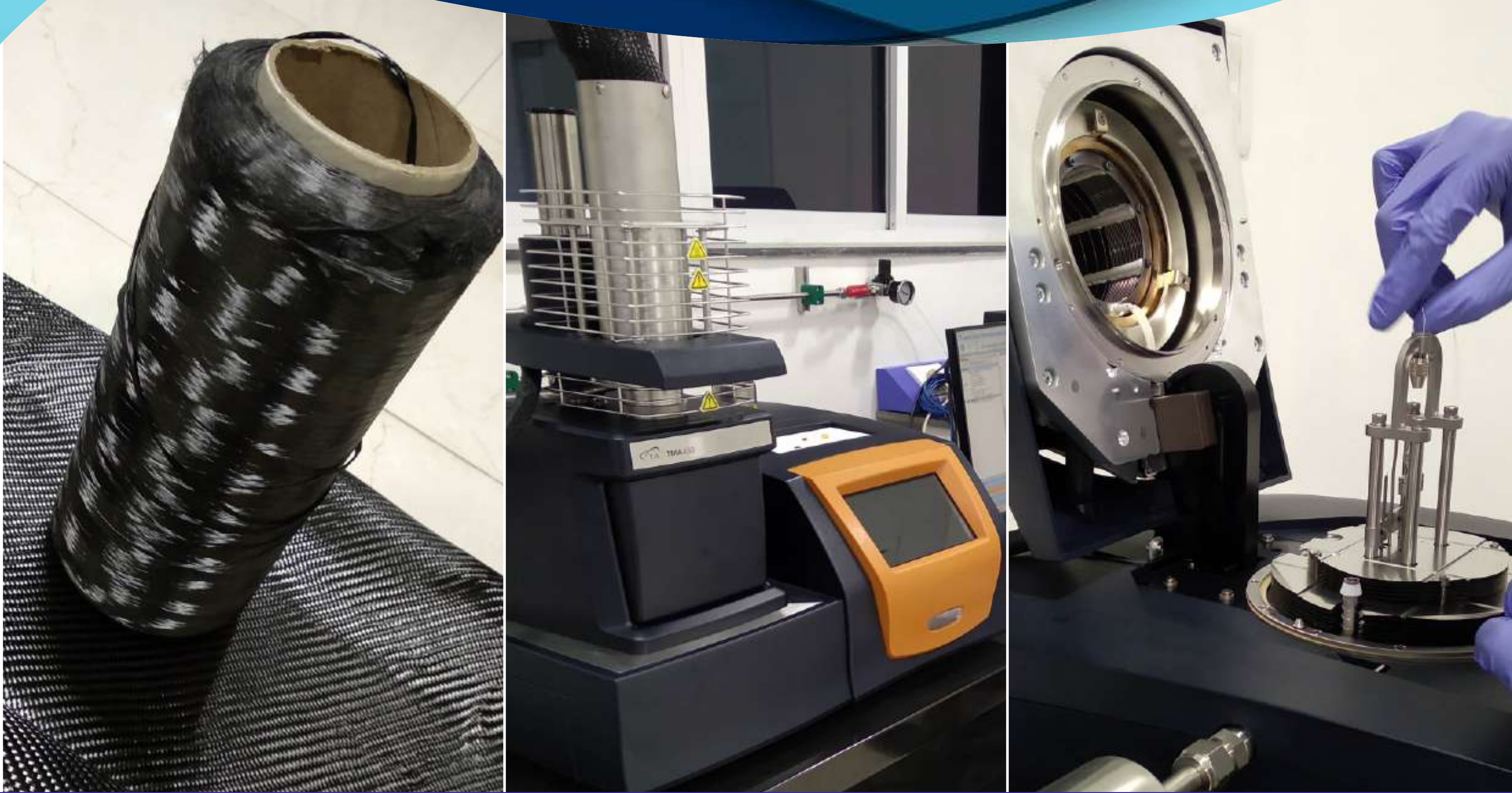
# The Bombay Textile Research Association

## ANNUAL REPORT 2021-22



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## MEMBERS OF THE GOVERNING COUNCIL



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We have great pleasure in presenting the 68th Annual Report of The Bombay Textile Research Association (BTRA). It highlights the R & D and other activities of BTRA and also presents the Audited Statement of Accounts for the year ending 31st March 2022.

## 1. INTRODUCTION

The pandemic in the last two years has caused a big loss not only in the Indian Textile industry but has also impacted the global economy as well. Before the pandemic, the textile industry had been booming, but it is currently challenged as Research and Development (R & D) sector and other pressing issues have taken the forefront. A lot of new research is required hence there is a need to train the talent for process and product innovation. Thus the industry has to keep innovating for its current needs in technical textiles which were being focused on during this time.

In the current scenario, the textile industry has been concentrating on developing value-added products in the high technology platform primarily focussing on medical textile and Geotextiles. Efforts are being made in product/process development and diversification into more technology-based products. At our Centre of Excellence, Geo-synthetics, we have strengthened several testing facilities in the year 21-22. Even at our Electro-spinning unit, we have undertaken designated jobs from DRDOs. Hence, BTRA has taken major steps with financial assistance from the Ministry of Textiles, the Government of India, and other funding agencies such as DRDO, BARC, and IREL to develop expertise and provide services to the textile industries.

Undoubtedly BTRA strongly believes in the importance of R & D, particularly for product/process development. The other focus is on cost reduction, and enhancing efficiency in textile mill operations. The main objective of R & D is two-fold (i) to make the existing products better, faster, and at affordable prices, and (ii) to develop new products. BTRA is also strengthening its training activities for providing need-based training to personnel of technical/supervisory and operator levels. Recently, in this regard, BTRA has also initiated the training activity on Effluent Treatment Plant, Water Recycling, and Sustainable Technology in collaboration with M/S Austro Water Technologies, Pvt Ltd, Tirupur. BTRA has been working on other thrust areas and a glimpse of some of the work carried out during the period under review is briefly highlighted as mentioned below:

**Overview**

- ❖ **On-going sponsored projects -** The number of ongoing sponsored projects is three for the period under review. Details are as follows.

- ✓ In the project entitled -'Development of Carbon Nanotube Reinforced Acrylic Precursors for Carbon Fibre' project, specification for precursor spinning machine and DMA with TMA attachment completed, and a global tender has been floated. Civil work of the Carbon fibre laboratory is almost complete (minor adjustments remaining). Initial experiments had been done for dispersing carbon nanotubes in Polyacrylonitrile (PAN) by varying CNT concentration in PAN. Results show improvement in thermal and rheological properties of PAN precursor with increasing CNT content. Based on obtained results, we also submitted an abstract for poster presentation in an international e-conference on "Nanomaterials and Nano-engineering" organized by APA Nanoforum-2022.

- ✓ The project entitled- 'Eco-friendly Natural Dyeing of Cotton and Silk using Rare Earth Metal Salts as Mordants' - The project is related to the natural dyeing of cotton and silk fabrics using non-conventional mordant salts. These nonconventional mordants are rare earth salts (RE salts) such as Cerous sulphate, lanthanum chloride, and yttrium chloride. They have been used for the first time in natural dyeing and the project is funded by IREL. The project is aimed to tackle some genuine problems faced by natural dyers. 13 different natural dyes have been demonstrated to show better results with RE salts as compared to conventional mordants. Even the quantity of rare earth mordant required to get desired results is about 60-80% less. Thus the use of rare earth mordant has good prospects in the natural dyeing of silk and cotton fabric. Another major issue is the natural dyeing of Polyester fabric. Since the polyester fabric has an inherent hydrophobic character the dye uptake under the conventional method is very poor for Natural colorants. We tried to take up this challenging issue. Thus we dyed polyester fabric with 5 natural dyes such as -Catechu, Maddar, Turmeric, Lac, and Turkey red to evaluate the improvement in dye uptake by the use of the same three RE salts. We have also used Plasma mediated dyeing technique for this purpose. The overall effect of Plasma and RE salts showed synergistic effects. Excellent results have been achieved for wash and light fastnesses of naturally dyed polyester. Even the dye uptake was very significant along with good dye adherence.

- ✓ In the project entitled- 'Development of a standard method for identification of dope dyed and exhaust dyed polyester fibers / fabrics'. The fabric of the same color but produced by dope and exhaust-dyeing routes looked similar. Dope dyeing is the process of adding dye or pigment during the melt or solution spinning of yarn. While in the exhaust dyeing process, dyeing of textile material is done after manufacturing. However, the performance of the dope dyed and exhaust dyed fabric in terms of colour fastness is different which may create shade-off or a tonal variation during use in Army uniforms. This project covers a systematic investigation to identify the dope dyed and exhaust dyed polyester and aramid filaments/fabrics by subjecting them to various test procedures. Different tests were conducted on exhaust dyed and dope dyed yarn. In sublimation, washing and lightfastness, thermal treatment in a muffle furnace, colour value of exhaust dyed yarn are reduced while there is not much change in dope dyed yarn. Shrinkage of exhaust dyed yarn is also less than that of dope dyed yarn because exhaust dyed yarn undergoes shrinkage during the dyeing process. While birefringence and TGA analysis did not provide any distinguishing results between the two. Experiments were also done with the aramid yarn dyed using cationic and disperse dyes. In the case of aramid yarn, the light and wash-fastness property of exhaust dyed yarn was found to be poor compared to dope dyed yarn. During the hot air treatment, shade change was observed in the case of exhaust dyed yarn. Experiments to identify the dye from its chemical structure are going on by extracting the dye from the yarn and doing HPLC analysis.

❖ **Product Development Assistance to the industry**

- BTRA developed a reusable protective face mask with high bacterial filtration efficiency.
- In the Nanoparticle mediated Antimicrobial coating with the Copper and Silver nanoparticle. The antibacterial effect (~99%)and the wash sustainability ( 10 wash cycles) of copper nanoparticles have been very good.
- BTRA is trying to develop a hydrophobic coating using cheaply available Rice husk. So far we have been able to get a contact angle of 127°, however, our target is to attain a contact angle of >150°. Work is in progress for minimizing the particle size of the silica which is likely to enhance the contact angle.

❖ **In-house project**

✓ In the project entitled- 'Atmospheric pressure plasma treatment of textiles for dyeing of various fabrics with natural and synthetic dyes'- Dyeing of plasma modified PP with acid dyes was carried out and optimisation of the plasma processing variables vis-a-vis plasma treatment time, power, and distance between the electrodes was optimized using the Design of Experiment (DoE) approach. It was found that the Plasma treatment time and Power are the most influencing factors than the inter-electrode distance. Plasma treatment time of 32sec at 3.3kW and 0.5mm electrode distance was found to be optimum for maximum improvement in dye uptake on PP fabric. Dyeing of Cotton, silk, jute, nylon, polyester and PP with natural dyes has been carried out and final project report writing is in progress.

✓ In the project entitled- 'Development of Nylon 6, Polypropylene/ Graphene, Graphene Oxide (GO) high-performance nanocomposite filaments'- Initially, the aim is to bring down the graphene oxide sheet size from micron to nano range for better dispersion stability to get their uniform distribution at the molecular level in the polymer matrix. For this, we have prepared the dispersion of graphene oxide in water/IPA solvent by magnetic stirred and yet ultra-sonicated for 5 h. After ultra-sonication, the stability of dispersion was found to be around 15 h. although, the particle size was found to be reduced still it was in the range of 2-4 microns. Nevertheless, we have prepared the master batches of polypropylene/graphene oxide with the loading of 0.2, 0.5, 1, 2, and 3 wt% and melt-spun multi-filaments were prepared. These composite multi-filaments were characterized by different analytical techniques. Parallelly, samples were prepared for electron beam irradiation for controlled reduction of graphene oxide.

✓ In the project entitled- 'Development of highly efficient and functional finished reusable protective face mask' – A purchase and installation of the Sewing machine (JUKI- Model DDL 8100e) are done. We have printed the 35K mask packaging bags. Fabric and chemical for functional finishing are procured. Designing the mask with a new style is in progress. Application and evaluation of the functional finished product on the procured fabric has been done.

### ❖ Calibration, Technical Services, and Training

- ✓ BTRA calibration laboratory received accreditation from NABL as per ISO/IEC 17025:2017 standards for Mass, Balance, and Volume. BTRA is ready to provide calibration services to other NABL accredited testing laboratories for Mass, Balance, Volume, and Force parameters.

- ✓ BTRA undertakes extensive liaison and consultancy services to solve problems related to quality, maintenance, productivity, water / energy conservation, ETP, etc., at various levels from time to time. Also, special studies such as vendor selection, valuation of fixed assets, manpower planning, etc. are undertaken for the mills. For the period under review, BTRA provided services in the areas of Accredited partner audits, boiler efficiency audits, and fabric inspection.

- ✓ BTRA conducted several training programs at the mills' premises covering subjects such as Technology, Upgradation, Quality Control and Third-party auditing of ETP, Fabric Inspection, Evaluation, Cluster Development, Cuprammonium fluidity test, and Good Work Practices & Utility Conservation. BTRA imparted training (theory and practical) at the testing laboratories/pilot plants covering subjects such as Technical Textiles (Geotech), Textile Terminology and Processing, Yarn testing, Sizing, Mechanical &Chemical Testing, and General elements of textiles. . Two hundred thirty-five personnel were trained during the period under review.

### ❖ Others

In a nutshell, research and development and consultancy activities at BTRA have been directed towards innovative product/process or test method development and providing an essential database for the industry. In the years ahead, BTRA will strive to make its mark in the area of technical textiles, utility conservation, effluent load reduction, chemical management system, and eco-management for process houses.

## 2. ON-GOING SPONSORED PROJECTS

### 2.1 Development of Carbon Nanotubes Reinforced Acrylic Precursor for Carbon Fibre

**Abstract**
With the increasing demand for advanced materials in the world, carbon nanotubes (CNT) have always been the first choice for material properties enhancement but their uniform dispersion is a big challenge for obtaining desired results in various applications. The recent developments of CNT and Polyacrylonitrile composite show that they not only act as a good reinforcing agent but also as property enhancers of carbon fibres produced from them. However, agglomerate size and dispersion of CNT play an important role in resultant carbon fibres, hence big agglomerate size results in a defect in fibre. In this research work, we are reporting the dispersion of ultra-sonicated single-wall carbon nanotubes in polyacrylonitrile dope solution by mechanical stirring. Significant improvement in the properties of polyacrylonitrile was obtained due to the effective dispersion of single carbon nanotubes which were characterized by optical microscopy, Brookfield viscosity measurement, and solvent resistance test.

**INTRODUCTION**

Carbon fibre is one of the hot topics among researchers due to its lightweight and high-strength properties. As reported by many research groups, the strength of Carbon fibre is 50 times as much as that of steel. Due to its lightweight and high strength, the use of this material is currently being explored in many applications like Aero-Space technology, Defence technology, Sports Technology, Automotive sector (futuristic automobiles). Although Carbon fibre has a unique set of properties these properties solely depend on the Carbon content present in the final produced fibre which is directly related to choosing of precursor. Many precursors for making Carbon fibre have already been explored in many studies like Polyacrylonitrile (PAN), Pitch, Rayon fibre, etc. Among these precursors, PAN has the highest share of about 95% in producing commercial Carbon fibre for various applications. The first PAN-based Carbon fibre was prepared by a Japanese scientist named Akio Shindo and due to its high Carbon percentage in Carbon fibre, it led to better performance and strength than other precursors.

A typical process of producing Carbon fibre from PAN includes PAN dope preparation, fibre spinning, Precursor winding, Stabilization (where PAN linear chains form a ladder-like structure), and lastly Carbonization. In many research papers, it has been reported that the addition of carbon-based nano-filler such as Carbon nanotube, graphene, etc. influences the properties of the produced carbon fibre and also helps in reducing the shrinkage ratio during the spinning process. Since the extremely small diameter of CNTs (typically of the order of nanometers) coupled with their large lengths (in the order of micro-meters) results in a very high aspect ratio. This higher aspect ratio provides more surface area for PAN polymer chains to wrap on them which makes the carbonization process more effective due to its high thermal conductivity. Carbon nanotubes are of various types depending on the number of carbon layers on the sidewalls, namely single-walled CNTs (SWCNTs), double-walled CNTs (DWCNTs), and multiwalled CNTs (MWCNTs). In SWCNTs, a single graphene sheet is rolled up and forms a seamless tube with both ends capped. In the case of MWCNTs, more than one graphene layer or few-layered graphene sheets are rolled up coaxially one over another to form a concentric cylindrical arrangement with an interlayer spacing of 0.34-0.36 nm. The diameter of SWCNTs ranges from ~ 0.4 to 2 nm, whereas for MWCNTs it varies from 4 up to 100 nm. The density of MWCNTs and SWCNTs are 1.75 gm/cc and 1.4 g/cc respectively.

The dispersion of CNTs in the polymer matrix has always been a great challenge. It has been reported that the dispersion of CNTs in any polymer matrix can be improved by ultra-sonication and high shear mixing but due to their high affinity of cohesion, they tend to combine and form agglomerate (bundle) once shearing force is not present. Another way of dispersing CNT in the polymer matrix is by reducing their surface cohesion energy by either making them functionalized i.e., covalent functionalized or non-covalent functionalized.

**Objectives and results**

➢ **To study the effect of SWCNT concentration on PAN / SWCNT composite:**

For PAN property enhancement we varied SWCNT concentration from 0.1 wt% to 1 wt% in the PAN matrix. The various characterization tests indicated improvement in thermal stabilization, high carbon residual weight during complete degradation under a Nitrogen atmosphere, improvement in solvent resistance, and increase in Viscosity.

- **To study the effect of SWCNT and dispersing co-agent on dispersion on SWCNT, Kinetic stabilization of PAN, and residual Carbon weight.**

The purpose of this experiment is to use an external co-agent/dispersing agent to improve the dispersion of SWCNT in PAN. The various characterization tests indicated a reduction in agglomerate size, reduction in Kinetic activation energy for stabilization of PAN, and higher residual Carbon during complete degradation under a Nitrogen atmosphere.

- **Development and study of Graphene oxide / SWCNT hybrid reinforced PANprecursor**

The purpose of this experiment is to develop a hybrid nano-filler that has better dispersion properties of Graphene oxide in PAN while maintaining the electrical, mechanical, and thermal properties of SWCNT.

## 2.2 Eco-friendly Natural Dyeing of Cotton and Silk using Rare Earths Metal Salts as Mordants

The current project is aimed at making significant improvements in the area of Natural dyeing by using rare earth salts. In this study, the eco-friendly rare earth salts were used as mordant in the natural dyeing of cotton & silk fabrics. The influences of dyeing conditions were studied. The cotton and silk fabrics dyed using rare earth as mordant exhibited higher colour shade stability against pH variation. Using rare earth as mordant in natural dyeing enhanced the colour fastness to washing, rubbing, and light of the cotton and silk fabrics as compared to $Fe^{2+}$ and $Cr^{6+}$. Rare earth salts were found to be more efficient, resulting in a decrease of mordant concentration in natural dyeing. Thus, rare earth salts were shown to be effective mordant in the natural dyeing of cotton and silk fabrics.

The ion of rare earth elements can form a bond with hydroxyl, carbonyl group, etc. of natural dyestuff and fibre, making rare earth salt a good candidate to be used in dyeing. We have shown that it can be used as pre-mordant as well as post-mordant depending on the type of the natural dye. In the case of Mulberry leaf extract, we have used RE as pre-mordant, while in the case of indigo dye we have used the RE salts as post-mordant.

In the pre-mordanting process of the silk fabric, the rare earth salt ion can be envisaged to improve capillary action by its ion causing swelling of fibre and structural relaxation for better dye diffusion as well as effective interaction with the fibre. In addition, rare earth elements can make colouring matter activation on the fibre by better coordination.

The rare earth salts used in our study were Cerium nitrate, Cerous sulphate, Lanthanum chloride, Lanthanum carbonate, Yttrium oxide, and Yttrium chloride. Cerous sulphate, Lanthanum carbonate, and yttrium oxide showed lesser solubility in water, thus citric acid was used with these RE salts. The complexation of the RE salt with citric acid has been shown in figure-1. This coordination with citric acid makes the RE salt not only solubilize but also act as a co-catalyst in mordanting step. These complexes were used in mulberry extract dyeing of cotton and silk fabrics.

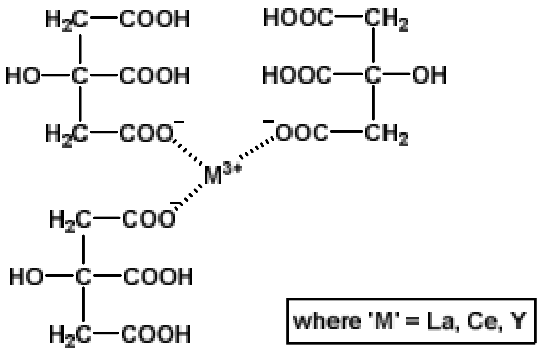



**Figure-1 RE salt and Citric acid complexation**

The usual drawback with some of the natural dyes is their fastness properties and it is for this purpose that mordants are used to bind the colorant to the fabric. The binding capacity of Lanthanides (La, Ce, and Y) is better than transition metal ions (Fe, Cr) as the rare earth salts have greater coordination as shown in figure-2 with an indigo colorant as an example,

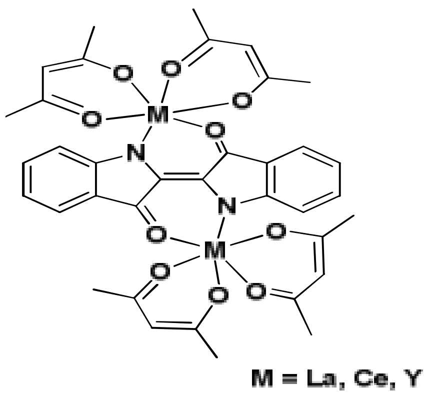



**Figure -2 RE salt with indigo dye**

Among the fastness properties- Wash, light rubbing, and perspiration, individual natural dyes show their characteristic behaviour. For example- Turmeric dye has poor wash and light fastnesses but has reasonable rubbing fastness. Indigo has a good wash and light fastness but poor rubbing fastness. Conventional use of Transition metal salts did not solve the fugitiveness of Turmeric dye, nor could they bring about improvement in the rubbing fastness of Indigo dye. Even Mulberry dye has a poor wash and light fastnesses.

We have been able to improve the fastnesses of Turmeric, Indigo, and Mulberry dyes with the use of RE salts. Here we have described the improvement in rubbing fastness in indigo dyeing in table-1 and the improvement in wash and light fastnesses in Mulberry dye in table-3.

Since rubbing fastness is a major issue faced by indigo dyers, we tried to experiment with rare earth salts -Cerous sulphate, Lanthanum chloride, and Yttrium chloride through post-mordanting. It is known that rare earth metals form chelates with dye molecules particularly with Yttrium salts as the results of rubbing fastnesses are shown in table-1.

**Table-1 Rubbing Fastness of Indigo dyed silk swatches**

| Indigo samples post mordanted | Rubbing fastness (dry) | Rubbing fastness (wet) |
|---|---|---|
| Control | 2 | 2 |
| 4 % Alum | 2 | 2 |
| 4 % Ferrous Sulphate | 2-3 | 2 |
| 0.4 % Cerous Sulphate | 3-4 | 3-4 |
| 0.4% Lanthanum Chloride | 3-4 | 3-4 |
| 0.4% Yttrium Chloride | 4 | 4 |

The best results were obtained with yttrium chloride. The rubbing fastness (dry and wet) both increased by 2 units as shown in the table-1. The control and alum mordanted silk fabrics showed the rubbing fastness as 2 while yttrium chloride mordanted fabric showed the values as 4.

This incremental value of rubbing fastness for indigo by post-mordanting with RE salts has proven that these RE salts have played a very pivotal role in arresting the colour of the fabric. With the optimum use of 0.4% of the concentration of RE salt as post mordanting, the results obtained were remarkable.

**Dyeing results with extract of Mulberry leaves**

The RE salts used in this research work were Cerous sulphate, Lanthanum chloride, and Yttrium chloride. It was proved that using RE salts in just 0.4 % as pre-mordant enhanced the colour fastness to washing, rubbing, and light of dyed silk fabrics. The colour depth was found to be better than the unmordanted and conventional mordant- which was used in 4 %. The best results of premordanting with RE salts with mulberry leaf extract dye were with lanthanum chloride and Yttrium chloride as can be seen in table -2. The colour depth in terms of K/S values obtained from $LaCl_3$ (126.23) and Y $Cl_3$ (127. 47) are far more than the unmordanted(52.33) and the alum mordanted ( 80.07) for silk swatches. It is known that Metal-complex dyes adsorbed on silk inhibit marginal migration due to the high stability of the dye–fibre linkages and produce invariably bright good shades with good light and wash fastness as shown in table-2.

The wash and light fastness showed in table-3 of dyed silk swatches pre-mordanted by RE salts show a higher value than unmordanted or even alum mordanted. The mordant quantity required for RE salt was just 0.4 %. The fastness properties values shown in table-3 also showed marked improvement.

**Table-2 CIELab values of the Dyed silk swatches with Mulberry leaves**

| S.No | Mordant | K/S Value | L | a | b | C | H | dE | Remark |
|---|---|---|---|---|---|---|---|---|---|
| Std | Control | 52.33 | 52.87 | -23.58 | 13.33 | 27.09 | 150.53 | -- | |
| 1 | Alum | 84.07 | 40.45 | -15.38 | 11.54 | 19.23 | 143.12 | 14.99 | |
| 2 | Ce Sul | 79.33 | 41.84 | -15.47 | 13.12 | 20.29 | 139.71 | 13.68 | |
| 3 | $LaCl_3$ | 126.23 | 32.54 | -11.54 | 6.05 | 13.03 | 152.32 | 24.72 | **Good** |
| 4 | Y $Cl_3$ | 127.46 | 31.91 | -10.96 | 4.04 | 11.69 | 159.77 | 26.16 | **Best** |

**Table -3 Wash and Lightfastness of the Dyed silk swatches with Mulberry leaves**

| Mordant | Wash Fastness | Light Fastness |
|---|---|---|
| Control | 3 | 1 |
| Alum | 3-4 | 2 |
| Cerous Sulphate | 4 | 2 |
| Lanthanum Chloride | 4 | 3 |
| Yttrium Chloride | 4-5 | 3 |

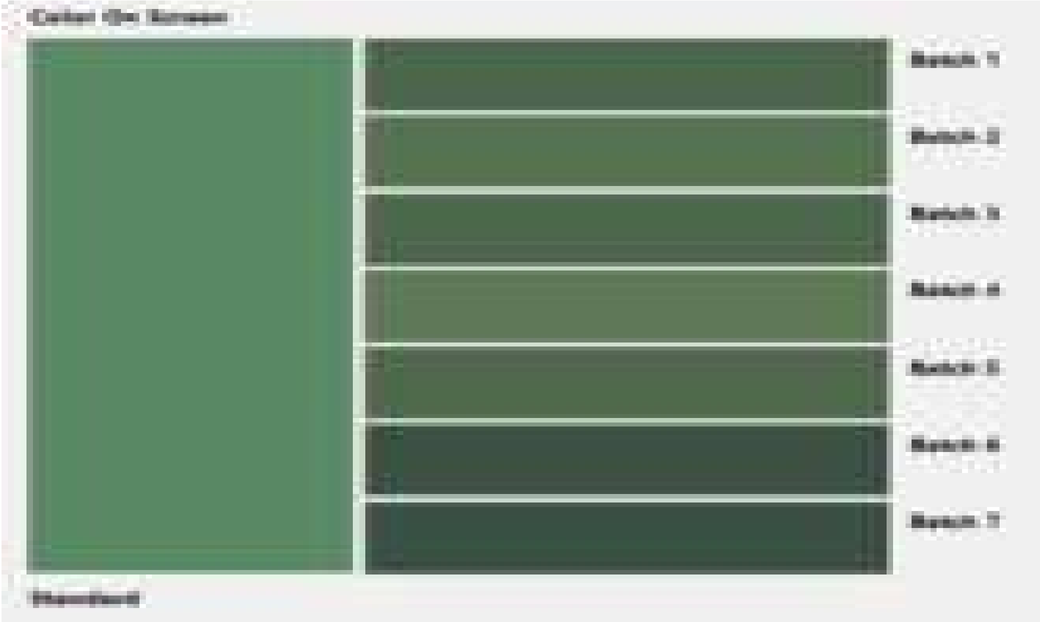


**Figure-3 Colour Palette from dyeing silk ( Std- control); Batch-1-Alum; Batch-2 Ce N:CA; Batch-3 La C :CA; Batch-4 YO: CA; Batch-5 Ce Sul ; Batch-6 La Cl; Batch -7 Y Cl**

**Conclusion:** The use of Rare earth salts as post-mordant in the case of Indigo dye made a good improvement in rubbing fastness, while in the case of Mulberry leaf extract pre mordanting with rare earth extract showed good colour depth. The major attributes of using rare earth salts are -Shorter dyeing time, reduction in usage of mordant percentage ( from 4 % in the case of Alum to 0.4% in the case of rare earth salts), and environmentally benign. This makes them an ideal additive for Natural dyeing even on an industrial scale.

### 2.3 Development of a Standard Method for Identification of Dope Dyed and Exhaust Dyed Polyester Fibers/Fabrics

**Abstract**

It is known that color fastness properties of the dope-dyed polyester are better compared to the exhaust dyed fibers/fabrics. Based on this, researchers have tried to explore the method for identification of the dyeing process through chemical properties and the dye stripping behaviour. But, these methods of analysis are not confirmative, because there are other types of fibre available that also behave similarly to dope dyed. However, there is no standard method available at the national as well as international level to identify the method of polyester dyeing. Therefore, in this project, a suitable and acceptable confirmative method will be developed to differentiate the dope dyed and exhaust dyed fabric.

**Introduction**

Dyeing is the coloration of the textile substrate by suitable substances called dyes or pigments. The former is widely used in textile wet processing. Different types of processes are available to dye polyester at any stage of the manufacturing of textiles such as fiber, yarn, fabric, or a finished textile product including garments and apparel, which depends on several factors including the type of material, generic type of fiber, size of dye lots and quality requirements in the dyed fabric.

The most widely used fiber in textiles is polyester (PET) because of its excellent properties such as high strength, abrasion resistance, well resistance to acids, oxidizing agents, and wrinkle-free characteristics. There are varieties of commercial forms of polyester available in the market viz., Texturized polyester, Bright polyester, Dull polyester, Cationic dye-able polyester, Cot look polyester, Microfiber polyester, Air punched polyester, Staple fiber polyester, and its blends. They are coloured through either dope dyeing with pigments during the melt spinning stage or exhaust dyeing after the production of filaments/fibers.

Dope dyeing of polyester filaments/fibers has gained considerable interest in academics as well as in the industrial community in recent years. This is primarily due to the intrinsic dyeing of polyester during fiber spinning. It has altogether good physical and chemical properties than exhaust dyed material. The use of dope-dyed polyester yarn is preferred in certain specific application areas like Army uniforms in Defence due to its higher fastness properties. In this context, it has also been realized that doped dyed polymer gives less burden on the environment. Despite this, the textile processors might compromise on this front because of a marginal increase in cost. Therefore, exhaust dyeing is still popular in the textile wet processing industry not only due to its lower cost and easy accessibility but also have much more choices of different colours, unlike dope dyeing where only fiber/filaments manufacturer have their choices with a limited number of coloured pigments.

The polyester fabric of the same colour but produced by dope and exhaust-dyeing routes looks similar. However, the performance of the dope dyed and exhaust dyed polyester fabric in terms of color fastness to various chemical agents and environmental conditions is different. Consequently, this difference in fabric performance may create shade-off or a tonal variation, which creates hurdles to achieving desired long-term properties. However, there is no standard method available to distinguish exhaust or dope dyeing methods of polyester fibers/fabrics. Efforts are being made in this direction, but no confirmative result has been reported yet. Therefore, there is a necessity to develop a standard method to understand whether the sample is dope dyed or dyed using the exhaust dyeing route.

The current project will cover a systematic investigation of the dope dyed and exhaust dyed polyester filaments/fabrics through physical, chemical, optical, thermal, microstructural, and morphological studies. The performances of the dope dyed and exhaust dyed polyester will also be evaluated by various appropriate analytical methods.

**Specific objectives of the study**:
(Indicating the methods to be followed for achieving each objective and verifiable indicators)

**Objectives**:

1. Melt spinning of polyester filaments with and without loading of the master batch.

2. Disperse dyeing of the FDY(Fully drawn yarn) polyester filaments by exhaust dyeing method at different shade %.

3. Evaluation and optimization of colour properties of the dope dyed and exhaust dyed PET in terms of L*, a*, b*, ΔE, and K/S values.

4. Characterization of the prepared dope dyed and exhausts dyed PET filaments/fabric concerning different fastness properties along with SEM, dielectric thermal analysis, TGA analysis, particle size analysis of dye present in the filaments, dye distribution, and other relevant analysis.

5. To establish the standard test method to distinguish the fabric dyed by dope dyeing and exhaust dyeing technique.

**Work plan**

**Step 1**
Melt spinning of pure polyester and loaded with masterbatches will be carried out in a melt spinning machine as shown in Fig. 1. The melt spinning parameters such as an extruder temperature, metering pump temperature and speed, spin head temperature, and winding of the extruded POY(Partially oriented yarn) filaments will be selected to get consistency in their denier and properties. The produced POY will be converted into stable FDY by drawing and heat setting.

The physical and mechanical properties of those filaments will be characterized

**Step 2:**
Disperse dyeing of FDY polyester filaments will be carried out at different shade% by the standard dyeing method

**Step 3:**
Absorbance / reflectance/ transmission of the light is affected by surface characteristic features of the material. Therefore, colour characteristics of disperse dyed and dope dyed polyester filaments/fabric will be evaluated and optimized in terms of L*, a*, b*, ΔE, and K/S values as per AATCC test method 173:2009. The small colour differences between that dope dyed and disperse dyed samples will be selected for further study based on the following interpretation of the results:

i) If ΔEcmc is less than or equal to 1.0, then samples are acceptable.

ii) If ΔEcmc is greater than 1.0, then samples are unacceptable.

**Step 4:**
Based on the colour characteristics, an optimized dope dyed and exhausts dyed polyester filaments/fabrics were further assessed by different analytical techniques.

**Work done**
PET raw white and the dope yarn were prepared in the laboratory by melt spinning. For this Reliance chips were dried at 90°C without a vacuum for 2 days and at 130°C with a vacuum for 5 hours. It was spun in a melt spinning machine by Textile Equipment Co. Ltd. with extruder temp 275 to 285, rpm 10, pressure 0.5 MPa, draw ratio 3. For Dope Dyed yarn, a Clariant Red master batch of 0.5 shade percentage was added.

PET raw white yarn is then dyed with dispersed dye by the exhaust method. Pre-treatment is done with Tween 80 1 GPL at 100 C for 15 min to remove oil and dirt. Dyeing was done with Colarene Red disperse dye with a 0.3 shade percentage. MLR was maintained at 1:20 with dispersing and leveling agent 1 GPL. Dyeing was done at a high-temperature high-pressure beaker dyeing machine at a temperature of 130 °C for 45 min maintaining pH 4-5. It was then treated with 2 GPL alkali and 3 GPL sodium dithionite to fix the remaining dye. Both the samples were taken for the investigations as discussed below.

### *Dye Stripping and Spectral Colour Analysis*

Stripping of the dye was done from the different samples using the Soxhlet method. Results show that more than 95% of colour was stripped in laboratory exhaust dyed samples, while colour of laboratory dope dyed samples remains intact. This is because dichloromethane helps in opening the structure of yarn by which dye particles on the surface of exhaust dyed yarn came out while larger particles in laboratory dope dyed yarn could not come out. In the case of industrial samples, more than 99% of colour stripping was observed in both industrial dope dyed and exhaust dyed samples which indicate that the particle size of dye in industrial dope dyed yarn is small and easily comes out from the polyester fiber during the stripping process.

To reconfirm the stripping behaviour of industrial dope dyed samples, industrial samples were subjected to another solvent Dimethylformamide (DMF) at a temperature of $70^{0}$C for 30 minutes. In this method also more than 95% of colour stripping was observed in both samples.

Similarly stripping of both dope dyed and exhaust dyed samples of meta-aramid (I) and meta-aramid (II) samples were also done and a reduction in colour strength value after stripping has been reported in Table 1.

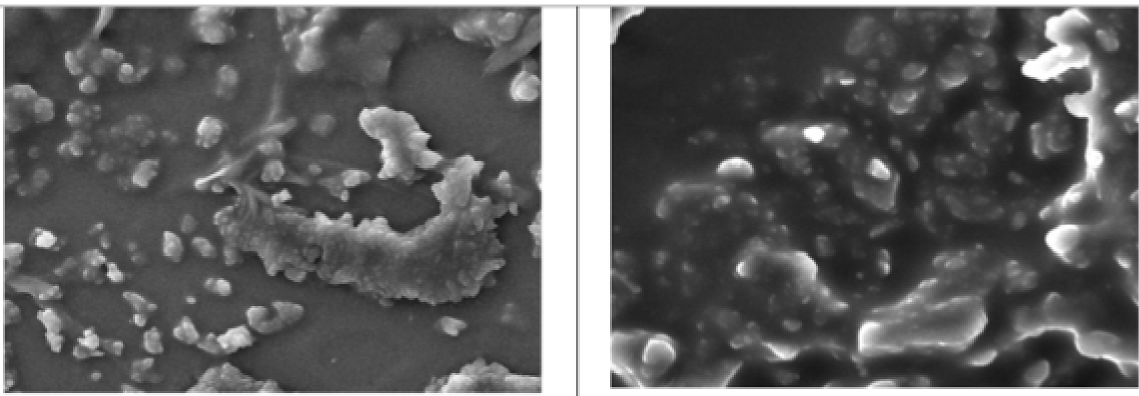
**Table 1:Colour Value of samples before and after stripping**

| Colour Strength | Before Stripping | After Stripping | Change in Colour Strength% |
|---|---|---|---|
| Laboratory PET Exhaust Dyed yarn (0.3%) in DCM | 10.5 | 0.2 | 97.9 |
| Laboratory PET Exhaust Dyed yarn (0.5%) in DCM | 14.6 | 0.08 | 99.5 |
| Laboratory PET Dope Dyed Yarn in DCM | 23.1 | 25.9 | 12.1 |
| Industrial PET Exhaust Dyed yarn (0.5%) in DCM | 5.71 | 0.04 | 99.3 |
| Industrial PET Dope Dyed yarn in DCM | 7.89 | 0.06 | 99.2 |
| Industrial PET Exhaust Dyed yarn (0.5%) in DMF | 5.71 | 0.07 | 98.8 |
| Industrial PET Dope Dyed yarn in DMF | 7.89 | 0.32 | 96.0 |
| Meta-aramid (I) Exhaust Dyed Yarn in DMF | 10.41 | 6.41 | 38.4 |
| Meta-aramid (I) Dope Dyed Yarn in DMF | 6.52 | 5.93 | 9.1 |
| Meta-aramid (II) Exhaust Dyed Yarn in DMF | 4.18 | 2.83 | 32.1 |
| Meta-aramid (II) Dope Dyed Yarn in DMF | 13.86 | 17.36 | 25.2 |

***SEM Analysis of extracted dye particles from dyed polyester***

SEM Images of extracted dye particles from the industrial sample are shown in figure 1

The average particle size from exhaust dyed sample is 1.7 microns while that of dope dyed sample is 5.9 microns.



Industrial Exhaust Dyed Sample | Industrial Dope Dyed Sample

**Figure 1**: **SEM images of extracted dye particles**

***DLS Analysis of Extracted dye particles***

The extracted dye solution was taken for the analysis of the particle size of the dye present in it. Results show that particle size of the dye in dope dyed yarn ranges from 2.42 to 13.43μ which is larger than the particles from exhaust dyed yarn ranging from 0.14 to 2.18μ.

***Boiling Water Shrinkage (BWS)***

The boiling water shrinkage of all the laboratory prepared and industrial samples were analyzed. The observed BWS values are given in table 2. In all cases, shrinkage of exhaust dyed yarn was observed less than the dope dyed yarn. This is due to the shrinkage of yarn during exhaust dyeing at high temperatures dyeing.

**Table 2: Boiling water shrinkage of yarns**

| Samples | Dope Dyed | Exhaust Dyed |
|---|---|---|
| Industrial PET Yarn | 4.88 | 3.57 |
| Meta-aramid (I) Yarn | 0.63 | 0.10 |
| Meta-aramid (II)Yarn | 0.37 | 0.29 |

***Analysis of Colour Fastness to Sublimation***

Colour fastness to sublimation of the industrial dope dyed and exhaust dyed yarns were checked in each case. Colour fastness values of polyester samples are given in Table 3 respectively. In this test, poor sublimation fastness was observed in the industrial dope dyed as well as exhaust dyed yarn at 210$^{0}$C but in the case of laboratory prepared sample, staining was observed in the exhaust dyed sample only at the same temperature but not in the dope dyed sample.

In the case of meta-aramid (I) colour fastness to sublimation was performed for a longer duration at 230$^{0}$C and the results were shown in Table 4. With the increase in time, more than 50% reduction in colour value was observed in exhaust dyed yarn while there was a mild decrease in colour value of dope dyed yarn.

**Table 3: Colour Fastness to sublimation of PET yarn**

| Temperature | 180°C | | 210°C | |
|---|---|---|---|---|
| Sample | Exhaust Dyed | Dope Dyed | Exhaust Dyed | Dope Dyed |
| Laboratory Sample | No staining | No staining | Staining in adjacent PET fabric | No staining |
| Industrial Sample | No staining | Staining in adjacent multifiber | Staining in adjacent PET fabric | High staining in adjacent multifiber |

**Table 4: Colour Fastness to Sublimation of meta-aramid (I) yarn**

| Time of exposure (min) | Colour value | |
|---|---|---|
| | Exhaust dyed | Dope dyed |
| 0 | 18.20 | 6.30 |
| 10 | 10.15 | 5.73 |
| 20 | 7.18 | 5.53 |

Similarly, colour fastness to sublimation of meta-aramid (II) samples was performed for a longer duration at 210°C, and the results were shown in Table 5. In this case also, after 15 min, there was a 25% reduction in colour value of exhaust dyed yarn while there was no significant change in dope dyed yarn.

**Table 5:Colour Fastness to Sublimation of meta-aramid (II) yarn**

| Time (min) | Colour value | |
|---|---|---|
| | Exhaust dyed | Dope dyed |
| 0 | 4.44 | 13.87 |
| 0.5 | 4.11 | 11.92 |
| 1.5 | 3.68 | 12.10 |
| 2.5 | 3.25 | 12.78 |
| 3.5 | 3.31 | 11.83 |
| 5.5 | 3.24 | 12.89 |
| 8.5 | 2.96 | 12.61 |
| 15.0 | 3.13 | 12.44 |

***Analysis of colour fastness to washing***

All the PET, meta-aramid (I), and meta-aramid (II) samples were subjected to washing to check the colour fastness to washing. The IS/ISO 105 C10 method B and C was used for the polyester yarns. There was no colour change or staining observed in the PET sample.

Meta-aramid (I) & (II) samples were tested by using method E. With the consecutive washes, there was a significant reduction (more than 50%) in colour value of exhaust dyed yarn while there was no significant change in dope dyed yarn. Colour values are given in Table 6.

**Table 6: Colour Fastness to washing of meta-aramid (I) & (II) yarn**

| No. of wash | Colour value | |
|---|---|---|
| **Meta-aramid (I)** | **Exhaust dyed** | **Dope dyed** |
| 0 | 22.30 | 6.54 |
| 1 | 9.70 | 6.66 |
| 2 | 5.89 | 6.37 |
| **Meta-aramid (II)** | | |
| | 4.17 | 13.78 |
| | 2.85 | 14.63 |
| | 2.58 | 15.38 |

***Analysis of colour fastness to light***

All the exhaust and dope-dyed samples such as PET, meta-aramid (I), and meta-aramid (II) were exposed to the light. After

63.5 h, industrial as well as laboratory exhaust dyed samples started fading.

The change in colour value of meta-aramid (I) samples concerning exposure time is shown in Table 7. In the exhaust dyed yarn, a reduction in colour value was observed after 3h of exposure while in the case of dope dyed yarn, no change in colour value was observed till 22h.

**Table 7**: **Colour value of meta-aramid (I) yarn after light exposure**

| Time of exposure (h) | Exhaust dyed | Dope dyed |
|---|---|---|
| 0 | 8.41 | 5.00 |
| 3 | 6.69 | 5.19 |
| 16 | 3.72 | 5.81 |
| 19 | 3.19 | 5.80 |
| 22 | 2.77 | 5.98 |

Similarly, in the case of the meta-aramid (II) yarn, a change in colour value was not seen after 7h of exposure in both exhaust dyed and dope dyed samples. The values are given in Table 8.

**Table 8:Colour value of meta-aramid (II) yarn after light exposure**

| Time of Exposure (h) | Colour value | |
|---|---|---|
| | Exhaust dyed | Dope dyed |
| 0 | 3.42 | 12.23 |
| 1 | 3.04 | 12.67 |
| 4 | 2.87 | 12.82 |
| 7 | 3.11 | 13.11 |

***Birefringence Test***

An important property of textile fiber is the birefringence value. This depends on the orientation of the polymer molecule concerning the fiber axis. It is expected that the presence of dye particles in the polymer during spinning may affect the orientation of molecules. So, the birefringence value of the polyester samples was measured and given in Table 9. There was no significant difference in the values between dope dyed and exhaust dyed yarn.

**Table 9: Birefringence value of PET yarn**

| Parameter | Average | Std Dev | CV% |
|---|---|---|---|
| Laboratory Exhaust Dyed Yarn | 0.0198 | 0.002 | 9.37 |
| Laboratory Dope Dyed Yarn | 0.0233 | 0.003 | 12.75 |
| Industrial Exhaust Dyed Yarn | 0.0163 | 0.002 | 9.41 |
| Industrial Dope Dyed Yarn | 0.0126 | 0.005 | 39.60 |

***Thermogravimetric Analysis (TGA)***

Thermogravimetric analysis (TGA) of all the PET samples was done to investigate the difference in thermal properties of the samples. There is no difference observed in the thermal behavior of both types of yarn. This shows the addition of pigments during dope dyeing does not affect the degradation behaviour of the polymer.

**Effect of high-temperature application for a short time**

Direct exposure of dye particles to high temperature affects the colour value of it so, experimentation was done on all types of dope dyed and exhaust dyed samples. The colour value of samples was compared after and before. The colour values of polyester samples after melting are given in Table 10. It was expected that the colour value of exhaust dyed yarn will decrease after melting due to the even distribution of dye particles in the polymer after melting, but in both cases reduction in colour value was observed.

**Table 10:Colour value of PET yarn before and after melting**

| Particulars | Before Melting | After Melting |
|---|---|---|
| Laboratory Exhaust D yed yarn (0.5%) | 14.6 | 8.8 |
| Laboratory Dope Dyed Yarn | 23.1 | 10.9 |

Similarly, aramid yarns were subjected to a furnace at a temperature of 300$^0$C for 2 minutes and found that there is a change in tone of aramid exhaust dyed samples compared to the dope dyed yarns. The colour values before and after heat exposure are given in Table 11.

**Table 11:Colour Value of aramid yarn before and after heat exposure**

| Particulars | Before heat exposure | After heat exposure |
|---|---|---|
| Meta-aramid (I)Exhaust Dyed Yarn | 20.73 | 3.90 |
| Meta-aramid (II) Dope Dyed Yarn | 6.58 | 6.59 |
| Meta-aramid (II) Exhaust Dyed Yarn | 4.18 | 11.67 |
| Meta-aramid (II) Dope Dyed Yarn | 13.87 | 14.39 |

**4.11. Analysis of thermal properties by Differential Scanning Calorimetry (DSC)**

In the first phase of this study, dope dyed and exhaust dyed yarn of both laboratory-prepared and industrial PET samples were analyzed. The melting temperature (Tm) of all samples is given in Table 12. The melting temperature of dope-dyed yarn is observed less than the exhaust dyed yarn in both cases. This is due to the presence of dye molecules inside the molecular chain of the polymer. Further experimentation on meta-aramid yarn is in progress.

**Table 12: Melting temperature of PET samples**

| Yarn | Melting Temperature (°C) |
|---|---|
| Laboratory PET exhaust dyed yarn | 257.22 |
| Laboratory PET dope-dyed yarn | 255.9 |
| Industrial PET exhaust dyed yarn | 252.74 |
| Industrial PET dope-dyed yarn | 249.04 |

**Summary of the findings**

The reported findings from the different tests such as colour fastness to sublimation, washing, light, and heat exposure for short time, show colour value of exhaust dyed yarn reduces while there is no significant change in dope dyed yarn. Shrinkage of exhaust dyed yarn is also less than that of dope dyed yarn due to relaxation during the exhaust dyeing process. The melting temperature of the PET dope dyed sample is observed less compared to the exhaust dyed yarns, while birefringence and TGA analysis did not provide any distinguishing results between the two. Further planned experiments are in progress.

**In-house project**

## 2.4 Atmospheric pressure plasma treatment of textiles for dyeing various fabrics with natural and synthetic dyes

**Abstract:**
This study aims to understand the effect of atmospheric pressure plasma treatment of woven Polypropylene (PP) fabric on dyeability with acid dyestuff. PP fabric was treated with plasma generated from helium and oxygen gases and dyeing was carried out using acid dyes. Optimisation of the plasma processing parameters vis plasma treatment time, plasma discharge power, and distance between the two electrodes were optimised using the Box-Behnken Design (BBD) model of Design of Experiments (DoE).

1. **Introduction:**

The use of synthetic fibres in technical textile, transportation, and apparel is increasing due to large availability and low cost. Polypropylene has some good properties such as low density, high strength, dimensional stability, resistance to friction, and chemicals. Despite that, the application of PP is limited due to poor wettability and dyeability. A good attractive colour is important for any fabric for widespread applications. The coloration of PP by chemical modification such as the introduction of polar functional groups at the polymer backbone, and addition of the dyestuff acceptor during melt spinning is possible, however, all such techniques fail due to undesired side effects, ecological problems, loss of some good textile properties and additional cost. On the other hand, plasma surface modification is a dry and clean process, does not affect the desired properties, and is an environmentally friendly technique. Hence, we have used the atmospheric pressure plasma surface modification technique to modify the PP surface to impart wettability and dyeability.

**2. Materials and Methods**

Woven Multifilament Polypropylene( PP) fabric with 130 GSM was supplied by Flexituff, India. Acid dyes used are from Colourtex India Pvt. Ltd. (CI Acid Blue 113CI Acid Red 114) Helium gas (He) with 99.995% purity was procured from INOX air products, India. Plasma treatment of the PP fabric: Plasma processing variables namely plasma treatment time, power, and distance between the electrodes were optimised using the BBD model of DoE. The levels of plasma variables are shown in table 1. Plasma treatment of PP fabric was carried out as per the BBD model and details of the experimental design along with response are given in table 2.

**Table 1. Experimental levels of plasma variables**

| Sr. No. | Variable | Unit | Level | | |
|---|---|---|---|---|---|
| | | | -1 | 0 | +1 |
| 1 | Plasma treatment time | sec | 15 | 30 | 45 |
| 2 | Plasma power | kW | 1.5 | 2.5 | 3.5 |
| 3 | Distance between the electrodes | mm | 0.5 | 1 | 1.5 |

**Table 2 Experimental design matrix with dependant variables (responses)**

| Sr.no. | Power (kW) | Time(Sec) | Distance (mm) | Responses | | | |
|---|---|---|---|---|---|---|---|
| | | | | K/S Red | K/S Blue | Dye absorbed Red mg/gm | Dye absorbed Blue mg/gm |
| 1 | 2.5 | 15 | 0.5 | 1.23 | 1.322 | 1.3105 | 1.32375 |
| 2 | 3.5 | 45 | 1 | 1.353 | 1.472 | 1.7698 | 1.7578 |
| 3 | 2.5 | 30 | 1 | 1.418 | 1.574 | 1.5927 | 1.621 |
| 4 | 2.5 | 15 | 1.5 | 1.028 | 1.179 | 1.1023 | 1.2065 |
| 5 | 3.5 | 30 | 1.5 | 1.355 | 1.402 | 1.548 | 1.6287 |
| 6 | 1.5 | 30 | 0.5 | 1.328 | 1.374 | 1.53527 | 1.5821 |
| 7 | 1.5 | 45 | 1 | 1.124 | 1.258 | 1.1079 | 1.466 |
| 8 | 3.5 | 15 | 1 | 1.093 | 1.395 | 1.0198 | 1.4078 |
| 9 | 2.5 | 30 | 1 | 1.4362 | 1.5495 | 1.641 | 1.6085 |
| 10 | 2.5 | 30 | 1 | 1.4359 | 1.3968 | 1.6439 | 1.5949 |
| 11 | 2.5 | 30 | 1 | 1.4265 | 1.3785 | 1.6448 | 1.5831 |
| 12 | 2.5 | 45 | 0.5 | 1.653 | 1.4195 | 1.84355 | 1.6796 |
| 13 | 2.5 | 45 | 1.5 | 1.108 | 1.231 | 1.2305 | 1.35935 |
| 14 | 1.5 | 30 | 1.5 | 0.99 | 1.112 | 1.211 | 1.1335 |
| 15 | 3.5 | 30 | 0.5 | 1.523 | 1.63272 | 1.7198 | 1.79578 |
| 16 | 2.5 | 30 | 1 | 1.2152 | 1.3769 | 1.34324 | 1.3906 |
| 17 | 1.5 | 15 | 1 | 0.922 | 1.108 | 1.095 | 1.1012 |

Dyeing of the plasma-treated PP fabric with acid dyes: untreated as well as plasma-treated PP fabric were dyed with CI Acid Blue 113 and CI Acid Red 114 dyes. The dyeing was carried out using 1:50 MLR, at 90°C for 60min. 0.5% dye shade was used on the weight of the fabric and 10% sodium sulphate was added to the dyeing bath. The pH of the dye solution was set to 4 using acetic acid. After dyeing the samples were washed with 2% non-ionic detergent at 40°C for 30min and allowed to dry overnight.

The dye solution left after dyeing was collected and the absorbance of the solution was measured using a UV-Vis spectrophotometer (Shimadzu UV/vis 1800). The dye adsorbed by the fabric was calculated from the initial and final absorbance values of the dye solution.

## 3. Characterization techniques

### *3.1 Optimisation of plasma processing parameters using design of experiment*

Effect of plasma processing parameters namely plasma treatment time (sec), plasma power (kW), and distance between the electrode (mm), on dyeability (K/S and dye adsorption on the PP surface) was optimised using the BBD model using Design Expert @7.0 software. A total of 17 experiments were carried out with 5 center points. Results were analysed by ANOVA and 3D surface response plots were drawn.

### *3.2 Surface chemical analysis*

The changes in the surface chemistry after plasma treatment were studied by ATR-FTIR. The ATR-FTIR spectra were recorded at a resolution of 4cm$^{-1}$ using the Perkin-Elmer spectrometer.

### *3.3 Mechanical properties*

Tensile strength of the untreated and plasma-treated samples was carried out on pyramid tensile testing machine model Tinius Olsen H50KL Aimil. ASTM D 5035 - 2015 standard test method was used to analyse the breaking strength of the samples. The average of the five tests specimen was considered as the tensile strength of the fabric

## 4. Results and Discussion

### *4.1 Optimisation of plasma processing parameters using the BBD model:*

The difference between the actual and predicted values of the response is plotted in the normal probability plot of residuals as shown in figure 1. It suggests that the predicted values calculated from the model and actual values obtained by experiments lie very close to a straight line and are randomly distributed over the plot area. Therefore, the assumption of the analysis indicates that the prediction by the selected model is accurate.

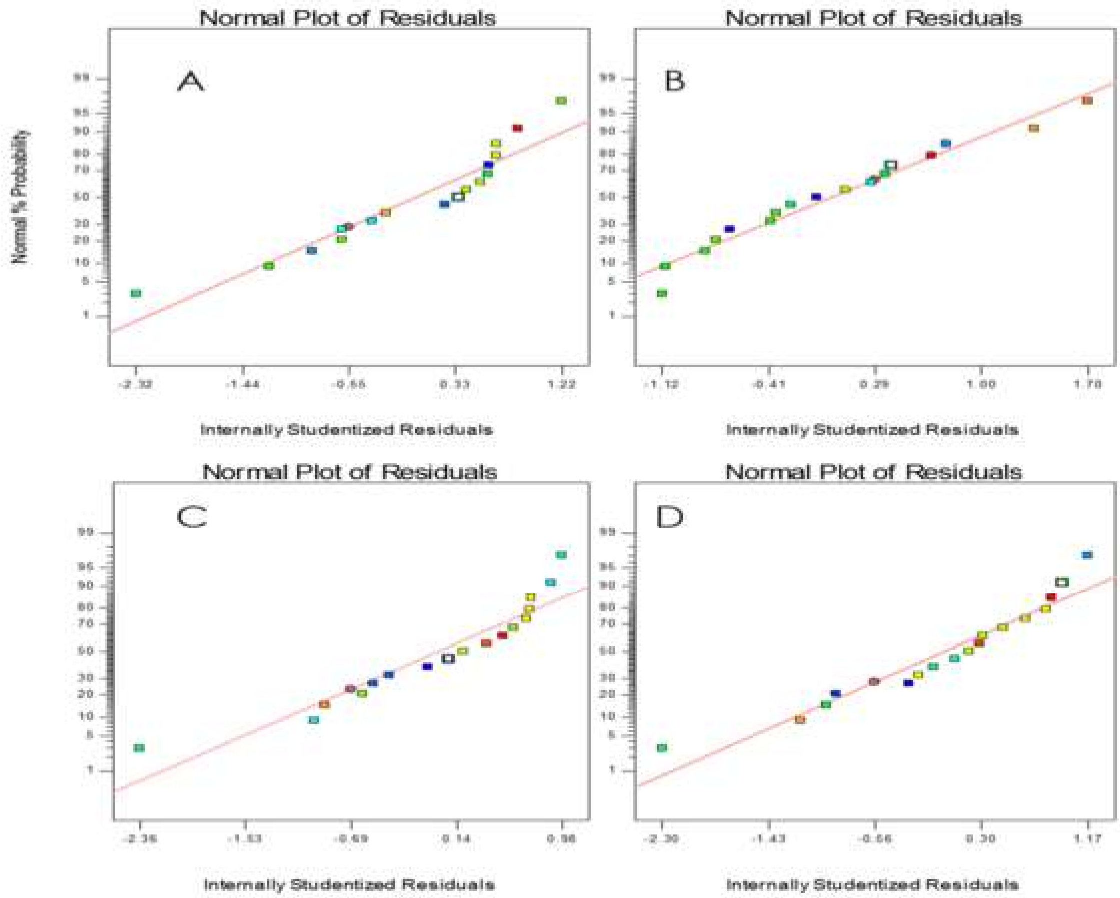



**Figure 1. Normal probability plots of residuals – A) K/S Red, B) K/S Blue, C) Dye absorbed Red mg/gm, D) Dye absorbed Blue mg/gm**

Effect of plasma variables on responses vis K/S and dye adsorbed of red and blue acid dyes are shown in 3D plots (figure 2-5). The interactive effect of the variables on response was studied by varying the two factors at a time while keeping the third variable constant.

It can be seen from figure 2A, that when the plasma power was fixed at 2.5kW, the

K/S values of the red acid dye increased with increasing plasma treatment time. At a plasma treatment time of 15sec, there is a marginal change in K/S values with a change in distance between the two electrodes. Figure 2B shows the interactive effect of plasma treatment time and power at a fixed distance of 1mm. We can see that with increased plasma power and time K/S values are increasing. Figure 2C shows that at a minimum distance and maximum power K/S value is highest when the treatment time is constant at 30 sec. This indicates that the plasma treatment time and power are significant factors for improving the dyeability of PP fabric with acid red dye. This improved dyeability can be attributed to plasma surface modification which resulted in the introduction of new functional groups as discussed in the FTIR section.

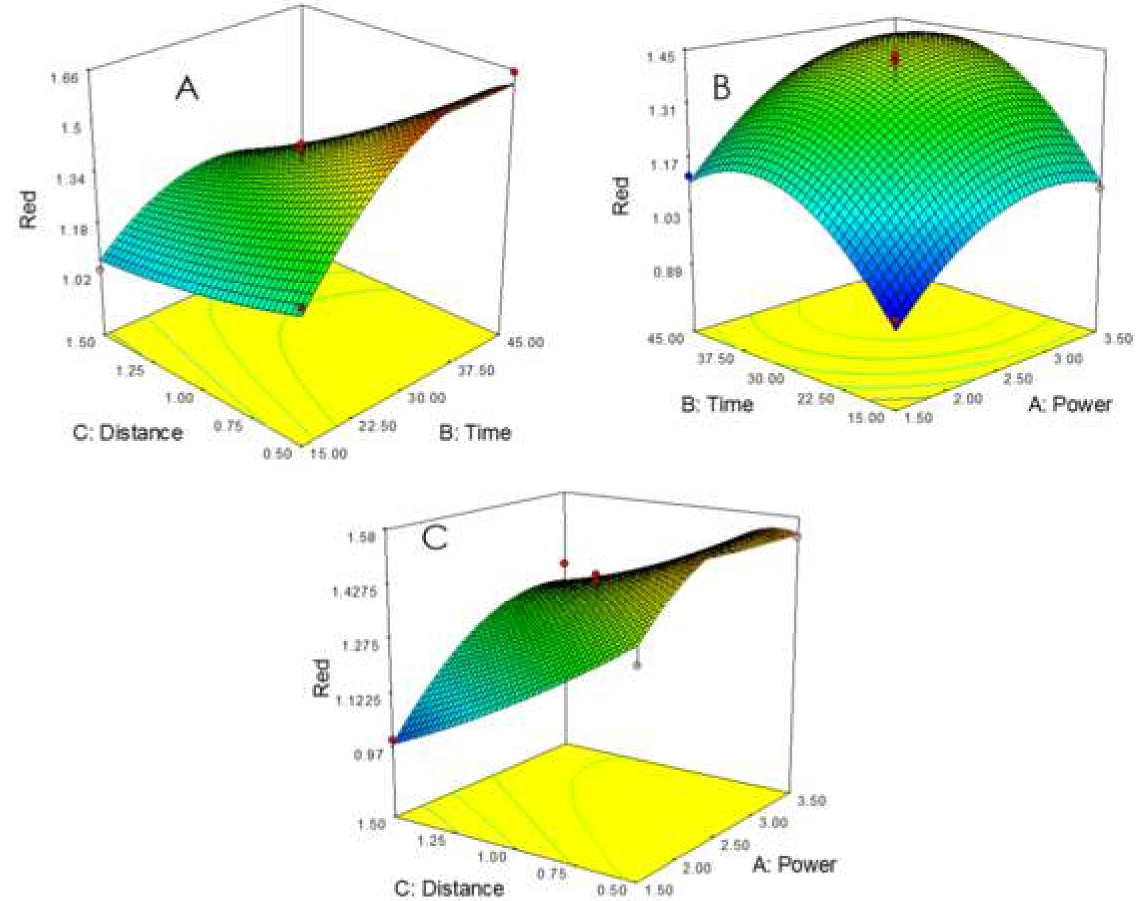



**Figure 2- 3D response surface plot- effect on dyeability of Red acid dye, A) plasma treatment time and distance between the electrodes at 2.5kW power, B) plasma treatment time and power at distance between the electrodes 1mm, C) plasma power and distance between the electrodes at 30 sec treatment time.**

The Dye adsorbed by the fabric after dyeing was measured by using the following equation

Dye adsorbed (mg/gm on PP fabric) = $(C_0 - C_f)\frac{V}{W}$

Where $C_0$ and $C_f$ are the initial and final dye concentrations of the dye solution respectively, V is the volume of the dye bath and W is the weight of the sample (gm).

Table 2 shows the results of dye adsorption of red and blue acid dyes. It is very well understood that the K/S is directly proportional to the dye adsorbed by the fabric and hence it can be seen in figure 3 (A-C). As can be seen from figure 3, follows the same trend as figure 2, and plasma treatment time and power are the significant factors to improve the dye adsorption.

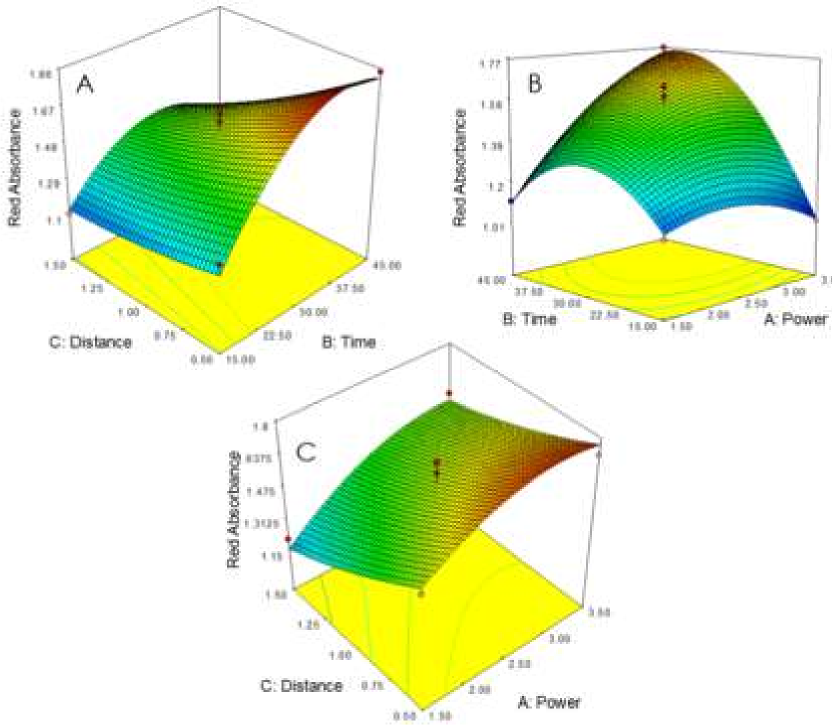



**Figure 3- 3D response surface plot- effect on dye adsorption of Red acid dye.**

Similarly, the effect of plasma processing parameters on the dyeability of PP fabric with blue acid dye is shown in figures 4 and 5. Here also it can be seen that the plasma treatment time and power are more significantly affected than the distance between the electrodes.

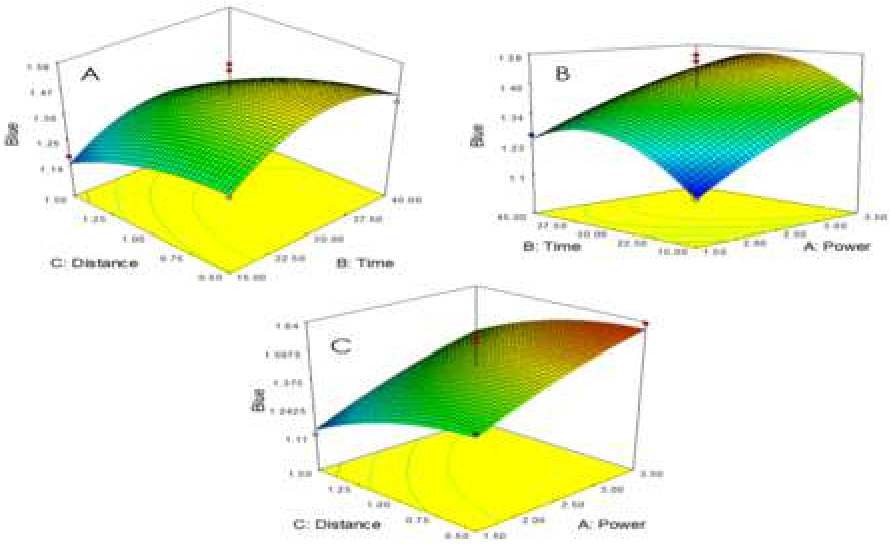



**Figure 4- 3D response surface plot- effect on dyeability of Blue acid dye.**

From the above results, it may be concluded that the plasma treatment time and power are the most important factors to impart the dyebility to PP fabric. Further, to optimise the plasma processing parameters desirability function of DoE was used. The plasma treatment time of 32 sec, 3.3kW power, and 0.5mm distance between the electrodes was found to be optimum for maximum improvement in dyeability with red and blue acid dyes.

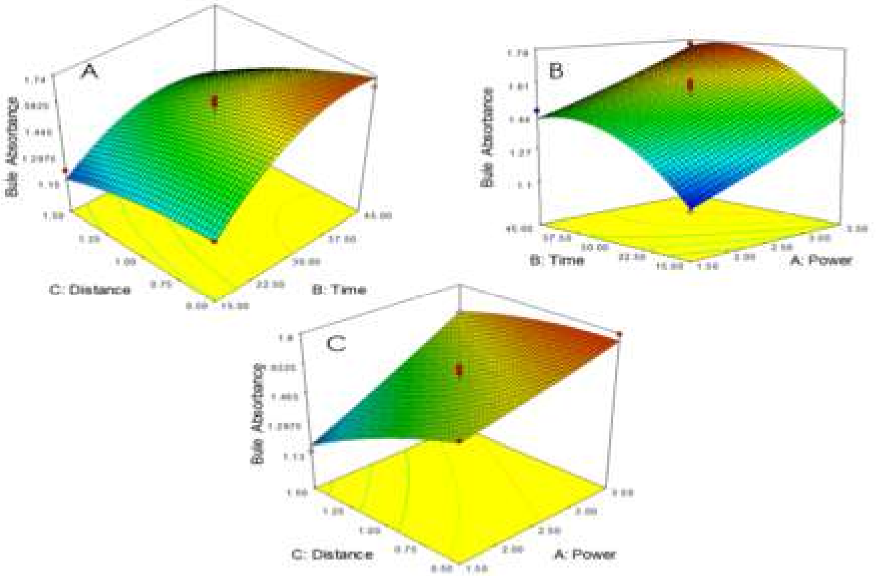



**Figure 5- 3D response surface plot- effect on dye adsorption of Blue acid dye.**

**4.2 Surface chemical analysis**

ATR- FTIR spectra of the untreated and plasma-treated PP fabric are shown in figure 6. Peaks at 2950, 2918, 2868, 2839, 1454 and1375 cm$^{-1}$ in spectra of untreated and plasma-treated Samples can be assigned to characteristic peaks of polymer. In addition to characteristic peaks of PP, extra peaks at 1734 and 1103 cm$^{-1}$ were recorded for plasma-treated samples. Out of these, the peak at1734 cm$^{-1}$ can be assigned to symmetrical vibrations of the carbonyl group C=O. This shows surface oxidation after plasma treatment and is responsible for the increase in wettability of plasma-treated samples, hence the improved dyeability. A new peak for plasma-treated PP samples was seen at 1103 cm$^{-1}$ which can be attributed to the stretching of the ester C–O–C bond.

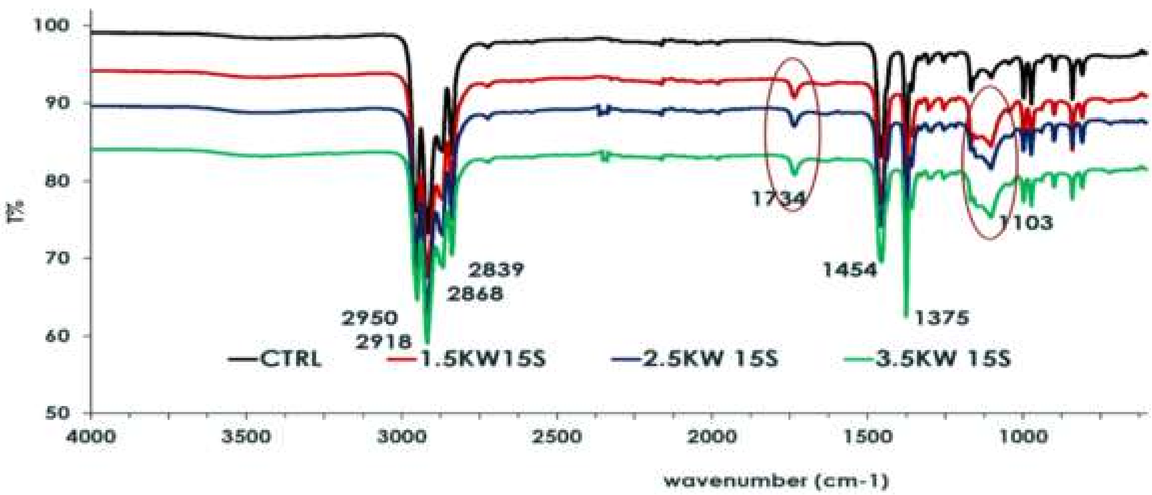



**Figure 6 ATR- FTIR spectra of untreated and plasma-treated PP fabric.**

### 4.3 Mechanical properties

The effect of plasma discharge power on the tensile properties of PP fabric was evaluated in the warp direction and depicted in Figure7. The initial tensile strength of untreated PP fabric was 32.86 N/mm and after plasma treatment, it was changed to 31.7 N/mm. It can be said that there is no significant change in tensile properties was observed as plasma is a surface modification technique and does not affect the bulk properties of the textile materials.

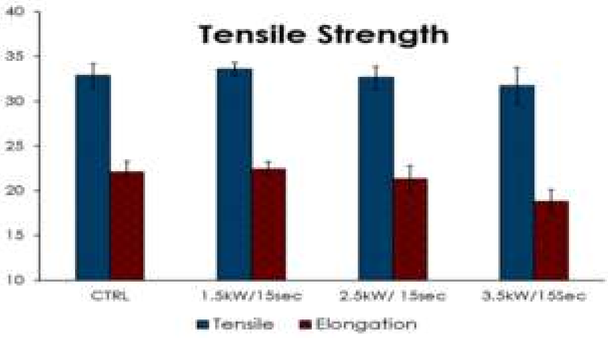



**Figure 7 Effect of plasma treatment on tensile strength of PP fabric**

### 5. Conclusions

Plasma treatment of PP fabric was carried out at atmospheric pressure plasma using helium and oxygen gases. Plasma-treated fabric was dyed with red and blue acid dyes and optimisation of the plasma processing parameters was carried out using the BBD model. Plasma treatment time of 32 sec, 3.3kW power, and 0.5mm distance between the electrodes was found to be optimum for maximum improvement in dyeability with red and blue acid dyes. The FTIR result showed the incorporation of new functional reactive groups which are responsible for improved dyeability of PP fabric. Further, the tensile strength of plasma-treated PP fabric remains unchanged without affecting the desired bulk properties.

## 2.5 Development of Nylon 6, Polypropylene / Graphene Oxide (GO) high-performance nanocomposite filaments

### 1. Introduction

A polymer nanocomposite (PNC) is made up of a polymer matrix in which nano-sized additives are incorporated. The nano-sized additives can be of zero-dimensional (nanoparticle), one-dimensional (nanofibres), two-dimensional (graphene sheets) or three-dimensional (spherical particles).PNCs have attracted considerable interest due to the infusion of a merely small quantity of inorganic nano-scale filler into the polymer matrix leading to prominent enhancement in mechanical, optical, electrical, and thermal properties of the resulting materials as compared to the neat polymers or micro fillers composite. The discovery of graphene has led to the succeeding development of graphene-based polymer nanocomposites. Sheets of graphene have a higher surface-to-volume ratio as compared to CNTs as polymer molecules are incapable to access the inner surface of the nanotubes. Thus graphene sheets seem to be a more favorable choice for altering mechanical, rheological, and permeability properties as well as the thermal stability of polymer matrix. The improvement in the mechanical properties of graphene-incorporated nanocomposites is also attributed to the better capacity of graphene to deflect crack growth. The wrinkled structures given rise by graphene sheets or platelets disseminated in polymer matrix tend to unfold instead of stretch when subjected to stress. This may, to a great extent reduce the stiffness of the material. Nevertheless, these structures could result in mechanical interlocking and allow load transfer between polymer matrix and graphene which could be the reason behind the improved mechanical strength. However, as graphene is expensive and relatively hard to produce, great efforts are made to find effective yet inexpensive ways to make and use graphene derivatives or related materials. Graphene oxide (GO) is one of those materials - it is a derivative of graphene which bears oxygen functional groups on its basal planes and edges. Nevertheless, structurally, GO is similar to a graphene sheet. The oxygen-containing functionalities in GO enable it to be well-dispersed in water and several types of polymer matrices at the same time it retains much of the properties of pure graphene. Additionally, GO is much easier and cheaper to process and produce in bulk quantities. These characteristics have made GO the more promising filler in the manufacturing of polymer nanocomposites. By solution blending GO has previously been successfully infused into some polymers including poly (methyl methacrylate) (PMMA), polycarbonate (PC), polystyrene (PS), polyimides, and polyacrylamide using this technique. By melt mixing nanocomposites fabricated includes polypropylene (PP)/GNP, high density poly(ethylene) (HDPE)/ nano clay, PMMA/glass flake, nylon-11/graphene and nylon-12/graphene. For the in-situ polymerization method, the filler is mingled in neat or multiple monomers to intercalate the monomers between layers of filler. Polymerization is carried out subsequently to separate the layers. The nanocomposite is subsequently produced through precipitation or solution casting. For instance, nanocomposites such as polyamide-6/GO, polyimide/GO, and Nylon-6/ADA-MONT have been developed through in situ polymerization. It has been reported that the properties of many polymers such as PVA, PU (polyurethane), epoxy, PC, PMMA, and PS have been successfully improved by the incorporation of GO. In this context, in this study, initially, the aim is to bring down the graphene oxide sheet size from micron to nano range for better dispersion stability to get their uniform distribution at the molecular level in the polymer matrix and later to investigate the processing, thermal, mechanical, microscopic, and spectroscopic properties of GO/PP nanocomposites filaments fabricated by melt mixing and spinning method.

## 2. Experimental section

### 2.1 Materials

The fiber-grade polypropylene granules were procured from Reliance Industries Limited Mumbai (India). Graphene oxide (GO) with black; pH: 6-8; bulk density 0.3 - 0.5 g/cc; the number of layers ≤ 10; lateral dimensions of D10 (9.5 μM) and D90 (17 μM); carbon (65-68%), and oxygen (23-25%) was purchased from Business Trillion Industries Private Limited, Jamshedpur (India). Analytical grade Isopropyl alcohol (IPA), and Acetone were obtained from Merck, India. Deionised (DI) water was used in all the experiments.

### 2.2 Preparation of highly stable graphene oxide (GO) suspension

In this typical procedure, the 2 mg/mL graphene oxide (GO) having a C/O of 2.7 was dispersed in an IPA/water solution (7:3 v/v). Then this dispersion was agitated in the ultrasonic bath for 15 min each batch. The total ultrasonic agitation time was 5 h. Further, it was continuously stirred at 4000 rpm for 5 h in a high-speed stirrer. Then, the product was separated by filtration and washed with a copious amount of DI water. The surface morphology of the diluted product was observed under SEM.

**3. Characterization**

Surface morphologies of the pristine and dispersed GO were observed under Scanning Electron Microscope (JEOL, JSM IT 200 LV, Japan). All samples were sputter-coated with gold before SEM analysis. SEM images were taken in a secondary electron mode at 10 kV accelerating voltage and 500x and 5,000x magnifications.

**4. Result and Discussion**

The dispersion stability of ultra-sonicated GO in the IPA/water mixture was found to be ~15 h. After high-speed stirring also, the improvement in dispersion stability was not seen.

The surface morphologies of the graphene oxide before and after ultra-sonication were observed by SEM as shown in Figure 1. From the SEM micrographs, the pristine GO has a large variation in particle size. It ranges from 10 to 18 µm. After ultra-sonication, the particle size was found to be reduced in the range of 2-4 µm. Further, after high-speed stirring also, the particle size was found in that similar range only. However, this particle size is not yet suitable for reinforcement in the PP polymer matrix. Therefore, the aim is to further reduce the size below 500 nm. Further work is in progress.

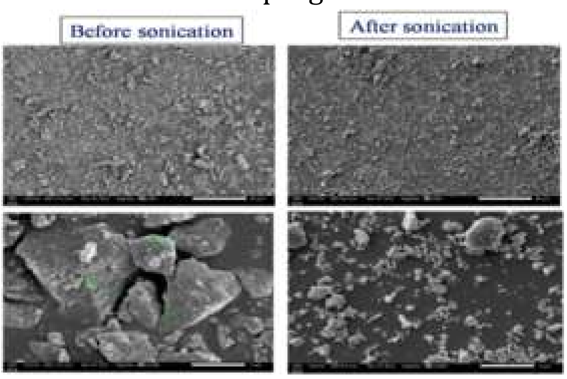



**Figure 1: SEM micrographs of graphene oxide at 500x and 5,000x magnifications.**

**2.6 Development of highly efficient and functional finished reusable protective face mask**

**Abstract:**

Wearing a face mask is a compulsory requirement for today's lifestyle due to Covid -19 pandemic. The non-woven-based disposable protective face is available at a low cost; however, they have comfort issues while wearing (fibre formation) and disposal problems. The fabric-based mask available in the market does not guarantee protection. Roughly face masks are categorised into three categories as fabric masks, surgical masks, and respirators. Fabric mask provides less protection on the other hand surgical mask and respirators gives good protection but are not recommended for common people. Hence, we at BTRA have designed and developed unique cotton-based 5layers highly protective face masks with improved comfort, breathability, and above 95% bacterial filtration efficiency. The BTRA-developed mask gives very good protection, is comfortable to use, and is recommended to use by common people. The mask is tested as per the requirements of Surgical Face Mask IS 16289 class 3 and passed all test requirements. Further, the wash durability of normal home laundering is also studied.

**1. Introduction:**

As a consequence of the Covid-19 pandemic, it is mandatory for the wearer of a protective face mask. The Government of India has also imposed strict regulations for use of face masks in public areas to prevent the spread of Covid-19. Therefore, everyone must buy it, and hence the demand for face covering is boomed. Disposable protective masks (N95 and similar) are the most commonly used protective mask, however, suffocation due to the synthetic fibres and fibre formation inside the mask makes it very uncomfortable to use and disposal of such used masks is another major issue. Therefore, some manufacturers grabbed this opportunity to make reusable and washable face masks however their efficacy is unknown. Hence, it is important to develop a washable, reusable mask with reliable protection and comfort properties.

Reusable cotton face masks are preferred over disposable non-woven masks due to their comfort. However, the fabric used for the mask is normally an open weave with large pores size. The porous nature of textiles means that viruses and bacteria can be trapped within the fabric structure, which possibly lowers the risk of the viruses being transferred. On the other hand, the size of bacteria, microbes, and viruses is in the range of 0.012 to 0.5 microns. However, the pore size of the fabric is much larger than the pathogens and they can easily pass through the fabric pores. Reduction of the pore size without affecting the breathing comfort is necessary to improve the efficacy of the mask. The use of nanofiber membrane as a filter may help in solving the problem and improve filtration efficiency. Hence, in this work, we have used the nano fibre-based membrane filter to reduce the pore size and improve the bacterial filtration efficiency. This work aimed to develop a washable, reusable, comfortable, and highly protective face mask.

## 2. Materials & Methods

### *2.1. Materials:*

100% Cotton fabric with 95 GSM, having 96 ends per inch and 62 picks per inches with warp and weft count of 40Nes and 34Nes respectively was procured from India mart supplier. Polypropylene spun bond nonwoven with 30 GSM was used. Elastic, nose wire, and elastic adjuster were procured for the local market.

### *2.2 Methods:*

*2.2.1. Electrospinning*

The measured amount of acetic acid and formic acid in the required ratio was taken in a conical flask and stirred using a magnetic stirrer. The polymer was added slowly during stirring and kept for 2h. The needleless electrospinning machine from ELMARCO (NS IS500 U) with wire electrode was used for the nanofiber spinning. Electrospinning parameters such as concentration of polymer, positive electrode voltage, negative electrode voltage, the distance between the electrode, and relative humidity were standardized. Morphology and diameter of Nylon 6 nanofibers were observed by Scanning Electron Microscope (SEM JEOL JSM 5400). Quanta chrome's 3G porometer operating under windows ® the 3G win software was used for the analysis of pore size. Nanofiber layer spun at optimized parameters was used to reduce the pore size of the designed mask.

*2.2.2.Mask design:*

The designing of the protective mask was the critical part. Considering the different patterns available and their drawbacks, we have designed a uniquely comfortable and proper-fitting mask in four different sizes as shown in table 1.

**Table 1. Different sizes as per weight groups**

| Sr. No. | Weight (kg) | Size | Dimensions | |
|---|---|---|---|---|
| | | | length | Width |
| 1 | 10-20 | XS | 19 | 10 |
| 2 | 21-40 | S | 21 | 12 |
| 3 | 41-65 | M | 23 | 15 |
| 4 | 65+ | L | 25 | 16.5 |

Mask should be worn in such a way that the nose and mouth should be covered fully, there should be minimum leakages from the sides and it should stay in the proper place. Figure 1 shows the correct methods to take the measurements for the proper fitting mask. The upper edge of the mask should be a little below the eye to provide clear vision and 0.5 to 1inch under the chin. The horizontal length of the mask must cover the full mouth and be 1 inch away from the ear.

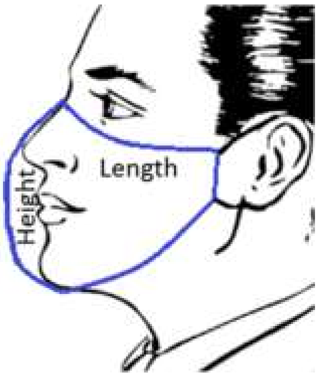



**Figure 1. Measurement of proper fitting face mask.**

One more important point to be noted is that the mask should not have a through cut at the centre to provide maximum protection. The mask having though out cut at the centre, stitching line may create pinholes at the centre through which the bacteria and viruses can penetrate through the mask directly near the nose and the purpose of wearing a protective mask can diminish. Therefore, our mask does not have a throughout cut at the centre. The pattern design is shown in figure 2.

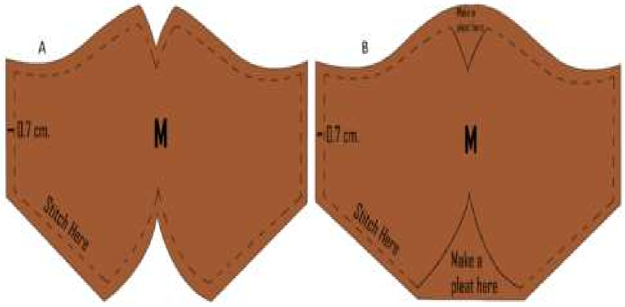



**Figure 2 Master pattern of the mask – A-for fabric cutting, B- for nonwoven filter cutting**

**3. Characterisations:**

Performance characterisation: Good performance of the protective face mask is one of the most important requirements. There are two Indian Standards (IS) wherein requirement criteria for the protective mask are given. Specification of the mask as per two different IS is listed in table 2.

**Table 2. Specification of the mask as per IS 16289 and IS 9473**

| Parameters | Surgical Face Mask IS 16289 | | | Respiratory protective devices IS 9473 | | |
|---|---|---|---|---|---|---|
| | Class 1 | Class2 | Class3 | FFP 1 | FFP 2 | FFP 3 |
| Bacterial filtration efficiency | 95 | 98 | 98 | -- | -- | -- |
| Differential pressure @8L/min, pa | 29.4 pa | 29.4 pa | 49.0pa | | | |
| Breathing Resistance @95l/min, mbar | | | | 2.1 | 2.4 | 3.0 |
| Splash resistance | -- | -- | 120 | -- | -- | -- |
| Sub-micron particulate filtration efficiency | -- | -- | 98% @ 0.1μ | -- | -- | 95% @ 0.3μ |
| Leakage | -- | -- | -- | <25% | <11% | <5% |
| Penetration- Paraffin oil | -- | -- | -- | NA | 2% | 1% |
| Flammability | -- | -- | -- | Yes | Yes | Yes |

It may be noticed from Table 2 that, bacterial filtration efficiency (BFE) and Breathability as differential pressure and breathing resistance are the most important parameters for surgical masks and respirators. Hence in our study, we have studied both the parameters for our developed mask.

***3.1 Differential pressure:***

A differential pressure test of the samples was performed according to IS 16289 as prescribed in annex C at an airflow rate of 8 L/min. five readings were taken from five different mask specimens and the average reading was recorded for the differential pressure value of the mask.

***3.2 Bacterial filtration efficiency (BFE):***

BFE of the BTRA-developed face mask samples was performed as per the ASTM F-2101. The test samples were challenged to Staphylococcus aureus bacteria with a mean aerosol particle size of 3.0 ± 0.3 microns with a flow rate of 28.5 L/min. the bacterial aerosol passed through the mask was collected on the Tryptic soya agar and incubated for 24hr at 37°C. The growth of the bacteria was counted as several CFU and the percentage of the BFE was calculated. Similarly, the BFE of the washed samples was also studied after 5 and 10 washing cycles.

***3.3 Fabric characterisation:***

All the cotton fabrics were subjected to colour fastness to washing, light, and rubbing tests using respective IS standards.

**4. Results and discussions:**

***4.1. Differential pressure:***

Differential pressure (DP) essentially measures the difference in pressure between two given points. When considering the DP of any mask it measures the resistance created by the mask at constant airflow. Lowering the resistance better is the breathability and the mask will provide more comfort. We have measured the DP of our samples at an airflow rate of 8L/min as per IS 16289. We received the DP value of 55.5pa/cm2 which is a little higher than that of the standard requirement as shown in table 2 for the class 3 mask. However, we have also compared our face mask with various N95 masks available in the market and found that the DP values of the commercial N95 mask samples are very high than that of our developed masks.

**Table 3 Differential pressure of the samples at 8L/min airflow**

| **Sample Name** | **Differential pressure (pa/cm2)** |
|---|---|
| Fabric only single layers | 6.12 |
| Nonwoven filter | 26.9 |
| Mask | 55.5 |

Table 3 shows the DP of various components of the mask. It may be noticed that the DP fabric is the result of its weaving pattern and cover factor by changing the weaving structure we can further reduce the DP of the mask and meet the requirement of 49 pa/cm2 for class 3 surgical masks.

***4.2 Bacterial filtration efficiency:***

BFE of the unwashed and washed samples is depicted in figure 3. It can be seen that initially before washing the BFE was 98%. This indicates that there is only 2% of bacteria can pass through the mask and the remaining 98% are filtered out. This high BFE can be attributed to the nano-membrane filter used as the middle layer of the mask. Nano membrane effectively works to reduce the pore size of the filter media without affecting breathability. This meets the requirement of IS 16289 class 3 masks. Further, after washing up to 10 washes the BFE is not reduced and can provide 98.5% bacterial protection.

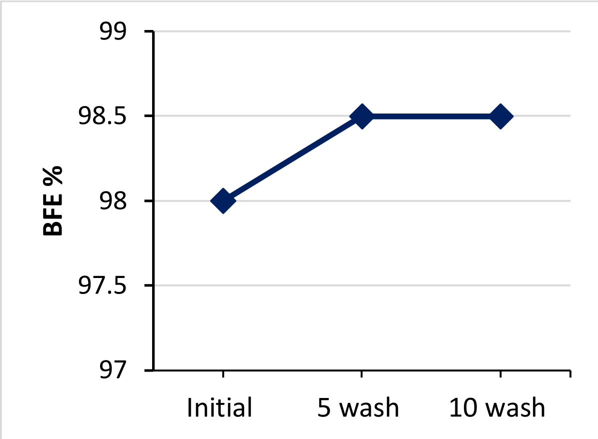



**Figure 3 BFE of the mask samples up to 10 wash**

### 4.3 Fabric characterisation:

The cotton fabrics used for the outer and inner layer of the mask were subjected to colour fastness to washing at 60°C for 30 min as per IS standard 105 C10 test method. The results are given in Table 4. Table 4 shows that all the samples have good colour fastness to washing. Similarly, colour fastness to natural sunlight was tested by accelerated test using IS 105 B02 standard method. It was found that all the samples have good colour fastness to light rating. Further, it can be seen from the table that only the black sample has poor colour fastness to wet rubbing.

Dimensional changes after washing were also analysed and reported in table 4 as % shrinkage.

**Table 4 colour fastness properties of the mask samples**

| Fabric colour | Colour fastness | | | | Shrinkage (%) | |
|---|---|---|---|---|---|---|
| | Washing | Light | Rubbing | | | |
| | | | Dry | Wet | warp | weft |
| White | NA | 5 | NA | NA | 6.4 | 2.1 |
| Black | 4-5 | 5 | 4-5 | 2 | 5.4 | 2.6 |
| Navy blue | 4-5 | 5 | 4-5 | 3 | 5.1 | 6.8 |
| Olive green | 4-5 | 4 | 4-5 | 4 | 6.0 | 1.3 |
| Mustered yellow | 4-5 | 4 | 4-5 | 4 | 4.6 | 4.8 |
| Purple | 4-5 | 4 | 4-5 | 3 | 5.2 | 5.6 |

### 4.4 Design and comfort:

The design of the mask is made in such a way that it should meet the specifications of both the standards and provide comfort to the wearer. Cotton fabric, polypropylene nonwoven, and nanofibre membrane are arranged in five different layers to make a protective mask. An adjustable nose chip provided at the top center of the mask ensures the proper fitting and keeps the mask at the proper position, eliminating the leakages and reducing the fogging effect. Further, elastic with little wider width (8mm) reduces the stress on the ear and an elastic adjuster makes it more comfortable to fit as per the choice of the individual.

The design and comfort of any face mask is the subject matter of an individual and hence cannot be tested quantitatively using any instrumental techniques. Therefore, the design and comfort of the mask were evaluated through the feedback of users. A total of 50 reviews from different users of 25 to 55 age groups were analysed and found that more than 95% of the users were happy with the comfort that is the breathability of the mask and the outer fabric feel. More than 70% are happy with the colours, print, and look of the mask. It is well understood that the colour, print, and design are the individual's choice and it would defer from person to person. Further, a few people were unhappy with the size of the mask. This issue can be resolved by choosing the proper size as suggested in table 1. Overall, it was concluded from the feedback that, the BTRA-developed mask provides comfort and also complies with the requirements of the standards.

**Conclusions:**

We at BTRA have developed a highly protective face mask. Differential pressure of the mask was found to be 55.5 pa/cm2 which gives better breathing comfort. 98% BFE provides very good protection against bacteria. The mask passes the requirement of IS 16289 class 3 surgical masks. Front and back cotton fabric is skin-friendly and absorbed more sweat. The adjustable nose clip avoids fogging on spectacles. The ear loop adjuster provides more comfort by reducing the stress on the ear.

**3. Centre of Excellence for Geotech**

BTRA (Bombay Textile Research Association) is recognised as the Centre of Excellence (COE) for Geotech in the year 2008. BTRA has an excellent state of art testing facility for Geosynthetics of International standard, accredited by NABL (India) as per ISO/IEC 17025 and GRI, USA. Over a period of time, BTRA has developed many testing facilities related to Geosynthetics, Geo Textiles, Geo Composites, and other technical textiles products. We have facilitated the manufacturers to do the required test within a short period with less cost and now they are not dependent on foreign labs. At the same time, they witness the test to get confidence in the test report and the product.

BTRA is the second commercial Geotech lab in Asia accredited by GRI, USA. BTRA has an information resource center having many publications, Journals, Periodicals, and Research report for the industry people. Details of raw material suppliers and geosynthetic manufacturers are available with contact details.

BTRA has a nonwoven development facility, needle punching, and hydroentanglement. Various nonwoven manufacturers have used this facility for the development of nonwoven products for technical applications and are used for the same. BTRA also has a small loom for the development of woven technical fabrics. BTRA has developed woven products like Geobag, and Geomattress for erosion and flood control applications.

BTRA contributed knowledge to the development of test standards and specifications for the Bureau of Indian Standards. BTRA also actively participated in establishing the specifications for high-performance fibers and geosynthetics.

BTRA is involved in standardising the specifications for products like Geogrid, Geocells, Geocomposites, PVD, and Geotextile both made from synthetics and natural fibres (Coir& Jute) for various applications. Awareness about the use of Geosynthetics is created by BTRA through awareness programs, Seminars, and Conferences. This awareness resulted in the growth of the use of Geosynthetics in India.

The Geotech Laboratory at BTRA is accredited by the Geosynthetics Institute (GSI), Folsom, Pennsylvania, USA under the

GAI – LAP Accreditation Programme for 24 tests of geosynthetics products. It is pertinent to mention that BTRA is the first institute in India and probably only the third institute outside the USA to get this coveted accreditation. What this means to the geosynthetics producers and users is that they can get the products tested in BTRA with utmost confidence that the accuracy of the results is as good as any other GAI-LAP accredited laboratories. They can get the tests done in India, thus saving time and money without compromising the quality of the results.

**Soil Mechanics Laboratory**

Bombay textile research association (BTRA) has started the soil and asphalt lab and organized to perform tests on soil and pavement materials. During the construction of bridges, buildings, dams, roads highways, and expressways it is necessary to evaluate the physical and mechanical properties of the soil and pavement materials and mixtures. This state-of-the-art laboratory is equipped with all necessary equipment for conducting tests and research in soil mechanics, foundation engineering, and transportation engineering. Research, consultancy, and regular soil testing works are conducted in this laboratory under the supervision of the head of the department and laboratory staff specializing in the area of Geotechnical Engineering and Transportation engineering. All the tests are conducted as per the Indian standards (IS), Indian Road Congress (IRC), American Society for Testing Materials (ASTM), and American Association for State Highway and Transportation Officials (AASHTO) standards. The laboratory tests comprise triaxial, direct shear, vane shear, oedometer test, soil classification test, Marshall Stability, wheel rutting, tensile strength ratio, etc. Apart from the laboratory testing, the soil and Asphalt lab can conduct field testing such as static and dynamic cone penetration tests, field CBR tests, plate bearing tests on soil, filed vane shear, filed density of bituminous pavements, lightweight deflector meter, and core cutting of pavements.

**BTRA staff attended the following related to Geotech.**

**Conferences / Meetings Attended**

- Attended BIS meeting of Tx 35 on 28th September 2021
- Attended BIS meeting of Tx 30 on 26th October 2021
- Attended Textile Committee viscose regulation meeting 24th November 2021
- Meeting with Textile commissioner on Jute project. 30th November 2021
- Conference attended on Sustainable Standards by Centre for Responsible Business Delhi, on 26th -29th October 2021.
- Meeting for viscose regulation organised by Textile Committee 24th Nov. 2021
- Techtextil Exhibition on 26th November 2021
- Attended APA conference at Delhi on 24th February 2022
- Attended International Conference on Technical Textile at Delhi on 11th March 2022
- Visited CRRI Delhi for Demo Center and collaborating works on 11th March 2022

**New Test Method**

- Installation damage of geosynthetics and its Reduction Factor for designing.
- Testing of Geostrap (para web)
- Different IS test standards for Geosynthetics

**Standards and Specification formulated:** Test Standard for Geotextile (4), Geomembrane (1), Geogrid (2) &
Specification for Geogrids (4), Geotextile (2), Geocomposite (1), Prefabricated Vertical Drain (1).

## 4. CALIBRATION LABORATORY

BTRA calibration laboratory received NABL accreditation as per 17025:2017 laboratory standards for Mass, Volume, and Balance. BTRA is ready to provide calibration services to their own and other NABL accredited testing laboratories for Mass, Volume, and Balance parameters for the following ranges.

| The parameter to be calibrated | Range |
|---|---|
| Balance | 1 mg to 5 kg |
| Weights | 1 mg to 5 kg |
| Volumetric glassware | 0.5 ml (500 µl) to 1000 ml |

The worth equipment available are Balance, Weight– Standard balance 220 g-1 no's, 3kg-2nos & 5kg- 1nos. weights 1 mg to 200 g, E2 class, 1 mg to 200 g F1 class and 500g, 1000g, 2000g, 5000g F1 class. Total certificates issued for Mass, Volume, and Balance in the last financial year was 287.

## 5. ACCREDITED PROFICIENCY TESTING PROVIDER

Testing laboratories play a major role in the evaluation of the quality of different products including textiles and geotextiles. The results being reported by the testing laboratories are crucial in deciding the fitness of purpose of a product manufactured. The results should be reliable, repeatable, and reproducible. The competence of the testing laboratory can be demonstrated by documenting and implementing a laboratory QMS as stipulated in the international standard ISO/IEC 17025:2017. One of the main critical requirements to be demonstrated by a laboratory as stated in this standard is participation in proficiency testing conducted by a third-party accredited agency.

The organization that conducts proficiency testing is called a Proficiency Testing Provider. The international organization for standardization has stipulated the QMS to be implemented by such an organization in ISO/IEC 17043:2010. NABL has started accreditation of PT Provider by the standard ISO/IEC 17043:2010 from 2011 onwards. So far, over 35 Proficiency Testing Providers are accredited by NABL for testing/calibration of different products/items.
The five main advantages of participation in PT Schemes are as under:

a) Evaluation of the performance of the laboratory for specific tests / calibrations;

b) Providing additional confidence to customers of the laboratory;

c) Identification of problems in laboratories and initiation of actions for improvement which, for example, may be related to inadequate test or measurement procedures, the effectiveness of staff training and supervision, or calibration of equipment ;

d) Education of participating laboratories based on the outcomes of such comparisons;

e) Validation of uncertainty claims of laboratories;

The deficiencies in the self-organized ILC are as under:

- Impartiality is not maintained as the organizer is also a participant.
- Robust statistical techniques are not used in performance evaluation.
- Confidentiality of the participants is not maintained and consequently, there is a possibility of collusion between the participants and falsification of the results.
- The number of participants is less in ILC (around 5 or 6 only) and hence the uncertainty in the assigned value is too large and the outcome of ILC is not dependable.
- Homogeneity and stability of the samples distributed are not ensured.
- Handling, storage, and transport of PT items are not satisfactory and consequently. The integrity of the sample is compromised.
- The competency of a laboratory to perform testing of any product can be ascertained only through PT participation and not ILC participation.

The above-mentioned deficiencies are rectified in proficiency testing conducted by ISO/IEC 17043:2010. Further, proficiency testing requires robust statistical methods to be used for (i) determination of assigned value for each measured or characteristic of the proficiency test item (i.e sample), (ii) determination of evaluation criteria such as Standard Deviation for Proficiency Assessment (SDPA), and (iii) performance evaluation in terms of Z score or Z prime score, etc. All these requirements are stipulated comprehensively in the standard ISO 13528:2018.

To meet the proficiency testing requirements of textile testing laboratories, BTRA has documented and implemented the QMS as per ISO/IEC 17043:2010 and secured accreditation by NABL during 2018. This includes most of the conventional mechanical and chemical tests including eco parameter tests like banned amines, formaldehyde, and heavy metals, being performed by textile testing laboratories.

First time by any laboratory in India and Asia, we have got accreditation for analytical test parameters (banned amines, formaldehyde, and heavy metals) to our PT scope. We have received a good response from the laboratories from India as well as abroad like Sri Lanka, Malaysia, Indonesia, Bangladesh, and Pakistan and our reports were well accepted by them.

*From April to March 2022,*

| PT Scheme Identity Mechanical or Chemical | Tests covered | Report dispatched on | Labs Participated |
|---|---|---|---|
| BTRA/PTB/2021/MECH<br>6 Tests<br>MECHANICAL | Tensile strength (Strip strength) Tear strength (Elmendorf method) GSM (Weight per square meter)<br>Failure in Sewn Seams of Woven apparel<br>Fabrics Pilling Resistance – Pill Box method<br>Bursting strength | 10/11/2021 | 31 |
| BTRA/PTB/2021/CHEM<br>8 Tests<br>CHEMICAL | Quantitative fibre analysis (Blend composition)<br>Dimensional Change after home laundering<br>Colour Fastness to Rubbing Colour Fastness to Perspiration Colour Fastness to Washing<br>Flammability of clothing textile (45° inclined flammability tester):<br>Banned aryl amines<br>Extractable (by acid artificial perspiration solution) Heavy Metals | 10/11/2021 | 32 |
| BTRA/2022/PT-2/YARN<br>4 Tests<br>MECHANICAL | Single Yarn Strength<br>Elongation at break<br>Plied twist<br>Linear Density of yarn | Ongoing | 11 |
| BTRA/2022/PT-3/MECH<br>6 Tests<br>MECHANICAL | Breaking load and elongation by Grab method<br>Diaphragm Bursting Strength Test<br>Tear Strength of fabric by Elmendorf tester<br>Random Tumble Pilling Tester<br>Martindale Abrasion Test<br>GSM (Weight per square meter) | Ongoing | 36 |
| BTRA/2022/PT-4/CHEM<br>6 Tests<br>CHEMICAL | Quantitative fibre analysis (Blend composition)<br>pH value of aqueous extract<br>Colour Fastness to Perspiration<br>Colour Fastness to Light<br>Water Soluble Matter<br>Flammability of clothing textile (Vertical) | Ongoing | 25 |
| BTRA/2022/PT-5 / ANALYTICAL<br>3 Tests<br>CHEMICAL (Analytical) | Free & hydrolyzed formaldehyde content (water extraction method)<br>Released formaldehyde content (Vapour absorption method)<br>Banned Aryl Amines (Azo colorants) content | Ongoing | 18 |
| BTRA/2022/PT-3/GEO<br>6 Tests<br>MECHANICAL | CRB Puncture Resistance<br>Trapezoidal tear strength<br>Static Puncture Strength<br>Water permeability by the permittivity<br>Wide width tensile strength of Non-woven<br>Melt Flow Index of Polymer | Ongoing | 7 |

## 6. TECHNICAL SERVICES

BTRA has provided extensive liaison and consultancy services to solve problems of quality, maintenance, and productivity at various levels for the textile units. The details are given below.

### 6.1 Overview

| | | |
|---|---|---|
| ✓ **Technical investigations carried out** | : | 69 |
| ✓ **Technical enquires attended** | : | 64 |
| ✓ **Local mill visits made [man-days]** | : | 12 |
| ✓ **Outstation mill visits made [man-visits]** | : | 34 |

### 6.2 Type of Assignments Undertaken

- Manpower complement study
- ETP Adequacy Audits
- Training for Non-Textiles
- Apprenticeship curriculum Jigger Machine Operator
- GMP Audit
- Discussion on the revised report and its submission
- Fabric Inspection
- Water audit
- N.C. John and Sons Co. Ltd
- Green Audit and Energy Audit
- Training in Industrial Fabric
- Dryer Efficiency Improvement
- LAPF Evaluation Program
- Training of Weaving Manpower
- Training in Textile Technology
- Textile Factory and Machinery making for Technical Textile

**Product Development Assistance to the industry**

❖ BTRA developed a reusable protective face mask with high bacterial filtration efficiency.

❖ In the Nanoparticle mediated Antimicrobial coating with the Copper and Silver nanoparticle. The antibacterial effect (~99%)and the wash sustainability ( 10 wash cycles) of copper nanoparticles have been very good.

❖ BTRA is trying to develop a hydrophobic coating using cheaply available Rice husk. So far we have been able to get a contact angle of 127°, however, our target is to attain a contact angle of >150°. Work is in progress for minimizing the particle size of the silica which is likely to enhance the contact angle.

## 7. TESTING SERVICES

BTRA Test Laboratories had undertaken a wide range of testing activities such as Fibre Properties, Yarn Properties, Fabric Properties, Fabric Defect analysis, Chemical Testing (chemicals & auxiliaries), Eco-parameters Testing, Geotextiles Testing, Soil Testing, Technical Textiles Testing (other than Geotech), Microbiology Testing, Scanning Electron Microscope Studies, Special Testing [Flammability, static charge measurement, FT-IR / DSC / TGA / X-ray / GPC analysis, Melt Spinning trials, etc.] and Material Testing (non-textile items such as water, paint, oil, etc.). The total number of tests conducted for the period under review is 27873 and section-wise details are as follows.

## 7.1 Overview

| Test Particulars | Number of Tests |
|---|---|
| Physical Testing | 5340 |
| Chemical Testing and Eco-parameters, Chemicals / Dyes / Auxiliaries Testing, and Material Testing ***(non-textile items, water, oil, etc.)*** | 10145 |
| Fabric Defect Analysis | 314 |
| Geotextile Testing | 5993 |
| Technical Textiles Testing ***(other than Geotech)*** | |
| Microbiology Testing | 776 |
| Scanning Electron Microscope | 1518 |
| Special Testing ***(Flammability, static charge, FTIR / DSC / TGA / X-ray/ GPC studies, Melt spinning trials, etc.)*** | 3500 |
| Calibration Testing | 287 |
| **TOTAL TESTS CONDUCTED** | **27873** |

### 7.1.1 Proficiency Testing Programs Participation

During the period under review, BTRA Test Laboratories participated in various proficiency testing programs to maintain its laboratory performance at par with national/international laboratories.

- AATCC Proficiency Test Program on 'Colour Fastness'
- AATCC Proficiency Test Program on 'FIbre Identification & Analysis

### 7.1.2 New Machinery/Instruments added

- Splash Resistance Tester
- Medical Mask BreathabilityTester
- Synthetic Blood Penetration Tester
- Ultrasonic Sewing Machine
- Ultrasonic Bath (Sonicator)
- Trinocular Polarizing Microscope PM-12 with Digital Eye Piece Camera
- Juki DDL8100e Sewing Machine

### 7.1.3 New Test Methods Launched

BTRA undertakes the following new test methods as per national and international standards.

- ❖ HPLC Test Method analysis of Curcumin content in turmeric powder and free phenol content in the effluent
- ❖ Analyzing Metofluthrin (MFT) in mosquito repellent coils by GC ECD
- ❖ Different IS test standards for Geosynthetics.

## 7.2 Technical Textiles Testing

BTRA carried out 5993 tests for geotextiles and technical textiles (other than Geotech). The following types of testing of technical textiles are undertaken at BTRA.

- ❖ FILTER FABRICS - Woven/ Nonwoven
- ❖ GEOTEXTILES – Woven / Nonwoven
- ❖ PVD BAND DRAIN
- ❖ GEO-MEMBRANE LINER
- ❖ GEO-GRID
- ❖ ROPE GABION
- ❖ METAL GABION
- ❖ NONWOVENS – Wadding, Cover Stock, Face Mask, Interlining,

Absorbing/Shoulder Pads, Insulation Pad and Carpets [Nonwoven Type]

- ❖ COATED FABRICS
- ❖ AUTOMOTIVE TEXTILES
- ❖ MEDICAL TEXTILES
- ❖ OTHER TECHNICAL TEXTILES - Narrow Fabrics, Conveyor Belts up to 13 Mm Thick [Dumbbel Shape], Nylon Ropes up to 12 Mm, Composites - Glass Composites / Glass Composites/Mats and Glass Roving / Fabrics.

Apart from conducting usual tests such as weight per square metre, weight per linear metre, thickness/density, yarn number, etc., certain unique tests are also undertaken. They are as follows.

- ✓ FILTER FABRICS (Woven and Nonwoven): Tear Resistance (Trapezoid Strength), Grab Strength, Water Permeability, Air Permeability, Pore Size by Porometer, Apparent Opening Size, Bursting Strength, Breaking Strength & Elongation.
- ✓ GEOTEXTILES (Woven and Nonwoven): Abrasion Resistance, Apparent Opening Size, Bursting Strength, CBR Puncture Strength, Cone Drop Test (Dynamic Puncture Test), Grab Breaking Load Machine Direction & Cross Direction, Grab Tensile Strength & Elongation, Index Puncture Resistance, Mullen Bursting, Pore Size by Porometer, Seam Strength, Static Puncture Strength (CBR Puncture Strength), Tensile Strength & Elongation (Warp and Weft), Tensile Strength (Before & After Exposure UV Xenon Arc), Trapezoid Tear Strength, UV Resistance Exposure to Light, Moisture & Heat in Xenon Arc, Water Permeability, Water Permeability of Filter, Wide Width Tensile Strength Machine Direction & Cross Direction.
- ✓ PVD BAND DRAIN: Tensile Strength & Elongation (Wide Width), Water Permeability of Filter, Tensile Strength of Core, Grab Strength & Elongation at Break for PVD Composite, Trapezoid Tear for Filter Component only.
- ✓ GEO-MEMBRANE LINER: Density, Tensile Strength, Tear Strength, Puncture Resistance, Carbon Black Content, Melt Flow Index, ESCR, 2% Secant Modulus of Polyethylene Geomembrane.
- ✓ GEO-GRID: Tensile Strength & Elongation (Single Rib) / Multi-Rib, Carbon Black Content, Melt Flow Index, Aperture Size & Number of ribs per metre.
- ✓ ROPE GABION: Size, Tensile Strength, Identification of material [TGA / DSC], UV Resistance Exposure to Light Moisture & Heat in Xenon Arc, Tensile Strength (Before & After Exposure UV Xenon Arc), Tensile Strength of Rope after Thermal Treatment (Heating).
- ✓ METAL GABION: Size, Thickness of Wire, Tensile Strength of Wire.

**NONWOVENS**

- ❖ **WADDING**: Compressional Recovery, Air Permeability, Thermal Conductivity.
- ❖ **COVER STOCK**: Mass [EDANA], Absorbency [EDANA], Liquid Strike through time [EDANA], Wicking Rate [EDANA], Tensile Strength & Elongation [EDANA].
- ❖ **FACE MASK**: Pore Size, Bacteria Filtration Efficiency [In-house Method].
- ❖ **INTERLINING**: Mass per square metre, Thickness [EDANA], Tensile Strength & Elongation, Heat Shrinkage.
- ❖ **ABSORBING / SHOULDER PADS**: Mass per square metre [EDANA], Thickness [EDANA], Absorbency [EDANA].

- ❖ **INSULATION PAD**: Mass per square metre [EDANA], Thickness [EDANA], Thermal Conductivity.
- ❖ **CARPETS** (Nonwoven Type): Mass per square metre, Thickness, Compressional Recovery, Hexapod Tumbler Test, Lisson Test [Treading Wheel test], Taber Wear Index [up to 300 cycles], Colour Fastness to Light up to 5 Rating, Dimensional Stability – Heat/ Water, Flammability at 45O, Horizontal Burning Rate, Pill (Camphor / Methanamine) Test, Tuft Withdrawal Strength (Piled Carpets), Static Charge measurement, Surface Resistivity, Volume Resistivity, Antimicrobial Activity, Antimicrobial Activity, Antifungal Activity.
- ✓ **COATED FABRICS**: Mass per square metre, Thickness, Tensile Strength & Elongation, Tongue Tear Strength, Single Rib Tear Strength, Bonding Strength Bonded / Coated, Application of Adhesive, Water Vapour Transmission [ASTM E: 96 by Gravi Test Instrument], Identification of Coating by FTIR, Taber up to 300 cycles, Hydrostatic Pressure Heat Test, Removal of Coating, Identification of Fibres, Yarn Count, Threads/Inch, Martindale Abrasion Test – 10,000 rubs, Pliability, Blocking Test, Gelling Test, Flexing Test [Dematia Method], Limiting Oxygen Index, Vertical Flame Test, Horizontal Burning Rate.
- ✓ **AUTOMOTIVE TEXTILES**: Mass per square metre, Thickness, Abrasion Resistance: Taber H18 / CS10 [Automotive Std.] up to 300 cycles, Flammability at 45O, Horizontal Burning Rate, Pill (Methanamine) Test, Relaxation Shrinkage, Thermal Shrinkage, Odour Test, Tensile Strength [Automotive Std.], Tear Strength [Automotive Std.], Colour Fastness to Light (up to 6), Colour Fastness to Crocking, Colour Fastness to Shampooing, Colour Fastness to Resistance to Cold - 20$^{O}$C for 2 hours, Pliability, Blocking Test, Gelling Test, Flexing Test [Dematia Method].

**MEDICAL TEXTILES**

- ✓ **COTTON WOOL PADS**: Acidity or Alkalinity [Methyl Orange / Phenolphthalein], pH at 26$^{O}$C, Absorbency Sinking Time, Water Holding Capacity, Water Soluble Substance, Ether Soluble Substance, Sulphated Ash, Fluorescence, Bioburden Test (4 Organisms), Drying Rate [67 + 2% R.H. & 27 + 2$^{O}$C Temp.].

**OTHER TECHNICAL TEXTILES**

- ✓ **NARROW FABRIC**: Seat Belt Strength, Tape / Webbing Strength & Elongation, Hot Water Shrinkage of Webbing, Tensile Strength & Elongation, Belt for Lift.
- ✓ **CONVEYOR BELT** up to 13 mm Thick (Dumbbell Shape): Tensile Strength [In-house Method].
- ✓ **NYLON ROPES** up to 12 mm: Tensile Strength, Diameter of Rope, Linear Density.

**COMPOSITES**

- ➔ **Glass Composites**: Flexural Strength, Lap Shear Strength.
- ➔ **Glass Composites / Mats**: Thermal Conductivity, Mass per square metre, Tensile Strength, Thickness, Density.
- ➔ **Glass Roving / Fabrics**: Mass per square metre, Yarn Number, Thickness, Density, Breaking Strength & Elongation at Break, pH of Aqueous Extract, Glass Content.

### 7.3 Special Testing

Apart from undertaking testing of fibers, yarns, and fabrics (for physical as well as chemical properties), numerous special tests (that are most sought after) are conducted at BTRA. The same is widely availed by the industry. BTRA carried out 3550 tests under special testing. The type of tests conducted here is as follows.

- ✓ Differential Scanning Calorimetry (DSC) Analysis
- ✓ Thermal Gravimetric Analysis (TGA)
- ✓ Gel Permeation Chromatography for Molecular Weight Distribution(GPC)
- ✓ X-ray Diffraction Analysis (Mineral analysis / Chart diffraction / Fibre orientation angle / Material identification)-(XRD)
- ✓ FT-IR spectroscopy (Material & Finish identification)-(FTIR)

**Scanning Electron Microscope**

- Longitudinal View of Fibres/Yarns
- Cross-section View of Fibres/Yarns
- Micrographs for Powder Sample

**Surface and cross-sectional view of**

- Fibers (natural and synthetic)
- Yarns
- Fabrics
- Hair samples
- Powder (Mineral, drug molecule)
- Pharmaceutical formulation powder/Pellets (Thickness/no. of layers)
- Pharmaceutical capsules/tablets
- Metal
- Ceramic
- Polymer films/membranes (Thickness / no. of layers/porosity)
- Medical samples
- Hollowness%, pore diameter/pore density of materials
- Other relevant samples
  Elemental composition of all above-mentioned samples by SEM-EDX analysis Automatic capillary viscometer (PET, PVC, Nylon, PS, and other polymers) to measure
- Relative viscosity
- Specific viscosity
- Inherent viscosity
- Intrinsic viscosity
- Dynamic viscosity
- K-value
- Viscosity number

- ✓ Static Charge Measurement
- Total Charge Developed and Half Decay Time [ASTM D:4238]
- Surface Resistivity [ASTM D:257]
- Volume Resistivity [ASTM D:257]

- ✓ **Pilot-scale facility for sample preparation**
- Melt spinning for the preparation of filaments
- Electrospinning for the preparation of nanofiber
- Melt Compounding for the preparation of Masterbatch
- Atmospheric pressure plasma for surface modification of textile fabric

- ✓ Other special tests were undertaken
- UV Protection Factor [AATCC-183]
- Surface Tension – drop volume method (or) contact angle method
- EMI Shielding Effectiveness [ASTM D 4935]
- Birefringence measurement by Polarising Microscope
- Particle Size Analysis
- Contact Angle
- Total Organic Carbon (TOC) Analyser
- Refractive Index of Liquids (Abbe's Refractometer)

- ✓ **Flammability Tests**
  **General Apparel**
- ➔ Ease of ignition of vertically oriented specimen [BS EN ISO 6940]
- ➔ Flame spread properties of vertically oriented specimen [EN ISO 6941 / BS EN 1103]

- UK nightwear safety regulation [BS 5438 / BS 5722 Test 1, 2 & 3]

**Curtain, Drapes, and Blinds**

- Ignitability of vertically oriented specimen [BS EN 1101]
- Flame spread properties of vertically oriented specimen [BS EN 1102]

**Personal Protective Clothing**

- Limited flame spread [EN 532 / ISO 15025 / BS 5438: 1976 Tests 1, 2 & 3]
- Limiting Oxygen Index [IS:13501 / ASTM D 2863]
- Vertical Flammability [IS:11871 / BS:3119 / NFPA 1975 / NFPA 2112]
- Horizontal Flammability [IS:15061 / ASTM D:5132 / FMVSS / SUZUKI]
- 45$^{0}$C Inclined Flammability [16 CFR 1610 / ASTM D:1230 / IS:11871(B)]
- Carpet Flammability [ASTM D:2863 / 16 CFR 1630 / ISO:6925 / BS : 6307]
- Vinyl Coated Fabric Flammability [IS:1259]

**Flammability of plastics**

- Vertical Burning Test [UL 94 (VO.V1.V2) / ASTM D:3801 / IEC 60695–11–10(B) / ISO:1210(A) / UL 94 (VTM) / ASTM D: 4804 / ISO:9773 (Non Rigid Sample) / UL 94 (5V) / ASTM 5048 / IEC 60695-11-20]
- Horizontal Burning Test (Wing Top Method) [ASTM D:4986 / ISO:3582 / ISO:9772]
- Horizontal Burning Test [UL94HB / ISO:1210(A) / ASTM D:635 / IEC:60695–11–10(A)]
- Determining deterioration of visibility due to smoke released on combustion of materials [using Smoke Visibility Tester] as per UIC 564.2 OR Appendix-15 method
- Determination of Toxicity Index [Fume Toxicity Tester] as per N.C.D. 1409 method

**7.4 Eco-parameters Testing**

The following types of tests are undertaken at BTRA.

- Formaldehyde Content in Auxiliaries as per GOTS
- Allergenic Disperse Dyes
- Glyoxal Content in Textiles
- Polycyclic Aromatic Hydrocarbons (PAH)
- Identification & Quantification of Virgin / Recycled Polyester Fibre
- Free Formaldehyde in Textiles and Leather
- Released Formaldehyde in Textiles and Leather
- Chlorophenol - PCP / TECP / OPP
- Pesticides – Organochlorine / Organo phosphorous / Others / Total pesticide residue
- Banned Aryl amines Released from Azo dyes
- Phthalates
- Chlorinated Organic Carriers (Benzene & Toluene)
- Poly Chlorinated Biphenyls
- Hexachloro benzene
- Organo Tin
- Heavy Metals as per Oekotex 100 and GOTS Specifications.
- Lead in Paints and Surface Coatings.
- Hexavalent chromium (Cr VI) in Textiles/Leather/Dyes
- Spectro photometric Evaluation of Dyes/Optical whitener.
- Analysis of Organic Compounds by - GC-FID /GC-ECD/ GC-MS {NIST library Search Report}
- Perfumery Analysis by GC-MS
- TLC Analysis of Organic Compounds
- HPLC Analysis of Organic Compounds
- Analysis of FAME, Triclosan, BPA, BHT, Solvents.
- Analysis of Mosquito repellents.

***… and many more***

**NABL activities:**

Ecolab has initiated to conduct proficiency testing of five eco parameters (banned amines, free formaldehyde, released formaldehyde, total metals and leachable metals).

### 7.5 Microbiology Testing

Textiles, being an integral part of our everyday life, have been involved in the search for hygienic functional garments with the application of anti-microbial finishes. BTRA carried out 776 tests under microbiology testing. The type of tests conducted at this laboratory is as follows.

- Antifungal activity, assessment on textile materials: Mildew and Rot Resistance of Textile materials Test-II – Agar Plate, *Chaetomium globosum* [AATCC 30 Test 2]
- Antifungal activity, assessment on textile materials: Mildew and Rot Resistance of Textile materials Test-III – Agar Plate, *Aspergillus niger* [AATCC 30 Test 3]
- Antifungal activity, assessment on textiles materials: Mildew and Rot Resistance of Textile materials Test –IV – Humidity Jar, Mixed spore suspension [AATCC 30 Test 4]
- Antibacterial Activity of Fabrics, Detection of Agar Plate Method [AATCC 90]
- Assessment of Antibacterial Finishes on Textile Materials [AATCC:100]
- Antibacterial Activity of Fabrics, Assessment of Textile Materials – Parallel Streak Method [AATCC:147]
- Antimicrobial Activity Assessment of New Carpets - qualitative antibacterial assessment / quantitative antibacterial assessment / quantitative antifungal assessment. [AATCC 174 – Parts 1 to 3]
- Determination of a Population of Microorganisms on Products [ISO 11737 – Pt I]
- Textile fabrics – Determination of Antibacterial Activity – Agar Diffusion Plate Test [ISO 20645]
- Textiles – Determination of the Antibacterial Activity of Antibacterial Finished Products [ISO 20743]
- Determination of the Antimicrobial Activity of Immobilized Antimicrobial Agents Under Dynamic Contact Conditions [ASTM E 2149]
- Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi [ASTM G 21]
- Test for Antibacterial Activity and Efficacy on Textile Products [JIS L 1902]
- Antimicrobial products - Test for antimicrobial activity and efficacy for plastics and other antimicrobial coated hard surfaces. (Film Contact Test Method) [JIS Z 2801]
- Microbiological Examination of Water [IS 1622 & IS 5403]
- Methods for testing Cotton Fabrics for Resistance to Attack by Microorganisms by Humidity Chamber Method [IS 1389]
- Evaluation of Bacterial Filtration Efficiency of Medical Textiles [In-house Test Method]
- Aerobic Plate count & Yeast and Mold count [Bacteriological Analytical Manual] 2021
- Above mentioned tests from 2020 are included.
- Standard Test Method for Resistance to Growth of Mold on the Surface of Interior Coatings in an Environmental Chamber (ASTM D 3273)
- Standard Test Method for Evaluating the Bacterial Filtration Efficiency (BFE) of Medical Face Mask Materials, Using a Biological Aerosol of *Staphylococcus aureus* (ASTM F 2101)

- Measurement of antibacterial activity on plastics and other non-porous surfaces (ISO 22196)
- Minimum Inhibitory Concentration (MIC) test by In-house method based on BSCI 424 Method (This is a laboratory-developed method).
- Suspension Time-Kill Test (ASTM E 2315)
- Sterility testing (ISO 11737-2)

***... And many more***

**Other Services**

BTRA continued the activity of supplying chemicals/gadgets, repairing/calibrating gauges/testing instruments, and testing store accessories for the mills. The details are given in Appendix-6.

**Powerloom Service Centres (PSCs)**

BTRA runs three Power loom Service Centers (PSCs) [at Ichalkaranji, Solapur, and Madhavnagar-Vita]. To improve the quality, operating efficiency, and productivity of power loom clusters, BTRA PSCs provide technical consultancy, testing services, training in loom working, loom maintenance, and disseminating information through training programs, workshops, demonstrations, and discussions. Liaison visits are made by BTRA staff to have a first-hand view of the problems faced by the power loom weavers/processors and on the spot, suggestions are made. The activities of these centers are given in the following Table-2.

**Table – 2**

**Activities of BTRA Powerloom Service Centres**

| **Activities** | | **Ichalkaranji** | **Solapur** | **Madhav Nagar-Vita** |
|---|---|---|---|---|
| Total yarn and fabric samples were tested for physicals & chemical properties | | 9711 | 3737 | 522 |
| Number of technical assistance/trouble shooting / consultancy given | | 220 | 312 | 13 |
| Total number of persons trained | | 134 | 152 | 48 |
| Total number of trainee man-days | | - | 878 | 782 |
| Total seminars/workshops conducted | | 4 | 8 | 02 |
| **Activities** | | **254** | **-** | **196** |
| Survey of closure of power looms | Units | 1624 | 392 | 2136 |
| | Looms | - | 6622 | 02 |
| Number of interactive workshops conducted for the TUF scheme and Group Insurance scheme | | - | - | - |
| Group insurance facilitations for power loom workers [number of beneficiaries] | | - | - | - |
| Number of Advisory / PPCICC meetings conducted | | - | - | - |
| Number of samples for design development [non-CAD] / Analysis | | - | -- | - |

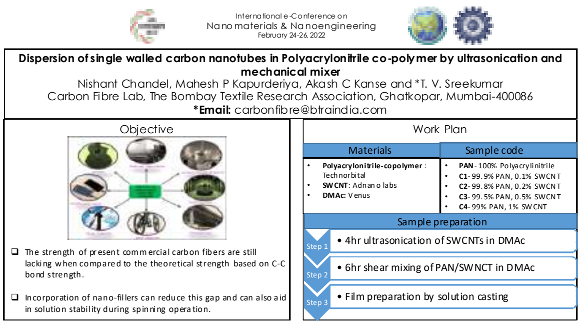
## 8. INFORMATION DISSEMINATION / INDUSTRY INTERACTION

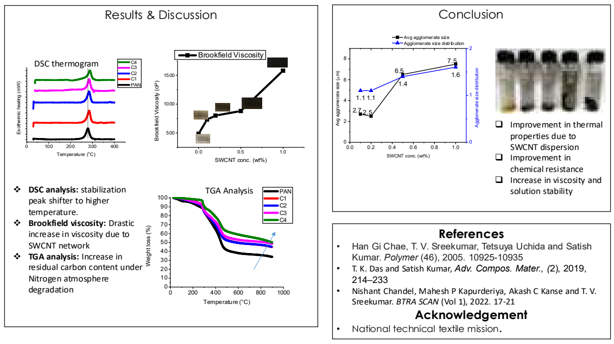
**(a)** BTRA library serves its users and textile units with 'Current Awareness Services' regularly, though we have revised and updated the new version of **"BTRA Norms for Chemical Processing"**

**(b)** The Industry Outlook Magazine has published a column, about how BTRA has contributed through R&D as well as advanced knowledge to help the textile industry. For the past 67 years, BTRA has been serving the industry in all possible ways- R&D, Consultancy, and product development to meet the technological needs of the textile industry throughout India. The publication is also available on https://www.theindustryoutlook.com/manufacturing/company-spotlight-textile-and-apparel-testing/the-Bombay-textile-research-association-torchbearers-in-the-textile testing-research-industry-for-the-last-67-years-nwid-2149.html

**(c) Participation in International E-Conference on "Nanomaterials and Nanoengineering"**

Based on the experiments done under the project 'Development of carbon nanotube Reinforced Acrylic Precursors for Carbon Fibre' BTRA presented one poster at the International E-Conference on "Nanomaterials and Nanoengineering" organized by APA Nano forum- on 24-26 February 2022.




**(d) RPL Training Programme for inmates at Nagpur Central Jail**

A Skill Certification Program aimed at helping prisoners with employment

opportunities in Powerloom weaving after their release from prison was organised under the "Udne Do" initiative as part of the Sankalp program by Maharashtra State Skill Development Society MSSDS. The two days RPL training program was organised during the period 23rdto 24th March 2022 at Nagpur Central Prison and was followed by an assessment on national skill standards on 25th March 2022. The program being implemented by Textile Sector Skill Council (TSC) was inaugurated by Smt. Deepa Agey, Dy. Superintendent, Nagpur Central Prison on 23rd March 2022. Mr. Vijay Gawde, The Bombay Textile Research Association (BTRA) provided skill interventions on entrepreneurship, digital literacy, and

technical aspects of weaving to 20 prisoners at the Prison.

During the training program, the prisoners learned about important aspects of powerloom to produce good quality fabric at a higher productivity rate, maintenance tips, good manufacturing practices, functioning of shuttleless machine w.r.t.shuttleloom, information about career progression and employment opportunities in the textile industry, the advantage of Skill India's Certifications, textile trend in the domestic and international market, information about cashless payment systems, insurance, savings, entrepreneurship, various government schemes, etc.

At the end of the training program, participants were undergone third-party assessment successfully.

**(e) EXHIBITION PARTICIPATION**

The Bombay Textile Research Association (BTRA) participated as a Centre of Excellence (COE) in Geosynthetics. BTRA had major perspectives to offer regarding the prevailing state and the level of development in the technical textile industry. Techtextil India 2021 exhibition was held from 25th November to 27th November 2021 at NESCO (Bombay Exhibition Centre), Goregaon, Mumbai. Various research publications, samples of technical textiles, and posters depicting the research, testing, training, and consultancy activities of BTRA were displayed during the program.


**BTRA Stall view at Techtextil India 2021**

**(f) During the period following BTRA staff has completed their Ph.D.**

| Name of the Staff | Project Title | Degree | Guide |
|---|---|---|---|
| 1. Shital Palaskar | Studies on Effect of Plasma Treatment on Different Textiles Fabrics | Ph.D. | Prof.Ravindra D.Kale (ICT Institute of Chemical Technology) |
| 2. Lekhaz Devulapalli | Evaluation of Reclaimed Asphalt Pavement in Stone Matrix Asphalt Mixtures Using Rejuvenators | Ph.D. | Dr. Saravanan K. (Vellore Institute of Technology) |

**8.1. Research Papers Published**

Many research papers are published in peer-reviewed journals. The same is given in Appendix–2.

**9. Training Programmes Conducted**

BTRA organised many training programs [at BTRA and Unit level] during the year under review. Details are provided in Appendix-3.

**9.1 BTRA Publications / Library**

A list of BTRA publications brought out during the period under review is given in Appendix–5. BTRA library serves its users and textile units with 'Current Awareness Services' regularly, through the publication of 'BTRA Scan (Quarterly)'.

BTRA Library has added many specialized books, especially in the areas of geotextiles, nonwovens, composites, and nanotechnology. The details of additions to the library are given in Appendix–7. It receives around 8 foreign and 20 Indian journals/magazines/newsletters regularly. As of 31st March 2022, the library has

22,961holdings. BTRA updates its website (www.btraindia.com) at regular intervals.

**9.2 Academic Activities**

BTRA offered an internship to 14 students from various technical education institutes during the period under review.

***Acknowledgments***

The major portion of R & D's work at BTRA is based on the financial assistance provided by the various sponsoring agencies. This is apart from various In-house projects that are being carried out. The generous support from the sponsors has also enabled BTRA to build a good and useful infrastructure, which efficiently supports the R & D work. Our in-depth gratitude goes to the Ministry of Textiles, Government of India for their generous support, and to the Board of Research on Nuclear Science, under the Department of Atomic Energy, Government of India, and Defence Research & Development Organisation, under the Ministry of Defence, Government of India. Thanks, are also due to members of BTRA for giving constant encouragement and support to BTRA scientists/technologists to continue their work in uplifting the industry.

**Appendix – 1**

## SPONSORED PROJECTS

**On-going Projects:**

***Defence Research & Development Organisation, Ministry of Defence, Government of India, New Delhi***

- ❖ Development of a standard method for identification of dope dyed and exhaust dyed polyester fibers/fabrics

***IREL (India) Limited, Govt. of India Undertaking-Dept. of Atomic Energy, Mumbai***

- ❖ Eco-friendly Natural Dyeing of Cotton and Silk using Rare Earths (RE) Metal Salts as Mordants

***Ministry of Textile, Government of India***

- ❖ Development of Carbon Nanotube Reinforced Acrylic Precursors for Carbon Fibre

**On-going In-house Projects:**

- ❖ Centre of Excellence for Geotech
- ❖ BTRA powerloom service centre – Ichalkaranji
- ❖ BTRA powerloom service centre – Solapur
- ❖ BTRA powerloom service centre – Madhavnagar

**On-going In-house Project:**

- ❖ Atmospheric pressure plasma treatment of textiles for dyeing of various fabrics with natural and synthetic dyes
- ❖ Development of Polypropylene, Nylon 6/ Graphene Oxide (GO) high-performance nanocomposite filaments
- ❖ Development of highly efficient and functional finished reusable protective face mask.

**Appendix–2**

## PAPERS PRESENTED IN CONFERENCES / SEMINARS/LECTURES

| Staff Name | Subject | Occasion/Venue/Date |
|---|---|---|
| Dr.Shital Palaskar | Adhesion properties of polypropylene fabric treated with atmospheric pressure plasma and coated with polyurethane: Effect of ageing | Advances in Plasma Science and Technology & quote; held online from 27th to 29th May 2021, organized by Sri Shakti Institute of Engineering and Technology, Coimbatore |
| Dr.T V Sreekumar | Structure Properties of Special Acrylic Fibre and Carbon Fibre | Invited as an expert in carbon materials area to deliver a talk on Carbon fiber organized by Tata Steel Limited, on 8th December 2021 |
| Dr.Lekhaz D | International Conference on Technical Textiles with the theme Creating the Winning Leap in Technical Textiles | Invited as a COE in Geo Textiles, organised by Ministry of Textile, GOI on 12th March 2022 |

**Appendix–3**

## PAPERS / ACCEPTED PUBLISHED IN JOURNALS

| Staff Name | Title | Journal Name |
|---|---|---|
| M. P. Sathianarayanan and Karishma Hemani | Development of Bio-degradable Cotton Waste based Super Oleophilic and Super Hydrophobic Sorbent for Oil Spill Clean-up | 'Journal of Institution of Engineers (India) series E, Springer' https://doi.org/10.1007/s40034-021-00211-7, April 2021. |
| Tanaji Kadam and A.Jeyakumar | Zero Liquid Discharge ETP-A Case Study (Part I) | 'BTRA Scan' Vol-L No.2, 1-4, April 2021. |
| Archana Gangwar | The Effect of Weave Pattern on the Moisture Management Properties of 100% Cotton Fabric | 'BTRA Scan' Vol-L No.2,5-10, April 2021 |
| Komal Kukreja | Geosynthetics: An overview | 'BTRA Scan' Vol-L No.2, 11-19, April 2021. |
| Shital S. Palaskar, Ravindra D. Kale and Rajendra R. Deshmukh | Application of natural yellow (curcumin) dye on silk to impart multifunctional finishing and validation of dyeing process using BBD model | 'Color Research and Application'. 2021;1–12. https://doi.org/10.1002/col.22678. |
| Tanaji Kadam and A.Jeyakumar | Zero Liquid Discharge ETP-A Case Study (Part II) | 'BTRA Scan' Vol-L No.3, 1-6. |

| Staff Name | Title | Journal Name |
|---|---|---|
| Archana Gangwar and Padma S. Vankar | Surface modified, Rare Earth mordanted cotton, dyed with Eupatorium extract | 'BTRA Scan' Vol-L No.3,7-11 |
| Saroj P. Vairagi | Study of Banned Amines Recovery' | 'BTRA Scan' Vol-L No.3,12-17. |
| Shital Palaskar | Adhesion Studies of Atmospheric Pressure Plasma Treated Nylon 66 Fabrics with Polyurethane | 'BTRA Scan' Vol-L No.3, 18-21. |
| Shital S Palaskar, Ravindra D. Kale, Rajendra R Deshmukh | Influence of Plasma Treatment on Dyeing Properties of Silk Weaves | 'Journal of Natural Fibers', 2021,1-13doi.org/10.1080 /15440478.2021.1944424 |
| Padma S. Vankar | Natural dyeing of biotreated silk with Eclipta | Paper submitted to 'Journal of The Institution of Engineers (India): Series E'. |
| Tanaji Kadam and A.Jeyakumar | Zero Liquid Discharge ETP-A Case Study (Part III) | 'BTRA Scan' Vol-L No.4, 1-5. |
| Archana Gangwar and Padma S. Vankar | Improved fastnesses through Modified Turmeric Dyeing using Rare Earth Salts as Mordants | 'BTRA Scan' Vol-L No.4, 6-.9 |
| Lekhaz Devulapalli | Comprehensive Overview of Installation Damage Test on Geo-textiles | 'BTRA Scan' Vol-L No.4, 10-14. |
| M.P.Sathianarayanan and Rina Nayak | Method Development for Analyzing Hexavalent Chromium in Water Soluble Dyes and its Validation | 'BTRA Scan' Vol-L No.4, 15-23. |
| Panda P.K.; Gangwar A.; Thite A.G., | Optimization of Nylon 6 electrospun nanofiber diameter in needle-less wire electrode using central composite design and response surface methodology | 'Journal of Industrial Textiles, 2021, DOI: 10.1177/15280837211058213 |
| Panda P.K, Gangwar A | Application of Nanofiber to improve the anti-clogging property of vertical drainage (PVD) | 'Indian Journal of Geosynthetics and Ground Improvement', Vol10(2),2021 |
| Lekhaz Devulapalli, Goutham Sarang, and Saravanan Kothandaraman | Characteristics of aggregate gradation, drain down, and stabilizing agents in stone matrix asphalt mixtures: A state of the art review | Journal of Traffic and Transportation Engineering, JTTE377_March 2022/1/13 |
| Shital S Palaskar, Prasanta K. Panda, Mahesh Kapurderiya, Karan Tarleja, Sakshi Mishra | Highly protective reusable face mask – designing and development | COTTON STATISTICS & NEWS – Issue No. 49,p.g.1-5 |

| Staff Name | Title | Journal Name |
|---|---|---|
| Smita Deogaonkar-Baride,Shital S Palaskar | Atmospheric pressure plasma treatment for enhancing the conducting properties of polypyrrole coated nylon fabric | Accepted in the Journal of Applied Polymer Science |
| Swapneshu Baser | Improved Sustainable, Environment Friendly, Green Technology for Textile Dyeing Using Supercritical Fluid | BTRA Scan' Vol-LI No.1, 1-6 |
| Nishant Chandel, Mahesh Kapuderiya, Akash C Kanse, T V Sreekumar | Dispersion studies of single-wall carbon nanotubes in Polyacrylonitrile | BTRA Scan' Vol-LI No.1, 12-16 |
| Shital S Palaskar, Prasanta K. Panda, Mahesh Kapurderiya, Karan Tarleja, Sakshi Mishra | Highly protective reusable face mask – designing and development | BTRA Scan' Vol-LI No.1, 19-22 |
| Smita Deogaonkar-Baride | Basics of Electrically Conductive Textiles: Manufacturing, Characterization, and applications | BTRA Scan' Vol-LI No.1, 07-11 |

**Appendix – 4**

## TRAINING PROGRAMMES CONDUCTED

| Subject | To Whom | Duration |
|---|---|---|
| | **On-Site Training** | |
| ISO/IEC 17025:2017 Standard and Internal Audit | BTRA, Mumbai | 3days in April 2021 |
| Training in textiles | JMD synthetics ( Mr. Manav Kothari) and Sulpa International ( Mr. Sarthak Sarkar) | 6 days July and August 2021 |
| ETP training | Participants from various Mills | 7 days in September 2021 |
| Training in Spinning Technology | Participants from various Mills | 3 days in September 2021 |
| Online Training for Geosynthetics | Participants from various Mills | 4 days in October 2021 |
| Online Training in Advanced Analytical Testing | Participants from various Mills | One 1day in October 2021 |
| Training in Weaving and related activities | Khosla Profil Pvt Ltd | 6 days in October 2021 |

| Subject | To Whom | Duration |
|---|---|---|
| | **On-Site Training** | |
| Advanced Analytical Chemistry and Data Interpretation | Participants from various Mills | 3 days in October 2021 |
| Training in Weaving and related activities | Khosla Profil Pvt Ltd | 3 days in November 2021 |
| Lecture on geotextile products, input material, and applications | Participants from various Mills | 4 days in November 2021 |
| Training on Testing and Wet Processing | Industry | 5 days in January 2022 |
| Training in Textiles | Participant from M/S Nahata Creations | 6days in February 2022 |
| Training in Textile Processing | Participant from M/S Mudit prints | 2 days in February 2022 |
| Training in Yarn Spinning | Participant from Count and Threads Ltd. | 9 days in February 2022 |
| Evaluation & Improvement Program | Maharaja Dyeing (P) Ltd | February 2022 |
| RPL training in power loom operations for Skill India Mission | Jail inmates from Central Jail Nagpur | 1 day in March 2022 |

**Appendix – 5**

## CONFERENCES / SEMINARS / TRAINING PROGRAMMES / WORKSHOPS ATTENDED BY BTRA STAFF TRAINING PROGRAMMES CONDUCTED

| Name of Staff | Occasion | Place | Date |
|---|---|---|---|
| Mr.Amol Thite | Attended TxD40 BIS Meeting | Mumbai | 28th April 2021 |
| Mr.Vijay Gawde | Attended BIS Meeting on Textile Machinery and Accessories Sectional Committee, TXD 14 | Mumbai | 2nd June 2021 |
| Mr.Amol Thite | Attended National Conference on – 'Recent trends in Textile manufacturing' | Kolkata | 30th June 2021 |
| Mr.Amol Thite | Attended online course "Advanced materials chemistry" | Mumbai | 14th June to 30th October 2021 |
| Mr. Tanaji Kadam | Attended online Meeting Three-year PSC review meeting - | Mumbai | 14th July 2021. |
| Mr. Tanaji Kadam | Attended zoom meeting with JD institute for deciding on joint activities of training, research, and testing | Mumbai | 14th July 2021. |

| Name of Staff | Occasion | Place | Date |
|---|---|---|---|
| Mr. Tanaji Kadam/ Mr.Vijay Shirole | Attended Meeting for discussion on commercial terms for MOU - ETP with Konark team | Mumbai | 26th July 2021 |
| Mr.Tanaji Kadam/ Mr.Vijay shirole | Attended webinar on 'Chemical management system' | Mumbai | 29th July 2021. |
| Mr.R.A.Shaikh | Attended the BIS TXD meeting | Mumbai | July 2021 |
| Mr. Vijay Gawde | Attended Meeting for discussion of new plant set up consultancy by BTRA Mumbai | Mumbai | 23rd August 2021 |
| Mr.Amol Thite | Attended virtual International Conference on Innovation in Textiles-Products & Processes organised by DKTE | Ichalkaranji | 2nd September 2021 |
| Mr.Amol Thite | Attended Txd 28 BIS Meeting | Mumbai | 7th September 2021 |
| Mr. Vijay Gawde | Attended the meeting on Discussion with Textile Commissioner on the project of Jute wagon cover at Textile commissioner office | Mumbai | 21st September 2021. |
| Mr. Tanaji Kadam/ Mr. Vijay Gawde | Attended online meeting with TSC for RPL program introduction conducted by TSC | Mumbai | 11th October 2021. |
| Dr. Prasanta Kumar Panda | Attended conference on 'Sustainable standards' by Centre for Responsible Business | Delhi | 26th to 29th October 2021 |
| Mr. Vijay Gawde/ Mr.Vijay Shirole | Attended online meeting with Stakeholder consultation for qualification packs of textile sector | Mumbai | 16th November 2021. |
| Mr. Vijay Gawde | Attended meeting with Textile commissioner for jute cover project proposal at Textile commissioner office | Mumbai | 1st December 2021. |
| Mr. Vijay Gawde | Attended meeting with Mr. K.N Singh ( chief- Freight transport manager, Indian railway, ) - for jute cover project proposal | Mumbai | 2nd December 2021. |
| Mr.Amol Thite | Attended Txd 37 BIS Meeting | Mumbai | 14th December 2021. |
| Mr. Tanaji Kadam | Attended meeting with Future advanced qualification packs - stakeholder at Textile Sector Skill Council | Mumbai | 28th December 2021. |

| Name of Staff | Occasion | Place | Date |
|---|---|---|---|
| Mr. Tanaji Kadam/ Mr.Vijay Shirole | Attended Mock presentation - CAC meeting of MPCB at D'Décor plant - G-7 | Boisar | 29th and 30th December 2021. |
| Mr.Riyaz Shaikh | Attended BIS meeting | Mumbai | 11th January 2022 |
| Mr.Riyaz Shaikh | Attended NABL PT meeting | Mumbai | 10th January 2022 |
| Mr. Tanaji Kadam | Attended NCVET and TSC - organised stakeholder consulting meeting related to Textile sector Qualification packs-virtually | Online | 20th January 2022. |
| Mr.Amol Thite | Attended online workshop on Standardization of technical Textiles by ITTA | Mumbai | 2nd February 2022 |
| Mr. Vijay Gawde | Attended 25th meeting of TAMC under ATUF | Mumbai | 22nd February 2022. |
| Mr.Riyaz Shaikh | Attended BIS meeting | Mumbai | 03rd February 2022 |
| Mr.Riyaz Shaikh | Attended Soil lab NABL Audit | Mumbai | 21st to 25th February 2022 |
| Mr.Riyaz Shaikh | Attended NABL PT Training | Mumbai | 3rd and 4th February 2022 |
| Mr. Tanaji Kadam/ Mr.Vijay shirole | Attended MPCB - CAC meeting for consent to operate - review of Ddecor exports and fabric limited | Mumbai | 26th February 2022. |
| Mr. Tanaji Kadam | Attended 14th PAMC meeting for ongoing projects at Textile commissioner office Churchgate | Mumbai | 26th February 2022. |
| Dr.Shital Palaskar | Attended BIS TxD meeting | Mumbai | 9th February 2022 |
| Mr.Riyaz Shaikh | Attended BIS meeting | Mumbai | 10th and 11th March 2022 |

**Appendix – 6**

**PUBLICATION RELEASED BY BTRA**

BTRA library serves its users and textile units with 'Current Awareness Services' regularly, though we have revised and updated the new version of **"BTRA Norms for Chemical Processing"**

**Appendix – 7**

**OTHERS**

| | |
|---|---|
| **PRODUCTS / CHEMICALS / INSTRUMENTS / GADGETS SOLD ON A REIMBURSABLE BASIS** | • Viscosity cups [31 no.]<br>• Cuprammonium solution [0.9ltr]<br>• Drave Test Hook [4 no.] |
| **INSTRUMENTS / GADGETS CALIBRATED** | • Various instruments at BTRA Test Laboratories and 3 BTRA PSCs are calibrated regularly |
| **INSTRUMENTS SERVICED** | • Servicing several types of equipment/instruments at BTRA Test Laboratories |

**Appendix – 8**

**NEW ADDITIONS TO BTRA LIBRARY**

- ♣ BTRA Norms for Chemical Processing-2021
- ♣ Toxicity of building materials By F Pacheco Torgal and S Jalali and A Fucic by F.Pacheco Torgal, S. Jalali and A.Fucic.
- ♣ 2021-2022 TECHNICAL MANUAL OF AATCC, USA.
- ♣ CONFEDERATION OF INDIAN TEXTILE INDUSTRY, CITI

**Soft Copy Downloads**

- ♣ **Latest International Standard Test Methods:** AATCC TM30, AATCC TM100, ASTM D3273, ASTM G21, ISO 20743, ISO 22196, ISO 16549,, IS 11056, IS 10971,IS 7702, IS 6789,IS 6489,IS 3442, IS 1969, IS 1966, ASTM D5867,ASTM D5587,ASTM D1004, ASTM D1424,ASTM F1862,DIN EN ISO 15025,ASTM D 1776,EN 14863,AATCC 197, AATCC 737,NFPA 701,ISO 11357, ASTM D6413,ASTM D5885,ASTM D1525ASTM D6392,ISO-20743,IS 15758,IS 15590,IS 15589,IS 11871, ISO 3071,ISO 5077,ISO 22069,ASTM D4491,ASTM 4533,ASTM D4595,ASTM D4833,ASTM D6693,ASTM D6767,ASTM D6706,IS 10971,IS 2720,ASTM D2101,ASTM D6392.

**Appendix –9**

**DIRECTOR'S ENGAGEMENTS**

| Month | Details |
|---|---|
| **July 2021** | ♣ Attended meeting with Hon'ble Minister, Shri. Piyush Goyal, Ministry of Textile on the topic of 'Review of Textile Sector Policies' at Textile Commissioner Office, Mumbai on 10th July 2021 |
| **September 2021** | ♣ Attended meeting with Mr. K.N Singh ( chief- Freight transport manager, Indian railway, ) - for jute cover project proposal, Textile commissioner office on 21st September 2021 |
| **October 2021** | ♣ Attended the convocation ceremony at IIT Jammu along with BTRA Chairman on 22nd October 2021 at Jammu. As BTRA already entered with MOU for research collaboration and Ph.D. student transfer as Quality Improvement Programme of BTRA Scientific staff. BTRA collaborates with the Saptharshi laboratory of IIT Jammu for testing. |
| **December 2021** | ♣ Attended meeting with Mr. Agarwal, Cotton Corporation of India on 21st December 2021 |

**Appendix – 10**

## DISTINGUISHED VISITORS TO BTRA

| Name of the Visitors | Company |
|---|---|
| Mr. Rajesh Kumar Jha | Employee's Provident Fund Organisation |
| Mr.Abhijit Chandrakant Malshe | Operations, Nina Percept Pvt Ltd, |
| Mr.Sohel Siddiqui | Nina Percept Pvt Ltd |
| Dr.Swapneshu Baser | Deven Super criticals Pvt.Ltd |
| Mr. Animesh Laha | Welspun India Limited |
| Dr.Anu Chaphekar | Croda India Company Pvt Ltd |
| Dr.Raghav Mehra | Croda India Company Pvt Ltd |
| Mr.Sameer Patil | S & R Geotechniques Pvt. Ltd |
| Mr.Kumar Salunkhe | S & R Geotechniques Pvt. Ltd |
| Ms.Kavita Bedi | Pulse Marketing |
| Mr.Ranjnish Thanekar | Perseus Enterprises |
| Mr.Rupesh D Khedekar | Waters(India) Private Limited |
| Mr.Rohit Tomar | Epsilon Aerospace Pvt Ltd |
| Mr.Deepak Kumar | Kewaunee Laboratoryway India Pvt Ltd |
| Mr.Hirok Bhuyan | B & B Chemcorp |
| Mr.Ramesh K Mehta | Dee Arch Design |
| Mr.Jotiba Kokitkar | EO Customer Services |
| Mr.G.Uthayasekaran | Khosla Profil Pvt Ltd |
| Mr.Narendra Dalmia | Strata Geosystems(India) Pvt Ltd |
| Mr.Rahul Bajaj | Khosla Profil Pvt Ltd |
| Mr.Vishal Patil | Usha Tech |
| Mr.Pradeep Singh | 5M Projects & Solutions |
| Mr.Jayesh Khanvilkar | Roop Telsonic Ultrasonix Ltd |
| Mr.Sachin Gupta | Roop Telsonic Ultrasonix Ltd |
| Mr.D.V.Kamat | Konark Fixtures Ltd |
| Mr.Rakesh S Gupta | Konark Fixtures Ltd |
| Mr.Vikas N Gadhave | Konark Fixtures Ltd |
| Mr.Ankur Kothari | Kusumgar Corporates Pvt Ltd |
| Mr.Hemant Godbole | Sealed Air |
| Dr.Kanchan Nautiyal | Analytical Laboratory |
| Mr.S.K.Tyagi | Donear House |
| Mr.Saket Kulkarni | ZDHC |
| Mr.Prasad Pant | ZDHC |
| Mr.Suresh Bhagwath | Aimil Ltd |
| Mr.Ajinkya Meshram | TATA Steel Limited |
| Mr.Avinash Misar | TEXPORTSyndiate(India)Limited |
| Mr.S.B.Akiwate | DKTE Textile & Engineering Institute |

| Name of the Visitors | Company |
|---|---|
| Mr.Manajit Paulchaudhury | Sarla Performance Fibers Ltd |
| Mr.Rajesh Chopra | Timetex Mills |
| Mr.Shibu Mathews | Savanna Water Technologies |
| Mr.A Bala Murali | 346 Samy & Co |
| Mr.R.Balaguru | 346 Samy & Co |
| Mr.Nishant Shah | Sealed Air |
| Dr.P.Ravi Chandran | Textiles Committee |
| Mr.Navee Chawla | Epsilon Aerospace Pvt Ltd |
| Mr.Kaushik Chakraborty | Epsilon Aerospace Pvt Ltd |
| Mr.Surjit Singh | SGMS Maintenence Service |
| Mr.Nithin P Raj | Xee Design |

**Appendix –11**

## OUTSTATION VISITS BY BTRA STAFF

- Aakash Fashion Prints, Ahmedabad
- Rinkoo Processors, Ahmedabad
- Samir Synthetics, Ahmedabad
- Balkrishna Textiles, Ahmedabad
- Swan Energy ltd, Ahmedabad
- Kudu Processors, Ludhiana
- Saachi Processors, Ludhiana
- Adinath Dyeing, Ludhiana
- PL Cottex Pvt Ltd, Ludhiana
- Ruby Mills, Thane
- Khosla Profil Pvt Ltd, Mumbai
- Pee Vee Textiles, Nagpur
- Mudi Prints, Rajasthan
- Ameen Silk Pvt Ltd, Surat
- Krishna Dyeing and Printing Mills, Surat
- Bindal Silk Mill Pvt Ltd, Surat
- Stuti Processor, Surat
- Gonawala Processors, Surat
- Global Nonwovens, Surat
- Coulourmate and Sons, Surat
- Ddecor exports, Boisar
- Khosla Profil Ltd, Wada
- N. C. Johns & sons, Tuticorin
- Donear Industries – Surat
- Indocount Industries Ltd, Kolhapur
- Pee Vee Textiles, Jamnagar
- Kongoor Textiles,Tirupur
- Victus Dyeing, Tirupur
- Bannari Aman spg, SIPCOT Perundurai
- RK Dyeing, Selam
- SSM processing Mills, Bhavani
- Maharaj Shree Umaid mills( MSUM) Ltd, Pali Rajasthan
- Mayank Processors, Ahmedabad
- Komal Texfab,
- Nisan Exim, Ahmadabad
- Kanti Fashions, Ahmadabad
- Devdeep Texfab Pvt Ltd, Ahmadabad
- PSC, Solapur
- MPCB Kolhapur
- PSC, Madhavnagar
- PSC, Ichalkaranji
- Shyam Fashion Pvt Ltd, Ahmedabad

**Appendix – 12**

## BIS MEMBERSHIP

BTRA staff involved in the following standard development committees of the Bureau of Indian Standards.

| Sectional Committees | Title |
|---|---|
| TXD 01 | Physical methods of test |
| TXD 05 | Chemical methods of test |
| TXD 07 | Textile speciality chemicals and dyestuffs |
| TXD 14 | Textile Machinery and Accessories |
| TXD 28 | Silk and silk products |
| TXD 30 | Geo-textiles and industrial fabrics |
| TXD 31 | Man-made fibres, cotton and their products |
| TXD 32 | Textiles protective clothing |
| TXD 33 | Industrial fabrics |
| TXD 35 | Technical Textiles for Agrotech applications |
| TXD 36 | Technical Textiles for Meditech purposes |
| TXD 37 | Technical Textiles for Sportech applications |
| TXD 38 | Technical Textiles for Mobiltech Applications |
| TXD 39 | Technical textiles for Clothtech purposes |
| TXD 40 | Composites and Speciality Fibres Sectional |

**Appendix – 13**

**MEMBERS OF THE GENERAL ADVISORY COMMITTEE**
FOR RESEARCH AND LIAISON
Jan 2021- Dec 2023

| | | |
|---|---|---|
| **Dr. Lalit Varshney**<br>Former Head, Radiation Technology Development Division,<br>Raja Ramanna Fellow, RRF, Electron Beam Centre, Kharghar Raintree Marg, Sector 7, CBD Belapur, Navi Mumbai, Maharashtra -410210 | **Dr. T.M. Kotresh**<br>Scientist 'G'/AD,<br>Defence Bioengineering and Electromedical Laboratory,<br>CV Raman Nagar,<br>Bengaluru-560093. | **Dr. G V Raghunath Reddy**<br>Scientist – F,<br>Technology Mission Division (Energy, Water, and Others), Department of Science & Technology, Ministry of Science and Technology, Technology Bhavan, New Mehrauli Road, New Delhi – 110016. |
| **Dr. T.H. Goswami,**<br>Defence Materials and Stores Research & Development Establishment (DMSRDE) DRDO, Ministry of Defence, Government of India, PO DMSRDE, GT Road, Kanpur-208013 | **Dr. Debarati Bhattacharjee**<br>Scientist, FIE,<br>Terminal Ballistics Research Laboratory,<br>Sector 30,<br>Chandigarh - 160 030. | **Dr. Arup R. Bhattacharyya**<br>Department of Metallurgical Engineering & Materials Science, Indian Institute of Technology Bombay,<br>Powai,<br>Mumbai-400076 |
| **Prof. Anirban Guha**<br>Department of Mechanical Engineering,<br>Indian Institute of Technology, Bombay, Powai, Mumbai 400 076 | **Dr. Asim Tewari**<br>Chair Professor Department of Mechanical Engineering<br>Indian Institute of Technology Bombay, Powai, Mumbai- 400076. | **Dr. Vijay Ramakrishnan**<br>Garware Technical Fibres Ltd.,<br>Plot No.11,<br>Block D-1, MIDC,<br>Chinchwad, Pune- 411 019. |
| **Dr. Milind Khandwe**<br>The Bhor Chemicals & Plastics Pvt Ltd,<br>Plot no. B/18/2/1, MIDC Ambad, Nashik – 422010. | **Mr. V. Kannan**<br>Flat No.303, Bldg 3B, Siddhachal Phase 6, Off Pokhran Road no.2, Near Vasanth Vihar School, Thane West 400610 | **Mr. K.L.Vidur**<br>B-401, NirmanVihar,<br>Rajmata Jeejabai Road,<br>Andheri (East), Mumbai 400093 |
| **Dr. M. K.Talukdar,**<br>M/s.Kusumgar Corporates,<br>101/102, Manjushree Bldg.,<br>Hatkesh Co-op. Society, Corner of N.S.Road No.5, JVPD Scheme,<br>Juhu, Mumbai 400 056. | **Dr. R. R. Deshmukh**<br>Institute of Chemical Technology,<br>Nathalal Parekh Marg,<br>Matunga, Mumbai 400 019 | **Mr. Shahrokh Bagli**<br>Technical Advisor<br>Strata Geosystems (India) Pvt Ltd,<br>Sabnam House, Plot No. A-15/16<br>Central Cross Road B, MIDC,<br>Andheri (E), Mumbai 400 093 |
| **Dr.Prakash Vasudevan**<br>Director,<br>The South India Textile Research Association,<br>13/37, Avinashi Road,<br>Coimbatore Aerodrome Post,<br>Coimbatore – 641 014 | **Mr. Arindam Basu**<br>Director,<br>Northern India Textile Research Association<br>Sector-23, Raj Nagar,<br>Ghaziabad-201002 | **Mr. Pragnesh Shah**<br>Director,<br>Ahmedabad Textile Industry's Research Association,<br>P.O. Ambawadi Vistar,<br>Ahmedabad - 380 015 |
| **Dr. T. V. Sreekumar**<br>Director,<br>The Bombay Textile Research Association,<br>Lal Bahadur Shastri Marg,<br>Ghatkopar (West),<br>Mumbai 400 086. | | |

**Appendix – 14**

## STAFF DETAILS

The total staff strength of BTRA as of 31st March 2022 was as follows:

| | |
|---|---|
| **Director** | **1** |
| **At BTRA** | |
| ◆ Scientific / Technical Officers | 19 |
| ◆ Scientific / Technical Staff | 29 |
| ◆ Skilled / Semi-skilled & Maintenance Staff | 18 |
| ◆ Administrative Staff | 16 |
| **Sub-total** | **83** |
| **At PSCs** | |
| ◆ Scientific / Technical Officers | 0 |
| ◆ Scientific / Technical Staff | 5 |
| ◆ Skilled / Semi-skilled & Maintenance Staff | 1 |
| ◆ Administrative Staff | 1 |
| **Sub-total** | **7** |
| TOTAL | 90@ |

**@ - Including 13 contractual staff & 5 Trainees**

**Director : Dr. T V Sreekumar**

**Research**
Advisor : Mr. S. Subramanian
Research Advisor : Dr. Padma S.Vankar

**Technical Services Division**
Chief Textile Technologist : Mr. Tanaji I. Kadam
Senior Scientific Officer Grade-I : Mr. V. A. Gawde
Senior Scientific Officer Grade-I : Mr. V. R. Shirole

**Library, Information & Publication**
Library Assistant : Ms. Sharayu Joshi

**Electronics**
Junior Technical Officer (Electronics & computers) : Mr. Peringeth Jithin

**BTRA Test Laboratories**

| | | |
|---|---|---|
| Laboratory Manager (Senior Scientist) | : | Mr. R.A. Shaikh |
| Senior Scientific Officer Grade-II | : | Mrs. M. P. D'Souza |

**(i) Physical Testing Division**

| | | |
|---|---|---|
| Junior Scientific Officer | : | Mr. D.R. Yadav |

**Scanning Electron Microscope**

| | | |
|---|---|---|
| Senior Scientific Officer Grade-II | : | Mr. Amol G. Thite |

**Geotech Cell**

| | | |
|---|---|---|
| Senior Scientist | : | Dr. Prasanta Kumar N. Panda |
| Senior Scientific Officer Grade-II | : | Mr. R. R. Menon |
| Junior Scientific Officer | : | Mr. G.R. Mahajan |

**(ii) Chemical Testing Lab.**

| | | |
|---|---|---|
| Senior Scientist | : | Mr. M. P. Sathianarayanan |
| | : | Mrs. S. P. Vairagi |
| | : | Mrs. Chandrakala L.M. |
| Senior Scientific Officer Grade-II | : | Ms. A. U. Shenoy |
| | | Mrs. SmitaA.Baride/ |
| | | Ms. Tejaswini R. Ghadyale |
| Junior Scientific Officer | : | Mrs. S. D. Mayekar |
| | | Ms. Karishma Hemani |

**(iii) Microbiology Lab.**

| | | |
|---|---|---|
| Technical Assistant | : | Ms. Ashwini P. Govekar |

**(iv) Plasma Lab.**

| | | |
|---|---|---|
| Senior Scientific Officer Grade -II | : | Dr. S.S. Palaskar |

**Engineering Services Section**

| | | |
|---|---|---|
| Junior Technical Officer (Engineering services) | : | Mr. Mohan B. Mane |

**Administration**

| | | |
|---|---|---|
| Administrative Officer | : | Mr.Jignesh S.Jani |
| Purchase Officer | : | Mr. M.H. Bondre |
| Accountant | : | Mrs. Veena A. Dwivedi |
| Executive Director Office | : | Mr.Vasant A. Gawade |

**Marketing**

| | | |
|---|---|---|
| Senior Scientific Officer Grade-I | : | Mrs.Snehal B Dhamdere |
| Officer - Marketing Co-ordination | : | Mrs. Rohini A. Bantwal Mangalore |

**Soil Testing Lab.**

| | | |
|---|---|---|
| Research Officer | : | Mr. Sunil K. Dighe |

**NTTM Proj.**

| | | |
|---|---|---|
| Research Scientist | : | Dr. Devulapalli Lekhaz |
| Research Scientist | : | Mr. Nishant Chandel |

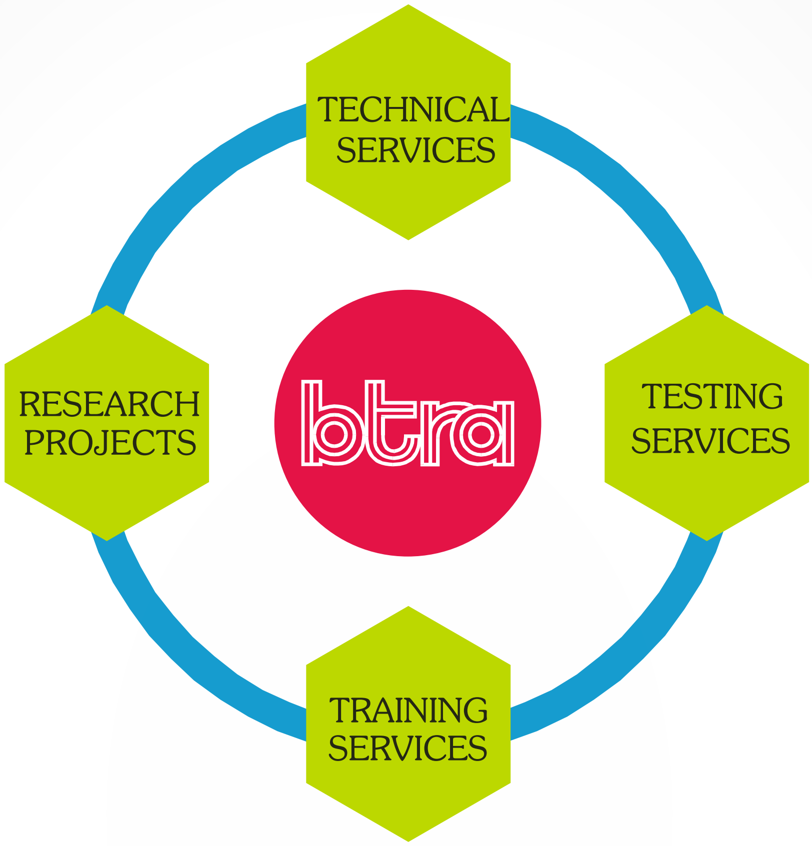
| | | |
|---|---|---|
| **BTRA PSC, Ichalkaranji** | : | Mr. Sachin R. Tambe |
| **BTRA PSC, Solapur** | : | Mr. A.V. Patil |
| **BTRA PSC, Madhavnagar** | : | Mr. N.A. Chavan |

**Appendix - 15**

## LIST OF MEMBERS

- Banswara Syntex Ltd., Rajasthan
- BMD Pvt. Ltd., Banswara
- BSL Ltd., Bhilwara
- Century Textiles& Industries Ltd., Mumbai(Birla Century, Gujarat)
- Century Rayon, Shahad (under the management & operation of Grasim Ind. Ltd.)
- Diversey India Hygiene Pvt.Ltd., Mumbai
- Entremonde Polycoaters Ltd, Nashik
- Finlay Mills Ltd., Mumbai
- Flexituff Ventures International Ltd., Mumbai
- Garware Technical Fibres Limited, Pune
- Hindoostan Mills Ltd., Mumbai
- Indian Oil Corporation Ltd., New Delhi
- Indo Count Industries Ltd., Mumbai
- Indonet Plastic Industries, Vadodara
- The Kadri Mills (Cbe) Ltd., Unit: Kadri Wovens, Tamil Nadu
- Kusumgar Corporates Pvt. Ltd., Mumbai
- Kudu Knit Process Pvt. Ltd, Punjab
- MaharsheeGeomembrane (India)Pvt. Ltd., Vadodara
- Morarjee Textiles Ltd., Mumbai
- Mohota Industries Ltd, Wardha
- OCM Private Ltd, Punjab
- Nagreeka Exports Ltd., Kolhapur
- National Textile Corporation Ltd.(Western Region), Mumbai
- Pee Vee Textiles Ltd., Wardha
- Khosla Profil Pvt. Ltd., Mumbai
- RedStar, Navi Mumbai
- RSWM Ltd., Mumbai
- Raymond Ltd., Thane
- Reliance Industries Ltd., Navi Mumbai
- The Ruby Mills Ltd., Mumbai
- S. Kumars Limited, Mumbai
- Siyaram Silk Mills Ltd., Mumbai
- Strata Geosystems (India) Pvt.Ltd., Mumbai
- Supreme Nonwoven Ind. Pvt. Ltd., Mumbai
- Techfab (India) Industries Ltd., Mumbai
- Technocraft Industries (India) Ltd.,Mumbai
- United Bleachers Ltd., Tamil Nadu
- Visaka Industries Ltd., Secundarabad
- Wellknown Polyesters Ltd., Mumbai
- Mirachem Industries, Mumbai
- Sparsh Fab Textiles Pvt. Ltd., Mumbai
- Sunny Sterile Products Pvt. Ltd., Mumbai
- Terram Geosynthetics Pvt. Ltd., Kutch, Gujarat
- Times Fibrefill Pvt. Ltd., Kolkata

NOTE :




The Bombay Textile Research Association
L. B. S. Marg, Ghatkopar(W), Mumbai 400086.
Tel. : 022-62023636 • Fax : 022-25000459
Email : info@btraindia.com
www.btraindia.com