

ANNUAL **REPORT**

2024-25



**The Bombay Textile Research
Association**

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BTRA Annual Report (2024-2025)

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We have great pleasure in presenting the 71st 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 2025.

1. INTRODUCTION

The textile industry is undergoing a global paradigm shift, and this past year has been particularly difficult for the Indian textile sector as the textile industry is facing several challenges. However, there is going to be growth in the technical textile and man-made fibre industry as the National Technical Textile Mission is focussing on research innovation and development. There will be more push towards attaining sustainability and traceability in manufacturing processes as well as in products and creating trained personnel.

The textile industry has been focusing on creating high-tech, value-added products lately, with a particular emphasis on technical and medical textiles that are most suited to the market at the moment. At BTRA, enormous attempts are being made to diversify into more technology-based products and develop new products and processes. We have reinforced a number of testing facilities at our Center of Excellence, Geo-synthetics. We are even taking on assigned tasks from DRDOs and other private entities at our Electro-spinning unit. In order to build knowledge and offer services to the textile industries, BTRA has made significant R&D advancements with support from the Ministry of Textiles (MOT), Government of India (GOI), and additional funding organizations including DRDO, BARC, IREL, KVIC, and RGSTC etc.

At BTRA, we recognize the value of research and development, especially when it comes to the development of innovative products and processes. Additionally, emphasis is placed on improving efficiency and cutting costs in textile mill operations. The essence of R & D work in BTRA is two-fold (i) to make the existing products better, faster, and at affordable prices and (ii) to develop new products in a sustainable manner to reduce environmental and ecological impacts. In order to give technical/supervisory and operator levels need-based training, BTRA is also stepping up its training initiatives. In this context, BTRA additionally began a training program on sustainable technology, water recycling, and wastewater treatment plants in partnership with M/S Austro Water Technologies, Pvt Ltd, Tirupur. A brief overview of some of the work completed during the time under review is provided below. BTRA has been working on these and other thrust areas.

❖ Product Development Assistance to the industry

- Plasma Treatment and testing of industry (WRA and Kusumgar)
- WVTR and CA Testing
- WVTR, Lightfastness and Static charge Decay charge meter are procured under project and installed and being used for research as well as for commercial testing
- Performed bituminous mix design and conducted asphalt testing for numerous high-profile projects including the Coastal Road Project, Navi-Mumbai Airport, Thane Creek Bridge-Mumbai, Mumbai-Pune expressway.

❖ Calibration, Technical Services, and Training

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

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- ✓ BTRA undertakes extensive liaison and consultancy services to solve problems of quality, maintenance, productivity, water/energy conservation, 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 Value Addition for Chaddar manufacturers, Fabric Inspection, Size Application, and Evaluation, 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 and sizing, Sizing and Testing, Mechanical & Chemical Testing, and General elements of textiles.

❖ 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 systems, and eco-management for process houses.

2. ON-GOING RESEARCH PROJECTS

2.1 Development of Carbon Nanotubes Reinforced Acrylic Precursor for Carbon Fibre

Abstract

Polyacrylonitrile (PAN) based precursor has a 95% share in the carbon fibre production market but with the growing demand for high-strength carbon fibres, composition modification in the conventional PAN precursor is highly desirable. The incorporation of carbonaceous nanofillers such as carbon nanotubes (CNT) has proven to result in increased strength of the PAN precursor and resultant carbon fibre but with the only limitation of its dispersion. This research work reports the development of carbon nanotube and graphene-oxide (GO) based hybrid nano-filler reinforced PAN precursor films and the synergistic effect of hybrid filler on the thermal stabilization reaction of PAN. Results indicate an earlier and improved thermal stabilization in PAN/hybrid films than in the pristine PAN and nano-filler reinforced PAN films. Various characterization techniques such as optical microscopy, scanning electron microscopy, and differential scanning calorimetry have been performed for hybrid filler and hybrid filler reinforced PAN property determination.

Introduction

Carbon fibre is one of the most important technical textiles available in the market which has huge applications in aerospace, defence, competitive sports gear, extreme machines etc. These fibres have a very high strength-to-weight ratio than metals, replacing them in various applications. Till now 95% of the carbon fibre is prepared after the carbonization of polyacrylonitrile (PAN) fibres. The PAN fibres are subjected to various heat treatments (Stabilization, carbonization and graphitization) which transform the repeating structure of acrylonitrile into all carbon graphitic structure carbon fibre. The stabilization process of PAN is the very first and important stage because the template structure attained here will become the base for the further heat treatment process. The thermal stabilization process itself consists of 3 individual processes i.e., Oxidation, nitrile crosslinking (cyclization) and dehydrogenation. Each of these reactions has significant importance in

transforming PAN structure into stabilized PAN (PANOX) structure. The cyclization process crosslinks the pendent -CN to the hexagonal structure, the dehydrogenation reaction removes the excess hydrogen from the PAN chains which increases the relative carbon content in the PANOX, and the oxidation reaction oxidizes the cyclized PAN structure and imparts more stability to the PANOX structure to the thermal degradation since stabilization reaction is a highly exothermic radical reaction. However, the reaction mechanism can also be switched to an ionic reaction from the radical reaction by introducing acidic co-monomers in PAN during the polymerization process which increases the temperature range over which stabilization takes place. This increased temperature range ensures less thermal degradation since the same amount of heat is released but in a longer period instead of in an instant which happens in a radical reaction.

Other research groups also reported a similar improvement where carbon nanotubes (CNT) improve the stabilization of PAN due to its graphitic structure which acts as a template structure for the PAN chains [6]. The high thermal conductivity of CNT also plays an important role during stabilization by extracting exothermic heat at a faster rate and preventing thermal degradation of PAN chains. However, the only limitation associated with CNTs is their dispersion due to high Van Der Waal forces of attraction which results in presence of agglomerates. These agglomerates in PAN fibres result in defect and forms the stress concentration areas resulting in fibre breakage during spinning operation. However, the dispersion of CNTs can be improved by various methods such as acid treatment, use of surfactants, and hybrid formation .

This research work reports the synergistic effect of a hybrid nano-filler synthesized from SWCNT/Graphene oxide on the thermal stabilization of Polyacrylonitrile along with its improved dispersion in the Polyacrylonitrile matrix. Various characterization techniques such as optical microscopy, scanning electron microscopy, differential scanning calorimetry, and thermogravimetric analysis have been used for the Polymer property assessment.

Experimental

Materials:

The polyacrylonitrile-methacrylic acid copolymer of 116000g/mol molecular weight was procured from Technorbital Advance Materials Pvt Ltd, Graphene Oxide was procured from TATA steel, Single wall carbon nanotubes were procured from Adnano Technologies Pvt Ltd, and Dimethyl acetamide was procured from Venus Trading Corporation.

Procedure:

1. Hybrid nano-filler was synthesized by simultaneous ultrasonication and high shear mixing techniques. Where both Graphene oxide and SWCNT were processed simultaneously in DMAc.
2. 4 different samples were made to assess the property of filler consisting of pristine polyacrylonitrile (PAN), PAN+1wt% GO (PG), PAN+1wt% SWCNT (PC) and PAN+1wt% hybrid (PCG).
3. Films were cast from all the samples via the solution casting method and samples were dried in a vacuum oven at 70oC.

Characterizations:

- Optical Microscopy: Optical microscopy experiments were conducted with an Almicro optical microscope (model P12).

- Scanning electron microscopy (SEM): SEM studies of the nano-filler were done with JOEL JSM IT 200 SEM.
- Differential scanning calorimetry (DSC): DSC thermograms of the samples were taken on Perkin Elmer DSC 8000 @ 15°C/min.
- Thermogravimetric analysis (TGA): Thermal degradation studies of samples were done with the TA instruments SDT Q600 @ 25°C/min.

Results and discussion

Optical microscopy:

Fig 1, shows the optical micrograph of the macro level dispersion of the SWCNT and the SWCNT/GO hybrid nano-filler in DMAc. It can be seen that due to the higher re-agglomeration affinity of the SWCNTs the hard agglomerates are much tougher to disperse than the hybrid where the presence of GO is attracting the DMAc solvent molecules inside the hybrid nano-filler agglomerates and making it comparatively easier for dispersion in PAN matrix.

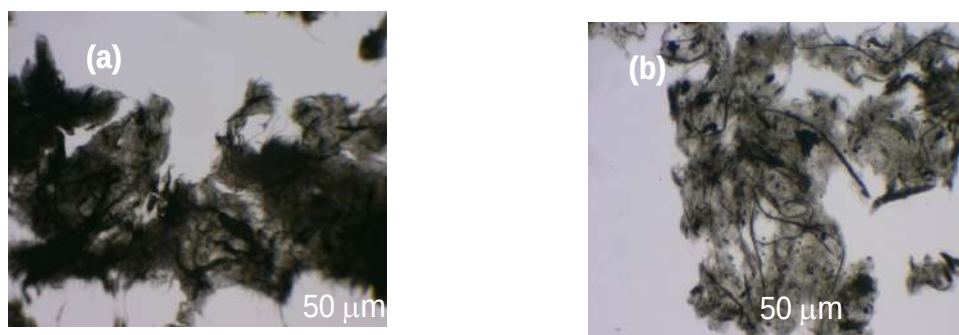


Fig 2: SWCNT/GO hybrid
(a) dried hybrid nanofiller (2mm scale); (b) hybrid dispersion in PAN (5mm scale)

Zhao et al also reported the better and agglomerate free dispersion of the GO in the PAN/DMF dope due to its polar nature and strong hydrogen bonding. In the case of only SWCNT, the PAN can disperse them only by covering its surface only via covalent functionalization but with the limitation that PAN can only cover/wrap the SWCNT surface which was opened during ultrasonication in DMAc. However, the improved dispersion obtained in the SWCNT/GO hybrid nano-filler can be associated with the presence of GO flakes at the junction points of the SWCNT network which opened up more SWCNT surfaces to the PAN polymer chains to cover/wrap and stabilize them.

Scanning electron microscopy:

Fig 2 represents the SEM images of the SWCNT/GO hybrid after the ultrasonication process. The GO flakes are found to be fully covered with the SWCNT which formed a network with the corresponding hybrid SWCNT/GO flakes. The synergistic effect of the combination of SWCNT and GO can be observed from the hybrid since the agglomerate size is drastically reduced due to the soluble nature of the GO in DMAc which also enhanced the solubility of the SWCNT in the DMAc. The nature of the formed hybrid of SWCNT/GO can be predictable from its dual nature where the solubility of the GO helped in dispersion and stabilized it in the DMAc solution. Fig 2(b) part, shows the dispersion of the SWCNT/GO nano-filler in the PAN matrix. It can be observed from the SEM micrograph that the overlapped SWCNT over GO is now exfoliated in the PAN matrix due to the higher soluble nature of SWCNT in the PAN dope solution than DMAc only. After shear mixing in the PAN matrix, the SWCNTs completely dispersed in the PAN matrix keeping the GO flakes at the junction points which keeps their dispersed network stable and prevents the re-agglomeration.

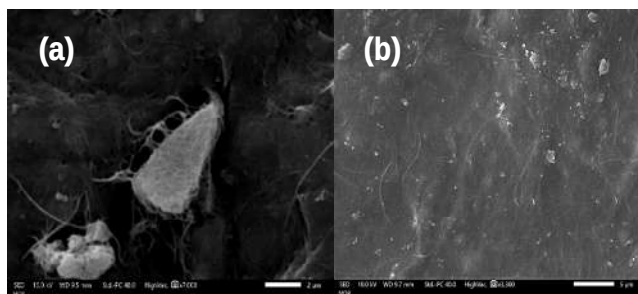


Fig 2: SWCNT/GO hybrid (a) dried hybrid nanofiller (2mm scale); (b) hybrid dispersion in PAN (5mm scale).

Differential scanning calorimetry:

Fig 3 illustrates the DSC scans of PAN, PC, PG, and PCG composites under the nitrogen atmosphere, representing the PAN's heat-induced stabilization without oxidation reaction (i.e., cyclization and dehydrogenation).

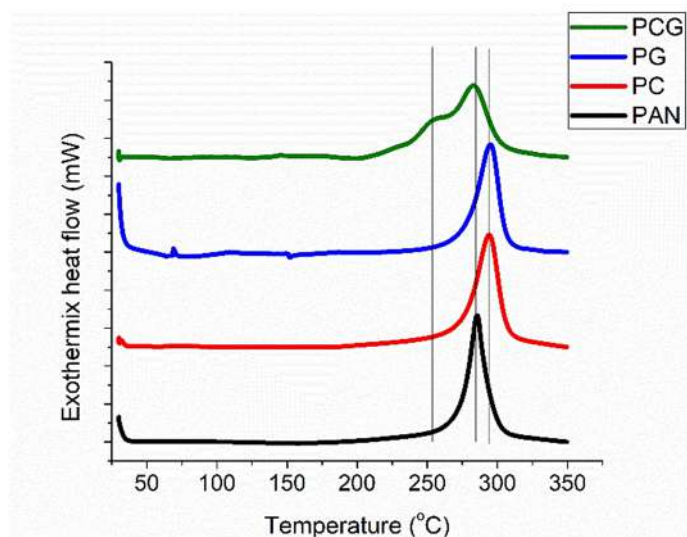


Fig 3: Thermal stabilization thermograms of PAN and PAN composites.

Sample PAN, PC and PG show a similar phenomenon where a single peak appeared in the DSC scan, representing the absence of oxidation reaction. We observed an increase in the stabilization temperature and stabilization enthalpy of the PC and PG sample films prepared from the addition of SWCNT and GO in the PAN matrix which represents the improved thermal stability of the composite samples after the incorporation of SWCNT and GO. The increase in peak stabilization temperature was also reported by Zhang et al., for PAN/MWCNT composite for amino-functionalized MWCNT/PAN composite. However, several groups reported a decrease in peak stabilization temperature by the incorporation of non-functionalized GO in PAN but at a higher concentration of GO >10wt% where GO forms a complete network inside the PAN. Here we dispersed on 1wt% GO in the PAN matrix which might not be enough to form a complete network hence preventing thermal decomposition and release of oxygen from GO. Also, the GO present in the PAN matrix might have constrained the movement of the PAN polymer chains by consuming the protons produced by the amide groups during the nitrile cyclization reaction. However, the sample prepared with the hybrid filler i.e., PCG shows 2 peaks at temperatures X1 and X2. The first peak is attributed to being the decomposition peak of forming CO, CO₂ and steam at ~200°C due to the decomposition of various groups attached to the GO surface. However, the decomposition of GO at the same concentration did not occur in the case of PG. This early decomposition of GO can be explained by the presence of the SWCNT network. The high thermal conductivity of SWCNT caused direct heating and

decomposition of the GO flakes while in PG the poor thermal conductivity of the PAN prevented the early thermal decomposition of GO in lower concentrations (<10 wt%). The second peak is attributed to the oxidation-assisted stabilization of PAN which appeared at a lower temperature than all samples. This can be explained by the presence of functional groups in GO wrapped up by SWCNT which caused the ionic reaction initiated by the functional groups.

Though higher exothermic stabilization enthalpy represents more nitrile cyclization which will act as a template structure for further process of carbonization and stabilization, the distribution of exothermic stabilization enthalpy is of great importance. Since the narrow distribution of exothermic enthalpy causes thermal damage to the polymer chains due to a high amount of heat release within a very short period while broad distribution does not. To compare the heat distribution in all samples we calculated the exothermic heat rate parameter ($\Delta H/\Delta T$). The lowest value was observed for the PCG composite followed by the PG, PC and PAN. The significant reduction in the exothermic heat rate in PCG also confirms the uniformly distributed network of GO/SWCNT hybrid nano-filler which was continuously extracting the amount of generated heat over the period. As a result, PCG reinforced PAN composite has a uniform stabilized structure with less thermal degradation which is essential for obtaining a perfect graphitic structure for high-performance carbon fibre.

Conclusion

The SWCNT/GO based hybrid nano-filler was successfully prepared by the combined effect of ultrasonication and high shear mixing. SEM analysis showed that, due to the similar graphitic structure of the SWCNT and Graphene oxide, the dispersion of hybrid filler uniform network of the SWCNTs with GO particles present at the junction points. The dispersion of hybrid was also compared with the dispersion of SWCNT on the macro scale. Due to the presence of GO in the hybrid filler, not only does it show better dispersion than SWCNT but also improved the thermal gradient of the stabilization process of the PAN. This synergistic effect not only improved the stabilization efficiency due to better interaction between polymer/filler interphase.

Acknowledgment

The authors would like to express their sincere thanks to the “National Technical Textile Mission” for providing financial funding for this research work.

2.2 Effective Electron Beam treatment along with biological treatment for Textile wastewater

Abstract:

This study examined the practicality of using electron beam treatment to treat actual textile wastewater. To do this, an effluent sample was taken from the industry's current ETP plant and a separate dyeing and printing process from the process house. The electron beam radiation was carried out at the Electron Beam Center (EBC), Kharghar, Navi Mumbai, with the beam energy and beam current of 10 MeV and 0.5 mA respectively. The effect of e-beam treatment on real textile wastewater samples was then assessed in terms of change in color and COD concerning e-beam dose. Irradiation with a 10kGy dose alone was found to be effective for the removal of color from dyeing effluent and incoming effluent to ETP, however, no significant reduction was observed in COD values except from collection and equalization effluent. Considering this, further investigation was carried out on effluent from the equalization tank to study the effect of pH variation on the impact of e-beam treatment. The results of this indicate that the impact of e-beam treatment is more favorable in alkaline conditions to reduce COD.

Material and Methods.:

Industrialeffluent collected from M/S Technocraft, Murbad to see the e-beam treatment performance towards industrial effluent. The initial characterization of these effluent samples is reported in Table- 1. The electron beam radiation was carried out at the Electron Beam Center (EBC), Kharghar, Navi Mumbai, with the beam energy and beam current of 10 MeV and 0.5 mA respectively. The impact of e-beam dose on industrial effluent was analyzed in terms of pH and COD.

Table-1 Initial Characterization of Industrial Effluent collected from different section of ETP

<u>Sr no.</u>	<u>sample</u>	<u>pH</u>	<u>COD(ppm)</u>
1	Equalization	6.64	1050
2	Collection	9.28	1880
3	Printing section	8.82	3360
4	Printing treated	12	336
5	MBR permeate	7.4	192
6	Fabric dyeing	6.61	496
7	RO Reject	7.28	2440
8	RO Treated	7.35	10

Results and Discussion:

Initial characterization of each section of ETP and Process house (Dyeing and Printing) effluent is already presented in Table 1. Over these samples, a 10kGy e-beam dose is applied and analyzed for COD and color change. With the application of the e-beam treatment, the color change was observed for some of the samples viz. treated dyeing and collection sample. However, except for equalization and collection tank effluent, no significant reduction was observed for COD values. Considering this, further investigation was carried out on effluent from the equalization tank to study the effect of pH variation towards the impact of e-beam treatment on industrial effluent. To carry out this study, pH of the collected sample was adjusted at variable ranges as 3, 5, 7, 9 and 11 using 1N sodium hydroxide and 1N sulphuric acid. Over these samples, the e-beam treatment was carried out at variable doses such as 2, 5, 10, 50, and 100kGy. In the case of pH 11, with the e-beam doses of 2, 5, 10, 50 and 100kGy, the COD reduction was achieved as 3, 6, 10, 22 and 29 % respectively. This result infers that alkaline condition favors the impact of E-beam on COD reduction.

Conclusion: Electron beam radiation was applied on real textile wastewater, and the results showed that Ebeam treatment significantly reduced the color and COD of the effluent with a low dose of E-beam up to 10kGy; however, maintaining the alkaline condition of the effluent is recommended for significant COD reduction.

(* Related work (in detailed) published as 'Application of electron beam treatment for degradation of pollutants in real textile wastewater' in radiation Physics and Chemistry Journal Volume 230, May 2025, 112567)

2.3 Development of Nanoparticles coated fabrics for antimicrobial focusing on antiviral applications

Abstract

This work describes the synthesis of silver nanoparticles by green method. The silver nitrate is used as a precursor salt, while Pinwheel flower extract is used as an eco-friendly reagent to synthesize silver nanoparticles. The formation of silver nanoparticles was characterized by UV-Visible spectroscopy, SEM, FTIR. UV-visible spectroscopy showed surface Plasmon resonance at 410nm. The morphology and size of the Ag-NP s were determined by SEM, which showed the average particle size of Ag in the range of 60 to 90nm. These synthesized AgNPs were then applied over cotton fabric using Pad-Dry-Cure method. Developed AgNP-finished cotton fabrics were then assessed in terms of antimicrobial activity (antibacterial and antiviral) and wash durability.

Biosynthesis and Characterization of silver nanoparticles (AgNPs) :PW flower extract was added to 50ml of precursor solution under continuous stirring at optimized temperature and duration. The silver nitrate solution's color then changed to dark brown suspension, indicating that the ionic silver was reduced to AgNPs (Fig.1).



Fig.1 Biosynthesized Silver Nanoparticles using Pinwheel flower extract

Further, the biosynthesized nanoparticles are characterized by UV-visible spectrum, FTIR and SEM investigation. After confirming the successful formation of AgNPs, the related solution was directly applied over cotton fabric by the pad-dry-cure technique. These AgNP-finished samples were further analyzed for SEM, antimicrobial activity, and wash durability.

The antimicrobial activity of AgNP finished fabrics showed excellent antibacterial activity i.e 99.80% and 99.71% towards Gram positive (*Klebsiella Pneumoniae*) and Gram-negative bacteria (*Staphylococcus aureus*) respectively and significant wash durability up to .10 numbers of washes.

CONCLUSION:

A simple method of bioreduction for AgNP synthesis has been reported. The appearance of these synthesized nanoparticles was confirmed by UV-visible spectroscopy and SEM characterization. Biosynthesized silver nanoparticles were then deposited over the cotton fabric using a simple pad-dry-cure method. It was assessed in terms of SEM-EDX, antimicrobial activity, and wash durability. The developed AgNP-deposited cotton fabric showed excellent antibacterial activity and durability towards washing.

2.4 Development and validation of test method for determination of chlorinated organic carriers in textile and textile product**Abstract:**

A test method for analyzing chlorobenzene and chlorotoluenes (commonly known as COC,s) in textiles and textile products has been developed and the same has been validated as per international validation protocol. 28 restricted COC,s in textiles as per Oekotex 100 standard were standardized by using GC MS. As a part of method validation, Detector linearity, Accuracy, Repeatability, Spike recovery, LOD, LOQ, etc. is established. A sample preparation method using a solvent extraction method is also developed based on extraction efficiency of a few solvents.

Introduction:

Chlorinated Benzenes and Toluenes generally called chlorinated carriers, are a group of organic compounds having one or more chlorine atoms attached to either a benzene or toluene ring. Chlorobenzenes and Chlorotoluenes have diversified application in several industries including textile and footwear industries. Chlorinated carriers are typically used as intermediates or precursors in the manufacture of textile dyes and auxiliaries. It is also used in polyester dyeing as a dispersing and levelling agent. After dyeing, polyester materials are washed with water to remove unfixed dyes and carriers. However, trace amounts of carriers may remain as impurities in the final dyed materials. COC,s and their isomers have potential health hazards. These compounds are harmful and may induce liver malfunction, irritation to mucous membrane and skin. Due to the hazardous nature of these chemicals many leading apparel and footwear brands have banned the use of chlorobenzenes and chlorotoluenes in the production and manufacturing of their products. In most of the European regulations, the limit value for the sum of the chlorobenzene and chlorotoluene is 1.0 mg/kg. At present there are no Indian/ISO standards to test COC,s for textile materials. Hence, in this R&D project, a validated test method has been developed, validated and formulated the same as a national standard.

Result and Discussions

A list of 28 restricted COC,s in textiles as per the Table-1 has been standardized by using GC MS.

Table-1 List of COC,s and their retention time in GC MS

Sr. No	Name of component	CAS number	Retention time (min)
1.	Chlorobenzene	108-90-7	3.1
	Dichlorobenzene isomers		
2.	1,2 Dichlorobenzene	95-50-1	10.7
3.	1,3 Dichlorobenzene	541-73-1	9.2
4.	1,4 Dichlorobenzene	106-46-7	9.57
	Trichlorobenzene isomers		
5.	1,2,3 Tri chlorobenzene	87-61-6	23.6
6.	1,2,4 Tri chlorobenzene	120-82-1	21.46
	Tetrachlorobenzene isomers		
7.	1,2,3,4 Tetra chlorobenzene	634-66-2	34.91
8.	1,2,3,5 Tetra chlorobenzene	634-90-2	31.69
9.	1,2,4,5 Tetra chlorobenzene	95-94-3	31.96
10.	Pentachlorobenzene	608-93-5	43.5
11.	Hexachlorobenzene	118-74-1	53.63
	Chlorotoluene isomers		
12.	2- Chlorotoluene	95-49-8	6.39
13.	3- Chlorotoluene	108-41-8	6.27

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Sr. No	Name of component	CAS number	Retention time (min)
14.	4- Chlorotoluene	106-43-4	14.37
	Dichlorotoluene isomers		
15.	2,3- Dichlorotoluene	32768-54-0	19.2
16.	2,4- Dichlorotoluene	95-73-8	17.27
17.	2,5- Dichlorotoluene	19398-61-9	17.54
18.	2,6- Dichlorotoluene	118-69-4	17.37
19.	3,4- Dichlorotoluene	95-75-0	19.33
20.	3,5- Dichlorotoluene	25186-47-4	17.02
	Trichlorotoluene isomers		
21.	2,3,4- Trichlorotoluene	7359-72-0	32.1
Sr. No	Name of component	CAS number	Retention time min
22.	2,3,6- Trichlorotoluene	2077-46-5	30.4
23.	2,4,5- Trichlorotoluene	6639-30-1	29.08
24.	Benzyl chloride	100-44-7	9.71
25.	Benzotrichloride	98-07-7	24.62
26.	4- Chlorobenzotrichloride	5216-25-1	36.17
	Tetrachlorotoluene		
27.	α α 2,3 tetrachlorotoluene	57058-14-7	46.07
	Pentachlorotoluene		
28.	2,3,4,5,6-Pentachlorotoluene	877-11-2	55.49

Method of analysis

A known weight of textile material (1-2g) depending the concentration of coc,s is weighed in a 25 ml stopper glass vial, and overlaid 10 ml dichloromethane (as per the extraction efficiency of solvents) .The test specimen is extracted for 20 min in an ultrasonic bath at ambient temperature. About 2.0 ml of the extract is taken with a disposable syringe and cleaned of interfering particles and fibres with the help of a membrane filter. After filtration, the extract is transferred into a GC vial. 2.0 μ l of the extract is injected into GC MS using an auto injector. The substances of the extract are separated on a capillary column and analyzed using a mass selective detector in selected ion mode (SIM) as per the conditions mentioned below. Detected chlorinated carriers are quantified against the corresponding standards under the same test conditions. A five point calibration graph has been plotted to quantify the coc,s.

- Instrument make and model: Shimadzu QP 2020NX
- Column: DB5 MS (30m X 0.25mm X 0.25 μ m)
- Carrier gas Helium
- Flow: 2.0 ml/min
- Injector temperature: 250°C
- Ion source temperature: 260°C
- Interface temperature: 270°C
- Oven temperature: 60°C (10 min), @ 2°C/min 150, @20°C/min 200°C
- Mass range (M/Z) : 40-400 amu
- Injection volume: 2 μ l
- Split ratio 1:10
- Ionization voltage: 70 ev
- Library: NIST23

The extraction efficiency is calculated from the spiked concentration and recovered concentration. Out of six solvents, Dichloromethane is found to be the suitable solvent with an extraction efficiency of 95-99%. Extraction efficiency of each solvent is given in Table-2

Table-2 Extraction efficiency of solvents

COC	Acetone	N Hexane	Cyclohexane	Toluene	Ethyl acetate	Dichloro methane
1,2 Dichlorobenzene	5.5 %	18.5 %	18.8%	19.5 %	25.5 %	98.5%
1,2,3 Trichlorobenzene	6.2 %	12.1 %	10.5%	15.5%	20.1%	95.2%
1,2,3,4 Tetrachlorobenzene	5.8 %	10.7%	13.4%	18.3%	15.9%	99.0%
2 Chlorotoluene	4.5 %	11.9%	11.9%	14.6%	16.4%	98.9%
2,3 Dichlorotoluene	6.9 %	15.0%	10.8%	11.9%	19.5%	95.0%

As a part of Method validation, GC MS detector linearity of each coc,s is established in scan mode as well as sim mode. It is found that in scan mode, the coefficient of determination (R^2) in the range of 2.5 µg/ml to 50 µg/ml is more than 0.99. Similarly in sim mode the coefficient of determination in the range of 0.1µg/ml to 1.0 µg/ml is also above 0.99 which is within the acceptable norms. Accuracy of the test method is validated by conducting a spike recovery study. The spike recovery of all the coc,s is found to be more than 90%. Limit of detection and limit of quantification is calculated from the calibration graph. It is found that coc in sample can be determined down to 1.0µg/g which is a limit value as per Oeko Tex 100 standard. Relative standard deviation (%) of repeatability and reproducibility of coc,s in sample is found to be less than 5.0% which is within the acceptable norms.

Conclusions

From the extraction efficiency of various solvents, Dichloromethane is found to be the most ideal solvent for coc analysis. A test method for the analysis of coc,s in textile material has been developed. The in-house developed test method has been validated for detector linearity, accuracy, precision, repeatability, and reproducibility, limit of detection and limit of quantification. All validation parameters were found to be within the acceptable range. With this developed test method, chlorinated benzene/toluene down to 1.0 mg/kg can be quantified. The developed test method will be submitted to BIS for formulating a national standard.

2.5 Preparation of Lyocell CNT Composite High-Strength Carbon Fiber

Introduction

Carbon fibers are of much interest due to their higher strength and light weight. These are extensively used as reinforced materials for aerospace applications, sports equipments, wind-turbine blades etc. The precursors for carbon fibres (based on their source of availability) are polyacrylonitrile (PAN), petroleum pitch and cellulose. Out of all these, PAN is the extensively used precursor for the synthesis of carbon fiber. But because of its high cost, finding of an alternative precursor to replace PAN has been intensified and the target is not only to reduce the cost of obtained carbon fiber, but also to use a biobased feedstock. Cellulose can be a suitable option in view of its high carbon content and oldest known precursor of carbon fibers. However, the tensile strength and yield of fibers developed from this precursor tend to be low. Despite of these disadvantages, cellulose based carbon fibers can be chosen over PAN-based fibers because of its abundance in availability, biodegradability and the processing is free of any environmental pollutants. Lyocell is an eco-friendly fiber based on cellulose obtained by dry-jet-wet-spinning method from direct dissolution of cellulose in N-methylmorpholine N-oxide (NMMO). Lyocell fibers exhibit higher mechanical and lower shrinkage properties than any other rayon-based fibers. Also, addition of flame resistant salts before stabilization of lyocell fibers helps to improve the yield as well as the strength of the resulting fiber.

Carbon nanotube (CNT) has received much attention due to its high strength, high modulus and higher electrical conductivity. It has been reported in literatures that incorporation of CNT to carbon fiber exhibits much reduction in shrinkage during carbonization process. So to enhance the tensile strength of the carbon fiber, CNT can be a good option. Treatment of lyocell fiber with flame retardant molecules helps to improve the carbon yield by preventing the process of combustion during carbonization step.

So in this work, we will be focusing on producing carbon fibers from lyocell-SWCNT composite along with the incorporation of the suitable flame retardant molecule to improve both mechanical strength and carbon yields.

Materials and Methods

Materials

Cellulose Pulp, N-methylmorpholine-N-oxide (NMMO), n-propyl gallate, SWCNT.

Methods

Optimization of the dispersion of CNT

Dispersion of CNT in 60% NMMO solution has been checked by using probe sonication. Optimization of % of CNT and dispersion time was varied and observed that 25-30 min. of dispersion is sufficient to separate the aggregated CNT bundles.

Dissolution of cellulose in NMMO-CNT slurry

76% NMMO solution is the requirement for the dissolution of cellulose. So, 60% NMMO solution was concentrated to 76% by removing extra water from it. Then dispersion of CNT has been carried out followed by the dissolution of cellulose in it. Dissolution of cellulose (10-12%) in CNT-NMMO slurry has been done in sigma mixer at 120-125 °C followed by removal of extra water by using vacuum. Finally the dope was prepared and taken out and kept in vacuum container.

Spinning of fiber

CNT dispersed dope was allowed for filtration using 200 µm and 50 µm mesh in order to avoid any kind of blockage or jam because of any larger undissolved or agglomerated particles during spinning. Then the filtered dope was melted at 120 °C for 2-3 h and spun through the spinneret using 100 µm mesh.

Characterizations

Prepared dope and fiber was characterised using different techniques.

Results and Discussion

Clear dispersion of CNT in NMMO has been observed through optical microscopy as depicted in Fig. 1.

After that cellulose was allowed to dissolve in the above slurry in a sigma mixer to get a dope. Finally a black color dope was obtained after removal of requisite amount of water. Then the dope was filtered to get rid of undissolved cellulose as well as agglomerated CNTs.

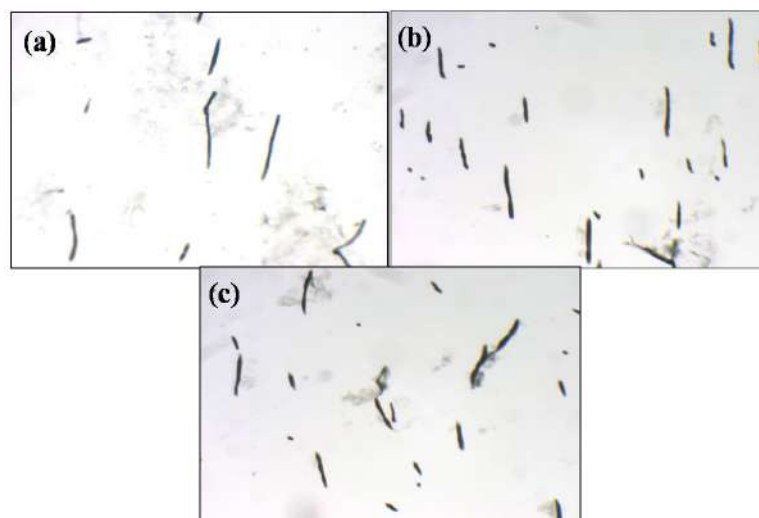


Fig. 1: Optical microscopic image of 25 min. sonicated samples; (a) 0.01 wt%, (b) 0.015 wt%, (c) 0.025 wt%

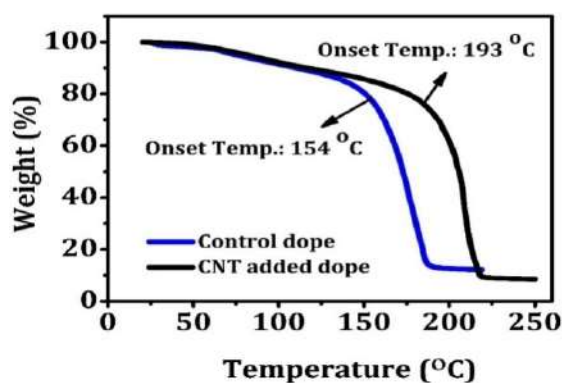


Fig. 2: Thermal analysis of the dope

Fig. 2 represents the thermal stability of the CNT incorporated dope. It can be seen that the onset temperature of the CNT added dope is higher than that of the control dope. Thereafter spinning of the dope has been carried out to get fibers.

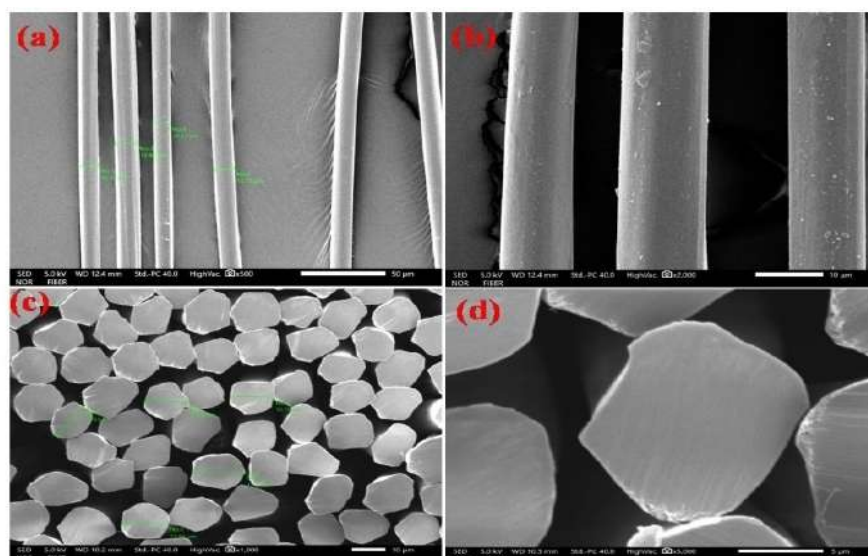


Fig. 3: SEM image fiber samples; (a) and (b) surface morphology; (c) and (d) cross-section morphology

Fig. 3 illustrates the SEM image of the obtained fibers, where both surface and cross-section can be seen clearly. The lyocell-CNT fiber shows a quite smooth surface, round cross-sections along with dense fibrillar structure.

Trials have been taken with variation of % of CNT w.r.t. cellulose and up to 0.45% of CNT, fiber drawing was smooth without any blockage. After that, continuous breaking of fiber was observed during spinning irrespective of the size of CNT.

Then flame retardant molecule is treated with the fiber to get rid of char formation during stabilization and carbonization of the fiber. There is no shrinkage of the fiber observed after stabilization. Also, the tenacity of the fiber has not reduced after stabilization. Carbonization of the fiber is in progress.

Conclusion

Clear dispersion of CNT in NMMO has been observed and the fibers obtained from lyocell-CNT composite are having similar morphology and improved tenacity. Further modification of the fibers with variation of CNT content has also been carried out and treatment of FR molecule to the fiber before stabilization has been done. Carbonization of the fiber is under process.

2.6 Sustainable Aroma Finish for Textiles and its Commercialization using Maharashtra Flora

This project was initiated in May 2023. During the year 2024 few R&D trials were conducted on textiles to fix the fragrance molecules onto textile materials. Few application techniques like nano encapsulations were found to be effective and found to have reasonable wash durability.

Abstract:

Functional finishing of textiles has been in great demand since the last two decades in domestic and industrial applications. Mosquito repellent textiles are one of the most demanded functional finished textiles in the current market. The investigation of this research is to study the combined effect of fragrance and mosquito repellent property on cotton fabric by using Lavender and Citronella essential oil by means of nano encapsulation. Nano encapsulated essential oil prepared via sol gel process and is applied on cotton fabric through nip-pad-dry method. The treated fabric is found to have good mosquito repellent property with reasonable wash durability up to five domestic washes. The fragrance release rate of treated fabric and washed fabric has been evaluated by headspace-gas chromatography/mass spectrometry (HS-GC/MS) by measuring the concentration of the major components in essential oil treated fabrics. The results reveal that in each wash cycle, the essential oil is released from the treated fabric as the concentration of chemical compounds decreases gradually. A panel assessment and a field trial of mosquito repellent property have been done to validate the HS –GC/ MS study.

Introduction:

Aroma finished textiles such as bed covers, table clothes, curtains etc. have a great demand in the current market and they have gained much more importance in day to day life. Mosquito repellent textiles are one of the most demanded functional finished textiles in the current market.

Essential oils have been studied for a wide range of applications including therapeutic and insect repellent purposes. Application of essential oil on textiles and to make it a durable finish has few challenges due to its low stability and high volatility. Basically in aroma textiles, the compounds need to be volatile and high in concentration so that it can be transported to the olfactory system in the

upper part of the nose which in turn transmits the stimuli to the olfactory centre in the brain where it is perceived as a pleasant odor. Nano encapsulation can effectively control the release rate of the fragrance compounds from essential oils as required which ensure the storage life of volatile substances.

The investigation of this research is to study the combined effect of fragrance and mosquito repellent property on cotton fabric by using Lavender and Citronella essential oil by means of microencapsulation. Citronella is basically a mosquito repellent and Lavender is used in aromatherapy for the treatment of insomnia.

Nano encapsulated essential oil prepared via sol gel process and is applied on cotton fabric through nip-pad-dry method. The treated fabric is found to have good mosquito repellent property with reasonable wash durability up to five domestic washes. The fragrance release rate of treated fabric and washed fabric has been evaluated by Headspace Gas Chromatographic Mass Spectrometer by measuring the concentration of the major components in essential oil. The results reveal that in each wash cycle, the essential oil is released from the treated fabric as the concentration of chemical compounds decreases gradually. A field trial has been done to validate the HS GCMS results by assessing the mosquito repellent properties. The mosquito repellent properties are established based on combined field trials and feedback from user panel members.

Results and Discussion:

Preparation of sol-gel solution

A solution comprising ethanol (200 ml), water (8 ml), and ammonia (10 ml) was added to a 500 ml reactor flask equipped with a reflux condenser, a magnetic stirrer, and a dropping funnel mounted on a thermostat-controlled heater. The temperature was maintained at 85 °C, and the stirring speed was set to 850 rpm. A mixture of 21 ml tetraethylorthosilicate (TEOS) and 13 ml ethanol was added drop wise into the reactor while maintaining the same temperature and stirring speed. The reaction continued at 85 °C for 2 hours. Subsequently, the temperature was increased to 100 °C, and a second mixture comprising 9 ml methyltriethoxysilane (MTES) and 25 ml ethanol was introduced into the flask. The reaction was allowed to continue for 24 hours under the same stirring speed (850 rpm) and temperature (100 °C). At the end of the process, SiO₂ nano particles (nano-SiO₂ sol) were obtained. The solution, sol or gel, solidifies the compounds of metal-organic (precursor) to form a sol or gel state, followed by development of an oxide by heat treatment. The poly condensation reaction transforms Si-OR to Si OH – comprising species into siloxane compounds which is the basic chemical principle of sol gel treatment of silica- based material.

Encapsulation of Essential Oils in Mesoporous Silica

10 % Essential oils (citronella and lavender) were encapsulated into the above prepared mesoporous silica, along with 1 ml surfactant (Tween 80), 20 ml citric acid (1% solution), and 10 ml hexadecyltrimethoxysilane (HDTMS). The mixture was stirred at 850 rpm for 3 hours at room temperature. The encapsulated oil-loaded mesoporous silica was then collected for further characterization and application

Application of nano capsules on to Cotton Fabric

The applications on cotton fabric take place in two stages. In the first stage, synthesized nano-SiO₂ sol applied on to cotton fabric by nip–pad–dry-cure method. The fabric was dried at 80°C for 5 min and cured at 130°C for 5 minutes. In the second stage of application, fabric was treated with encapsulated aroma sol gel by spraying on both sides of fabric by using a spray gun. A final curing step was performed at 110°C for 2 minutes.

The chemical modification of the fabric occurred in two main stages. In the first stage, when a sol-gel is applied on cotton fabric, the nano – SiO₂ particles are deposited on the surface of cotton fabric. The condensation reaction between the -OH group forms the surface of cotton fabric and SiO₂ covalently bonded on to the cotton fabric, silica particles deposited on the surface increase the hydrophobic effect of the textile material by decreasing the surface energy. The -CH₃ bunch makes the SiO₂ particles with the hydrophobicity. The combination of nano- roughness of nano SiO₂ and the inherent micro-roughness of fabrics created a nano-binary surface roughness on cotton fabrics surface, which would greatly enhance the wetting behavior of the surface of fabrics. In the second stage, the sol-gel treated fabric was further treated with HDTMS, which hydrolyzes in aqueous ethanol to form alkyl silanol. These react with the surface hydroxyl groups to form a self-assembled monolayer. This treatment locks in the encapsulated aroma (the “active agent”) within a core-shell structure, where the oil represents the core or payload, and the SiO₂ serves as the protective shell. Upon mechanical triggers like abrasion or friction, the capsule wall ruptures, releasing the aroma into the environment.

Wash durability of citronella oil, lavender oil and mixture of citronella oil and lavender oil treated fabric.

Citronella essential oil, Lavender essential oil and a mixture of citronella oil and lavender oil treated fabric was subjected to machine wash (front loading washing machine) using 1% detergent at 300C for 15 minutes wash-rinse cycle. The qualitative evaluation of fragrance was assessed by a panel of judgment. Treated fabric and washed fabric was given to a 10 member panel for fragrance rating in the order of 0-5 (No fragrance –very strong fragrance). The average ratings of panel members for treated fabric and one washed fabric is 5 and 4.7 respectively. This clearly shows that treated fabric is durable to one domestic wash. The washing cycle was repeated further four times and asked the same panel members for their rating. Most of the panel members could detect the fragrance in fabric up to 5th wash cycle with an average rating of 1.0. However, after 5th wash cycle most of the panel members could not detect the presence of fragrance in washed fabric. This indicates that citronella oil treated fabric is durable up to 5 washes.

Field trials

25 treated pillow covers along with pillows were supplied to Janiv Ashram, an old age home situated in Kharad village, Thane district. After using the pillows for one month a feedback was sought from the inmates of the Ashram. Each inmate was asked to fill up the feedback questionnaire about the mosquito repellent property, comfort level, sleep quality, wash durability etc. Majority of the inmates opined that the pillow has a pleasant smell and lasts for a couple of washes. All the inmates agree that while using these pillows no mosquitoes enter the bed room. Few inmates reported that by using these pillows their sleep quality improved.

Conclusions

Fragrance compounds in essential oil are volatile in nature. The most challenging task in preparing a fragrance emitting textile is how to prolong its life time in terms of odor. Nano encapsulation is an effective technique to solve this issue. The storage life or wash durability of fragrance fabric can be enhanced by applying essential oil by means of nano encapsulation. Nano encapsulated citronella oil and lavender oil applied on cotton fabric is found to be durable up to 5 washes. In this study, lavender oil and citronella oil were successfully encapsulated with sol-gel technique. Synthesized nano capsules were in the size range of 80 nm to 286 nm. These nano capsules can be applied on to cotton fabric by a simple spray dry process. HS GC /MS analysis of treated and washed fabrics shows treated fabrics are durable up to five laundry washes. The same has been confirmed by panel members by assessing the fragrance. A feedback obtained from the user panel reveals that citronella and lavender oil treated pillow covers have a good mosquito repellent property with a pleasant

fragrance. The treated pillow covers are durable up to five washes. The same has been validated by HS GC/MS analysis by measuring the fragrance intensity. Hence, home textiles such as curtains, table cloths, sofa covers, sheets etc. which are not required for frequent laundering may be applied with nano encapsulated citronella and lavender oil.

2.7 Development of Flame Retardant Aircraft Interior Fabrics by Plasma-Assisted Chemical Treatment

Abstract

The polyester fabric underwent atmospheric plasma treatment and was infused with commercially available 3-hydroxyphenyl phosphinyl-propanoic acid (3HPP) as a flame retardant using the high-temperature high-pressure (HTHP) dyeing process. Different concentrations of 3HPP in water, reaching up to 4% w/v, were utilized employing the HTHP technique. The plasma treatment improved wettability and wicking, while also promoting greater absorption of 3HPP onto the polyester. The treatment demonstrated a significant improvement in the limiting oxygen index (LOI), increasing from 20.8% for the untreated control fabric to 30% for the cloth treated with plasma and a 4% 3HPP solution. Moreover, the use of 3HPP in absence of plasma treatment did not provide any notable enhancements in flame-retardant (FR) capabilities. The combined therapy of plasma and 3HPP yielded a LOI of 29% with a 2% 3HPP treatment, but at the same concentration without plasma treatment, the LOI value was 26.8%. The increased LOI was mainly due to the presence of phosphorus, confirmed through high-performance liquid chromatography and energy-dispersive X-ray spectroscopy. The analysis of wash durability for plasma-processed and 3HPP-treated samples revealed persistent flame retardancy, exhibiting a LOI of roughly 28% after 20 wash cycles. Vertical flammability and cone calorimetry additionally validate enhanced flame-retardant qualities post-treatment. The mechanical characteristics and surface morphology of the cloth remained unchanged after both plasma and chemical treatments.

Introduction

The development of flame-retardant aircraft interior fabrics is crucial for enhancing fire safety in aviation. Addressing flame retardancy is becoming a critical safety requirement for fabrics used in key and interior applications. In a wide variety of settings, fabrics with flame-retardant characteristics play an essential role in preventing fire hazards. Flame-retardant textiles provide a dual function by protecting persons as well as preserving valuable assets and equipment. In settings where combustible materials or equipment provide a hazard, the use of flame-retardant textiles is crucial in hindering the rapid spread of fire, thus reducing damage to buildings, machinery, and other important assets. In the occurrence of a fire, timing is the critical component. Flame retardant materials are essential for prolonging evacuation periods by inhibiting flame propagation and reducing the emission of harmful gasses. This extended escape time is crucial during crises, perhaps aiding in the preservation of life. Numerous approaches are available for enhancing flame retardancy in polyester fibres, with a common technique being the integration of chemical additives during production. These additives include halogenated chemicals, phosphorus-based compounds, and intumescent agents. Halogenated flame retardants have become disfavored owing to their linked health and environmental risks. On the contrary, phosphorus-based flame retardant (FR) chemicals are favoured due to their non-toxic characteristics.

This work addresses a method for integrating flame-retardant phosphorus-based compounds into polyester fabric. We have utilized plasma treatment for surface activation and a high-temperature, high-pressure dyeing process to facilitate the penetration of molecules into the polyester polymer fibers. This process facilitates the effortless conversion of any polyester fabric into flame-retardant (FR) fabric. This will also decrease the total production cost, as the FR material may be included during the dyeing process of polyester fabric.

Materials and Methods

Materials: 100% Polyester RFD fabric (190 GSM, 1x1 Plain Weave), 3HPP

Plasma Treatment: Fabrics made of polyester were subjected to plasma treatment using a system that operated on the dielectric barrier discharge (DBD) principle and operated at atmospheric pressure. A piece of polyester fabric, measuring 50 cm in width, was treated by passing it through the plasma zone. Total plasma exposure was 30 seconds at 2.5 kW, with the plasma being created from a combination of helium and oxygen gasses.

Treatment with 3 HPP:

Using the high temperature high pressure (HTHP) dyeing technique, samples of plasma pre-activated fabric and virgin polyester were impregnated with 3-HPP. HTHP was performed at 130°C for 45 minutes using different concentration of solutions of 3-HPP in distilled water. At room temperature, we also treated samples of plasma-activated polyester fabric with a 3HPP solution for comparison's sake.

Result and Discussion

Wicking Properties

Polyester is intrinsically hydrophobic. Plasma treatment may significantly improve the hydrophilicity of polyester textiles. It can alter the polyester surface by including functional polar groups. Table 1 presents the wicking characteristics of the polyester materials prior to and following plasma treatment.

Table 1

Type of Fabric	Direction	Distance Travelled by Water after 30 mins	Travel Time of Water up to 20 mm
Virgin Polyester Fabric	Warp	7.6 cm	3.10 min
	Weft	7.1 cm	3.3 min
Plasma (He) Treated Polyester Fabric	Warp	11.1 cm	15 sec
	Weft	11.5 cm	13.3 sec

Flame Retardancy/ Limiting Oxygen Index (LOI)

The LOI is a critical factor in sectors including aircraft, automotive, and construction, where materials with minimal flammability are preferred. It assists in the selection of suitable materials for particular applications and in evaluating their fire safety performance.

The phosphinyl group is the primary functional group in 3HPP that imparts flame retardant characteristics. Consequently, the phosphorus level in the treated samples was analyzed using High Performance Liquid Chromatography (HPLC). The concentration of phosphorus in the 3HPP treated at ppm level is documented in Table 2. The sample codes VTR and PTR denote the virgin and plasma-treated samples, respectively, with the numbers in parentheses indicating the concentration of 3HPP. It is noteworthy that as the concentration of 3HPP grew, the LOI values of the samples rose progressively, and the phosphorus content exhibited a similar pattern.

Table 2

Limiting Oxygen Index (LOI%)		Phosphorous content (ppm)
Virgin Polyester	20.8	2.45
VTR(0.5%)	25	
PTR (0.5%)	26.6	554
VTR(1%)	26 (*22.7)	
PTR (1%)	27.2 (*25)	705
Limiting Oxygen Index (LOI%)		Phosphorous content (ppm)
VTR(2%)	26.8	
PTR (2%)	29	2364
VTR(4%)	28	
PTR (4%)	30	
PTR _{20W} (4%)	28	2584

* LOI of fabrics treated by normal Dipping

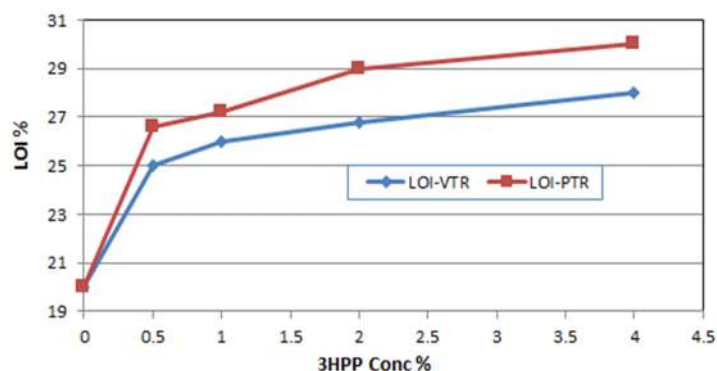


FIG 2 Changes LOI of polyester with variation in concentration of 3 HPP

Vertical Flammability

Table 3 displays the vertical combustion behavior of virgin polyester and several modified polyester textiles. The virgin polyester cloth burned fiercely and maintained the after flame for 17 seconds with intense dripping, resulting in 15 cm of damage. On the contrary, the treated polyester did not burn, but rather formed bead formations with little dripping. The after flame was also dramatically decreased, from no after flame to 2s in the case of unclean and twenty washes.

Table 3

	Washing Cycle	Damage Length (cm)	After Flame (sec)	Behaviour
Virgin Poly		15	17	Dripping observed
PTR (4%)-10 Post Plasma Exposure	0	11.0	No after flame	No dripping observed
PTR (4%)-10 Post Plasma Exposure	10	11.4	1	Slight dripping observed
PTR (4%)-10 Post Plasma Exposure	20	12.3	2	Slight dripping observed

Cone Calorimetric Studies

Table 4 shows the maximum average heat emission (MARHE), peak heat release rate (PHR), total heat released (THR), ignition time (TI), and smoke density (Dms). Virgin polyester outperformed all other FR-treated textiles in terms of heat release rate. Unwashed treated polyester has a MARHE value of 30.49 kW/m², but virgin polyester had a value of 34.4 kW/m². After several washes of treated polyester cloth, the MARHE values increased. After 20 washes, the MARHE climbed to 33.09 kW/m². Peak HRR and THR levels exhibit similar tendencies. The treated polyester has a lower MARHE, Peak HRR, and THR than virgin polyester due to the presence of phosphorous-containing FR chemical in the treated fabric, and the burning process has been delayed, impeded, or retarded by the action of the FR-agent.

Table 4

	Washing Cycle	MARHE (kW/m ²)	Peak HRR (kW/m ²)	THR (MJ/m ²)	TI (Sec)
PTR (4%)-10 Post Plasma Exposure	0	30.49	184	1.7	51.2
PTR (4%)-10 Post Plasma Exposure	10	31.97	193	1.8	40.45
PTR (4%)-10 Post Plasma Exposure	20	33.09	207	1.95	36.0
Virgin Poly	0	34.4	241	2.38	33.45

This is substantiated by the longer time of ignition (TI) found in treated polyester fabric. The virgin polyester torched intensely and ignited for 33.45 seconds with very no ash content, but the treated polyester without washing ignited for 51.2 seconds. The ignition time decreases as the number of washings increases because the phosphorus-based FR agent is leached off.

Washing Fastness

The washing fastness of flame-retardant (FR) materials is critically significant, especially for textiles utilized in clothing and other items that undergo frequent laundering. Washing fastness denotes a fabric's capacity to maintain its flame retardant quality over several laundering cycles. Fabrics with excellent washing fastness retain their Limiting Oxygen Index (LOI) after several washes, but those with inferior washing fastness may suffer a reduction in flame retardant chemicals, resulting in heightened flammability.

Fig 2 depicts the decrease in the LOI corresponding to an increase in the number of washings. The LOI values shown a notable decrease over the first five washes, falling from 30% to 21%, and further declining to 20.5% after 20 washes. Although 3HPP may penetrate deeply into the fiber using the High Temperature High Pressure (HTHP) approach, it is clear that the chemical is susceptible to solubilization when washed repeatedly with soap.

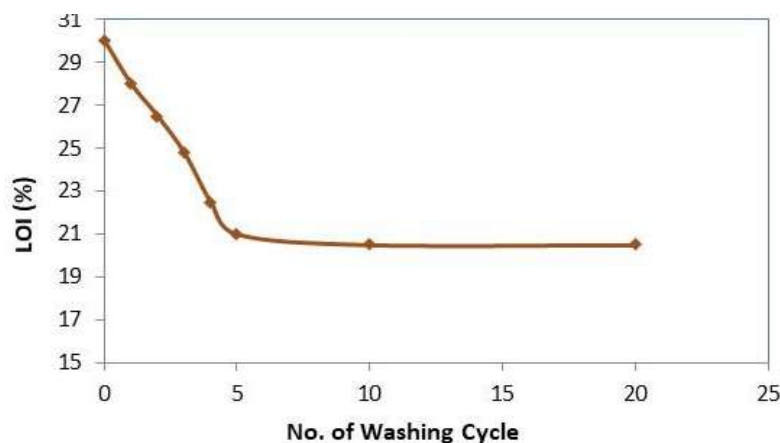


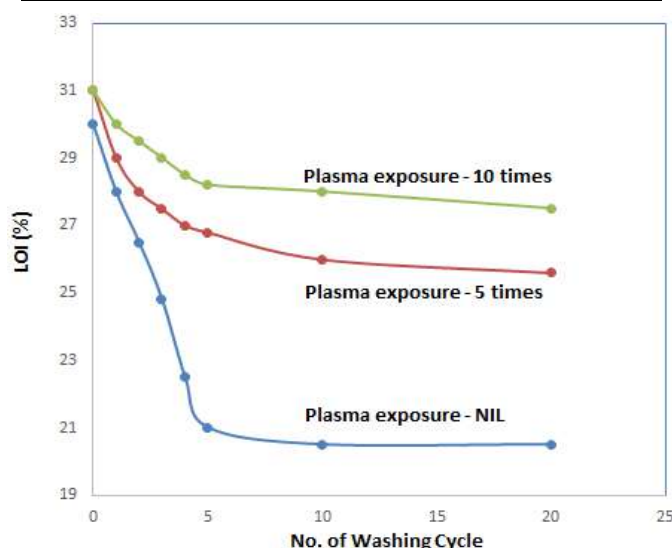
FIG 2 Effect of washing on LOI of FR treated polyester fabrics.

Effect of Post HTHP Plasma treatment on washing fastness

Table 5 and Fig 3 demonstrate how the LOI decreases as the number of washes increases. As previously noted in section 4.3, the LOI decreased dramatically to about 20% after 10 washes. While textiles that received post-HTHP plasma treatment preserved their FR properties significantly better even after 10 washes than those that did not get post-HTHP plasma treatment. The graph clearly shows that the reduction in FR characteristic occurs slowly after several plasma treatments.

Table 5

No. of Washing	Plasma Exposure after HTHP		
	0	5	10
	LOI (%)	LOI (%)	LOI (%)
0	30	31	31
1	28	29	30
2	26.5	28	29.5
3	24.8	27.5	29
4	22.5	27	28.5
5	21	26.8	28.2
10	20.5	26	28
20	20.5	25.6	28

**FIG 3 Effect of Plasma exposure on wash fastness of FR treated polyester fabrics.****Scanning Electron Microscopy (SEM)**

It is easy to study surface morphology and element presence using SEM/EDX investigations. In Fig 4, we can see the scanning electron microscopy pictures of virgin polyester fabric (A) alongside washed polyester textiles treated with plasma and chemicals. Fig (A) displays the smooth texture of virgin polyester, whereas fig (B) displays a somewhat rough and grainy texture. This may be because the cloth was etched during the plasma treatment and 3 HPP was deposited into its surface. The general structure of the cloth and its fibers is unaltered. There was nothing detrimental done to the fiber and fabric during the 10 passes of plasma therapy. This is crucial since the fabric will have many uses in the commercial, industrial, and garment industries. Firefighter costumes, parachutes, aircraft interiors, and other industrial uses for flame-retardant textiles require materials with strong mechanical characteristics and structural integrity.

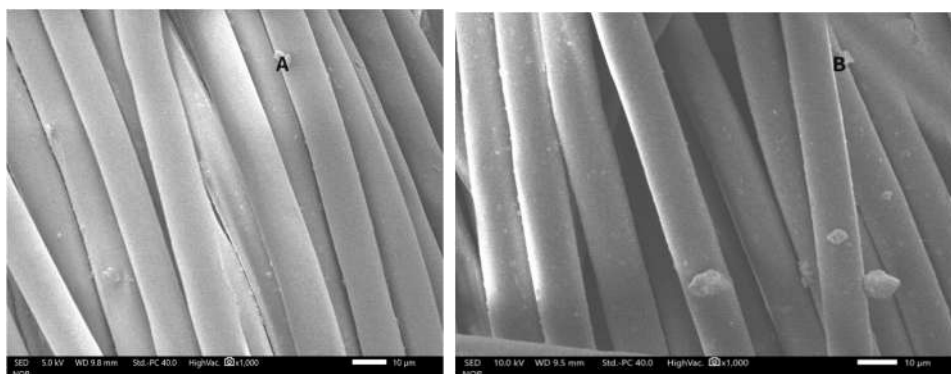


FIG 4 SEM images of A) virgin polyester and B) plasma and chemical treated fabric

Fig 5 illustrates the EDX spectra of chemically and plasma-treated, washed cloth, revealing an approximate phosphorus concentration of 2.8%. This contradicts the HPLC data shown in Table 2, which indicated that the identical fabric contained approximately 0.28% phosphorous. This indicates that the bulk concentration and surface concentration of phosphorus vary. This indicates that the phosphorus on the fabric's surface is firmly attached, but the phosphorus within the fabric is weakly bound and removed upon laundering. This may be attributable to the increased activity of the plasma near the surface. This unequivocally demonstrates that following several plasma treatments, the FR chemical is preserved on the cloth surface. This is due to plasma facilitating the formation of covalent bonds between the fabric and the chemical, which are difficult to disrupt during laundering.

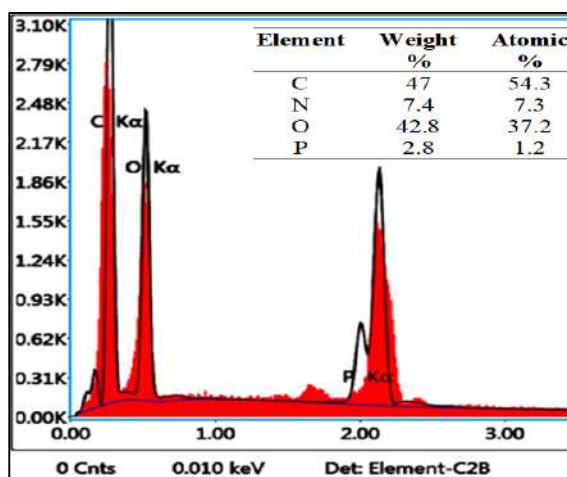


FIG :5 EDX spectrum of plasma and chemical treated washed polyester fabric

Conclusion

This research presents a new method for making flame-resistant clothes by combining plasma treatment with a straightforward chemical treatment. Plasma surface modification allows for successful attachment to polyester fabric using the phosphorus-based chemical 3-Hydroxyphenyl phosphinyl-propanoic acid (3HPP), while the appropriate mechanical qualities are maintained. Importantly, the addition of 4% 3HPP showed the best improvement in LOI values, with a maximum of 30%. In addition, the study found that plasma treatment significantly increased the LOI values of Polyethylene Terephthalate (PET) textiles at a concentration of 3HPP that was comparable to the control group. By promoting a chemical link between the flame-retardant additive and the polyester fabric, the results demonstrate that plasma treatment amplifies washing fastness. Studies using vertical flammability and cone calorimetry showed that adding a FR agent greatly reduces flammability and delays ignition. In the event of a fire, this would widen the escape route. The FR textiles produced using this process are technically and commercially viable options due to their high bending rigidity and enhanced wicking characteristics, and they are classified as flame-retardant (FR) fabrics when their LOI values are more than 28%.

2.8 Development of Alkaline Resistance Polyester for the Geosynthetic Application

Abstract:

Polyester-based Geosynthetics, like geogrids, are essential for soil stabilization but degrade in alkaline environments. This study enhances polyester's alkali resistance by coating and crosslinking PVA with Aldehyde Crosslinkers. Among tested Crosslinkers, Glutaraldehyde achieved the highest crosslinking (94–98%), making it the optimal choice. The coated polyester yarn showed significantly improved stability under alkaline conditions (pH 9–13). This optimized coating method offers a durable solution for Geosynthetics, with potential for large-scale application in construction.

Introduction:

Within the geosynthetic family, geogrid stands out as a key member. Polyester (PET) has gained significant commercial recognition for its role in manufacturing high-strength geogrids, geotextiles, and woven geotextiles. This preference is attributed to its impressive attributes, including exceptional strength, minimal elongation, and outstanding creep resistance, which surpass those of other fibers like polypropylene and polyethylene. Moreover, the widespread availability, high production capacity, and cost-effectiveness of polyester further bolster its application in geotextiles. In the other hand, alkali resistance of the polyester is poor because of hydrolysis due to its chemical structure so the geogrid made out of it is not suitable for the use in alkaline environment. Although, there are few fibers such as glass, UHMWPE are alkaline resistant but due to very low production globally, high cost, unavailability, no production in India and other related limitations, those fibers are not gaining popularity among the geosynthetic manufacturers. To counter this issue; the primary goal of this project is to develop polyester with enhanced resistance to alkaline conditions.

This research aims to develop alkaline-resistant polyester for geosynthetic applications in construction, where exposure to alkaline environments degrades polyester, limiting its lifespan. Polyester-based geosynthetic, such as geogrids, are commonly used for soil stabilization and structural reinforcement, but their susceptibility to alkaline degradation is a significant issue. This project focuses on enhancing polyester's resistance to alkaline conditions, particularly by cross-linking with polyvinyl alcohol (PVA) or modifying the surface chemistry of the material. Methods such as in-situ crosslinking, surface chemistry alteration through plasma or UV energy, and electron beam treatment will be explored to improve polyester's durability in alkaline environments.

Materials and Methods:

Materials

PVA (Molecular weight = Approx. 1,15,000, Hydrolysis degree = 98 - 99%), Sodium Hydroxide pellets 98%, Sulphuric Acid (AR) 98%, Sodium Sulphate Anhydrous 99%, 40% Glyoxal, 37% Formaldehyde, were buy from Loba Chemie Pvt Ltd, 07, Wodehouse Rd, near Bank of India, Cuffe Parade, Mumbai, Maharashtra, India, 400005. Glutaraldehyde 50 % (in water) solution, purchased from Tokyo Chemical Industry Co. Ltd, 6-15-9 Toshima, Kiti-Ku, Tokyo, Japan. Shanghai Lingfeng chemical reagents co. LTD (Shanghai, China),

Methods

PVA, recognized for its chemical resistance, presents a viable solution for creating an alkaline-resistant coating on polyester, particularly in geo-environmental applications. This research focuses on enhancing polyester's alkali resistance through surface modification. Furthermore, the study will investigate how to integrate the developed method with existing manufacturing processes. The most effective technique will be applied during polyester melt spinning and utilized in geogrids, with pilot-scale demonstration followed by potential industrial scale-up.

1. Application of an alkaline-resistant polymer coating to polyester surfaces.
2. Integrate the selected method with the pilot-scale melt spinning process and directly applying it to the polyester geogrid. Evaluate properties and collaborate with the industry to scale up production.
3. Also, exploring additional innovative approaches such as offline modification of polyester surfaces using chemicals, combined with plasma or radiation.

Result and Discussion:

In the initial phase of our work, we investigated the cross-linking of PVA using a broad range of chemicals, including Glutaraldehyde, Formaldehyde, Glyoxal, Cyanuric Chloride, Oxalic Acid, Acetic Acid, Maleic Acid, and others. However, we later observed that acid-based Crosslinkers form ester bonds, which are susceptible to hydrolysis in alkaline environments. As a result, we selected effective aldehyde-based Crosslinkers, which form acetal bonds that provide resistance to alkaline conditions. After reviewing the existing literature, we selected three specific aldehydes such as Glutaraldehyde, Formaldehyde, and Glyoxal for further study. These aldehydes were used for PVA crosslinking under similar conditions to enable a systematic assessment. This evaluation helps us to determine which aldehyde provides the most effective results; this approach successfully resulted in the production of water-insoluble PVA sheets.

Preparation of PVA / glutaraldehyde, Glyoxal, and formaldehyde Crosslinked films:

This process ensures efficient polymer crosslinking in two steps. First, a PVA solution (5% w/v) is prepared by dissolving PVA in water at 85°C with stirring, then cooled to 30°C, mixed with crosslinking agents (as per Table 1), and cast into thin films using the solution-casting method. The films are dried at 70°C and subsequently crosslinked in a bath containing 5% sulfuric acid and 20% sodium sulfate at 50°C for 5 minutes. After washing and drying, the films are ready for use. For direct coating applications, the film formation step can be skipped, and the PVA-coated material can be crosslinked and dried in 10 minutes, significantly reducing the processing time.

Table 1. Composition ratio of crosslinking agents and PVA

Aldehyde to PVA ratio		
Glutaraldehyde / PVA	Formaldehyde/ PVA	Glyoxal/ PVA
1.0	1.0	1.0
0.8	0.8	0.8
0.6	0.6	0.6
0.4	0.4	0.4
0.2	0.2	0.2

Degree of crosslinking:

The degree of crosslinking was determined of prepared PVA sheets by measuring the weight loss of the films before and after soaking in water. Initially, all prepared films were dried to a constant mass and weighed as m_0 . After being immersed in water for 72 hours, the films were considered to have reached solubility equilibrium. The insoluble portion of the films was then dried in an oven at 85°C to a constant mass and weighed as m_d . The degree of crosslinking was calculated using the following formula:

$$DC = m_0/m_d \times 100$$

Fig 1, presents the crosslinking percentage versus the aldehyde/PVA ratio, with values provided in Table 2. Glutaraldehyde achieves a consistent crosslinking degree of 94–98% across ratios of 0.2–1.0. Formaldehyde reaches only 94% at a 1.0 ratio, while Glyoxal achieves 89.42% crosslinking at the lowest ratio, with its crosslinking degree decreasing as the concentration increases. Therefore,

Glutaraldehyde provides the best degree of crosslinking among the three aldehydes, making it the chosen crosslinking agent for preparing alkaline-resistant coatings.

Table 2. Degree of crosslinking

Degree of Crosslinking			
Aldehyde/ Polymer Ratio	Glutaraldehyde	Formaldehyde	Glyoxal
1.0	96	94	64.42
0.8	98	92	66.45
0.6	98	91	68.17
0.4	96	90	76.87
0.2	94	88	89.42

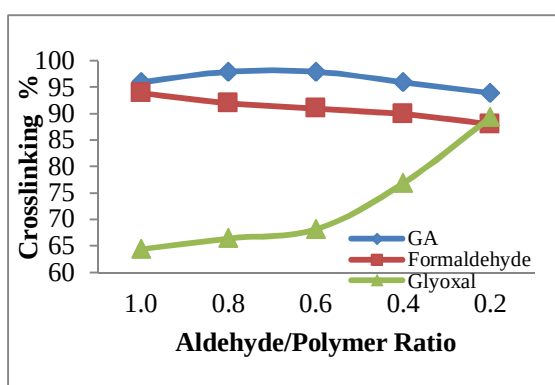


Fig 1: Degree of Crosslinking

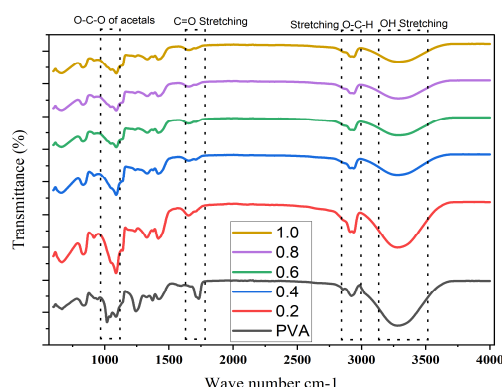


Fig 2: TIR spectra of GA/PVA ratio

Fourier Transform Infrared Spectroscopy (FTIR):

The crosslinking between PVA and glutaraldehyde was confirmed using FTIR spectroscopy. Changes in the chemical structure of the PVA film were observed through FTIR analysis, as shown in Fig 6. The FTIR spectrum of pure PVA exhibits a broad band around 3320 cm⁻¹, which corresponds to O-H stretching, along with peaks at 2940 cm⁻¹ and 2890 cm⁻¹ that indicate the asymmetric and symmetric stretching of methylene groups, respectively. Additionally, a band at 1090 cm⁻¹ is associated with C-O stretching.

Comparison of weight loss (%) between virgin polyester and coated polyester after exposure to alkali solution for one week:

After optimization, we proceeded with the real-time applications of coating on polyester yarn to evaluate its alkali resistance. Initially, we assessed the alkali resistance of virgin polyester yarn. To do so, the yarn was exposed to different pH levels (9 – 13) and temperatures (30 - 80°C) for one week, and its stability were monitored. As the temperature and pH of the solution increase, the weight loss also increases. Following this, we applied the optimized coating onto the polyester yarn and repeated the same procedure to test its alkali resistance. The results obtained from both tests are presented in the fig 4.

Through this study, we observed that the applied coating effectively enhanced the alkali resistance of the polyester yarn. The coating demonstrated significant resistance to alkaline conditions, maintaining the stability of the yarn under varying pH and temperature conditions. This confirms the efficacy of the coating material in providing robust protection against alkaline degradation, making it a suitable solution for applications requiring enhanced alkali resistance.

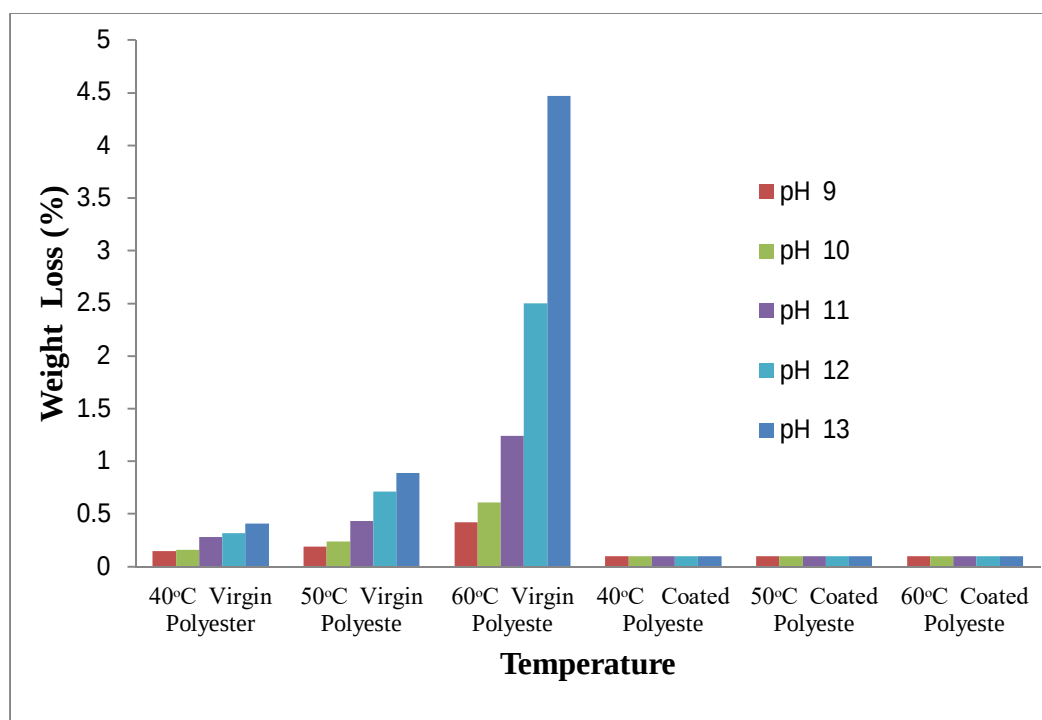


Fig 3: Comparison of weight loss (%) between virgin polyester and coated polyester after exposure to alkali solution for one week.

Conclusion:

In conclusion, this study is actively developing an alkaline-resistant coating for polyester yarn by crosslinking PVA with glutaraldehyde, aiming to enhance its stability under varying pH conditions. While initial results show promising improvements in alkali resistance, further optimization of the coating material and process is ongoing to enhance tensile strength and other critical properties. The coated yarn is being evaluated through weight loss analysis and tensile strength testing based on the DIN geosynthetic alkali resistance standard. Additionally, efforts continue to refine the process for seamless inline integration into existing manufacturing systems, ensuring its feasibility for large-scale industrial application.

2.9 Preparation of cellulose/silica based aerogels and its composite for thermal insulation application

Abstract

Cellulose aerogel composite was prepared with cellulose aerogel and polyester batting by dissolving cellulose in N-methyl morpholine N-oxide solvent. Cellulose solution was then allowed to form gel within batting, which was regenerated with water, washed and freeze dried. The prepared composite has three-dimensional porous structure. Density of the prepared composite is 0.05 g/cm³ and porosity is 96.5%. The thermal insulation value of prepared composite is 0.133 m²K/W which is 48.27% higher than the batting. The tensile strength and elongation was found - 36N and 20.8% respectively.

INTRODUCTION

The amount of energy required for environmental comfort in a building is governed by the thermal performance of the building envelope such as walls and roofs which separates the indoor from outdoor. With the proper application of thermal insulation material in building envelope, the rate of heat transmission and energy consumption for heating and cooling of building internal environment can be reduced. Thermal insulation can be measured in terms of R-value and for the clothing

material; it can be expressed as a clo value. Higher the R-value and clo value, higher is the insulation. Polystyrene, polyurethane forms and aerogels are such type of thermal insulation material.

EXPERIMENTAL

In it cellulose was first dissolved in N methyl morpholine oxide at an appropriate temperature, solidifying in mould along with batting. The composite was then repeatedly washed with distilled water and freeze dried to obtain aerogel composite.

Density and porosity of the aerogel composite was calculated. SEM and XRD confirm the formation of aerogel in batting. Thermal insulation and tensile property of composite was then evaluated.

RESULTS AND DISCUSSION

Density and porosity of the prepared composite is calculated as 0.05 g/cm³ and 96.5% respectively. Fig 1 shows the SEM image of batting and composite. SEM image of batting shows the random arrangement of fibers where as SEM image of composite material shows interconnected porous structure of aerogel embedded within the fibers.

The XRD spectra of polyester and composite are shown in fig 2. Peaks at 2 θ position 17.85°, 23.21° and 26.15° represents the crystalline peaks of polyester in batting. In case of composite material, peak at 2 θ position 9.48° and broadening between 15° to 25° is due to the presence of cellulose.

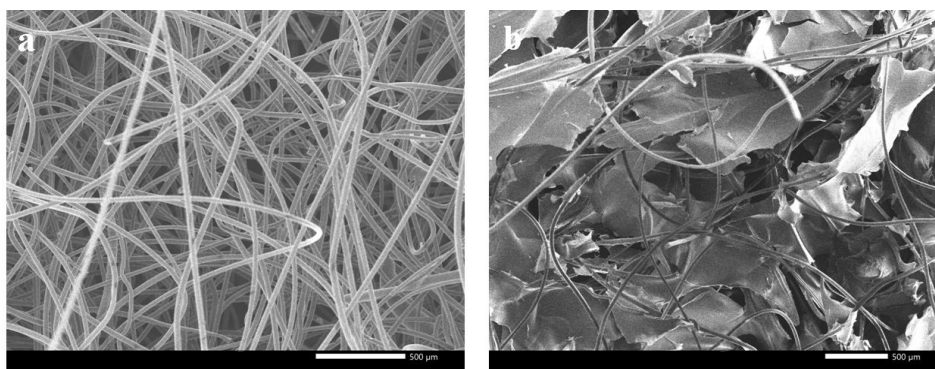


Fig 1 SEM images of (a) batting and (b) composite

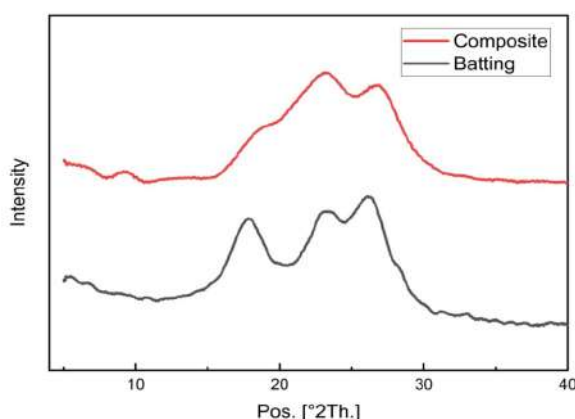


Fig 2 XRD graph of polyester batting and composite

The targeted property of the prepared composite related to thermal insulation is found 0.86 clo compared to 0.58 for batting. R-value of the batting and composite is found 0.089 and 0.133 m²K/W respectively. This is because of porous structure formed by the aerogel in between the batting causes air entrapped and avoids the heat loss through conduction and radiation process. Tensile property is shown in table 1. The composite has much higher tensile strength which is approximately four times of batting and 37% reduction in tensile elongation. This is because aerogel material between the batting fibers helps in binding those results in overall increase in strength and decrease elongation.

Table 1 Tensile property of batting and composite

Sample	Batting	Composite
Tensile strength (N)	9.15	36
Elongation (%)	33.06	20.8

CONCLUSION

Cellulose aerogel composite was successfully prepared with cellulose aerogel and polyester batting by dissolving cellulose in N-methyl morpholine N-oxide solvent. Cellulose solution was then converted into gel by sol-gel process, moulded with batting and then regenerated with water and freeze dried. The prepared composite has three-dimensional porous structure. Density of the prepared composite is 0.05 g/cm³. Porosity of prepared composite is 96.5%. The thermal insulation of prepared composite is 48.27% higher than the batting. This material has potential application in providing heat insulation to the building envelope, aerospace interiors and clothing.

2.10 Atmospheric plasma assisted dyeing of polypropylene with graphene nano material to impart antistatic and conductive properties

Abstract

This study explores straightforward surface modification techniques and establishes permanent antistatic properties for woven polypropylene (PP) fabrics. Atmospheric plasma treatment was applied to the PP surface to impart graphene nanomaterials. Atmospheric oxygenated helium plasma, with various power levels and treatment times, was utilized to functionalize the PP fabric surface before nanomaterial grafting. Pristine graphene, known for its exceptional electrical conductivity and mechanical strength, was uniformly deposited through a controlled padding-drying-curing and beaker dyeing process. Comprehensive characterization techniques, including scanning electron microscopy (SEM) and electrical conductivity measurements, confirmed the successful integration of graphene and its uniform distribution on to the PP fabric. Before washing, the modified fabrics exhibited significantly reduced surface resistivity, decreasing from 10¹² Ωsq⁻¹ to 10⁶ Ωsq⁻¹, with a half decay time of less than 5 seconds. Washing was performed according to the AATCC – 2018 procedure using 1993 AATCC standard reference detergent. After washing, the surface resistivity was up to 10⁹ Ωsq⁻¹, with a half decay time of less than 10 seconds, indicating good antistatic properties.

Introduction:

Polypropylene (PP), a thermoplastic polymer, is widely used owing to its excellent chemical resistance, low density, high melting point, and versatility in processing methods. It finds extensive use in packaging, automotive parts, textiles, medical devices, and consumer goods. Particularly it is useful in textile suits due to its lightweight, moisture-wicking, and quick-drying properties. It has low water absorption, which helps keep the fabric dry and comfortable, making it ideal for sportswear, activewear, and outdoor wear. Additionally, PP fibers offer good thermal insulation, helping regulate body temperature by trapping heat in colder conditions. Its resistance to staining, UV degradation, and most chemicals ensures durability, colour retention, and longevity of the textile suits.

In textile suits, antistatic properties play a crucial role by preventing the buildup of static electricity on the fabric surface. Polypropylene fibers, can accumulate static charges, especially in low-humidity environments, causing discomfort for the wearer and attracting dust and lint. Integrating antistatic agents or fibers into the fabric helps to dissipate this static charge, improving the comfort, cleanliness, and functionality of the suit.

Experiment details**Plasma treatment of PP fabric**

Initially, woven spun-yarn PP fabric was taken for atmospheric pressure plasma treatment. Helium (5 lpm) and oxygen (0.5 lpm) were used as carrier and active gases respectively for plasma generation. The fabric was treated with continuous flow at different power energies (1, 2, 3 kW), and the treatment was applied for various durations (15, 30, 45, 60 seconds). After the plasma treatment, the fabric samples were cut into pieces measuring 30 x 30 cm for the Pad- dry-cure process.

Fabrication of PP fabric with graphene using Pad-dry-cure method

The PP fabric was pre-treated then impregnated with the graphene dispersion using a padding mangle, where the fabric passed through rollers to ensure uniform coverage. 1 atm pressure and 200 rpm were used for the padding procedure. Excess dispersion was squeezed out, and the fabric was then dried at 80-100°C for 15 minutes to evaporate the solvent. After drying, the fabric was cured at 125°C for 20 minutes to bond the graphene particles firmly to the fabric.

Results and discussion:**Surface resistivity of the plasma treated samples**

The surface resistivity of the samples treated with plasma for 60 seconds and subjected to pad-dry-cure process was thoroughly evaluated to assess their electrical performance and stability. The results, summarized in Table 1 highlight the influence of plasma treatment on improving surface conductivity. This analysis provides valuable insights into the effectiveness of plasma treatment in enhancing the functional properties of the material. The fabric achieved the desired conductivity with 1, 2, and 3 kW plasma treatments. The enhanced deposition of graphene onto the polypropylene (PP) surface resulted in a significant decrease in resistivity. Notably, with the 3 kW plasma treatment the resistivity dropped below $10^6 \Omega \text{ sq}^{-1}$ demonstrating optimal performance for further testing.

Table 1. Surface resistivity of Pad-dry-cure

FABRIC	UN TREATED	1 kW	2 kW	3kW
No washing	7.6×10^{11}	1.1×10^8	6.3×10^7	1.5×10^6
After 1 wash	7.6×10^{12}	1.1×10^9	6.3×10^8	1.5×10^6
After 3 wash	7.6×10^{12}	1.1×10^{10}	6.3×10^9	1.5×10^7
After 5 wash	7.6×10^{12}	1.1×10^{11}	6.3×10^{10}	1.5×10^8

The unit of the surface resistivity values is $\Omega \text{ sq}^{-1}$

Static discharge half decay time

The static discharge half-decay time is a critical parameter for evaluating the electrostatic behaviour of materials, particularly in applications requiring quick dissipation of static charge. Plasma-treated PP fabrics were analysed to determine their static discharge half-decay time under varying treatment conditions. The plasma treatment alters the surface properties of the PP fabric, introducing functional groups and enhancing surface roughness. These modifications improve the fabric's conductivity, leading to a more efficient dissipation of static charge. Fabrics treated with different plasma power levels (1 kW, 2 kW, and 3 kW) and durations (up to 60 seconds) were tested. The results indicate that the static discharge half-decay time decreases significantly with increasing plasma power and treatment duration after padding with graphene. At 3 kW plasma treatment and the pad-dry-cure process, the static discharge half-decay time was minimized below 5 sec, demonstrating excellent antistatic properties. These findings suggest that plasma treatment is an effective method for enhancing the electrostatic performance of PP fabrics.

Table. 2. Impresses Peak Voltage and its regrading Half decay time for various time interval for 3 kW treated PP fabric.

S. No	Time in (s)	Impressed Peak Voltage	Half decay time in (s)
1.	UT	2050	>300
2.	15	1548	9.2
3.	30	1327	4.8
4.	45	1548	5.6
5.	60	1133	4.1

Scanning Electron Microscopy Analysis of PP Fabric Coated with Graphene

Fig 1 shows the surface morphology of the untreated PP fabric examined using Scanning Electron Microscopy (SEM). The SEM images shows a smooth and clean surface of PP fabric without sign of any significant deposition. A minute number of partials can be seen may be due the surface deposition of dust and surface contamination take place during handling of the sample.

The SEM images (fig 1 B and C) revealed a well-adhered coating layer on the PP fibers, with the graphene sheets distributed across the surface. The graphene sheets appeared embedded within the fibre matrix, forming a continuous network that maintained intimate contact with the fabric fibers. The coating exhibited minimal cracks or defects, suggesting effective adhesion between the graphene and the PP surface. This uniform coating is critical for enhancing the fabric's electrical and thermal properties, making it suitable for advanced applications.

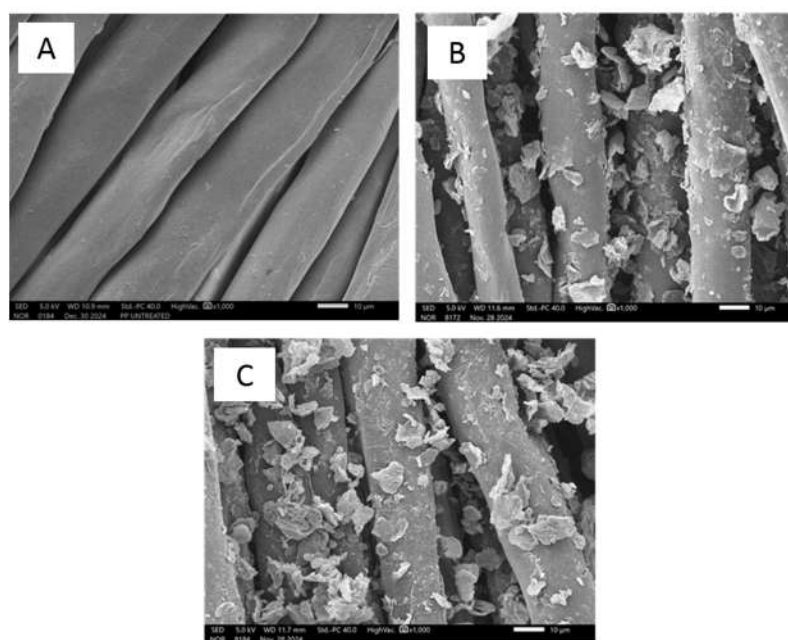


Fig 1. SEM Images of PP Fabric coated with graphene A- Untreated, B 1kW plasma treated, C- 3kW plasma treated.

Conclusions:

The optimal plasma treatment conditions (power and time) were identified and their repeatability was checked for better enhancements. The treated fabrics demonstrated excellent flexibility and durability, making them suitable for the textile industry. These findings suggest that atmospheric plasma-assisted graphene deposition is a promising approach for enhancing the functionality of polypropylene fabrics in advanced textile applications, particularly in the fields of smart textiles and wearable electronics.

2.11 Development of Spinnable grade Meta- and Para-Aramid polymers and their Fibre Spinning

Abstract

Aramid fibers, specifically meta- and para-aramid polymers, are widely used in aerospace, defence, and industrial applications due to their exceptional mechanical and thermal properties. The research focuses on developing spinnable-grade aramid polymers and optimizing the fiber spinning process. The study highlights the synthesis of aramid polymers, their rheological behaviour, and fiber spinning techniques, particularly dry-jet wet spinning. The findings contribute to the indigenisation of aramid fiber production, reducing dependency on imports and enhancing domestic manufacturing capabilities.

Introduction

Aramid fibers are a class of advanced synthetic fibers that exhibit remarkable mechanical strength, thermal stability, and resistance to wear and chemical degradation. These attributes make them indispensable in various high-performance applications, including ballistic protection, aerospace components, and industrial reinforcement materials. Research on aramid fibers has gained traction due to their superior strength-to-weight ratio and high impact resistance, making them ideal for personal protective equipment, such as bulletproof vests and fire-resistant suits. Commercially available aramid fibers, such as Kevlar and Nomex, have traditionally been produced by global industry leaders, primarily in the United States and Europe. However, recent studies emphasize the need for localised production to reduce supply chain dependencies and enhance national security (Smith et al., 2018). Developing indigenous production capabilities requires a comprehensive understanding of polymer synthesis, rheological behaviour, and fiber spinning techniques. Several studies have explored the synthesis and spinning of aramid fibers. Research indicates that optimising polymerisation conditions and refining fiber spinning parameters can significantly enhance fiber performance. Additionally, studies on liquid crystalline polymer solutions suggest that controlling solvent composition and polymer concentration plays a crucial role in determining fiber morphology and mechanical properties.

This study aims to develop high-performance aramid fibers through optimised polymerization and fiber spinning techniques. The objective is to establish a sustainable domestic production process that meets industrial and defence-grade requirements, ensuring self-reliance in aramid fiber technology.

Materials and Methods

Materials

The primary raw materials used in this research include:

- **Aromatic Diamines:** p-Phenylenediamine (PPD) and m-Phenylenediamine (MPD)
- **Aromatic Dicarboxylic Acid Halides:** Terephthaloyl Dichloride (TDC) and Isophthaloyl Dichloride (IDC)
- **Solvents:** N-Methylpyrrolidone (NMP), Calcium Chloride (CaCl_2), and concentrated Sulfuric Acid (H_2SO_4)

Methods

Polymer Synthesis

Aramid polymers were synthesised using a controlled polycondensation reaction between aromatic diamines and dicarboxylic acid halides. The reaction was carried out in a solvent mixture of NMP-

CaCl₂ under an inert atmosphere at -10°C. The resulting polymer was precipitated in water, washed, and dried under a vacuum.

Rheological Analysis

The solution viscosity of aramid polymers in H₂SO₄ was analysed using a rotational rheometer to determine the optimal polymer concentration for fiber spinning.

Fiber Spinning Process

The optimised polymer solution was subjected to dry-jet wet spinning, which included:

- Extrusion of polymer solution through a spinneret
- Passage through an air gap before coagulation in a cold water bath
- Washing, neutralisation, and drying of the spun fibers
- Post-spinning heat treatment to enhance crystallinity and mechanical properties

Results and Discussion

Fiber Spinning and Characterization

The spun fibers were characterised for mechanical and thermal properties:

- **Tensile Strength:** 2.2 - 2.9 GPa
- **Modulus:** 60 - 70 GPa
- **Elongation at Break:** 4 - 5%

SEM analysis confirmed uniform fiber morphology with minimal defects, while thermal analysis using DSC and TGA demonstrated high thermal stability of the produced fibers.

Conclusion

The study successfully synthesised and optimised spinnable-grade meta- and para-aramid fibers using optimised polymerisation and dry-jet wet-spinning techniques. The developed fibers exhibit excellent mechanical and thermal properties, suitable for defence, aerospace, and industrial applications. Future research will focus on scaling up the production process and improving fiber performance.

2.12 Development of high-performance gel spun UHMWPE fibers and tapes for bullet proof and geo-girds/ geo-composites applications

Abstract

Ultra-high-molecular-weight polyethylene (UHMWPE) has currently gained popularity because of its excellent physicochemical and tribological characteristics. Furthermore, it is suitable for numerous industrial uses due to its low density, solubility, and exceptional mechanical characteristics, including high Young's modulus and tensile strength, particularly in drawn films. The primary uses of UHMWPE fibre in the military and commercial sectors for the making of rope, composite materials, and ballistic applications. Fiber production from UHMWPE polymer is challenging because it is very difficult to process in the melt phase, so solution preparation using a suitable solvent is usually preferred. Based on the challenges and characteristics of the UHMWPE polymer, the current research project aims to prepare UHMWPE fibers and tapes and further transforming them into successful ballistic and geo-composite applications.

Introduction

The natural and synthetic textile fibres have restricted applications in the aerospace, protective clothing, armour and advanced composites industries due to their inadequate mechanical performance. Based on the limitations of conventional textile fibre, Staudinger, proposed the fundamental criteria for manufacturing a high strength, high modulus synthetic fiber in 1932. The most prominent type of high modulus synthetic fibre is high modulus polyethylene (HMPE), which is usually produced by gel-spinning process and termed as ultra-high molecular weight polyethylene. Ultra-high molecular weight polyethylene polymer, which has more significant characteristics than typical low-density and high-density PE, therefore it has recently gained attention. The ultra-high molecular weight polyethylene shows superior mechanical properties due to highly oriented structure linked with high molecular weight or high molecular chain length. Due to its durability, toughness, and biological inertness, UHMWPE has been utilized to substitute metal and ceramic for different applications especially for joint replacement, for past many years. The impact energy is nearly twice as high as that of para-aramid fiber, with good abrasion resistance and low friction coefficient, but the melting point under stress is only 145-160 °C. On a weight-to-weight basis, UHMWPE offers 35% higher strength than aramid fibers and the lowest density among high strength fibers.

Based on the characteristics on the UHMWPE polymer, present research is focused on development of high-performance gel spun UHMWPE fibres and tapes for bullet proof and geo-grids/geo-composites application.

Materials and Methods

Materials

The UHMWPE powder of molecular weight 3.5 million grams/mole were purchased from Mitsui Chemicals Inc. Pvt. Ltd. The primary solvent, paraffin oil with a density of 0.86 gm/cc was purchased from the local market. For the antioxidant, pentaerythritol, tetrakis (3,5-di-tert-butyl-4-hydroxy-hydrocinnamate) was used. The n-hexane of 99% concentration was procured from Loba Chemie Pvt. Ltd.

Methods

Rheological analysis of UHMWPE solution

Initially UHMWPE powder was dissolved in paraffin with different UHMWPE concentrations such as 3%, 5% and 6% including 0.2% antioxidant for each concentration. The solution was prepared using an oil bath and an IKA high-speed stirrer by dispersing at room temperature and slowly heating to 170°C with continuous stirring for a total time of 2 hours.

Rheological tests were performed on Haake Rheostress 6000 rheometer using a 35 mm parallel plate geometry. The viscoelastic properties, such as storage modulus (G') and loss modulus (G''), were obtained from oscillation frequency sweeps in the frequency range of 0.6 to 100 rad/s in the temperature range of 130-170°C.

Design and fabrication of lab scale gel spinning line

The gel spinning line has been designed and manufactured in collaboration with E-spin, Kanpur, UP, and Steer World, Bengaluru, Karnataka. A twin-screw extruder is incorporated into the spinning line, where the UHMWPE polymer mixes directly with solvent (liquid paraffin or decalin) to form a UHMWPE gel solution. The gel spinning line is now available at BTRA and ready for installation.

Gel spinning of UHMWPE solution

A trial was carried out in which the conversion of the UHMWPE powder to gel solution and extrusion of the gel filament were done simultaneously by the aforesaid twin-screw extruder through 1 mm spinneret diameter and the extruded gel monofilament is collected. During spinning of UHMWPE gel filament the higher UHMWPE concentrations e.g., 10% and 15% were used.

Post spinning operations of UHMWPE gel filaments

The collected gel filament of aforesaid concentrations were been drawn approx. 30 to 40 draw ratio at a temperature of 80°C to 130°C using hot roller and hot air duct to achieve different fineness of UHMWPE filaments.

Characterization of UHMWPE filaments

The prepared UHMWPE fibers are characterized based on its mechanical and thermal properties such as tenacity, elongation, melting point, degree of crystallinity and orientation, etc. For the aforesaid characterisation UTM, Sem, and XRD have been used.

Results and discussion**Rheological analysis**

The rheological behaviour of the UHMWPE solution of different polymer concentrations (3%, 5% and 6%) have been analysed and shown in Fig 1 using Han plots. It is seen that, the curves collapse into a single curve, which can be considered an indication of homogeneity of solutions. As per reports those concentrations which are close or lie on the $G' = G''$ line are most suited for spinning. Thus, it appears that 5% and 6% concentrations appear relatively more suited for gel spinning.

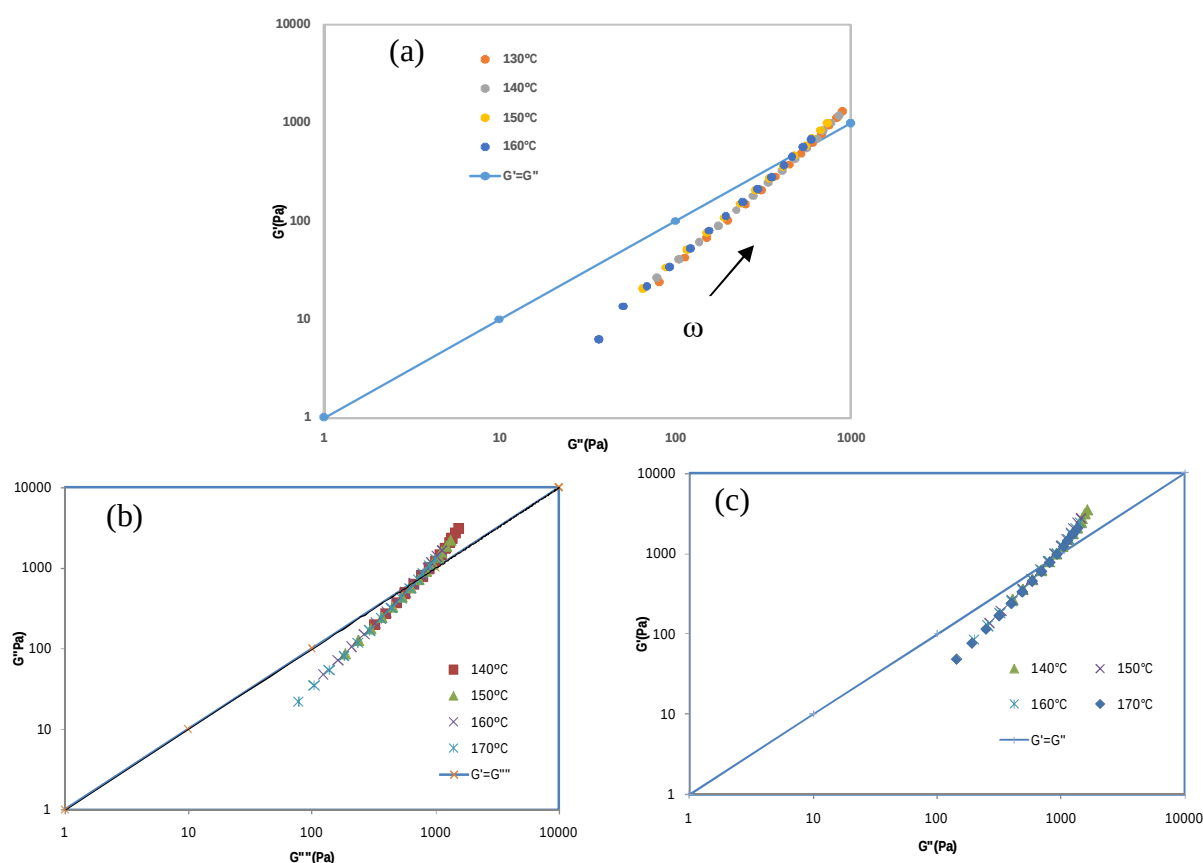


Fig 1: Han Plots of Storage modulus (G') versus Loss modulus (G'') for (a) 3%, (b) 5% (c) 6% UHMWPE solution

Drawing and Characterization of UHMWPE fibre

The preliminary produced gel filaments are drawn in 3 stages of draw ratio 45 is shown in Table 1. Nearly 30 denier and 70-100 μm of UHMWPE fibre has been produced. The maximum tenacity is achieved up to 36 grams per denier, while the elongation is achieved in between 3-4%. SEM analysis

(Fig 2) showed that the fiber is a rough surface in the longitudinal direction and nearly square in cross-section is produced. The XRD curves (Fig 3) showed that the degree of crystallinity is 65% and orientation angle of 8-9°.

Table 1: Drawing and mechanical parameters of UHMWPE fibre

Initial fineness (denier)	Heating Media	Stage	Temperature (°C)	Draw ratio	Net draw ratio	Final fineness (denier)	Maximum tenacity (g/d)	Average elongation (%)
1400 to 1600	Hot roller and Hot air duct	1 st	80	10	$10 \times 3 \times 1.5 = 45$	31.5	36.2	3-4
		2 nd	110	3				
		3 rd	130	1.5				

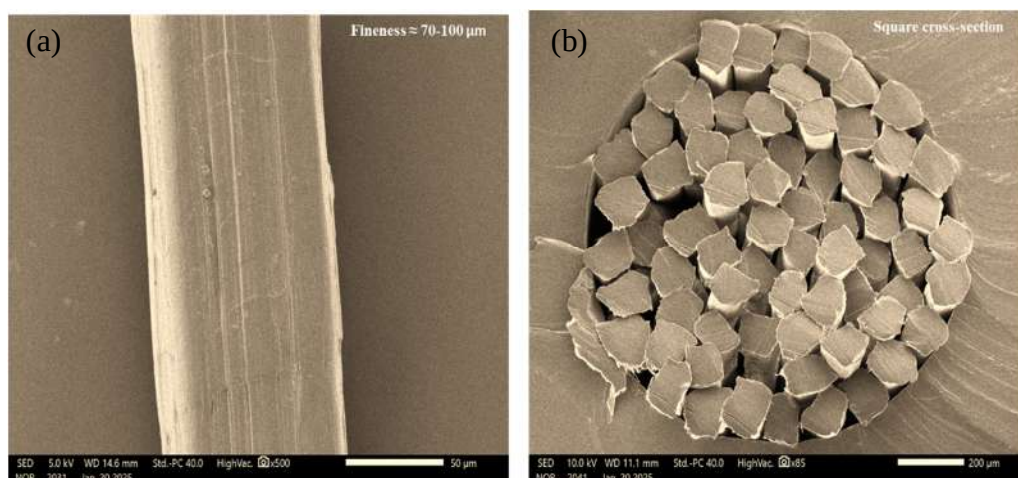


Fig 2: SEM analysis showing a)longitudinal, and b) crosssectiona view of UHMWPE fibre

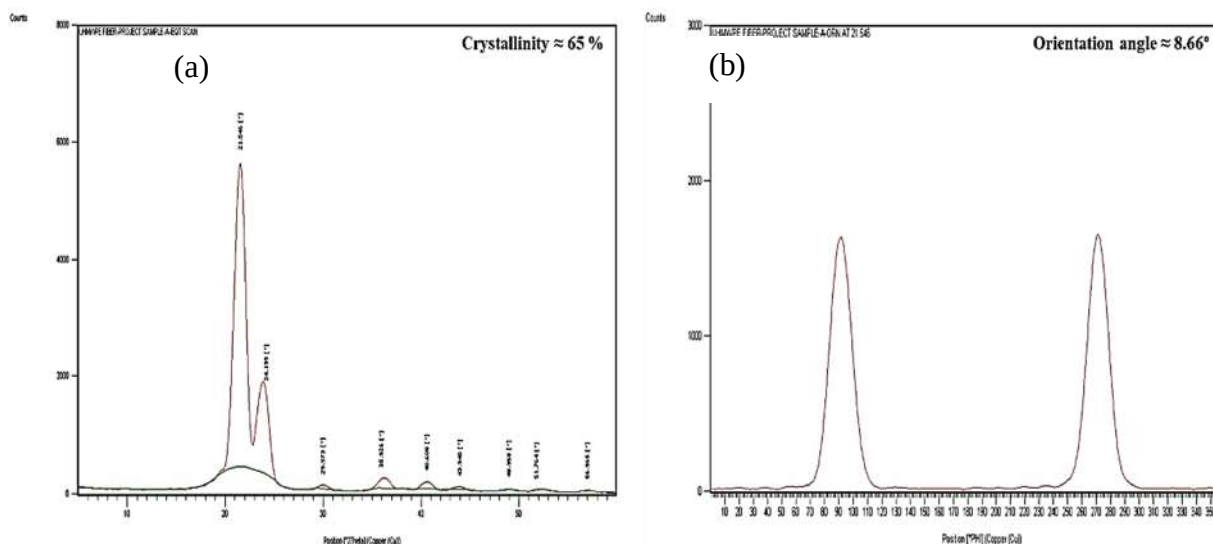


Fig 3: XRD curve showing a)crystallinity,and b) orientation angle of UHMWPE fibre

Conclusions

The rheological study was used to validate the processing parameters of temperature and time used to homogenize the solutions and to provide a framework for predicting the spinnability of the solutions, which can be used to optimize the spinning parameters. The preliminary study of UHMWPE fiber production using a gel spinning line was analyzed using liquid paraffin as a solvent.In

the preliminary stage of UHMWPE fiber production, the good mechanical and thermal properties were observed. Further study is under progress.

2.13 Plasma Assisted Waterless Dyeing of High-performance Textiles using Supercritical Fluid for Application in Technical Textiles

Details of the functional antimicrobial finishing using Plasma technology :

Plasma technology has been proven to be having tremendous potential in textile finishing. It is useful and advantageous as it is a clean, dry and energy-saving technology, thus sustainable. Exposure to plasma does lead to surface modification at nano level without affecting the bulk of textile material, and creates additional polar functional group which facilitates the interaction of the chemicals with the fabric surface. Polyoxazoline (PO)_x as an antimicrobial agent is gaining importance as it plays an important role in combating against pathogens and proven to be cytocompatible. The aim of this study is to coat the polyoxazoline on the cotton surface using the plasma enhanced chemical vapour deposition (PECVD) method from 2-methyl – oxazoline and 2-ethyl-oxazoline. The plasma polymerization was done in atmospheric pressure plasma using Helium gas as a carrier gas. The surface chemical changes on the fabric were studied using FTIR. AATCC 100 test method was used to measure the antimicrobial activity and it has shown highly effective against *Klebsiella pneumoniae* and *Staphylococcus aureus*. The developed antibacterial cotton fabric has a huge scope of application in biomedical textile for wound dressing, bandages etc.

Keywords- Plasma polymerization, pathogens, 2-methyl-oxazoline, 2-ethyl-oxazoline, antimicrobial activity.

Introduction

Textile finishing and processing have shown substantial benefits from plasma technology. It is a clean, dry and energy saving process, thus will be an environmentally friendly approach towards the sustainable finishing of the textiles. Plasma treatment leads to a nano level surface modification without affecting the bulk properties of textiles. The ionized gas creates polar functional groups on the fabric surface which favours the better adherence of the chemicals. Antimicrobial finished textiles have always been in demand in the market, but the current epidemic has increased the demand and significance of antimicrobial textiles to unprecedented levels. Traditional techniques for antimicrobial finishing on textiles, such as pad-dry-cure and exhaustion procedures, require a lots of water, chemicals and energy, which as results increases the environmental load considerably. Keeping in mind the current scenario and the future demand of the antimicrobial finished textiles, it is the utmost need of the hour to find the alternate clean, dry and eco-friendly method, thus retaining a safe environment. The use of plasma in textile finishing is a novel method that can drastically cut down on water and energy consumption as it doesn't require drying or water for treatment. When considering antimicrobial finishing the benefits of plasma over traditional wet treatments like the pad-dry-cure procedure or exhaustion method are enormous.

Polyoxazoline (PO)_x as an antimicrobial agent is gaining importance as it plays an important role in combating against pathogens. Polyoxazoline-based or polyoxazoline-derived polymers clearly have a significant application potential as an antimicrobial agent. (PO)_x have potential for medication delivery due to their biocompatibility and stealth qualities. (Nico Adams et.al 2007).

Pavel Stahel et.al (2023) works on coating of polymer film with 2-Ethly 2- oxazoline and 2- methyl 2-oxazoline using plasma polymerization in a volume dielectric barrier discharge (DBD) burning in nitrogen at atmospheric pressure shows a very promising results in antimicrobial activity and also it was seen to be cytocompatible. Siyuan Sui et.al (2024) did polymer grafting of QAC (quaternary ammonium compound) on PVC (poly vinyl chloride) using Ar and Ar-O₂ Plasma and their characterisation reveals a significant antibacterial activity on the polymer coated surface.

Yong Wang et.al (2024) investigated plasma polymerized NO-coatings using a helium-isopentyl nitrite on aluminum samples. The results of this investigation indicate a promising potential for use in the biomedical field.

Since the potential of use of Polyoxazoline (PO)x as an antimicrobial agent has shown very promising results in biomedical sectors, so we attempted the polymerisation of 2-methyl-2-oxazoline and 2-ethyl-2-oxazoline on the cotton surface using Plasma chemical vapour deposition technique (PCVD).

Materials and Methods:

Materials:

Ready for dyeing 100% cotton fabric with the GSM 132 of 40s count in warp and weft direction with 144 and 72 ends per inch and picks per inch was procured from the local supplier. Helium gas with 99.9 % purity was used as carrier gas for plasma generation and 2-methyl-2-oxazoline and 2-ethyl-2-oxazoline of analytical grade was procured from the Merck chemicals.

Plasma treatment of the cotton fabric:

Atmospheric pressure plasma (APP) dielectric barrier discharge (DBD) was used for the polymer deposition of the 2-methyl-2-oxazoline and 2-ethyl-2-oxazoline on to the cotton fabric. Plasma enhanced chemical vapour deposition of thin film of the monomers was deposited on to the surface of cotton fabric using helium as a carrier gas. Plasma exposure for 80sec, 160sec and 240sec was done at the power of 3kW and a fixed distance of 0.5mm between the top and bottom electrodes. Finally a silane monomer was deposited on one side of the treated fabric for 80sec. using same plasma enhanced chemical vapour deposition technique to introduce the hydrophobicity.

Results and Discussion:

Resistance to bacterial growth:

The aim of this study is to develop the antimicrobial cotton fabric using PECVD technique. Therefore, the treated cotton fabric was evaluated using AATCC 100 test method to check the ability of the fabric to resist the growth of gram-positive (*Staphylococcus Aureus*) and gram-negative (*Klebsiella pneumoniae*) bacteria. Table 1 shows the result of the tested samples and the respective images are represented in fig 1.

Table 1. Antibacterial activity of the untreated and plasma treated cotton samples as per AATCC 100 test method.

Samples details	Antibacterial activity (bacterial reduction %)	
	gram- negative (<i>Klebsiella pneumoniae</i>)	gram- positive (<i>Staphylococcus Aureus</i>)
Untreated cotton	No reduction	No reduction
2-methyl-oxazoline- 80 Sec 3kW	99.77	99.96
2-methyl-oxazoline- 160 Sec 3kW	99.60	99.98
2-ethyl-oxazoline- 80 Sec 3kW	96.33	96.31
2-ethyl-oxazoline- 160 Sec 3kW	99.89	99.95

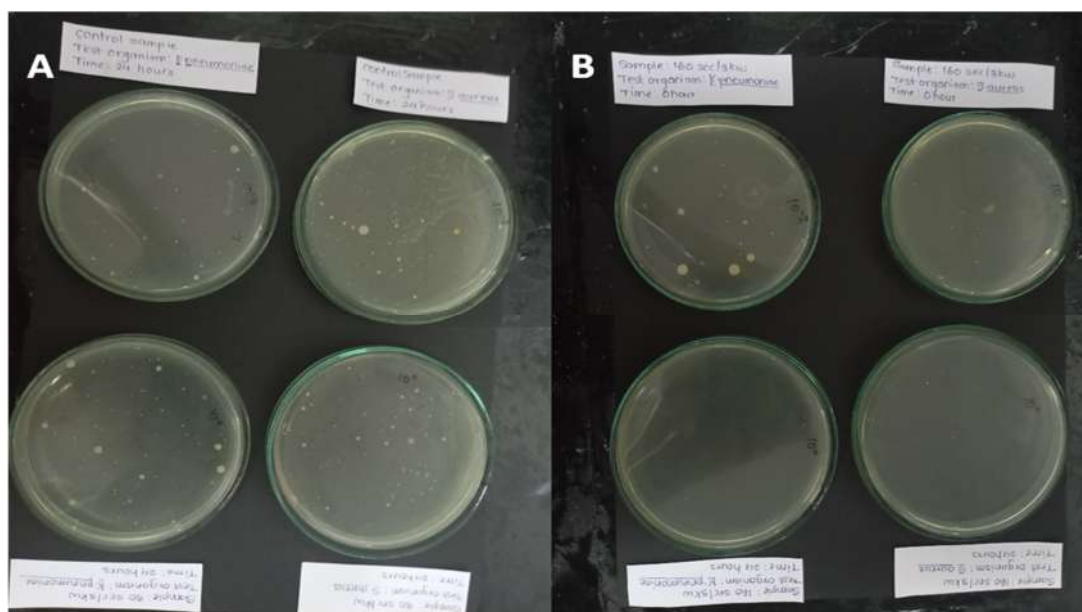


Fig 1. Images of the antibacterial activity of the untreated (A), and PECVD treated 160 sec samples (B).

As can be seen from the table that untreated cotton fabric has no ability to resist the growth of the bacteria. In fact it is well known that the bacteria grows on cellulosic material. However the PECVD treated samples showed the very good resistance to bacterial growth. Further as can be seen from the table 1, that the resistance the bacterial growth has increased with increased plasma exposure duration. From the table 1 it can be said that 2-methyl-oxazoline can give the better results as compared to 2-ethyl-oxazoline at lesser duration of the plasma exposure.

Analysis of surface chemical changes:

Surface chemical changes after PECVD of 2-methyl – oxazoline and 2-ethyl-oxazoline was studied by ATR-FTIR technique and results are given in fig 2. As can be seen from the fig 2. Untreated cotton samples show all characteristic peaks of for the cellulose. Further the additional peak is observed at wave no. 1645 for 2-ethyl-oxazoline treated sample which can be attributed to N-C=O mainly responsible for antimicrobial activity.

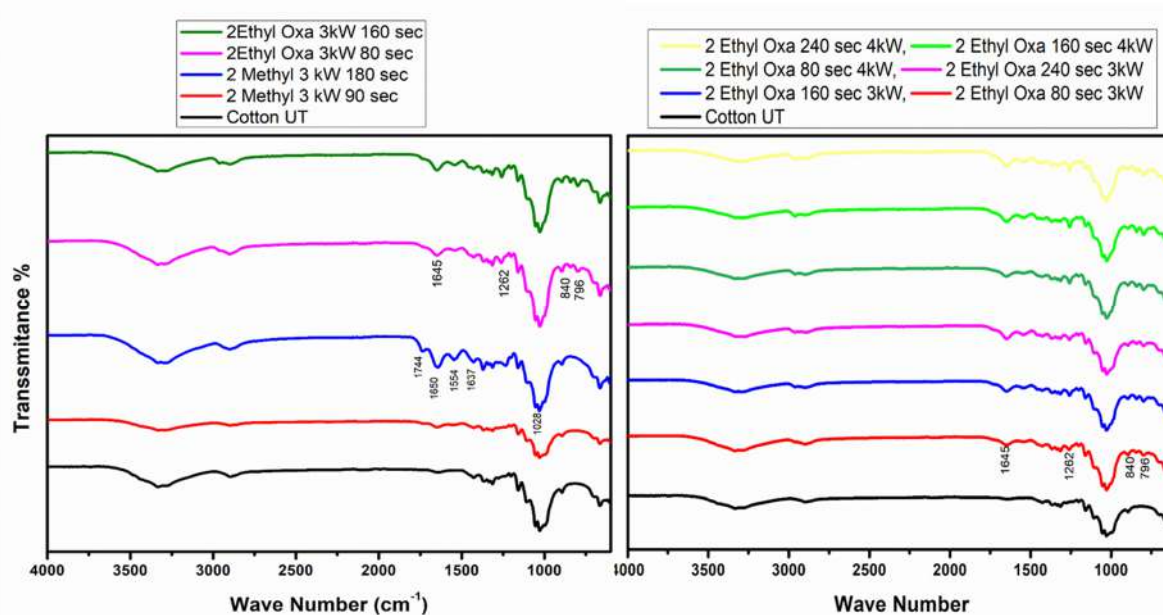


Fig 2. ATR-FTIR spectra of the untreated and PECVD treated cotton samples

Conclusion:

Plasma enhanced chemical vapour deposition of two Polyoxazoline monomers have been carried out successfully to impart the antibacterial properties. It was observed that 2-methyl – oxazoline monomer can give the better results in terms of bacterial reduction at less plasma exposure duration as compared to 2-ethyl-oxazoline. The ATR-FTIR results confirm the formation of functional groups of the surface of the cotton fabric which is mainly responsible for antibacterial activity.

2.14 The Development of treated Geosynthetic reinforced Asphalt Pavements

Abstract:

The increasing traffic loads and premature failures in asphalt pavements necessitate innovative reinforcement techniques to enhance durability and extend service life. Geosynthetic reinforcement, particularly geogrids, has shown improving crack resistance, load distribution, and rutting performance. However, the effectiveness of geogrid-reinforced asphalt pavements depends on factors such as material compatibility, bonding mechanisms, and reinforcement selection criteria.

This study investigates the influence of tack coat selection on the bonding and performance of geogrid-reinforced asphalt layers, as well as the rutting resistance of different geogrid types. Laboratory tests, including shear strength, wheel rut, indirect tensile strength, and installation damage assessments, were conducted to evaluate the structural integrity and performance of reinforced pavements. Results indicate that polymer-modified bitumen (PMB) tack coats enhance bonding, reducing delamination risks, while geogrid selection should consider factors beyond tensile strength, such as aperture size and rib configuration. A rutting coefficient was developed as a selection criterion for geogrids to optimize pavement resistance against permanent deformation.

The findings provide valuable insights into material selection and design improvements for geosynthetic-reinforced asphalt pavements, contributing to the development of more resilient and long-lasting road infrastructure.

Introduction

The increasing demand for durable and long-lasting pavements has driven the need for innovative reinforcement techniques to combat premature failures such as rutting and cracking. Previous studies have demonstrated that geosynthetics, particularly geogrids, enhance the structural integrity of asphalt pavements by improving crack resistance, load distribution, and moisture resilience. However, the effectiveness of geogrid reinforcement is influenced by several factors, including material compatibility, bonding with asphalt layers, and placement techniques.

One critical aspect influencing the performance of geogrid-reinforced asphalt pavements is the bond strength at the interface of asphalt layers, which may be affected by the type of tack coat used. However, the extent to which different tack coats influence layer integrity, shear resistance, and delamination remains unclear. Additionally, while geogrid tensile strength is commonly considered in reinforcement design, its adequacy as the sole selection criterion is uncertain. Other factors, such as aperture size, rib structure, and overall material configuration, may also play a significant role in improving pavement resistance to deformation under repeated loading. Therefore, a comprehensive investigation is necessary to understand the combined effects of tack coat selection and geogrid properties on the overall performance of reinforced asphalt pavements.

To optimize the performance of geosynthetic-reinforced pavements, it is essential to establish reliable selection criteria for geogrids and tack coats, supported by laboratory evaluations and performance-based assessments. This report delves into the critical factors influencing the performance of geosynthetic-reinforced asphalt pavements, offering a comprehensive analysis of

bonding mechanisms, reinforcement efficiency, and material selection strategies for improved pavement longevity.

Materials and Methodology

The specimens for testing were cast with two layers, Dense Bituminous Macadam (DBM) as the base and Bituminous Concrete (BC) as the surface layer. To study the compatibility of tack coat they are categorized based on the presence of geogrid reinforcement and the type of tack coat applied between the layers. The six categories include unreinforced and reinforced specimens with no tack coat, Rapid Setting Emulsion tack coat, or Polymer Modified Bitumen tack coat. To study the rutting coefficient three different geogrids namely: geogrid-50, geogrid-60 and geogrid-150 were used.

This research involves multiple tests to evaluate the performance of geogrid-reinforced asphalt pavements. Initially, the compatibility of tack coats is assessed through indirect tensile strength tests to determine how well the tack coat bonds with the geogrid and asphalt mixture. This bond is crucial for ensuring the structural integrity of the pavement, as the tack coat plays a significant role in interlayer bonding. Shear strength tests are performed to evaluate the resistance of the geogrid-asphalt interface to shear failure. Installation damage tests are also conducted to understand the impact of the installation process on the geogrid's integrity. Scanning Electron Microscopy (SEM) is used to examine any potential microstructural damage or degradation of the geogrid material after installation.

In addition to these tests, a geogrid rutting coefficient is developed to guide the selection of geogrids for reinforcement. This coefficient is calculated based on various parameters like tensile strength, wheel load, air voids, and the number of ribs in the geogrid. Different geogrids are tested to assess their resistance to rutting and their ability to enhance pavement stability under traffic loading. The rutting depth is measured, and the coefficient helps in identifying the most effective geogrids for improving asphalt pavement durability.

Results and Discussions

The indirect tensile strength and shear strength tests were conducted to assess the impact of geogrid reinforcement and tack coat type on bituminous specimens. Results indicated that adding a geogrid generally reduced tensile strength, likely due to altered stress distribution or bonding issues. The type of tack coat also played a crucial role. Specimens with Rapid Setting Emulsion tack coat showed complete delamination, suggesting its less suitability for geosynthetic-reinforced asphalt. Shear strength tests revealed that unreinforced samples exhibited higher shear strength than reinforced ones, except for those with Polymer Modified Bitumen tack coat, which improved shear strength by 2.9%. The most significant reduction was observed in specimens reinforced with Rapid Setting Emulsion tack coat, showing a 10.34% decrease compared to their unreinforced counterparts.

Further evaluations, including installation damage and wheel rut tests, confirmed that geogrid reinforcement enhanced durability by mitigating rut depth and crack formation. Polymer Modified Bitumen reinforced specimens exhibited the least rutting, while unreinforced specimens without tack coat showed the most severe cracks. Image analysis of rutting and shear failure confirmed that geogrids effectively reduced crack propagation, improving structural performance. The geogrid rutting coefficient further highlighted that Geogrid-60 and Geogrid-150 were effective in resisting deformation. The findings highlight that tensile strength alone does not ensure optimal performance; geometric properties like aperture size and rib density per unit length are crucial for enhancing rutting resistance.

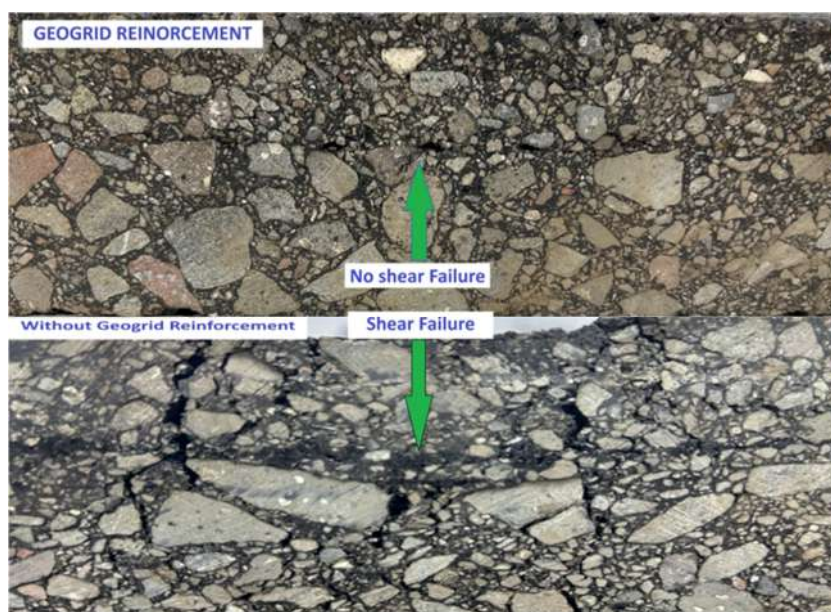


Fig. 1 Shear failure of geogrid reinforced and unreinforced specimens

Conclusions

This study demonstrates that both the type of tack coat and the presence of geogrid reinforcement significantly influence the tensile and shear strength, rutting resistance of the asphalt mixtures. While geogrid reinforcement improves structural integrity, its effectiveness depends on proper bonding and installation to prevent premature failure. These findings emphasize that tensile strength of geogrid alone is not sufficient to guarantee optimal performance; rather, geometric properties such as aperture size and number of ribs per unit length play a major role in improving rutting resistance. Therefore, selecting geogrid reinforcements with appropriate geometric characteristics is crucial for improving the long-term durability and performance.

3. In-house Projects

3.1 Development of sustainable hygiene products from sugarcane bagasse

Abstract

The present study highlights the issues of non biodegradability of personal hygiene products and how it has become a serious environmental concern all over the world. Hence, this research work envisaged to develop a sustainable eco friendly sanitary napkin by utilizing sugar cane bagasse which is obtained as a waste byproduct from sugar industries. Sugarcane bagasse has been processed and converted to a fine cellulosic pulp and used as an absorbent core material. A prototype of a SCB sanitary napkin comprises permeable inner layer absorbent cotton gauze fabric, three layers of SCB pulp sheet as absorbent core material and a hydrophobic cotton fabric outer layer has been developed on a laboratory scale. The developed SCB sanitary napkin has better functionality in terms of absorbency and fluid holding capacities and is fully biodegradable.

Introduction:

In recent times consumers as well as environmentalists are demanding eco-friendly sustainable products for their day to day uses. This has increased the demand for eco-friendly products in the commercial market. Hygiene sanitary products such as children's and adults diapers, feminine hygiene products such as sanitary napkins etc. have great demand in the current market. Most of the commercially available absorbent sanitary products are non-biodegradable hence, not eco-friendly or

having sustainability. Commercially available sanitary napkins are having 30-40% non-bio-degradable materials such as synthetic fibres, polyethylene, polypropylene sheets, super absorbent polymers etc. Most of the branded multinational products are having a thin layer of perforated polypropylene sheet in the innermost layer which is in contact with body to keep it dry, super absorbent polymer or cellulosic material in the middle core portion and hydrophobic polyethylene sheet on the outer surface to make it leak proof. Hence, after use disposal of such products are a major concern to environmentalists as well as regulatory authorities like Municipal solid waste management departments. In order to acquire super absorbent property, synthetic polymers are widely being used in diapers as they have higher absorption capacities than natural fibres .

Sugarcane is a cash crop that has been a significant source of revenue in many countries around the world. In India, Uttar Pradesh, Maharashtra and Karnataka together contribute 80% of total sugar production. From the harvest to the final processing, there are four main sugarcane waste products. They are Sugarcane Bagasse (SCB), dry leaves, sugarcane tops, sugarcane press mud and molasses. Every 100 tons of sugarcane, after removal of juice, roughly 30 tons of bagasse waste is being generated. Sugarcane bagasse is a fibrous material having roughly 40-50 % cellulosic material, remaining hemicelluloses, lignin and wax. Sugarcane bagasse has been chosen as an ideal raw material for manufacturing absorbent hygiene products because of its availability as a waste byproduct throughout the year. Since 50 % of bagasse is cellulosic materials it can be easily converted to fibre/ pulp. No hazardous chemicals are being used during the process. Bagasse is a natural product, fully bio-degradable; hence, bagasse-based hygiene products will be sustainable. Converting a waste material to a value-added product by using green technology will be a major achievement.

Hence, this research work envisaged to develop a sustainable eco friendly sanitary napkin by utilizing sugar cane bagasse which is obtained as a waste byproduct from sugar industries. Sugarcane bagasse has been processed and converted to a fine cellulosic pulp and used as an absorbent core material. A prototype of a SCB sanitary napkin comprises permeable inner layer absorbent cotton gauze fabric, three layers of SCB pulp sheet as absorbent core material and a hydrophobic cotton fabric outer layer has been developed on a laboratory scale. In this R&D work, efforts are being made in replacing synthetic materials used in commercial sanitary napkins with cotton fabric and SCB pulp sheets without affecting the functionality.

Result and Discussion

Synthesis of pulp sheet from sugarcane bagasse

A known weight of sugarcane bagasse was washed with water to remove the wax and residual sugar and dried. The dried bagasse was given a pre-treatment with dilute sulphuric acid to remove lignin content. The residue washed with water and further alkali treatment was given to remove hemicelluloses and convert to a cellulose pulp. The alkali treatment was given with NaOH having various concentrations ranging from 0.5 % to 2.0 % at 100°C as trials to optimize the process. The obtained pulp was washed till to get a neutral pH and molded into a thin layer of sheets. Concentrations of alkali and synthesis conditions were optimized based on the absorption property and softness of the pulp. The weight of pulp obtained in each process was measured to monitor the yield. Softness and flexibility of the pulp sheet was also monitored.

Analysis of pulp sheet and SCB sanitary napkin

Absorbency of the pulp sheet and prototype of SCB napkins were evaluated as per IS 5405 test method. The research was carried out by performing absorbency tests on commercial sanitary napkins and on prototypes developed using a blood substitute fluid. Blood substitute fluid was prepared in the laboratory using a saline solution with 896 ml water and 164 g salt and 100 mg red dye. Vertical wicking property was analyzed as per AATCC 197. Fluid retention capacity was

measured as per in-house test method. Air permeability was measured as per IS 11056. Eco parameters were measured as per Oeko -Tex guidelines.

Pulp sheets synthesized from SCB using various concentration of alkali is given in Table-1

Table-1 yield and nature of pulp synthesized from SCB using different concentrations of NaOH

NaOH Concentration (%)	Product	Nature of product	Yield (%)
0.25	Fibre	Thick loose fibre.	90-95
0.5	Mixture of fibre and pulp	Soft sheet	45-47
1.0	Pulp	Soft sheet	40-42
1.5	Pulp	Slightly stiff sheet	35-37
2.0	Pulp	Very stiff sheet	33-35

From Table -1 it can be seen that bagasse treated with 0.25 % NaOH solution is in fibre form and cannot make a sheet. The yield of fibre is 90-95% which indicates that it is a mixture of hemicelluloses and cellulose fibre. Bagasses treated with 0.5% and 1.0% solution of NaOH are in the form of pulp and can easily be molded to a thin sheet. The yield of this pulp is 47% and 42% respectively. Bagasses treated with 1.5% and 2.0% solution of NaOH are also in the form of pulp sheets but comparatively sheets are stiff. Probably this could be due to the formation of pure pulp without any fibre as in higher concentration of alkali all fibres are converted to pulp. The yield of pulp is also lower than the pulp obtained in 0.5% and 1.0% alkali treatment. This indicates that the optimum concentration of NaOH required for synthesizing a soft pulp sheet is 0.5-1.0%.

Water absorbency of SCB pulp sheet

Water absorbency of the obtained pulp was qualitatively checked as per AATCC - 79 (drop test). A drop of water is allowed to fall from the tip of a burette kept at 10 mm height above the specimen and the time taken for the drop of water to lose any light reflection and change to a dull, wet spot is recorded. Table 2 shows water absorbency values of each pulp as per drop test method.

Table-2 Absorbency of SB pulp sheet

Concentration of NaOH for making pulp	Character off pulp	Absorption time (sec)
0.25	No pulp formation. Loose fibres	> 3
0.5	Soft pulp sheet	< 1.0
1.0	Soft pulp sheet	< 1.0
1.5	Slightly stiff pulp sheet	< 1.0
2.0	Very stiff pulp sheet	< 1.0

From Table-2 it can be seen that pulp synthesized using 0.5 to 2.0 % NaOH have good absorbency (below 1.0 second) whereas, the pulp synthesized using 0.25 % NaOH have poor absorbency (more than 3.0 Seconds). This indicates that 0.25% concentration of NaOH is not sufficient enough to make an absorbent pulp.

Absorption property of SCB pulp sheet as vertical wicking time

Water absorbency of the pulp sheet as vertical wicking was measured as per AATCC 197 test method. The rate (distance per unit of time) liquid travels along and through the specimen by means of capillary action were visually observed, manually timed and recorded at specific intervals. This test method was used to evaluate the wicking ability of vertically aligned test specimens, where wicking is influenced by gravity. Specimens of 165 mm in length and 25 mm width are marked 5 mm from the end of the specimen to be tested. The 5 mm line denotes the level to which a specimen is to be

lowered into the fluid in the beaker which is the test start time. Above this 5 mm, 20 mm, 50 mm and 100 mm line is marked. The specimen was allowed to hang into the flask. Fluid was added into the flask to the level at which the specimen's 5 mm line was reached and started the stopwatch. Rise of the fluid through capillary action was monitored. The time taken for the fluid to reach 20 mm and 50 mm and 100 mm height was recorded. Wicking time for the pulp synthesized using 0.5, 1.0, 1.5 and 2.0% NaOH is given in Table-3.

Table-3 Wicking time of bagasse pulp sheet

Concentration of NaOH for making pulp	Vertical height 20 mm	Vertical height 50 mm	Vertical height 100 mm
	Time (Seconds)	Time (Seconds)	Time (Seconds)
0.5%	7	49	277
1.0%	6	50	360
1.5%	8	64	394
2.0%	10	122	638

From table-3 it can be seen that pulp synthesized using 0.5% NaOH has low wicking time which indicates faster capillary action due to the presence of fibres. Increasing the concentration of NaOH, results in more pulp formation and less fibre content thereby low capillary action and high wicking time.

Water retention property of bagasse pulp sheet

Water retention capacity of an absorbent is the maximum volume of water which can absorb per gram of material and is expressed in ml/g or g/g. To determine the water retention property of pulp sheet, two layers of pulp sheets were weighed and fixed on a stand which is kept at 45° inclined angle and coloured water is added on the top of sheet at a rate of 5ml/min from the burette of 50 ml capacity. Water will absorb on the pulp sheet from top and gradually down to bottom of sheet till it saturates. The flow from the burette is stopped when the first drop of water comes out of the sheet. Burette reading is noted and water holding capacity is calculated as g/g. Time taken to absorb the water is also noted. Water retention capacity of bagasse sheets synthesized from 0.5 % 1.0% and 1.5% concentration of NaOH is given in Table 4.

Table-4 Water retention capacity of bagasse pulp sheet

Concentration of NaOH	Weight of Bagasse pulp sheet (g)	Absorption time (min)	Volume of water (ml)	Water retention capacity (ml/g)	Average (ml/g)
0.5%	3.9290	3.0	25.0	6.3	6.15
0.5%	4.7832	5.0	28.9	6.0	
1.0%	3.8985	2.5	30.0	7.7	7.7
1.0%	3.7428	2.5	29.0	7.7	4.4
1.5%	3.4196	3.0	15.6	4.5	
1.5%	3.7095	3.2	16	4.3	

From Table 4 it can be seen that bagasse pulp synthesized using 0.5%, 1.0% and 1.5 % NaOH have an average water holding capacities of 6.15 ml/g, 7.7 ml/g and 4.4 ml/g respectively. This clearly indicates that pulp synthesized using 1.0% NaOH is having higher water holding capacity than 0.5% and 1.5% NaOH. Absorption time is also lowest for the pulp synthesized using 1.0% NaOH.

From the above various trials of synthesis of bagasse pulp using NaOH, and based on the performance of the bagasse pulp sheet, it is observed that pulp synthesized using 1.0% NaOH is

having better water absorption and water holding capacity. This pulp sheet is found to be more soft/flexible than the pulp synthesized using 0.5% and 1.5% NaOH. Hence, in laboratory scale, about 100 bagasse pulp sheets of approximately 30 cm length and 9 cm width and 2mm thickness were synthesized from bagasse using 1.0% NaOH. Since our objectives were to develop sustainable hygiene products from sugarcane bagasse, utmost priority has been given to eco friendliness and biodegradability without compromising the performance and comfort level. Eco friendliness was evaluated by testing a few eco parameters such as Plasticizer, Chlorophenols, Formaldehyde and Bisphenols. Biodegradability was evaluated by conducting soil burial tests. Performance evaluations were made with respect to tests of absorption capacity and rate of absorption Fig 1 and Fig 2 are the photographs of sugarcane bagasse and pulp sheets synthesized from SCB.



Fig.1 Sugarcane bagasse



Fig.2 Pulp sheet synthesized from SCB

SCB sanitary napkin prototype design

About 30 SCB sanitary pads were prepared in the laboratory for conducting performance evaluation. SCB napkins consist of one hydrophobic cotton fabric in top layer and 3 middle layers of SCB pulp sheets followed by one inner layer of absorbent cotton gauze fabric. These three layers were stitched together throughout their outer border after giving the shape of a sanitary napkin. Most of the branded commercial sanitary napkins consist of a polyethylene sheet in the outer layer, cotton fibre or super absorbent polymer (SAP) in the middle layer and perforated polypropylene sheet in the inner layer. These three layers will be thermally bonded. Since SCB napkins have no thermoplastics, all the layers have been stitched together. A photograph of a SCB sanitary napkin and its cross section is given in Fig 3 and 4 respectively.

Fig.3 is the photograph of prototype SCB sanitary napkin and Fig.4 is the photograph of different layers of SCB napkins.



Fig.3 photograph of SCB napkin



Fig.4 photograph of Different layers of SCB sanitary napkin

Conclusions

In the present study, we produced laboratory scale sugarcane bagasse based sanitary napkins. SCB sanitary napkins are promising solutions in the form of cost effective, hygiene and sustainability. 1.0 % NaOH is sufficient enough to convert bagasse to a soft absorbent pulp which can replace super absorbent polymers used in branded commercial napkins. SCB pulp sheet proved to be a good alternative for manufacturing of biodegradable sanitary napkins. The developed SCB napkins have demonstrated their efficacy through a series of laboratory tests. The absorbent tests have confirmed the SCB napkins have excellent fluid absorption capacity over a few commercial sanitary napkins. The developed SCB napkin is found to be free from all the toxic substances and is fully biodegradable as no synthetic materials are being used during the production. Since bagasse is a waste material and converting a waste material to a value added product with a green technology is the novelty of this project work. The developed SCB napkin can be economically manufactured by rural women particularly in regions where sugarcane industry is available. Overall a new path has been opened for the entrepreneur to initiate a plan to produce economically affordable, eco friendly and sustainable sanitary napkins.

4. Centre of Excellence for Geotech

BTRA (Bombay Textile Research Association) is recognized 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 standards, accredited by NABL (India) as per ISO/IEC 17025 and GRI, USA. Earlier manufacturers of geosynthetics and the User Industry were sending their samples to foreign laboratories, spending a lot of money and time. Now they save both money (3 to 5 times) and time. At the same time, they witness the test to get confidence in the test report which is not possible with foreign laboratories. BTRA has an excellent Asphalt and Soil testing laboratory facility.

BTRA is the second commercial Geotech laboratory in Asia accredited by GRI, USA. BTRA has an information resource centre 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 needle punching nonwoven development facility. Nonwoven manufacturers have used this facility for the development of nonwoven products for technical application. 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 imparts training to entrepreneurs, students, and industry persons regarding the development of products and testing. Few entrepreneurs have started manufacturing geotextile after taking training in BTRA. BTRA continuously helps the industry resolve its process or product-related issues (especially the nonwoven industry).

BTRA is engaged in the development of test standards and specifications for the Bureau of Indian Standards. BTRA also actively participated in establishing the specifications for Woven / Nonwoven geo bags for the Ganga Flood Control Division, Ministry of Water Resources.

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

4.1 Infrastructure

Product Development and Pilot Facility

Nonwoven

- DILO needle punching pilot plant

Woven

- Local Sizing and Single-end warping machine

Electrospinning Unit:

For nanofibers spinning for different applications.

Plasma Processing Unit:

For imparting various finishes on fabrics (Hydrophobic, Hydrophilic, Antistatic, Antimicrobial, Antibacterial, etc).

Nonwoven Product Developments

*Needle-punched nonwoven geotextiles developed for manufacturers from Synthetic (Polyester and Polypropylene) and Viscose Rayon Fibres Spunlace nonwoven developed from Viscose Rayon Fibres

Various Geotextiles were developed as per the specifications given by the manufacturers.

4.2 Testing Facility

BTRA has fully-fledged testing laboratories. All laboratories are accredited by NABL, India as per ISO 17025. Whereas Geotech Laboratory is accredited by GRI, USA also apart from NABL. BTRA's Geotech Laboratory is the second commercial Laboratory in Asia. This laboratory now full fills the requirements of manufacturers and the user Industry.

Earlier manufacturers were sending their products to Foreign Laboratories and the huge amount paid by them. Due to BTRA Geotech laboratory, now they save a considerable amount in testing.

Geosynthetics

BTRA is recognized (based on earlier experience, expertise, and facility) as a Centre of Excellence for Geotech by the Ministry of Textiles, Government of India. State-of-Art facilities for testing Geotech are set up at BTRA. The new laboratory has all testing facilities for geosynthetic products like Geotextiles, Geomembranes, Geocomposites, Gabions, Geosynthetic Clay Liner, Geogrids, Prefabricated Vertical Drain, etc. Also, BTRA is strengthening its information resources on Geotech by procuring various books and test methods.

The Geotech Laboratory at BTRA is accredited by the Geosynthetics Institute (GSI), Folsom, Pennsylvania, USA under the GAI – LAP Accreditation Programme for 27 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 laboratory. They can get the tests done in India, thus saving time and money without compromising on the quality of the results.

For Raw materials: Full fledge Polymer Laboratory accredited by NABL. (Having testing facilities such as DSC, FTIR, X-Ray Diffraction, TGA, etc)

For Yarn and Fabric: Physical Testing Laboratory accredited by NABL for Fibres, Yarns, and all types of Fabrics.

Chemical testing Laboratory: Almost all Chemical tests of geosynthetics are possible. Laboratory accredited by NABL.

Microbiology testing Laboratory: Microbiological Testing Laboratory accredited by NABL.

Soil Mechanics and Asphalt Materials laboratory

The 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 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, bitumen tests, aggregate tests, binder extraction and recovery 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 test, field CBR test, plate bearing test on soil, filed vane shear, filed density of bituminous pavements, lightweight deflector meter, and core cutting of pavements.

4.3 Training

As BTRA has different plants for the manufacturing of Nonwoven, Woven fabrics and processing with Plasma and Nano technology, BTRA can offer practical training on the same. Also, BTRA imparts practical training in the testing of Geosynthetics and other technical Textiles along with chemical and Polymer testing.

4.4 Consultancy

BTRA gives consultancy in the setting up of manufacturing Plants, Setting up of Testing Laboratory, and accreditation of Laboratory, Product development. BTRA also gives consultancy for overcoming problems in nonwoven geotextile manufacturing and improving the quality.

4.5 New Test Method

- Rutting test on Asphalt mixture – ASTM D8292
- Superpave mix design for asphalt mixtures – Asphalt Institute MS-2
- Fatigue Four-point bending – ASTM D5
- Dynamic Shear Rheometer – IS 15462 – 2019
- Development of Advance Asphalt binder laboratory

4.6 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).

5. 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 is 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. The total number of certificates issued for Mass, Volume, and Balance in the last financial year was 203.

6. 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 the 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 Providers 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, maybe 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.

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- 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.
- The 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) the determination of assigned value for each measured or characteristic of the proficiency test item (i.e sample), (ii) the 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 in 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.

From April 2024 to March 2025,

- a. BTRA has completed two PT programs as per ISO/IEC 17043:2010 covering Mechanical, Chemical and Analytical tests. A total of 39 and 46 textile testing laboratories respectively from different parts of the country and abroad have participated in these PT programs.
- b. We have recently launched another PT program in Mechanical and Chemical tests of Fabric and Yarn recently in Jan 2025.

We have received a good response from the laboratories as well and our reports were well accepted by the users.

➤ New Test Facility incorporated

- ✓ Pressure Sensitive Adhesive Tape Testing
- ✓ Circular Bending
- ✓ High Performance fibre testing

7. 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.

7.1 Overview

- Technical investigations carried out : 66
- Technical enquires attended : 108
- Local mill visits made [man-days] : 30
- Outstation mill visits made [man-visits] : 29

7.2 Type of Assignments Undertaken

- Handbook preparation- BTRA norms for weaving
- LAPF Evaluation and Improvement Program
- Consultancy for Venner dyeing
- Time Motion Study
- Bulk to Bulk shade consistency audit
- Competency assessment of workers
- Garment stitching machines valuation
- Work load study for weaving and processing
- Development of sizing specifications for School Uniform
- Lab set up work

8. TESTING SERVICES

Testing activities continued to receive a good response from the industry in the wake of new testing services [microbiology / technical textiles] starting and thrust given on special testing apart from physical/chemical testing.

8.1 Overview

BTRA Test Laboratories has undertaken a 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 44981. Details are as follows.

Test Particulars	Number of Tests
Physical Testing	11877
Chemical Testing and Eco-parameters, Chemicals / Dyes / Auxiliaries Testing and Material Testing (non-textile items, water, oil, etc.)	10529
Eco Testing	1889
Defect Analysis	380
Geotextile Testing	12704
Soil Testing	187
Microbiology Testing	829
Scanning Electron Microscope	1423
Special Testing (Flammability, static charge, FTIR / DSC / TGA / X-ray / GPC studies, Melt spinning trials, etc.)	4966
Calibration Testing	197
TOTAL TESTS CONDUCTED	44981

8.1.1 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.

8.1.2 New Machinery / Instruments added

- X-7259-K Ballast Kit , Xe-3
- 12 W Electric Baby Boiler
- Ultrasonic sonicator with accessories LMUC6D
- Water Transmission Tester
- Knitting machine
- Gyratory Compactor and automatic asphalt mixer with automatic softening point attachment
- Micro pore analyzer
- APT/S Auto Air Permiability Tester
- Water Vapour Transmission Rate Tester SKU : W3/031
- Split Roller grip capacity 250Kn
- Automatic asphalt compactor and shaper ACS30
- Electrolux wascator FOM71 CLS
- Precision cutting machine
- Shimadzu Gas Chromatograph Mass Spectrometer QP-2020 NXEI
- Stand alone servo pneumatic four point bending system
- Absolute and kinematic viscosity testing equipment
- Compression testing machine
- Laboratory muffle furnace with digital temperature control
- Electric Steam Boiler and Steam Chamber
- Hot Air Oven
- UHMwPE Spinning Machine Line
- Tensile Testing Machine
- Lab scale type plunger dry jet wet spinning machine
- Decay Meter
- Flexural attachment for CTM Automatic
- UTM 30KN standard actuator servo-hydraulic machine with accessories
- Shimadzu Universal Testing Machine

8.1.3 New Test Methods Launched

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

- Pressure Sensitive Adhesive Tape Testing
- Circular Bending
- High Performance fibre testing
- Rutting test on Asphalt mixture – ASTM D8292
- Superpave mix design for asphalt mixtures – Asphalt Institute MS-2
- Fatigue Four-point bending – ASTM D5
- Dynamic Shear Rheometer – IS 15462 – 2019
- Development of Advance Asphalt binder laboratory

8.2 Technical Textiles Testing

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

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- ❖ MEDICAL TEXTILES
- ❖ OTHER TECHNICAL TEXTILES - Narrow Fabrics, Conveyor Belts up to 13 Mm Thick [Dumbbell 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 meter, weight per linear meter, 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 meter.
- ✓ 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 450, Horizontal Burning Rate, Pill (Camphor / Methenamine) 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 450, 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°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°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°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.
- ➔ **Carbon composites:** Strength, Flexural modulus

8.3 Special Testing

Apart from undertaking tests of fibres, yarns, and fabrics (for physical as well as chemical properties), numerous special tests (that are most sought after) are conducted at BTRA. The same are widely availed by the industry. The types of tests conducted here are as follows.

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

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

✓ **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 the Master batch

✓ **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°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

8.4 Eco-Parameters Testing

The following types of tests are undertaken at BTRA. 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
- Plasticizer/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.
- Analysis of free & unreacted monomers
- Analysis of cyclosiloxines (D4,D5,D6)
- Analysis of solvents
- Volatile Organic Carbon (VOC's)...

And many more

8.4.1 New test methods launched :

1. During the year two new GC MS test methods have been developed. They are analysis of specific migration of restricted substances in food packing containers and Fatty Acid Methyl Ester (FAME) in hygiene products.

New Instruments Purchased:

Ecolab has purchased a new GC MS (Shimadzu QP 2020 NX) under two joint projects. One project entitled “Sustainable aroma finish for textiles” sponsored by RGSTC and another project entitled “Development of sustainable products from sugarcane bagasse” sponsored by BTRA (internal project).

NABL Activities:

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

8.5 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. The types of tests conducted at this laboratory are 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]

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- 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
- 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)
- AATCC 30 Part 1 is a soil burial test for materials intended to come into direct contact with soil. Standard testing for Part 1 runs for 2 weeks but can last up to 6 weeks.
- EN 12225:2020- Geosynthetics - Method for determining the microbiological resistance by a soil burial test.
- Determination of percent degradation by In-House method.
- IEC 60068-2-10 Environmental testing - Part 2-10: Tests - Test J and guidance: Mould growth.
- ISO 846 – Antimicrobial Test – Plastics
- ASTM D 5511- Standard Test Method for Determining Anaerobic Biodegradation of Plastic Materials Under High-Solids Anaerobic-Digestion Conditions
- CEN/TS 14416:2014: Geosynthetic barriers- Test method for determining the resistance to roots

... And many more

8.6 Soil Mechanics and Asphalt Testing

- Specific Gravity fine aggregate - IS 2720 (part 3 & sec 1): 1980 (RA 2016)
- Liquid limit IS 2720 (part 5): 1985 (RA 2015)
- Plastic limit IS 270 (part 5): 1985 (RA 2015)
- Shrinkage limit IS 270 (part 6): 1971 (RA 2015)
- Direct shear IS 2729 (part 13): 1986 (RA 2015)
- Swelling pressure IS 2720 (part 41): 1977 (RA 2016)
- CBR IS 2720 (part 16): 1987 (RA 2016)
- Vane shear IS 2720 (part 30): 1980 (RA 2016)
- Free swell index IS 2720 (part 40): 1977 (RA 2016)
- Water content dry density heavy compaction IS 2720 (part 8): 1983 (RA 2015)
- Sieve analysis and hydrometer IS 2720 (part 4): 1985 (RA 2015)
- Consolidation test IS 2720 Part 15: 1973
- Field CBR test IS 2720 part 31

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- Rutting test on Asphalt mixture – ASTM D8292
- Superpave mix design for asphalt mixtures – Asphalt Institute MS-2
- Fatigue Four-point bending – ASTM D5
- Dynamic Shear Rheometer – IS 15462 – 2019
- Development of Advance Asphalt binder laboratory
- Concrete lab
- Resilient modulus - Asphalt
- Dynamic creep – Asphalt
- Indirect Fatigue test – Asphalt
- Semi circular bending test - Asphalt
- Pullout testing machine
- ... ***And many more***

8.7 Activities:

Performed bituminous mix design and conducted asphalt testing for numerous high-profile projects including the Coastal Road Project, Navi-Mumbai Airport, Thane Creek Bridge-Mumbai, Mumbai-Pune expressway.



Dynamic Shear Rheometer



Fatigue four-point bending



***Gyratory compactor –
Superpave mix design***



Advance Asphalt binder testing lab

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 Appendix9.

Powerloom Service Centres (PSCs)

BTRA runs three Powerloom Service Centers (PSCs) [at Ichalkaranji, Solapur, and Madhavnagar-Vita]. To improve the quality, operating efficiency, and productivity of the 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 centres are given in the following Table2.

Table 2: Activities of BTRA Powerloom Service Centres

Activities		Ichalkaranji	Solapur	Madhav-Nagar-Vita
Total yarn and fabric samples tested for physical & chemical properties		9128	6081	374
Number of technical assistance/troubleshooting/consultancy given		233	582	24
Total number of persons trained		275	220	87
Total number of trainee man-days		3781	3094	1442
Total seminars/workshops conducted		10	5	4
Survey of the closure of power looms	Units	421	408	342
	Looms	5062	10734	3098
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		2	--	1
Number of samples for design development [non-CAD] / Analysis		--	--	--

9. INFORMATION DISSEMINATION / INDUSTRY INTERACTION

- ❖ In an exclusive interaction with The Interview World, Dr. T. V. Sreekumar, the esteemed Director of BTRA, provided illuminating insights into the institute's multifaceted research and development initiatives. Dr.T.V. Sreekumar underscored BTRA's significant contributions to advancing high-performance carbon fiber and elucidated its diverse applications across various industries. He further emphasized how BTRA's endeavours fulfil the government's strategic vision, particularly in the context of domestically manufacturing high-performance carbon fiber, thereby fostering self-reliance and technological advancement. His insightful interview is available on: <http://theinterview.world/btra-strives-to-commercialize-carbon-fiber-technology>
- ❖ Dr. T. V. Sreekumar, Director, BTRA was the panellist at the National Symposium on Advancements in Composites, Speciality Fibres and Chemicals, at India Habitat Centre, New Delhi on 9th May 2024.



❖ BTRA conducted the training and consultancy services to solve problems of quality, maintenance, and productivity at various levels for the textile units, as follows:

- a. Training on LAPF evaluation and improvement program at True colour pvt Ltd, Navasari in May 2024.
- b. Training on Good manufacturing practices at Kadri Woven-SIPCOT, Perundurai in May 2024.
- c. LAPF evaluation at M/S Arvind Mills Limited Ahmadabad, September 2024
- d. Arvind and Grasim Team-Technical points discussion in Ahmadabad, September 2024
- e. BTRA/Birla cellulose jointly organised Seminar on Energy conservation and Good manufacturing practices at Tirupur on 13th December 2024
- f. BTRA jointly with Grasim Industries and Thermax conducted seminar in good manufacturing practices and energy conservation in textile processing at Tirupur Liva studio on 9th October 2024
- g. BTRA jointly with Grasim Industries and Thermax conducted seminar in good manufacturing practices and energy conservation in textile processing at Noida, New Delhi on 17th October 2024
- h. Mr. Vijay Shirole achieved certification for Water auditor from Water audit council , New Delhi
- i. BTRA/Birla cellulose jointly organised Seminar on Energy conservation and Good manufacturing practices at Surat on 9th January 2025.
- j. BTRA/Birla cellulose jointly organised Seminar on Energy conservation and Good manufacturing practices at Jaipur on 29th January 2025.
- k. BTRA conducted training on Training in Textiles for Sehyog Enterprises- Ms Navreesh Kaur from 24th Feb 2025 to 4th March 2025 for one participant.



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BTRA, Arvind and Grasim team - technical points discussion -LAPF audit at M/s Arvind Ltd Ahmedabad



LAPF evaluation at M/s Arvind mills limited, Ahmedabad- closing meeting for technical discussion for improvements at shopfloor



BTRA jointly with Grasim Industries and Therman conducted seminar on GMP and Energy saving in textile processing at NODA delhi on 17/10/2024



Dr. T V Sreekumar in Association with BTRA Mumbai
Member's seminar on textile manufacturing process and
Management at Noida on 29/11/2024

- ❖ Dr.T V Sreekumar attended and the National Conference on Recent Advances in Composites-2024 held on 8th and 9th November 2024 at Taj Dccan, Banjara Hills, Hyderabad.He also delivered the lecture on Recent advances in Carbon fibre precursor development under National Technical Textile Mission.
- ❖ BTRA attended the228th Mid-Term Council Meeting of the Indian Roads Congress (IRC) and had the opportunity to present research on "Evaluating the Tack Coat Compatibility and Performance of Geogrid Reinforced Asphalt Pavements."



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❖ BTRA visited the following Textile Units in Kolkata in the month of June 2024.

- | | |
|-----------------------------------|---------------------------------|
| a) Pioneer Textiles :Ranaghat | d) Bongtex :Shantipur |
| b) ManomohanTextiles :Ranaghat | e) TagDevelopers Pvt.Ltd.:Gurap |
| c) BhishnupriyaTextiles: Ranaghat | |



❖ The Bombay Textile Research Association (BTRA) Welcomes New Textile Minister Shri. Giriraj Singh, Smt. Rachna Shah (Textile Secretary) Shri. Rajeev Saxena (Joint Secretary), Smt. Roop Rashi Mahapatra (Textile Commissioner), Shri. S P Verma (Joint Textile Commissioner) on 13th July 2024. Main objective of the visit is to understand the activities of the research Institute, Center of Excellence and review the projects under NTTM.

The Minister visited BTRA premises and various labs of BTRA, the main attraction was the carbon fiber precursor pilot plant, which was recently started and open for industry for carbon fiber sampling and manufacturing. After the visit there was a small presentation with BTRA and BTRA council members. BTRA presented their innovation, research and various activities.

BTRA has proposed 800 tons per annum carbon fiber precursor plant in any of the Textile Park.

BTRA also showcased its ability to produce 1K,2K,3K and 4K precursor tows.

The Minister was overwhelmed and confident on the BTRA CAPABILITY.

SASMIRA shared some success stories about their researched products.

The Wool Research Association (WRA) also presented their activities and various innovative projects.



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- ❖ The Memorandum of Understanding (MoU) has been signed between The Bombay Textile Research Association (BTRA) and Thermax(Pune) for the energy conservation activities for Textile sector - on the 14th of August 2024.



MoU signed with BTRA and Thermax for the energy conservation activities for Textile sector - on the 14th of August 2024

- ❖ The Memorandum of Understanding (MoU) has been signed between The Bombay Textile Research Association (BTRA) and ARCI (Hyderabad) - on 12th of August 2024



MoU signed with BTRA(Mumbai) and ARCI (Hyderabad) - on 14th August 2024

- ❖ The Memorandum of Understanding (MoU) has been signed between The Bombay Textile Research Association (BTRA) and IFBEC for training and sustainability in Textile sector in November 2024.



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- ❖ BTRA attended FICCI Bharat R&D Summit 2024, a two-day Conference to be held from 03rd-04th October 2024 at FICCI, New Delhi

Aims to strengthen the connection between industry and academia. It emphasizes the importance of fostering communication among stakeholders and implementing policy reforms to support the country's innovation ecosystem. The conference aligns with the Government of India's efforts to promote a dynamic R&D culture and elevate India's position in the global innovation landscape.

Key Highlights of the Summit:

- ✓ Commercialization of Research
- ✓ Role of S&T Clusters in Industry-Academia Linkages
- ✓ Case Studies in Industry-Academia Collaboration
- ✓ Research Opportunities in AI
- ✓ Quantum Technologies: Role of Academia & Industry
- ✓ R & D Funding
- ✓ Showcase of Research Work

The focus of the summit is to facilitate and strengthen collaboration between industry and academia. This will be achieved through in-depth discussions regarding the potential opportunities and by shedding light on the key challenges that need to be addressed. More details available on <https://textilevaluechain.in/news-insights/ficci-bharat-rd-summit-2024>

- ❖ BTRA attended Road Development of India conference was held on **November 21-22, 2024**, in, Mumbai

The **mission** of this conference is to discuss the key trends and developments in the road sector, highlight new initiatives, discuss risks and challenges, and identify future growth areas. The conference will also provide a platform to showcase some of the innovative technology solutions and sustainable practices being deployed.

- ❖ BTRA attended Indian Roads Congress 83rd Annual Session, 8th to 11th November, 2024 at Pandit Dindayal Upadhyay Auditorium & Science College Ground GE Road Raipur (CHHATTISGARH).

On the Invitation of Government of Chhattisgarh, the 83rd Annual Session of Indian Roads Congress will be held at Pandit Deendayal Upadhyaya Auditorium and Science College Ground, GE Road, Raipur (Chhattisgarh) from 8th-11th November, 2024. This important event commenced with the inauguration by Union Minister for Road Transport and Highways, **Shri. Nitin Gadkari**.

Over 3,000 participants are attended the convention. This includes experts, scientists, and engineers from across India. Their collective expertise enriches discussions and technical sessions. The diverse representation encourages collaboration among various stakeholders.

During the Annual Session of IRC, there has been a practice for various firms/organizations to make Technical Presentations on their products/technologies & case studies.

BTRA (The Bombay Textile Research Association) is thrilled to share that BTRA recently participated in the prestigious Indian Roads Congress (IRC) Annual Session. Our team had the opportunity to present our latest research on geosynthetic reinforced asphalt pavements. This innovative approach is paving the way for more durable, sustainable, and cost-effective road infrastructure.

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In addition to showcasing our research, we also highlighted the capabilities of our Center of Excellence (COE) in geotextile and testing facilities for asphalt and soil. Our state-of-the-art facilities are dedicated to advancing industry standards and fostering innovation in pavement engineering and geosynthetics. More details available on <https://www.technicaltextiles.in/83rd-indian-roads-congress-annual-session/>

❖ BTRA scientists received following Certificate of Appreciation from the industry;

- ➔ Dr.ShitalPalaskar has been honoured with Advance Materials Young Scientist Medal in recognition for their contribution to Nanomaterials and Nanotechnology in 61st Assembly of Advanced Materials Congress on 24th to 26th September 2024 at Jodhpur, India.
- ➔ Ms.Afreen Begum has been received Certificate of Appreciation for presenting the paper in 37th National Convention of Textile Engineers and National Seminar on “Quality, profitability and sustainability in Textiles” 28th to 29th September 2024 at Brilliant Convention Centre, Indore.

❖ BTRA Creates Cutting-Edge Precursor Fibres for Superior Carbon



The Bombay Textile Research Association (BTRA) is pleased to report significant progress in the manufacturing of premium precursor fibres designed especially for the fabrication of high-performance carbon fibres.

Significant progress has been achieved by the Bombay Textile Research Association in creating premium precursor fibres that are intended especially for the production of high-performance carbon fibres. Under the direction of BTRA Director Dr. T V Sreekumar, BTRA has created two distinct kinds of precursors: CNT-reinforced PAN (PAN/CNT) precursor fibre and ordinary polyacrylonitrile (PAN) precursor fibre.

Unleashing the Power of Carbon Fibre: Carbon fibres are widely used in a variety of sectors, such as sports equipment, automotive, aerospace, and construction, due to its remarkable strength, stiffness, and lightweight nature. BTRA's These amazing carbon fibres are made from state-of-the-art precursor fibres, which allow for the creation of novel and high-performing materials. Excellent strength equivalent and above 600 MPa, a necessary benchmark strength for the creation of high-performance carbon fibres, are possessed by both of these precursors, PAN and PAN/CNT fibres. We routinely produce up to 720 PAN precursor fibres MPa.

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Even superior qualities are displayed by the PAN/CNT precursor fibres, which have greater strength and less shrinking than the PANOX version. In light of the advancements brought forth by these findings, the PANOX fibres.

Due to their improved graphitic structure, PAN/CNT precursors should show notable performance features. With its state-of-the-art research facility built as the centrepiece of the National Technical Textile Mission (NTTM) project, BTRA is currently able to produce these cutting-edge precursor fibres in the two sizes of 1K, 2K, 3K, and 4K filaments. With this expertise, BTRA is positioned at the cutting edge of material science, where it can play a major role in supplying precursor fibre for carbon fibres needed for vital applications including defence and aerospace. More details available on <https://www.technicaltextiles.in/btra-creates-cutting-edge-precursor-fibres-for-superior-carbon/>

- ❖ BTRA jointly organized Birla cellulose, BTRA and Thermax jointly organized the seminar on "Good work practices in textile process house" and "Energy Conservation in Textile processing " on 10th Oct 2024 at LIVA studio Tirupur . The processors from across Tiruppur and SIPCOT Perundurai and Erode zone participated in the event.

The feedback received was overwhelmingly positive, with many attendees expressing appreciation for the topics discussed. They found the information relevant and beneficial for implementing these energy conservation measures and good work practices in their operations.

- ❖ BTRA celebrated the "National Safety Week 2025" on 4th to 7th March 2025 at BTRA premises: The event was inaugurated by the esteemed Director Dr. T.V. Sreekumar, various Safety Awareness Lectures were organised by BTRA.



- ❖ BTRA organised the A session on Organisational Effectiveness through Self Development by Shri. Sandesh C Kadam, Ex-President-Reliance Industries Limited on 26th March 2025.



9.1 Papers Presented & Published

Many research papers of topical interest are presented in various meetings and published in journals. The same are given in Appendix–2 and 3.

9.2 BTRA Publications / Library

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 also it receives around 2 foreign and 20 Indian journals/magazines/newsletters regularly. BTRA updates its website (www.btraindia.com) at regular intervals.

9.3 Academic Activities

BTRA offered an internship to 30 students from various technical education institutes during the period under review.

10. EXHIBITION and CONFERENCE PARTICIPATION

- ❖ BTRA participated in the following exhibitions and various research publications and posters depicting the research and consultancy activities of BTRA were displayed during the occasion.

- a) FABTEX-2025, 18th Edition to Fibre & Yarns Expo. at Jio World Convention Centre, Bandra, Mumbai between 23rd February to 25th January 2025



BTRA Stall view at Fibre N Yarns Expo 2025

- b) BHARAT TEX-2025, Global Textile Expo at Bharat Mandapam, New Delhi between 14th February to 17th February 2025.

Hon'ble Prime Minister-Shri Narendra Modi visited at BTRA stall during the BHARAT TEX-2025, Global Textile Expo at Bharat Mandapam, New Delhi. **Dr. T. V. Sreekumar**, Director, BTRA, welcomed the Ministers at BTRA stall and explains on BTRA Develops Advanced Precursor Fibers for High-Performance Carbon Fiber. The Carbon fiber precursor pilot plant, which was recently started and opens for industry for carbon fiber sampling and manufacturing. BTRA also discussed about the other R&D innovation, research and various activities during the meet.



Dr.T.V.Sreekumar, Director,BTRA interacts with Hon'ble Prime Minister Shri. Narendra Modi during Bharat Tex-2025



BTRA Stall views in Bharat Tex – 2025 Exhibition

- c) BTRA participated in the Nonwoven Tech Asia 2024 during 22-24th August 2024 at Bombay Exhibition Centre, Mumbai. Various research publications and posters depicting the research and consultancy activities of BTRA were displayed during the occasion.



BTRA Stall view in Nonwoven Tech Asia Exhibition 2024

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- d) BTRA participated in the TECHTEXTIL Frankfurt in Germany during 23rd -26th April 2024. Various research publications and posters depicting the research and consultancy activities of BTRA were displayed during the occasion.



BTRA Stall view in TECHTEXTIL Frankfurt in Germany during 23rd -26th April 2024

11. Acknowledgements

The major portion of R & D's work at BTRA is based on the financial assistance provided by the various sponsoring agencies. 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(BRNS), Department of Atomic Energy(DAE), Defence Research and Development Organizations (DRDO), Ministry of Defence(DAF), Government of India. Thanks are also due to members of BTRA for giving constant encouragement to BTRA scientists/technologists to continue their work in uplifting the industry.

RESEARCH PROJECTS

Ministry of Textile, Government of India

- ➔ Development of Carbon Nanotube Reinforced Acrylic Precursors for Carbon Fibre
- ➔ Development of Alkaline Resistance Polyester for Geosynthetic Applications
- ➔ Development of High-Performance Gel Spun UHMwPE Fibres and Tapes for Bullet Proof and Geo-Grids/Geo-Composites Application
- ➔ The Development of treated Geosynthetic reinforced Asphalt Pavements
- ➔ Plasma Assisted Waterless Dyeing of High-performance Textiles using Supercritical Fluid for Application in Technical Textiles
- ➔ Development of Flame Retardant Aircraft Interior Fabrics by Plasma Assisted Chemical Treatment
- ➔ Development of Spinnable grade Meta- and para-aramid Polymers and their fibre-spinning
- ➔ Preparation of Lyocell CNT Composite High Strength Carbon Fibers
- ➔ Preparation of cellulose/silica-based aerogels and its composite for thermal insulation application

Defence Research and Development Organisation

- ➔ Atmospheric plasma assisted dyeing of polypropylene with graphene nanomaterial to impart antistatic and conductive properties

Board of Research in Nuclear Sciences

- ➔ Effective Electron Beam treatment along with biological treatment for Textile wastewater

Rajiv Gandhi Science & Technology Commission

- ➔ Development of Nanoparticles coated fabrics for antimicrobial focusing on antiviral applications
- ➔ Sustainable Aroma Finish for Textiles and its Commercialization using Maharashtra Flora

Bureau of Indian Standard, Ministry of Consumer Affairs

- ➔ Development and validation of test method for determination of chlorinated organic carriers in textile and textile product

In-house Projects:

- ➔ Development of Sustainable Hygiene products from Sugarcane Bagasse
- ➔ Centre of Excellence for Geotech
- ➔ BTRA powerloom service centre – Ichalkaranji
- ➔ BTRA powerloom service centre – Solapur
- ➔ BTRA powerloom service centre – Madhavnagar

PAPERS PUBLISHED IN JOURNALS

Authors Name	Title of the Paper	Journal Name
Tanaji Kadam	Energy conservation audit and approaches for energy saving in textile process house - Part 2	"BTRA Scan" - Vol. LIII No. 2- April, 2024, Page no. 1 to 4
M.P Sathianarayanan, Karishma Hemani and Shraddha Gaonkar	Analysis of sugar composition in honey samples using HPLC separation and RI detection	"BTRA Scan" - Vol. LIII No. 2- April, 2024, Page no. 5 to 8
Yogesh Hande	A concise overview of the aramid fiber spinning process	"BTRA Scan" - Vol. LIII No. 2- April, 2024, Page no. 9 to 16
Tanaji Kadam	Energy conservation audit and approaches for energy saving in textile process house- Part 3	"BTRA Scan" - - Vol. LIII No. 3- July, 2024, Page no. 1 to 4
Supriya Sonawane, Shital Palaskar	Review on Benzophenone and its derivatives used as UV absorbers in textile	BTRA Scan" - - Vol. LIII No. 3- July, 2024, Page no. 5 to 16
Komal Kukreja, Prasanta K. Panda	Review on chemical resistance of geosynthetic materials	"BTRA Scan" - Part 3- Vol. LIII No. 3- July, 2024, Page no. 17 to 27
Amol G. Thite, Atanu Jha, Subhendu Ray Chowdhury, Ravindra D. Kale, Kalpak P. Patil	Effect of Electron Beam Irradiation on Triallyl Isocyanurate Grafting and Thermo-mechanical Properties of Sheep Wool Fabric	Fibers and Polymers https://doi.org/10.1007/s12221-024-00684-4
Komal Kukreja, Prasanta K. Panda	Aramid fiber, its composites and application	Synthetic and Mineral Fibers, Their Composites and Applications. (2024). United Kingdom: Elsevier Science, ISBN: 9780443136238, eBook ISBN: 9780443136245
Prasanta K. Panda and Geetanjali Mishra	Impact of surfactants on SWCNT dispersion in N-methylmorpholine N-Oxide	Journal of the Indian Chemical Society' https://doi.org/10.1016/j.jics.2024.101210
Amol G. Thite, Ravindra D. Kale, Prasanta K. Panda	Development of highly bacterial filtration efficient and antibacterial cellulose acetate/gum rosin composite nanofibers for facemask application	International Journal of Biological Macromolecules
Shreyasi Nandy, T.V.Sreekumar, Shital Palaskar and Neha Mehra	Plasma-assisted incorporation of flame-retardant chemicals for improved flame retardancy of polyester fabricss	Polym Eng Sci. 2024;1-15.doi:10.1002/pen.26924
Sandeep Padmakar Jape	Energy Rheology of UHMWPE/ solvent systems: A literature review	BTRA Scan" - Vol. LIII No. 4- October, 2024, Page no. 14 to 25
Amol G. Thite, Geeta P. Jawdekar, Manasi D. Kadam, Soumya S. Behera	Root Cause Analysis of Textile Defects Using Scanning Electron Microscopy	BTRA Scan" - Vol. LIII No. 4- October, 2024, Page no. 5 to 13.

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Omkar Sadalkar, Shital Palaskar	A Comprehensive Review of High Performance Synthetic Fibers for composite Materials & it's Application	BTRA Scan" - Vol. LIII No. 4- October, 2024, Page no. 26 to 31.
Vijay Shirole	Carbon footprint assessment in textile wet processing industries	Textile Value Chain (TVC) https://textilevaluechain.in/in-depth-analysis/carbon-footprint-assessment-in-textile-wet-processing-industries , Nov-24
Vijay Shirole	Carbon footprint assessment in textile wet processing industries	Indian Textile journal (ITJ) https://indiantextilejournal.com/carbon-footprint-assessment-in-textile-wet-processing-industries/ , Dec-24
Chandel, N., Kapurderiya, M.P., Kanse, A.C., Rohini, R. and Sreekumar T.V	Oxygenated moiety enhanced thermal stabilization, mechanical, and thermomechanical performance of polyacrylonitrile/single wall carbon nanotubes films.	Polymer Composites, 45(12), pp.10911-10924
M. P. Sathianarayanan, Karishma Hemani & Shraddha Gaonkar	Development and validation of test method for determination of chlorinated organic carriers in textiles	BTRA Scan" - Vol. LIV No. 1- January 2025, Page no. 5 to 15.
M.Amarnath, Shreyash Mohite, Shital Palaskar	Energy Harvesting/ Storage Textiles: Integrating Sustainability into Wearable Technology	BTRA Scan" - Vol. LIV No. 1- January 2025, Page no. 16 to 27.
Sreelakshmi S, Lekhaz Devulapalli	Study on Prefabricated Geosynthetic-Reinforced Asphalt Slabs for Emergency Road Repairs	BTRA Scan" - Vol. LIV No. 1- January 2025, Page no. 28 to 32.
Smita Deogaonkar-Baride, Sirisha Majji , Mitesh Koli , P. Saroj , Asavari Dhavale	Application of electron beam treatment for degradation of pollutants in real textile wastewater	Journal of Radiation Physics and Chemistry, https://doi.org/10.1016/j.radphyschem.2025.112567 in January 2025.
Tanushree Tandel, Ashwini Govekar ,Smita Deogaonkar-Baride	Development of Excellent Antimicrobial and Wash Durable Fabric With Biosynthesized Silver Nanoparticles Using Soluble Starch, Maize Starch and Rice Extract	Journal of Applied Polymer Science, https://doi.org/10.1002/app.56926 ,1-15,February 2025.

POSTER/PAPERS PRESENTED IN CONFERENCE/SEMINAR/LECTURES

Authors Name	Title of the Paper	Occasion/Venue/Date
Shital Palaskar	Atmospheric Pressure cold Plasma processing of textiles – applications in functional finishings	International conference Plasma Tech 2024 to be held in Vienna, Austria on 17 - 19 Apr, 2024
Shital Palaskar	Plasma functionalization of textiles fabrics – A sustainable Approach	ITA Group International Center for Sustainable Textiles RWTH Aachen university on 23 rd April 2024
Shital Palaskar	Plasma functionalization of textiles fabrics – A sustainable Approach	The 61 st Assembly of Advance Material Congress, 24-26 the September 2024 at Jodhpur.
Smita Baride	Lab scale feasibility of electron beam treatment to real textile effluent'	National Symposium on Electron Beam Technology and Applications held at DAE Convention Center, BARC, Mumbai- 22 nd August 2024
Smita Baride	Characterization, Synthesis, and Applications of Conductive Polymers coated Fabric	10 th August 2024, organized by NISTI.
Prasanta Kumar Panda	Development of Lyocell CNT composite fiber for carbon precursor	62nd Joint Technological Conference , Northen India Textile Research Association, October 2024.
Shreyasi Nandy	"Flame Retardant Cotton Fabric By Plasma Assisted Chemical Treatment"	62nd Joint Technological Conference , Northen India Textile Research Association, October 2024.
Prasanta Kumar Panda	Dispersion study of CNT in the Lyocell dope	APA, Jaipur, October 2024
Shreyasi Nandy	"Flame Retardant Polyester By Plasma Assisted Chemical Treatment"	APA 2024, Jaipur Conference
Lekhaz Devulapalli	Tackcoat compability of geogrid reinforced asphalt pavement	228th Mid-term council meeting, Indian roads congress – Siliguri.
Smita Baride	Conductive Textiles for fashion and Wearables	National conference on 'Cutting Edge Fashion Blending Innovation, functionality, Sustainability and AI integration organized by Textile Engineering division Board, IEI in association with the Department of Fashion Technology Sona College of Technology, Salem on 17th October 2024
Shital Palaskar	Antimicrobial functional finishing on cotton using plasma technology for biomedical application	62nd Joint Technological Conference , Northen India Textile Research Association, October 2024.
Komal Kukreja	Polymers for Advanced Technology	APA 2024 Jaipur on 16-18 October, 2024
Nishant Chandel	Industrial spinning of 1K filament PAN/CNT precursor fibers for carbon fiber	Oral Talk Materials symposium organized by IIT Kanpur and IIT Jammu in March 2025

TRAINING PROGRAMMES CONDUCTED

Subject	To Whom	Duration
	On-Site Training	
Awareness program on the future of handloom and textiles	Department of handloom and textiles Telagana	1 day in May 2024
Good manufacturing practices	Kadri wovens SIPCOT Perundurai	1 day in May 2024
Process house requirement during expansion	True colour pvt Ltd - Navsari Surat	1 day in May 2024
Awareness program on the future of handloom and textiles	Department of handloom and textiles Telagana	1 day in May 2024
Good manufacturing practices	Kadri wovens SIPCOT Perundurai	1 day in May 2024
Process house requirement during expansion	True colour pvt Ltd - Navsari Surat	1 day in May 2024

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

Name of Staff	Subject /Occasion
Shital Palaskar	Visited RWTH Aachen university, April 23rd 2024
Shital Palaskar	Visited Swiss federal laboratories for materials testing and research (empa) April 28th 29th 2024 Zurich
Tanaji Kadam, Vijay Shirole Vijay Gawde	Attended meeting for MOU to work in the area of ETP, Energy conservation at Thermax , Pune on 3rd April 2024.
Tanaji Kadam	Attended online CPCB - BREF CGE on 3rd April 2024.
Tanaji Kadam	Attended PSC review meeting for FY 2022-23 and 23-24 at Textile commissioner office - Nistha Bhavan , Churchgate on 4th April 2024.
R.A.Shaikh	Attended BIS TxD 1 meeting on 10th and 23rd April 2024.
Vijay Gawde	Attended meeting on Geo tech Course development on 14th May 2024
R.A.Shaikh SnehalDhamdhere	Attended BIS meeting on Quality Control Orders on 10th May 2024.
Vijay Gawde	Attended meeting on discussion with M/s Axismyindia for NSDC survey on skilling at BTRA, Mumbai on 10th May 2024
Snehal Dhamdhere Shital Palaskar	Attended Techtextil Germany 2024 –expo –April 2024
Snehal Dhamdhere	Attended Vienna Austrian -Plasma-tech conference–April 2024
Snehal Dhamdhere	Attended BIS Mumbai conference/meeting- 10th MAY 24.
Snehal Dhamdhere	Attended WestBengal cluster Kolkata visit -assignment for specification Pioneer Textile: Ranaghat, Manomohan Textiles :Ranaghat, Bhishnupriya Textiles :Ranaghat, Bongtex:Shantipur, Tag Developers Pvt Ltd.: Gurap.- 29th -31ST May 24
Snehal Dhamdhere	Attended Siliguri IRC 228th conference 14th & 15th June 24
Snehal Dhamdhere	Attended BMC office meeting-Mr. Bellale-Commissioner -soil project 2nd July 24

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Name of Staff	Subject /Occasion
Snehal Dhamdhare	Attended Mantralaya PWD secretary (Mr. Salunkhe) Maharashtra Enhance marketing -testing scope in geo & soil asphalt testing and R&D project approach 25th July 24
Snehal Dhamdhare	Attended Texprocil director meeting skill development -Mumbai head office- 7th Aug 24
Snehal Dhamdhare	Attended SRTEPC Ravi kumar ji meeting director Mumbai head office- 7th Aug 24
Prasanta K.Panda /Snehal Dhamdhare/Sharayu Joshi/Vijay Gawde	Attended Nonwoven tech Asia expo participation -22-24th Aug 24
Vijay Shirole	Attended meeting for Skill development textile domenain - meeting rganised by Govt of Maharashtra Textiles Ministry on 22 nd August 2024.
Tanaji kadam/ Vijay shirole	Attended exhibition of Boiler India 2024 on 27 th September 2024 CIDCO, Vashi.
Vijay Gawde	Attended FICCI conference at Hotel Trident, September 2024, Mumbai
Tanaji kadam/ Vijay shirole	Attended Online CGE meeting for BREF documentation of textile sector, September 2024, Mumbai
R.A.Shaikh	Attended BIS meeting on 7,8 and 13 th August 2024.
R.A.Shaikh	Attended BIS meeting on 2 nd and on 10 th September 2024.
Snehal Dhamdhare	Attended Labour ministry meeting- 22nd August 2024
Snehal Dhamdhare	Attended Textile secretary meeting at mantralaya -skill development- 22nd Aug
Snehal Dhamdhare	Attended NTH Lab-Andheri visit- 30th August 24
Snehal Dhamdhare / Shreyasi Nandy	Attended Mantralaya -PWD secretary meeting Sep 24
Snehal Dhamdhare	Attended FICCI conference –Mumbai- 20th Sep 24
SnehalDhamdhare/Shreyasi Nandy	Attended FICCI R& D CONFER DELHI 3 rd & 4 th Oct 24
Snehal Dhamdhare	Attended The world of concrete expo visit Oct 24
Snehal Dhamdhare	Attended IFAT expo visit Oct 24
Snehal Dhamdhare	Attended Boiler expo visit Oct 24
Snehal Dhamdhare	Attended PWD secretary mantralaya Oct 24
Prasanta K.Panda /Shreyasi Nandy/Shital Palaskar/Smita Baride	Attended 62nd Joint Technological Conference, Northen India Textile Research Association, October 2024.
Snehal Dhamdhare	Attended IRC Annual conference Raipur 7-12 th Nov 24
Snehal Dhamdhare	Attended Publication in ITJ, Tecoya, Textile value chain Nov 24
Snehal Dhamdhare	Attended Road development conference Mumbai 22 nd Nov 24
Tanaji kadam	Attended Workshop on sustaianbility organised by CITY at opera house- on 5 th November 2024.
Vijay Gawde	Attended meeting on Automation and robitics in textile and garmenting on 5 th November 2024,Textile Association, Mumbai

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Name of Staff	Subject /Occasion
Tanaji kadam, Vijay Shirole	Attended Online CGE meeting for BREF documentation of textile sector Mumbai on 19 th November 2024
Vijay Gawde	Attended NTTM meeting for technical textiles courses on 15 th October 2024 at New Delhi
Tanaji kadam, Vijay Shirole	Attended Online CGE meeting for BREF documentation of textile sector Mumbai on 28 th October 2024
R.A.Shaikh	Attended BIS meeting on 8 th and 16 th October 2024.
Snehal Dhamdhere	Attended Metro politician -MUMBAI-Rubal Agarwal-Director Metro 3 RD Dec 24
Snehal Dhamdhere	Attended Just textile -plasma trails -factory visist 24 th Dec 24
Vijay Gawde	Attended NTTM meeting for tech textile training NTTM for tech textile training on 30 th January 2025 Udyog Bhavan, Delhi
Vijay Gawde	Attended Fashion Forward Summit by IFBEC 10 th January 2025, Mumbai
Vijay Gawde	Attended Technical textile course inauguration in SASMIRA, January 2025
R. A. Shaikh	Attended BIS meeting at Mumbai in 7 th January 2025
Vijay Gawde	Attended GTTS exhibition at Mumbai in February 2025
Vijay Gawde, Sharayu Joshi, Nishant Chandel, Smita Baride, Mitesh Koli, Prasanta K.Panda	Attended Fibre and Yarns Expo- exhibition at Mumbai in February 2025
Vijay Gawde	Attended Poshak printing associates, Bhivandi (Cluster) meeting at Mantralaya, Mumbai on 28 th February 2025.
R.A.Shaikh	Attended meeting with Jhunjhunwala College for Technical discussion on 25 th February 2025.
Vijay Shirole	Attended Griyastha Textile Associates, Bhivandi (Cluster) meeting at Mantralaya, Mumbai on 28 th February 2025.
Vijay Shirole	Attended Water auditor certification training by Water audit council on 21 st to 22 nd February 2025.
Tanaji kadam	Attended CPCB bref final draft documentation CGE online meeting, on 11 th March 2025.
Vijay Gawde	Attended BIS section comitee 14 meeting on 18 th March 2025.
R.A.Shaikh	Attended BIS meeting at Mumbai in 3 rd March 2025.
T.M. Amarnath	Attended 8 th international Conference on Nanoscience and Nanotechnology organised by Department of Physics and Nanotechnology. SRMIST, Tamilnadu on 26 th March 2025.
Prasanta K. Panda, Nishant Chandel, Shreyasi Nandy, Snehal Dhamdhere	Attended Bharat Tex 24-Delhi-expo February 2025
Snehal Dhamdhere	Attended IFBEC 25 CONFERNEENCE acitive participation 10 th January 2025
Snehal Dhamdhere	Attended "Jute Mark India (JMI) Scheme" in Mumbai-March 2025

Appendix – 6**OTHERS**

PRODUCTS / CHEMICALS /INSTRUMENTS / GADGETS SOLD ON A REIMBURSABLE BASIS	• Viscosity cups [18pieces] • Cuprammonium solution [2250ML] • Drave Test Hook [8nos] • Calibration Cup[1nos]
INSTRUMENTS/ GADGETS CALIBRATED	• Various instruments at BTRA Test Laboratories and 3 BTRA PSCs are calibrated regularly
INSTRUMENTS SERVICED	• Servicing of several types of equipment/ instruments at BTRA Test Laboratories

Patents Filed

Patent: A Process For Enhancing The Alkaline Resistance Of A Substrate

Application No: 202421050104

Inventors -T.V.Sreekumar, Prasanta Kumar Panda

Appendix – 7**NEW ADDITIONS TO THE BTRA LIBRARY**

- ♣ Textile Research Journal 2024
- ♣ BTRA Scan-2024-2025
- ♣ Encyclopaedia on Textile 2025: Vol:9 (Textile Terminology)

Appendix – 8**BIS MEMBERSHIP**

BTRA staff are 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 33	Industrial fabrics
TXD 35	Technical Textiles for Agrotech applications
TXD 36	Technical Textiles for Meditech purposes
TXD 38	Technical Textiles for Mobiltech Applications
TXD 39	Technical textiles for Clothtech purposes
TXD 40	High Performance Fibres, Fibrous Structure and Textile Components of Composites Sectional Committee
TXD 41	Smart Textiles Sectional Committee

MEMBERS OF THE GENERAL ADVISORY COMMITTEE
FOR RESEARCH AND LIAISON
Jan 2024- Dec 2026

Dr. Lalit Varshney RRF Room No: 209 Electron Beam Centre, Kharghar, Raintree Marg Sector 7, CBD Belapur Navi Mumbai, Maharashtra-410210	Dr. T. M. Kotresh Scientist 'G'/AD, Defence Bioengineering and Electromedical Laboratory, CV Raman Nagar, Bengaluru-560093.	Dr. G.V. Raghunath Reddy Scientist – F, Technology Mission Division (Energy, Water and Others), Department of Science & Technology, Ministry of Science and Technology, Technology Bhavan, New Mehrauli Road, New Delhi – 110016.
Mr. Anjani Prasad Managing Director & Vice President-South Asia Textile Effects Archroma India Private Limited , 9th Floor, D, Mbc Park, Ghodbunder Rd, near Hypercity Mall, Sai Nagar, Anand Nagar, Thane West, Thane, Maharashtra 400615	Dr. Debarati Bhattacharjee Sr.DGM 4th Floor, B Wing, Defence Engg Building, Gate No.1 Larsen and Turbo, Powai Mumbai-400072	Dr. Vijay Ramakrishnan Garware Technical Fibres Ltd., Plot No.11, Block D-1, MIDC, Chinchwad, Pune- 411 019.
Dr. Milind Khandwe The Bhor Chemicals & Plastics Pvt Ltd, Plot no. B/18/2/1, MIDC Ambad, Nashik – 422010.	Dr. M. K. Talukdar, M/s.Kusumgar Corporates, 101/102, Manjushree Bldg., Hatkesh Co-op. Society, Corner of N.S.Road No.5, JVPD Scheme, Juhu, Mumbai 400 056.	Prof. Arup R. Bhattacharyya Department of Metallurgical Engineering & Materials Science, Indian Institute of Technology Bombay, Powai, Mumbai-400076
Prof. Asim Tewari Chair Professor Department of Mechanical Engineering Indian Institute of Technology Bombay, Powai, Mumbai- 400076.	Prof. Rajendra R. Deshmukh Institute of Chemical Technology, Nathalal Parekh Marg, Matunga, Mumbai 400 019	Prof. Anirban Guha Department of Mechanical Engineering, Indian Institute of Technology, Bombay, Powai, Mumbai 400 076
Mr. Shahrokh Bagli Technical Advisor Strata Geosystems (India) Pvt. Ltd, Sabnam House, Plot No. A- 15/16, Central Cross Road B, MIDC, Andheri (E) Mumbai 400 093	Dr. Nilesh Revagade Reliance Industries Ltd. Reliance Corporate Park, Bldg 8B, First Floor WS-304 Thane Belapur Road, Ghansoli	Dr. Sandip Patil E-Spin Nanotech Pvt.Ktd 406, Third floor, Techno Park IIT, Uttar Pradesh-208016

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Dr. Prakash Vasudevan Director, The South India Textile Research Association, 13/37, Avinashi Road, Coimbatore Aerodrome Post, Coimbatore – 641 014	Dr. Arindam Basu Director, Northern India Textile Research Association Sector-23, Raj Nagar, Ghaziabad-201002	Mr. Pragnesh Shah Director, Ahmedabad Textile Industry's Research Association, P.O. Ambawadi Vistar, Ahmedabad - 380 015
Dr. T. V. Sreekumar Director The Bombay Textile Research Association Lal Bahadur Shastri Marg, Ghatkopar (West), Mumbai 400 086.		

Appendix – 10

STAFF DETAILS

The total staff strength of BTRA as of 31st March 2025 was as follows:

Director	1
At BTRA	
◆ Scientific / Technical Officers	26
◆ Scientific / Technical Staff	39
◆ Skilled / Semi-skilled & Maintenance Staff	22
◆ Administrative Staff	18
Sub-total	106
At PSCs	
◆ Scientific / Technical Officers	1
◆ Scientific / Technical Staff	4
◆ Skilled / Semi-skilled & Maintenance Staff	1
◆ Administrative Staff	1
Sub-total	7
TOTAL	113[@]

@ - Including 29 contractual staff & 7 Trainees

Director : **Dr. T. V. Sreekumar**

Research

Assistant Director : Dr. Prasanta Kumar Panda
("Research"-Chief Scientist)

Advisor : Mr. S. Subramanian

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

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Library, Information & Publication

Senior Assistant-HR and LIB. : Ms. Sharayu Joshi

Electronics

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

Junior Engineer : Mr. Kamlesh Desai

BTRA Test Laboratories

Laboratory Manager : Mr. R. A. Shaikh
(Senior Scientist)

Senior Scientific Officer Grade-II : Mrs. Maria P. D'Souza

(i) Physical Testing Division

Senior Scientific Officer Grade-II : Ms. Shreyasi Nandy

Junior Scientific Officer : Mr. D. R. Yadav

: Mrs. Sheetal M. Salunkhe

Scanning Electron Microscope

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

Geotech Cell

Senior Scientific Officer Grade-I : Mr. R. R. Menon

Senior Scientific Officer Grade-II : Mrs. Komal Kukreja

Junior Scientific Officer : Mr. G. R. Mahajan

Mr. Pramod D. Pandey

(ii) Chemical Testing Lab.

Senior Scientist : Mr. M. P. Sathianarayanan

: Mrs. S. P. Vairagi

: Mrs. Chandrakala L. M.

Senior Scientific Officer Grade-I : Mrs. Smita A. Baride

Senior Scientific Officer Grade-II : Ms. Tejaswini R. Ghadyale

Mrs. Shilpa D. Mayekar

Junior Scientific Officer : Ms. Karishma Hemani

(iii) Microbiology Lab.

Senior Laboratory Assistant : Ms. Anupama D.Chandel

(iv) Plasma Lab.

Senior Scientific Officer Grade -I : Dr. Shital S. Palaskar

Senior Scientific Officer Grade -II : Ms. Afreen Begum

Engineering Services Section

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

Administration

Administrative Officer : Mr. Jignesh S. Jani

Section Officer : Mrs. Swati P. Wadkar

Accounts Officer : Mr. Rashmi Ranjan Nayak

Chief Accountant : Mrs. Vaishali P. Mane

Store-In-Charge : Ms. Pooja S. Dohale

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Marketing

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

Soil Testing Lab.

Senior Scientific Officer Grade-I : Dr. Devulapalli Lekhaz

High Performance Fibre

Junior Scientific Officer : Mr. Akash C. Kanse
: Mr. Mahesh Kapurderiya

NTTM Projects

Research Scientist : Mr. Nishant Chandel
Dr. Gyan Ranjan Behera
Dr. Sandeep P. Jape
Mr. Shyambabu K. Sainik
Mrs. Supriya S. Sonawane
Research Officer : Dr. Geetanjali Mishra

DRDO Projects

Research Associate : Dr. Amarnath Marimuthu
Junior Research Fellow : Mr. Shreyash R. Mohite

RGSTC Projects

Senior Research Fellow : Ms. Tanushree Tandel
Junior Research Fellow : Ms. Shraddha S. Nitturkar

BTRA PSC, Ichalkaranji

: Mr. Sachin R. Tambe

BTRA PSC, Solapur

: Mr. Amar V. Patil

BTRA PSC, Madhavnagar

: Mr. Namdev A. Chavan

Appendix – 11

LIST OF MEMBERS

- ❖ BanswaraSyntex 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
- ❖ EntremondePolycoaters Ltd, Nashik
- ❖ Flexituff Ventures International Ltd., Mumbai
- ❖ Garware Technical Fibres Limited, Pune
- ❖ Indo Count Industries Ltd., Mumbai
- ❖ Kusumgar Corporates Pvt. Ltd., Mumbai
- ❖ Maharshee Geomembrane (India)Pvt. Ltd., Vadodara
- ❖ Morarjee Textiles Ltd., Mumbai
- ❖ OCM Private Ltd, Punjab
- ❖ Nagreeka Exports Ltd., Kolhapur
- ❖ Pee Vee Textiles Ltd., Wardha
- ❖ Khosla ProfilPvt. Ltd., Mumbai
- ❖ RSWM Ltd., Mumbai

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- ❖ Raymond Lifestyle Ltd., Thane
- ❖ Reliance Industries Ltd., Navi Mumbai
- ❖ The Ruby Mills Ltd., 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
- ❖ Terrapro Geosynthetics Pvt. Ltd., Kutch,
GujaratTimes Fibrefill Pvt. Ltd., Kolkata
- ❖ Shivoham Fabtech Pvt. Ltd., Surat, Gujarat
- ❖ Proto9 Materials Pvt. Ltd., Mumbai
- ❖ ESG Resin Pvt. Ltd., Raigarh
- ❖ Jayatma Industries Ltd., Gujarat
- ❖ Sealed Air Packaging Materials (India)LLP
Mumbai
- ❖ Virendera Textiles,Uttarpradesh
- ❖ Enviro Axis India Pvt Ltd, Mumbai
- ❖ Vishwa Samudra Engineering Pvt Ltd,
Hyderabad
- ❖ Geotech Industries Pvt Ltd, Gujarat
- ❖ PPG Asian Paints Pvt Ltd, Mumbai
- ❖ Kasare Vanya Silk Mill Pvt Ltd,Chhattisgarh
- ❖ Suntech Geotextile Pvt Ltd,Chhattisgarh
- ❖ Indore Composite Pvt Ltd, Mumbai

Information from Vishakha Committee for the year 2024



THE BOMBAY TEXTILE RESEARCH ASSOCIATION

Phone : 91-22-6202 3636
Fax : 91-22-2500 0459
E-mail : info@btraindia.com
Website : www.btraindia.com

(Approved Body of the Ministry of Textiles, Govt. of India)

Lal Bahadur Shastri Marg, Near
R-City Mall, Ghatkoper (West),
Mumbai - 400 086.

Date: - 15.01.2025

To,
The Director,
The Bombay Textile Research Association

Subject: - Information from Vishakha Committee for the Year 2024

Dear Sir,

Vishakha Committee ^{did} not receive any complaint against Sexual Harassment at work place of The Bombay Textile Research Association.

Thanking You,

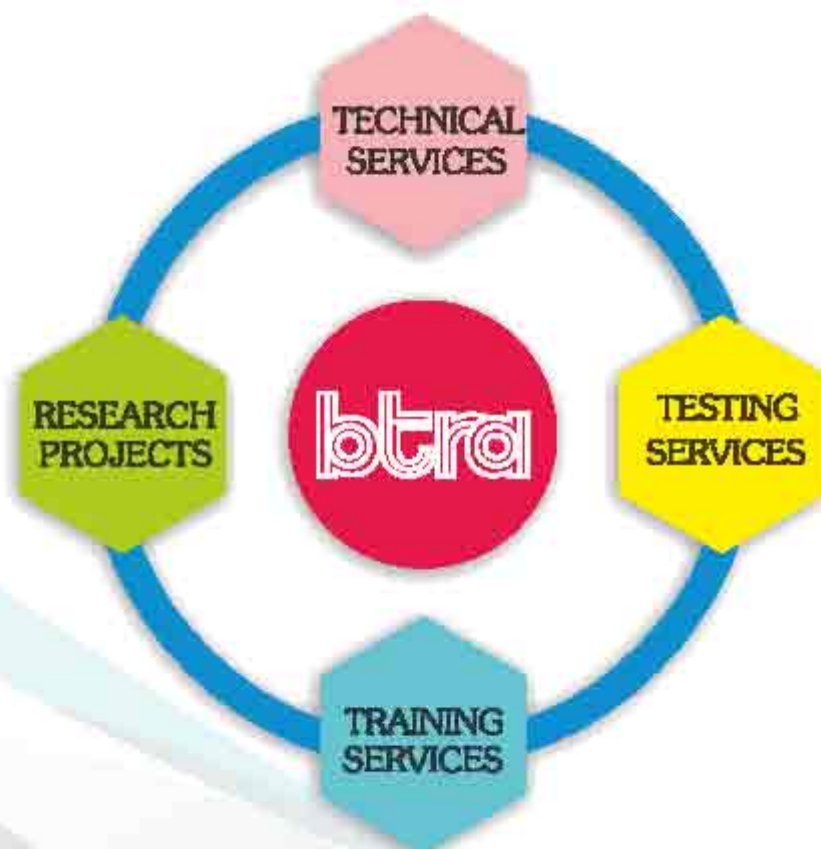
(Sarb) Vairagi
Chairman- Vishakha Committee

(Swati Wadkar)
Member- Vishakha Committee

(Chandrakala Madichetty)
Member- Vishakha Committee

(Jignesh Jani)
Member- Vishakha Committee

(Sunita Kulkarni)
Member- Vishakha Committee



The Bombay Textile Research Association

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