ICTN-2026

8th International Conference on Technical Textiles and Nonwovens

ICTN
2026, NEW DELHI

6-8 February | IIT Delhi, India

THEME: Bridging Performance and Sustainability: The Future of Technical Textiles and Nonwovens

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Souvenir

Prof. Deepti Gupta
Head
Department of Textile and Fibre Engineering
Indian Institute of Technology Delhi

Message

Dear Esteemed Participants and Distinguished Guests,

It is my honour and privilege to welcome you to the 8th International Conference on Technical Textiles and Nonwovens (ICTN 2026) as the Head of the Department of Textile and Fibre Engineering, IIT Delhi, the proud organizer of this global event.

ICTN 2026 continues to serve as a premier platform for academicians, researchers, industry leaders, policymakers, and students to come together and deliberate on the latest advancements in the rapidly evolving field of technical textiles and nonwovens. The conference reflects our department's enduring commitment to promoting innovation, encouraging interdisciplinary collaboration, and advancing sustainable and high-performance textile technologies.

In today's fast-transforming technological landscape, technical textiles play a vital role across diverse sectors including healthcare, mobility, infrastructure, defence, and environmental protection. This conference offers a unique opportunity to exchange knowledge, engage in thought-provoking discussions, and explore emerging research and industrial practices that are shaping the future of the industry. The carefully curated technical sessions, plenary talks, exhibitions, and networking opportunities are designed to capture the depth, diversity, and dynamism of this field.

As we gather at IIT Delhi, I encourage all participants to make the most of this occasion by building meaningful connections, fostering collaborations, and contributing actively to the exchange of ideas. The collective expertise assembled here has the potential to address pressing challenges and unlock new pathways for growth and innovation in technical textiles and nonwovens.

I extend my heartfelt appreciation to the organizing committee, speakers, sponsors, partners, and participants whose dedication and support have made ICTN 2026 possible. Your involvement is instrumental in strengthening this conference as a significant event in the global technical textiles calendar.

Thank you for being part of ICTN 2026. I wish you a productive, engaging, and enriching experience, and hope that your time at IIT Delhi will inspire new ideas and lasting partnerships.

Warm regards,

Deepti.

Prof. Deepti Gupta
Head
Department of Textile and Fibre Engineering
Indian Institute of Technology Delhi

Prof. Apurba Das
Conference Chair
Email: apurbadas65@gmail.com

Message

Dear Esteemed Colleagues and Distinguished Participants,

It gives me immense pleasure to welcome you to the 8th International Conference on Technical Textiles and Nonwovens (ICTN 2026), organized by the Department of Textile and Fibre Engineering, Indian Institute of Technology Delhi, from February 6–8, 2026, at IIT Delhi, New Delhi, India.

ICTN 2026 continues the proud legacy of fostering meaningful dialogue and collaboration among global leaders from academia, industry, research organizations, and government bodies. As the technical textiles sector rapidly evolves through technological advancements, sustainability imperatives, and expanding application areas, this conference provides an important platform to deliberate on emerging trends, share pioneering research, and explore innovative solutions shaping the future of the field.

We are privileged to host an exceptional gathering of distinguished scientists, researchers, industry professionals, policymakers, and students from across the world. This convergence of expertise is expected to stimulate insightful discussions, inspire new ideas, and strengthen partnerships that will drive the next phase of growth in technical textiles and nonwovens.

I sincerely hope that your participation in ICTN 2026 will be intellectually enriching and professionally rewarding. Your valuable contributions are central to the success of this collaborative endeavor and will undoubtedly help advance knowledge and innovation within our community.

I extend my heartfelt gratitude to our sponsors, partners, speakers, organizing committee members, and volunteers whose dedication and support have made this event possible.

May ICTN 2026 serve as a platform for inspiration, knowledge exchange, and impactful collaborations, paving the way toward a more sustainable, technologically advanced, and interconnected future.

I warmly welcome you to IIT Delhi and look forward to your active participation in making this conference a grand success.

Warm regards,

Prof. Apurba Das
Conference Chair

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Plenary Speakers

From Classroom to Company: Building Something Real While You're Still on Campus

Mr. Anand Yadav

MD, Mekr Technologies Pvt. Ltd.

Abstract

The journey from a campus laboratory to a commercial enterprise requires more than just a visionary idea; it necessitates a strategic transition from academic inquiry to industrial execution. In this session, Anand Yadav (IIT Delhi, B.Tech 2019) shares his firsthand experience in building a deep-tech startup legacy. The narrative begins with the "Promising Insights" phase, detailing how his 2019 B.Tech Project (BTP) and core textile coursework provided the technical foundation for what would soon become a national-scale intervention.

A cornerstone of the talk is the rapid trajectory of Kawach Mask, a project that evolved from IIT Delhi startup ETEX Healthcare Pvt Ltd into a national-scale pandemic intervention. This serves as more than just a success story; it is a definitive case study in the high-velocity pivot of academic research into life-saving technology under global pressure. The experience of running operation and business at ETEX has helped Anand to further stretch his insights on launching future ventures. The experience of spearheading operations and business strategy at ETEX provided the crucible in which Anand's entrepreneurial insights were forged and tested. Leveraging the lessons of pandemic-era agility and supply chain resilience, he launched Mekr in 2022. Today, Mekr operates as an ODM of Consumer Appliances for some for various leading brands in India, with a strong focus on indegenizing import dominated product categories, specifically designed to bridge the gap between innovative prototyping and industrial-grade execution. Today, Mekr indigenously manufactures ~3million units of various consumer appliances products.

Anand will challenge the audience to envision textiles as the next frontier for data collection, specifically across three high-growth sectors: Elderly Care, involving smart mattresses and floorings for non-intrusive health monitoring; Wearable Tech, moving toward wash-durable, integrated e-garments; and Sports E-Textiles, designed for real-time biometrics in support of India's 2036 Olympic ambitions. Crucially, the talk outlines how Indian startups can secure a competitive advantage against China by pivoting away from low-cost mass production toward specialized, design-led innovation and "small-batch" customization. By matching Product-Market Fit for both domestic price-sensitive users and stringent international regulatory standards, this session provides a comprehensive roadmap for students to build high-value, tech-integrated textile companies.

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From Potential to Powerhouse: India's Rise as a Global Technical Textile Hub

Kanav Gupta

Associate Director, Business Co-ordination House Pvt Ltd

Corresponding Author Email: kanav@bch.in

Abstract

BCH is a Advisory and consulting company dedicated 100% to the Technical textiles and Nonwovens sector of India since 2005. BCH is also the strategic partner of ICTN since its inception, facilitating the translation of innovation into market-ready solutions.
The Indian technical textile industry is experiencing strong growth of 10-12% CAGR, the market is projected to grow from $29 billion in 2024 to $309 billion by 2047.
This paper will cover key technical textiles sectors, and more importantly the key pillars / themes on which this sector would have to focus in the next 10 years in order to become a powerhouse sector.
To support the existing and advanced applications, India must secure raw materials, manufacturing capability, and core technologies, many of which are presently dependent on imported oil- and mineral-based inputs and foreign know-how.
Topics like importance of Fibre security, technology building, Role of Policy, Strengthening R&D, Make in India, Strategic FTA's and their impact, Domestic market and export potential will be covered to understand the roadmap for India to become a Global Hub for Technical textiles
The paper will also deep dive into 1 sub sector – Medical textiles and Hygiene products and will bring out success stories of 2 important companies in this sector who have build systematically and consistently and grown in this segment.

From Fossil to Renewables: Strategies for a Future-Ready Indian Textile Sector

Prof Thomas Gries

RWTH Aachen University, Germany

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Abstract

The textile sector is entering a period of profound structural transformation driven by the shift away from fossil resources and the growing need for resilient and sustainable material cycles. This development is shaped by three converging forces: industrial modernisation, sustainability and defossilisation, and rapid digitalisation. Global market trends are considered alongside evolving dynamics in India, where fibre consumption, production patterns, and waste-management systems are changing at high speed. The presentation outlines four complementary pathways for defossilising textile value chains: the use of natural fibres, renewable bio-based building blocks, carbon-capture-derived raw materials, and advanced recycling approaches. Their technological foundations, scalability prospects, and economic implications are examined with respect to future material availability and industrial competitiveness.

Testimonial

ICTN has become one of the most relevant platforms for scientific and technological exchange in the global textile sector. The conference brings together leading experts from research, industry, and policy to address future-oriented innovations, sustainability challenges, and the transformation of textile value chains. I am pleased to contribute to this dialogue and look forward to engaging with colleagues at IIT Delhi in 2026.

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Regional Movements in Europe and the USA Driving the Evolution of Hygiene Nonwovens

Rahul Bansal

Vice President & Head - Nonwovens Business, Birla Cellulose

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Abstract

The global hygiene and medical nonwoven industry is experiencing a technology-led transition driven by regulatory, material, and consumer developments originating in Europe and the United States. The total global nonwoven market is estimated at approximately 50,000 tons per day (TPD), with hygiene applications forming the largest share. Wet wipes represent nearly 7,000 TPD (?13%), while absorbent hygiene products (AHP), including diapers and feminine hygiene, contribute around 12,000 TPD (?24%). Medical nonwovens account for about 4% or 2,200 TPD. Due to their high volumes and predominantly single-use nature, hygiene applications are increasingly targeted by sustainability-focused regulations and material redesign initiatives. Raw material consumption in hygiene nonwovens is still dominated by synthetic polymers, with polypropylene (PP) resin at ~28%, PET at ~19%, and PP fibre at ~6%. Renewable materials such as man-made cellulosic fibres (MMCF) currently account for approximately 6%, while pulp represents ~11%, highlighting a clear gap between regulatory intent and material reality. Regulatory frameworks such as the EU Single-Use Plastics Directive (SUPD), Extended Producer Responsibility (EPR), and evolving global standards are accelerating the shift toward renewable, biodegradable, and recyclable substrates, while increasing scrutiny on flushability, chemical safety, and end-of-life performance.

Value-chain insights further validate this transition. Industry survey conducted by Birla Cellulose indicate that diapers and feminine hygiene products are emerging as the primary growth drivers for MMCF usage In nonwovens. Fibre selection is governed by a tight balance between performance and cost, with softness, strength, and absorbency remaining critical functional requirements. At the same time, chemical safety, skin compatibility, biodegradability, and compostability are gaining importance due to the next-to-skin nature of hygiene products. Cost competitiveness and measurable performance improvement continue to be the most important focus areas for fibre innovation.

Advances in hybrid wetlace technologies, bio-based polymers and circular or recycled fibres are enabling new substrate architectures. However, significant innovation gaps remain, particularly in superabsorbent polymers (SAPs), PET-based back sheets, plastic top sheets, and fossil-based adhesives. These gaps present strong opportunities for Indian innovators to develop bio-based SAP alternatives, high-absorbency natural polymers,

biodegradable top sheets and back sheets, and bio-based adhesive systems. Supported by strong cellulosic fibre capabilities and scalable manufacturing, India is well positioned to transition from material supply to solution-led innovation, shaping the next generation of sustainable hygiene nonwovens.

Latest Developments in Spun melt Nonwovens – Opportunities and Challenges

Simon Finianos

Sales Director, Reifenhäuser Reicofil

Abstract

This talk will provide an overview of the latest advancements in spunmelt technology for nonwovens, with a particular focus on „excentric core/sheath“ (filament design for Extra High Loft XHL) and the multirow spinning technology in meltblown production.Special attention will be given to the technical and commercial implications of those configurations, which offer unique opportunities for product differentiation and performance optimization.

Key themes include the drive for sustainability through material reduction (downgauging), the integration of biodegradable polymers, and the adoption of AI-driven process optimization – the AI Chatbot.

Recent common industry developments highlight collaborations with partners such as Flexiramics and Innovatec®, which have enabled the creation of innovative filament technologies and the use of diverse materials. These advancements open new possibilities for nonwoven products, including enhanced absorption, improved breathability, and tailored functionalities for specific applications.

Attendees will be invited to engage in partnerships to further advance spinning technologies and unlock new functionalities in nonwovens. This session aims to provide valuable industry insights and inspire the development of next-generation nonwoven materials and processes.

Design of Hybrid Filter Media: Performance Surface Engineering for Industrial Filters

Utssav Gupta

Director, Supertech Fabrics Pvt. Ltd.

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Abstract

Industrial filtration systems have historically been designed around stable assumptions of particle size, fuel chemistry, and operating conditions. Conventional filter media—such as depth felts, woven high-temperature fabrics, and membrane laminates—were optimised within these predictable boundaries using established filtration physics. However, this stability has eroded as industrial processes undergo rapid transformation driven by stricter emission norms, alternative fuels, higher production loads, and evolving raw materials.

Modern emissions are not necessarily dirtier, but fundamentally more complex. Gas streams now contain finer and mixed-morphology particulates, higher surface-area dusts, sticky hydrocarbons, aggressive acidic and alkaline species, fluctuating moisture conditions, and volatile thermal profiles. These changes disrupt classical filtration mechanisms and expose limitations in legacy media architectures, resulting in cascading failure modes such as permanent blinding, pressure-drop instability, chemical degradation, moisture-induced mudding, and premature mechanical failure—ultimately compromising efficiency, lifespan, and process reliability.

This work frames the challenge as a growing mismatch between evolving process realities and traditional filter media design paradigms. As filtration performance becomes increasingly governed by surface-level interactions rather than bulk capture alone, the need emerges for hybrid filter media architectures that integrate filtration physics with surface engineering and protective chemistries, offering a system-level pathway to restore stability and performance in contemporary industrial environments.

Fiber (MMF) Power 2030: Navigating Geopolitics - Technology innovation and global expectations

Debabrata Ghosh

Vice President, Head of Sales & Marketing
Oerlikon Textile India Pvt. Ltd.
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Abstract

Global fiber production increased from around 125 million tonnes in 2023 to a record 132 million tonnes in 2024. This is predominantly due to growth in the production of new virgin fossil-based synthetics.Since 2000, when global fiber production was 58 million tonnes, production has more than doubled and it is expected to grow to 169 million tonnes in 2030 if business as usual continues. While the industry has made commitments to align with the Paris Agreement by keeping global warming to a 1.5°C pathway, trends, such as the industry's reliance on virgin fossil-based synthetic materials and the limitations of textile- to-textile recycling, threaten to undermine the industry's commitments to its climate goals. The market share of recycled fibers remained at around 7.6% in 2024. The vast majority of this was recycled polyester made from plastic bottles, which accounted for 6.9% of all fiber produced worldwide. Overall, less than 1% of the global fiber market was from pre- and post-consumer recycled textiles. Polyester continues to be the most widely produced fiber in the world, accounting for 59% of global fiber production in 2024, up from 57% in 2023. In terms of volume, polyester fiber production increased from 71million tonnes in 2023 to 78 million tonnes in 2024.

Recycled polyester fiber production increased from around 8.9 million tonnes in 2023 to around 9.3 million tonnes in 2024. However, due to the larger increase in virgin polyester production, there was a decrease in the overall market share of recycled polyester from around 12.5% of global polyester production in 2023 to around 12.0% in 2024. Systems for polyester textile-to-textile recycling are in development but are only estimated to account for around 2% of all recycled polyester. The interest in, and use of, ocean or ocean-bound plastic is increasing, but overall market shares remain very low and make up less than 0.005% of all recycled polyester. Recycled polyester is still primarily made from plastic bottles (98%). The market share of biobased polyester fiber remained very low at around 0.01% of global polyester production—mainly due to issues around price and availability, as well as questions about the sustainability of currently available biobased polyester. The report also highlights new innovations, such as fibers made from captured CO.

Air Filtration Media: Advancements and Solutions for India

Mahesh Kudav

Managing Director, Venus Safety & Health Pvt Ltd

Abstract

Recent surges in Air Quality Index (AQI) due to pollution and high PM levels demand advanced filtration and its techno-commercial evaluation for India. Technological advancements in focus are triboelectrically charged nonwoven media, hydrocharged meltblown fabrics, nanofibers, and nanoparticles that can enhance filtration efficiency. The Government of India is also strengthening domestic manufacturing via Quality Control Orders (QCOs) and new Indian Standards (IS), replacing ANSI and EU standards with regulations tailored to India's market needs.

Development of Polylactic Acid Fibrous Materials with Improved Mechanical and Biodegradability and Enhanced Daylight Photoactivity

Gang Sun and Yufa Sun

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Abstract

Polylactic acid (PLA) is a biobased and biodegradable polymer with many promising properties suitable as a sustainable alternative of fossil-based thermoplastics. However, PLA has some drawbacks in mechanical properties limiting the applications in certain fields. Its biodegradation rate is slow, affecting its acceptance as a biodegradable material. Functionalization of PLA is also relatively difficult due to its inert and hydrophobic polyester structure. In a recent research project on developing biobased, biodegradable and reusable antibacterial facemask materials, we have explored modification processes of blending PLA with additives of biocompatible photoactive agents and edible plasticizers. The results revealed that vitamin K3 and several other photo-sensitive colorants could provide daylight-induced functions on PLA, measured by amounts of hydroxyl radicals, singlet oxygen and hydrogen peroxide, so called reactive oxygen species (ROS) generated under light irradiation, while addition of biobased plasticizers could significantly improve mechanical and biodegradable properties of PLA and properly increase photoactivity of the blended polymers. Interestingly, the photoactive functions of PLA containing type I photosensitizers and plasticizers with special structural features could be dramatically enhanced due to a synergistic effect between both additives. These findings provide a promising route toward development of sustainable personal protective equipment (PPE) aligned with both public health demands and environmental goals. The reaction mechanisms and performances of some colorful antibacterial fibers will be discussed in the presentation.

Next Generation CBRN Protective Textiles for Defence Application

Vikas Baburao Thakare

Scientist G & Associate Director

Defence Research & Development Establishment

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With the increasing need to safeguard individuals from both conventional and unconventional threats of chemical and biological agents, the demand for advanced personal protective equipment (PPE) is rising. Current CBRN (Chemical, Biological, Radiological and Nuclear) protective suits used by military and emergency responders fall into two main categories i.e. activated carbon-based permeable technologies and impermeable barrier technologies. However, current technologies face significant drawbacks, including heavy weight, discomfort, reduced mobility, and unpredictable service life. Therefore, there is a pressing need to develop advanced, lightweight, and multifunctional PPE to address these challenges and improve the safety and effectiveness of military and emergency responders. In addition to that, the threat of attacks involving chemical and biological agents drives the need for new materials that can neutralize toxic chemicals at ambient temperature and humidity.

In order to address these challenges, a wide range of highly porous advanced materials (such as Metal Oxides, Metal Organic Frameworks (MOF), Covalent Organic Frameworks) embedded electrospun based nanofibrous polymeric membranes, graphene doped textile substrates, polymer coated super amphiphiobic textiles, Phase Change Materials, Self-Healing fabrics, Functionalized Activated Carbon Fabric are being explored worldwide for further reduction of weight, discomfort with enhanced functional properties.

In a nutshell, the future of advanced textile and polymer-based CBRN protective clothing is likely to see significant advancements driven by innovations in materials science, technology, and design which consist of synthesis of advanced materials, enhanced comfort and mobility by ergonomic design, integration of wearable technology, sustainability and improved performance testing. The journey ahead will be defined by how effectively these cutting-edge innovations are harnessed to safeguard against the evolving spectrum of chemical, biological, and radiological threats, ultimately enhancing safety and resilience in a complex global landscape.

Barmag Recycling Technologies - Closing the Loop, Opening Potential

Sudipto Mandal

Regional Sales Director, Oerlikon Barmag

Abstract

Barmag, a subsidiary of the Swiss Rieter Group with its product brands Barmag and Neumag is one of the leading providers of technologies for the production of man-made fibers and offers gear metering pumps for the textile and other industries, including the automotive, chemical and paint industries.

Our technologies enable our customers to achieve a closed-loop economy in the plastics industry, particularly in the packaging and chemical fiber industries. From melt preparation and cleaning to melt conveying, granulation, and spinning—we have all the technologies in-house, everything from a single source. High-quality melt has a direct impact on the end product. It forms the basis for high-quality bottle, film, and fiber polyester.

Oerlikon Barmag Huitong Engineering (OBHE's) homogenization technology stands for the thermomechanical recycling of processed post-industrial polyester waste such as bottle flakes and film. The Oerlikon Barmag Homogenizer ensures a homogeneous melt, enabling a targeted increase in viscosity to produce defined rPET precursors for further processing, such as melt, granulate or fiber material for direct spinning.

Further, Barmag's joint venture company Barmag Brückner Engineering (BBE) has been an expert in extrusion and filtration for decades. BBE has been intensively involved in the development of efficient technologies for plastics recycling for many years. In addition to a broad portfolio of extruders, melt filters, and the Spinnanlage VarioFil® R for PET recycling, the company offers VacuFil®, a fully integrated system for innovative PET LSP recycling (liquid state polycondensation).

VacuFil® combines large-area, gentle melt filtration with precise IV control, ensuring consistently high quality of the rPET melt. The modular system concept allows flexible adaptation to different material qualities and application areas in the recycling process. The central component of the system is Visco+®, a liquid phase polycondensation unit for precise viscosity adjustment. Continuous adjustment of the IV results in a homogeneous melt with optimum processing properties – ideal for high-quality end products in the fiber, film, or packaging industry.
Barmag is also extensively involved in R&D activities focusing on bringing technologies for Chemical Recycling, one of the upcoming technologies will be from OBHE i.e., crPETpro - glycolysis based chemical Recycling. Further, we will have another technology offering from Barmag and Evonik i.e., crPETevo - glycolysis based chemical Recycling.
We believe all of you may have many questions related to Circular Economy, Energy Efficiency, New Materials, Digitalization, Traceability, Recycling…for everything Barmag is the answer.

Leading Nonwoven Technology - Innovation Engineered for Performance

Mr. Shridhar Dhumal

Regional Sales Director, Oerlikon Barmag

Abstract

The global nonwoven industry is undergoing rapid transformation driven by increasing demand for high-performance materials in hygiene, filtration, medical, automotive, and geotextile applications. This presentation highlights Oerlikon Nonwoven's leading technologies—Airlaid, Spunbond, and Meltblown—that enable sustainable, efficient, and advanced nonwoven production. It provides an overview of key application areas, including HVAC and automotive filtration media, wipes, personal protection materials, sanitary products, geotextiles, roofing substrates, and next-generation functional materials such as battery separators and hot-gas filters.

The presentation showcases Oerlikon's innovation leadership in Meltblown technology, emphasizing superior spinning uniformity, advanced secondary-air management, polymer versatility, and globally proven performance across more than 80 installations. Breakthrough solutions such as hycuTEC hydrocharging enhance filtration efficiency while reducing production costs.

In Spunbond technology, Oerlikon demonstrates advancements in PET and PP spinning, bico-filament designs, optimized quenching, improved draw-slot systems, and engineered downstream processes to meet high-strength and technical-grade requirements for geotextiles and construction membranes. Airlaid technology innovations enable sustainable production of fibers from pulp and biodegradable polymers with precise forming, dosing, and bonding techniques suited for hygiene and recycling applications.

Together, these technologies empower manufacturers to achieve higher productivity, improved material performance, and sustainable production aligned with the vision of **Textiles 2030**. Oerlikon Nonwoven further strengthens industry innovation through its dedicated laboratory facilities supporting customer-focused product development and raw-material evaluation.

Sustainable Technical Textiles Manufacturing: Using Safer Processing Chemicals

Umasankar Mahapatra

Managing Director, Pulcra Chemicals India Pvt. Ltd.

Abstract

Fashion & textile industry in one of the tops in terms of its negative environmental footprints. There is immediate need to adopt more sustainable products. Various material innovations are happening in the area of sustainable fibers, but unless those are treated using safer and cleaner Textile processing chemicals, its not complete. Textile processing chemicals can be produced from renewable sources and having lesser environmental footprints during its manufacturing and while using the same in textile manufacturing process. These can also help in reducing resource utilisation like water, steam, energy during production. It can help to reduce overall time required by shortening the processing cycle time. At the end it plays a big role in making the products safe for use by consumers and lowering environmental impact during service life of the products (low temp washing, quick drying) and at end-of-life recycling/disposal. Various functional performance finishes are available to improve product functionalities, such as thermal regulations, moisture management, safer DWR and stain release finishes. Health & hygiene of wearers can also be improved by using performance finishing such as plant-based antimicrobial, skin moisturising finishes, finish which can improve sleep quality. There are performance finishes using probiotics for allergen control on textiles. Biobased flame retardants which can replace existing hazardous solutions are under development. Case studies of these chemical solutions are available from Pulcra – Devan range. For more details, please visit www.pulcra-chemicals.com and www.devan.net.

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Sustainable Cellulose-Based Nanocomposites for Advanced Medtech Applications: Wearable Sensors for Personal Health Monitoring

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Abstract

The integration of sustainable materials with advanced functionality is paramount to advancing next-generation technical textiles, particularly in the Medtech sector. The current research aims to harness the exceptional properties of nanocellulose, synthesized from both lignocellulosic biomass (jute fiber) and recycled fabrics, to develop durable, multifunctional composite hydrogels for wearable sensor applications. Previously, highly functional carboxylated and crystalline cellulose nanocrystals extracted from jute fiber facilitated the development of cellulose nano- and microcrystal-based nanocomposites suitable for biocompatible, environmentally friendly applications. Consequently, a novel class of polyvinyl alcohol (PVA)-borax hydrogels containing cellulose nano- and microcrystals has been developed. These hydrogels are synergistically reinforced with cellulose micro- and nanocrystals and augmented with two-dimensional MXene nanosheets. The resulting composites exhibit exceptional mechanical strength, self-healing properties, and recyclability. Importantly, these hydrogels serve as highly sensitive, multifunctional sensors capable of detecting and monitoring human motion, physiological signals, and tactile pressure with high accuracy and stability. By successfully integrating cellulose microfibers derived from textile waste, this work not only advances the principles of the circular economy but also demonstrates a scalable, sustainable pathway to producing high-performance Medtech textiles for personal health monitoring and human-machine interface applications.

Oral Presenters

Design & Characterization of Laminated Activated Carbon Fabric for Critical Military Applications

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Abstract

Activated carbon is known to be apotential adsorbent for different adsorptional applications due to large surface area and internal porosity. Presently, activated carbon in fabric form i.e. activated carbon fabric (ACF) and laminated activated carbon fabric (LACF) therefrom is being used as an essential component in military chemical protective clothing. LACF is primarily responsible for adsorption of potential chemical warfare agent during combat operations. We, report here preparation of Activated Carbon Fabric (ACF)and LACF from a commercially available rayon based carbon fabric through a process of treatment of carbon fabric in CO2atmosphere. The prepared ACF was assessed for Brunauer-Emmett-Teller (BET) surface area measurement, internal porosity, pore size distribution, average pore diameter and adsorption isotherm. Further, LACF was prepared by laminating ACF with suitable textile materials on both sides to enhance the physical and functional characteristics. Functional properties of LACF were assessed for chemical endurance by measuring di-chloro-propane break through time (DCP-BTT), sulfur mustard break through time (HD-BTT), air permeability and water vapour transmission rate (WVTR).Similarly, physical properties viz; mass, thickness, bending length, flexural rigidity, peel strength and tensile strength/bursting strength were also studied. Durability of LACF was also assessed by evaluating physical and functional properties before and after six wash cycles. The findings in our study reveal that this type of material may find many usages in critical military clothing like chemical protective suit, face let mask and breathable gloves for protection of military personnel's in chemical warfare environment.

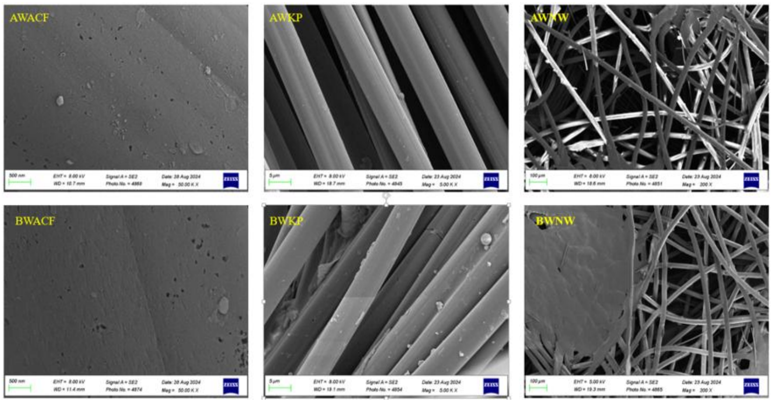

Figure 1: FESEM Image of before & after wash ACT, Knitted polyester and Nonwoven fabric

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AI Integration in the PPE Textile Lifecycle: From Design to Laundry for Performance and Sustainability

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Abstract

Artificial intelligence (AI) is redefining how personal protective equipment (PPE) textiles are developed, produced, and optimized, offering new ways to improve both performance and sustainability. From material innovation and weaving quality control to finishing and industrial laundering, AI technologies are reshaping the PPE textile lifecycle—enhancing defect detection accuracy and reducing resource waste in manufacturing processes (Ozek et al., 2025).

This paper presents a systematic case-based review of recent AI applications in the PPE sector, examining five representative deployments spanning design and prototyping (AI simulations and virtual prototyping for protective laminates), manufacturing quality control (vision systems detecting microscopic defects and foreign particles in knitted and woven fabrics), inspection of high-performance aramid fabrics (deep-learning systems improving first-pass yield and compliance), cutting and material utilization (AI-enabled nesting for higher marker efficiency), and care and longevity (laundry optimization platforms that adapt cycles to soil level and fabric condition to extend service life).

Together, these cases demonstrate how AI creates measurable gains at different stages of the PPE textile value chain. By linking design innovation, production efficiency, and extended service life, the paper positions AI not just as a technological upgrade, but as an enabler of intelligent lifecycle management.

The outcome of this systematic review will be a practical design framework supported by an evidence map of AI use cases in PPE textiles. The analysis will synthesise common patterns in reported outcomes and constraints. From this synthesis, the paper will provide clear design recommendations and decision points for material selection, quality control, and care practices that balance performance and sustainability (reviewed in broader textile contexts; e.g., "AI in Textiles" 2024).

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Lightweight Bio Aerogels and it's Integration into Thermal Insulating Textiles for Cold Weather Conditions

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Abstract

Recent advances in the clothing for thermal management have opened up prospects for its exploration in heat and mass transfer from the human skin to the environment via textile as a medium by simply tuning the physical properties of the material or modifying the chemistries during the development stages. Development of new functional materials and structures are being exploited for fabricating advanced textiles and clothing structures being light in weight and flexible in nature. These lightweight and flexible clothing materials can be developed by integration of aerogels which have mesoporous structure with porosities reaching up to 99 % making them ultralight in weight. Apart from these properties aerogels are known to have a large specific surface area (500-1500 m2/g), low density (0.003 g/cm3), low thermal insulation values (0.015 W/m·K), fire retardant properties and so on. Owing to these superior properties aerogels have found multiple applications in the real time application domains such as thermal and acoustic insulation, fire fighter clothing, aerospace applications, packaging, cryogenic insulation, sensors, biomedical applications, environmental remediation, etc. Aerogels developed from biobased precursors are extracted due to numerous available functional groups, tunable properties, sustainable extraction process, non-toxic solvents and environmentally friendly crosslinking procedures. Due to its superior mechanical properties aerogels developed from biobased precursors do not show brittle behaviour and avoid the problem of dusting in the fabric making it more friendlier to the skin. Here in we have developed aerogels using a sea-weed derived biopolymeric precursor as the matrix agent and a crystalline cellulose derived material as a reinforcing agent to enhance its mechanical properties so that it can sustain the harsher conditions during the freeze-drying procedures. The developed aerogels would show densities from 0.025-0.060 g/cm3and the porosities ranging from 96-98 %. Although light in weight the developed aerogels can withstand more than 1500 times its own weight and can undergo deformation at upto 80 % strain rate showing around 500 kPa compressive strength. After a suitable silane based modification the biobased aerogels can be hydrophobized showing water contact angle of 139°. With the modification the thermal degradation stability of the aerogels also increase. Due to its low density and highly porous structure the thermal conductivities of the monolithic aerogels showed in the range of 0.015-0.045 W/m·K and the fabrics showed the thermal resistance values of 0.085-0.117 m2·K/W with a Clo value reaching near to 1 Clo for the nonwoven fabrics.

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Acknowledgement

The author acknowledges the financial support received from the Science and Engineering Research Board (SERB), Department of Science & Technology (DST), India (Project Code:RP0435904G)

ICTN-2026
8th International Conference on
Technical Textiles and Nonwovens

Assessment of Convective and Radiative Heat Transfer Coefficients of Extreme Cold Weather Clothing on a Newton Thermal Manikin

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Abstract

The convective and radiative heat transfer coefficients of a clothing are important parameters for determining the thermal comfort provided by the clothing. Several studies have been conducted on the convective and radiative heat transfer coefficients of the naked human body, and these coefficients have been used for predicting the thermal comfort of clothed bodies. There are limited studies on convective and radiative heat transfer coefficients for the clothed human body. A few studies conducted on thermal manikins have found differences in these heat transfer coefficients between the nude manikin and clothed manikin and also between different clothing ensembles. In this study, the convective and radiative heat transfer coefficients of various layers of an Extreme cold weather clothing (ECWC) were assessed on a 34-zone Newton thermal manikin at various ambient temperatures in an environmental chamber. The first two layers were studied at +20°C and +10°C ambient temperatures and the third and fourth layers were studied at +20°C, +5°C, -10°C and -25°C. The heat transfer coefficients were determined from the heat flux through the clothing, the clothing surface temperature and the radiative temperature of the environmental chamber. The heat flux through the clothing was determined from the thermal manikin and the clothing surface temperature and radiative temperature were determined by using thermocouples (Figure 1). The convective and radiative heat transfer coefficients vary for different clothing layers and vary with different ambient temperatures for the same clothing layer. These variations in the heat transfer coefficients also result in the variation of convective and radiative heat loss percentage. The assessed convective and radiative heat transfer coefficients of the various layers were used to predict their predicted mean vote (PMV) index and IREQ values.

Fig 1 ECWC layers worn on Newton thermal manikin with thermocouples

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Development of Textile Based Fruit Covering Bags

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Abstract

In this research paper, the rising demand for sustainable and eco-friendly agricultural practices has driven innovation in protective fruit cultivation techniques. To produce high-quality fruits, constant monitoring and care are necessary. Constant care can be done in several ways. Generally, protective layers of textile-based fruit bagging stand out among the several methods.

This experimental work analyses the mechanical and physical properties of the reference cotton woven samples of 60 GSM and commercially used spun bonded non-woven samples of 17 GSM. Both woven and non-woven samples revealed distinct performance differences. woven sample shows a better tensile strength, tearing strength, bursting strength. Whereas light transmission values were nearly similar: 49.61% for the non-woven sample and 46.19% for the woven sample. Air permeability values are also almost the same: 191 $ft^3/ft^2/min$ for woven and 192 $ft^3/ft^2/min$ for non-woven.

Comprehensive analysis was conducted on key mechanical and physical properties of woven and knitted fabric structures fabricated using cotton yarns with varying specifications. Fruit covers with these fabric properties highly fulfilled the requirement of good quality fruits aspects like appearance, defects, texture, and flavour, ensuring both consumer safety and product quality, as per standards established by the Bureau of Indian Standards (BIS) and the Food Safety and Standards Authority of India (FSSAI).

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Acknowledgment

The author acknowledges no financial support from external source.

ICTN-2026
8th International Conference on
Technical Textiles and Nonwovens

Advancing Textile Sustainability: Natural Dyed Plant Based - Blended Yarns for Craft Industry Implementation

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Abstract

Growing environmental awareness has compelled the textile industry to adopt eco-conscious alternatives to conventional practices. This research conducts a comparative investigation of plant-based blended yarns (60:40 cotton-bamboo, cotton-jute, cotton-hemp, cotton-pineapple, cotton-banana), dyed with natural colourants derived from sappanwood, onion peels, pomegranate rind, and alkanet roots. This study examines the colour fastness and colour bleeding properties of the yarns through various tests, including visual appearance, crocking, wash fastness, Perspiration fastness and sunlight fastness, alongside evaluations of aesthetic appeal in crocheted samples. Data suggest that plant-based fibre production consumes up to 60% less energy than synthetic fibre manufacturing, and natural dyes reduce toxic chemical discharge by 99% when compared to synthetic dyes. Cotton-jute yarns dyed with onion peels and cotton-pineapple yarns dyed with alkanet roots exhibited superior fastness and high biodegradability. These findings highlight the practical viability of implementing plant-based blends and natural dyed yarn in the craft industry, which focuses on doll making, toys, and gift articles, which now predominantly rely on synthetic blends and synthetic dyed yarns. This transition offers a decisive step toward achieving textile sustainability, while supporting both ecological mandates and the market's preference for responsibly crafted products. Furthermore, the implications of this research could influence industry practices, policy and improve their market standing towards more sustainable textile production methods.

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A Study on Properties of Union Fabrics Developed with Sisal Fibre for Textile Application

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Abstract

The present study aimed to develop a new range of sisal blended fabrics to enhance the market value of sisal fibre. In the study, three blends of sisal fabrics were manufactured, i.e., sisal/cotton, sisal/viscose and sisal/polyester, with yarn spun at 50:50 of both fibres. The developed fabrics were analysed based on their physical properties, such as, thread count, fabric thickness, fabric weight, drapability, crease recovery, bending length, abrasion resistance, tearing strength and tensile strength. The result shows that, the maximum thread count was seen in sisal/viscose blended fabric, fabric thickness in sisal/cotton blended fabric and maximum weight/unit area in sisal/polyester blended fabric. Maximum drapability was observed in sisal/cotton blended fabric followed by sisal/polyester blended fabric then least in sisal/viscose blended fabric. Tearing strength, tensile strength, crease recovery, abrasion resistance as well as bending length was maximum in sisal/polyester blended fabric in comparison to the other two blended fabrics of sisal fibre. The study concluded that, with the increasing awareness and demand of the natural fibres, sisal-based blends offer potential for diversified applications. The developed fabrics are particularly suitable for home furnishing and decorative articles such as curtains, room divider, table runner, wall hanging, bags, etc. However, due to their coarse texture, they are less suited for apparel unless the fibres are softened prior to spinning.

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Development of Fancy Yarn using Local Sheep Wool of Himachal Pradesh

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Abstract

The tradition of wool spinning and weaving is part of the everyday culture of the people of Himachal Pradesh. The wool is sourced from the local sheep reared in the high altitude of this region. The most common sheep breed found in this region is called the Gaddi sheep, known for its soft and fine fiber with a micron count of 19-23 µm in diameter and around 17 mm in length. It is a preferred material for clothing among the local people for its softness, fineness, good elasticity and breathability. The wool, locally known as the desi oon is commonly used to make ethnic clothing, coats, shawls and blankets, as well as knitted socks and sweaters. The wool is generally hand-spun by villagers using a hand spindle or charkha to produce the yarn, and it is found in three natural shades - creamy white, brown and black. Though this wool has a traditional use, the application of unconventional fancy yarn is not seen with this wool. The present project aims to develop types of fancy yarn with this local variety of wool. The Gaddi sheep wool is selected as the raw material, and the natural colour shades are used for the experiment. The wool is ideal for doing experiments in yarn spinning for its long fibers. The lab experiment followed the traditional process of wool scouring, carding and spinning to make it production-friendly for the local spinners. Explorations are done with the thickness of yarn, uneven twist and texture, and mixing and blending two shades in different ratios. A range of fancy yarn samples is developed under the categories of slub yarn, melange yarn, knop yarn, boucle yarn, marl yarn and sequin yarn. The results are impressive, and the yarns are suitable for knitting and crocheting.

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Acknowledgement

The authors acknowledge the facilities of the Textile Design Department Lab in NIFT Kangra.

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Developing Sustainable Textiles from Parali Fibres (Rice stubble): Valorization of Rice Stubble for Eco-Friendly Textile Applications

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Abstract

Agricultural residues represent a largely untapped resource for sustainable materials. In India, rice stubble (Parali) produces millions of tonnes each year, the majority of which is incinerated, significantly contributing to air pollution and greenhouse gas (GHG) emissions. Parali refers to the lower segment of the paddy crop that remains after harvesting and is regarded as waste by farmers. By utilizing rice stubble for high-value fibrous applications, it is possible to enhance the economic value of rice crops, offer a sustainable source of fibre, and mitigate environmental pollution [1] . This study investigates the potential of Parali fibres as a raw material for sustainable textiles, highlighting their environmental advantages, processing techniques, and functional uses [2]. These fibres can be extracted through chemical, mechanical, or enzymatic methods to yield biodegradable, high-performance materials suitable for apparel, nonwovens, and technical textiles. Cottonised Parali fibres extracted from rice stubble were analysed for their physical and chemical characteristics (Table 1). The fibres demonstrated a fineness ranging from 32 to 50 denier, a bundle strength of 15 to 25 g/tex, and exhibited partial hollowness in their structure. Their chemical composition included 35 to 47% cellulose, 20 to 27% hemicellulose, 15 to 20% lignin, and a moisture regain of 9 to 12%. These fibres were blended with wool, cotton, and polyester to create yarns with diverse properties. Parali nonwoven fabrics were evaluated for thermal performance, FTIR and TGA analysis. Needle-punched nonwovens (4.5 mm thick) exhibited a thermal resistance of 0.1892 m^2K/W, while partially needle-punched samples (4.6 mm thick) showed an improved value of 0.2498 m^2K/W. The increase indicates that partial bonding enhances air entrapment, improving insulation efficiency.

ble

From the perspective of greenhouse gas (GHG) emissions, Parali fibres have a minimal impact, with estimated emissions of around 0.5–1.0 kg CO_2e per kilogram of fibre, primarily due to avoided emissions from stubble burning. In comparison, the lifecycle emissions of cotton range from 1.1–4.1 kg CO_2e/kg fibre, attributed to extensive fertiliser application, irrigation, and energy consumption. Synthetic fibres, such as polyester, generate approximately 2.5–5.0 kg CO_2e/kg fibre during their production and polymerisation processes [3]. This study illustrates that Parali fibres serve as an environmentally sustainable, economically feasible, and technically viable alternative for the next generation of sustainable textiles. By transforming agricultural waste into valuable fibrous products, Parali presents a promising solution to environmental issues while delivering functional, high-performance materials suitable for a variety of textile applications.

Table 1: Properties of parali fibre

CELLULOSE %	Hemicellulose %	Lignin %	Moisture regain (%)	Fineness (Denier)	Bundle strength (g/tex)	Hollowness
35–47%	20-27	15-20	9-12	32-50	15-25	Present Hollow structure

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Exploring Sustainability through Interactive Digital Design Space for Digitally Printed Textiles

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Abstract

Design thinking has been envisioned as a space with overlapping activities that cannot be sequenced. These steps are inspiration, ideation, and implementation. This paper explores ideation as a shared process between designers and users through an Interactive Digital Design Space with a set of pre-meditated interactive ideas or concepts. Participatory or co-design is a global design process used by many global brands offering interactive/shared spaces for design but also embrace sustainability by reducing the inventory and design rejection by consumers. Post-COVID, Indian consumer looks forward to online shopping due to smooth services and user-friendliness. However, the consumer is also conscious of balancing the price point, value, and sustainability. The aesthetics, too, play a significant role in purchasing decisions and may vary from customer to customer with minor modifications such as colour, pattern, and layout. It's intriguing that, in the modern world of neo-manufacturing, the majority of brands rely on mass-production methods. The customization and personalization concepts are being practised by a few bespoke brands and interior design service providers. Whereas, the digitalization is pushing the boundaries of adapting to newer systems of designing, workflow, and the production and presentation of products to consumers.

Inkjet digital printing technology advancements have transformed the printing method on textiles. The screen-making process has been eliminated to simplify the entire printing process. However, colour reduction and editing of print designs are necessary for colourway generation and design precision. Print-on-demand services have witnessed an upsurge in the last decade. Therefore, there is a need to explore the print-on-demand opportunity to extend newer manufacturing methods that support sustainable production. The paper discusses how a design process curation can make way for new working models that promote sustainability. The paper presents a thorough comparison between traditional printing and the proposed customization method, along with consumer perspectives on the customization opportunities. The paper explores creative segmentation for print design as a technique to create various design choices by permutation and combination of design subsets. It also discusses offering interactive online design customization to consumers for the sustainable manufacturing of digitally printed textiles for simple pattern products such as home furnishings.

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Acknowledgement

This research wouldn't have been possible without the support of the National Institute of Fashion Technology, Mumbai, and the students of Dept. of Textile Design Batch 2018–2022, 2019–2023, and 2020–2024. The researcher would like to express gratitude to the students who participated in this research.

Sustainable Textile-Reinforc ed Composites: An Interdisciplinary Platform Approach from Materials to Applications

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Abstract

The transition towards sustainable and circular composite materials demands coordinated innovation across the entire composites value chain, integrating material development, textile reinforcement engineering, manufacturing technologies, and life-cycle-based decision-making. This contribution presents the Sustainable Composites Platform at the Institute for Textile Technology (ITA) as a mission-oriented, interdisciplinary research framework addressing these challenges through a holistic, systems-level approach.

The platform consolidates expertise spanning fiber and yarn technologies, flat and tubular textile reinforcements, nonwovens, composite production, and construction composites to enable sustainability-driven composite solutions. Six overarching research themes structure the activities: extending product lifecycles, converting waste into value, replacing petroleum-based constituents with bio-based alternatives, improving material and energy efficiency in production, enabling renewable energy applications, and supporting a sustainable workforce. Life Cycle Assessment (LCA) and Safe-and-Sustainable-by-Design principles are systematically employed to guide material selection, process development, and application-specific optimization.

Representative demonstrators illustrate the applied methodology, including flax-based non-crimp fabrics combined with bio-based epoxy resins, thermoplastic hybrid yarn systems for pultruded natural-fiber composites, and recycled or upcycled material concepts for interior and consumer applications. Forming strategies for complex geometries and the suitability of biodegradable composites for applications with limited durability requirements are critically evaluated. In addition, a structured methodology for sustainability potential analysis in industrial production environments is presented, combining data acquisition, Gemba walks, expert interviews, and strategic workshops to identify priority actions for sustainable manufacturing and circular economy implementation.

The presented framework demonstrates how interdisciplinary integration, application-driven research, and transparent sustainability metrics can accelerate the industrial adoption of sustainable composite materials and processes.

Three-Dimensional Weaving Machines - Technical Challenges in Their Development

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Abstract

This paper discusses the emerging technology of 3D weaving machines that are being actively developed within the country. 3D composites have promising applications in both Polymer Matrix and Ceramic matrix segments of the strategic sector. However, the bottleneck has been the availability of 3D preforms for which continuous production 3D weaving machines becomes a pre-requisite. CSIR-NAL has been involved in the development of at least three types of these machines. The crux of this paper details about the technical challenges that are inherent in these developments and the approach adopted to resolve them. A prototype of Dual plane shedding-based 3D weaving machine was developed during 2012-2015 under the ACECOST phase III, AR & DB programme. All the sub-elements required for weaving viz., dual plane shedding, dual plane picking, converging beat-up (primary), linear screw rod take-up system and creel-based warp let-off were demonstrated during this phase. (figure 1). The technology developed demanded deviation from convention loom building and the concepts for the sub-elements evolved from first principles of textile weaving principles. To address the requirements of Orthogonal and angle interlock weaving technology, a 24 shaft shuttle based Dobby weaving loom was developed during the phase 2015-2020. This development was through an industrial partner. The Loom had several unique features such as remote blue tooth operation of weaving pick-by-pick, positive rack driven shuttle, take-up-at cawill (required to build the 3D structure) and multi-beat-up options for increased compaction. Several preforms like T stiffener, tapered structures and jet engine nozzle flaps (having projections, tapers etc.) were woven on this loom using carbon tows (Fig 2). For continuous weaving (required for the generation of Design allowable) the concept for multi rapier weaving approach was put in place and another weaving machine (figure 3) was developed through funding from GTMAP board during the period 2018 -2024, AR & DB. In this concept of weaving, pseudo shedding concept, simultaneous guided weft insertion, linear beat-up, linear conveyor-based take-up and reversible creel for taking the slack warp threads were developed. This paper summarises the technical challenges and possible solutions required to develop industry compatible 3D weaving machines based on the expertise gained through the above developments.

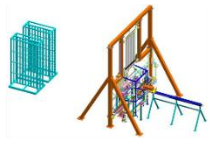

Figure 1: 3D CAD model of the Dual plane shedding-based Prototype

Figure 2: 24 Shaft Dobby loom for weaving

Figure 3: Multi-rapier 3D weaving machine

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B S Sugun (editor), Practical Approach to 3D weaving, ISBN 78--030-80423-7, Materials Horizon : From Nature to Nanomaterials, Springer Nature, pages 170, copyright NAL-Bangalore, year of publication 2021.

Acknowledgment

1. Dr A R Upadhya and Mr. Jadhav (Former Directors) Dr. Abhay Pahilkar, Current Director , Dr. Ramesh Sundaram (former Head , ACD), Dr G N Dayananda (former Head , CSMST), Dr Ramesh Kumar (Head, ACD), Mr. Kotresh (Deputy head , ACD) - All From CSIR - NAL for their suppport during these developments.
2. ACECOST Phase III, AR & DB for funding during the period 2012-2015
3. GTMAP board, AR & DB for funding during the period 2016-2025 (currently ongoing)

Analysis of Physico-Mechanical and Aging Properties of Coarse Wool- Natural Rubber Composites

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Abstract

This work represents the preparation and characterisation of medium and coarse-grade wool-natural rubber composites. The medium coarse and highly coarse wool was harvested from the Chokla and Malpura sheep breed, respectively. These fibers were initially transformed in to yarn and fabrics. The fabrics were then milled, scoured, and dried. The fabrics were then coated with 25 and 40 DRCs of natural rubber latex and vulcanized under pressure. The physico-mechanical properties of the fabrics and wool-NR composites, such as thickness, abrasion resistance, moisture content and regain, water diffusion, static and dynamic friction, tensile strength, elongation, modulus, etc were analyzed using standard protocols. Further, Fourier Transform Infrared (FTIR) and Scanning Electron Microscopy (SEM) were used to analyze possible chemical reactions as well as to study the cracked surface morphology of the developed wool-NR composites. The aging properties with respect to soil degradation, high temperature, and UV exposure were also determined. The results derived a direct correlation between the mechanical properties of the developed composites with rubber content. The mechanical properties of the NR latex coated medium coarse wool-NR composites were better than the counterpart. The prolonged exposure to high temperature and UV radiation causes a considerable reduction in the mechanical properties. SEM images revealed uniform penetration of natural rubber latex inside the composite structure. The soil degradation studies showed that the developed composites have a high degree of bio deterioration under soil. The wool- NR composites are flexible and could find potential application in lifestyle accessories.

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Acknowledgement

The authors acknowledge the financial support received from Central Wool Development Board to carry out the research.

ICTN-2026
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Natural Fibre Reinforced Cactus Leaf Gel Infused Natural Rubber Latex Dressing Based Biodegradable Engineered Flexible Composite

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Abstract

For the first time, engineered flexible composite material was engineered by using natural fibre as reinforcement material and cactus leaf gel infused natural rubber formulation as polymer matrices. The structure and physico-mechanical properties of fibre denote that jute fibre has excellent strength and modulus whereas cotton fibre has high extension, toughness, and fineness, combinely assisting in enrichment of the mechanical properties of the flexible composite. Surface modified jute and cotton fibre based needle punched structure was coated with natural rubber loaded with cactus leaf gel by following standard procedure and dried. Prepeg was hot-pressed, conditioned and one side of it was colored by using standard chemical formulation. It was found that fibre content inside the developed flexible composite was around 35-40% whereas areal densities were found to be around 250 g/m2 to 550 g/m2. Additionally, optimized tensile strength and tear strength of the developed composite material are 8-9 N/mm2 and 90-110 N/mm, respectively. Material sustained for 40000 flexing cycles before cracking while 3-4% weight loss has been observed after 15000 cycles of abrasion. The crystallinity of the composite was examined by XRD, whereas surface roughness, morphology, cross-section and chemical group analysis were also investigated by AFM, SEM and FTIR analysis techniques. Besides, the chemical mechanism of the structure of fibrous flexible composite has also been hypothesized.

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Acknowledgement

Authors are thankful to ICAR- Consortia Research Platform on Natural Fibres (CRP-NF) for funding

ICTN-2026
8th International Conference on
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Study of The Mechanical Properties of High-Performance Thermoplastic Composites

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Abstract

High-performance composites are revolutionizing structural applications across various high-end load-bearing applications, including aerospace, automotive, and construction industries, by offering superior performance characteristics. Recent advancements have enabled significant enhancements in mechanical properties and durability along with ease of processing addressing critical engineering challenges. Thermoplastics polymers have several advantages over thermosets including ease of repair and recyclability. But their drawbacks like higher viscosity problems and weak interfacial adhesion with fibrous materials have constrained their usage in composite applications. The higher viscosity reduces the flow index of matrix causing poor fiber impregnation which causes void generation in composites which adversely affects composite's mechanical properties. This calls for the need of heavier molds with higher consolidation pressures and temperatures during composite fabrication. In the textile process, there is direct control over fiber placement and ease of handling. In addition to economic benefits, textile technologies ensure a homogeneous distribution of the matrix and reinforcing fibers. Textile processes offer excellent fiber hybridization for reinforcement and matrix materials which can be used to produce composite yarns and preforms which eventually reduces melt flow distance and other processing related issues. This research reports a novel commingling technique using which composite yarns composed of Kevlar and Polypropylene multifilament were produced. This composite yarn was utilized to fabricate unidirectional composites which exhibited reasonable mechanical properties and can be employed in high performance applications.

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Acknowledgement

I am immensely grateful to my supervisor Dr. Sohel Rana for his valuable insights, support and guidance. I am also thankful to my seniors and peers for their ideas and support during this research work.

ICTN-2026
8th International Conference on
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Designing Support Pillows for Individuals under Palliative Care

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Abstract

Palliative care offers patients (including children and adults) with a serious illness a team-based approach to support them and their families. It focuses on enhancing quality of life by identifying and treating pain and other physical symptoms early on, while also addressing the psychological, social, and spiritual aspects of suffering. Most adults who need palliative care are living with chronic diseases, particularly cardiovascular diseases (38.5%), cancer (34%), chronic respiratory diseases (10.3%), AIDS (5.7%), and diabetes (4.6%), as per WHO (2020). Individuals on palliative care often are unable to support themselves to sit up, move, and need help with activities like feeding, dressing, medication, etc. This leads to pressure sores and bedsores in many individuals, particularly in areas that are in constant contact with the bed. During a pilot study in 2025 with three senior oncologists, nurses, physiotherapists, caregivers, followed by an ethnographic research in a palliative care hospice at Bangalore, India, it was observed that current pillows that are available commercially and generally used in the hospice or at homes are not ideal for individuals under palliative care, leading to discomfort, adding to disordered sleep, and exacerbated issues such as pressure ulcers and bed sores. Additionally, there are limited studies in the Indian context in this area, and the commercially available support pillows are not designed to meet the requirements of individuals under palliative care. Therefore, the objective of this research was to design user-centric support pillows for individuals in India under palliative care to assist with caregiving activities. The research methodology used was a user-centered design research method, and data were collected in the real hospice environment during 2025, before conceptualization of the design, co-designing, prototyping, and user testing.

Research showed that about 25% of palliative patients develop pressure ulcers and experience poor sleep. As these patients weaken, 75 % need additional pillows for feeding, wheelchair transfers, and maintaining seated positions, with specific needs varying per individual (e.g., support for side-lying, ankles, hips, head, and hands). The pillows must offer support without causing extra pressure. Additionally, pillow covers for patients with draining wounds need water-repellent and antimicrobial properties. A variety of ergonomic pillows were designed as a result of this research to help palliative care patients. These pillows, customized with fillings like memory foam or hollow polyester fibers, are tailored to provide specific types of support.

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Acknowledgement

The authors are grateful to Bangalore Hospice Trust : Karunashraya.

ICTN-2026
8th International Conference on
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Development of Germicidal Textiles Based on Polyprrole and MXene Coated Cotton Fabrics

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Abstract

The rising need for antimicrobial and self-disinfecting materials has driven interest in germicidal textiles for healthcare, protective clothing, and technical applications. Cotton, while widely used for its comfort and breathability, lacks inherent antimicrobial activity and requires functional surface modification. In this work, cotton fabrics were coated with polypyrrole (PPy), carbon nanotubes (CNTs), and MXenes to develop durable germicidal textiles with multifunctional properties. PPy provides intrinsic conductivity and redox activity, CNTs contribute high surface area, mechanical strength, and microbial membrane-disrupting ability, while MXenes, a novel class of two-dimensional carbides/nitrides, exhibit sharp-edge interactions and photothermal antibacterial effects. The cotton fabric was modified through in-situ oxidative polymerization of pyrrole, CNT dip-coating, and MXene layer deposition, resulting in uniform and stable coatings.

The functionalized fabrics showed excellent antimicrobial activity against Staphylococcus aureus and Escherichia coli, achieving >99% reduction in bacterial colonies within short contact times. Antiviral tests with model strains further confirmed their infection-control potential. The germicidal action was attributed to a combination of electrostatic interaction, membrane rupture, oxidative stress, and photothermal heating under light exposure. Structural and surface analyses using SEM, FTIR, and Raman spectroscopy confirmed successful coating, while tensile strength and air permeability tests indicated minimal compromise of comfort or durability. Importantly, the coatings retained activity after repeated washing cycles.

The integration of PPy, CNTs, and MXenes not only imparts germicidal efficacy but also enhances electrical conductivity, enabling future applications in smart and multifunctional textiles. These coated cotton fabrics present a scalable and sustainable approach for advanced protective materials in healthcare, PPE, and consumer products, addressing challenges of antimicrobial resistance and infection control.

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Acknowledgement

The author acknowledges the financial support received from the Ministry of Textiles (MoT), India, under NTTM project “Functionalized Textiles for Germicidal Applications”.

Development of Antibacterial Silk-Based Implants With Electrospun Cefiderocol Nanofibers and PEO-Coated Mg_3ZnCa

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Abstract

Antibacterial functionality for silk-based implants remains an area needing improvement. This study presents a novel, stepwise antibacterial concept for infection-resistant implants. First, a Mg3ZnCa (ZX31) alloy was selected for its biodegradable properties and coated on the silk base, which was further enhanced using plasma electrolytic oxidation (PEO) for corrosion resistance. Next, electrospun nanofibers loaded with the cefiderocol were applied to the PEO-coated surface. Finally, bacteriophages were immobilized onto the nanofibers. The structure and antibacterial performance of each step were characterized using clinical analyisi including electron microscopy imaging. Antibacterial testing against E. coli using ATCC 25922 demonstrated that phage–antibiotic co-release achieved complete bacterial eradication within one hour, compared to eight hours for cefiderocol-loaded fibers alone. Additionally, magnesium corrosion contributed to sterilization after ten hours. These results show the strong synergistic potential of combining magnesium degradation, antibiotic delivery, and phage therapy to prevent early-stage infections on silk implants, offering a promising route for future clinical applications.

Acknowledgement

The authors acknowledge support from the open access fund of TU Berlin. The authors appreciate the support of the DAAD scholarship for the financial support. The authors recognize and amplify the support offered from the Central Silk Technological Research Institute, Central Silk Board, India. Authors thank Mrs. Mahta Sadat Shariatrazavi from Materials Engineering Department, University of Windsor and Iran University of Science and Technology (IUST) for providing ZX31 alloy, and Dr. Sara Timm from/and the core facility for electron microscopy of the Charité for support in acquisition of the data. The authors appreciate Prof. Dr. Michael de Wild and Dr. Fabian Züger from Institute for Medical Engineering and Medical Informatics, University of Applied Sciences and Arts Northwestern Switzerland (FHNW) for facilitating access to the electrospinning machine; and Dr. Reinhard Meinke, Ms. Michelle Schumann from Material Engineering Department, TU Berlin, and Mr. Markus Malcher from Institute of Machine Tools and Factory Management, TU Berlin.Smart Textile Actuator using Stress Memory

ICTN-2026
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Engineering the Osteochondral Junction: A 3D Bioprinted Full Thickness Cartilage-Bone Model

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Abstract

Osteoarthritis (OA) is a progressive and debilitating joint disease which affects more than 600 million people globally, marked by cartilage degradation, subchondral bone sclerosis, and limited natural repair capacity. A significant contributor to the OA pathology is the hypertrophic differentiation of chondrocytes, which drives matrix mineralization and cartilage loss. Current in vitro models and engineered grafts fail to recapitulate the complex osteochondral interface or maintain chondrocyte phenotypic stability under inflammatory conditions. To bridge this gap, the fabrication of the 3D bioprinted cartilage-bone model would replicate the native architecture of the cartilage-calcified cartilage-bone interface. The development of the biology-inspired tissue engineered model would use silk fibroin-gelatin bioinks with covalently conjugated small molecules which would be further studied for chondrocyte hypertrophy modelling. The engineered construct incorporates spatially organized bioinks tailored for chondrogenic, hypertrophic, and osteogenic zones, bioprinted using a gradient-based strategy. These constructs will be assessed for extracellular matrix composition, mineralization, and cellular phenotype under OA-mimicking conditions. The ultimate goal is to model osteochondral remodelling and develop phenotypically stable, anti-hypertrophic cartilage grafts that also regenerate subchondral bone. The development of the 3D bioprinted cartilage-bone model promises both the novel therapeutic avenue for the OA and an ethical, high-fidelity in vitro model to study osteochondral pathophysiology and screen regenerative strategies.

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Acknowledgement

The author acknowledges the financial support received from the MFIRP under the Sorbonne University, France-IIT Delhi, IRD IIT Delhi

Sustainable Nano-functionalised Textiles for Advanced Wound Care and Wellbeing

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Abstract

Diabetic foot wounds remain one of the most challenging complications in diabetes management. Patients with diabetes are highly susceptible to infections and inflammation due to impaired immune responses, and the overuse of antibiotics has further contributed to the emergence of resistant bacterial strains. These factors highlight the urgent need for designing a nanomaterial-embedded innovative textile as a vital step in producing a versatile and therapeutic treatment to expedite the healing of diabetic wounds and reduce bacterial resistance. In this study, the green synthesis method was used to synthesise silver nanoparticles (AgNPs) by using Catharanthus roseus leaf extract (AgNP@CR), a plant known for its antibacterial and regenerative properties. The AgNPs were immobilised on graphene nanosheets to form a nanocomposite, which was subsequently embedded into cotton fabric to create a functional wound dressing. The nanocomposite and its textile integration were characterised using multiple analytical techniques. HR-TEM and FE-SEM analyses confirmed successful impregnation of the nanocomposite into the cotton matrix. Antibacterial test revealed that the dressing exhibited superior activity against gram-negative E. coli and gram-positive B. subtilis compared to untreated fabric. In vivo experiments further demonstrated that the nanocomposite dressing significantly enhanced wound closure relative to control groups. These findings suggest that the synergistic combination of plant-derived AgNPs, graphene nanosheets, and textile substrates provides a versatile and eco-friendly approach to diabetic wound care. Overall, this unique combination is a potential technique for advanced diabetic wound care and its management.

Next-Generation Cut-Resistant Yarns: Para-Aramid/UHMWPE Composites without Metallic Reinforcement

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Abstract

Metal wire reinforcements such as stainless steel and tungsten are commonly employed in the development of high cut- and heat-resistant para-aramid yarns. Although these metallic cores provide excellent cut performance and thermal stability, they pose significant challenges in terms of recyclability and end-of-life processing. To overcome these limitations, this study presents an alternative approach: para-aramid/UHMWPE core-spun yarns reinforced with hard particle-impregnated UHMWPE cores instead of metallic wires. The para-aramid sheath ensures superior thermal resistance, while the engineered UHMWPE core enhanced with hard particles [1] achieves cut performance comparable to 100 % para-aramid protective textiles. By eliminating metallic components, this design enables easier recycling, reduces environmental impact, and maintains the protective properties that are essential for demanding applications. The findings demonstrate that hard particle-impregnated UHMWPE cores can successfully replace many metal-wire-based solutions in high-performance protective textiles, offering a more sustainable and efficient pathway for developing next-generation cut-resistant yarns. An example of yarn utilising this concept is shown in figure 1.

Figure 1 Para-aramid/UHMWPE core-spun yarns

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Sustainable High-Performance Gloves from Cotton/Recycled Para-aramid/HDPE Blends

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Abstract

In this study, tri-blend yarns consisting of cotton, recycled para-aramid, and HDPE fibers were developed in three different proportions (70/20/10, 50/40/10, and 30/60/10) to investigate the effect of blend composition on protective performance. A 20s Ne yarn count was produced using the ring spinning system, and seamless gloves with a fabric weight of 280 GSM were knitted on a Shima Seiki glove knitting machine. The developed gloves were systematically evaluated for TDM cut resistance, blade cut resistance, puncture resistance, abrasion resistance, flame resistance, and contact heat resistance in accordance with EN 388, EN 407, and ISO 13997 standards. The results demonstrated that quality of recycled para-aramid fibre and its strength was affecting the properties of gloves, while cotton contributed to comfort and HDPE improved cut reinforcement of the gloves. The findings highlight the potential of recycled para-aramid-based blends for producing sustainable and high-performance protective gloves for industrial applications.

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Acknowledgment

The author acknowledges the financial support received from the National Technical Textile Mission, Ministry of Textiles, Government of India under grant number 03/03/2023-NTTM (Revised MoU)/6th MSG/20.

Studies on Cut-Protective Performance of Composites Yarn Based Knitted UHMWPE Textiles in Real-world Industrial Applications

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Abstract

The safety of workers in hazardous environments depends on advanced protective textiles capable of withstanding various real-world challenges, especially in automotive, glass, aerospace, mining, construction, and food industries where cut hazards are prevalent. Developing flexible, high-performance cut-protective textiles is essential to meet these needs. These cut-resistance clothing are often exposed to harsh workplace conditions, including elevated temperatures, which can compromise their structural integrity and diminish their cut-protection efficacy. The present work investigates the effect of temperature on the cut-resistance performance of core-spun UHMWPE yarns integrated with stainless-steel and glass filament-based knitted fabrics. Cut-performance was assessed across industrial work handling temperatures ranging from 30 °C to 75 °C. Furthermore, thermal cut performance was analyzed by structural characterization and surface morphology of the samples. The results revealed a general decline in cut performance with increasing temperature for all samples, with stainless steel-reinforced UHMWPE fabrics experiencing the most pronounced reduction % compared to their glass fiber-reinforced and 100% UHMWPE counterparts. These results are substantiated by analyses of surface temperature distribution profiles and X-ray diffraction (XRD) outcomes. This study benefits industry workers, guiding them in selecting effective protective clothing for varied thermal conditions.

Thermal Comfort Behaviour of Cut Protective Workwear fabric made from Filament Twisted Core Sheath yarn

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Abstract

Cut protective clothing is plagued by several issues, including bulky fabric, intricate donning procedures, inadequate comfort, and restricted mobility. When choosing the most comfortable cut-resistant fabric, it is essential to consider the individual requirements of the end users. This study seeks to improve the understanding and optimization of protective clothing for enhanced occupational safety and protection by examining the complex relationship between material composition, yarn structure, and comfort factors. Various filament twisted core sheath yarns, comprising stainless steel with high-performance polyethylene and polyester wraps, were utilised to manufacture thermo-physiologically pleasant cut protective workwear fabric. Twelve cut protective fabrics were fabricated using a 6-end satin weave using filament twisted core sheath yarn of five different linear densities (98 tex, 74 tex, 59 tex, 49 tex, 39 tex) with keeping constant areal density of 200 g/m². Following the established standard, the fabric samples were used to evaluate the thermophysiological properties, including air permeability, dry and evaporative heat resistance, thermal conductivity, moisture permeability, wettability, and moisture wicking. The cut resistance of each sample was measured under EN 13997. The cut protection and thermo-physiological comfort characteristics of cut-resistant clothing are significantly affected by the content of core material (stainless steel) and the structural parameters of the yarn (linear density, twist direction), as evidenced by the analysis of the observed data. The augmented core material content (stainless steel) enhances fabric thickness and reduces bulk density, hence affecting the thermophysiological comfort characteristics of the engineered cut protective workwear fabric. Fabric composed of a greater amount of core material (stainless steel) with reduced bulk density demonstrated adequate cut protection and superior performance regarding thermo-physiological comfort qualities.

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Tensile Performance of Cut Protective Woven Fabrics Made With Metallic/Glass Core Hybrid Yarns

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Abstract

The development of cut-protective textiles requires careful optimization of yarn architecture, fabric density, and structural orientation. In this study, twelve types of hybrid yarns were engineered by embedding either stainless steel or glass fibers as the core, while surrounding them with sheath layers of polyester and ultra-high-performance polyethylene (UHPWPE). The sheath filaments were arranged in either S/S or S/Z directions to see the impact of twist direction of the sheath layers. Total 36 satin woven fabric samples were produced at three areal densities of 150, 200, and 250 g/m² using these yarns. Experimental results demonstrated that the tensile strength of the fabrics was highly sensitive to thread density. Higher thread density in warp or weft direction consistently exhibited higher tensile strength, which was also reflected in their tear strength characteristics. The tensile modulus of the fabrics was measured in the range of 600–900 MPa, however, a nominal increase observed for higher areal density fabrics. Tensile strain was also influenced by thread density and its direction, confirming the structural dependence of extensibility. The resistant performance of the fabrics was directly related with the areal density and thread density of the fabrics. Higher areal density with lower thread density performed a little bit lower cut resistant performance than both higher areal and thread density fabrics. A maximum 2930 gf cutting load was observed for 250 g/m^2 fabrics with maximum thread density of 864 per cm^2. Yarns of lower dense fabrics showed rolling effect over the mandrel due to cutting load resulting early exposure of the fabric and experienced lower cut through distance. These results exhibited critical role of yarn architecture with fabric construction to determine the cut resistance performance of the fabric with optimum tensile performance.

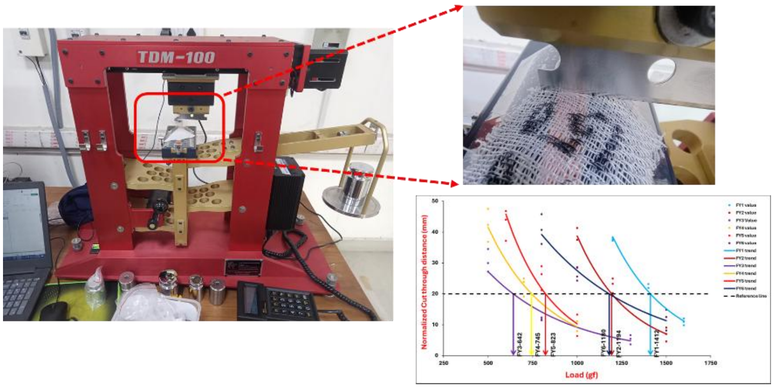

Figure 1. Cut resistant performance evaluation using TDM 100

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Technical Textiles for Personal Protection: Current Scenario

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Abstract

Technical textiles for personal protection play a critical role in safeguarding human life across industrial, defense, healthcare, and emergency response sectors. With increasing occupational hazards, stringent safety regulations, and rising awareness of worker well-being, the demand for high-performance protective textiles has grown significantly. These textiles are engineered to provide protection against multiple risks such as flame and heat, chemicals, mechanical impact, while ensuring comfort, durability, and ease of movement.

Arvind, as a leading player in advanced textile and apparel solutions, has been actively contributing to the development of protective textiles focused on human protection. Leveraging advanced fiber technologies, innovative fabric constructions, and specialized finishes, Arvind's protective textile solutions address the evolving requirements of sectors such as firefighting, defense, industrial safety, and healthcare.

Life Cycle Extension of Aramid Fibres: A Sustainable Approach

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Abstract

Aramid fibres, synthesized through polycondensation of aromatic diamines and aromatic diacids, are high-performance polyamides characterized by exceptional chemical, physical, and thermal stability. Their superior properties have enabled widespread applications across diverse sectors, including technical textiles, aerospace, automotive, and military industries. However, despite being produced through resource-intensive and costly processes, aramid-based products are predominantly disposed of in landfills at the end of their service life. Such disposal not only results in the loss of valuable resources but also imposes a significant environmental burden. Recycling aramid fibres offers a promising approach to extend their life cycle, conserve fossil resources, and reduce ecological impacts. This systematic review examines the current strategies for aramid fibre recycling, evaluates their feasibility, and outlines potential pathways for sustainable utilization in future applications.

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Acknowledgement

The author acknowledges the support of The Technological Institute of Textile & Sciences, Bhiwani for the resources.

Waste Utilization in the Textile Sector: Recycling Garment Industry Waste into Handbags

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Abstract

The growing demand for sustainable fashion has emphasized the importance of recycling garment industry waste into innovative and eco-friendly products. The textile and garment manufacturing sector is one of the largest contributors to global solid waste, generating significant quantities of pre-consumer and post-consumer fabric discards that often end up in landfills or incineration. Addressing this challenge, recycling and up-cycling emerge as essential strategies to minimize environmental impact and create value-added products. This study explores the potential of waste utilization through the design and development of handbags created from hosiery fabric waste and alternative sustainable materials. A total of ten handbags were constructed using various recycling techniques, including handcrafted, khesh weaving, batik, and vegan leather applications. These handbags were specifically designed to appeal to young women and categorized under Type 1 recycled handbags (HC1–HC4).

A consumer acceptability survey was conducted among young women to assess awareness, preferences, and willingness to pay for sustainable fashion products. Findings revealed that 83% of respondents were knowledgeable about recycling, 98% valued the uniqueness and aesthetic appeal of recycled handbags, and 65% expressed a willingness to pay a premium for handcrafted sustainable products. Additionally, 84.4% appreciated the eco-friendly attributes of the handbags. However, awareness of traditional crafts such as khesh weaving remained low, highlighting the importance of integrating cultural heritage into modern sustainable products. Statistical analysis reinforced these insights, with a strong positive correlation between sustainability awareness and preference for recycled handbags ($r = 0.83$, $p < 0.01$). A second correlation ($r = 0.71$, $p < 0.01$) confirmed that price sensitivity directly influenced willingness to purchase, suggesting affordability as a key determinant for market acceptance. The research further extended into a vegan leather recycling project, employing eco-friendly raw materials such as glycerol, soy wax, bees wax, and gum rosin, along with cold brand reactive dyes. Testing confirmed excellent light fastness, good crocking fastness, and overall strong water fastness, validating vegan leather's viability as a sustainable alternative to animal-based materials. Visual assessments ranked bees wax and gum rosin as the most effective resist agents, producing samples with superior aesthetic appeal. Overall, the study highlights the dual potential of sustainable handbags: addressing environmental concerns through recycling while simultaneously promoting Indian textile heritage via traditional crafts. The findings demonstrate consumer acceptance, aesthetic appreciation, and willingness to invest in eco-friendly accessories, thereby underscoring the market potential for sustainable fashion products. The integration of handcrafted techniques, recycled materials, and vegan leather points toward innovative design solutions that balance ecological responsibility with cultural preservation.

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Acknowledgement

The author acknowledges the weavers and craftsmen who were involved in making of the products.

High-Throughput Screening of Textile Wastewater-Derived Electroactive Biofilms on Diverse Thin Film Electrodes in a Microfluidic Reactor array

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Abstract

This study presents a novel microfluidic PCB-based bioelectrochemical microreactor array with 96 individually addressable microreactors for high-throughput screening of materials and electroactive microbes utilized in Bioelectrochemical systems. Each microreactor comprises a gold working electrode surrounded by reference and counter electrodes within a 3 mm deep well, replicating the standard microtiter plate format. This design enables parallel enrichment of electroactive biofilms from wastewater under controlled potential using a multichannel potentiostat. We demonstrate the utility of this platform by investigating the influence of twelve different thin film metal electrodes on biofilm development, power generation, dye degradation, and chemical oxygen demand (COD) removal from textile wastewater. Time-of-Flight Secondary Ion Mass Spectrometry (ToF-SIMS) analysis of the biofilm-electrode interface provided insights into microbe-metal interactions and potential biofilm secretions relevant to electron transfer and dye degradation. This platform offers a powerful tool for accelerating the discovery and optimization of bioelectrochemical materials for wastewater treatment applications.

Sustainable Knitwear Solutions from Recycling Tasar Silk Waste for Eco-Friendly Textile Innovation

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Abstract

Tasar silk is a valuable variety of wild silk, renowned for its natural golden sheen, coarse texture, and high tensile strength. Predominantly cultivated in the tropical forest regions of Central India, it plays a crucial role in supporting rural livelihoods and promoting biodiversity through sustainable sericulture practices. Reeled Tasar silk, obtained from intact cocoons, is extensively used in premium sarees, stoles, dress materials, upholstery, and traditional crafts. However, a considerable portion of the Tasar silk such as pierced or defective cocoons, deflossing waste, reeling waste, pelade waste, and peduncle—is unsuitable for reeling due to the lack of filament continuity. These underutilized by-products hold significant potential for recycling and circular innovation in textiles. In this study, Tasar silk waste were processed into long staple spinning technology through optimized pre-processing, spinning, and post-spinning techniques to produce recycled Tasar spun silk yarns. Key fiber properties such as staple length, diameter, denier and tensile strength were evaluated, along with yarn characteristics including hairiness, imperfections, evenness, and tensile behaviour. The performance of the recycled Tasar spun silk yarns was compared with commercially available Eri spun silk yarns, which are exclusively produced from staple fibers due to Eri silk's inherently non-reelable, open-ended cocoon structure. A techno-economic analysis of the production process confirmed its viability at scale, highlighting efficient material utilization and potential for mill-level adoption. Importantly, as knitwear applications of Tasar silk remain largely unexplored, the performance of the recycled spun silk yarns was evaluated using a circular knitting machine. The study involved optimizing machine settings and process parameters to achieve smooth operation, consistent fabric quality, and dimensional stability. Furthermore, the feasibility of producing various single jersey structures—such as honeycomb, bird's eye, and piqué knit—were also explored, demonstrating the yarn's adaptability to diverse knitwear designs. The findings validate the feasibility of transforming Tasar silk waste into value-added knitwear, promoting circular innovation, waste reduction, and sustainable enterprise development. This model aligns with India's vision for a circular textile economy—enhancing resource efficiency, diversifying silk products, and fostering eco-conscious rural industries.

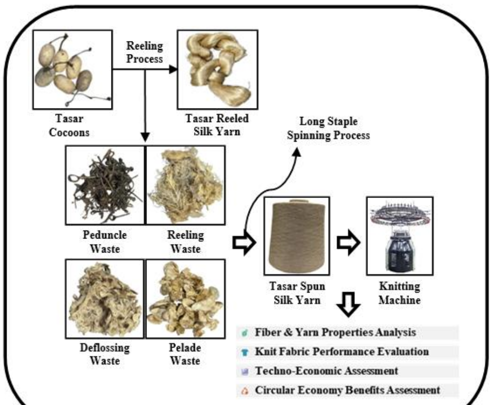

Fig: Research Methodology

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Acknowledgment

The author gratefully acknowledges the financial support provided by the Central Silk Board (CSB), Bengaluru, India, under Project Code: CFW 07042 SIC.

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Waste-Derived Cellulosic Fibres For High Strength and Thermal Energy Storage Applications

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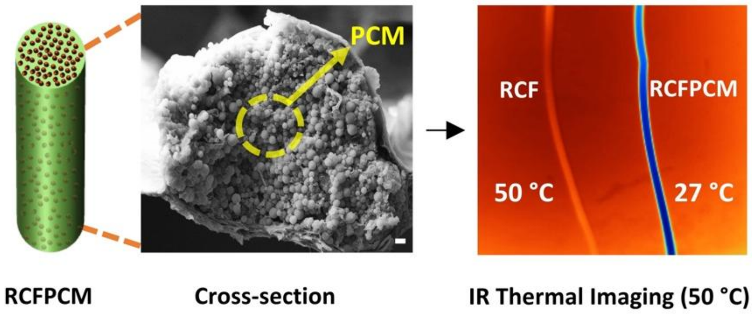
Abstract

The escalating global textile waste crisis, coupled with the demand for sustainable advanced materials, necessitates innovative recycling strategies that ensure both high performance and environmental responsibility. This work presents a sustainable approach to valorizing textile waste by converting it into high-performance cellulosic fibres, addressing one of the major environmental challenges of the textile sector. A selective dissolution process was employed to efficiently recover cellulose from hard-to-recycle cotton–polyester blends, which was subsequently regenerated through an eco-friendly wet-spinning route. The resulting fibres exhibited high tenacity (49.8 ± 1.4 cN/tex), demonstrating their mechanical robustness. To impart added functionality, phase change material (PCM) microcapsules were incorporated into the cellulose matrix, enabling reversible thermal energy storage. At 40% PCM loading, the fibres achieved an energy storage capacity of 66.6 J/g while maintaining excellent washing durability, ensuring long-term performance. By combining green chemistry with advanced fibre engineering, this study highlights a scalable circular strategy for textile waste valorization, paving the way for next-generation thermoregulatory materials with potential applications in technical and sustainable textiles.



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Acknowledgement

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Valorization of Biomass-Derived Molecule for Engineering Multifunctional and Comfortable Cotton Fabric

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Abstract

The increasing prevalence of mosquito-borne diseases highlights the urgent need for sustainable strategies, as conventional synthetic pesticides, although effective, present serious concerns for human health and the environment. This work presents a green approach based on the synergistic combination of biomass-derived coumalic acid (CA) and biocompatible branched polyethylenimine (bPEI), integrated onto cotton fabric through a layer-by-layer (L-b-L) self-assembly technique. Successful incorporation of the CA/bPEI system onto the textile substrate was confirmed using comprehensive analytical characterization. The engineered cotton fabric exhibited remarkable mosquito repellency over 95% and strong antimicrobial activity above 99% against both Gram-positive Staphylococcus aureus and Gram-negative Escherichia coli. It also demonstrated high antioxidant activity greater than 94% and an excellent ultraviolet protection factor of 50+. Importantly, key physicochemical and comfort properties, including air permeability, water vapor permeability, fabric stiffness, tensile strength, and color strength (K/S), confirmed the effectiveness of the L-b-L deposition without compromising fabric performance. Furthermore, the multifunctional properties were retained even after 25 domestic laundering cycles and one year of storage, indicating excellent durability. Overall, the findings suggest that the L-b-L-coated cotton fabric serves as a robust, multifunctional textile platform that provides protection against mosquito bites and microbial contamination, demonstrates strong radical scavenging activity and superior UV shielding, and shows no toxic effects. As illustrated in Figure 1, the study integrates biomass valorization with textile functionalization. Figure 1a outlines the sustainable production of CA from lignocellulosic biomass via fermentation, emphasizing its renewable origin. Figure 1b depicts the subsequent fabrication of the multifunctional cotton fabric through the sequential layer-by-layer self-assembly of CA and bPEI, demonstrating the systematic development of sustainable cotton fabric without compromising the comfort properties.1

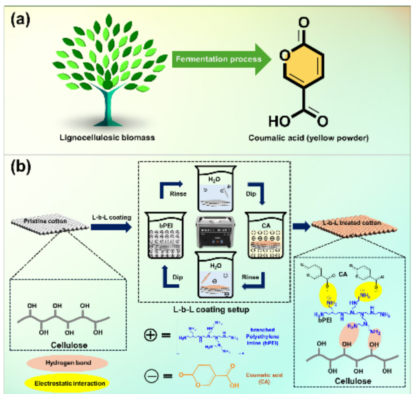

Figure 1. (a) Sustainable production of biomass-derived CA from lignocellulosic feedstock through a fermentation pathway. (b) Development of multifunctional cotton fabric via sequential layer-by-layer (L-b-L) self-assembly of CA and bPEI onto the textile substrate.

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Real Time Data monitoring of Garment Production Floor using Needle Time

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Abstract

21st-century Industrial Revolution is digital. **Industry 4.0**, the Fourth Industrial Revolution refers to the current era of connectivity, advanced analytics, automation, and advanced-manufacturing technology that has been transforming global business for years. Digitization helps improve scheduling, automation and monitoring from the frontlines of the plant floor and the supply chain to all the way to the top floor. There are several systems used to help with this such as **MES** and **ERP** which being particularly commonly used in manufacturing. So basically, a MES helps a manufacturing unit to achieve transparency, improve productivity, and overall efficiency. So, as one of the performance measures (KPI) for sewing floor, knowing the needle down time of a manufacturing unit is very important.

The purpose of the study was to determine needle running time using the pedal movement. In the clothing industry, the phrase "**needle running time**" is usually used to refer to the whole time, or a portion of the total time, that a sewing machine is operating when sewing a garment together. Studies on different sewing machines have been done in which industrial sewing machine has been our main interest. Among all the machines, a detailed analysis has been done on SNLS (Single Needle Lock-Stitch) machine that includes its working and the flow of power transmission.

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Artificial Intelligence (AI) and Digital Sustainability: Transforming the Future of Textile Manufacturing

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Abstract

Artificial Intelligence (AI) is redefining traditional manufacturing processes through intelligent automation, data-driven decision-making, and self-optimizing systems, creating a paradigm shift in the textile sector. This study investigates how key textile processes including fibre manufacturing, weaving, dyeing & printing, finishing, surface embellishment, and garment manufacturing are being transformed by AI-driven solutions such as machine learning, computer vision, and predictive analytics. By enabling predictive maintenance, defect detection, dynamic production scheduling, and real-time quality control, AI technologies enhance efficiency, accuracy, and agility. These advancements not only improve product consistency and minimize waste but also empower the industry to adapt quickly to evolving consumer preferences and sustainability imperatives.

In parallel, the integration of digital technologies is reshaping sustainability practices within the textile industry. Innovations such as block chain, advanced software systems, 3D modelling, and virtual sampling (CLO) are promoting resource efficiency, transparency, and circular economy models. Block chain ensures traceability across the supply chain, strengthening ethical sourcing and sustainable production practices. Digital design tools further reduce material waste and carbon emissions by optimizing product development and minimizing reliance on physical prototypes.

This article addresses the potential and difficulties presented by digital transformation in the textile industry. Although digital solutions offer much promise for sustainability, their extensive adoption necessitates investment in technology, established frameworks, and skill enhancement. Digital technology provides robust solutions to enhance sustainability in the textile business. The intentional incorporation of these advances provides a feasible approach to diminishing the sector's environmental footprint while sustaining profitability and competitive edge.

AI in Textiles

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Abstract

Artificial Intelligence (AI) is transforming the traditional and technical textile industry by enhancing efficiency, quality, sustainability, and market responsiveness across the value chain. AI-driven systems are very much useful in textile production for automating tasks and improving quality control. Use of AI in design and product development creates innovative patterns and styles based on market data, which enables faster, data-driven creative processes. AI is also useful in reducing the textile industry's environmental footprint. It optimizes fabric cutting to minimize material waste and controls resource-intensive processes like dyeing to reduce water and chemical usage. Moreover, AI in the supply chain and retail sectors improves demand forecasting by analysing textile market trends and consumer behaviour, helping manufacturers and retailers to optimize production schedules and inventory levels. It also enhances the user experience with personalized recommendations and virtual try-ons. This review article highlights the significance of Artificial Intelligence in various sections of Textile Industry.

Acknowledgement

The author acknowledges the financial support received from the Department of Textiles, DKTE's Textile and Engineering Institute Ichalkaranji.

Weaving Sustainability: Generative AI Framework for Craft Preservation in Indian Textiles

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Abstract

India's rich legacy of textile crafts is facing an existential challenge due to industrial homogenization, generational knowledge gaps, and limited digital integration. This paper proposes a novel Generative AI framework—titled "Maheshwari Saree – timeless elegance", designed to digitally archive, contextualize, and regenerate the intangible heritage of Indian weaving practices. The framework utilizes Large Language Models (LLMs), customized through prompt training and layered with domain-specific datasets, including weaver surveys, visual design references, regional lore, and historical archives.

The case study focuses on Maheshwari sarees—a centuries-old weaving tradition from Madhya Pradesh—interpreted as a digitally responsive textile system. The GPT was trained to simulate expert-level responses on topics such as weaving techniques, loom anatomy, motif symbolism, sustainable yarn alternatives, and policy advocacy for artisans. The research methodology integrates AI content curation with ethical knowledge translation, enabling the tool to serve not only as a design informant for contemporary creators but also as a conversational repository for students, policy researchers, and craft revivalists.

The resulting framework showcases how Generative AI can act as a craft custodian, bridging intergenerational transmission, promoting sustainable design ideation, and empowering heritage clusters. It fosters a dialogic model of preservation that moves beyond static documentation, creating a living, responsive knowledge system for Indian textiles. This project demonstrates the viability of using AI not as a replacement, but as a respectful co-creator, to sustain the material, cultural, and human ecosystems of traditional crafts.

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Acknowledgement
The author gratefully acknowledges the artisan clusters of Maheshwar, Madhya Pradesh, and the survey respondents who contributed to the dataset. Special thanks to LWRN Studio for providing the infrastructure to build and test the custom GPT model.

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Development of CNN-Based Defect Detection System for Garment Quality Inspection

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Abstract

Quality control is a critical aspect of garment manufacturing, ensuring product consistency, reducing defects, and maintaining customer satisfaction. Traditional manual inspection methods, while widely used, suffer from limitations such as human subjectivity, high labor costs, and inefficiencies in large-scale production. To overcome these challenges, this project introduces an AI-powered automated defect detection system for quality assurance in shirt manufacturing, leveraging Convolutional Neural Networks (CNNs) and computer vision. The study explores the limitations of conventional defect detection techniques and investigates the potential of deep learning models to enhance accuracy and efficiency. A custom dataset of defective and non-defective garments was developed using data collected from multiple garment manufacturing units. The dataset includes common defect categories such as stitching errors (broken, skipped, loose stitches), seam defects (raw edges, misalignment), missing buttons, stains, and fabric damage. Various CNN architectures were evaluated, including ResNet, Faster R-CNN, YOLOv5, YOLOv7, and YOLOv11, with YOLOv11 emerging as the most effective model due to its high precision, real-time processing capabilities, and optimized computational efficiency for defect detection. The methodology, as shown in the flow chart (Figure 1), involves data pre-processing, model training, validation, and real-time testing. The defect detection model was trained using an 80-10-10 split for training, validation, and testing, with performance metrics including Intersection Over Union (IoU), mean Average Precision (mAP), and F-score. A prototype system was developed and tested under real-world factory conditions, comparing its performance with traditional manual inspection processes. The findings demonstrate that the automated defect detection system significantly improves inspection accuracy, reduces human dependency, and enhances efficiency in garment quality control. By integrating AI-driven defect detection into the production workflow, this project proposes a scalable and adaptable solution for quality assurance in apparel manufacturing. Future research will focus on expanding the dataset, improving defect classification accuracy, and optimizing the system for real-time deployment across different apparel categories.

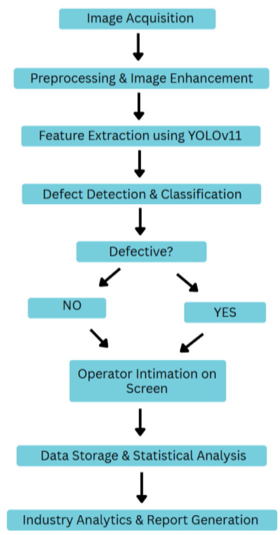

Figure 1: System Flowchart

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MRI-Based Artificial Intelligence Grading of Knee Osteoarthritis to Enable Severity-Specific Orthopaedic Interventions

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Abstract

Knee osteoarthritis (OA) is a progressive degenerative joint disorder that significantly affects mobility and quality of life worldwide. Accurate and early diagnosis of knee OA is crucial for effective disease management and timely therapeutic intervention; however, conventional diagnostic approaches largely rely on subjective clinical evaluation and visual interpretation of imaging data, resulting in limited consistency and sensitivity, particularly during the early stages of disease progression. **[1]** In this study, an artificial intelligence (AI)–driven framework is developed for the automated diagnosis and severity grading of knee OA using magnetic resonance imaging (MRI). A comprehensive knee MRI dataset was curated and annotated to capture clinically relevant pathological features, including osteophyte formation, eburnation, bone marrow lesions (BMLs), and variations in cartilage thickness. Multiple deep learning architectures—ResNet50, DenseNet121, VGG16, and ResNet101—were trained and evaluated using the annotated dataset to assess their ability to accurately identify OA-associated features. Model performance was rigorously validated through statistical analysis and expert radiologist assessment, demonstrating reliable diagnostic accuracy and robust grading consistency across different disease stages. A key contribution of this work is the introduction of a novel OA grading approach that incorporates eburnation as a primary indicator of disease severity, thereby enhancing objectivity and clinical relevance beyond conventional grading systems. The proposed AI-based system reduces observer-dependent variability, streamlines diagnostic workflows, and supports personalized treatment planning.**[2]** Furthermore, AI-derived OA severity metrics enable the rational integration of this work with medical textile–based orthopedic interventions, including silk-based artificial cartilage systems incorporating small therapeutic molecules, thereby facilitating severity-specific treatment strategies tailored to the progression of osteoarthritis**.**

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Acknowledgment

The authors would like to acknowledge Apollo Hospitals Indraprastha, New Delhi, India for their support in providing the human tissue samples for our study.

Smart Textiles for Flexible Battery and Supercapacitor Applications

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Abstract

Smart textiles and nonwoven fabrics are explored for flexible and stretchable energy storage solutions. Electrospinning is a simple and versatile method to produce nonwoven fabric with controlled properties. Also Atomically dispersed single metals sites on carbon fibres offer a promising strategy for enhancing electrochemical energy storage. One of the most distinctive features of lotus plant (Nelumbo nucifera) is the presence of a thread-like filaments embedded within the stems. These filaments (lotus threads or LTs) form a fibrillar network around the plants internal air cavities. Such cavities play a vital role in facilitating gaseous exchange between the submerged roots and aerial tissues. Lotus threads gently weave through the hollow aerenchyma chambers and serves as an internal support system. We envisage that the ordered arrangement of cellulose fibrils within the lotus threads upon thermally carbonized into carbon fibres yields a biomaterial with unique inherent order and surface properties ideally suited for electrochemical energy storage applications. We anticipate that atomic dispersion of metal sites on such carbon frameworks of fibrous network may significantly enhance electrochemical performance of batteries and supercapacitors by maximizing the utilization of active sites and promoting efficient redox activities. When Fe atoms are uniformly dispersed at the atomic scale, they exhibit high surface reactivity while anchored on the heteroatom doped carbonaceous matrix. This atomic-level integration facilitates rapid electron transfer and improves the accessibility of metal ions to electroactive sites, thereby boosting charge storage capacity of batteries and supercapacitors. The smart textiles and fibers prepared are employed in different energy storage devices such as lithium ion batteries, sodium ion batteries and super capacitors. The smart textiles are explored for flexible and stretchable textile/fiber supercapacitors, the next generation energy storage solutions. The employment of these smart textiles not only enhanced the electrochemical properties and charge discharge cycling and rate capability of the batteries but also significantly improved the thermal stability and safety of the batteries, which can safely operate at very high temperature above 200 °C.

Exploring the Influences of Pretreatment Process and Structural Parameters of Nonwovens on their Triboelectric Energy Harvesting Performance

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Abstract

Limited availability of fossil fuels and adverse environmental impacts of their uses demand constant search for renewable energy sources. In this context, mechanical energy harvesting techniques are surfacing as promising candidates to partially mitigate the problem of energy crisis. Triboelectric energy harvesting technique is a mechanical energy harvesting technique that transforms frictional motions into electricity. Triboelectric nanogenerator (TENG) utilizes triboelectrification and electrostatic induction effects to convert ubiquitous mechanical energy to electrical one. The conventional TENGs experience few limitations that can be overcome with the help of textile-based TENGs. In this work, needle punched nonwovens were used as one of the triboelectric layers in TENGs. The carding process was utilized for web formation and needle punching was employed as web bonding technique. Needle punching process allows flexibility in raw material selection and also develops robust fibrous structures. Three different nonwovens were developed comprising acrylic fibres of different fineness. Further, the effect of pretreatment process on the triboelectric energy harvesting performance of nonwovens was studied. The pretreatment process was found to change the triboelectric charge generation phenomenon noticeably. Moreover, the influence of structural parameters of nonwovens on their triboelectric energy harvesting ability was explored in a systematic way. Lastly, the potential of the device made of the optimum sample was explored demonstrating a few electronic applications.

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Development of Highly Conductive Metallic Thread for Wearable Strain Monitoring

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Abstract

Wearable health-monitoring with smart textiles meets the future development needs the textile and has quickly become a hot point of research. By integrating conductive threads directly into textile garments, this study aims to develop a seamless, and lightweight health-monitoring system compatible with daily use. This work introduces a novel approach leverages metallized conductive threads, fabricated through optimized techniques, to develop the flexible strain sensors for continuous monitoring of human movements. The development of a highly conductive metallized cotton thread by electroless deposition of copper-nickel (Cu-Ni) particles onto the cotton thread, with the primary focus on strain sensing applications. Structural and elemental analyses confirmed the formation of uniform deposition of the Cu-Ni metallic layer with nanoscale distribution, across the cotton thread surface, while XRD and XPS revealed oxidations states and metallic (Cu-Ni) layer formation with minor phosphorus incorporation. The metallized Cu-Ni thread shows excellent conductivity (1.9 Ω/cm) and stable ohmic behaviour with improved mechanical properties. Electromechanical characterization demonstrated reliable and repeatable resistance changes under applied strains, with high sensitivity in the low strain region, validating its potential as a robust textile-based strain sensor. Compared to single-metal coatings, the metallized Cu–Ni thread imparted enhanced durability against washing, oxidation, and mechanical cycling, ensuring long-term stability. These findings highlight a scalable and cost-effective approach for producing wearable e-textiles sensor matrix capable of capturing human motions in varying physical conditions with high precision

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Acknowledgement

I extend my sincere gratitude to the Department of Science and Technology (DST), Government of India, for awarding me the DST-INSPIRE Fellowship (Grant No. IF230293).

Study on Properties of Luminescent Material in Yarns and Fabrics

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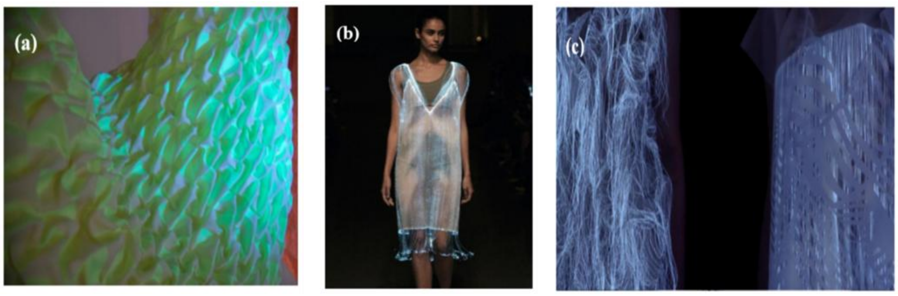
Abstract

Advance functional materials have attracted much attention as a next generation of textile fibres. The fibres functionality depends on end-use and covers wide range of applications. Luminous material is one of the functional materials in which rare earth minerals with luminescent properties are added in proper proportion to get desired luminescence. This type of material can be used to produce novel functional fibres also known as Luminescent Fibres. It is a fibre/filament which can emit its own light. Luminescent fibres have wide range of applications in textile like curtains, panels, fixed structures, decorative clothes, light-emitting slippers, light plush toys, knitting products, embroidery products etc. It also has various applications in technical textiles for fire-fighting personals and military personals. Figure shows Luminescent Fabric prepared by: a) jacquard weaving with photoluminescent elastic yarn, b) weaving with optical fibres, and c) weaving with luminescent thread. There are many methods to prepare Luminescent materials like by solid state method using furnace or microwave, wet chemical methods include precipitation, aerosol pyrolysis, sol-gel method, and combustion synthesis. In the present work, luminescent material, the rare-earth strontium aluminates have been procured from the market and the fibre-forming polymer matrix of PET masterbatch for the production of recycled photoluminescent filaments by the process of melt spinning and then fabric sample formation. The structure, composition and photoluminescent properties of luminescent material and fibres/filaments have been done by FTIR, SEM, XRD, DSC and UV and Emission spectroscopy.



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Acknowledgment

The author acknowledges the MLV Textile & Engineering College, Bhilwara and the Guide (Dr.) Deepti Sharma, Associate Professor, Department of Textile Engineering for the support and encouragement.

Relating Haptic Properties and Perceived Similarity in Fabrics and Natural Materials

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Abstract

Functional textiles have gained huge popularity for many applications, including healthcare, sports, workwear, and packaging. A lot of research has been done to biomimic natural materials and create functional textiles with, e.g., the superhydrophobicity of the lotus leaf, hydrodynamics of shark skin, moisture management features of pinecones, and the combination of adhesion and superhydrophobicity of rose petals (1). Nevertheless, the tactile properties of these natural materials lack investigation. Yet, these tactile properties may influence the user's perception of its quality (2). Specifically for textiles, the tactile properties can be quantified either objectively using a haptic testing system (Figure 1, ii & iii), or subjectively by human evaluation, e.g., using expert panel judgements, ranking, rating or forced-choice methods (Figure 1, i).

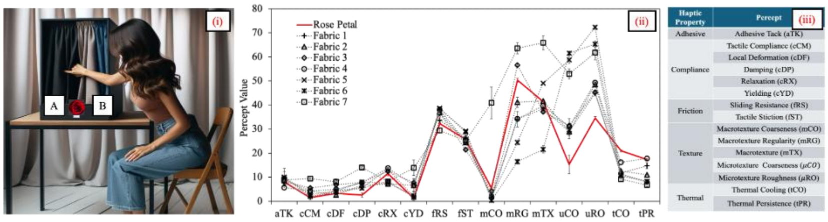

Figure 1: (i) Forced-choice method (AI-image) (ii) Objective testing haptic method (iii) haptic percepts and dimensions

The current research evaluates the objective and subjective tactile properties of rose petals as a natural material (3) and compares them against various sportswear fabrics (University of Alberta Ethics: Pro00145692). Objective measurements were performed using the Toccare haptic system and a thermal effusivity tester. Perceptual similarity was assessed through a two-alternative forced choice protocol, where participants compared fabric samples to natural materials. The study aims to correlate perceptual rankings with objective data, providing insights into characteristics of engineering fabrics that replicate the tactile qualities of natural materials. Findings will guide future textile development for enhanced sensory experiences.

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The author would like to acknowledge MITACS's Accelerate fellowship program and Lululemon Athletica Inc. (Canada) for financial support. The authors also want to thank the Protective Clothing and Equipment Research Facility (PCERF) at the University of Alberta (Canada), and Lululemon Athletica Inc. for access to their lab facility.

Protective Gloves for Para-Military Forces: Integrating Cut, Fire, and Impact Resistance

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Abstract

Riot-control para-military forces are equipped with impact- and stab-resistant body protectors, yet gloves are often absent, leaving hands vulnerable during mob control operations. In some cases, leather gloves are used; however, these provide little to no protection against thermal or mechanical hazards. Considering that human hands contain over 27 bones along with dense networks of nerves, injuries to the palmar and dorsal regions can result in long-term functional damage. This work addresses the critical gap by developing cut- and fire-resistant gloves with integrated impact protection. These gloves are designed to withstand sharp-edged weapons such as knives, screwdrivers, blades, pointed stones, broken glass, sheet metal, and moulded plastics, which are frequently encountered in violent encounters. The design prioritises continuous wear throughout a duty shift, ensuring both protection and comfort, and accommodates sizing for both male and female para-military personnel.

Beyond riot-control forces, these gloves have broader utility for traffic police, jail guards, private security agencies, and bodyguards, who often confront aggressive individuals in high-risk environments. Furthermore, their protective features make them suitable for bikers and two-wheeler riders, offering enhanced safety against road crashes.

By integrating thermal resistance, cut protection, and impact absorption into a single wearable solution, present research work aims to significantly reduce hand injuries in high-risk occupations, while contributing to the advancement of protective textile technology.

Acknowledgement

The authors gratefully acknowledge DRDO for funding this research work

Development of FR non-woven using indigenously developed FR PA66 fibres

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Abstract

Nylon 66 is a high-performance polymer valued for its strength, durability, and resistance to heat and chemicals; however, its inherent flammability restricts its use in safety-critical applications. This work addresses this limitation by developing flame-retardant (FR) nylon 66 nonwoven fabrics using a halogen-free FR additive. Nylon 66 was synthesised via condensation polymerisation of adipic acid and hexamethylenediamine to form nylon salt, followed by polymerisation at high temperature and pressure under an inert atmosphere. The resulting chips were blended with a halogen-free FR masterbatch at three ratios during melt spinning to produce FR nylon filament yarns. These filaments were cut into short fibres and processed into nonwoven fabrics using a thermal bonding technique, which offers dimensional stability and enhanced uniformity.

The properties of nylon chips, filaments, and nonwovens were evaluated through intrinsic viscosity, relative viscosity, melt flow index (MFI), and differential scanning calorimetry (DSC) for thermal behaviour, along with tensile strength testing for mechanical performance. The vertical flammability test (IS 11871 Method A) assessed the flame-retardant properties, while air permeability and fabric thickness measurements were conducted to characterise the nonwoven structure. The melting points of nylon salt and nylon chips were 205 °C and 256.78 °C, respectively. Pure nylon 66 nonwoven burned completely with melt dripping, whereas FR-modified samples exhibited improved flame resistance with reduced dripping.

This study demonstrates that halogen-free FR masterbatch combined with thermal bonding can produce flame-retardant nylon 66 nonwoven fabrics suitable for protective apparel, automotive interiors, and technical textile applications.

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Acknowledgment

The author acknowledges the financial support received from the National Technical Textile Mission (NTTM), India (Project ID: 972300112).

ICTN-2026
8th International Conference on
Technical Textiles and Nonwovens

Study on the Enhancement of The Total Heat Loss and Thermal Comfort in Extreme Heat Protective Garments

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Abstract

Over the past few decades, the increase in accidental fire incidents has become a serious threat to property, human life, and the global environment. Urbanization, industrial expansion, and the widespread use of flammable materials are key factors contributing to these incidents. Furthermore, inadequate fire safety measures, lack of awareness, and weak enforcement of safety regulations have exacerbated the problem. Therefore, there is an urgent need for effective fire management strategies and advanced protective systems to minimize hazards and safeguard communities. Among these safety measures, firefighters play a crucial role during fire and emergencies. They face numerous life-threatening challenges in both structural and wildland firefighting. Personal Protective Clothing (PPC) and Personal Protective Equipment (PPE) serve as essential barriers against these high-risk conditions. The efficiency of PPC is evaluated based on its ability to ensure safety and prevent injuries, which depends on factors such as the type of fire, garment design, and specific material properties. Standard protective gear is typically heavy and bulky to provide sufficient thermal protection. However, this often leads to heat stress and discomfort due to the accumulation of moisture from perspiration. During evacuation or fire-extinguishing operations, the body generates substantial perspiration due to intense physical activity and thermal load, further aggravating discomfort and reducing endurance. In this study, we conducted an experimental investigation on various fabric samples to assess their thermal and evaporative resistance, total heat loss, and composite porosity. Measurements were performed using a sweating guarded hot plate apparatus to evaluate each fabrics ability to resist heat and moisture transfer. These results were then used to calculate the total heat loss through the fabric system under controlled conditions.

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Acknowledgment

The author acknowledges the financial support received from the Defence Research and Development Organisation (Project Code: RP04899G).

Development of a Bench-Scale Instrument for Radiant and Flame Protection Performance in Various Orientations

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Abstract

Thermal clothing is essential for protecting persons from fire and high-temperature conditions. Although extensive research has been undertaken on the thermal protective performance (TPP) of fabrics, most current testing methodologies are restricted to a singular, static orientation, failing to accurately replicate real-world conditions when garments encounter heat flux from many angles. To rectify this deficiency, we have created an innovative bench-scale apparatus designed to assess the thermal protective performance (TPP) of multilayer assemblies in any orientation. The device incorporates copper calorimeter sensors, a dynamic orientation adjustment mechanism, and data collecting software to quantify heat transfer through materials subjected to radiant and convective heat. It facilitates regulated modification in exposure angles, yielding a thorough comprehension of the influence of orientation on thermal protection. Initial experiments on multilayer thermal protective fabric systems indicate that orientation significantly influences heat transfer rates, with specific angles enhancing thermal protective efficacy. The results indicate a significant effect of orientation and thermal protective performance, providing new insights for optimizing fabric designs against multidirectional risks. The results indicate that structural characteristics can be used to provide enhanced protection in diverse exposure circumstances. This tool is a crucial advancement in connecting laboratory testing with real-world performance. It offers researchers and producers a multifaceted instrument for assessing fabric systems in realistic situations, promoting advancements in thermal protective gear design. This study examines the instrument's design, operational principles, and testing results, highlighting its significance for enhancing the safety standards of protective fabric.

Acknowledgment

The author acknowledges the financial support received from the Department of Science & Technology (DST), India (Project Code: RP04091).

Fabrication and Evaluation of Thermal Protective Performance and Mechanical Characterization of the Outer Layer of Firefighters' Suits

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Abstract

Numerous fire-related accidents worldwide cause significant human and material damage, whether intentionally or accidentally. Balancing fire protection and wearer comfort is challenging. This study explores the outer layer of heat-resistant clothing, woven in a honeycomb pattern. It examines how the amount of para-aramid fibre content, ranging from 0% to 100%, affects protection performance as well as mechanical properties. The impact of various factors on multilayered extreme heat protective clothing is investigated, focusing on the type of material used for the outer layer and the heat flux generated from a fire source at different distances. The outer layer was woven in a honeycomb pattern, and para-aramid fibres of varying content percentages were analysed. 3D response surface methodology was used to analyse the impact of different parameters on the thermal protection time (t). ANOVA analysis was conducted to determine the impact of the developed model as well as the coefficients of all the terms present in the equation. A notable increase in the protection time was observed with the increase in para-aramid content from 0% to 100%, at a constant radiative heat flux and air gap. Increasing the air gap from 0 to 12.5 mm, while maintaining a certain heat flux and using the maximum para-aramid content, led to a substantial increase in the protection time. During the tensile and tear characterization, para-aramid showed better performance compared to the meta-aramid samples. It was found that blended fabrics show a special tensile failure behaviour during testing. The overall protective and mechanical performance of these fabrics provide a clear idea of material selection for the development of firefighters' protective clothing.

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Gond-Inspired Upcycled Denim: A Sustainable Approach to Toddler Fashion

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Abstract

The Gond tribe's vibrant wall paintings, inspired by nature, religion, and folklore, offer a rich source of design themes for children's clothing. However, the textile industry poses a significant environmental challenge, with denim waste being a major pollutant. Upcycling is the best way to minimize waste from textiles. To mitigate these issues, upcycling denim waste into toddler wear featuring Gond art motifs not only preserves and popularizes this unique cultural heritage but also promotes sustainable fashion practices, reduces waste, and helps manage the environmental impact of the textile industry. This research contributes to the United Nations' Sustainable Development Goals (SDGs) 8 (Decent Work and Economic Growth), 9 (Industry, Innovation and Infrastructure), and 12 (Responsible Consumption and Production) by developing a sustainable method for upcycling denim waste into eco-friendly toddler wear featuring Gond tribal motifs. The study aimed to preserve and popularize Gond art while promoting sustainable fashion practices through a mixed-methods approach. Denim waste was collected, Gond art documented, and digital prints featuring fauna-based motifs applied on childrens' garments. A final poll gauged the acceptability of the patterns developed using a two-way ANOVA statistical analysis. Results showed that upcycled apparels were perceived as creative and appealing, with a significant positive correlation between fashion design and overall attractiveness. This research demonstrates the potential for sustainable fashion innovation, cultural preservation, and waste reduction, aligning with the SDGs and promoting a more responsible and environmentally friendly fashion industry while providing improved livelihood to the Indian rural artisans.

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Acknowledgment

The authors acknowledge the contribution of Gond artists from Patangarh, Madhya Pradesh, India for their assistance in gathering the data needed to chronicle Gond art and its motifs.

Development of Fashion Garments by Upcycling the Textile Waste

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Abstract

In the last few decades, the world population has increased tremendously. The living standards, in general, have also improved. This has led to an increase in textile consumption, which has resulted in a corresponding rise in textile production. The production and consumption of textile goods generate waste, making this industry the second most polluting in the world. Ecological harm is increasing as the business develops, resulting in 5% of global landfills being occupied by textile waste. In fact, all the waste generated from the textile and apparel sector can be and should be recycled; however, unfortunately, only a minimal amount is recycled. The amount of catch cord waste produced in India is enormous, whereas the upcycling of this waste is practically null. The research aims to find a new and innovative way of utilising catch cord waste (Figure 1) in the garment industry, using the minimum amount of resources and money, thereby bringing a new dimension to the field of sustainable clothing through upcycling of textile waste, offering hope for a more sustainable future.

Figure 1: Catch cord waste

Figure 2: Substrate made from catch cord waste

Figure 3: Garment developed and draped on the model

The fabric substrate (Figure 2) is developed using cotton yarns as the warp and a combination of cotton yarn and catch cords as the weft. The performance properties, such as tensile strength, tear strength, colourfastness to washing and dry cleaning, seam strength, and thermal insulation value of the developed substrate, were measured and found satisfactory for further development of fashion garments (Figure 3). Subsequently, customer feedback and perception analysis were undertaken among the target customers and found to have remarkable acceptance, reassuring about the market potential of this innovative approach. Therefore, it can be concluded that this project was a successful initiative in showcasing innovative ways of upcycling textile waste into fashion garments with improved aesthetic and functional properties, thereby ensuring the utmost user satisfaction of the target customers.

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Harnessing Coarse Wool for Eco-Conscious Plant Growth: A Textile Solution for Sustainable and Organic Farming

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Abstract

Microplastic pollution in soil and marine life created havoc for ecosystems. Only 9% of plastic is recycled globally. Millions of plastic bags are used every year as sapling bags in nurseries. The fate of the young sapling often remains unknown. At the same time, plastic bags make their presence felt prominently, adding no value to the seedlings, worsening the soil, and contributing to the complexities of environmental pollution. This research attempted to address this giant issue through a sustainable solution by harnessing coarse wool. Indigenous wool fibre obtained from sheep has immense potential for agriculture and horticulture applications due to its excellent moisture content and retention. Sapling bags were prepared using coarse wool nonwoven fabrics. Coarse wool is comprised of > 40 µm fibre diameter and > 50% medullation (hollow air space at the centre of the fibre). The bags were prepared using needle punching and handloom technology. Areal density, thickness, and tensile strength of the bag were determined. A seed germination experiment was conducted for 30 days with watermelon seeds. The seed germination and plant growth performance were studied and compared with the conventional plastic bags. The plastic sapling bags yielded only 12% germination, while the wool germination bags showed 41%. The plant growth performance 30 days after sowing was also analysed. The plants in wool bags showed significant improvement in plant height from 5.8 cm to 6.8 cm. The leaf area and the number of leaves were also significantly higher ($p<0.05$) than in plastic bags. To summarize, wool sapling bags performed better compared to plastic bags. These environmentally friendly bags are certainly a viable alternative to non-biodegradable plastic sapling bags. The developed wool sapling bags can be used for nursery plants, agriculture, horticulture, and forestry applications besides the tissue culture laboratories.

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Acknowledgement

The author acknowledges the financial support received from the Indian Council of Agricultural Research (ICAR), India (Project Code: TMTC/2021-2025/02).

Mechanical Recycling of P-Aramid Fabric Waste

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Abstract

The growing consumption of para-aramid fibres in high-performance and protective textile applications has resulted in a significant increase in pre- and post-consumer waste, necessitating sustainable recycling approaches. Mechanical recycling is considered an environmentally benign method. however, the inherent high strength and rigid molecular structure of p-aramid fibres make them highly susceptible to damage during mechanical processing. This study investigates the progressive degradation of p-aramid fibres during mechanical recycling, with particular emphasis on the influence of successive opening stages. Waste p-aramid fibres were initially processed through a vertical cutting machine, followed by shredding and subsequent opening using an opening machine comprising multiple beater stages. Fibre properties were evaluated after each processing stage to understand the cumulative effect of mechanical action. Tensile strength, mean fibre length, and span length were measured to assess mechanical and dimensional degradation. Structural and molecular changes were examined using Fourier Transform Infrared Spectroscopy (FTIR) and X-ray Diffraction (XRD), while fibre surface morphology and damage characteristics were analyzed through Scanning Electron Microscopy (SEM).

The results demonstrate a progressive reduction in tensile strength, mean length, and span length with each successive beater stage in the opening machine, indicating increasing fibre damage due to repeated mechanical stresses. FTIR and XRD analyses revealed a reduction and slight alteration in molecular orientation after opening at each beater stage, suggesting structural disturbances induced by mechanical recycling. SEM image analysis showed pronounced surface degradation, characterized by fibril formation, an increase in nep content, and growth in fibre entanglement size as the fibres progressed through successive opening stages. The findings highlight that the opening stage plays a critical role in governing fibre integrity during the mechanical recycling of p-aramid fibres. Understanding the damage mechanisms at each processing stage provides valuable insights for optimizing recycling parameters and improving the quality and reusability of mechanically recycled p-aramid fibres for value-added textile applications.

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Acknowledgment

The author acknowledges the Atal Center of Textile Recycling and Sustainability, High Performance Textiles Pvt Ltd., CRF and NRF in the Indian Institute of Technology, Delhi, for providing research facilities.

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Development and Comparative Characterisation of Bioplastics Films from Water Hyacinth and Sugarcane Bagasse Cellulose Reinforced Natural Polymers

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Abstract

The global rise in plastic pollution has intensified the search for sustainable alternatives to petroleum-based materials. Bioplastics derived from renewable resources have gained significant attention due to their biodegradability, reduced environmental footprint, and potential to replace conventional plastics in various applications. In this study, bioplastic films were developed using cellulose isolated from two abundant biomass sources: Eichhornia crassipes (water hyacinth), an invasive aquatic weed, and sugarcane bagasse, an agricultural byproduct. The objective was to fabricate and comparatively evaluate bioplastics produced from these two cellulose sources in combination with different natural polymers.

Fourteen formulations were prepared by blending either water hyacinth cellulose (WHC) or sugarcane cellulose (SCC) with pectin, sodium alginate, carboxymethyl cellulose (CMC), and microcrystalline cellulose (MCC). Citric acid was used as a cross-linker, and sorbitol acted as a plasticizer to enhance flexibility. The films were fabricated via the solvent casting method, ensuring uniform thickness and homogeneity. Comprehensive characterization was conducted to evaluate the physicochemical, mechanical, thermal, structural, and optical properties of the developed bioplastics. Mechanical performance was assessed using a micro tensile tester, while thermal stability and phase transitions were analyzed through thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC). Fourier-transform infrared spectroscopy (FTIR) was used to investigate functional group interactions and cross-linking mechanisms, whereas UV-VIS-NIR spectrophotometry was employed to examine optical transmittance and light-barrier properties.

Comparative analysis across the 14 formulations revealed significant variations in tensile strength, elongation at break, thermal resistance, and optical performance depending on the cellulose source and polymer composition. In general, SCC-based films demonstrated slightly higher thermal stability, while WHC-based films exhibited better flexibility and transparency when blended with pectin and sodium alginate. The findings highlight the potential of utilizing invasive and agro-waste biomass for the development of sustainable bioplastics with customizable properties. This study offers a promising pathway toward eco-friendly packaging materials and other green alternatives to conventional plastics.

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Acknowledgement

I sincerely thank Dayalbagh Educational Institute for funding and supporting this project.

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One-Step, Pretreatment-Free E-Textile Coating with Cosolvent-Blended AgNW/PEDOT:PSS Ink on Cotton Fabric

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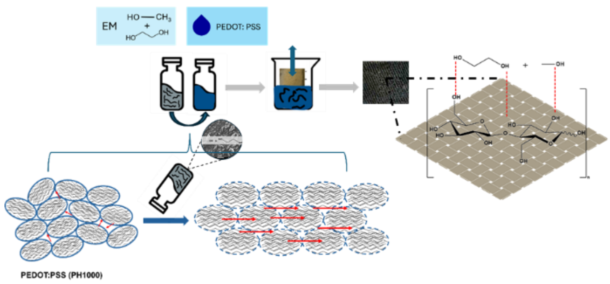
Abstract

The development of flexible, textile-based electrodes with superior electrical, thermal, and mechanical properties is critical for advancing wearable electronics. In this study, we report the development and fabrication of a highly conductive silver nanowire (AgNWs)/poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate) (PEDOT:PSS) nanocomposite electrode for cotton textiles through a single step dip coating process. The hybrid ink was exclusively formulated to elevate the electrical conductivity of flexible electronics, enhance the nanocomposite adhesion into fabric, and mechanical properties. Ink formulation was achieved by PEDOT:PSS modification with ethylene glycol (EG) and methanol (MeOH) cosolvent mixture (EG: MeOH) that was initially blended with AgNWs, and sequentially mixed with PEDOT:PSS. The synergistic effect between AgNWs, cosolvent, and PEDOT:PSS was closely investigated, revealing a structural transformation of PEDOT:PSS that facilitates improved charge transfer, enhanced adhesion, and enhanced physical performance. An optimal sheet resistance of 1.86 $\Omega \cdot sq^{-1}$ was achieved by incorporating 4% metallic load of the conductive ink. The nanocomposite textile has maintained efficient electrical performance over 1000 bending cycles, while adhesion quality was assessed via abrasion and washability tests. The textile electrode demonstrated multifunctionality in two main applications, including outstanding electromagnetic interference (EMI) shielding effectiveness of up to 56.6 dB in the X-band and efficient Joule heating performance, reaching power outputs of 1.3 W to 7.39 W under applied voltages ranging from 2 V to 5 V.



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Acknowledgement

L. A.; and M. A. acknowledge Khalifa University of Science and Technology for financial support under the startup fund (FSU-2023-002) No. 8474000455.

Functional Finishing of Cotton Fabric with Microencapsulated Grapefruit Essential Oil for Dual Protection against Mosquitoes and UV Radiations

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Abstract

Textile research today is increasingly focused on eco-friendly functional finishes that combine health protection with sustainability. Among natural resources, citrus fruits have gained attention for their bioactive compounds, particularly grapefruit, which is rich in terpenes, phenolics, and nootkatone. While often discarded as waste, grapefruit peels and seeds are a potential source of essential oils with proven antibacterial, antifungal, UV-shielding, and mosquito-repellent activities. Nootkatone, in particular, is recognized for its strong efficacy against mosquitoes, ticks, and other vectors, along with benefits in skin-care and photo-protection.

In this study, grapefruit essential oil was encapsulated in gelatin–gum arabic microcapsules via the complex coacervation method and subsequently applied to cotton fabric. The microcapsules were analyzed through SEM and FTIR to confirm morphology and chemical interactions. Encapsulation showed a yield of 75.43% and enabled controlled release, maintaining performance even after 20 wash cycles. The treated fabric demonstrated excellent UV resistance, with UPF values of 90 before washing and 75 after repeated washes. Mosquito repellency was also significant, with 100% effectiveness initially and 85% retention after 20 washes.

Overall, the findings suggest that grapefruit oil-based microencapsulation offers a sustainable and durable alternative to chemical finishes. The developed cotton fabric successfully integrates dual functionality—mosquito protection and UV shielding—highlighting the potential of citrus-derived bioactive compounds in advanced protective textiles.

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Role of Magnetic $NiFe_2O_4$ and Conductive rGO in Tailoring the Dielectric and EMI Shielding Properties of TPU Nanocomposite Films

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Abstract

The increasing demand for lightweight, flexible, and high-performance electromagnetic interference (EMI) shielding materials has motivated the development of multifunctional polymer nanocomposites. In this study, novel ternary thermoplastic polyurethane (TPU) nanocomposites were engineered by incorporating reduced graphene oxide (rGO) and nickel ferrite ($NiFe_2O_4$) nanoparticles through a solution casting method. The strategy aimed to exploit the complementary functionalities of conductive rGO and magnetic $NiFe_2O_4$ within a soft, processable TPU matrix.

Morphological investigations using scanning electron microscopy (SEM) and transmission electron microscopy (TEM) confirmed the uniform dispersion of rGO nanosheets and $NiFe_2O_4$ nanoparticles, along with strong interfacial compatibility. The wrinkled surface of rGO facilitated the creation of interconnected conductive pathways, which enhanced charge transport, while the embedded $NiFe_2O_4$ nanoparticles contributed magnetic dipolar relaxation and natural resonance, both of which are critical for EMI attenuation.

Dielectric characterization demonstrated a substantial increase in permittivity, with the dielectric constant (ε') reaching values around 450, indicating enhanced polarization mechanisms such as interfacial polarization and dipole alignment. Electrical studies further revealed improved conductivity and loss tangent, particularly with increasing rGO loading. These synergistic effects translated into effective EMI shielding, with shielding effectiveness (SE) values approaching ~20 dB in the X-band frequency region (8.2–12.4 GHz). The shielding mechanism was primarily governed by the combined contributions of conduction loss (via rGO networks) and magnetic loss (via $NiFe_2O_4$), with absorption dominating over reflection.

Overall, the study highlights the promising role of TPU/rGO/$NiFe_2O_4$ nanocomposites as flexible, lightweight, and multifunctional candidates for EMI shielding applications in emerging portable and wearable electronic systems. Their tunable dielectric response, processability, and balanced mechanical-functional performance underscore their potential in next-generation communication and defense technologies.

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Coating of Cotton with Ternary Blend of Sodium Alginate, Sugar and Bio-Latex for a Sustainable Waterproof Textile with Moisture Vapour Permeability

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Abstract

Cotton fabric was coated with a ternary blend of sodium alginate, sugar, and natural rubber latex employing a knife-over-roll coating technique, followed by vulcanization with a sulphur curing system. The resulting coated fabric, when subjected to water treatment via a pad-dry technique, exhibited an appreciable moisture vapour transmission rate (MVTR) and water proofness, attributed to the formation of micropores within the waterproof coating.Optimal results in terms of exceeding 1850 g/m²/24 h of MVTR value and waterproof properties, demonstrated by resisting the 90 cm water head test on a hydrostatic head tester and a 48-hour cone test, were achieved for coating one side of fabric with a formulation comprising 100 phr of natural rubber latex, 25phr- 50 phr of sodium alginate, and 20phr- 30 phr of sugar.Incorporation of only sodium alginate into the natural rubber latex moderately increased the MVTR of the coated sample, reaching up to 1176 g/m²/24 h. In contrast, incorporation of only sugar led to coagulation of the natural rubber latex, rendering it unsuitable for coating applications. However, sugar appeared to act as a dispersing agent, aiding the dispersion of sodium alginate within the aqueous natural rubber latex system.Scanning electron microscopy (SEM) and pore size analysis revealed development of micropores ranging from 1.21 µm to 1.72 µm within the coating matrix, to the leaching of water-soluble sugar. This porous structure allowed moisture vapour to pass through the coated cotton fabric while liquid waterto penetrate through it. Atomic force microscopy (AFM) of the coated fabric further supported the observation of coating matrix erosion or loss due to sugar leaching, reinforcing the mechanism the formation of the microporous waterproof coated structure.

Processing and Characterization of Flex Banner Waste into Reinforced Roofing Materials

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Abstract

Waste management is a critical issue impacting environmental, social, and economic dimensions of human life. Despite efforts by governments and communities, significant progress remains elusive in addressing the accumulation of waste, which poses a long-term threat to environmental sustainability. Initiatives such as the 3R movement—Reuse, Reduce, and Recycle—encourage the reuse of materials for the same or new purposes, minimizing waste production, and recycling waste into valuable products. One challenging waste material to recycle is flex banners, often used for advertising or as event backdrops. Flex banners play an essential role in modern advertising but can be handled more sustainably through creative reuse and recycling methods. Considering the challenges involved in waste management and reusing and recycling flex banners, it is important to explore alternative eco-friendly options to reduce their impact of environment. Flex banner is a structure made of polyester cloth laminated or coated with polyvinyl chloride resin compounds. In case of degradation, after burning flex banners residues contains harmful gases which affects environment and human beings. Hence is the scope to find out alternatives for its recycling. This work focuses on development of reinforced composite for roofing sheet material by recycling flex banners. Polyester fibres derived by shredding of wastage flex banners, used as reinforcement along with epoxy resin Bisphenol-A-based and Hardener HY 951 for fabrication of composites. Samples were prepared with different fibre weight percentage (20 to 40 %) along with fibre length of 15 mm and 30mm. The samples were cast and prepared with hand –lay method on compression mould technique. Tensile and flexural testing of composite samples were conducted to evaluate mechanical properties. Fiber weight percentage and length proportionate shows significant improvement in strength and stiffness properties. Among all compositions sample with 30% fiber weight and fiber length of 30 mm demonstrates the best overall performance. It achieves the highest tensile strength 27.7 MPa, tensile modulus 652.8 MPa, Impact strength 3.0 J, and flexural strength 83.2 MPa, and flexural modulus 7409 MPa, making it the most effective composition in terms of mechanical properties.

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Climate-Resilient Natural Fiber Geotextiles: Enhancing Road Performance under Wetting–Drying and Soaking Conditions

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Abstract

With rising climate variability, unpaved roads are increasingly exposed to cycles of wetting, drying, and prolonged soaking, which accelerate rutting, settlement, and premature failure—especially when constructed on soft soils. Geotextiles offer reinforcement and separation functions to mitigate these issues, but conventional polymeric geotextiles raise concerns of cost and long-term environmental impact. This study explores the potential of treated natural fiber geotextiles, particularly coir, as climate-resilient reinforcements for unpaved road models. Four geotextile types (woven W1, W2 and nonwoven NW1, NW2) were chemically treated with a formulation of unsaturated polyester resin, bitumen emulsion, styrene monomer, and methyl ethyl ketone peroxide to enhance their mechanical and durability characteristics. The performance of untreated and treated geotextiles was evaluated through California Bearing Ratio (CBR) tests and monotonic load tests under both soaked and unsoaked conditions, simulating waterlogging scenarios. Results revealed that:

1. Reinforcement with coir geotextiles improved the bearing ratio by 40–60% compared to unreinforced soil.
2. Treated geotextiles showed superior resilience, with 15–25% higher tensile strength and improved load distribution under soaked conditions.
3. Among all variants, woven Type W2 and nonwoven Type NW2 exhibited the best climate durability, maintaining bearing capacity even after prolonged soaking.
4. SEM analysis confirmed that chemical treatment reduced surface cracks and voids, enhancing fiber–soil interaction.

The findings highlight that treated natural fiber geotextiles not only enhance the load-bearing capacity of unpaved roads but also demonstrate resilience under adverse climatic conditions, making them a sustainable alternative to synthetic geosynthetics. This research contributes toward the development of eco-friendly, climate-adapted road infrastructure suitable for rural and peri-urban regions.

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Acknowledgement

The author acknowledges the support of J.N. Government Engineering College, Sundernagar, Himachal Pradesh, and expresses gratitude to colleagues and collaborators for their guidance during this research.

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Investigation of Interface Shear Behaviour with Sand and Clay for Treated Coir Geotextiles with Benzyl Chloride and Dimethylformamide

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Abstract

Soil-reinforcement interaction are influenced by the characteristics and attributes of both the reinforcement and the soil. In road pavement, engineers encounter multiple issues owing to weak and soft soil, such as reduced load-bearing capability, inadequate stabilisation and soil settlement created by daily traffic. This research assesses the influence of treatment of coir geotextile with benzyl chloride and dimethylformamide on the interface shear behaviour of geotextiles with sand and clay interfaces. Nine different treated geotextiles were prepared by using Taguchi (L9) design by varying concentration, temperature and time during treatment. This treatment is intended to improve the interface shear behaviour of the pavement materials in road construction. The interface friction behaviour of the soil-geotextile interface was investigated using a direct shear apparatus. Subsequently, TOPSIS multi attribute decision making technique was used to rank various geotextile samples. The best results for interface friction behaviour were obtained for a geotextile sample treated with benzoyl chloride and dimethylformamide having 1:5 mixture ratio at 50℃ temperature for 20 minutes. The best selected treated coir geotextile sample demonstrates improved interface behaviour with both clay and sand when compared with untreated coir geotextile sample. The treated geotextile shows a 45% increase in adhesion and a 26% increase in friction angle with clay, while with sand, adhesion increases by 38% and the friction angle increases by 29%. The observed improvement in mechanical strength and are bonding caused by modifications in the chemical composition of coir geotextiles following treatment, particularly the addition of new functional groups. Fourier Transform Infrared (FTIR) analysis verifies these alterations. The SEM confirm that treatment of coir geotextile reduces surface defects by sealing cracks and filling up of gaps. The results of TGA confirm that the chemical treatment also enhanced the thermal stability of the treated coir geotextile. The results shows that main decomposition range for untreated coir geotextile is at 250- 450˚C whereas for selected treated coir geotextile at 280- 480˚C.

Acknowledgement

The authors extend sincere thanks to Jawaharlal Nehru Government Engineering College, Sundernagar for providing the necessary facilities to carry out this work.

Microstructural Analysis and Engineering of Polyethylene Terephthalate and Olefins for Significant Impact on Geotextile Products

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Abstract

The fundamentals for achieving the critical objectives of compressive load resistance for PET yarns have been experimentally definitive in our studies on the following aspects, Secondary creep coordinates, the work done to fatigue and eventual rupture are functionally determined by the following critical factors classified as results:

1. Linear density and consistency therein of the parasol. Impact weight on a stochastic mode: 0.88
2. Microstructural compatibility between spectroscopic masses after cracking of crystalline and amorphous zones as well as redistribution of spatial configurations within the body of the polymer into even or homogenous spaces. Impact weight on a stochastic mode: 0.95
3. Significant disintegration of the dielectric field leads to lowered flux strength. Impact weight on a stochastic mode: 0.98
4. IV or effective intrinsic viscosity governing the properties of the polymer at various creep coordinates. Impact weight on a stochastic mode: 0.98
5. Finally, the thermogravimetric induced MFI or molten flow index of the polymer at the extrusion stages. Impact weight on a stochastic mode: 0.98

The features of our calibrated roadmap were as follows:

Working on the existing heat system in the pre-extrusion zone to achieve cracking temperatures of 320-335 degrees Celsius at a parasol dynamic pressure of 3-3.5 bar effectively. Creating an infrastructure at site with IPR derivatives for treating differentially the incoming polymers at various copolymerization levels for achieving IV of < 0.6 and MFI > 250. Treatment of olefinic polymers for higher order weld strength for influences parameters of OIT and weld strength (Key results -seam extrusion (14 - 15 MPa) and bending strength (32-33 MPa). Experiments revolved around the ZN – catalyst injection for a distribution between isotactic and syndiotactic polymerization for enabling consistent OIR – oxidation induction resistance. An ideal Al/Metal ratio and the hexachloninated radical to metal ratio in the olefinic body were the factors for achieving the outcomes.

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Reprocessing of Textile Fiber Waste into Sustainable Agrotech

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Abstract

Textiles, being a highly versatile domain, have applications across diverse sectors, with technical textiles witnessing significant growth in recent years. These include categories such as mobiltech, meditech, geotech, agrotech, oekotech, and sportech, among others. The 2024 review of the Indian agro-textiles market projected a CAGR of 4.09% for the period 2025–2033, underscoring India's growing potential in this field. However, alongside this progress, the country also generates nearly 7.8 million tonnes of textile waste annually, arising from both pre-consumer and post-consumer sources such as fibers, yarns, and fabrics. The increasing environmental footprint of the textile industry, coupled with mounting waste management challenges, calls for sustainable solutions in agrotech. In this context, a study was undertaken using viscose rayon and wool fiber waste in varying proportions (100%, 50:50, and 70:30), through needle-punching method. A comparative study of herbal finish treated and untreated composites was done. The results revealed that when herbal finish was applied on the developed composites and were tested on physical parameters as well as for specialised finishes; hemp: wool 50:50 (herbal finish treated) combination showed 97.71% UV blocking and the moisture content increased to 10.8 % with good antimicrobial property. It was found that composites with herbal finish treatment showed better results and can be used for agrotech applications like shade nets, mulches, fruit covers and natural fruit ripeners. This research highlights the importance of recycling textile waste fibers as a sustainable strategy, presenting innovative approaches to reduce the ecological impact of textile production and disposal while supporting greener agricultural practices.

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Acknowledgement

The author acknowledges the farmers of Nashik city for providing farms for field trials.

Impact of Hollow and Solid Polyester Fiber Cross-Sections on Filtration Performance in Needle-Punched Nonwovens

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Abstract

The cross-sectional shapes and blend ratios of hollow and solid polyester staple fibers significantly influence the surface area, mechanical properties, and filtration performance of needle-punched nonwoven fabrics. This study systematically evaluated eighteen samples fabricated from 15 denier, 51 mm hollow and solid polyester fibers, varying in basis weights (150, 250, and 350 GSM) and blend ratios (80/20, 50/50, 20/80 hollow-to-solid). Each set included calendered and non-calendered variants, produced using a Truetzschler needle-punched nonwoven machine with consistent processing parameters to isolate the effects of fiber characteristics. The samples were tested for air filtration efficiency, pore size, air permeability, bursting strength, tear strength, tensile strength, breaking elongation, and thickness. Two-way ANOVA was employed to analyze the influence of blend ratio and GSM on fabric properties, while paired t-tests compared calendered and non-calendered samples. The results indicate that both fiber blend and GSM had a significant impact on key properties of both calendered and non-calendered fabrics. Notably, fabrics with 80% hollow polyester exhibited the lowest air permeability and pore size, along with the highest strength and filtration efficiency when compared to blends dominated by solid or circular fibers. Increasing the proportion of hollow fibers consistently enhanced filtration effectiveness and mechanical strength, with calendering further improving select parameters. These findings emphasize the critical role of fiber cross-sectional architecture and processing techniques in optimizing the performance of technical nonwoven filter media.

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Acknowledgment

The author acknowledges the support received from the DKTE COE and DKTE TEI, Ichalkaranji for sample production and testing received.

Recent Developments in Pervaporation Membranes

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Abstract

Recent developments in pervaporation membranes have significantly enhanced the efficiency and applicability of pervaporation technique for liquid separation processes, particularly in dehydration and organic–organic separations. Traditional polymeric membranes such as polyvinyl alcohol (PVA), chitosan, and sodium alginate have been modified through chemical crosslinking, blending, and surface functionalization to improve selectivity, thermal stability, and resistance to swelling. The emergence of **mixed matrix membranes (MMMs)**, which incorporate inorganic fillers like zeolites, silica, graphene oxide, or metal–organic frameworks (MOFs) within polymer matrices, has enabled synergistic improvements in permeability and selectivity. **Inorganic membranes**, including zeolite and silica-based thin films, offer superior thermal and chemical stability and are being optimized for large-scale fabrication through sol–gel and chemical vapour deposition methods. Recent research also explores **nanocomposite and hybrid membranes**, combining the flexibility of polymers with the rigidity of nanostructured fillers for enhanced durability and performance. These advances focus on architecting thin, defect-free selective layers supported on mechanically robust nonwoven substrates to combine high permeation flux with long-term stability. Progress in fabrication includes electro spun and spun bond nonwoven supports with tailored porosity, surface treatments to improve adhesion, and interfacial polymerization and dip-coating techniques that produce ultra-thin selective films. Additionally, advancements in **thin-film composite (TFC)** and **asymmetric membrane structures** have reduced transport resistance, leading to higher flux rates. These innovations predominantly indicate a transition toward more energy-efficient, robust, and application-specific pervaporation membranes, strengthening their role in sustainable biofuel production and solvent recovery.

Acknowledgement

The author acknowledges the financial support received from the Department of Textiles, DKTE's Textile and Engineering Institute, Ichalkaranji.

Nanofibers, Nonwovens, and Beyond: Next-Generation Textile Filtration Systems

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Abstract

Technical textile materials have become indispensable in modern filtration technologies due to their high surface area, tunable porosity, mechanical flexibility, and cost-effectiveness. They are widely used in air purification, water treatment, and industrial emission control. However, textile-based filtration still faces key challenges, including clogging and pressure drop due to particle accumulation, reduced durability under harsh operating conditions, and environmental concerns associated with the use of synthetic fibres. In certain applications, combining different filtration media—such as filter fabrics and membranes—is necessary to meet specific performance requirements. Beyond these functional needs and standards, the environmental implications, structural design, and production technologies of textile filters are also key considerations.

The adoption of advanced textile-based filters offers a sustainable and cost-efficient approach to enhancing operational efficiency while minimising environmental impact. To address these issues, recent innovations include nanofiber-based membranes, advanced surface modifications, multilayer and hybrid filter structures, and the development of sustainable biodegradable fibers. These solutions not only improve filtration efficiency and longevity but also align with global sustainability goals.

This paper discusses the role of textiles in filtration, identifies current limitations, and highlights emerging pathways toward next-generation, eco-friendly, and high-performance filtration systems.

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Sustainable Acoustic Materials from Silk Waste and Natural Fiber-Based Nonwovens

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Abstract

Silk has been one of the most renowned natural fibers used in textile manufacture across the globe, owing to its unique luster, strength, and versatility. Unlike synthetic filament fibers such as polyester and nylon, silk offers superior comfort and eco-friendliness, making it a preferred choice for garments. However, silk reeling processes generate substantial residues in the form of short fibers and defloss, which are generally converted into sheets through sheet-making machines. These sheets are predominantly exported for use in quilts abroad, leading to a significant loss of value addition opportunities within the country.

In parallel, the demand for soundproofing materials such as acoustic panels is increasing in theatres, auditoriums, and convention halls. Conventional acoustic products primarily rely on synthetic polymers like PVC and polyester, which, while functional, raise concerns over long-term environmental sustainability. Addressing this challenge, the present work explores the potential of utilizing silk waste in combination with natural fibers such as hemp, flax, and sisal to develop sustainable nonwoven structures through the needle punching technique.

The physical and functional properties of the developed nonwovens were systematically characterized to evaluate their suitability as acoustic materials. The results indicate that these silk waste-based nonwovens provide effective sound absorption, while simultaneously reducing reliance on non-biodegradable polymers. This study demonstrates a viable pathway to transform silk residues into eco-friendly, value-added acoustic products, thereby supporting circular economy practices and promoting sustainability in the textile sector.

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Acknowledgement

The author acknowledges the financial support received from the Central Silk Board, GoI.

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Modelling and Experimental Study on Acoustic Behaviour of Tricot Fabrics

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Abstract

Tricot warp-knitted fabrics present considerable potential for multifunctional use in both architectural and automotive interiors, including curtains, mattress covers, upholstery liners, seat covers, headliners, and interior panels. While these structures are well established in household and automotive applications due to their favourable mechanical and structural properties, their acoustic performance remains largely unexplored. This study provides a systematic investigation of the acoustic behaviour of a range of tricot fabric structures and develops predictive models of their sound absorption characteristics. Results demonstrate that underlap pitch is the most influential structural parameter, owing to its impact on straight pore fraction and areal density. Although the addition of nonwoven backings reduces the fabric's direct structural contribution, the knitted layer still enhances noise reduction coefficient (NRC) values by 14% to 138%. To interpret and model the experimental results, three established approaches were applied: Maa's micro-perforated panel theory, the Garai–Pompoli equivalent fluid model, and the Johnson–Champoux–Allard (JCA) microstructural semi-empirical framework. Collectively, the findings establish tricot fabrics as lightweight, effective acoustic materials with strong potential for noise mitigation in automotive and architectural contexts. Beyond demonstrating their suitability, the study also advances the methodological toolkit for characterising and modelling complex fibrous materials, thereby opening new pathways for the design of multifunctional textiles in sound management.

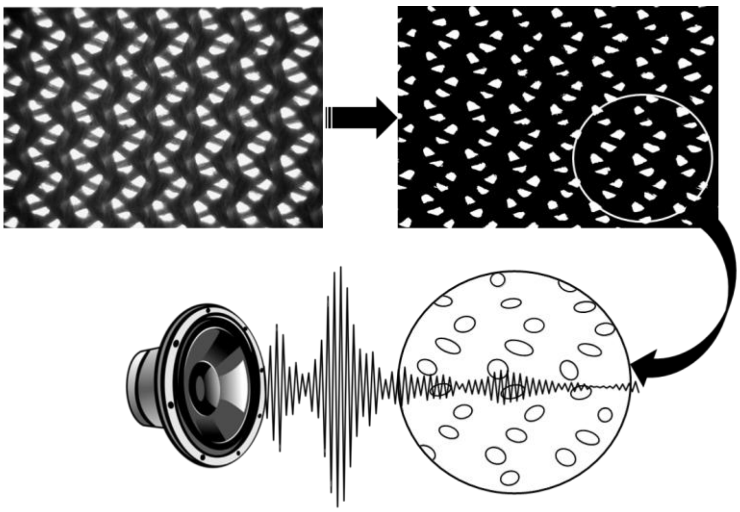

Figure 1. Microstructural analysis of tricot fabric for sound absorption application.

Effect of Bonding Techniques and Process Parameters on Thermal and Acoustic Properties of Nonwovens

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Abstract

Efficient management of heat and noise is important in several applications such as building insulation, automotive interiors, and industrial enclosures, where comfort and energy efficiency are crucial performance requirements. In these applications, nonwoven fabrics are often preferred over other textile materials because of their porous structure, low weight, and design flexibility. In this study, the influence of bonding parameters and bonding techniques (thermal bonding and mechanical bonding) on the thermal and acoustic behavior of polyester fibre-based nonwoven fabrics was investigated. In thermal bonded nonwoven fabrics, the proportion of binder fibres (CoPET/PET bi-component sheath–core fibres) was systematically varied, and it was found that an increase in the binder fibre proportion led to a reduction in the radiative heat transmission and sound absorption. For the mechanically bonded (needle-punched) nonwoven fabrics, the single and interactive effects of needle penetration depth and punch density were investigated. It was observed that increasing either parameter led to deterioration in sound absorption and an increase in radiative heat transmission. A comparative assessment between the bonding techniques showed that thermal bonded nonwovens exhibited significantly better acoustic performance than needle-punched nonwovens mainly due to their higher thickness. However, radiative heat transmission was similar for both bonding techniques, indicating that thickness does not play a dominant role in this property. Further analysis revealed meaningful correlations between air permeability, sound absorption, and radiative heat transmission, highlighting the interdependent nature of these properties. The outcomes of this study provide useful information for designing and optimization of nonwoven structures intended for thermo-acoustic insulation applications.

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A Life Cycle Assessment Study: Is Bacterial Cellulose Leather a sustainable alternative to conventional textile products?

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Abstract

The fashion and textile sector, acknowledged as the third-largest contributor to global pollution, faces significant environmental challenges, particularly due to the extensive reliance on synthetic fibres that contribute to environmental pollution and microplastic accumulation. In response, there has been a growing interest in bio-based materials due to their potential to offer sustainable alternatives. Derived from renewable resources, materials such as bacterial cellulose leather are not only biodegradable but also produced through eco-friendly processes, which can have immense potential to replace conventional textiles.

Nevertheless, the development of a robust framework for systematically evaluation of the environmental impacts of these alternative leathers remains underdeveloped. The absence of comprehensive assessment methods and interdisciplinary collaboration constrains both technological progress and commercial scalability.

This research addresses this gap by performing an in-depth environmental evaluation of bacterial cellulose leather (BC leather), from raw material acquisition to the finished product. A Life Cycle Assessment (LCA) framework is developed to evaluate the material's environmental performance and compare them in terms of impact category against synthetic and animal leather. The fabrication of BC leather was done using cellulose producing bacterium Komagataeibacter xylinus bacteria, the inventory data were derived from laboratory experiments, and the functional unit was adjusted to 1 m2 (area) for comparison against existing leather products. Furthermore, this study identifies the key environmental hot spots along the fabrication process and provides sensitivity analysis and mitigation strategies to reduce associated impacts. The key findings of the hotspot analysis reflect a higher impact in the involvement of fermentation time; electricity usage and chemicals used during finishing phase. Thus, scenario modelling approach has been implemented to evaluate the change in impact categories after possible alteration of the raw material inputs of production process. The resulting sustainability profile provides a valuable knowledge base for industry stakeholders, highlighting both the benefits and future improvements of BC leather production. These findings provide a platform for advancing innovation in sustainable materials and their integration into textile and fashion supply chains, thereby contributing to the sector's progression toward circular economic models.

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Acknowledgement

This research was supported by the IMPACT+ Network, funding by the UKRI Circular Fashion and Textiles Programme: NetworkPlus—a trilateral initiative from the Natural Environment Research Council, Arts and Humanities Research Council and Innovate UK (Grant Ref: NE/Y004035/1).

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CA-AIS Framework for Textile Supply Chain Emission Accounting

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Abstract

As the textile industry is under increased pressure to decarbonize, there is an urgency for these transparent, data-driven systems that can quantify emissions throughout the production and logistics pathways, and provide manufacturers and policymakers with data that can inform appropriate mitigation actions. This study introduces a CA-AIS (Carbon-Aware AI System) (Figure 1) for Textile Supply Chain Emission Accounting: an explainable framework that utilizes multi-resolution data, hybrid modeling, and human-centric explainability to address decision-making for sustainable production and logistics. The system integrates public and exclusive data, including plant-level energy and process audits (cluster-level audits from the Bureau of Energy Efficiency), standardized emission factors (TERI , MoEFCC), national production and trade statistics (annual reports from the Ministry of Textiles),and real-time IoT-based streams (energy meters, machine usage), into a single data model. A hybrid modeling stack integrates physics-informed emission estimators, gradient-boosted trees (XGBoost) for facility-level carbon intensity predictions, and CNN(Convolutional Neural Networks) for image-based efficiency signals; ensemble outputs are reconciled through Bayesian calibration to generate uncertainty-aware emissions inventories. Importantly, the framework includes explainability at two levels: (1) feature-level attributions (SHAP) to identify drivers of facility emissions, (2) counterfactual explanations to highlight high-impact operational changes.The proposed framework offers a sensible pathway to trustworthy, explainable carbon accounting that connects sound AI-based methodologies with operational decision-making in the real world.

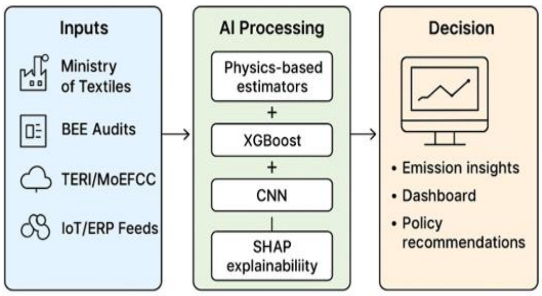

Figure 1: Explainable CA-AIS framework for Textile Supply Chains

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Acknowledgment
The authors would also like to thank everyone—individuals and institutions—who supported and encouraged this work.

Environmental Impacts of Cotton vs. Milkweed Fibres: A Cradle-to-Gate Life Cycle Assessment

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Abstract

Environmental challenges, especially those stemming from the overexploitation of natural resources, are accelerating the search for sustainable alternatives. This shift is increasingly focused on responsibly sourced raw materials, eco-friendly production processes, and the use of secondary raw materials to replace conventional ones. In the textile sector, this transformation is fuelling the rise of alternative fibres, with milkweed emerging as a promising contender. Often regarded as a weed in regions like Asia, Europe, and the USA, milkweed produces pods filled with a soft, silky, cellulosic floss. This floss has a remarkably low density (0.89 g/cc) and about 70% hollowness, allows it to effectively trap still air, making it an excellent insulator. Milkweed is gaining significant traction in the production of clothing designed for extreme cold climates due to its remarkable thermal insulation properties. Other than excellent thermal and sound insulation property, Milkweed possess the property of high moisture regain, indicating milkweed fibre can absorb and retain moisture from the air more efficiently than many other natural fibres, including cotton. Given the promising properties of milkweed, its environmental sustainability was evaluated and compared to that of cotton. A cradle-to-gate Life Cycle Assessment (LCA) was conducted for both fibres, focusing on cultivation over a one-hectare plot. The analysis considered soil type, climate, water and fuel consumption, and inputs such as seeds and fertilizers across five key stages: soil preparation, sowing, growth, harvesting, and post-treatment. Although cultivation typically contributes less to the overall environmental impact than textile processing or consumer use, it significantly affects water use and eutrophication potential. To complement the LCA, the Air Pollution Tolerance Index (APTI) was calculated for both crops. Milkweed demonstrated an APTI value three times higher than that of cotton, indicating greater resilience to air pollution and environmental stressors. These results highlight milkweed's potential as a more sustainable, low-carbon alternative to cotton. However, further research across the full fibre production and processing chain is essential to validate its viability for sustainable textile applications.

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Acknowledgement

The authors gratefully acknowledge the financial support provided by the National Technical Textile Mission (NTTM), Ministry of Textiles, Government of India.

Game-Theoretic Modelling of Circular Economy Rebound Effect and Track & Trace Capabilities in Sustainable Fashion

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Abstract

The fashion industry operates as a trillion-dollar market that functions as an economic leader yet remains among the worst polluters of the environment. Global CO_2 emissions from the fashion industry, which produces 4–5 billion tonnes yearly. Quick product manufacturing periods together with soaring consumer needs accelerate the production of waste while diminishing essential resources along with raising greenhouse gas emissions. Circular Economy (CE) along with Track & Trace (T&T) digital technologies have not provided clear sustainability results and outcomes.

The study unites Resource-Based View (RBV) and Institutional Theory (IT) to construct a multi-theoretic framework which explains sustainability policy adoption. This synthesis reinforces the game-theoretical model to give firms structured evaluation capabilities for their reactions under regulatory, market-based and hybrid sustainability policies which connect compliance expectations with competition strategies and adaptive sustainability approaches in circular economy transformations. A game theoretic framework creates models to investigate how policies affect enterprise compensation rates along with their compliance behaviour and delivery network availability. Game theory examines firm rewards as well as adherence patterns under five different policy schemes which are evaluated using data from a sustainability initiative in the UK. The Market-Driven policy created reliable payoffs for firms with high EPS through ESG demand while Phased policies made compliance less complicated and improved future performance. The firm financial situation under Scenario A (Strict Regulation) experienced severe pressure but Scenario B (Balanced) provided risky tax incentives while Scenario E (Deregulated) provided maximum business flexibility (Figure 1 and Table 1).

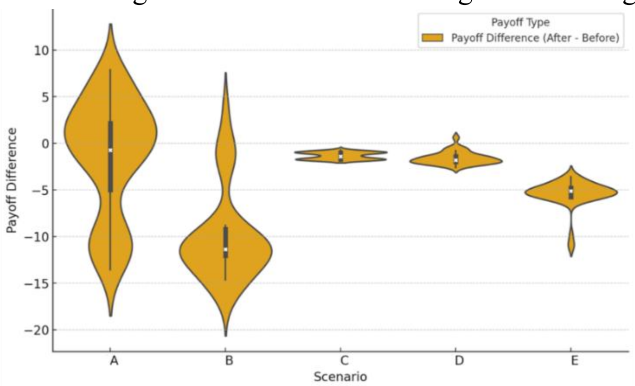

Figure 1. Violin Plots of the difference between pre-implementation and post-implementation firm payoffs (Source: Authors own work)

Table 1. Summary statistics of the difference between pre-implementation and post-implementation firm payoffs

	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E
No. of firms	100	100	100	100	100
Mean	-1.39	-10.02	-1.33	-1.59	-5.4
Standard Deviation	6.21	4.86	0.38	0.67	1.46
Minimum	-13.56	-16.78	-1.79	-2.6	-10.97
25th Percentile	-4.98	-12.06	-1.71	-1.95	-5.75
50th Percentile	-0.75	-11.37	-1.39	-1.82	-5.11
75th Percentile	2.16	-9.21	-1.01	-1.39	-4.8
Maximum	7.86	3.7	-0.71	0.62	-3.58

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Carbon Footprint Assessment of Indian Handloom Production

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Abstract

The environmental impact of textile production is gaining attention for its high use of natural resources and significant emissions. This study aims to support India's handloom sector in area of hotspot identification, accurate measurement, actionable insights for effectively reducing its carbon footprint as the nation moves toward a greener, more sustainable future based on real case studies across India. This study uses ISO 14067 guidelines to assess the carbon footprint of 100% cotton or silk handloom products, such as saris and bedsheets. The analysis covers all stages from raw material sourcing to the finished product, based on the field surveys within the functional unit and system boundary. GHG emission factors (kg CO_2-eq) from the Ecoinvent v3.1 database were applied to calculate emissions for each process. Energy and fuel use (wood, coal, electricity) are the main contributors to carbon emissions in handloom production, making up 40–69% of the total. Chemicals add 1.7–15.3%, while water, waste, and transport have smaller shares. A handloom cotton bedsheet's footprint (1.30 kg CO_2-eq) is nearly four times lower than a comparable power loom product. This supports handloom weaving as a low-carbon process and sustainable method to produce fabric.

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Assessment of Barriers to Circular Economy Implementation in Indian Textile Industry using ISM MICMAC Technique

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Abstract

The transition toward a Circular Economy (CE) has become imperative for achieving sustainability in the Indian textile industry, one of the largest global contributors to resource consumption and waste generation. Despite growing awareness, the sector continues to face numerous challenges in adopting CE principles effectively. This study aims to identify, structure, and analyze the interrelationships among key barriers impeding CE implementation within the Indian textile supply chain using the Interpretive Structural Modeling (ISM) and Cross-Impact Matrix Multiplication Applied to Classification (MICMAC) techniques. Drawing upon an extensive literature review and expert consultations from leading textile manufacturing clusters, ten critical barriers were identified such as lack of CE awareness, inadequate infrastructure, and poor information sharing, to high investment cost and weak reverse logistics systems. The ISM model hierarchically structures these barriers to reveal their driving and dependent relationships, while the MICMAC analysis categorizes them into autonomous, dependent, linkage, and driver clusters. Findings indicate that limited awareness of CE concepts, perception of CE as a waste-management approach, and insufficient infrastructural and reverse logistics support act as the most influential driving barriers, triggering other dependent constraints such as collection and separation inefficiencies and high implementation costs. The study provides a systematic framework for industry practitioners and policymakers to prioritize strategic interventions and develop targeted policies to accelerate CE adoption in the textile sector. The integrated ISM–MICMAC approach enhances understanding of the structural hierarchy of barriers and supports decision-makers in designing effective circular transition strategies for sustainable textile production and supply chains in India.

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Acknowledgment

The authors gratefully acknowledge the Department of Mechanical Engineering, Dronacharya Group of Institutions, Greater Noida, India, for their continuous support, valuable guidance, and for providing the necessary facilities and arrangements for the successful completion of the present research work.

Smart and Functional Textile Surfaces by Coating Applications using Effect Pigments and Functional Pigments

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Abstract

Textile materials are broadly used in daily life as clothing and as technical textiles in industrial processes. For many applications especial functional properties are demanded for the textile based products. The term functional properties covers a wide field from physical, chemical to even biological functions added to a textile by a certain finishing or coating process. Prominent examples for functional properties are electromagnetic shielding, UV protection, heat management, flame retardancy or antimicrobial properties. These functional properties are gained by application of a functional additive to the textile material. In best case the applied property is stable and permanent in its function. In comparison, textile surfaces can be also modified with additives showing a certain functional property only in case of a certain influence – as a kind of stimuli-responsive action. Prominent examples in this fields are thermochromic and photochromic materials showing a reversible change of coloration in case of exposure to a certain heat or light impact. Such stimuli-responsive textiles can be also named as smart textiles, because the functional property appears as response to a certain influence. Effect pigments and functional pigments are powerful carrier of functional properties and can be applied onto textile surfaces by coating applications. The current presentation is dedicated to pigment functionalized textile surfaces and their advantageous properties. Metallic and pearlescent effect pigments are shown for realizing properties as angle dependent coloration, reflection of infrared light, UV protection, antimicrobial properties, EMI-shielding and electroconductive coatings. Different inorganic phosphorescent pigments are presented for realization of luminescence and afterglowing properties. Organic pigments are shown for their capability to realized thermochromic and photochromic properties on textile surfaces. Finally, it can be stated that based on a broad range of different functional pigments and by variation of application parameters, it is possible to realized smart and functional textile surfaces with new and useful properties leading finally to fascinating textile applications and products.

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The authors owe many thanks to Dipl.-Ing. Simone Wagner for her kind help in the finishing lab.

Commercial-Scale Eco-Printing of Silk Fabric Using Natural Mordants and Manjishtha-Based Pigments

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Abstract

The textile printing industry is facing growing pressure to transition toward environmentally responsible, low-toxicity, and resource-efficient coloration technologies. Traditional eco-printing processes, while sustainable in principle, are challenged by poor reproducibility, low color fastness, excessive water usage, and limited industrial scalability. This project, conducted in collaboration with M/s Cocoon Kapas, Gurugram, aims to develop a commercially scalable eco-printing methodology for silk fabrics using natural mordants and bioactive dye sources while achieving industrial-grade durability and enhanced functionality.

A re-engineered printing protocol was developed using a dual pre-mordant system of soya milk (30–50 g/L) and alum (10–15 g/L), enabling improved pigment anchoring via bio-polymeric binding and metal-complex scaffolding. This approach was combined with localized application of natural pigments derived from Manjishtha (Rubia cordifolia)—a waste-to-resource dye source rich in bioactive compounds such as alizarin, purpurin, and munjistin. Further optimization was achieved through steam fixation at 110–120°C for 1–2 hours, reducing energy and water requirements while enhancing pigment–fiber integration.

The modified process demonstrated significant technological advantages, including 70% reduction in water consumption, elimination of synthetic thickeners, and 33% decrease in processing time compared to conventional eco-printing. Performance evaluation showed substantial improvement in coloration durability, with wash fastness (4–5), light fastness (>5), and crocking fastness (4–5) on the standard grey and blue scales—surpassing commercial benchmarks. Antimicrobial analysis (AATCC 100) indicated >99% bacterial reduction, attributed to Manjishtha's inherent phytochemical activity.

The developed method (Patent published with application number – 202511066774) demonstrates strong potential for adoption in applications such as luxury apparel, medical textiles, and outdoor wear, where ecological integrity and functional performance are equally critical. This work further contributes to circular economy principles by valorizing agricultural byproducts and reducing chemical pollution in textile coloration. Overall, the project establishes a commercially viable, sustainable alternative to synthetic dyeing, aligning with global goals for responsible production and eco-innovation.

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2. Patent application no. CN106758401A, Publication date : 31.05.2017
3. Patent application no. CN101338518A, Publication date : 07.01.2009

Acknowledgement

I express my sincere gratitude to M/s Cocoon Kapas, Gurugram, for providing industrial access, technical guidance, and valuable insights throughout the project. I also thank IIT Delhi for academic supervision and infrastructural support, which played a crucial role in completing this work.

Electrochemical Dyeing Using Indigo Colour

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Abstract

Indigo is the oldest vat colour with a high popularity for use even in the most modern clothing. There is a wide use of indigo in denim worn across demography. Conventionally, strong reducing agent and strong alkali of large quantities, in excess of their stoichiometric proportions are required for dyeing with the vat colours. Disposal of the exhausted dyebath and the waste water in this case causes a variety of problems due to the non-ecofriendly nature of the decomposition products like sulphite and sulphate generated from sodium hydrosulphite used for reduction of the dye. To decrease the use of the strong chemicals in indigo vat colour, electrochemical method of dyeing has been attempted in the present work. The hydosulphite and NaOH content has been significantly decreased. Graphite anode and copper plate cathode are used for initial reduction of synthetic indigo dye. The reduced dye is then applied on 100% cotton fabric. Dyeing at different percentage shades of 1%, 2% and 3% are carried out with initial voltages of 3,5 and 7 Volts. Also the electrochemical bath treatment time is maintained at three different levels of 20,30 and 40 min. Experimental design has been applied taking these three parameters into consideration, namely dye depth, voltage and time. The optimised conditions so obtained were then applied on natural indigo colour (Bio Indigo) too, the results of which are quite satisfactory. The colour strength obtained by this technique, measured in terms of K/S in the computer colour matching system is found to be comparable to that of the conventional ones. Fastness to washing has been found to be quite good in all the samples prepared for testing. No decrease in tensile strength is observed in this electrochemical dyeing of synthetic as well as natural indigo vat colours. Further, the waste dye liquor was assessed in terms of TOC (Total Organic Carbon) to verify the environmental sustainability of the suggested process.

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Extraction and Characterisation of Natural Dye stuff obtained from Cannonball Tree Bark

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Abstract

Nature has been a profound source of colours and cures since ancient times. In the field of textiles, there has been a growing global interest in rediscovering plant-based natural dyes due to environmental concerns, the toxicity of synthetic dyes, and the increasing demand for sustainable alternatives . Among underexplored botanical resources, the Cannonball tree (*Couroupita guianensis*) stands out for its multifaceted properties and cultural significance. The Cannonball tree, native to the tropical forests of Central and South America, is now commonly found in India and Southeast Asia, often planted for its ornamental value and religious importance. Preliminary studies have also looked into the colour potential of the tree's flowers and leaves, which yield soft to vibrant hues, depending on the extraction and mordanting techniques used. This research focus on exploring the possible usage of cannonball tree bark, due to presence of tannins in the bark which indicates good binding affinity with textile fibres. The dye was extracted from bark of the cannonball tree and the conditions were optimised by varying solvent, pH, time, and temperature. The infra dyeing machine which was used for the extraction of colourant from *Cannonball* bark powder Optimisation of extraction of colour was done on the basis of extract yield % (for selecting best solvent); K/S value and for optimising other conditions like MLR, temp, pH and time. The results were analysed and presented.

Figure 1. Infra for Extraction

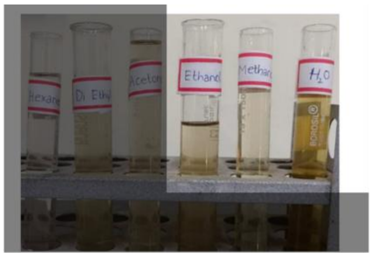

Figure 2. Solvents used for Extraction

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Acknowledgement

The author acknowledges the support received from the Central Silk Board, Bengaluru for carrying out the experiments.

Sustainable Dyeing of Cotton with Sesbania grandiflora Extract and Zinc Oxide Nanoparticle Finishes for Improved Color Strength and Functional Properties

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Abstract

The integration of natural dyeing techniques with nanotechnology presents an eco-friendly route for producing functional textiles. This research utilized aqueous extracts from Seemai Agathi (Sesbania grandiflora) leaves, a sustainable source of flavonoid pigments, to dye cotton fabrics. After the dyeing process, the fabrics were treated with zinc oxide (ZnO) nanoparticles, which were synthesized through an environmentally friendly method, to improve the interaction between the dye and fiber, enhance fixation, and add multifunctional properties. The characterization of both the dyed and nanoparticle-treated textiles was performed using FTIR, SEM, and UV-Vis spectroscopy to verify the bonding between pigments and fibers, as well as to observe surface modifications. The colorimetric assessment (K/S values) indicated a deeper shade, while tests for wash, rub, and light fastness showed marked progress compared to untreated fabrics. In addition, the ZnO nanoparticle-coated textiles displayed improved antimicrobial properties and UV protection, demonstrating added value beyond mere coloration. This research illustrates that the dye from Seemai Agathi, in conjunction with ZnO nanotechnology, provides a sustainable and multifunctional method for environmentally conscious textile processing.

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Acknowledgement

The authors gratefully acknowledge the management of PSG College of Arts & Science (PSG CAS) and the Department of Costume Design and Fashion, PSG CAS, Coimbatore, India, for their support.

Effect of Sustainable Pretreatments and Dyeing on Protective Bamboo/Cotton fabrics

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Abstract

This study investigates the effect of sustainable pretreatments method and dyeing on physical properties of bamboo-cotton (70/30) single jersey rib knitted fabric dyed with ***Acacia Catechu***, a natural tannin-rich sustainable dye with UV protective Properties. Conventional pretreatments in cotton fibre with hydrochloric acid (HCl) and sodium hydroxide (NaOH) as desizing and scouring agent were compared with a sustainable route involving enzymatic desizing (α-amylase at 1%–9%) followed by scouring with bentonite clay (0.5%–2.5%). A novel bio-mordant, fermented apple juice naturally rich in tannic acid was used prior to dyeing as a natural mordant. The dyed fabric was evaluated for color strength, whiteness index, air permeability, shrinkage, wicking height, absorbency and fastness properties along with UPF values. Surface and structural changes were analyzed using FTIR and SEM. It was concluded that sustainable pretreatments possess superior dye pick up and fastness ratings, while minimizing weight loss and chemical usage as compared to Conventional Pretreatments and Dyeing. The enzymatic-clay pretreatments with natural mordant treated and natural dye dyed fabric shown improved hydrophilicity and reduced environmental impact with UV protective properties as compared to conventional treatments. This work highlights a sustainable and efficient alternative to conventional methods, suitable for eco-conscious textile processing.

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Intercalation of α-zirconium phosphate With Amines Used as Epoxy Additives and Catalysts

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Abstract

Intercalated α-zirconium phosphate with amines used in epoxy additives extensively used in electronic applications such as automobile industries, smart phones, aeroplane industries and wearable devices. It has outstanding comprehensive performance, especially strong interfacial adhesion, which can be stored under ambient temperature and can be activated under heating conditions. In this review, the basic intercalation properties of α-zirconium phosphate with different amines and the progress of polymer synthesis with epoxy resins are discussed in detail. In addition, the mechanism for exfoliation of α-ZrP and the assembling approaches of α-ZrP nanosheets to form various structures are briefly discussed. Moreover, the catalyzing effects, thermal stability, and mechanical properties of amine intercalated α-zirconium phosphate with epoxy have various applications are also reviewed.

Effect of Twist Multiplier on Wick ability of Siro-spun Yarns

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Abstract

The wicking behavior of yarns is one of the fundamental attributes of fabric comfort. The effect of varying the number of plies of Siro spun ring cotton yarns and yarn variables such as twist multiplier (TM), diameter, twist angle, and linear density, on the optimization of wick ability was considered. Siro spun yarns of 32.8 tex with (3.09 & 3.67 TM) and 24.5 tex (3.49TM) with single, double, triple, four, and five ply configurations are considered. The twist level was maintained at 516, 614, and 673 twists per meter (TPM) for 32.8, 32.8, and 24.5 tex Siro yarns. The wicking rate followed a similar trend in Siro-plied yarns; however, when converting into ply yarns, a decreasing trend of wicking height and wicking rate was observed which is shown in Fig. 1(a) and Fig. 1 (b). It is also observed when increased the TM level (3.67) of plied Siro spun yarns curve S1, S2 and S3, S4 wicking aspect is going to merged. The wicking height was achieved at the highest at a twist multiplier of 3.05. The higher-plied Siro yarns exhibited larger diameter capillaries, which exerted a lesser wicking force than smaller diameter capillaries. This study will provide a fundamental background for the development of high-quality fabric. The Siro ring-spun bipartite yarns will explore new roles in product development.

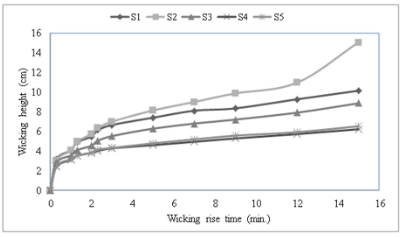

Fig. 1(a) - Plied Siro yarn's wicking behavior for 32.8 tex (3.09 TM) ply counts

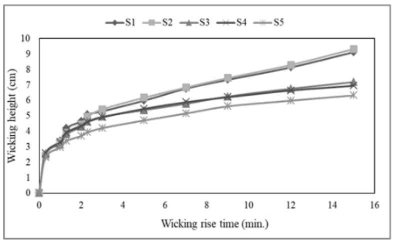

Fig. 1(b) - Plied Siro yarn's wicking behavior for 32.8 tex (3.67 TM) ply counts

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Acknowledgment

The author acknowledges the support received from the IIT Delhi India (Project Code: During Khadi Project working in the year 2008-09).

Computational Fluid Dynamics (CFD) Analysis of Process Parameters and Nozzle Design in Melt blowing

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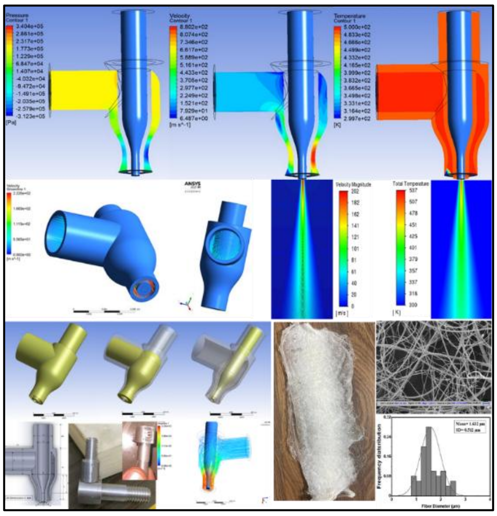
Abstract

Melt blowing is a versatile technique for producing nano/microfibres used in filtration, biomedical, and functional textile applications. The performance of the melt blowing process is highly sensitive to the thermo-fluidic behavior of gas flow from the nozzle, such as inlet air temperature, back pressure, and nozzle geometry, along with its interaction at the collector screen. In this study, a detailed CFD analysis is conducted to investigate the effect of key process parameters, specifically the inlet air temperature and back pressure, as well as the die-to-collector distance (DCD), on the flow dynamics and thermal field from an in-house designed melt blowing nozzle. A two-dimensional axisymmetric model is developed using ANSYS Fluent, employing the k-ε turbulence model coupled with energy equations to simulate the high-speed air-polymer interaction. The results indicate positive effects of increase in inlet air temperature on the overall drag effects in the gas flow field, which should ideally promote finer fibre formation. Similarly, variations in back pressure also influences the flow field and temperature distribution, which, again, should impact fibre uniformity and morphology (figure). Meanwhile, variation in the die-to-collector distance has a strong effect on the web uniformity. The findings offer valuable insights into optimizing nozzle design and operating conditions for improved fibre quality and process stability. Using the knowledge gained from the CFD analysis an in-house meltblowing nozzle was designed and the effects of process parameters were checked in the final web formation.



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Acknowledgement

The authors gratefully acknowledge the financial support provided by the National Technical Textile Mission (NTTM) under the Ministry of Textiles, Government of India (Project Code: RP04675).

ICTN-2026
8th International Conference on
Technical Textiles and Nonwovens

Comprehensive Analysis of Denim Fabric Properties: Influence of Fiber Composition and Weave Architecture

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Abstract

Denim was incepted as serviceable workwear fabric. However, over the years its application spread into a versatile textile sector viz: contemporary fashion and performance apparel and many more. Thus, key driving areas of innovations in this sector are comfort, durability, functional performance, and environmental responsibility. This study systematically investigates the influence of fiber blend composition and weave architecture on the performance characteristics of denim fabrics, with the goal of identifying fiber–structure combinations that optimize the requirement in the space of end-use functionality and sustainability. A total of 44 denim fabric specimens were engineered by blending 11 fiber compositions viz: natural fibers (cotton), regenerated cellulose fibers (Tencel, viscose, modal), synthetic fibers (polyester filament and staple), and elastomeric fibers (spandex) in varying proportions, across four structural variants: 1/1 plain, 2/2 twill, 3/1 twill, and knit-like formations for this study.

Mechanical properties were evaluated via tensile strength, tear strength, bursting strength, abrasion resistance, crease recovery, and flexural rigidity etc. The comfort-related attributes were assessed through air permeability, moisture management, vertical and horizontal wicking, water vapor permeability, absorbency, and uniaxial stretch-and-recovery. Additional durability parameters included dimensional stability (shrinkage), and appearance retention, while fabric cover factor was also determined. Sustainability considerations were integrated through the use of regenerated cellulose fibers with lower water and chemical footprints, reduced reliance on virgin synthetics & inclusion of recycled fibers, and the potential for extended product lifespan through enhanced wear resistance.

Performance mapping revealed statistically significant correlations between fiber composition, structural design, and functional outcomes, enabling the identification of configurations that deliver superior mechanical integrity, moisture regulation, shape retention, and reduced environmental impact. These findings provide a materials-engineering framework for developing next-generation denim textiles that meet evolving consumer expectations for comfort, durability, and sustainability.

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Comprehensive Analysis of Denim Fabric Properties: Influence of Fiber Composition and Weave Architecture

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Abstract

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Beyond Clothing: Unveiling the Role of Non-Apparel Textiles in Everyday Use

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Abstract

While textiles are predominantly associated with clothing and fashion, their influence extends far beyond apparel into numerous everyday products that often go unnoticed. From the cotton used in tea bags and coffee filters to the nonwoven fabrics in diapers, sanitary products, and wet wipes, textiles are deeply integrated into daily life. Technical textiles and nonwovens have become indispensable in sectors such as healthcare, agriculture, filtration, and packaging, providing enhanced performance, hygiene, and sustainability benefits.

This study aims to explore the hidden role of non-apparel textiles in modern living, with a focus on their material composition, functional properties, and diverse application areas. The study examines case studies from multiple domains, Health and Hygiene: Nonwoven fabrics in surgical masks, gowns, wound dressings, and hygiene products that ensure protection and comfort. Food and Beverage: Filter fabrics and heat-resistant cotton blends in tea bags, coffee filters, and packaging materials. Agriculture: Technical fabrics in crop covers, shade nets, and soil-protection textiles that improve yield and resource efficiency. Protective and Functional Products: High-performance textiles in filtration systems, insulation materials, and environmental protection solutions.

The study also addresses the role of innovation in developing functional textiles with properties such as absorbency, filtration efficiency, antimicrobial resistance, and biodegradability. Sustainability considerations will be discussed, including the adoption of recyclable and biodegradable materials, reduction of environmental impact, and circular economy opportunities within the non-apparel textile sector.

By highlighting the scale and diversity of these applications, this paper seeks to raise awareness among both industry stakeholders and the consumers about the pervasive role of textiles beyond clothing. It aims to bridge the gap between consumer perception and the actual scope of the textile industry, underscoring its critical contribution to healthcare, environmental protection, and everyday convenience. Such awareness can further drive research, innovation, and policy support for sustainable development in technical textiles and nonwovens.

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Acknowledgement

The authors express their sincere gratitude to MKSSS's School of Fashion Technology, Pune, for providing academic and institutional support. Special thanks are extended to the Principal, MKSSS's School of Fashion Technology, Pune and my Co-Author Dr. Garima Bhalla for encouraging research on emerging and unconventional areas of textile applications.

Innovative Smart Textile Application: Reflective School Uniforms for Student Road Safety

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Abstract

The present study investigates the integration of reflective safety strips into school uniforms as a cost-effective solution to improve the visibility and safety of students during early morning and late evening commutes. With the alarming rise in road accidents involving children, the study emphasizes the potential of smart textiles as an innovative yet affordable intervention for public safety.A mixed-method research approach was employed. The study reviewed existing uses of reflective materials in occupational and road safety apparel. Subsequently, prototype school uniforms were developed using retro-reflective strips strategically placed on collars, sleeves, shoulders, and back panels. These prototypes were tested under controlled low-light and headlight conditions to measure visibility enhancement. Durability assessments included multiple washing cycles, comfort trials, and user acceptance studies among students and parents. The results revealed a significant improvement in visibility for reflective uniforms compared to standard designs. The reflective material maintained its effectiveness even after repeated washes. Cost analysis indicated a marginal increase of only 5–10% in uniform production costs, thereby ensuring feasibility for large-scale adoption in both urban and rural school systems. The findings confirm that the inclusion of reflective safety strips in school uniforms can effectively reduce road-related risks for school-going children. This integration is both economically sustainable and socially beneficial. The study underscores how practical smart-textile innovations can enhance everyday safety without complex technological dependencies.

Future Scope: Subsequent research could explore the incorporation of photo-luminescent or LED-based elements, energy-harvesting fabrics, and large-scale pilot implementations. Policy-level advocacy for the mandatory inclusion of reflective components in school uniforms within high-risk zones may further strengthen student safety frameworks.

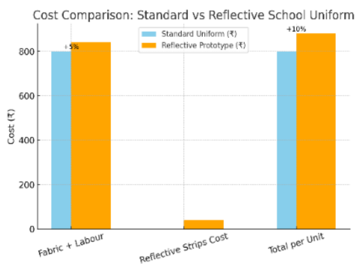

Figure 1. Cost Comparison between Standard and Reflective School Uniforms.
The graph illustrates a modest increase in production cost for the reflective prototype (₹880) compared to the standard uniform (₹800). The inclusion of reflective safety strip

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Acknowledgment:

We would like to express our sincere gratitude to Guru Gobind Singh Indraprastha University, Delhi, for their continuous academic support and to all the participating schools, students, and parents for their valuable feedback.

Poster Presentations

ICTN-2026
8th International Conference on
Technical Textiles and Nonwovens

Recent innovations in smart textiles and the role of AI in textile industry

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Abstract

The present paper reviews – relevance, advantages and disadvantages of lates innovations in smart textiles and sustainable textiles. For instance -some smart fabrics monitor body temperature or heart rate, which can help athletes optimize training or aid medical patients. Others change color based on sunlight exposure or adjust breathability based on humidity. These innovations blend fashion with technology, creating clothing that is functional and adaptive. Another key area of concern is sustainability. To lessen textile waste, designers and researchers are creating recycled textiles from used clothing or plastic bottles. By supporting circular fashion-where clothing is made to be recycled or reused rather than thrown away—and producing collections from recycled materials, companies like Patagonia and Stella McCartney are setting the standard. New options for lowering pollution are provided by biodegradable fabrics manufactured from plant fibers like hemp, bamboo, or even materials created in laboratories. Fabrics that resist bacteria or stains without the use of dangerous chemicals are made possible by advanced technologies like nanotechnology. The present paper then reviews relevance, advantages, disadvantages and role of AI in textile industry – Design and Development (Pattern and Texture Creation, Personalization, Material Selection); Manufacturing and Production (Optimized Production Processes, Automated Quality Control, Predictive Maintenance, Color Matching, Yarn and Fiber Analysis, Fabric Analysis); Supply Chain Management (Demand Forecasting, Efficient Logistics, Sustainable Practices); Smart Textiles and Wearable Technology (AI-powered sensors, Personalized Wearables); and AI and Sustainability (Waste Reduction, Resource Optimization, Eco-friendly Materials). AI is significantly revolutionising the textile industry to enhance efficiency, reduce waste, implement sustainable practices, reduce labor intensiveness, and more data driven. The paper concludes with a textile timeline for India, history, contemporary and future of textiles in India as is imminent from the research.

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Acknowledgement

The research acknowledges Jamia Millia Islamia – D/o Design and Innovation, Faculty of Architecture and Ekistics and MMTTC for support.

NBC Protective Textiles

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Abstract

Protection and safety of human resource are major concern in occupations that involve hazardous work conditions. Ensembles made up of protective textiles are used to safeguard the wearers from external workplace hazards. Textiles employed for protective clothing necessarily require to meet specific standards and certain ergonomic requirements. Essential properties are those that are necessary for a particular applicable condition either due to regulations or user requirement. On the other hand, desirable properties are those which are preferred by users for aesthetics and appearance. Fibres are the basic elements for textiles, which are usually converted in to yarn and then in to fabric. A textile fibre can be natural or artificial. Fabric behaviour and characteristics are vital in the design and development of a functional textile. Depending upon functionality of protective textile various types of hazards can be reduced exposure to are numerous: mechanical, chemical, biological, thermal, electrical, noise, radiations, etc. Among these various hazards, protection against biological and chemical warfare agents (CWAs) is currently considered as a most crucial issue. Historical malicious reputation of chemical warfare use in world war and frequent use by terror attacks in some countries result in numerous injuries or deaths that make it imperative to employ chemical barrier equipment for various regular and specialised civilian and military occupations.

Chemical protective clothing is generally used by military personnel, paramilitary forces and defence personals in various wartime and peacetime operations, including chemical warfare, chemical production and spillage accident, riot control activity. A protective clothing system includes a respirator, a hood, a coverall, overboots along with gloves. NBC Protective ensembles are continually being developed to overcome the new challenges due to exposure to toxic chemicals.

Various polymeric materials such as butyl rubber, nitrile rubber, neoprene, polyvinyl acetate (PVA), and poly(vinyl chloride) (PVC) & Carbon based fabric are commonly used for the fabrication of protective gears and the selection of these materials is mainly based on the chemical nature of the CWAs and biological agents.

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Acknowledgement:

The authors are thankful to Dr. Manmoham Parida, Director, Defence Research and Development Establishment, Gwalior for hos constant encouragement.

NATURAL COLOURS

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Abstract

Natural dyes are found from natural sources such as plants, animals, and minerals. The natural color may not have the desired shade or fastness since natural dyes are applied without using any sort of chemicals. These are applied directly to the fabric without using any chemicals. But some chemicals such as copper sulfate and ferrous sulfate are used as catalysts. The fabric used for dyeing should be 100% cotton and linen, which are free from any chemicals.

Since people are becoming increasingly health-conscious, the world over, herbal remedies such as neem, turmeric, aloevera, pomegranate, marigold, onion, etc. have the ability to protect from various skin diseases. The medical properties of herbs cause no damage to the human body. This dyeing process makes the process eco-friendly and hygienic.

Most of the textile export houses have started relooking at maximum possibility of using natural dye for dyeing and printing. These dyes have some drawback, the low color fastness properties in one. But no study is reported on improving the color fastness properties of natural dyes with natural dye fixing agents.

Acknowledgement

The author acknowledges the uses of natural color from Indian Institute of Handloom Technology,Bargarh.

Repurposing of jackfruit waste into non – woven fabric

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Abstract

In the healthcare sector, traditional non-woven fabrics primarily composed of synthetic polymers like polypropylene which cause major sustainability challenges. Their non-biodegradable nature results in biomedical waste accumulation, while their single-use design limits reusability and scalability. Additionally, poor biocompatibility and recyclability hinder their integration into sustainable biomedical applications. This research introduces a biodegradable alternative by repurposing jackfruit waste into eco-friendly non-woven fabric. Jackfruit cultivation yields significant organic waste, particularly from peel and core, which is rich in cellulose, pectin, and lignin. These biopolymeric compounds form the basis for natural fiber development and its applications. In the field of medical textiles, nonwoven fabrics find a major role, especially as disposable products like Clothes Bag, Pillowcase, Shoe cover, Bedsheet, Facemask, Surgical Cap. Furthermore, the integration of natural antimicrobial agents and biocompatible coatings expands the application of non-woven fabrics widely. This work underscores the value of agro-waste into value enhanced positions jackfruit-derived fabrics as a sustainable solution for medical-grade non-wovens.

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Acknowledgment

The author acknowledges the support received from the PBL SFS, Department of Biotechnology, Department of Textile technology, Kumaraguru college technology.

Sustainable fiber recovery from Cigarette waste for Technical textiles

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Abstract

In 2016, global cigarette production surpassed 5.7 trillion units, with the vast majority incorporating cellulose acetate filters—a polymer notorious for its limited biodegradability (Novotny et al., 2011). These discarded cigarette butts, among the most ubiquitous forms of litter worldwide, encapsulate over 4,000 toxic chemicals and pose severe ecological and public health risks to humans, wildlife, and both marine and freshwater ecosystems (Araújo & Costa, 2019). Cellulose acetate filters may persist in the environment for up to a decade, gradually leaching heavy metals and toxic compounds (Beutel, 2020). Although cellulose acetate can undergo photochemical degradation under UV irradiation at wavelengths shorter than 280 nm, its limited chromophore content restricts degradability under natural sunlight, further exacerbating environmental concerns (Al-Odaini et al., 2023; Liu et al., 2023). To mitigate these impacts, repurposing recycled cellulose acetate fibers from cigarette butts offers multifaceted benefits—mitigating pollution while contributing to sustainable material innovation. Investigated applications include sound-absorbing materials, corrosion inhibitors, asphalt concrete, fired clay bricks, decorative products, mats, and geotextiles (Kaliyathan et al., 2020; Araújo & Costa, 2019). Moreover, the outer paper wrapping of cigarette filters can be repurposed into new paper products, transforming a major pollutant into a valuable feedstock (Mohajerani et al., 2016). This review critically examines the current state of research concerning the application potential of cellulose acetate fibers extracted from cigarette butt waste. By exploring extraction methodologies, evaluating material properties, and assessing novel reuse pathways, the review aims to highlight sustainable solutions that address both environmental pollution and resource recovery.

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The Role of Textile Sensory Feedback on Attention Span Among College Students

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Abstract

Textiles are often studied for their aesthetic and functional properties, yet their potential psychological influence remains underexplored. Clothing interacts with the body through constant sensory feedback, which can affect comfort, mood, and cognitive function. With an emphasis on how various fabric textures may influence cognitive engagement and distractibility, this study examines the impact of textile sensory feedback on college students' sustained attention.

For the study, 30 undergraduate students between the ages of 18 and 24 were chosen as a sample. Participants completed the Digit Span Test (forward and backward) as a standardized measure of attention span, while wearing two different experimental conditions: rough-textured garments (such coarse synthetic mixes) and soft-textured fabrics (like cotton). The rationale was that although rough or uncomfortable materials could compete for cognitive resources and diminish attention span, soft, breathable clothes would promote physical ease and lessen body distraction, supporting attentional resources.

Preliminary findings supported this hypothesis. When compared to students wearing rough textiles, those wearing soft textiles showed considerably greater results on attention tasks, as well as prolonged sustained focus and fewer lapses. The association between perceptual ease and factual cognitive function was further supported by the participants' increased reports of comfort in the soft-texture condition. Rough textiles, on the other hand, were linked to greater distractibility and decreased attentional stability, demonstrating how even minor sensory discomfort might impede higher-order cognitive functions.

The significance of incorporating psychological viewpoints into textile studies is highlighted by this study. The study creates new avenues for creating clothing that improves focus and productivity by demonstrating how tactile aspects of clothing might impact cognitive performance. The results have implications for clinical groups that need high levels of continuous attention, workplace apparel, and student uniforms.

Acknowledgement

The authors would like to thank all the participants for their time and contribution to this study. No financial support or funding was received for the conduct of this research.

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On Adaptive Surface Textile with Automotive Textile

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Abstract

Adaptive surface textiles represent a new generation of functional materials designed to respond dynamically to environmental stimuli such as temperature, light, pressure, and moisture. By integrating advanced textile fibres, these surfaces can alter their structural, mechanical, or optical properties to achieve real-time adaptability. This research explores the design, fabrication, and functional performance of adaptive surface textiles utilizing shape-memory fibres, conductive yarns, and responsive coatings. The study highlights mechanisms of actuation, including thermal expansion, electroactive deformation, and moisture-induced swelling, that enable controlled surface transformation for applications in automotive interiors, protective gear, and aerospace structures. Furthermore, the potential of bio-inspired fibre architectures is discussed for achieving self-adjusting textures, variable permeability, and enhanced comfort. Experimental results demonstrate significant improvements in adaptability, durability, and energy efficiency compared to conventional textile surfaces. This advancement opens pathways for developing next-generation smart textiles with multifunctional capabilities, bridging the gap between material science and engineering design.

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Acknowledgement

The authors acknowledge the support of the faculty members of the Indian Institute of Handloom Technology, Bargarh, for their encouragement and guidance, and to peers who contributed valuable discussions on the future of Automotive textile.

Bio-based Fiber-Enhanced Geotextiles for Sustainable Unpaved Road Infrastructure

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Abstract

The global demand for roads is accelerating due to rapid population growth and peri-urban expansion. A significant portion of rural and secondary roads are constructed on weak and expansive soils, resulting in premature failures caused by settlement, rutting, and intermixing of base aggregates with fine-grained subgrade. While synthetic geotextiles have been widely used for subgrade reinforcement, their high cost, non-biodegradability, and environmental risks have prompted the search for sustainable alternatives. This study investigates the potential of bio-based fiber-enhanced geotextiles, specifically coir, as ecofriendly reinforcements for unpaved roads. Coir fibers are abundant, renewable, and possess good tensile strength; however, their inherent limitations—high moisture absorption, degradation tendency, and surface irregularities—necessitate surface modification. To address this, woven (W1, W2) and nonwoven (NW1, NW2) coir geotextiles were chemically treated with a formulation comprising unsaturated polyester resin, bitumen emulsion, styrene monomer, and methyl ethyl ketone peroxide. The reinforced soil models were tested through California Bearing Ratio (CBR) and monotonic load tests under soaked and unsoaked conditions. The results revealed that the inclusion of coir geotextiles improved the bearing ratio by up to 60% compared to unreinforced soil, while chemically treated samples exhibited a further 15–25% increase in tensile strength. Among all variants, woven Type W2 and nonwoven Type NW2 achieved the best performance, with ultimate bearing capacities of up to 280 kPa under unsoaked conditions. This research demonstrates that treated coir geotextiles can effectively enhance the structural and functional performance of unpaved roads while aligning with global sustainability goals. The findings open pathways for field-scale adoption, standardization, and commercialization of bio-based geotextiles in infrastructure development.

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Acknowledgement

The author acknowledges the support of J.N. Government Engineering College, Sundernagar, Himachal Pradesh, and expresses gratitude to colleagues and collaborators for their guidance during this research.

Positioning of Textile Supply Chain in Sustainability

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Abstract

The global textile and apparel industry has increasingly moved toward sustainability through mindful textile usage and the integration of digital tools such as blockchain for supply chain transparency. In the past decade, major brands like Zara, H&M, and Marks & Spencer (M&S) have implemented initiatives such as sustainable fiber sourcing, renewable energy adoption, and pilot projects in recycling and resale. However, it remains essential to evaluate where the industry stands after ten years of progress and what must be done to ensure long-term sustainability for the next century. Surveys conducted among manufacturing units and logistics partners of these brands reveal significant improvements in water and chemical reduction, improved traceability through blockchain, and the growth of circular practices. At the same time, challenges persist: overproduction inherent to fast fashion models, uneven adoption of circular systems, gaps in labor rights, and limited large-scale recycling infrastructure. To move forward, the study suggests prioritizing large-scale textile recycling innovations, expanding closed-loop production, strengthening blockchain-based transparency and engaging consumers in mindful consumption and garment care. Policy interventions and stricter environmental standards will also be necessary to ensure accountability and scalability. By aligning environmental responsibility, economic viability, and social equity, the textile supply chain can transition from incremental progress to transformative sustainability for the next hundred years.

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The authors would like to express sincere gratitude to the participating manufacturing units and logistics partners for their valuable time and insights during the survey process. Their openness in sharing practices, challenges, and perspectives made this research both meaningful and practical. Appreciation is also extended to industry experts and academic mentors whose guidance helped shape the direction of this study.

Upcycling Nonwoven and Woven Polypropylene Packaging Waste through Surface Manipulation for Functional Textile Development

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Abstract

This project is an experiment in innovative application of textiles, reimagining waste as a resource by transforming discarded packaging materials into functional textile products. The study focused on two widely available waste streams: non-woven Polypropylene packaging bags commonly used in Kangra, Himachal Pradesh, and large woven Polypropylene rice bags discarded in bulk from the college mess. The materials were explored through traditional surface techniques such as patchwork, appliqué, quilting, and hand embroidery, reinterpreted on unconventional substrates. Experimental processes were also introduced—most notably heat-setting the rice bags with a domestic iron, which generated striking textures and opened new avenues for material innovation. Complementing these, surplus muslin fabric from test fits in the fashion design department was incorporated as a secondary material. The outcome was a collection of samples of textile surfaces that combined functionality with sustainable design practice. Each piece embodied the idea of upcycling by extending the lifecycle of single-use materials and elevating them into aesthetically compelling and durable products. By situating everyday waste within a design context, this project demonstrates how craft techniques, when applied thoughtfully, can generate fresh possibilities for sustainable textiles while addressing pressing concerns of material waste and environmental responsibility.

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Acknowledgement

The author acknowledges Nirmal Chaya NGO, Dharamshala and Mr. Aritra Bhattacharyya for their valuable insights on textile waste management and surface work processes, which significantly informed this study.

Mechanical properties of natural fibre woven geotextiles

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Abstract

The mechanical behaviour of geotextile is important in the application where it is required to perform a structural role and survive installation damages and localized stresses. The mechanical behaviour of geotextiles is greatly influenced by their weave design. Properties such as tensile strength, elongation and puncture resistance can be obtained by different weave pattern. Derivatives of plain and twill weaves exhibit higher tensile strength and better textural stability compared to basic weaves. A dense weave pattern can enhance both strength and puncture resistance. In this work, the effect of weave pattern on mechanical properties of geotextile has been studied. The abundantly available coir yarns were woven in different weave pattern by employing loom to prepare closely woven geotextile. The prepared geotextiles were tested for tensile strength, elongation and dynamic puncture behaviour. The role of weave pattern on the mechanical behaviour of geotextile were investigated.

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Breathable Polymeric Coatings for Textile Upholstery Application

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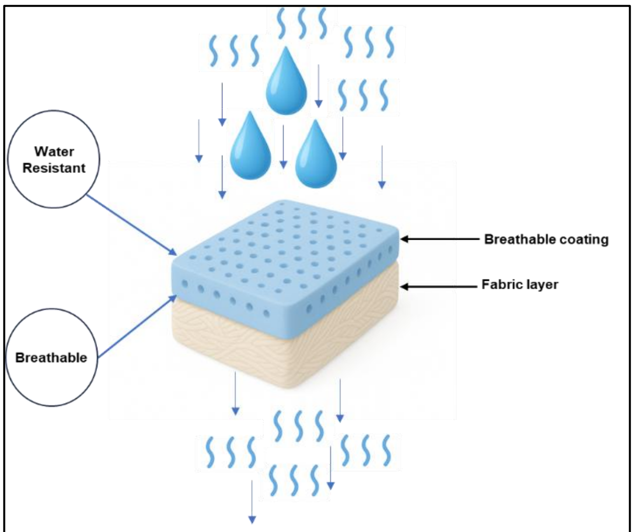
Abstract

Enhancing comfort in coated textiles remains a challenge, as conventional coatings restrict moisture vapour transmission and cause discomfort. Breathable polyurethane coatings enable vapour transfer while blocking liquid water, but their high cost and high solvent content limit industrial adoption. A few thermoplastic polymeric coatings, widely applied in upholstery and leather substitutes, provide durability at low cost yet lack breathability. This study presents a cost-effective, scalable approach to engineer breathable polymeric coatings through the incorporation of pore-forming agents and stabilisers without altering established manufacturing processes. A standard transfer coating system was employed, where pore-forming agents induced micro-porosity and stabilisers-maintained foam integrity. Scanning Electron Microscopy confirmed the formation of uniform microporous structures, while functional analysis revealed a Moisture Vapour Transmission Rate exceeding 25 g/m²/day and air permeability more than 0.50 $cm^3/cm^2/s$, representing a five-fold increase compared to control samples. Adhesion strength and flexibility remained within industrial specifications, demonstrating that this dry-additive formulation based on different coagulation methods provides a sustainable pathway for breathable coatings, combining enhanced user comfort with durability, scalability, and cost-effectiveness for upholstery and leather-substitute applications.



Schematic of Breathable Coating

Acknowledgement

The authors acknowledge the Central Research Facility (CRF), Indian Institute of Technology Delhi for allowing the use of SEM facility.

Permanent Ink-Lock Technology for Lifetime-Preserved Textile Memorabilia

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Abstract

Textiles used for farewell events, ceremonies, and DIY applications often serve as personal memorabilia. However, conventional printing or hand-marking techniques suffer from ink bleeding, fading, and deterioration over time, reducing their sentimental and functional value. This research proposes the development of an ink-lock textile system that enables permanent, non-spreading, and washable inscriptions or prints, thereby preserving garments for a lifetime. The innovation lies in creating a micro-layered surface finish on cotton or polyester fabrics using Nano-polymeric coatings and microencapsulation of ink pigments, which ensures permanent bonding at the fiber level. Unlike conventional surface printing, the proposed method employs a dual-layer approach:
1. A hydrophobic Nano-finish to prevent ink spreading and capillary wicking.
2. A reactive binding layer that cross-links pigments with fiber polymers, ensuring high fastness to wash, UV exposure, and abrasion. Initial laboratory trials demonstrate an 85–90% reduction in ink spread compared to untreated fabric, along with color retention after 50+ wash cycles (Table 1). The technique preserves the fabric's softness, breathability, and tensile strength, making it suitable for both DIY applications and commercial production. Potential applications include farewell and event memorabilia, collectible sportswear, uniforms with personalized messages, and high-value merchandise requiring permanent custom designs. Beyond emotional value, the technology contributes to sustainability by extending garment life, reducing reprints, and minimizing ink waste.

Parameter	Conventional Fabric	Ink-Lock Treated Fabric
Average Ink Spread (mm)	2.8	0.3
Color Retention After 50 Washes (%)	55	92

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Acknowledgement

I would like to express my deepest gratitude and profound respect to Director Prof. G.H.S. Prasad and Joint Director Dr.Janmay Singh Hada, for their valuable guidance and encouragement throughout the research.

Sustainability in Style: Risa Fabric as a Bridge between Handloom Traditions and Modern Wear

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Abstract

Tripura is a hilly state of North-Eastern State of India. Tribes residing in Tripura weave and wear a traditional dress named as Risa. It is basically a female upper garment, sometimes worn as a headgear, a stole or a present to show respect. This fabric is woven in traditional handloom know as loin loom. This traditional fabric of the tribe community faced historic challenges. Despite its cultural importance, the fabric remains largely confined to local use and has limited exposure in mainstream fashion markets. With the growing global emphasis on cultural sustainability and the fusion of tradition with innovation, there exists a strong potential to reintroduce Risa as a versatile fabric within the contemporary fashion industry. This research paper aims to interpret the traditional fabric into a modern style while preserving its essence intact. By exploring the weaving techniques of Risa, the study investigates how this handloom fabric can adapted into modern silhouettes. The research also emphasis the sustainable practices, considering eco-friendly and artisanal value of Risa Weaving with consumer acceptance, market feasibility, and sustainability implications of modernized Risa products. Insights are drawn from surveys, designer interviews, and market analysis to understand how cultural textiles can thrive in mainstream fashion without cultural dilution. By emphasizing eco-friendly handloom practices, artisanal empowerment, and cultural preservation, the study highlights the dual role of Risa as both a fashion innovation and a cultural ambassador of Tripura. Ultimately, the research seeks to create a design framework that ensures the survival, promotion, and global recognition of Risa fabric while empowering the artisans of Tripura.

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Acknowledgement

I sincerely thank Jagannath University for providing guidance, resources, and encouragement that enabled the successful completion of this research.

Development and Characterization of Bio-Based Flame Retardant Finishes on Cotton Fabrics Using Chitosan for Sustainable Textile Applications

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Abstract

The growing need for sustainable and environmentally friendly textile finishing has prompted the investigation of bio-based alternatives to traditional flame-retardant (FR) chemicals, which frequently present environmental and health risks. Chitosan, a biopolymer derived from chitin, has attracted considerable interest due to its biodegradability, ability to form films, and natural nitrogen content, making it a viable option for flame-retardant uses. This research centers on creating a bio-based flame-retardant finish utilizing chitosan for cotton fabric applications. The study encompasses the synthesis and optimization of chitosan-based FR formulations through chemical modifications and the inclusion of synergistic bio-sourced additives. Techniques such as pad–dry–cure will be used to achieve long-lasting finishes. The treated fabrics will be assessed for flame retardancy utilizing Limiting Oxygen Index (LOI), vertical flammability, and cone calorimetry assessments, alongside evaluations of durability after multiple laundering cycles. Additionally, the effects of the finish on fabric handle, tensile strength, air permeability, and comfort characteristics will be examined. Structural characterization methods such as FTIR, SEM, and TGA will be utilized to verify the chemical interactions between chitosan and the textile substrate. The goal of this study is to show that chitosan-based flame-retardant systems can serve as a sustainable, non-toxic, and durable alternative to traditional halogenated and phosphorus-based finishes. The results are anticipated to aid in the advancement of green textile finishing technologies that align with global sustainability objectives.

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Post – consumer textile waste management: A holistic approach towards a circular economy while bridging socio – cultural and socio – economic gaps.

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Abstract

With a remarkably growing fast fashion trends, the global textile waste production is 92 – 120 million metric tons annually wherein India generates 7.8 – 7.9 million tons of textile waste approximately. This data which is inclusive of both pre – consumer and post – consumer textile waste, positions India among one of the world's largest textile waste producers. In Indian context, over 50% of this annual textile waste comes from post – consumer sources such as discarded clothing and home textiles. Today, a significant amount of this textile waste is being reused or recycled in India but it is an undeniable fact that, a large portion still ends up in landfills which occupies valuable space and releases toxic chemicals. These pollutants are responsible for contaminating ecosystem while creating serious health risks. To overcome the challenges many policies and strategies are being taken into consideration. Many organizations are also contributing at different levels but more effective circular practices are required. From creating awareness to outlining principles for reducing waste, bridging socio – cultural and socio - economic gaps, integrating supportive government policies, developing circular skills and expertise, investing in infrastructure such as recycling facilities, and shifting consumer mindsets to encourage sustainable choices will certainly play a vital role in terms of making this environmentally conscious effort work more effectively. The project outlines the need for equal opportunities and access to resources and skills while encouraging community engagement and heading towards a circular economy.

Development of Biodegradable Polymer based Orthopaedic Implants

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Abstract

Nature offers sophisticated examples of structural architectures formed through mechanical instabilities that are simultaneously optimized for strength, lightweight performance, and efficient fluid or gas exchange. Translating these design principles into engineered systems has catalysed the emergence of biofabrication, an interdisciplinary approach that integrates biomaterials, bioactive molecules, and living cells to generate biomimetic constructs capable of replicating native tissue microenvironments in both structure and function. The field is currently undergoing rapid expansion, with a global market size estimated at USD 2.63 billion in 2024 and a projected compound annual growth rate of 28.3% between 2025 and 2034. This growth is driven by demographic and epidemiological transitions, including population expansion, increased life expectancy, and the rising incidence of age-associated degenerative disorders and traumatic injuries. Consequently, musculoskeletal disorders (MSDs) have become a major contributor to the global health burden. According to the Global Burden of Disease (2024) database, MSDs rank among the top five causes of disability-adjusted life years (DALYs) worldwide and in Europe, and within the top ten in India. Epidemiological evidence also suggests a higher susceptibility of females to bone fractures compared with males. As per the World Health Organization, the most prevalent MSDs include low back and neck pain (40–50%), osteoarthritis (15–20%), soft tissue disorders (10–15%), bone fractures (10–15%), and inflammatory conditions (5–10%). Although many MSDs are amenable to conservative or interventional management, bone fractures exceeding the critical defect size typically necessitate surgical intervention, thereby highlighting the clinical relevance and transformative potential of biofabrication-based regenerative strategies. Herein, we highlight the development of such a biomimetic orthopaedic implant through combination of emulsion templating and 3D printing using polycaprolactone.

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Acknowledgement

The author acknowledges the financial support received from Ministry of Education, India and Central research facility IIT Delhi.

Textile Sustainability and Recycling: Towards a Circular Future

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Abstract

The textile and apparel sector, while being one of the world's largest industries, is also a significant contributor to environmental degradation, resource consumption, and waste generation. With the rise of fast fashion, millions of tons of textile waste are landfilled or incinerated annually, leading to critical ecological challenges. Textile sustainability and recycling have therefore emerged as essential strategies to reduce the industry's environmental footprint and transition toward a circular economy. Sustainable approaches include the use of eco-friendly fibers, green dyeing and finishing technologies, water- and energy-saving processes, and circular business models. Recycling methods such as mechanical recycling, chemical recycling, and upcycling help recover fibers and create value-added products. Case studies from global brands and Indian recycling hubs demonstrate practical advancements and their impact on waste reduction. Integrating sustainability with recycling not only conserves resources and reduces pollution but also fosters innovation and economic opportunities. Strengthening collaboration among academia, industry, and policymakers is essential to achieve a greener and more sustainable textile future.

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Acknowledgment

The author acknowledges the financial support received from the Department of Science & Technology (DST), India.

ICTN-2026
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CRISPR-Based Microorganisms for Smart Textile Finishes

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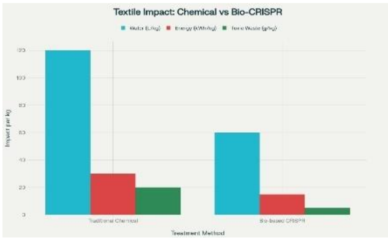
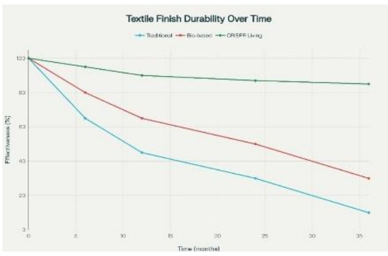
Abstract

The textile industry today faces a major challenge in reducing its dependence on harsh chemical treatments that harm the environment. Biotechnology, and more specifically genetic engineering using CRISPR-Cas9, provides a new and powerful solution. With this approach, microorganisms such as bacteria and yeast can be genetically modified to produce valuable natural substances like antimicrobial peptides, eco-friendly pigments, and UV-protective compounds. These bio-based products can then be applied to fabrics through innovative processes such as bio-coating or fermentation-assisted finishing. Unlike traditional chemical methods, these systems have the potential to lower water and energy consumption, reduce toxic waste, and extend the useful life of textile finishes. Moreover, CRISPR-modified microbes could enable the development of "living finishes," where fabrics renew or regenerate their protective properties over time. This concept represents a shift from traditional passive textiles to next-generation active and smart textiles. By merging advances in biotechnology with textile engineering, CRISPR-driven microbial systems could open the way for sustainable, self-sustaining, and high-performance fabrics that meet both industrial and environmental needs.





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Acknowledgment

I would like to express my gratitude to my teachers and mentors at Government Women Polytechnic College Jaipur, India for their valuable guidance and encouragement throughout this project. I am thankful for the support and resources provided by my institution, which helped me in completing my research.

Systematic Review of Diabetic Wound Healing Using Nonwoven Antimicrobial Silver-Ion Embedded and Alginate Dressings

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Abstract

Diabetic foot ulcers (DFUs) are among the most challenging chronic wounds to manage, particularly due to delayed healing, high infection risk, and poor vascularization. This systematic review explores the effectiveness of nonwoven antimicrobial silver-ion embedded dressings and alginate-based dressings in promoting wound healing in patients with DFUs. The review includes findings from clinical trials, preclinical studies, and in vitro research to assess outcomes related to wound closure rate, infection control, tissue regeneration, and biocompatibility. Silver-ion dressings, often composed of nonwoven materials embedded with ionic silver, exhibit potent antimicrobial activity and have shown promising results in enhancing wound healing. Studies report significant reductions in ulcer size—up to 67.8%—along with accelerated epithelialization and granulation tissue formation. These dressings are particularly effective in infection-prone or heavily exudating wounds. However, in vitro data highlight concerns over cytotoxicity, including reduced fibroblast viability (by 54–70%) and decreased collagen production (by 48–68%), which may impact long-term tissue integrity. Alginate dressings, made from seaweed-derived polysaccharides, are valued for their biocompatibility, high absorbency, and ability to maintain a moist wound environment. Clinical evidence supports their role in managing moderate to heavily exuding wounds, with minimal cytotoxic risk. Despite these advantages, systematic reviews and clinical trials have found no consistent evidence of alginate dressings being superior in achieving full wound closure or faster healing times when compared to other modern dressings. Notably, animal studies suggest that silver-free alginate gels may enhance granulation and skin structure regeneration more effectively than nanosilver formulations. The results of this systematic review indicate that while silver-ion dressings offer rapid healing benefits and superior antimicrobial protection, they may carry cellular toxicity risks that warrant cautious application. Alginate dressings remain a safe and effective option for moisture balance and absorption, though their healing outcomes may be limited in certain wound types. Clinicians should tailor dressing choices based on wound characteristics, patient condition, and risk of infection.

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Study on use of reusable cloth diapers made from sustainable fabric

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Abstract

The diaper industry predominantly utilizes either cloth or synthetic disposable materials. Reusable cloth diapers typically consist of three components: an absorbent core made from chemical-free organic fabric, an inner fleece layer that keeps the baby dry, and an outer waterproof layer. Modern cloth diapers are designed for convenience and ease of use, similar to their disposable counterparts. They offer significant cost savings, potentially reducing expenses by up to ₹20,000 per year compared to disposable diapers. The global challenge of utilizing fruit and vegetable waste has led to the development of sustainable materials like orange fabric. Made from discarded orange peels, this biodegradable fabric is soft, shiny, and gentle on the baby's skin. Enriched with natural oils containing Vitamins A, C, and E, it nourishes the skin without feeling oily. Alongside orange fabric, materials such as hemp and bamboo are designed to meet the innovation, and sustainability demands of fashion brands. Cloth diapers made from these materials are often praised for being environmentally friendly and beneficial for the baby's skin. Cloth diapers are estimated to have better health, environmental, and cost factors than disposable diapers, excluding convenience. This paper aims to understand the main environmental concerns of different types of diapers and address how to reduce them by using cloth diapers made from sustainable fabrics that will not harm the baby. By choosing cloth diapers, we contribute to reducing landfill waste, as disposable diapers can take hundreds of years to decompose. Using environmentally friendly materials ensures that quality, functionality, and customer demands are satisfied while revitalizing the goods industry. In addition to it, the designing of orange peel cloth diaper have been discussed in detail in this paper.

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Diversifying Gamchhas of Kenjakra in West Bengal for Sustainable Livelihoods: A Study on Innovative End-Uses

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Abstract

Gamchhas are chequered and striped multicoloured cotton towels from Bengal. Currently number of weavers has reduced to 60-80 from 300 due to rising cost of raw materials, poor salaries, increased usage of synthetic yarns and competition from cheaper mill-made counterparts. Despite this, there are advantages including excellent aesthetic value, high-quality weave with useful properties, inexpensive capital requirements and room for product diversity. Thus, an effort was made to preserve this endangered art and offer greater variation in its usage and improved livelihood for the weavers through a new product line like stationery. The developed artefacts can serve as mementos from this little Bengali community. This study aimed to preserve the traditional art of Gamchha weaving from Bengal by diversifying its usage and creating new products, such as innovative stationery items, thereby promoting sustainable livelihoods for artisans and aligning with the United Nations' Sustainable Development Goals (SDGs), particularly SDG 8 (Decent Work and Economic Growth) and SDG 12 (Responsible Consumption and Production). Despite the decline of Gamchha weaving due to various challenges, including rising costs and competition from cheaper alternatives, the research highlighted the advantages of this traditional weave, including its excellent aesthetic value, high-quality weave, and potential for product diversity. The study involved several stages, including documentation of the traditional craft through visits to Kenjakura in West Bengal, identification and construction of new products, preparation of 48 different stationery items, and assessment of their acceptance among textile designers and office workers. The results showed that most respondents found the stationery items made from Gamchha fabric to be incredibly innovative and appealing, with a substantial positive correlation between the overall attractiveness of the products. By creating new products like stationery items, the study aimed to not only preserve the traditional art of Gamchha weaving but also provide a potential source of income for the struggling weavers and promote the cultural heritage of the Bengali community. The findings suggest that Gamchha-based products can be a unique and appealing way to showcase the craftsmanship and aesthetic value of this traditional textile, ultimately enhancing the livelihoods of artisans and supporting the preservation of this endangered art form.

Development of Environmentally Friendly Antimicrobial Cotton Fabrics Using Turmeric Nanocoatings

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Abstract

The incorporation of antimicrobial activity in fabrics represents a topic of strong scientific and economic interest, primarily with regard to healthcare, personal protection, hygiene, and environmentally friendly material construction. Traditional techniques for giving antimicrobial activity to fabrics primarily depend on costly metallic nanoparticles—such as silver or copper—whose preparation and implementation pose noticeable difficulties for college students, like cost, sterility concerns, and ecological issues. This challenge has led to developing an environmentally friendly, cost-effective, and realizable method for creating antimicrobial fabrics with natural-derived nanomaterials and simple fabrication procedures amenable to execution with a collegiate background. The core activity of this task is to prepare an "Eco-Nano Antimicrobial Fabric" from turmeric extract for its wide-spectrum antimicrobial action and documented safety profile, as the key active component. Turmeric (Curcuma longa) contains curcumin and other polyphenolics that in nanostructured dispersions powerfully inhibit bacterial and fungal growth. Preparation begins with extraction and nanosizing of turmeric through mechanical blending and filtering to enable enhanced surface area and reactivity. The extracted liquid is thereafter used to impregnate natural fiber substrates such as cotton with simple methods such as soaking, manual padding, or spray coating. A soft, edibility-grade binder (e.g., vinegar) is optionally used to enhance adhesion and antimicrobial finish stability. Treated fabrics are subsequently air-dried and oven-cured with common household equipment, such that overall fabrication remains elementary and safe for student groups with no special laboratory facility. To analyze effectiveness of the antimicrobial treatment, a systematized prototype testing regimen was applied with the agar diffusion technique—the "parallel streak test" that is visual and sturdy for undergrad laboratories. Swatches of both untreated (control) and treated fabrics were incubated on prepared agar plates seeded with safe-to-handle test organisms, such as baker's yeast and bread mold. After 24–48 hours incubation at room or controlled temperature, clear areas free of visible growth indicative of successful antimicrobial activity in the form of zones of inhibition were visible around treated textile swatches. Zone diameters were measured with a ruler or digital calipers to give semi-quantitative antimicrobial strength comparisons between diverse samples. Repeat assays were carried out after stressing treated textiles with standard wash procedures to test durability and retention of bioactivity after laundry—a key for real-world implementation. Control experiments with untreated fabrics were performed to ensure that seen effects were related to applied nanostructured coating and not base material properties. The findings showed that nano-coatings made from turmeric exhibited significant inhibition zone growth against yeast and mold cultures, while untreated control samples enabled free growth. Moreover, antimicrobial activity was preserved after multiple laundering cycles, albeit with reduced activity, signaling importance for future versions of optimizing binders. The affordability, non-toxicity, and fast-paced nature of fabrication facilitates scalability in college laboratories or resource-poor locations. Additionally, natural, renewably-sourced, and environmentally friendly agents used meet mounting regulatory and environmental requirements of textile finishing chemicals. Overall, our experiment offers a scalable and repeatable path to functionalizing everyday textiles with antimicrobial activity through green nanotechnology and student-accessible tools. Antimicrobial activity confirmed by brief, comparative microbiological assay shown by our experiment thus asserts scientific and practical validity for our technique. Our technique and findings can also serve as a template for future experiments for low-cost, green nanotechnology for textiles and can further inspire broader societal efforts for public health, environmental responsibility, and innovation in material sciences.

Acknowledgement

We express our sincere gratitude to Kumaraguru College of Technology, Coimbatore, for providing laboratory facilities and research support, and to the Department of Textile Technology for guidance in experimental design and analysis. We also acknowledge the contributions of faculty mentors for their valuable technical insights that shaped this work.

Statistical Optimization and Recombinant Expression of Native Laccase in *Pichia pastoris* for Enhanced Thermo- and pH-Stable Biocatalysis in Textile Dye Degradation

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Abstract

Laccase, multicopper oxidase, is a green catalyst capable of oxidizing various organic substrates in the presence of oxygen. It has gained more interest in environmental applications because of its broad substrate range and high redox potential. The sources of laccase vary from bacteria, fungi and plants. Among them the bacterial laccase, also called versatile laccase has higher stability in terms of temperature, pH, salinity and heavy metal presence which favours them for biodegradation applications [1]. However, the productivity and redox potential of bacterial laccase is limited compared to other eukaryotic hosts. Hence, in this study, a bacillus drentensis laccase (BDLaccase) which was previously isolated from textile effluent release site in our laboratory [2] has been heterologously expressed in a eukaryotic host which Pichia pastoris for improved post translational modification and productivity. The laccase coding gene of Bacillus drentensis was amplified from the whole genome and ligated into pPICZαA vector which can secrete the laccase enzyme extracellularly with 6X His tag in its O terminal which will enable ease of purification through metal affinity chromatography. The Pichia pastoris GS115 clone that expresses laccase was identified and through sequential optimization steps of One Factor At A Time, Plackett Burman Design and Artificial Neural Network assisted Genetic Algorithm, the laccase activity was improved to 1.493 U/mL which is 3.1 fold higher than the unoptimized laccase production. Then, further purification through Ni-NTA chromatography has resulted in a purification fold of 9.2 and purification yield of 73.6%. The recombinant laccase also demonstrated exceptional stability across a temperature range of 20–70°C, pH range of 3.0–8.0 and heavy metal presence. Finally, this purified laccase was utilized for the bioremediation synthetic dyes, which is Acid red-27 (AR-27) and Direct Blue-6 (DB-6). Under 50 ppm of dye concentration, the enzyme showed maximum degradation efficiency of 99.76% and 92.58% against AR-27 and DB-6 respectively within 3 h. The degraded products were analysed through UV-Vis spectroscopy, FTIR and LC-MS which showed the complete mineralization of synthetic dyes by the laccase mediated oxidation. These results indicates that the synthesized PBDLaccase is an efficient bioremediation agent for the dye removal.

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Sequential Azoreductase-Laccase mediated Biodegradation of Azo-dye by Brevundimonas naejangsanensis AJZ05 and Neobacillus cucumis L03: A sustainable Strategy for Textile Effluent Treatment

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Abstract

Improper discharge of untreated industrial effluents, especially from textile sector, pollutes aquatic ecosystems, disrupts ecological balance, and poses severe health hazards due to the high toxicity and persistence of synthetic azo dyes, which remain recalcitrant owing to their azo bond (–N=N–). As the second-largest polluter globally, the textile industry demands effective and eco-friendly dye degradation strategies. Microbial degradation using enzyme-mediated pathways offers a sustainable, cost-competitive solution with high specificity and potential for zero waste. Among these, azoreductase (EC 1.7.1.6), an oxidoreductase, cleaves the azo bond under anaerobic conditions, but generates toxic aromatic amines as by-products, necessitating further treatment. Laccase (EC 1.10.3.2), a green catalyst, oxidizes aromatic amines and phenolics in the presence of oxygen into simpler, non-toxic products such as CO_2 and water. Hence, this study developed a sequential azoreductase–laccase mediated microbial treatment approach for complete mineralization of azo dyes. Azoreductase-producing Brevundimonas naejangsanensis AJZ05 was isolated from textile effluent site and identified via 16S rRNA sequencing. Using Plackett–Burman design, dye concentration, yeast extract, and inoculum level were identified as key parameters for degradation, while glucose, yeast extract, and inoculum influenced enzyme activity. Response Surface Methodology (RSM) optimization established optimal conditions at Direct blue dye concentration 101.76 mg/L, glucose 5.19 g/L, yeast extract 5.87 g/L, and inoculum 5.45%, achieving 98.50% degradation and 0.761 U/mL azoreductase activity. UV–Vis, FTIR, and GC–MS confirmed degradation and revealed aromatic amines and phenolic intermediates, including naphthalene and phenols, as major products. To further mineralize these intermediates, laccase-producing strain, Neobacillus cucumis L03, was isolated from the same site. Multi-response optimization determined ideal conditions of glucose 5.26 g/L, $CuSO_4$ 0.247 mM, and inoculum 4.15%, achieving 98.50% degradation of intermediates and 2.63 U/mL laccase activity. HPLC and GC–MS analyses confirmed breakdown metabolites, elucidating the degradation pathway and leading to the formation of mineralized products such as fumaric acid. Phytotoxicity assays with Vigna radiata demonstrated a drastic reduction in toxicity across sequential treatment stages, culminating in completely non-toxic effluents. This integrated azoreductase–laccase mediated biodegradation process highlights the synergistic potential of Brevundimonas naejangsanensis AJZ05 and Neobacillus cucumis L03 for efficient, sustainable, and complete mineralization of azo dyes, offering a viable green technology for industrial effluent remediation.

Acknowledgment

The author extends sincere gratitude to the DCIF, Department of BSBE and CIF, at IIT Guwahati, for providing the necessary instrumentation facilities to conduct my research, and to the Department of Chemical Engineering & Technology, IIT (BHU), Varanasi for their research support. Additionally, I (PMRF ID: 1903282) am deeply thankful to the Ministry of Education (MoE), India, for the Prime Minister's Research Fellowship for funding the research work.

Chemically treated flame-retardant cotton vis-a-vis inherent para-aramid fabric in reference to multiple washing

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Abstract

This study presents a comparative evaluation of flame-retardant treated cotton and inherently flame-retardant para-aramid fabrics after five wash cycles. Flame-retardant textiles are vital for protective clothing in industries such as firefighting, electrical work, and manufacturing, where exposure to fire hazards is common. The research investigates the durability and performance of these two types of flame-retardant fabrics under repeated laundering. The cotton fabric was chemically treated with a flame retardant, whereas the para-aramid fabric naturally exhibits flame-retardant properties due to its chemical structure. Both the fabrics were subjected to five standard washing cycles, and their flame-retardant effectiveness was evaluated by measuring key parameters such as flame resistance, thermal stability, and physical changes in the fabric. Results revealed that although both fabrics initially demonstrate flame resistance, the inherent flame-retardant para-aramid fabric retained its protective properties far more effectively after multiple washes. In contrast, the treated cotton fabric showed a noticeable reduction in flame resistance, indicating decreased performance following multiple washing/repeated laundering. These findings highlight the advantages of using inherently flame-retardant materials such as para-aramid for long-term protective applications, where durability and sustained flame resistance are essential. The study provides valuable insights into the performance of flame-retardant textiles and supports the development of more reliable and sustainable protective fabrics. Further, additional thermal testing was carried out—comparing contact heat, convective heat, and radiant heat—to evaluate the impact of multiple wash cycles on both fabrics. A follow-up study is planned to assess their performance after contamination with oil, grease, and mud, which commonly occurs during routine use of uniforms made of such fabrics.

Artificial Intelligence in Apparel: Balancing Efficiency, Sustainability and Virtual Fashion Commerce

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Abstracts

Artificial Intelligence (AI) is transforming the garment industry by embedding itself into the essential processes of design, manufacturing, and customer engagement. This study examines two major aspects of AI adoption: its impact on design and production efficiency, and its influence on consumer behaviour through personalization technologies.AI-driven solutions such as computer-aided design (CAD), automated pattern generation, and advanced sewing systems have reshaped traditional workflows in apparel design and manufacturing. These innovations enable rapid prototyping, reduce material waste, and support mass customization, allowing companies to respond quickly to evolving fashion trends. In production, robotic cutting machines, defect-detection algorithms, and predictive maintenance systems enhance accuracy, minimize downtime, and improve product quality. Intelligent resource planning further optimizes the use of energy, water, and chemicals, reinforcing circular fashion principles and promoting sustainable manufacturing practices. AI is also redefining how consumers shop and interact with fashion brands. Recommendation engines analyse demographic data, browsing histories, and purchasing patterns to deliver tailored product suggestions. Virtual fitting technologies, powered by computer vision and body scanning, bridge the gap between online and offline shopping by simulating garment fit and style. At the same time, chatbots and conversational AI improve customer service, while predictive analytics assists retailers with demand forecasting and inventory management. To assess the practical impact of AI integration, this study adopts a mixed-methods approach, combining consumer surveys, expert interviews, and field visits to AI-enabled apparel units. It highlights both advantages and challenges, including workforce adaptation, implementation costs, and data privacy concerns. The findings emphasize AI's transformative potential in building garment ecosystems that are agile, sustainable, and customer-centric. Ensuring responsible, inclusive, and scalable adoption will require coordinated collaboration among government, industry, and academia.

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Acknowledgment

The authors acknowledge the valuable guidance of mentors, experts, and institutions whose support enriched this study.

Influence of Biomolecule on Long-Term stability of Piezoelectric Properties of Poly(vinylidene fluoride) Composite Nanofibers for Athlete Training

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Abstract

Piezoelectric pressure sensors are highly promising for integration into wearable electronics, yet achieving a combination of high sensitivity and long-term operational stability remains a significant challenge. This work addresses this limitation through the development of a novel composite nanofiber system. We present a strategy utilizing a biomolecular additive within a poly(vinylidene fluoride)(PVDF) matrix to fabricate advanced piezoelectric nanowebs via electrospinning. We hypothesize that specific interfacial interactions between the biomolecule and the PVDF chains-such as dipole-dipole interactions and hydrogen bonding-serve to stabilize the electroactive polar phase, thereby enhancing durability. Comprehensive material characterization confirmed that the composite structure promotes a higher fraction of the piezoelectric beta phase and an increased dielectric constant compared to pura PVDF. the fabricated sensor demonstrated a high and quantifiable pressure sensitivity across different pressure ranges. Furthermore, the device generated sufficient power for practical applications and exhibited exceptional output stability, maintaining performance over an extended period exceeding several months. To validate its real-world applicability, the sensors was successfully integrated into sports insole and effective monitored human physical activities, showcasing its potential for use in next generation wearable health and performance monitoring systems.

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Acknowledgement

The author acknowledges Central Research Facility of IIT Delhi and CMERI Durgapur for providing SEM and XRD, respectively.

Integrating Textile Sustainability into Plus-Size Fashion for a Responsible Future

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Abstract

The intersection of sustainable textiles and plus-size fashion is a yet unrealized frontier of the fashion industry, while demand for sustainable and varied fashion continues to escalate. Although plus-size consumers are a substantial and growing share of the market, sustainable fashion efforts have heretofore centred on standard sizes, thus, de facto, excluding a considerable segment from having any stake in circular fashion economies. This research paper critically examines balancing of sustainability and plus-size fashion. It addresses concerns like fabric wastage and consumption because of plus garment sizes, unavailability of sustainable fabrics in plus-sizes, and how fast fashion is sustaining unsustainable fashion on plus-sizes. From critical evaluation of consumer & business trends, and creative sustainable fabrics, the study aims to examine ways to design size-inclusive, sustainable clothing. As it fills the gap between sustainability and diversity, the article emphasizes the importance of an integrated approach that justifies body diversity in the name of ecological balance in pursuit of a fairer, future-proofed fashion system.

Acknowledgment

The author sincerely acknowledges the guidance and support of the faculty members and colleagues whose insights contributed to the development of this abstract. Gratitude is also extended to the institution for providing the necessary resources and encouragement to present this work at the conference.

Consumer Perceptions and Behavioral Insights on Recycling and Upcycling of Post-Consumer Textile Waste: A Case Study from North India

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Abstract

There is a longstanding twin challenge present in the textile industry: the rapid accumulation of post-consumer waste and the pervasive perception of recycled products as being of a lesser quality and of less appeal. While recycling is often portrayed as an environmental inevitability, it is the consumer psyche that is the key to acceptability in markets (1). Sustainability must be successfully linked with fashion, functional ability, and identity for recycled textiles to graduate from the "eco-compromise" product to a desired commodity product. This study examines consumer behavior and perceptions regarding recycling and upcycling of post-consumer textile waste (PCTW) in the North Cultural Zone of India, focusing on Punjab. Data were collected through a structured questionnaire, yielding 300 valid responses. Results revealed that most consumers adopt a need-based purchasing pattern (42.3%) and prioritize quality, durability, and comfort over price or discounts when selecting garments. Donation (77.3%) and household repurposing (47%) were identified as the predominant garment disposal methods, whereas systematic recycling participation remains limited. Although environmental awareness was high (86.2%), only 43% of respondents were familiar with the concept of upcycling, signaling a knowledge gap. Social stigma and hygiene concerns persisted for second-hand clothing while making purchase decisions; however, upcycled garments were viewed positively, associated with creativity, innovation, and cultural relevance. Respondents expressed willingness to adopt recycling and upcycling practices when supported by convenient collection infrastructure and motivational drivers such as DIY workshops, unique design aesthetics, and social endorsement. The findings emphasize the potential of recycling and upcycling as effective strategies to divert PCTW from landfills while reducing resource depletion, greenhouse gas emissions, and water usage (2,3). By integrating consumer preferences into design development and enhancing brand visibility, circular fashion can transition from a niche practice to a mainstream solution, offering significant environmental and socio-cultural benefits (4). The study underscores the need for targeted consumer education, incentivized collection systems, and community-based engagement to foster large-scale adoption of circular economy practices in the apparel sector.

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Acknowledgment

The author expresses sincere gratitude to the Ministry of Textiles, Government of India, for providing a grant to develop infrastructure under the National Technical Textiles Mission in the Department of Apparel and Textile Technology, Guru Nanak Dev University, Amritsar, which is very beneficial for the completion of this work.

VALUE ADDITION TO OLD CHILDREN'S CLOTHES USING UPCYCLING TECHNIQUES

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Abstract

A significant amount of textile waste is generated by the global fashion industry, and children's clothing is one category that is often overlooked. Children require more clothing than adults due to their fast growth and frequent washing of clothing.Approximately 20-30% of children's clothing is hardly worn once, especially in high-income families, and the remaining 70-80% is discarded after minimal use, which contributes to increased post-consumer waste [1,2,3]. Upcycling children's clothing involves innovatively reusing or recycling old, outgrown, or worn-out children's apparel to produce new, trendy and superior quality clothing and other items [4]. To ensure relevance and applicability, this study uses a three-pronged methodological approach that includes people-centred research, product development, and product review.Together, these approaches give a comprehensive framework for the research, making it practical and valuable to a wide range of individuals.

The current work focuses on four fundamental upcycling techniques: garment downsizing, surface decoration, additive reconstruction, and repurposeful pattern making to convert discarded children's clothing into useful clothing and other products. The study emphasizes incorporating upcycling into children's fashion through both culturally sensitive design techniques and consumer education. The research offers scalable approaches for lowering textile waste at the home and community levels and supports circular economy activities in clothing by combining skill development, awareness, and creative reuse.

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Acknowledgement

The author expresses sincere gratitude to the Ministry of Textiles, Government of India, for providing a grant to develop infrastructure under the National Technical Textiles Mission in the Department of Apparel and Textile Technology, Guru Nanak Dev University, Amritsar, which is very beneficial for the completion of this work.

Marketing Strategies for Bridging Performance and Sustainability: Promoting Innovative Technical Textiles and Nonwovens for a Greener Future

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Abstract

The convergence of sustainability and high performance in technical textiles and nonwovens requires the development of innovative marketing strategies to effectively convey value propositions across sectors such as healthcare, automotive, and construction. This study investigates strategic marketing methodologies aimed at reconciling the performance-sustainability dichotomy and increasing market acceptance of environmentally friendly technical textile products. Utilizing a mixed-method research approach, the study gathers primary data through surveys targeting industry buyers and end consumers to discern key factors influencing purchasing decisions related to sustainability and performance. In-depth interviews with marketing experts and sustainability leaders offer insights into strategic campaign formulation, messaging challenges, and the significance of certifications in establishing credibility. Focus group discussions further explore consumer perceptions and preferences concerning sustainable product marketing. Secondary data analysis situates findings within the context of current industry trends. Quantitative results emphasize drivers such as transparency, product efficacy, and ecological advantages, while qualitative analysis identifies effective communication strategies, including storytelling, leveraging certifications, and multi-channel engagement. The research highlights the essential role of targeted segmentation, ethical claims, and digital media campaigns in overcoming skepticism about greenwashing and fostering brand loyalty. The findings provide actionable marketing frameworks for companies to position sustainable technical textiles as both high-performance and environmentally responsible solutions. This study enhances the understanding of how marketing strategy can drive the adoption of sustainable innovations, supporting commercial success alongside environmental stewardship in the technical textiles industry.

Characterizing Desert Cotton as a Material Filler for Neck Pillow

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Abstract

Polyfill, Viscoelastic foam, air, and microbeads are inorganic fillers found in most neck pillows presently available in high-end sales outlets in urban settings. Sometimes, after use, they end up as waste, which is difficult to manage. Nature-conscious travelers do prefer cotton, wool, silk, bamboo fibres, and kernel pillows. This preference is based on the softness or feel that these materials provide. A sturdier neck pillow made of latex also becomes a choice for some people. These material choices are based on distinct human behaviour, portability, as well as aesthetics. Further feathers left by the birds are also a choice of some, for the filler material is a waste reuse strategy. Neck pillows with traditional ecological knowledge and traditional medicine are almost negligible in the markets. In this article, wild desert cotton (Aerva tomentosa) is proposed as a new filler material. Here, wild desert cotton or Bui (in Marwari dialect) is examined for its shape, material properties, traditional medicinal properties, and performance characteristics. The material's cellulosic nature was established through FTIR spectroscopy. Unlike cotton, the Bui imagery confirms a singular weak adhesion character and a bead-like morphology, akin to microbeads. XRF confirms the presence of elements helping its antimicrobial behavior, which elevates its health-based effects. The compression and dimensional stability of the Bui-filled neck pillow are at par with the international standards on neck pillows. These attributes position Bui as a promising, eco-friendly, and socially impactful alternative to conventional filling materials for neck pillows, offering both sustainable product innovation and rural livelihood support.

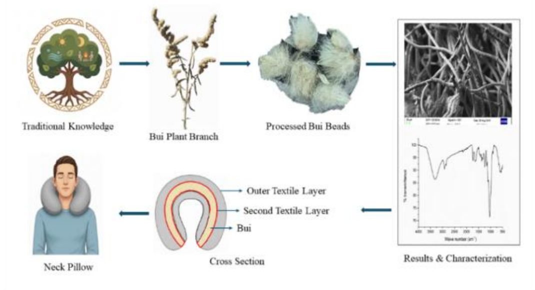

Figure 1. Processing and evaluation of Aerva tomentosa flower as a functional fill material from traditional collection → extraction and treatment → testing of physical, mechanical, and comfort properties → integration into a neck pillow prototype showing performance

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3.

Acknowledgement

We are thankful for the Central Research Facility of the Indian Institute of Technology Jodhpur.

Chikankari Embroidery and Sustainable Textile Innovation: Bridging Heritage and Technical Practices

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Abstract

Chikankari embroidery is also known as white embroidery or shadow work. This craft is centuries-old traditional craft from Lucknow, Uttar Pradesh. Traditionally in this craft cotton white muslin fabric and cotton threads were used for this craft which reflecting a low-impact and eco-friendly approach to textiles. In recent years according to fashion demands the craft has increasingly shifted toward synthetic dyes, manmade artificial fabrics, and machine embroidery. While with these kind of changes the process have enhanced scalability and affordability but they also reduce the environmental and cultural sustainability inherent in traditional methods. This paper looks at Chikankari embroidery as an example of how traditional crafts can be used for sustainable textile innovation, combining old techniques with modern practices. The study looks at three main areas: material sustainability, which compares natural and synthetic fibers and dyes; process sustainability, which looks at energy, water, and chemical use; and functional integration, which explores eco-friendly finishes like biodegradable treatments. The comparison shows that going backt o natural fibers and dyes can lower environmental impact, while new eco-friendly finishes can improve performance without affecting the look. Additionally, the research addresses the socio-economic dimension, emphasizing the role of artisans particularly women—in promoting sustainable livelihoods. By integrating case studies, literature review, and preliminary life cycle assessment of hand-embroidered versus modern synthetic-fabric products, the paper demonstrates measurable environmental advantages and offers practical guidelines for eco-conscious production. The findings position Chikankari embroidery not only as a cultural heritage asset but also as a replicable model for sustainable technical textiles, relevant to both academic research and industry applications. By connecting traditional practices with modern sustainability strategies, this study provides insights into how artisan-based crafts can inform low-impact, innovative textile solutions in the broader context of circular economy and slow fashion.

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Acknowledgement

The author acknowledges that no financial support received from anywhere.

Reshaping the throwaway culture, through Rhizomorphic bio-textiles for regenerative disposable packaging: A techno-economic analysis

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Abstract

The global Throwaway Culture finds its most severe expression in the high-volume disposable packaging industry, which is directly responsible for massive fossil fuel dependence and linear waste. Traditional natural fibre sourcing and processing are prohibitively costly and energy-intensive, creating an economic bottleneck that prevents their competitive adoption against cheap plastics. This research focused on Root-Structured Bio-Materials (RSBMs) regenerative textiles formed by guiding plant root systems (Rhizomorphic Design) into functional matrices as a disruptive, cost-effective solution. RSBM production was moulded using Controlled Environment Agriculture (CEA) Bio-Fabrication, which enables:Rapid, controlled growth (shortening the material production cycle from months to days).

Zero-waste, low-energy processing (as the "weaving" is biological).Complete end-of-life (biodegradability).

Through conducting the Techno-Economic Analysis (TEA) and Life Cycle Assessment (LCA), the feasibility of this new bio-material product was established. These tools were essential for quantifying the competitive advantages of the RSBM technique over the current, resource-intensive production model. Traditional production is intensive, requiring multiple steps: fibre harvesting and processing into material, and subsequent manufacturing into a final product. In stark contrast, the RSBM method dramatically improves Sustainable Material Sourcing and Product Development through a self-assembly process. By bypassing those costly, energy-intensive steps, the potential for RSBMs to establish a strong, viable pathway toward a circular packaging economy is argued.The RSBM technique facilitates product self-assembly, which drastically reduces the need for external mechanical effort and specialized fabrication machinery. This streamlining of the supply chain enables the establishment of localized, decentralised bio-manufacturing facilities that utilize agriculture as feedstock.

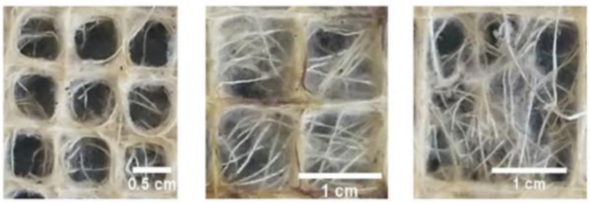

Figure:01 Adapted from Kousar, H., & Khan, H. A. (2022).

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A Hybrid Energy-Harvesting Smart Textile Integrating Thermochromic Sensing and ECG Monitoring for Patients

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Abstract

Continuous physiological monitoring in clinical settings is essential for early detection of patient deterioration but remains limited by battery dependence, device maintenance and e-waste generation. This research presents a modular medical smart-textile system integrating thermochromic temperature sensing, textile ECG monitoring and hybrid energy harvesting from both motion and body heat within a cradle-to-cradle framework.The disposable textile layer incorporates microencapsulated thermochromic pigments for rapid, passive fever visualization and silver-coated yarn electrodes for powering ECG acquisition. A detachable, reusable electronic module houses triboelectric (TENG) and piezoelectric (PVDF- TrFE) harvesters for micro-movement energy, along with a flexible thermoelectric generator (TEG) coupled to a phase-change material (PCM) buffer that stores and stabilizes thermal gradients for continuous power trickle. The approximate estimated harvested energy — estimated at 50 – 500 µW under $\Delta T \approx 3$–5 °C or light motion is regulated through a low-loss power-management circuit to enable duty-cycled ECG sampling and BLE telemetry. Additionally, a thermochromic color-change functionality can also be achieved using micro-encapsulated leuco dye-based thermochromic pigments that shift between color and colorless states at predetermined temperature thresholds. For applications needing more precise temperature mapping cholesteric liquid-crystal thermochromic pigments can also be integrated to display gradual, multi-tone color transitions.The implementation of this smart textile system is expected to enable faster detection of heat stress, reduce thermal injuries and improve real-time monitoring accuracy, strengthening safety in dynamic and high-risk environments. Beyond medical use, the system can be applied in industrial workplaces, defence and disaster- response operations, sports performance apparel, elderly and childcare monitoring—where continuous thermal and physiological tracking is essential. While the human body generates significant heat, only a small fraction can be realistically harvested. However, this harvested energy is sufficient to support low-power wearable sensors such as ECG microcircuits or emergency signal modules, ensuring functionality even during power cuts or critical events.

From the reviewed results, this system ensures hygiene by separating disposable and reusable components. Modules are sanitized and redeployed, minimizing e-waste and cost. The integration of visual thermochromic triage, self-powered physiological sensing and circular design represents a scalable pathway for sustainable patient monitoring garments that reduce manual intervention and enhance safety for hospital patients.

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Acknowledgment

The author sincerely acknowledges guidance from faculty mentors at NIFT Bhubaneswar.

Upcycling The Single-Use Plastic in Circular Fashion

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Abstract

Sustainability in textiles has become a critical area of exploration as the fashion industry continues to grapple with its environmental footprint. Among the most pressing challenges is the menace of single-use plastics, which constitute a major share of global waste and pollution. According to the Central Pollution Control Board (2019–20), India alone generates 3.5 million metric tonnes of plastic waste annually, with packaging and other short-lived products accounting for nearly half of global plastics production. These plastics, often used once and discarded, not only overwhelm landfills but also contribute significantly to marine pollution. Against this backdrop, innovative approaches such as upcycling offer transformative possibilities for the textile and fashion sector. Our project, Transforming Single-Use Plastic into Sustainable Fashion, exemplifies the potential of upcycling as both a design strategy and a sustainability model. Drawing on the concept first articulated by Reiner Pilz in 1994, upcycling enhances the value of discarded materials rather than diminishing it, as in traditional recycling. In this initiative, we repurposed single-use plastic bags and tarpaulin into a functional raincoat (Fig. 1 & 2), thereby converting non-biodegradable waste into a durable and usable garment. Furthermore, a skirt was enhanced using plastic ropes (Fig. 3), demonstrating how aesthetic appeal and creative design can be achieved while simultaneously addressing environmental concerns. This approach reflects the principles of a circular economy, where waste is not simply discarded but reintegrated into new production cycles with enhanced value. The outcomes highlight how unconventional materials, often dismissed as waste, can be harnessed to meet the dual goals of sustainability and innovation in fashion. Beyond the environmental benefits of waste reduction, such practices also open new avenues for consumer awareness, skill development, and sustainable entrepreneurship in the textile sector. The broader significance of this project lies in its alignment with global sustainability goals and India's national policies on plastic waste reduction, such as the Plastic Waste Management Amendment Rules, 2022. By showcasing the creative and practical possibilities of transforming waste into fashion, the project contributes to a growing discourse on sustainable design. It emphasizes that sustainability is not a limitation but an opportunity for innovation, responsibility, and meaningful impact.

Fig. 1 & 2

Fig. 3

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Acknowledgement

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Valorization of Polyester Waste into Thermoregulatory Polyester Fibre

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Abstract

The expansion of clothing and textile industry and the fast fashion trend among consumers have caused a rapid global increase in textile waste in the municipal solid waste (MSW) stream. Worldwide, 75% of textile waste is landfilled, while 25% is recycled or reused. Polyesters, a vital class of plastics, are ideal feedstocks for recycling due to the easily de-polymerizable ester bonds compared to polyolefins. Among them, polyethylene terephthalate (PET) is the most widely used product, making its recycling to a circular carbon resource a hot topic with significant concerns. Phase Changing Materials (PCM) portrays proficiency to liberate perceptible amount of latent heat on the course of phase transformation between liquid-solid or solid-liquid, thereby creating momentary warmth or cooling effect (Figure 1a & b). This work presents an advanced upcycling pathway that transforms waste PET into high-performance, thermoregulatory fibers for smart textile applications. Recycled polyester chips are melt-spun into fibers embedded with PCMs, which enable passive thermal regulation by absorbing, storing, and releasing heat. The integration of PCMs within the fiber matrix provides thermal buffering, enhancing wearer comfort and reducing dependence on active climate control systems. Mechanical characterization confirms that these recycled fibers retain performance properties comparable to virgin polyester, supporting their reintegration into functional apparel and technical textiles. By aligning waste valorization with functional material innovation, this approach supports circular economy goals and contributes to the development of sustainable, climate-resilient fiber-based composites.

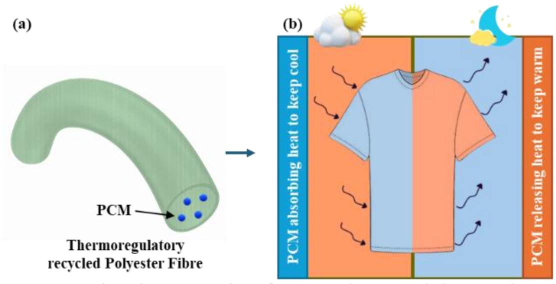

Figure 1. Schematic representation of (a) PCM incorporated thermoregulatory recycled polyester fibre, (b) Real world application of the fibre.

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Acknowledgement

The authors gratefully acknowledge the Department of Textile and Fibre Engineering, IIT Delhi, for research support.

Woodland Camouflage with in-situ Functional Finish

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Abstract

Designing woodland camouflage using liquid-phase reflectance of natural chromophore solutions as the main colour standards for creating vivid colour schemes. To create stable liquids with distinctive spectral signatures, solutions of tannic acid (for khaki-ground shade), sulphonised lignin (for brown- print), chlorophyll (for green-print), and carbon black dispersions (for black-print) are made at regulated quantities. Their L*, a*, and b* colour coordinates are measured directly in liquid form and then tuned by concentration to fit the target terrain's reflectance profile. During dyeing and printing, these liquid L*a*b* values are utilised as final colour guidelines. Compared to other computerised or conventional solid-fabric shade matching methods, the use of liquid natural-chromophore reflectance as a colour standard generation approach gives realistic hues to achieve visual concealment which offers high reproducibility, optimal terrain accuracy, and rapid adaptability in terms of shade matching. Additionally, a functional finish is embedded onto it by adding a phase-change material (PCM) coating mainly composed of cetostearyl alcohol (CSA) as PCM and cetostearyl ethoxylate (CSA-20) as a Co-PCM to the camouflage fabric developed in the preceding manner. The CSA-CSA-20 binary PCM/Co-PCM system creates lamellar-type structures that collect and release thermal energy during phase transition, an endothermic transition at 40 and 55 °C, sufficient for the epidermis, considering woodland terrain. The coating is applied which is embedded in a polyacrylate binder emulsion matrix. It also consists of C40 mole ethoxylate for giving moisture-managing property, along with the inclusion of yellow oxide emulsion for Near Infra-Red (NIR) concealment. The coating is dried and cured to produce a uniform, thermally active layer that maintains the visual and NIR camouflage accuracy established from liquid-reflectance colour standards. The combination of spectrally matched camouflage achieved by a unique liquid-phase chromophore standardisation approach and a CSA/CSA-20-based PCM thermal-regulating layer yields a dual-function smart textile.

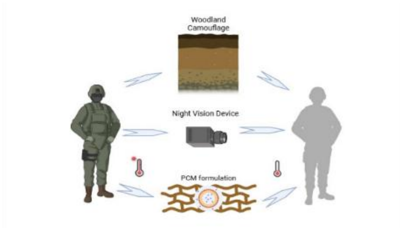

Figure 1. Woodland Camouflage Pattern Design with NIR Concealment and Functional Finish

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Acknowledgment

The author acknowledges the support received from the Department of Fibres & Textile Processing Technology, ICT Mumbai, Textile Testing and Evaluation Support: Indokem Ltd., Chemical Support: Rossari Biotech Ltd., SIF Pune.

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From Farm Waste to Future Materials: Sustainable Composites for Advanced Applications

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Abstract

Agricultural waste is one of the substantial environmental challenges around the globe. With 23.7 million tons of crop residues produced every day, burning it in open fields as its disposal mechanism leads to severe air pollution. This study presents a sustainable alternative for transforming agricultural residues into natural fibre composites (NFCs) to address twin issues of waste management and need for eco-friendly materials. Traditionally, commercial fibers such as hemp, flax and cotton which have established market value are used in producing NFCs. However, there is an increasing focus on leveraging agricultural waste: rice straw, wheat stubble, bagasse, coconut shell, coir, macadamia nutshells and other crop wastes which typically have limited economic use and are frequently discarded, burnt. When processed into fibres, these agricultural wastes can reinforce polymer matrices to produce composites suitable for advanced applications across various industries such as automotive, packaging, medical and construction. While fibre-reinforced composites are based on synthetic polymer matrices like epoxies, polyesters, and polypropylene; bioresins like polyhydroxyalkanoates (PHAs), polylactic acid (PLA), and epoxidized vegetable oils derived from castor and soyabean present ecofriendly alternatives. Cowpea resin used as a matrix material is good at being hydrophobic and having tensile strength. This property enhances its impact resistance and soil burial bio-degradability when reinforced with natural fibers. Apart from environmental enhancements, sustainable by-products generate a new source of income in rural communities, leading to sustainable industry development and socio-economic growth. Although commercial natural fibers dominate the market, agricultural waste fibers expect to propel sustainable composites industry through an introduction of scalable and low cost raw materials when developed with bioresins to overcome their intrinsic constraints. The paper reviews the scope for the use of various raw material sources from farm to future sustainable matrices for composites and their advanced applications.

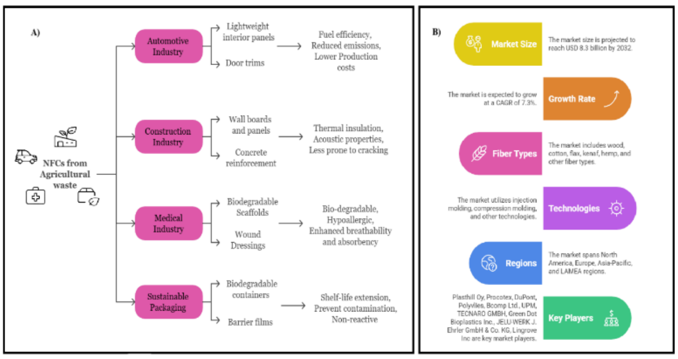

Figure 1: A) Applications across various industries; B) Market Analysis

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Molecular Ferroelectrics: Harnessing the power of Triglycine Sulphate, a sustainable approach for next-generation energy materials

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Abstract

Molecular Ferroelectrics (MOFEs), having excellent piezoelectric properties, offer promising applications in flexible electronics, sensors and energy harvesting systems. Due to their low processing temperature, light weight and environmentally friendly synthesis, these materials have increasingly drawn attention as sustainable alternatives for conventional organic and inorganic compounds. However, although 100 years are passed since the discovery of ferroelectric effects in 1920, MOFEs combine flexibility and strong dipolar interaction with stability and piezoelectric performance compared to rigid inorganic and unstable organic ferroelectrics. Among various MOFEs, Triglycine Sulphate (TGS) exhibit a second order phase transition at Curie point of about 49°C and piezoelectric charge coefficient d_{33} of 16pC N^{-1} , making it a sustainable material owing to its non-toxic composition, ease of crystal growth from aqueous solution, and low-energy processing requirements. Triglycine Sulphate (TGS) finds wide applications in infrared detectors, pyroelectric sensors, and energy harvesting devices due to its high sensitivity to temperature and electric field variations. This review presents an overview of the molecular ferroelectric Triglycine Sulphate (TGS), highlighting its role in offering a sustainable pathway for future functional material development.

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Sustainable Functional Textiles: Surface-Modified Cotton Dyed with Grape Skin Extract for UV and Antibacterial Protection

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Abstract

Developing textile designs and fabrics with ultraviolet protection (UPR) is crucial for manufacturers and consumers, as UV radiation is a potent physical carcinogen. In this study, UV-protective cotton fabric was successfully fabricated using an anthocyanin-rich grape skin extract as a natural dye. Gas Chromatography–Mass Spectrometry analysis of the ethanolic grape skin extract confirmed the presence of anthocyanins and various bioactive phytocomponents. The antioxidant potential of the extract was evaluated using a DPPH radical scavenging assay, demonstrating effective free-radical inhibition. The anti-inflammatory activities of different concentration of grape skin extract evaluated using the Egg Albumin Assay reveals good results. To enhance dye uptake, the cotton fabric surface was modified using Fenton's reaction, resulting in significant adsorption of ferrous ions, quantitatively analyzed using UV–Visible spectroscopy. The presence and interaction of ferrous ions on the modified fabric were further characterized by Fourier Transform Infrared Spectroscopy, Scanning Electron Microscopy, Energy-Dispersive X-ray spectroscopy, and X-ray Photoelectron Spectroscopy. Ultraviolet–Visible Diffuse Reflectance Spectroscopy and Ultraviolet Protection Factor studies revealed that double-folded dyed fabrics provided superior UV protection compared to untreated cotton. The antibacterial performance of the dyed fabrics was evaluated against *Staphylococcus aureus* and *Escherichia coli* using standard test methods, demonstrating enhanced bacterial inhibition in mordanted and dyed cotton relative to non-mordanted samples. Furthermore, the treated fabrics exhibited excellent color fastness properties, including resistance to washing, water exposure, and wet and dry rubbing. Overall, this study highlights the potential of anthocyanin-rich grape skin extract applied to surface-modified cotton fabric for the development of sustainable, UV-protective, and antimicrobial textiles suitable for sportswear applications.

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