---|
| 1. | Hydrogen Peroxide ($H_2O_2$) |
| 2 | Sodium Silicate ($Na_2SiO_3.5H_2O$) |
| 3. | Sodium Hydroxide (NaOH) |
| 4. | Wetting agent |
| 5 | Sodium Sulphate ($Na_2\ SO_4$) |
| 6 | Trisodium Phosphate (TSP) |
| 7 | Soap solution |

**3.1.3 Enzymes selected for the study: (Table: 7)**

| Sl.No | Name of the Enzymes | Manufacturer |
|---|---|---|
| 1 | Microbiological treatment: 100% microbial consortium | Developed and maintained at CIRCOT under anaerobic condition |
| 2 | Diastase | Commercial enzyme |

### 3.1.3 Commercial Dyes selected for the study:

- 100% Grey Cotton plain woven fabrics: **(Table: 8a)**

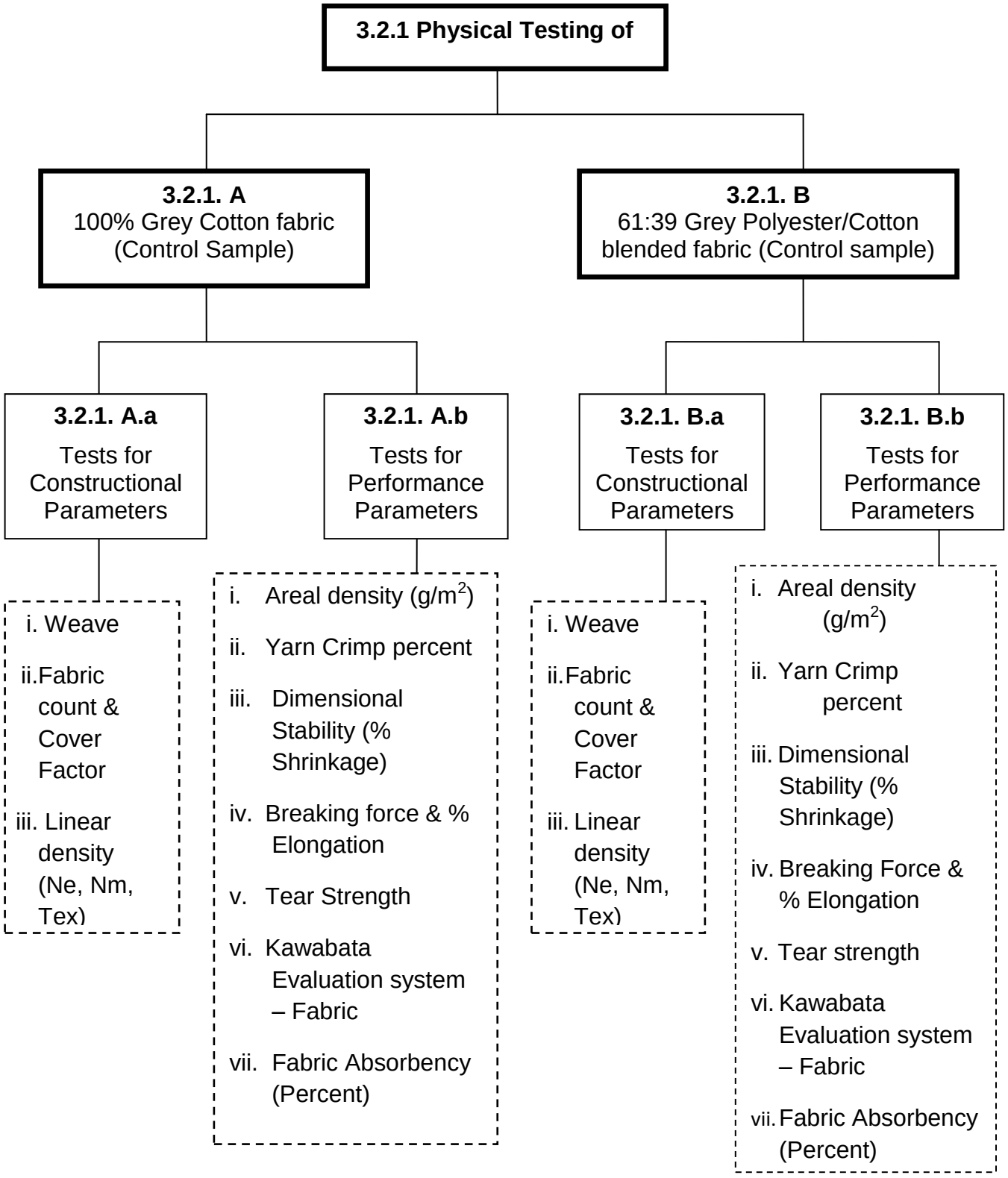
| Sl.No. | Commercial name | Colour Index name | Group | Manufacturer |
|---|---|---|---|---|
| 1 | Reactive dye | Reactofix (Navy Blue) | H E brand | Jaysynth Dyechem Ltd |

- 61:39 Grey Polyester/Cotton blended plain woven fabrics: **(Table: 8b)**

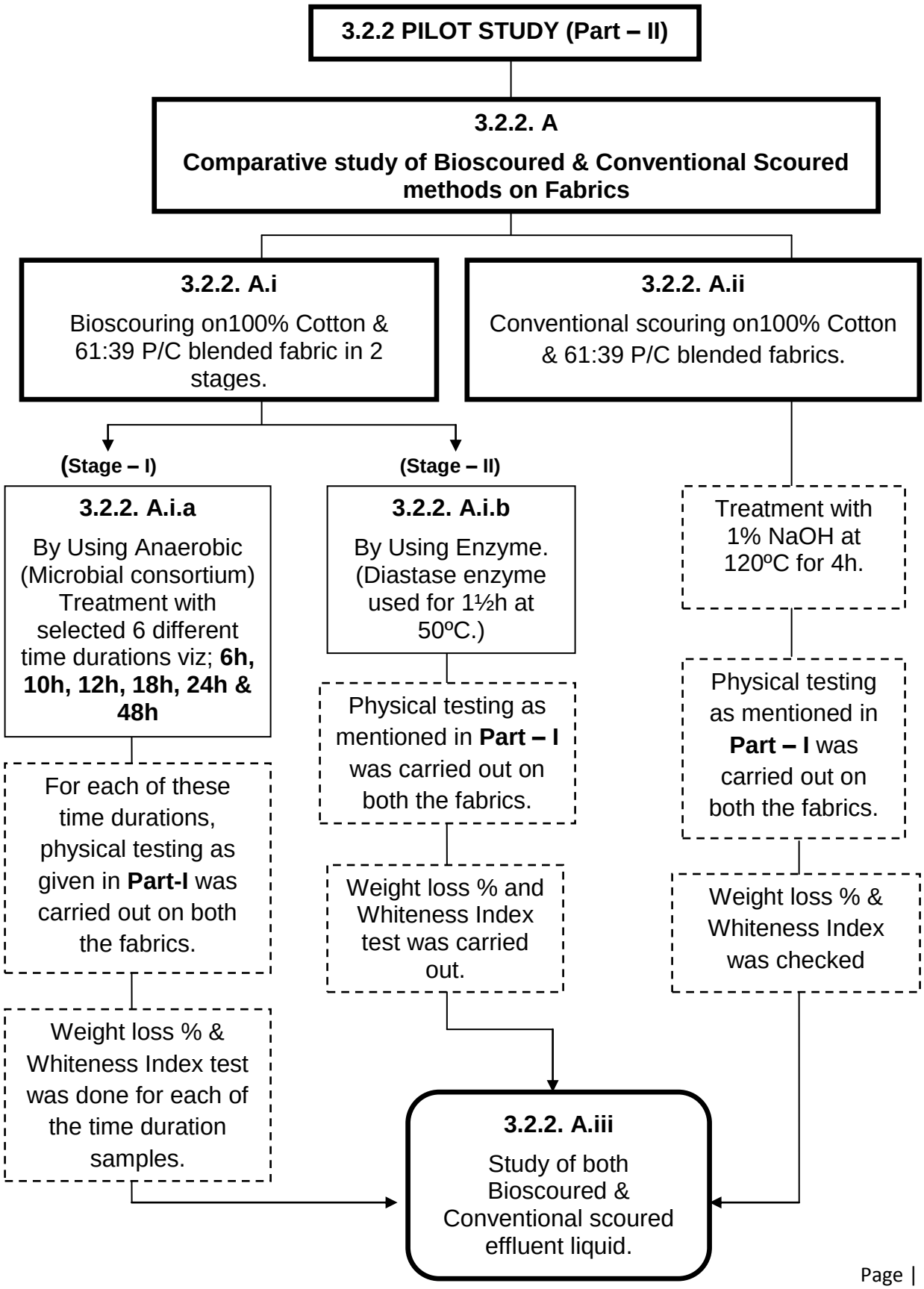
| Sl.No. | Commercial name | Colour index name | Group | Manufacturer |
|---|---|---|---|---|
| 1. | Disperse dye | Terenix (Navy Blue) | H E brand | Jaysynth Dyechem Ltd |
| 2. | Reactive dye | Reactofix (navy blue) | H E brand | Jaysynth Dyechem Ltd |

## 3.2 SCHEMATIC LAYOUT OF THE EXPERIMENTAL WORK (Part – I)

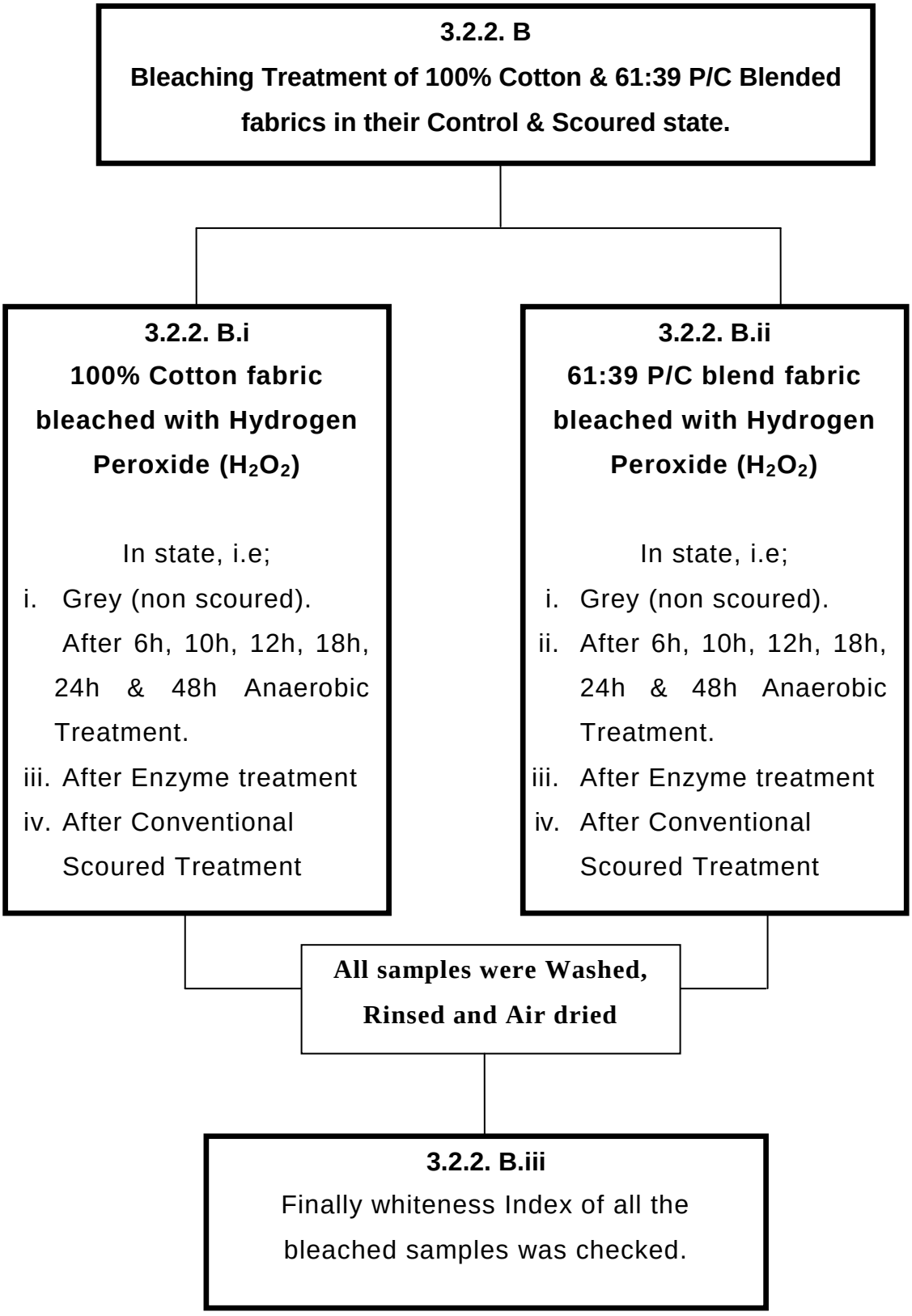
**(Table: 9)**



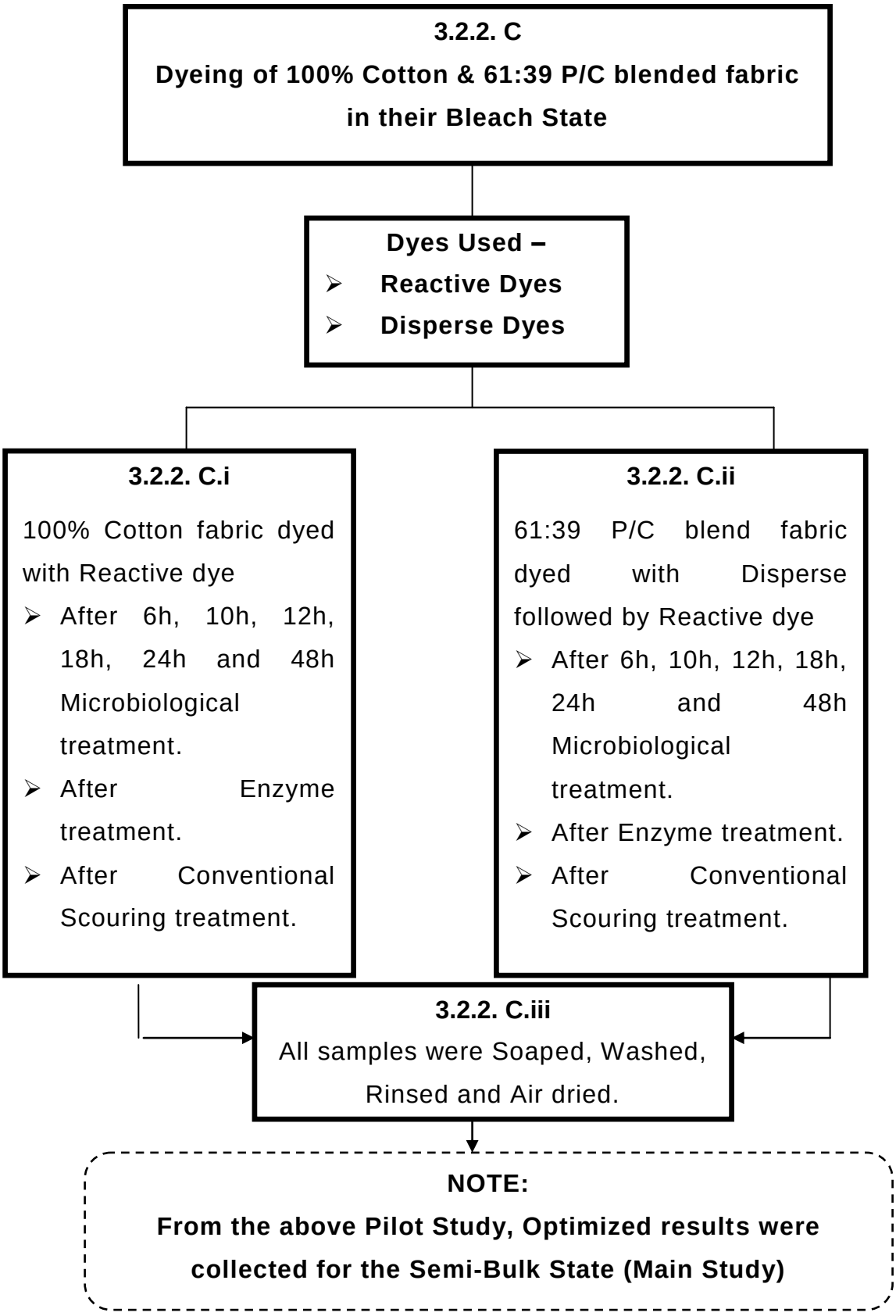
**(Table: 10)**


3.2.2 PILOT STUDY (Part – II)
3.2.2. A
Comparative study of Bioscoured & Conventional Scoured methods on Fabrics
3.2.2. A.i
Bioscouring on100% Cotton & 61:39 P/C blended fabric in 2 stages.
3.2.2. A.ii
Conventional scouring on100% Cotton & 61:39 P/C blended fabrics.
(Stage – I)
(Stage – II)
3.2.2. A.i.a
By Using Anaerobic (Microbial consortium) Treatment with selected 6 different time durations viz; 6h, 10h, 12h, 18h, 24h & 48h
3.2.2. A.i.b
By Using Enzyme. (Diastase enzyme used for 1½h at 50ºC.)
Treatment with 1% NaOH at 120ºC for 4h.
For each of these time durations, physical testing as given in Part-I was carried out on both the fabrics.
Physical testing as mentioned in Part – I was carried out on both the fabrics.
Physical testing as mentioned in Part – I was carried out on both the fabrics.
Weight loss % & Whiteness Index test was done for each of the time duration samples.
Weight loss % and Whiteness Index test was carried out.
Weight loss % & Whiteness Index was checked
3.2.2. A.iii
Study of both Bioscoured & Conventional scoured effluent liquid.

**(Table no: 11)**


3.2.2. B
Bleaching Treatment of 100% Cotton & 61:39 P/C Blended fabrics in their Control & Scoured state.
3.2.2. B.i
100% Cotton fabric bleached with Hydrogen Peroxide ($H_2O_2$)
In state, i.e;
i. Grey (non scoured).
After 6h, 10h, 12h, 18h, 24h & 48h Anaerobic Treatment.
iii. After Enzyme treatment
iv. After Conventional Scoured Treatment
3.2.2. B.ii
61:39 P/C blend fabric bleached with Hydrogen Peroxide ($H_2O_2$)
In state, i.e;
i. Grey (non scoured).
ii. After 6h, 10h, 12h, 18h, 24h & 48h Anaerobic Treatment.
iii. After Enzyme treatment
iv. After Conventional Scoured Treatment
All samples were Washed, Rinsed and Air dried
3.2.2. B.iii
Finally whiteness Index of all the bleached samples was checked.

**(Table no: 12)**


3.2.2. C
Dyeing of 100% Cotton & 61:39 P/C blended fabric in their Bleach State
Dyes Used –
Reactive Dyes
Disperse Dyes
3.2.2. C.i
100% Cotton fabric dyed with Reactive dye
After 6h, 10h, 12h, 18h, 24h and 48h Microbiological treatment.
After Enzyme treatment.
After Conventional Scouring treatment.
3.2.2. C.ii
61:39 P/C blend fabric dyed with Disperse followed by Reactive dye
After 6h, 10h, 12h, 18h, 24h and 48h Microbiological treatment.
After Enzyme treatment.
After Conventional Scouring treatment.
3.2.2. C.iii
All samples were Soaped, Washed, Rinsed and Air dried.
NOTE:
From the above Pilot Study, Optimized results were collected for the Semi-Bulk State (Main Study)

**In the present investigation, the Methodology was divided into Two Parts –**

- **3.2.1** - Part – I: Physical Testing of 100% Cotton and 61:39 Polyester/Cotton Blended Plain Woven fabrics (Control Samples).
- **3.2.2** - Part – II: Pilot Study on Comparative study of Bioscoured and Conventional Scoured methods on Fabrics.

**3.1.4 Fabrics:** The fabrics selected for the study was 100% Cotton and Polyester/Cotton Blended (61:39) grey woven fabric. This fabric was procured from wholesale dealer M/s. Praffulchandra M. Shah, Dadar, Mumbai. **Total 50 metres** of each quality of fabric was procured (i.e. 50 meters of 100% Cotton and 50 metres of Polyester/Cotton blended fabric).

**3.2.1. A & B - Physical Parameters of the grey fabric (Control):** The 100% Cotton and Polyester/Cotton blended (61:39) woven grey fabric was tested for various physical parameters. These physical parameters were further classified into – Constructional Parameters and Performance Parameters.

**3.2.1. A.a & B.a Constructional Parameters** for 100% Cotton and Polyester/Cotton blended (61:39) woven grey fabric respectively. Bureau of Indian Standard was used as the basis for comparison. Some of the test procedure was also followed as per the methods detailed in Hand Book of Tests method. The following standards were followed to determine the physical parameters of the Grey fabrics:

**3.2.1.A.a.i & B.a.i** Determined the weave analysis of 100% Cotton and Polyester/Cotton blended (61:39) woven fabrics respectively. The weave of both the fabrics were analyzed through pick glass and it was observed that both the fabrics were plain woven fabrics.

**3.2.1. A.a.ii & B.a.ii** (IS: 1963 : 1981) Determination of Threads per Unit Length for 100% Cotton and Polyester/Cotton blended (61:39) woven fabrics.

The standard prescribed methods for determination of warp per unit length and weft per unit length in woven fabrics were used. The methods are applicable to all textile fabrics irrespective of their composition (i.e. whether they are made of cotton, wool, silk, jute, man-made fibres or blends of two or more such fibres) manufacturing processes and finishing treatments. The two methods for determination of warp threads and weft threads per unit length in woven fabric as per the standard are: Method – A: By Traversing Thread Counter and Method – B: By Dissection of fabric.

For the present study, Method - A: Traversing Thread Counter was applied. The number of readings taken was 10 from all over the fabric and the results were expressed in inches. Averaged all the observed values and noted the values so obtained as the number of warp and weft threads per inch.

The fabric was laid on a flat table and smoothened it out. Placed the counting glass with the pointer at zero on the piece in such a way that on turning the screw the pointer moved in a direction parallel or perpendicular to warp threads, depending upon which set of threads (warp or weft) being counted and the pointer coincided either with the right hand or left hand edge of the thread, depending on whether the counting is started from right to left or from left to right direction. Counting same set of warp and weft threads more than once should be avoided.

**3.2.1. A.a.iii & B.a.iii** (IS: 3442: 1980) Method for determination of Count of yarn (Linear Density) removed from fabrics.

The standard prescribed a method for determination of Count of yarn removed from any textile fabric in which yarns were intact and can be removed in measureable length.

The test specimen was conditioned under standard atmospheric condition. This parameter helps in determining the universal count, i.e. In Tex and also the Indirect Count ($N_e$) of the yarn removed from the fabric. The 10 yarns of 200mm length was removed from the fabric in both the direction of the yarn (i.e.10 yarn warp way & 10 yarn weft way). The mass of 10 yarns from each direction were determined in milligram. Total 3 readings were taken of the mass of yarns and average of 3 was found. The data thus obtained determined the approximate universal count of the yarn in Tex was calculated by the following formula:

$$\textbf{Universal count in Tex} = \frac{M}{L}$$

Where,

L = Total length in millimeters of the yarns, and

M = Total mass in milligrams of 10 yarn (either warp yarn or weft yarn).

The yarn count was also expressed in the Indirect system ($N_e$). The following formula was used for calculation:

$$\textbf{Count in the Indirect system} = \frac{L}{M \times 1000} \times C_2$$

Where,

L = Total length in millimeters of the yarns,

M = Total mass in milligrams of 10 yarn (either warp yarn or weft yarn), and

$C_2$ = A constant corresponding to the count in the indirect system in which the result is desired, i.e. Cotton (English) count. The constant value is 590.4

**3.2.1. A.b & B.b Performance Parameters** for 100% Cotton and Polyester/Cotton blended (61:39) woven grey fabric respectively. Bureau of Indian Standard was used as the basis for comparison. Some of the test procedure was also followed as per the methods detailed in Hand Book of Tests method.

**3.2.1. A.b.i & B.b.i** (IS: 1964: 2001) Methods for determination of Mass per Unit Area of fabrics.

The method prescribed in this standard is applicable to all other textiles fabrics irrespective of their composition (that is, whether they are made of cotton, wool, silk or man-made fibres or blends of two or more such fibres), manufacturing processes and finishing treatments.

Prior to the test the fabric specimens was conditioned properly. To determine the mass per unit area 5 readings was carried out with the specimen size of 100mm x 100mm (10cm x 10cm) as per the template. Each of the fabric specimens were measured in weighing balance and mean weight of the sample was calculated. Total weight of the fabric specimen was determined and later calculated the weight of the fabric expressed in $g/m^2$.

**3.2.1. A.b.ii & B.b.ii** (IS: 3442: 1980) Method for determination of Crimp of yarn removed from fabrics.

The standard prescribed a method for determination of Crimp of yarn removed from any textile fabric in which yarns were intact and can be removed in measureable length.

From the various portions of the fabric comprising the test sample, 5 warp way test specimen (yarn) and 5 weft way test specimen (yarn) was cut out. Care was taken to see that the same group of warp and weft yarn did not repeat. The test specimens were conditioned under the standard atmospheric condition. Twist tester was used to determine the crimp of yarn. A device capable of measuring the straightened length of yarn provided with two clamps, the distance between the clamp was adjusted to 200 mm under tension.

One test specimen (yarn) $P_1$ was taken and two parallel marks 200mm were drawn over the yarn. Around 250mm length of yarn specimen was raveled form

the fabric marked with 200mm. fastened the one end of the yarn marked to a fixed clamp, so that the marks coincided with the inner edge of the fix clamp. Without stretching the yarn, clamped another end of the yarn marked to the tension clamp. Released the stopper of the tension clamp, as soon as the tension clamp released, it pulled the yarn, making it stretch (or remove the crimp from the yarn). Noted the stretch scale in the graduated scale in mm. removed the yarn from the clamp after the test was over. The tests were repeated. The following formula was used for calculating the crimp percentage –

$$\text{Crimp \%} - \frac{L_1 - L}{L} \times 100$$

Where, $L_1$ = average length in mm of the yarns when straighten, and

$L$ = length in mm of the yarn while in cloth.

**3.2.1. A.b.iii & B.b.iii** (IS: 2977: 1989) Methods for determination of Dimensional changes on soaking in water.

This standard prescribed the method for determination of dimensional changes of woven fabric. The method is intended only for the assessment of dimensional changes undergone by fabrics subjected to single soaking procedure.

Prior to the test, the test specimen was conditioned. The two samples were drawn from the fabric measuring 250mm (25 cm) x 250mm (25cm) with edges parallel to length and width of the fabric. Prior to soaking the actual measurement of the specimen length and width have noted. Soaked the measured specimen laid flat after removal of all creases and wrinkles by hand.

Fabric was kept for 2h in water in the watertight tray containing water and 05g/l of an efficient wetting agent at room temperature. After 2h, the liquid was taken out and specimen was removed without distortion from the tray and placed it flat on a towel. The excess water was removed by lightly pressing another towel on top of the specimen. Laid the specimen on a smooth flat surface and allowed to

dry at room temperature for exactly 24h. After drying re-measure the distance between the lined marked lengthwise and widthwise. From each sample three specimen measurements were obtained of both the direction. The mean value of the original dimensions and the mean value of the final dimension for each fabric treated sample were calculated. The percentage shrinkage was calculated using the following formula.

$$\text{Dimensional change, percent} = \frac{100\ (a-b)}{a}$$

Where,

a = mean original dimension before treatment for each test specimen, and

b = mean final dimension after treatment for each test specimen

**3.2.1. A.b.iv & B.b.iv** (IS: 1969: 1985) Methods for determination of Breaking strength and Elongation of woven textiles fabrics.

This standard was used for the determination of breaking strength and elongation at break of woven fabric using raveled strip method on constant rate of traverse machines.

One set of the 5 specimen was cut from the fabric for each direction for the test, (i.e. 5 specimen cut from the warp direction and 5 specimen cut from the weft direction) using the template (or cutting die). The size of the each specimen was 325mm x 60mm before raveling of yarns and 325mm x 50mm after raveling of yarn. The clamp of the tensile instrument was adjusted in such a manner that the distance between the clamps was 200mm. The specimen was clamped securely with equal amount of tension while tightening the jaw.

The load applied and the speed was set up in the computer. The moving clamp was set under constant rate of traverse motion and as soon as the yarn starts breaking (or rupturing) the tensile machine stops automatically, showing the data of breaking load and elongation on the computer screen. The data was noted later.

The ends of the broken specimen were removed and returned the position of the moving clamp to the zero position or re-adjust the clamps distance to 200mm. the above procedure was repeated for rest of the specimen. The reading of the warp direction strip and weft direction strip were noted separately. Calculated the mean breaking strength separately for warp and weft way test specimen as follows $\overline{L} = \frac{\Sigma L_1}{n}$

Where,

$\overline{L}$ = the mean breaking strength.

$L_1$ = the sum of the observed value of breaking strength

n = the number of observation.

The elongations at break separately for warp way and weft way test specimens were calculated and the mean percentage elongation was calculated as follows:

$$\overline{E} = \frac{\overline{E_e} \times 100}{n \times \text{Gauge length}}$$

Where,

$\overline{E}$ = the mean elongation percent at break

$\overline{E_e}$ = observed value elongation at break

n = number of observation.

**3.2.1. A.b.v & B.b.v** (IS: 6489: 1993) Determination of Tear resistance by the falling pendulum method.

This standard specifies the force required to propagate the tear, through a specific distance and from a specific slit, cut in a test specimen of textile fabric, under specified conditions of loading. This test method is suitable for all types of woven fabrics.

One set of 5 specimens was cut for each direction for the test, using the cutting die (i.e. 5 specimen cut from warp direction and 5 specimen cut from the weft direction). Each set of specimens have been cut from the sample in such a

manner that no two specimens in the set include the same threads. The specimens were conditioned before carrying out the test.

Before testing, the apparatus with the leveling screw was adjusted to level the testing instrument and check the equilibrium position of the pendulum and the zero reading. The load capacity of the apparatus was selected as per the fabric to be tested. For 100% cotton woven fabric the load capacity selected was 3200g and for the polyester / cotton blended woven fabric 6400g. Before carrying out the actual test, the preliminary test was carried out to determine the appropriate range.

Before starting the test, the instruments setting was checked and adjusted properly. The pendulum was raised to the starting point and it was secure with the pendulum release mechanism and the pointer was also set against its stop. The specimen was clamped securely into the jaw and closed the jaw by tightening the setting screw; using approximately the same tension on both the side. After mounting the specimen the slit was given to the specimen with the cutter provided within Elmendorf tester. The pendulum and pressed to release mechanism with the thumb and the pendulum was allowed to move forward (swing) towards the specimen and the specimen was torn. As soon as the pendulum swung backward, the pendulum was held by hand without disturbing the position of the pointer. The pendulum was secured against the stop mechanism. The position of the pointer was recorded as indicated.

**3.2.1. A.b.vi & B.b.vi** Determination of Fabric Hand Value on Kawabata Evaluation System (KES – FB)

Traditionally, aesthetic and comfort value of fabrics are assessed by experts using their intuitive knowledge. Such an assessment system had the inherent limitations of subjectivity. Availability of experts and the agreement of evaluation between the experts were posing major problems to industry. Kawabata and his coworkers in collaboration with Hand Evaluation and Standardization Committee (HESC) put forward the idea of objective evaluation of fabric hand with the help

of low stress mechanical properties of fabrics. These mechanical attributes that are measurable objectively are used to predict “fabric hand”, a traditional way of expressing aesthetic quality of fabric. Hand of fabric can be defined in many ways as given below:

I. A person’s estimate when feeling fabrics between fingers and thumb.
II. The sum total of sensations expressed when a textile fabric is handled by touching, flexing of fingers, smoothing and so on.
III. What man sensorily assesses from the mechanical properties of fabrics.

The judging of feel or handle of the fabric is generally made of sensation such as stiffness or lumpiness which depends on Bending property, hardness and softness which depend on Compression properties and roughness related to Surface properties. These are known to be important in the determination of fabric aesthetic quality. Kawabata and his coworkers generated a set of fabric descriptors depending on the end use of the fabric for describing its aesthetic qualities. These descriptors are referred to as **“Primary hand”** expression. The primary hand expressions are graded by using a scale of 1 to 10 where the value 1 indicates the weakest feeling and the value 10 indicates the strongest with regard to the particular descriptors. These hand values are called Primary Hand Value (PHV) for particular end use.

Kawabata defined an index called **Total Hand Value (THV)** which is an integrated index describing the suitability of a particular fabric for a particular end use from aesthetic point of view.THV is calculated by using a set of new transformation equation involving PHVs for that use derived through testing of the fabric. THV gives the consolidated index reflecting the suitability of the fabric for predetermined applications in a scale of 0 – 5. A THV of 5 indicates that the fabric is ideal for the intended use while a THV of 0 suggests its unsuitability.

**KES-FB system consists of four different instruments.** These are:

I. KES-FB1 – Tensile and Shear tester.
II. KES-FB2 – Pure Bending tester.
III. KES-FB3 – Compression tester.
IV. KES-FB4 – Surface tester.

Objective evaluation of fabric hand using KES-FB involves the following steps:

I. Measurement of basic low stress mechanical properties and some related fabric properties.

II. Calculation of Primary Hand Value (PHV) form low stress mechanical properties using a data processing system employing specific software.
III. Deriving Total Hand Value (THV) form Primary Hand Value, again using different data processing software. Description of Primary Hand Expressions is detailed below.

| Sl. No | Japanese | English | Description |
|---|---|---|---|
| 1. | Koshi | Stiffness, Firmness, Resilience, Solidity, Springiness | A feeling related to stiffness. A springy property promotes this feeling. A fabric having a compact weave density and made from springy and elastic yarn would give higher value for Koshi. |
| 2. | Numeri | Smoothness Sleekness, Silkiness, Softness. | A mixed feeling resulting from a combination of smooth, supple and soft feelings. |
| 3. | Fukurami | Fullness & Softness, Loftiness | A feeling coming from a combination of bulky rich and well formed impressions. |

| | | | |
|---|---|---|---|
| 4. | Shari | Crispiness | A feeling resulting from a crisp and rigid fabric surface. This is found in a tightly woven fabric made from a hard and strongly twisted yarn. |
| 5. | Hari | Anti-drape stiffness, hardness, boardiness. | The opposite of limpness. Assesses the springiness of the fabric. |

**(Table no: 13) Description of Primary Hand Value**

Both the fabrics, i.e. 100% Cotton and Polyester/Cotton blended woven fabrics were tested with above mentioned standards and the results of the tests were documented. Data were considered as the Control Parameters for the further study.

### 3.2.2. A.i Bioscouring Pretreatment:

In this study, Bioscouring was carried out in two categories, i.e. Microbiological Scouring and Commercial Enzyme scouring.

**3.2.2. A.i.a Microbiological Scouring Method:** The present study is aimed at scouring the 100% cotton and polyester / cotton blended fabric with minimal pollution and less energy consumption through biochemical approach. The anaerobic technique developed at CIRCOT for the degradation of the lignocellulosic waste was employed to carry out scouring operation on 100% cotton fabric as well as on polyester / cotton blend. This technique is cost effective as the desired enzymes are produced *in situ* by a consortium of microorganisms.

One hundred percent Cotton and Polyester / Cotton blended woven fabric of medium weight (122.02 g/m and 133.02g/m) respectively was used. The fabric was in grey state. The required quantity of fabric (approx. 2m for each treatment) was subjected to anaerobic treatment for 6h, 10h, 12h, 18h, 24h and

48h respectively. Total 12 metres of each fabric were used for this treatment (i.e. 12 metres of 100% Cotton and 12 meters of Polyester/Cotton blended woven fabric). The anaerobic treatment was carried out in a water sealed tank employing a 100% mixed flora developed and maintained at CIRCOT. **(Plate No: 1)**

**Bioscouring plant:** The plant has been fabricated by Fibre Reinforce Plastic (FRP) with a volume of one cubic metre so that 600 litres of Microbial Consortium could be maintained leaving sufficient volume for handling the material to be treated. This is a circular drum and the outer wall is double walled with 2 inch gap to hold fresh tap water. A circular gas holder of the same size is kept so that the outer wall is placed in the water jacket. A GI pipe outlet is filled to one side of the top portion to take out the gas produced by the consortium. This outlet is filled with a flexible rubber hose and the free end of the hose is immersed in a small vessel containing water. The gas produced in the chamber is bubbled out and anaerobic condition is maintained always. This is shown diagrammatically in the following **Fig.5**

**Fig. 5: line diagram of Bioscouring Plant**

**Microbial Consortium:** A slurry of cattle waste was made (10%), filtered through 10 mesh sieve to which 10 litres of sea water was added. In addition to this, one litre of algal bloom maintained in the laboratory was added. Wheat bran was added as carbon and nitrogen source (0.1%) and the assembly was closed and left for 15 days. The consortium got stabilized. Bubbling indicates that the consortium is active. There is always positive pressure in the chamber and hence bubbling. The fabric or yarn in question is placed in the chamber and scored out after the treatment, washed and boiled in water containing 0.1% NaOH, bleached in $H_2O_2$ and dyed. The consortium is to be supplemented with wheat bran once in 30 days to maintain optimum activity.

**Maintenance of Microbial Consortium:** The microbial Consortium was maintained in 10l corning bottle as shown in the **Fig. 6**. Cattle waste slurry (10%) was added in the 10l bottle. One litre sea water was mixed with 500ml algal bloom and mixed with the cattle waste slurry. Wheat bran (0.1%) was supplemented and the bottle was closed with a one holed rubber cork. This was connected to an air trap with a rubber tube. The gas generated is bubbled out through water in the air trap. 100% anaerobiosis is maintained. Bimonthly recharge is required to maintained active consortium.

**Isolation and identification of Anaerobic Microorganisms:** The data of Desai (2006) is utilized in the present investigation. It is not out of place to mention here that an inexpensive method developed and patented by Ashtaputre, has been utilized to isolate anaerobic microorganisms. The assembly is shown in **Fig. 7**.

Microbial consortium was used to treat the fabric. The consortium comprised both aerobic and anaerobic types. Species belonging to *Bacillus* and *Micrococcus* sp. from Gram positive group and *Beijierinckia, Pseudomonas*, *Xanthomonas* and *Flavobacterium* were Gram negative ones. *Aspergillus, Penicillium* and *Mucor* were from fungi and *Streptomytes* was the lone

*Actinomycete*. All these were from the aerobic ones surviving under the anaerobic conditions. As and when the system was disturbed, these were acting as scavengers of oxygen and aid in setting anaerobiosis. Among anaerobic groups, species of *Methanomicrobium, Desulfotomaculum, Clostridium, Chlorobium, Ectothiorhodospira, Thiodictyon and Rhodospirillium* were predominant. One species of protozoan belonging to the genus *Monocercomonas* was also present in the consortium.**(Plate no: 2)**
The treatment was carried out at room temperature (25ºC - 32° C). At the end of the treatment period, the samples were boiled in 0.1% NaOH solution (o.w.f) for 15 min, washed and air dried. **(Plate no: 3)**

**3.2.2. A.i.b Commercial Enzyme Scouring:** For Commercial Enzyme Scouring process, IS: 1383 – 1977 standard was followed, i.e. “Methods for determination of scouring loss in grey and finished cotton textile materials”.

For this treatment approximately 2 metres of fabric was taken for each fabric quality type (i.e. 2 metres of fabric for 100% Cotton and 2 metres of fabric for Polyester/Cotton blended woven fabric) Before this treatment both the fabrics (i.e. 100% Cotton and Polyester / Cotton blend) weight was recorded. They were dipped in the solution (weighing 20 times the mass of the specimen), containing 5 g of Diastase and 10g of Sodium Chloride per litre, at 50° C and at pH of 6.5 – 7.7. They were allowed to remain in the solution for 1½ h. At the end of the process, the fabrics were removed, washed thoroughly with hot and cold water successively using 50ml of water in each wash and dried.

The weight of the fabric was checked to understand the percentage weight loss after the bioscouring treatment. After the treatment, out of 2 metres of fabric, 1 metre of fabric was used for the test of physical parameters of the fabric and remaining 1 meter was used for the bleaching treatment.

Bioscoured fabrics were tested for various physical parameters such as Fabric count, Crimp percentage, Yarn Count, Grams per Square meter, Shrinkage percentage, Breaking load & Elongation, Absorbency test and Kawabata Evaluation System for Fabric Hand Value. These physical parameters were carried out following the same standard as mentioned above (No: 3.2.1).

### 3.2.2. A.ii Conventional Scouring Pretreatment:

Two metres of each fabric quality were taken for the treatment (i.e. 2 metres of 100% Cotton and 2 metres of Polyester/ Cotton blended woven fabric). These fabrics were weighed prior to the treatment, to understand the percentage weight loss of the fabric after treatment.

Both the fabrics were dipped in the solution (weighing 20 times the mass of the specimen) containing 1% NaOH on o.w.f and 1ml/l wetting agent. Pressure was maintained till it reached 15 lb/inch$^2$ at 121°C for 4 h in the autoclave. Conventional Scouring pretreatment is explained in the schematic diagram as shown below.

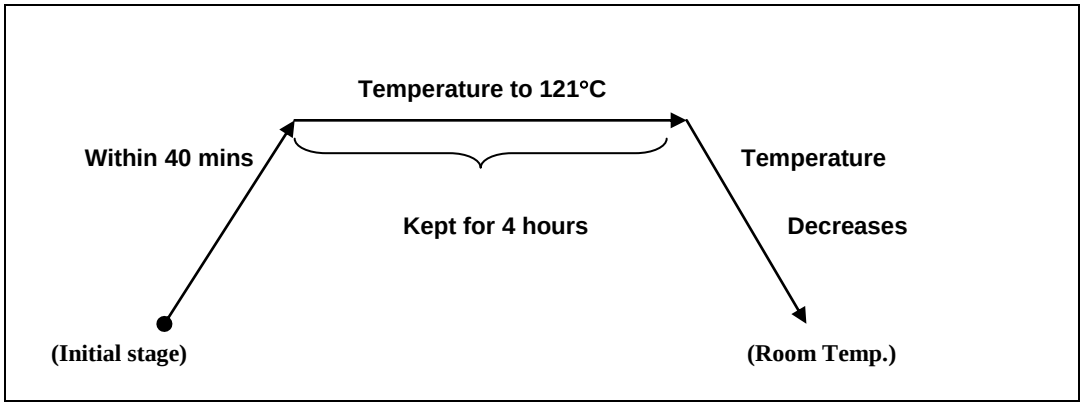



**Fig: 8. Conventional scouring Treatment**

After 4 h, fabric was removed from the autoclave, washed with tap water, rinsed thoroughly and air dried.

Industrial textile processing comprises several processes which include pretreatment, dyeing, printing and finishing processes. Besides consuming large amount of energy and water, these processes generate lot of waste products. Generally the effluents generated in textile processes have the following shortcomings – heavily coloured, contains high concentration of salts, exhibit high BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand).

COD is the total measurements of all the chemical in the water that can be oxidized. BOD is supposed to measure the amount of food (or organic matter) that bacteria can oxidize. Permissible limit of COD is 250 to 500 ppm and BOD is 30mg/l. to explain it further the microbes present in polluted water consume the dissolved oxygen for respiration and nitrification. These bacteria consume pollutants and then use dissolved oxygen to convert the pollutants into energy. Other bacteria consume ammonia to nitrate a process called nitrification. This is important to control COD and BOD as water high in BOD can deplete oxygen in the receiving water, causing fish kills and ecosystem damages. Low BOD also helps in further treatment.

The best way to reduce pollution is to prevent it at the first place. This can be done in many ways such as controlled impact, re-engineering processes to reuse by-products, improving management practices and employing substitution for toxic chemicals. Most of the pollution preventing activities in textile industries is based on reducing the chemical use, reusing the process waste and reducing all solid waste. Due to emerging environmental awareness and the increasing pressure of legislative restrictions on coloured effluent, the potential of biotechnology in this application area has been recognized and explored. The application of biotechnology is mainly attributed to the removal of colour from the dye house effluents. Living organisms are used to bind and degrade colour (e.g. artificial reed beds) or dead organisms (e.g. straw, chitin/chitosan, micro-fungal hyphae etc). Selected microbes or isolated enzymes may be used to assist specific areas.

**Techno-economic Feasibility of the Microbiological Scouring process-** The present study is on a very small scale. The study carried out by Balasubramanya for his Emeritus Scientist Scheme in 2013 was on 500 kg 100% cotton yarn in hank form for microbiological scouring. He exhaustively worked on yarn scouring, dyeing with natural indigo, weaving in Handloom Sector and production of Readymade Garments. About 600 jeans pants were made and consumer reactions were sought. The costing done by him has been utilized here since the main purpose of this investigation is to highlight the importance of Microbiological Scouring. **(Plate no: 4, 5& 6)**

After drying, weight of the fabric was checked to determine the percentage weight loss. After the treatment, out of 2 metres of fabric, 1 meter of fabric was used for the test of physical parameters of the fabric and remaining 1 meter was used for further bleaching treatment.

Conventional scoured fabrics were tested for physical parameters such as Fabric count, Crimp percentage, Yarn Count, Grams per Square meter, Shrinkage percentage, Breaking load and Elongation of the fabric, Absorbency test and Kawabata Evaluation System for Fabric Hand Value. These physical parameters were carried out following the standard methods mentioned above (No: 3.2.1). The results on the physical parameters of Bioscoured pretreatment and Conventional pretreatment were documented for further study in the prescribed format of the Bureau of Indian Standard.

The effluents of Bioscouring and Conventional scouring treatment were compared. Various parameters such as BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand) were measured.

### 3.2.2. B Bleaching Treatment of the fabric:

The Bioscoured pretreated fabric and Conventionally Scoured pretreated fabric were further taken for the bleaching process. The bleaching process was carried

out with bleaching agent, Hydrogen Peroxide ($H_2O_2$) - 3g/l, along with alkali stabilizer Sodium Silicate – 1.5g/l and to remove the remaining kitties from the fabric. The total time duration for the bleaching treatment was 1h at 90°C at 9.5 – 11pH. After the treatment the fabric was washed, rinsed and air dried. Later, Bioscoured-bleached fabrics as well as conventionally scoured-bleached fabrics were tested for whiteness and absorbency parameters. The whiteness index of the fabric was carried out using Jaypak – 4802 computerized colour matching system as well as wettability of the fabrics were also analyzed.

- **Methods for the determination of Whiteness of fabrics:**

The method to determine the whiteness of the fabric was carried out in CIRCOT. The estimation of optical whiteness in substrate is really a difficult problem. To evaluate the whiteness of the fabric, various techniques are used, *viz;* Visual assessment and instrumental assessment. In this present study, Spectrophotometer was used to assess the whiteness of the bioscoured and conventional scoured as well as bleached 100% Cotton as well as 69:31 Polyester/ Cotton blended woven fabrics respectively.

Bleached fabrics were placed in the spectrophotometer, which is totally computerized. Spectrophotometer simply measures the spectral reflectance, from which Whiteness Index (Stensby) 10Deg/D65 values are calculated on the basis of spectral energy distribution of the light source. Whiteness Index (Stensby) 10Deg/D65 was observed and studied to estimate the whiteness of the bleach fabric for both 100% Cotton and 69:31Polyester/Cotton blend woven fabric treated with bioscouring method as well as Conventional scouring method.

- **(IS: 2349: 1963) Method for determination of Wettability of cotton fabrics.**

This standard prescribes a method for the determination of wettability of cotton fabrics. This method is also applicable for assessing the efficiency of scouring. In this present study wettability test of 100% cotton and Polyester/cotton blended (69:31) were carried after microbial scouring, commercial scouring,

conventional scouring as well as after bleaching treatment. Prior to evaluation, the test sample was conditioned. The test specimen size was 20cm x 20cm and the test was carried out in duplicates (2 fabric specimens of each fabric quality). This test specimen was treated with distilled water at 30°C, with a material to liquor ratio of 1:50 for 30 minutes. Then the present moisture was removed by pressing the test specimen between the filter paper and dries them at room temperature. The test specimen was marked with the pencil a square measuring 10cm x 10cm. Subdivided the square into 25 small squares, each measuring 2cm x 2cm.

The test specimen was mounted on the embroidery frame so as to have taut surface. The electric lamp was switched on of the apparatus. The burette was filled with distilled water. The test specimen was mounted on the frame was placed on the base of the apparatus. The height of the burette was adjusted such that the surface of the cloth is just two drops beneath the burette and that the drop falls on one of the squares.

The drop was allowed to fall on the specimen and at the same time the stop-watch was started. The image of the lamp was observed on the face of the drop through the viewing ring. When the image disappears at the edge of the drop the time was recorded with the help of a stop-watch. Longer the time taken to disappear, then poorer is the wettability property of the fabric. The average of 5 readings was noted. The time taken for the image to disappear at the edge of the drop was calculated in seconds.

### 3.2.2. C Dyeing of fabrics:

After bleaching the Bioscoured and Conventionally scoured woven fabrics of both 100% Cotton and Polyester/Cotton Blend, it was further taken for the dyeing process. The 100% Cotton woven fabric was dyed with Reactive Dye and the Polyester/Cotton blended woven fabric was dyed with Disperse + Reactive dye.

**3.2.2. C.i Dyeing of 100% Cotton woven fabric:** The 100% Cotton woven fabric was dyed with Reactive dye – Reactofix HE (Navy Blue Colour). The Material to Liquor Ratio (M: L) was 1:30 and dye shade percentage was 2%. The dyeing was carried out in a Laundreometer dyeing bath. The bleached fabric (Bioscoured as well as Conventional scoured) samples (approximately 10g) was taken for dyeing. Dyeing was done in the dyeing beaker by placing the fabric in required amount of dye solution and the glauber salt (Sodium Sulphate) 40g/l. The dyeing was carried out at room temperature for 10 mins. Then the temperature was raised to 85°C. At this temperature, Trisodium phosphate (TSP) was added to the dyeing solution and then dyeing was continued for 45 mins. After 45 mins, temperature was brought down to room temperature. The fabric sample was removed from the beaker, washed in soap solution (2g/l) at 60°C, washed in tap water and air dried. This is schematically shown as detailed below.

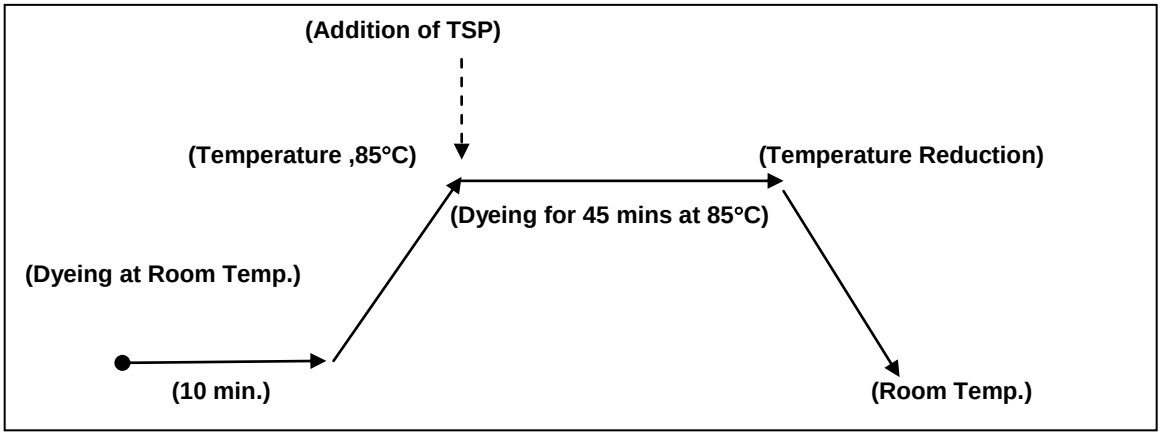
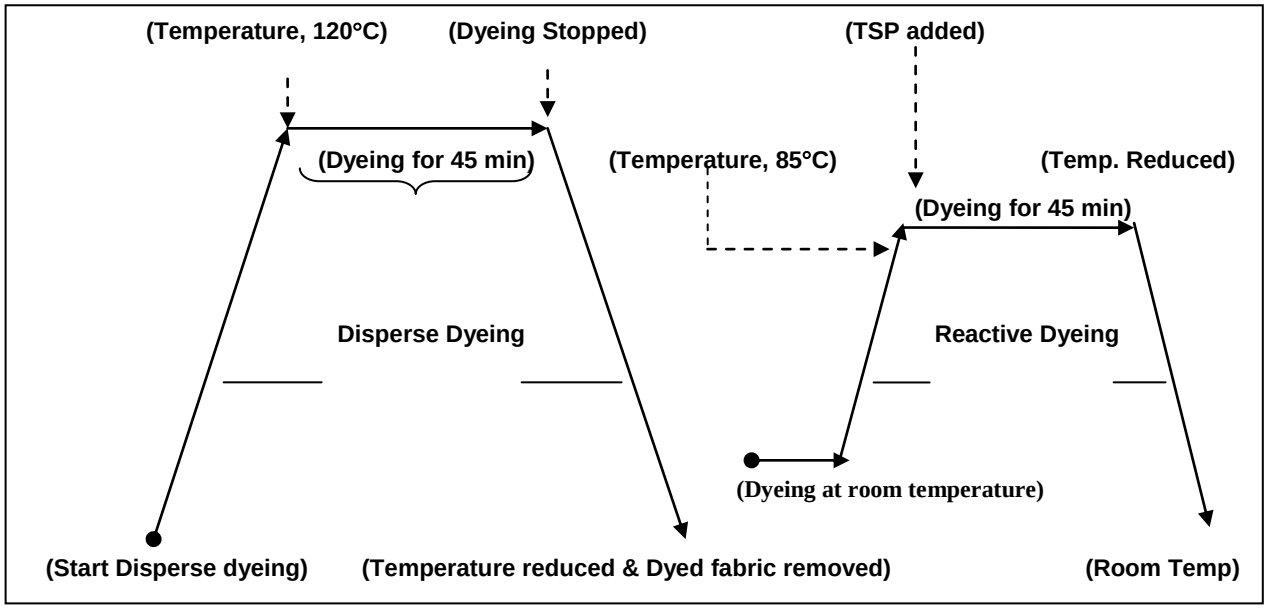



**Fig: 9. Dyeing of Cotton with Reactive dye**

**3.2.2. C.ii Dyeing of Polyester/Cotton blended (61:39) woven fabric:** The Polyester/Cotton blended woven fabric was dyed with Disperse + Reactive dye. The Material to Liquor Ratio (M: L) was 1:30 and dye shade percentage was 2%. This blended fabric was dyed in two stages. The polyester component in the fabric was dyed with disperse dye at High Temperature and pressure (HTHP) machine and cotton component present in the fabric was dyed with reactive dye in Laundreometer dyeing bath. The bleached fabric (Bioscoured as well as Conventional scoured) samples (approximately 10g) were taken for the dyeing process.

➢ **Dyeing with Disperse dye:** The polyester component present in the (61:39) polyester/cotton blended woven fabric was dyed with disperse dye - (Terenix Navy Blue). Dyeing was carried out on the fabric using required amount of disperse dye solution in a beaker. Beaker was placed in the HTHP machine. The temperature was raised to 120°C and maintained for 45 mins. After 45 min., the dyeing was stopped and HTHP machine was allowed to cool. After cooling, the fabric sample was removed, washed and continued with reactive dyeing for cotton component present in the blended fabric.

➢ **Dyeing with Reactive dye:** The cotton component present in the (61:39) polyester/cotton blended woven fabric was dyed with the reactive dye – Reactofix HE brand. For the blended fabric dyeing was carried out with the disperse dye followed by the reactive dye with glauber salt – 40g/l at room temperature for 10 min. Therefore, the temperature was raised to 85°C with addition of Trisodium phosphate (TSP). Dyeing was continued for 45 min followed by washing. After 45 min the dyed fabric was washed. Soaping was carried out with 2g/l soap solution (MLR – 1:50) till the temperature reached to 60°C, then washed, rinsed and air dried. Schematic diagram is given below.




**(Fig: 10. Dyeing of Polyester/Cotton blended fabric)**

**3.2.2. C.iii Physical parameter of the dyed fabric:** All the dyed 100% Cotton and Polyester/cotton blended woven fabric with the Bioscoured treatment and the Conventional treatment were further carried out for various Colourfastness test and also dye uptake test. To determine the colourfastness of the dyed fabric, the Bureau of Indian Standard was followed. Following tests were carried out.

- **(IS: 766 – 1988) Methods for determination of colourfastness of textile materials to Rubbing**

This standard prescribes a method for determination of colour fastness of textile materials of all kinds. Crockmeter consists of a cylinder of 1.6cm diameter moving to and fro in a straight line along a 10.0cm track on the specimen with a down ward force of 9 N shall be used. Rubbing cotton cloth desized, bleached, without finish cut into square 5 X 5cm. grey scale for evaluating staining. Two pieces of samples from the dyed fabric, not less than 14 X 5cm for dry rubbing were taken. The test specimen was fixed to the rubbing device by means of clamps such that the long direction of the specimens follows the track of the device. With the dry rubbing cloth placed over the end of the finger of the testing device, it was rubbed to and fro in a straight line along a track 10 cm long on the dry specimen, 10 times to and fro in 10 seconds, with the downward force on the finger of 22 N or 9 N. This test was carried out to all the bioscoured and the conventional scoured (100% cotton as well as 69:31 polyester/cotton blend) fabric. The fabric was assessed with the help of the Grey scale.

- **(IS/ISO 105-C10 :2006) Part C10 colour fastness to Washing with soap or soap and soda**

The tested dyed fabric along with the adjacent fabric was cut to 100mm X 40mm. The tested dyed fabric was placed between the two adjacent fabrics. All the three fabric samples were stitched along side. The composite specimen was placed in the container along with the necessary soap solution pre-heated to

60°C temperatures ±2°C. The material to liquor ratio was 50:1 ml/g. The container was closed and the machine was run at a temperature of 60°C and for 30min. The samples were removed and the excess water was removed from the composite specimen by squeezing the test specimen by hand. The composite specimen was opened by cutting the stitches except one shorter side. The specimen was dried by pressing it flat between new filter papers to remove excess water, in air at a temperature not exceeding 60°C, with the parts in contact only at the line of stitching. The change in colour of the specimen was accessed and the staining of the adjacent fabric with reference to the original specimen either the grey scales.

- **(IS: 2452 – 1985) Methods for determination of colourfastness of textile materials to Artificial Light (Xenon lamp)**

This method is applicable to textile material of all kinds and in all forms to the action of artificial light source. The specimen was cut to be tested of 1 X 4.5cm from each of the coloured material, mounted on an opaque material like thin black chart paper, cardboard, aluminum foil etc. $¼^{th}$ area of the specimen to be covered with opaque material. The specimen mounted on the card was of the same size as the standard blue wool patterned in order to avoid error in assessments. The standards blue wool pattern consists of rating number – 1(very poor to light fastness) to rating number – 8 (very high to light fastness) according to BIS.

The test specimen was exposed and the standard wool pattern to artificial light simultaneously fixing them on the loop provided on the inner side of the light fastness tester. Initially, the specimen was exposed for 5h. Fastness rating was done after 24h. After 5h, observe the effect of light was observed by lifting the opaque material. When the change in colour was noticeable for blue wool standards no.3, the test specimens were evaluated and their fastness is rated numerically.

The specimen was exposed under a specified condition along with 8 dyed wool standard patterns to the artificial light. The fastness was assessed by comparing the change in specimen colour with that of the standard patterns.

- **(IS: 971 – 1983) Methods for determination of colourfastness of textile materials to Perspiration**

This standard prescribes method for determination of colourfastness of textile materials of all kinds and in all forms to the action of the human perspiration. Perspirometer instrument was used. A testing device consisting of a frame of stainless steel into which a weight piece of mass 5kg and a base of 11.5 X 6cm is closely fitted, with acrylic resin plates of the same size and of 0.15cm thickness. And incubated in an oven 37±2°C, Two adjacent fabrics each measuring 10 X 4cm, dyed specimens each of 10 X 4cm, Grey scale for assessment, Alkaline solution and Acidic Solution (artificial perspiration solution).

The specimen was thoroughly wetted in alkaline solution at a liquor ratio 50:1 and allowed it to remain in the solution at room temperature for 30 min. the excess solution was taken out between two glass rods. They were later placed in between two acrylic resin plates measuring about 11.5 X 6cm under pressure. Subsequently transferred in the oven for 4 hours at 37°C±2°C and dried in air. The second composite specimen was also treated similarly using acidic solution. The change in colour of the treated test specimens was done on grey scale.

- **Method for determination of colour measurements of the textile material**

The colour strength (k/s) values of bioscouring and conventional scouring fabrics (i.e. 100% cotton and 69:31 polyester/cotton blended woven fabrics) dyed with reactive dye and disperse/reactive dye were measured respectively. These dyed fabrics were measured with colour matching spectrophotometer. This instrument was standardized with a white tile. The evaluation of the k/s was examined using graphical method where the graphs were plotted reflectance vs wavelength.

The colour strength k/s is based on the Kubelka – Munk theory. The relation between the reflectance and the scattering and absorption co-efficient of the dyed substrate was first suggested by empirically by Kubelka and Munk.

The k/s value indicates the amount of dye present on the surface of the fabric. It is measured in terms of reflectance value of the dyed sample.

The colour co-ordinates *viz.,* L, a, b, C and h values of 100% cotton and 69:31 polyester/cotton blended woven dyed fabrics with different scouring processes was measured with colour matching spectrophotometer.

Lab are based on E. Herrings Opponent Colour theory which states that red, green and blue signals get converted into three component channels – lightness/ darkness, red/ green and yellow/ blue.

**L:** is a measure of the lightness / darkness which ranges from 0 (black) to 100 (white). 0 value signifies that it is darkest and value 100 signifies that the sample is undyed.

**a:** is a measure of redness (+ ve) / greenness (- ve)

**b:** is a measure of yellowness (+ ve) / blueness (- ve)

**c:** is a measure of chroma or saturation and represents the distance from the neutral axis.

**h:** is a measure of hue and is represented as an angle ranging from 0° to 360° angles that ranges from – 0° to 90° are reds, oranges and yellow; 90° to 180° are yellows, yellow greens and greens; 180° to 270° are greens, cyan (blue green) and blues; from 270° to 360° are blues, purples, magentas and again to reds.

- **Standard conditions for Bioscouring:**

The standard conditions were recorded and the same was adopted for carrying out scale-up trials.

The comparative study was carried out to understand the merits and demerits between the Bioscoured fabric and the Conventional Scoured fabric.