The Textile Institute
NISTI (Regd.)

NISTI-IIT DELHI CONFERENCE ON

Sustainability in Textiles and Clothing: Emerging Trends in Fibers, Fabrics, Processes, and Fashion

14th December, 2024, IIT Delhi

Exploring Future of Sustainable Textiles Together

Conference Proceedings
&
Book of Papers

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Conference Program

14th December, 2024 LH-114 LH Complex, IIT Delhi

Welcome Address: Dr. R. A. Lal, Conference Chairman.

Conference Theme Overview: Prof. Abhijit Majumdar, Conference Coordinator, IIT Delhi.

Addresses by the Guests of Honour:

Prof. R. Alagirusamy: Head, Department of Textile and Fibre Engineering, IIT Delhi.

Shri R.K. Vij: Advisor (Polyester), M/s Indorama Synthetics (India) Limited and Secretary General Polyester Textile Apparel Industry Association

Shri Anil Jain: Chairman, Jain Cord Group of Industries.

Keynote Address: Ms. Roop Rashi, IA&AS, The Textile Commissioner, Government of India.

Vote of Thanks-Dr. Vijay Yadav -Conference Co-Ordinator, NISTI**.**

Technical Session 1- -- 11:00 AM - 12:30 PM

Session Chairman:-Prof. R. Alagirusamy, Head, Department of Textile and Fibre Engineering, IIT Delhi.

1. *Chemical Management in Wet Processing – The Sustainable Way- Prof. (*Dr.) **Arun K. Patra** , Professor, U.P. Textile Technology Institute, formerly Government Central Textile Institute (GCTI), Kanpur

2. Initiatives to Ensure Sustainability in Textile and Clothing- **Mr. Amit Ghosal , Ms Ayushi Purohit and Ms Tulika Saxena**, Trident Group

3. Transformative Technology for Chemical-Free and Organic Cotton- **Mr. V R Sai Ganesh** Chief Operating Officer, Zydex Group Vadodara.

4. Circularity and Sustainability in Traditional Indian Apparel & Textiles and their Modern Applications- ***Ms. Pooja Kapoor****, Creative Director/Founder, Pooja Kapoor Womenswear*

Technical Session 2-----12:30 PM - 1:30 PM

Session Chairman: Prof. Mangala Joshi*, Professor, Department of Textile Technology, IIT Delhi*

1. *Advancing a More Circular Economy Through the Use of Bio-Based Materials-* ***Shri Akshay Sardana****, Director & Head, Huafon India P Ltd & Covation Bio India Technology Center, Gurugram*

2. *Sustainability Meets Performance: Designing Eco-Friendly Sports Shoes for Amateur Athletes-*

Dr. Manpreet Mansahia *Assistant Professor, Amity University*

3. *Unlocking the Power of Indian Wool-* ***Dr. Vinod Kadam****, Senior Scientist (Textiles), ICAR-Central Sheep and Wool Research Institute, Avikanagar, Rajasthan*

Poster Review-2.15-2.30 PM

Technical Session 3----2:30 PM - 3:30 PM

Session Chairman:--Shri Kamal Misra, Partner, Sterling Sales Pvt. Ltd and Member, Governing Council, TAI Delhi.

1. Beyond the Bandage: The Environmental Impact of Medical Textiles- ***Dr. Chirag R. Gajjar*** *Principal R&D Engineer, North Carolina State University:*

2. Design and Development of Smart Zonal Sports Apparel & Accessories- ***Dr. Yamini Jhanji****, Associate Professor and* ***Dr. G.K. Tyagi****, Director, TIT&S, Bhiwani*

3. *Liva in Handloom and use of Natural Dyes-* ***Ms. Priyanka Priyadarshini*** *Aditya Birla Group*

Panel Discussion--3:30 PM - 4:15 PM

Chairman- Dr. Vinod Shanbhag, *Chairman Emeritus, NISTI.*

Theme: *Sustainability and Circularity in Textiles and Clothing – How to make It happen*

Panelists:

1. Shri Nirbhay Rana, *Assistant Professor, IILM University, Gurugram.*

2. Shri Shailesh Kaushik*, Techno Commercial Professional*

3. Shri Ajay Pandit, *Jt. Textile Commissioner and Joint Mission Director, NTTM, Ministry of Textiles, Government of India*

4. Shri Madhav Bhatt, *Textile Technologist, Bhatt Bros Ahmedabad*

5. Prof. Nien Siao, *Professor, JSID, New Delhi*

6. Shri Kishore Motwani, *Consultant, Intergartek.*

7. Dr. Garima Singh, *Assistant Professor, Department of Textile Science and Design, Acharya Narendra Dev University, Ayodhya*

Valedictory Session--4:15 PM - 5:00 PM

Acknowledgement and recognition of Lifetime Achievers, Sponsors, Speakers, Poster Participants, Concluding remarks and Vote of Thanks.

Dignitaries on dias:

Ms. Roop Rashi, IA&AS, The Textile Commissioner, Government of India.

Shri Ajay Pandit, *Jt. Textile Commissioner and Joint Mission Director, NTTM, Ministry of Textiles, Government of India*

NISTI-IIT DELHI CONFERENCE ON

SUSTAINABILITY IN TEXTILE & CLOTHING

14TH DECEMBER, 2024 LH-114 LH COMPLEX, IIT DELHI

Chairmen Emeritus:

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Dr. Sailen Chaudhuri

Shri Vijay Bhalla

Dr. Kuldip Kumar Sharma

Dr. Vinod Shanbhag

Chairman- Dr. R.A. Lal

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Hon. Jt. Secretary-Shri A N Bajpai

Office Assistant- Ms. Mamta Kargeti

Conference Co-Ordinator- NISTI-Dr. Vijay Yadav

Conference Co-Ordinator- IIT –Prof. (Dr.) Abhijit Majumdar

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Shri A N Bajpai

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Shri Gopal Bhasin

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Head, Design Dept, NSUT, New Delhi

Dr. Nandan Kumar

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Shri Dileep Gianchandani

Dr. A.K. Tyagi

Shri Inder Mohan Aggarwal

HOD, Fashion Design Department, LPU Jalandhar

Representative of NIFT Delhi

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It is with immense pride and heartfelt appreciation that we reflect on the success of the NISTI- IIT Delhi Conference on Sustainability in Textiles & Clothing. This conference stood as a testament to our shared commitment to transforming the textile and clothing industry by embracing sustainability, innovation, and responsible progress.

It was an incredible opportunity to unite leaders, experts, and stakeholders in the pursuit of a more sustainable future for the textile sector.

Acknowledgments and Gratitude

I would like to extend my profound gratitude to **Ms. Roop Rashi, IA & AS, the Union Textile Commissioner, Mumbai**, who graciously inaugurated the conference and delivered the keynote address as our Chief Guest. Her presence and insightful guidance greatly enriched our discussions, setting the stage for future initiatives aimed at the holistic development of the textile and clothing industry.

I also extend a warm thank you to **Shri Anil Jain, Chairman of Jain Cord Group of Industries Pvt. Ltd., Gurugram**, who joined us as our Guest of Honour. His unwavering dedication to sustainability and leadership in the textile sector inspired us all to pursue meaningful change, and his presence strengthened our collective resolve to move forward with our shared goals.

We were privileged to have **Shri R. K. Vij**, a distinguished technocrat, on the dais as a Guest of Honour. His extensive experience working at senior positions in textile companies and associations fostered a fruitful dialogue on sustainability during the conference.

A special acknowledgment goes to **Prof. R. Alagirusamy, Head of the Department of Textiles & Fibre Engineering, IIT Delhi**, whose unwavering support and guidance at IIT Delhi facilitated the successful execution of this event. I would also like to thank **Ms. Jyoti Kumar** for her instrumental role in connecting NISTI with IIT Delhi.

Sponsors and Supporters

Our heartfelt thanks go to our sponsors, whose generous support made this event possible. Their commitment to fostering innovation and sustainable practices was a powerful reminder of the importance of collaboration in addressing global challenges. I would also like to recognize the efforts of **Shri Vijay Bhalla Ji, Chairman Emeritus**, who played a crucial role in connecting NISTI with many of our sponsors.

I would like to express my sincere appreciation to **Dr. Vijay Yadav, Hon. Secretary & Treasurer**, **Shri A.N. Bajpai, Hon. Jt. Secretary**, and **Ms. Mamta Kargeti** for their tireless efforts in ensuring the success of this conference from day one.

Engagement and Perspectives

To all the delegates, researchers, industry leaders, and participants, I extend my deepest gratitude for your invaluable contributions. Your expertise and enthusiasm were at the heart of the conference, and your engagement played a key role in the vibrant exchanges and discussions that took place. Many of you traveled from distant corners of the country, devoting your precious time to the noble cause of sustainability. Your participation was truly appreciated.

A special mention must be made of the speakers, who shared their knowledge and expertise with us. They brought forward ideas that will shape the future of sustainability in the textile industry. I thank **Prof. Abhijit** and **Prof. V. K. Kothari** for their diligent work in identifying and securing the best speakers for the event.

Future Leaders and Collaboration

We were also fortunate to witness the participation of young minds who presented their excellent ideas and visions through Poster Presentations. I hope you had the chance to visit the posters and appreciate the work of these future leaders, who will play an important role in driving sustainability in the industry. Additionally, students from colleges across northern, southern, and western regions of the country joined us. Their enthusiasm and ideas added a fresh perspective to the event. They made up about 25-30% of our total registrations, and we were truly honored to have them as part of the conference.

Conference Proceedings Available

The conference management was constrained with the time limitation to allow the esteemed speakers, the time needed to present their views in totality. This book of papers takes care of that and presents before you the treasure of knowledge as delivered by these domain leaders during the conference. These papers have been published by Colour Publications Private Limited Mumbai in January to April 2025 issues of their esteemed Journal “Colourage” The book of papers in your hand should serve as an important document worth preserving and to take you to the journey of Sustainability in Textiles and Clothing. You will also find these papers on NISTI’s website https://nistiregd.in

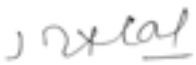
Join the NISTI Community

We invite you to join NISTI and be a part of our growing community dedicated to driving sustainable innovation in the textile industry. Learn more and connect with us through the 'Outreach Drive Link' on our website.

Summary

The NISTI- IIT Delhi Conference on Sustainability in Textiles & Clothing was a resounding success, bringing together leaders, experts, and students to advance sustainability, innovation, and responsible practices in the textile industry. The event fostered collaboration and highlighted the importance of collective action in addressing global challenges. With insightful discussions and a focus on future leaders, the conference paved the way for a more sustainable future for the textile sector.

With Best regards,



Dr R.A. Lal

(Chairman, NISTI)

Message from Chief Guest Ms. Roop Rashi

रुप राशि
वस्त्र आयुक्त
ROOP RASHI IA&AS
TEXTILE COMMISSIONER

सत्यमेव जयते

भारत सरकार
GOVERNMENT OF INDIA
वस्त्र मंत्रालय
MINISTRY OF TEXTILES
वस्त्र आयुक्त का कार्यालय, मुंबई
OFFICE OF THE TEXTILE COMMISSIONER, MUMBAI

Message

With immense pleasure, I extend my heartfelt congratulations to the organizers of the **NISTI-IIT Delhi Conference on Sustainability in Textiles & Clothing** which is happening on 14th December, 2024 in the campus of IIT Delhi, an Institution of Technical excellence.

We are aware, India's textile sector stands as a pillar of our economy, addressing domestic needs, driving exports, and generating employment for millions. This conference is both timely and crucial, urging us to adopt sustainable practices grounded in circular economy principles—focusing on resource efficiencies, reusing of textile resources and exploring longer end-of-life alternatives for textiles.

The **Circle Back campaign**, launched by the Ministry of Textiles, underscores this vision by advocating for behavioural shifts towards a more responsible and circular textile industry. It is particularly heartening to see the campaign's focus on empowering youth as changemakers, a sentiment echoed here at this conference.

As Textile Commissioner, I am keen to motivate the institutions engaged in the holistic development of the textile industry. North India Section of Textile Institute (NISTI) is playing a pivotal role in such initiatives. I am impressed with the setup of NISTI which comprises outstanding textile professionals, academicians, researchers, designers and planners who have achieved great heights in their career and now they are putting their experience to mentor industrial professionals, faculty and students. The entity (NISTI) is functioning without any external financial support and this passion of professionals attached to this organization is an example of Excellence in knowledge domain.

The collaboration between the **North India Section of the Textile Institute (NISTI)** and **IIT Delhi** provides an exceptional platform to advance the mission of sustainability, circularity and traceability in textiles and clothing industry. NISTI's dedication to research and innovation, combined with IIT Delhi's global expertise, creates the ideal environment to address challenges, explore and develop solutions for sustainable manufacturing aligning to circularity.

I understand that renowned professionals, Industry leaders, academicians, researchers, designers, sustainability activists from India and abroad shall dive deep in the area of research and innovations, technologies and initiatives being undertaken by Indian companies and world over. I am also given to understand that a large number of senior functionaries from textile companies, textile and design colleges, research institutes, export houses, textile consultants, sustainability activist, footwear design professionals and students from all over the country would be participating in this prestigious conference. I look forward to consolidation of ideas and initiatives by collaborative approach among all islands of Excellence.

Another important activity in this conference would present a freedom to young minds to express their ideas and vision on Sustainability through poster presentation. You will have ample opportunity to source talent for your company from these young minds. We need to build and strengthen Mentorship for these ideas/ innovations.

I look forward to be part of such an inspiring initiative. I wish all attendees a productive and enriching experience.

(Roop Rashi)

निष्ठा भवन, (न्यु.सी.जी.ओ. बिल्डींग), ४८, न्यु मरीन लाइन्स, मुंबई ४०००२०.
Nishtha Bhawan, (New C.G.O. Bldg.,) 48, New Marine Lines, Mumbai 400 020.
Tel. : 022-2200-4510 / 2201-4446 • Fax : 022-2200-4693 • Website : www.txcindia.gov.in • www.technotex.gov.in

Message from Guest of Honour – Shri Anil Jain

JAIN CORD

JAIN CORD INDUSTRIES PVT. LTD.
38th Milestone Behrampur Road,
Delhi Jaipur highway, Gurugram - 122001, Haryana, India
Ph: +91 124 4036351, Email - info@jaincord.com,
Website - www.jaincord.com
CIN - U17299HR2012PTC045155

Date: 14th December'2024

Message from Shri Anil Jain, Chairman, Jain Cord Group of Industries, the Guest of Honour

I would like to congratulate and appreciate the efforts made by NISTI and IIT Delhi to promote and educate the industry trade and students on the subject of sustainability through NISTI-IIT Delhi Conference on Sustainability in Textiles and Clothing organized at IIT Delhi on 14th December, 2024.

Today sustainability is the new norm for growth. Along with quality, competitive pricing, customer satisfaction, sustainable textiles is the need of the hour for today's market.

In layman's language, Sustainability in textiles means that the damage to the nature and Mother Earth is reduced to the minimum while manufacturing textile products.

Maximum damage to the earth has happed by way of

1. Poor AQI levels, Means poor quality of air
2. Scarcity of fresh drinking water
3. Reduction of fertility

AIR

As of now, we are most aware about the poor quality of air because we are living in the zone, which has become the most polluted area not in the country only, but the most polluted area in the whole world.

Efforts have to be made that while manufacturing textiles we reduce the carbon emissions by way of

1. Avoiding use of more polluting fuels like coal, pet coke and furnace oil.
2. Use maximum green energy like solar and wind power.
3. Use abatement technologies to reduce the pollutants in the air emissions.

WATER

The humanity is facing a serious crisis regarding the shortfall of drinking water.

Whereas 70 % of the earth is surrounded by water, only 4% of total water is drinkable. Out of this 2.5% is in shape of glaciers and snow on the mountains. So we are left with only 1.5% of the total water which is drinkable.

In the recent years, we have seen many areas on earth being declared as black zones or water scarce areas, means the drinkable water in these areas is finishing very fast.

Looking at the water crises, there is a dire need of conservation of potable water in the industry.

This can be done in two ways

1. By reducing use of water in the processing by way of adopting

   A. Continuous process, which consumes lesser water.

   B. Low material to liquor ratio exhaust dyeing machines.

   C. Technology, which helps in using lesser chemicals and lesser water like waterless dyeing.

2. Most Effective way of conservation of water is by using recycled STP water in processing wherever it can be made feasible, thereby saving fresh drinkable water.

FERTILITY

Third most important area is the fertility of the Mother Earth.

With the use of synthetic fertilizer and pesticides, the fertility of land has reduced to such an extent that the fertility of land will be reduced to zero in next 60 years means we will not be able to grow anything on earth after 60 years.

JAIN CORD

JAIN CORD INDUSTRIES PVT. LTD.
38th Milestone Behrampur Road,
Delhi Jaipur highway, Gurugram - 122001, Haryana, India
Ph: +91 124 4036351, Email - info@jaincord.com,
Website - www.jaincord.com
CIN - U17299HR2012PTC045155

To retain and increase the fertility of the land, we have to adopt organic farming, For this use of organic cotton has to be promoted. Also the use of recycled material (termed as circularity) will reduce the burden on natural resources.

I congratulate the organizers and participants for having engaged to find solution of most crucial issue, the sustainability in manufacturing and use of Textile and Clothing.

All the best:

Anil Jain

Message from Guest of Honour – Shri R.K. Vij

POLYESTER TEXTILE APPAREL INDUSTRY ASSOCIATION
(Formerly known as PTA Users Association)

Message from Shri R.K. Vij, Secretary- General, Polyester Textile Apparel Industry Association, the Guest of Honour

I extend my heartfelt gratitude to the organizers of the NISTI-IIT Delhi Conference on Sustainability in Textiles & Clothing for the privilege of participating in this significant event. The conference served as an exceptional platform to address critical issues surrounding sustainability in India's textile sector, highlighting challenges such as resource depletion and environmental impacts, alongside the opportunities for transformative solutions.

The diverse sessions—from technical discussions on fibers and fabrics to deep dives into sustainable dyeing and processing—were both enlightening and thought-provoking. The focus on circular economy principles as a pathway to industry transformation was particularly impactful. The poster competition, which showcased the creativity and innovation of young professionals and students, was a true testament to the promising future of the industry.

This collaboration between NISTI and IIT Delhi has set a commendable benchmark for advancing sustainability through research, innovation, and interdisciplinary dialogue. It is through such collective efforts that we can bridge the gap between vision and action, driving meaningful change across the value chain.

As we move forward, I urge all participants to build on the strategies and insights shared during the conference. Together, we have the opportunity to lead India's textile sector toward a greener, more resilient, and sustainable future.

Please remain connected with NISTI for knowledge up gradation and knowledge transmission for holistic development of Textile Industry.

Thankfully yours,
R.K. Vij

No. 75, A-1 Block, Safdarjung Enclave, New Delhi – 110 029. Mobile: 9999910119
E-mail: ptausersassociation@gmail.com

Message from Guest of Honour – Prof. R. Alagirusamy

प्रो॰ आर. अलगिरुसामी
प्रोफेसर एंव विभागाध्यक्ष
Prof. R. Alagirusamy
Professor & Head

भारतीय प्रौद्योगिकी संस्थान दिल्ली
INDIAN INSTITUTE OF TECHNOLOGY DELHI
टैक्सटाइल एवं फाइबर इंजीनियरी विभाग
Department of Textile and Fibre Engineering
हौज खास, नई दिल्ली–११००१६, भारत
Hauz Khas, New Delhi-110016, INDIA
Tel.: +91-11-2659 1401, 2659 1419, 2659 6619
E-mail: hodtextile@admin.iitd.ac.in, rasamy@textile.iitd.ac.in
alagiru@gmail.com

Dear Colleagues and Participants of NISTI – IIT Delhi Conference on Sustainability in Textiles and Clothing.

It was an immense privilege to be part of the NISTI-IIT Delhi Conference on Sustainability in Textiles & Clothing held at IIT Delhi on 14th December 2024. The conference was well planned, well organized and a truly transformative event that brought together visionaries, innovators, and changemakers to address the critical challenges and boundless opportunities in driving sustainability within the textile industry.

The conference sessions, spanning topics such as sustainable fibers, fabrics, and strategies for responsible production and consumption, offered profound insights into the multifaceted nature of sustainability. The panel discussions delved into practical approaches for integrating circularity across the value chain, while the poster competition was an inspiring showcase of the ingenuity and creativity of our young minds—the future stewards of this industry.

I extend my heartfelt appreciation to NISTI and the Department of Textile and Fiber Engineering, IIT Delhi for their visionary leadership in organizing this impactful event. Platforms like these are indispensable in bridging the gap between cutting-edge research, industry practices, and policymaking, fostering collaborations that drive actionable change.

As we move forward, let us build upon the valuable knowledge and connections formed during the conference. Together, we can shape a sustainable future for textiles—one that aligns innovation with environmental stewardship, creating meaningful benefits for society and the planet alike.

Best Regards,

R ALAGIRUSAMY

Message from Conference Coordinator -NISTI- Dr. Vijay Yadav

It is with immense pride and gratitude that I extend this message on the successful completion of the Conference on Sustainability in Textiles & Clothing, jointly organized by NISTI and the Department of Textile and Fibre Engineering, IIT Delhi.

The conference has proven to be a significant milestone in fostering meaningful discussions, knowledge-sharing, and collaborations to address the pressing need for sustainability in the textile and clothing industry. The engaging sessions, led by our esteemed speakers, session chairpersons, and experts, have provided invaluable insights and actionable takeaways that will serve as guiding principles for innovation and transformation in the sector.

We were privileged to have Ms. Roop Rashi Ji, Textile Commissioner, Government of India, as our Chief Guest, whose inspiring vision and leadership continue to motivate the industry towards sustainable growth. I extend my heartfelt gratitude to all our distinguished speakers, session chairs, delegates, and participants for their enthusiastic involvement and valuable contributions throughout the conference.

A special note of appreciation goes to our sponsors, whose generous support has been instrumental in the success of this event. We are deeply grateful to:

- Grasim Industries and Birla Cellulose
- RSWM Limited
- Covation Biomaterials LLC
- Anubha Polyweaves Pvt. Ltd.
- Zydex Industries Pvt. Ltd.
- Jain Cord Industries
- Trident Group
- Intagartek

- Polyester Textile Apparel Industry Association
- JS Institute of Design

Your contributions underscore your commitment to sustainability and innovation in the textile sector, and we truly value your partnership in this endeavor.

My sincere thanks also go to the volunteers, the organizing committee, executive committee and the young technocrats from IIT Delhi, JS Institute of Design and other institutions, whose energy, enthusiasm, and hard work ensured the seamless execution of this conference.

This conference has reaffirmed the importance of collaboration between academia, industry, and policymakers in creating a roadmap for a greener and more responsible textile ecosystem. As we move forward, I encourage the textile community to take inspiration from the discussions and work collectively to implement sustainable practices that drive positive change.

On behalf of NISTI, I invite all stakeholders to become an integral part of our mission by joining us as Patrons, Associates, or Change Makers. Together, let us continue this momentum to shape a future defined by innovation, responsibility, and sustainability.

We look forward to building upon the outcomes of this conference and strengthening our shared commitment to sustainability in textiles and clothing.

Thank you once again to all who contributed to making this conference a remarkable success.

Jai Hind!

Message from Conference Coordinator -IIT

Prof. Abhijit Majumdar

I feel deeply grateful and satisfied as I reflect on the remarkable success of the NISTI-IIT Delhi Conference on Sustainability in Textiles and Clothing, which took place on 14th December 2024 at the Indian Institute of Technology, Delhi.

In a time when sustainability is a global priority, the conference served as a key platform for researchers, industry professionals, and policymakers to come together and exchange innovative ideas and strategies for promoting sustainability in the textiles and clothing sector. The discussions focused on tackling critical challenges and exploring pathways to a greener, more responsible future for the industry.

I am pleased to note that the insightful presentations, vibrant discussions, and valuable networking opportunities led to meaningful collaborations and actionable insights. The conference was an eye-opener to all of us, underscoring the potential to collectively transform challenges into opportunities and contribute significantly toward achieving sustainable development goals.

I extend my heartfelt thanks to all the participants, speakers, jury members, session chairs, sponsors, and the organizing team for their invaluable support in making this event a resounding success.

Warm regards,

Prof. Abhijit Majumdar

Conference Coordinator

Chemical management in wet processing – the sustainable way

Arun K Patra
U.P. Textile Technology Institute, Kanpur 208001

Introduction

TEXTILE wet processing as the name suggests is a treatment in aqueous medium and is in fact a water-intensive operation. Also termed chemical processing, it involves substantial use of a wide range of chemicals and auxiliaries. Being an important input in textile manufacturing, these chemicals pose serious problems from human health and environmental point of view. In fact, they find their way to four outputs: the final product (finished fabric, yarn and garment), waste water, sludge and air. Earlier a chemical was classified as hazardous mainly owing to toxicity, causing death through oral, dermal and inhalation routes. An additional aspect was skin or eye irritation or sensitization. But new findings have led to 18 hazard end-points which include Carcinogenicity, Mutagenicity, Reprotoxicity (CMR), Endocrine disruption, Target Organ Toxicity, Developmental/Neurotoxicity, Persistence, Bioaccumulation and Aquatic toxicity. With passage of time more and more revelations of textile chemicals took place and those which were considered to be an asset to the processing industry proved to be a serious liability [1]. This clearly makes some of the conventional chemical processing operations unsustainable. Most of the restricted substances if avoided or used in very limited quantities can make industrial wet processing sustainable.

Background and precedence

The ban or restriction on certain chemicals and colours is not very new and dates back to over half a century from now. Benzidine, which was used in synthesis of many of the dyes then was found to be carcinogenic. Workers and family members of workers involved in production and use of benzidine-based dyes had reportedly a high incidence of bladder cancer. In 1967, production of benzidine was banned in UK while Bayer, Europe's leading producer then, voluntarily stopped production of benzidine in 1971. Other European dye makers too ceased production of benzidine based dyes voluntarily while similar initiatives followed in the USA and Japan [2]. Similarly, formaldehyde used in resins, dye fixing agents, some binders, leather softening etc was found to cause dermatitis, a skin disease and even suspected to be a carcinogen by some researchers, was restricted to a certain limit for use. The ceiling for free formaldehyde was first set way back in 1975 by the Textile Industry Goods Bureau of MITI (Ministry of Trade and Industry) of Japan and has been followed by many throughout the world. German ban on certain azo dyes which on reductive cleavage produced carcinogenic amines took the industry by surprise in 1994 [3]. Alongside their use in textiles, chemicals in everyday products too were analyzed scientifically for their environmental impact and attempts were made to regulate the use of toxic chemicals at major international fora beginning in 1972 Stockholm convention.

Consequently, legislations were brought in by many countries and groups were formed promoting product safety and ecological acceptability. In textiles, the Oeko-Tex standard 100 emerged as a leading eco-label and has been in place since 1992. The American Apparel & Footwear Association (AAFA) came into being in August 2000 to promote best practices in clothing and footwear industry. In 2004, Apparel and Footwear International RSL Management Group, known as AFIRM was founded which has its own RSL (Restricted Substances List). The list is revised at regular intervals, the latest being version 9 brought out in April 2024. Restricted substances are basically chemicals and other materials whose presence is banned or otherwise restricted either by legislation or by brands in a particular manufacturing process. Hence, a restricted substance should be absent from a finished product or present in limited concentrations. As on date AFIRM RSL is widely followed in the processing industry. GOTS (Global Organic Textile Standards) is another entity, which started in 2006 mainly with organic cotton. The voluntary standards laid out by it, have also undergone many revisions with the latest

version 7.0 covering processing, manufacturing, packaging, labelling, trading and distribution of textiles. European Union brought in REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) as a single integrated system for chemical management which came into force on 1st June 2007. According to this, all companies manufacturing or importing chemical substances into the European Union in quantities of one ton or more per year are required to register these substances with a new European Chemicals Agency (ECHA) in Finland. REACH also addresses the continued use of Substances of Very High Concern (SVHC) because of their potential negative impact on health or environment [4-6].

In 2011, the global NGO Greenpeace published a report based on its study of wastewater discharges from two large textile plants in China, one being the Youngor Textile Complex, located on the Yangtze river delta while the other was Well Dyeing Factory Limited situated on a tributary of the Pearl River delta. The report captioned "Dirty Laundry" revealed that both the manufacturing facilities were discharging a range of hazardous chemicals into the respective river deltas. Persistent chemicals with hormone-disrupting properties and other serious hazards were detected in the waste water of these plants. On investigation, it came to light that some major international textile brands were sourcing processed fabrics from the two manufacturing units. This led to the Greenpeace campaign, 'Detox now' highlighting the use and discharge of hazardous chemicals in textile production across the globe, prompting the global apparel and footwear brands to collaborate and lead the industry to eliminate the problem across all pathways in their supply chains [7]. As a consequence, ZDHC (Zero Discharge of Hazardous Chemicals) came into existence when six global brands came together to address the challenge. The initial commitment it was started with was to eliminate the release of hazardous substances from their supply chain by the year 2020. The ZDHC Foundation has now grown to 34 signatory brands, 117 value chain affiliates (from the textile, leather and chemical industry), 18 associates and 18 'Friends of ZDHC'. The first version of ZDHC Manufacturing Restricted Substances List (MRSL) was released in 2014, setting a paradigm shift in the approach to chemical management towards input chemical management and moving the onus on the chemical industry to conform. With subsequent revisions, the newer version MRSL 3.1 has come up recently addressing textile, leather, rubber, foam and adhesives. The concept therefore is to eliminate hazardous substances in input chemical itself for the industry.

Restricted substances

Out of the millions of substances registered in CAS (Chemical Abstract Service), the impact of the majority, on human health is yet to be known. Basic organic compounds like benzene are found to be toxic and not allowed in toys and parts of toys in a free state in excess of 5 mg/kg. The negative effects of many chemicals on human health can vary, ranging from skin allergy to cancer. The substances of very high concern (SVHC) identified by REACH are relevant in this context and the following criteria is considered in listing restricted chemicals for use [8].

i) Either carcinogenic, mutagenic or toxic to reproduction ie reprotoxic (CMR)
ii) Persistent, bio-accumulative and toxic (PBT), or
iii)) Very persistent and very bio-accumulative(vPvB) and/or
iv) Substances of equivalent level of concern which seriously and/or irreversibly damage the environment or human health, such as endocrine disruptors, neurotoxins etc.

The listing of restricted chemicals as discussed are therefore broadly of two types - RSL and MRSL. They represent two different approaches to controlling hazardous substances in consumer textiles. RSL focuses on the end product, setting limits for harmful substances that may be present in finished items like clothing, shoes, toys, and furniture. On the other hand, MRSL targets the manufacturing process itself, establishing restrictions on dangerous substances in the raw materials - including chemicals, auxiliaries, and dyes - used to make these products.

A clearer way to explain the key differences between RSL (Restricted Substances List) and MRSL (Manufacturing Restricted Substances List) based on certain criteria is given below.

1. Focus and Purpose:
- RSL concentrates on final product safety by restricting certain substances in the end product
- MRSL addresses environmental safety by controlling trace amounts of banned chemicals that might unintentionally appear in chemical formulations during manufacturing

2. Development Approach:
RSL is primarily driven by regulatory requirements
- MRSL is developed collaboratively with manufacturers through industry consensus

3. Relationship:
- MRSL limits are specifically set to ensure final products meet RSL requirements
- However, meeting RSL standards doesn't automatically ensure MRSL compliance

4. Scope of Impact:
- MRSL has a broader environmental scope, covering water, air, and other environmental factors
- RSL focuses more narrowly on end-user safety

5. Compliance Methods:
- RSL compliance relies on proper chemical selection, following manufacturer guidelines, and implementing best practices in chemical handling (storage, transport, dispensing, and usage)
- MRSL compliance requires stricter input chemical control and management systems within the manufacturing facility.

The Restricted Substances List (RSL) developed by AFIRM, which initially gained prominence in Europe, gradually evolved into a globally recognized standard. Beyond this collective approach, individual fashion and apparel brands such as Nike, Adidas, H&M, Levi's, Hugo Boss, Marks & Spencer and

Decathlon have also established their own unique RSLs. Currently, approximately 52 brand-specific RSLs exist in the marketplace. These brand-specific RSLs serve as useful communication tools within their supply chains, articulating precise requirements regarding restricted chemical substances. Importantly, these lists can vary significantly between different brands and may diverge from the AFIRM standard. When formulating their individual RSLs, brands typically consider three primary factors: the geographical scope of their operations, the specific types of products they market, and the potential health and environmental risks associated with particular chemical substances.

The Manufacturing Restricted Substances List (MRSL) on the other hand serves as a crucial safeguard for multiple stakeholders, including consumers, production workers, local communities, and the environment by regulating hazardous chemical usage. Optimal implementation of MRSL focuses on a proactive approach of chemical input management. By carefully monitoring and controlling the procurement of chemicals and ensuring that purchased substances do not include any restricted compounds listed in the MRSL, manufacturers can effectively mitigate potential risks. The fundamental principle underlying this approach is that by controlling the chemical inputs at the source, the overall sustainability and safety of the final product can be significantly enhanced. When the initial chemicals and auxiliary materials used in the manufacturing process are inherently free from restricted substances, the likelihood of the final product containing harmful chemicals is greatly reduced, unless there is some other interfering activity during the manufacturing process.

Among the large number of restricted substances, a few important classes are mentioned below.

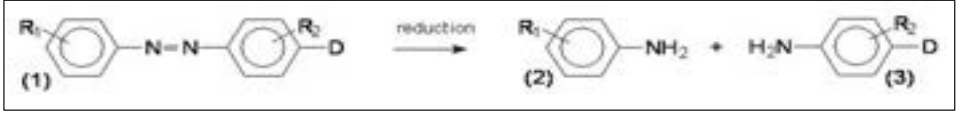
- AP and APEO (Alkylphenol and Alkylphenol ethoxylate)
- Azo-amines and arylamine salts
- Bisphenols
- Chlorinated paraffins
- Chlorophenols
- DMFu (Dimethyl Fumarate)
- Forbidden dyes (owing to toxicity)
- Formaldehyde
- Halogen based flame retardants (brominated compounds)
- Heavy metals
- PAH (Polycyclic aromatic hydrocarbons)
- PFC (Perfluorinated compounds)
- Phthalates
- Quinoline
- UV absorbers
- VOCs (Volatile Organic Compounds)

AP and APEO

They have traditionally found use in preparatory processes, printing pastes and dyeing mainly as non-ionic surfactants, emulsifiers and wetting agents. Also having dispersing, antistatic and lubricating properties, Alkylphenol ethoxylates (APEOs) and alkylphenols (APs), pose significant environmental and health risks. Research by Lintelmann et al demonstrates that these compounds can accumulate in various aquatic organisms, including plants, algae, and fish [9]. Endocrine disruptors like these chemicals interfere with hormonal systems by mimicking natural hormones. A prime example is 4-Nonyl Phenol, which acts similarly to Oestradiol, potentially disrupting critical physiological processes such as development, reproduction, neurological function, and immune response.

The harmful effects of APEOs extend beyond hormonal interference. These substances are toxic to aquatic life and can cause damage to human biological systems, particularly affecting the respiratory tract, eyes, and skin. Specifically, nonylphenol demonstrates moderate bioaccumulation and poses extreme toxicity to aquatic species. Of particular concern is the impact on male reproductive health. Exposure to nonylphenol and octylphenol can lead to serious reproductive complications, including testicular damage, reduced testicular size, diminished sperm production, and overall dysfunction of the male reproductive system. Owing to these hazards, the ZDHC MRSL restricts the limits of Nonylphenol (NP) and Octylphenol (OP) along with mixed isomers to 250 ppm. For Nonylphenol ethoxylates (NPEO) and Octylphenol ethoxylates (OPEO), the permitted concentration is slightly higher at 500 ppm. However, when considering the finished products, these limits are further reduced to a maximum of 100 ppm by AFIRM RSL, ensuring stringent control over the presence of these potentially harmful substances in the final textile and leather goods [10,11]. An alternative to NPEO and OPEO is the use of alcohol ethoxylates, which are easily biodegradable. Products such as Ultravon ECP by Huntsman (now Archroma) and Sera Wet C-AS by DyStar belong to this category. Among other alternatives are the sulphur-based anionic emulsifiers and dispersing agents such as alkyl or aryl ethoxy sulphates, sulphonates and alkyl sulphates.

Azo-amines and arylamine salts – This mainly relates to those azo dyes which on reductive cleavage produce harmful amines causing serious sickness like cancer and environmental damage too [12]. The general reaction is precisely shown below.



A lot of literature is available on this starting from mid 1990s to early 2000 in the wake of German ban. The list of forbidden amines also got revised with time, now the number stands at 28, the latest inclusion being aniline. However, there are no legal and scientific limit values for aniline and therefore, GOTS has kept its limit under 100 mg/kg, higher than the other MAK III categories which is less than 20 mg/kg. There are in fact many dyes based on azo chromophore, which do not produce such amines and are therefore very much in use without posing any

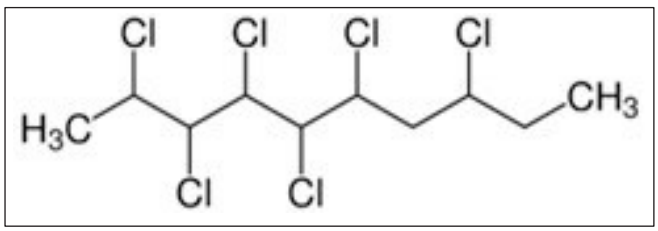
health hazard. On the contrary, azo is the most important chromophoric group used in the entire gamut of textile dyes.

Bisphenols

Bisphenols are used as one of the precursors for making of plastic materials like polyvinyl chloride (PVC) and polycarbonates. Among bisphenols, BPA ie Bisphenol A is the most commonly used BPA is found to act as oestrogenic mimic, affecting hormone levels, cardiovascular health, reproductive system in both males and females, neuro-behavioural development in children and causing hormone-driven cancer [13]. At high temperatures in acidic and basic pH, polymers made from it are likely to hydrolyze causing BPA to leach into nearby materials. Hence, commonly used items having BPA, like plastic bottles, baby bottles, toys etc have a risk of leaching and contamination problem [14]. Because of high toxicity, the compound is listed as a substance of very high concern (SVHC).

Chlorinated paraffins

They are basically complex mixtures of polychlorinated n-alkanes and find use in flame retardants, plasticisers in plastics, rubbers, inks, paints, adhesives and surface coatings. The three types of chlorinated paraffins are, Short-chain Chorinated Paraffins (SCCPs) with 10 to 13 carbon atoms, the Medium-chain Chlorinated Paraffins (MCCPs) with carbon chain length of 14 to 17 and the long chain ones, LCCPs having chain length of C_{18}-C_{30} [15]. Chlorinated paraffins are toxic to aquatic organisms and may cause long-term adverse effects in the aquatic environment at certain exposure levels, posing hazards to human health and the environment. However, LCCPs are much less toxic to aquatic life compared to related short-chain and medium-chain CPs. An example of chlorinated paraffin is shown below.



The regulatory standard, AFIRM RSL has set the maximum allowable concentration of both SCCP and MCCP at 1000 ppm. While Gas Chromatography-Mass Spectrometry (GC-MS) continues to be the predominant analytical technique for identifying these compounds, researchers are actively exploring and developing innovative instrumental methods, with a particular focus on creating more precise techniques to differentiate between the different chain lengths of chlorinated paraffins.

Chlorphenols

Chlorophenols serve as protective agents for textile and leather goods, preventing fungal and bacterial growth during storage and transport. These compounds can inadvertently appear as contaminants in raw materials used for dye production. Additionally, they are employed as preservatives in print pastes. Chlorophenols may be generated or detected in wastewater after bleaching processes with elemental chlorine for textiles, paper or during disinfection of wastewater and drinking water[11]. Many of the chlorophenols have health hazards, and are endocrine disruptors, affecting oestrogen levels and the thyroid. Carcinogenicity of chlorophenols as an issue was raised as early as 1970s and AFIRM RSL restricts its limit to 0.5 ppm. Products containing PCP (pentachlorophenol), a known culprit are likely to form highly toxic substances on incineration, releasing dioxins, one of the most dangerous substances in the world.

DMFu

It is a biocide and a strong anti-mould agent used in consumer products in sachets as an accompaniment to keep the products dry. Often used in the storage and transportation of leather goods like footwear particularly in humid climate dye to its dehydrating action, DMFu also has good fungicidal power. Over a period of time, it evaporates on to products, protecting them from dampness. DMFu has been used as an alternative to the classic silica gel[16].

Chemically, it is a methyl ester of fumaric acid ($HO_2CCH=CHCO_2H$). DMFu is an odourless white crystalline solid with the molecular formula $C_6H_8O_4$ and molecular weight of 144.13. Between 2006 and 2008, skin irritation, itching, redness, burns were however reported against the products it accompanied. In fact, the biocide evaporated from sachet to the products, and on contact further penetrates the skin of the wearer. On subsequent tests and studies, DMFu was finally prohibited in Europe in 2009 with a maximum allowable limit of 0.1 mg per kg of the product or part of the product. In addition to the allergic reaction, DMFu also causes painful dermatitis which affects the parts of the body in contact with article such as feet, trunk and limbs.

Forbidden dyes

These include some Acid, Basic, Direct and Solvent dyes that are restricted for use due to toxicity, either inherent to the colourant or caused by its breaking down into more hazardous substances. Their toxicity concerns include suspected carcinogens, mutagens or reproductive toxicants, aquatic toxicity and skin allergy. Dyes of this category are listed both in AFIRM RSL 09 and ZDHC MRSL 3.1. Some disperse dyes suspected to cause allergic reactions are also prohibited from use. However, there are alternatives available to these dyes and hence replaceable.

Formaldehyde

Formaldehyde use is a very old concern and many

developments have come since then. They have been in use in many textile chemicals and auxiliaries like anticrease agents, anti-shrink resins, dye fixing agents for direct and reactive colours, binders for printing, some antimicrobial agents, preservatives, reducing agents in printing (Zinc Formaldehyde-Sulphonate), products for tanning and softening of leather etc. Prolonged exposure to formaldehyde at lower concentrations can cause dermatitis, a skin disease and even in some cases bladder cancer of workers engaged in the manufacturing of high concentration formaldehyde resins [17,18]. The present day anticrease agents like DMDHEU and modified DMDHEU are however low formaldehyde crosslinkers and don't pose any serious threat. Formaldehyde-free agents like DMeDHEU (Dimethyl dihydroxy ethylene urea) and polycarboxylic acids (Butane tetracarboxylic acid, Citric acid) can alternatively be used, but with their own share of problems. Dye-fixers without formaldehyde have also come up well showing good performance[19].

Halogen based flame retardants (brominated compounds)

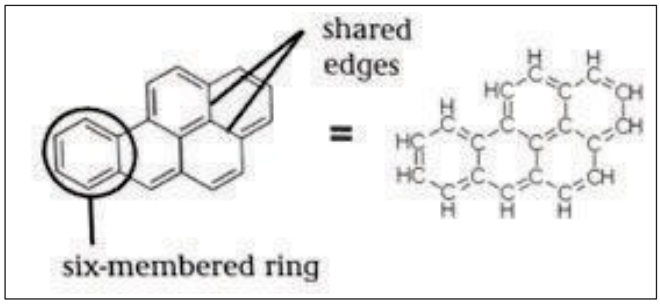
Bromine based flame retardants were very widely used some years back because of their high efficiency. Statistics shows that by early 2000s about 25% of all flame retardants contained bromine [20]. More than 75 different aliphatic, aromatic and cyclo-aliphatic compounds were being used as brominated flame retardants [21]. Among these, polybrominated diphenyl ether (PBDE)s demonstrated high efficiency and were used in very large quantities. But later they were found to be toxic having persistence in the environment and lacking biodegradability. Risk assessment of penta- and octabrominated diphenyl ethers following REACH regulation, resulted in stopping their sale in the region. In fact, penta BDE is believed to be more toxic than octaBDE showing potential health risk in terms of neurotoxicity, endocrine disrupting behavior and suspected oestrogenic activity. As on date, the entire organohalogen class of flame retardants is considered unsafe for use in textiles, leather and footwear. It appears in times to come mostly flame retardants in textiles will be phosphorous based only, with use of halogenated compounds getting severely restricted.

Heavy metals

Metal and metalloid elements with densities ranging between 3.5 to 7g/cc are usually categorized as heavy metals. Although not clearly defined, another criterion for an element to be a heavy metal is to have density above 5 g/cc i.e. five times greater in density than that of water. So, generally speaking, they are metals with high density, atomic number, and atomic weight. Not all heavy metals are toxic, although many of them are toxic and poisonous even at low concentrations. Their toxicity can result in damaged central nervous function, lower energy levels, and damage to blood composition, lungs, kidney liver and other vital organs [22]. In AFIRM List for restricted substances, antimony, arsenic, barium, cadmium, chromium, cobalt, copper, lead, mercury, nickel and selenium have specific permissible limits while the ZDHC MRSL includes tin and silver in addition to the above elements. Heavy metals are often risky to use because they are bio-accumulative too. Out of the list, arsenic, lead, cadmium, mercury and chromium have a higher potential to cause harm.

PAH (Polycyclic aromatic hydrocarbons)

PAHs are a group of compounds composed of two to seven rings of carbon and hydrogen atoms, naphthalene being the simplest of them all. There are more than 100 chemical agents in this group with different configurations where carbon-hydrogen units are joined along shared edges. Most of them are of 6-carbon-hydrogen rings as shown below.



Some of the PAHs such as benzo(a)pyrene $C_{20}H_{12}$, shown above are carcinogenic beyond a certain level and on long term exposure. PAHs are also bio-accumulative and /or reprotoxic. The waste water from textile chemical processing plants containing dyes, their breakdown products and other auxiliaries are likely to have PAHs[23,24]. Being highly lipid soluble, PAHs are easily absorbed from the gastrointestinal track of mammals. Leading apparel and footwear brands have banned the use of certain PAHs in manufacturing of their product.

PFC

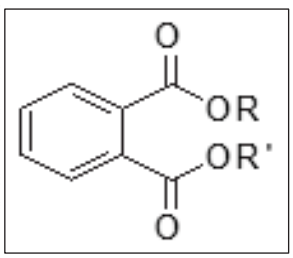
Perfluorinated compounds, more commonly called fluorocarbons or fluorochemicals, are very effective in imparting fluid-repellent finishes on textile fibres. The applications include water, oil and stain repellence, soil-release and anti-soiling effects. They are a class of synthetically produced organic chemicals, not occurring naturally [25]. Among the PFCs, perfluorooctanoic acid (PFOA) and perfluorooctane sulphonate (PFOS) are the predominant forms showing up in human and environment samples. However, the two forms are known to induce severe health consequences like neonatal mortality, neurotoxicity and immunotoxicity besides being biopersistent [26]. Beyond certain exposure level, they are found to affect the lever and may even result in the development of cancer [10]. For decades, the conventionally used PFC for repellent finishes have been based on C8 chemistry. They are very efficient fluid repellents but are highly persistent and virtually indestructible when released into environment. On the contrary, C6 based fluorochemicals when used, produce PFHA (perfluorohexanoic acid), which is 40 times

less bioaccumulative than PFOA. Since C6 fluorochemicals don't contain PFOA, they breakdown in the environment with reasonable ease. But a C6 based product is less effective compared to a C8 ones, and has to be used in higher concentration and cured at higher temperature, mostly in the range of 170-180°C. The products are now widely available commercially and many experimental works have also been carried out using them [27]. Chemical manufacturers are trying to use even smaller perfluorocarbon segment like C4 in their relent finishes, to facilitate more rapid breakdown in the environment.

Phthalates

Phthalates are often used to increase the flexibility of plastics in various consumer products. As regards textiles and allied materials, they find use in wall hangings, table cloths, rain coats, furniture upholstery, carpet backing, shower curtains, inflated toys, shoes, automotive upholstery etc. Their applications also include personal-care products such as soaps, shampoos, hair spray, skin care products, cosmetics and nail polish where there is a possibility of ingestion [28, 29]. In textile manufacturing they can be used in making of printing screens, heat transfer inks, plastisol inks, etc while some phthalates can be effective solvents.

Chemically, phthalates are esters of ortho-phthalic acid, as shown above. When mixed into polymers as external plasticizers, they have no chemical bonding with the polymers and therefore get easily leached out of the material during use, resulting in exposure to people and the environment. Unfortunately, phthalates pose serious hazards to human health. Besides being bioaccumulative, they are suspected endocrine disruptors and can reduce fertility. Asthma and problems with thyroid gland may even be caused by phthalates. The Consumer Product Safety Improvement Act (CPSIA) in USA has banned the use of three phthalates namely di-2-ethylhexyl phthalate (DEHP), dibutyl phthalate (DP) and butyl benzene phthalate (BBP) in toys and child care articles at concentrations above 0.1%. Some years back, in a study done by NimkarTek of Mumbai, phthalates were found even in commodity chemicals like acetic acid, oxalic acid, sodium chloride, soda ash, hydrosulphite, ammonium sulphate and potassium permanganate. Their presence in acids could be attributed to possible use of acid slurry containing contaminants, in preparing the industrial grade chemicals.



Quinoline

It is a heterocyclic aromatic compound with formula C_9H7N. It is used in a very few dyes. It helps in giving yellow and greenish yellow colours. Its use is restricted due to variety of human health hazards caused, including carcinogenic and mutagenic behaviour. Also due to high water solubility of quinoline, its toxicity has potential to harm downstream aquatic life when dyed textiles are washed during wet processing. Even laundry can be a source for its emission into household water while washing garments. Residual amounts in garments during usage can also cause skin irritation.

UV absorbers

In the incident sunlight, about 5% is the Ultra Violet radiation. To protect from the harmful effects of UV light, suitable UV absorbers are used which absorb light in the range of 290-360 nm. The high energy short-wavelength UV radiations excite these absorbers to a higher energy state, and the energy so absorbed is essentially dissipated as longer wavelength radiations. Although UV absorbers are used in a variety of polymers in the industry, some of them are restricted due to health hazards. For example, benzotriazoles are classified under REACH as SVHCs while drometrizole, another UV absorber is known as a skin sensitizer and is very toxic to aquatic life.

VOCs

Volatile Organic Compounds exhibit high vapour pressure of over 10.3 Pa under normal environmental temperature and pressure conditions. Due to this high vapour pressure, they have low boiling point and hence evaporate at room temperature. VOCs include a large group of carbon-based chemicals and are a common air pollutant. Some of them like benzene and tetrachloroethylene are potent carcinogens [30]. In sunlight, VOCs photochemically react with nitrogen oxides and other chemicals triggering formation of smog [31].

Both in textile and footwear industry, VOCs are widely used in chemical preparations. Some of them find use in printing inks, coatings for fabric and leather, adhesives and synthetic leather. Their presence as impurities in polystyrene-based resins used for making plastic trims, buttons etc is also a clear possibility [11]. Besides these, VOCs like chlorinated solvents (trichloroethylene, perchloroethylene etc) are quite useful in dry-cleaning operations. As mentioned earlier, VOCs become gases or vapours easily, thus causing exposure on inhalation. They may also enter the human body on eating or drinking contaminated food or water. VOCs have a wide-ranging damaging action on human health starting from skin, eye, and respiratory irritation to causing cancer and reproductive harm.

Conclusion

The restriction on use of chemicals in the textile manufacturing is increasing day by day. This is mainly due to scientific revelations about their impact on our health and environment by investigations not done earlier. As a consequence, many of the chemicals and processes which were conventionally used, are becoming unsustainable. Hence alternatives are to be worked out without which the manufacturers will lose business particularly in the export

market. In some of the leading textile units now have a Department of Sustainability, to cater to the concerns of human health and pollution in different forms. The concept of RSL and MRSL is fast catching up with growing demand by brands. Environmentally benign processes like use of enzymes in place of strong chemicals are a step towards that. A lot of innovations are further required before phasing out efficient chemicals in use. In fact, finding suitable substitutes to the restricted chemicals in many of the cases is a serious challenge. The chemical manufacturers, processors and never the less academia have to come together to solve these issues at the earliest. Many significant changes have already taken place with a sizable number of process houses turning ZLD (Zero Liquid Discharge) units. With the global problems like climate change and water scarcity, sustainable industrial manufacturing is the by-word and responsible use of chemicals is an absolute imperative.

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Transformative technology for chemical free and organic cotton

V R Sai Ganesh
New Technology Platform, Zydex Industries

THE Zydex technology platform of Bio-fertilizers, special adjuvants and biological products, offers improved soil structure, enhanced soil biology that builds tolerance against biotic and abiotic stresses in the crop plants resulting in better crop yield and produce quality.

Complete chemical fertilizer (DAP, Urea, SSP, MoP, ZnSO4 etc) replacement without yield penalty has not been successful in past. Zydex for the first time has made a technological breakthrough to make it a reality along with improved soil quality, lower water requirement and better cotton quality.

Our flagship program – Prakalp Sanjivani delivers improved crop output with 100% bio-fertilizer technology compared to chemical farming. The soil becomes soft and porous with enhanced water holding capacity, reducing the need of frequent irrigation. Our technology package addresses better bio-composting on the surface as practiced by farmers for fertility improvement and supports bio-farming (1,000 Kg/ acre compost available for use in cotton crop). This technology addresses both irrigated and rainfed farming for cotton farmers, supporting effective drought management by trans evaporation management technology and bio-protection technology.

To sum it up, one crop cycle transition to bio-farming of cotton crops is possible with yield improvement and water conservation and soil biology improvement. The above benefits fit extremely well with the farmer's need for improved soil health, reduced harmful effects of pesticides and reduced water consumption.

We are already working with a large number of cotton farmers across the country and will be glad to collaborate with more to improve the life of cotton farmers.

We are confident that our Prakalp Sanjivani and our bio-protection technology will benefit the textile value chain by enhancing the credibility with regards to traceability from the farm level itself and avoid the wrong documentation in the traceable documents.

Encl: Some pics of farmer fields showing ZM treated fields compared to chemical fertilizer fields

Fig. 1: ZM treated on right has faster germination

Control

ZM treated

1. Plant size slight higher than control
2. More Square and Monopodia and cympodiya than control 50 days after sowing

Control

ZM treated

1. Plant size slight higher than control
2. More Square and Monopodia and Cympodiya than control 60 days after sowing

Control

ZM treated

Good squire- flowering and Till crop better or same as control. 120 days after sowing

Control

ZM treated

Only ZM 30 kgs per acre and FYM. No chemicals fertiliser while control has NPK 15kg/ acre Ba sel.

Plant height and growth & crop condition same as Control – 135 days after sowing

Control

ZM treated

Only ZM 30 kgs per acre and FYM. No chemicals fertiliser while control has NPK 15kg/acre Ba sel.

Longer root zone and prosperous soil than control. Yield ZM Treated 7 QTLS and 6.5 QTL in control ■

Circularity and Sustainability in Traditional Indian Apparel & Textiles and their Contemporary Applications

Pooja Kapoor
Founder and Creative Director, Pooja Kapoor Womenswear

Abstract

The global apparel market's rapid growth has led to an alarming increase in textile waste due to the disruptions caused by the rise of fast fashion. According to a report by the Ellen MacArthur Foundation (2017), over 150 million tonnes of clothing waste are estimated to end up in landfills by 2050 if current consumption patterns remain prevalent. This unsustainable trend has prompted a growing focus on sustainable fashion practices, one of which is circular design. Circular design, a system that aims to minimize waste and pollution while maximizing resource efficiency, offers a promising solution to the fashion industry's environmental challenges.

Indian design has a rich history of circularity and sustainability. Traditional Indian societies embody principles of circularity, incorporating practices that promote resource conservation and waste reduction. These practices, often passed down through generations, have been integral to the sustainable livelihoods of Indian artisans and communities. They not only contribute to environmental protection but also promote economic and social benefits within the society. However, with the rise of globalization and industrialization, these traditional methods have faced challenges in adapting to contemporary fashion trends.

This research explores the potential of circular design in modernizing traditional Indian circular ethos while preserving their inherent sustainability. By examining the historical and cultural context, we can identify key elements of circularity both in design and manufacturing. Additionally, we will investigate how these practices can be adapted to meet the demands of the modern fashion market without compromising on their environmental and social benefits.

This research will employ both quantitative and qualitative methodology, including questionnaires and in-depth interviews with older individuals from traditional Indian communities and comparing these perspectives with those of a younger Generation Z. We aim to identify the circular design principles embedded within traditional practices and their heirloom value. Additional research will be conducted on traditional apparel production processes, material usage and techniques. Through this comprehensive analysis, we seek to develop a framework for integrating circular design principles into contemporary fashion practices, thereby addressing the significant textile waste generated by fast fashion.

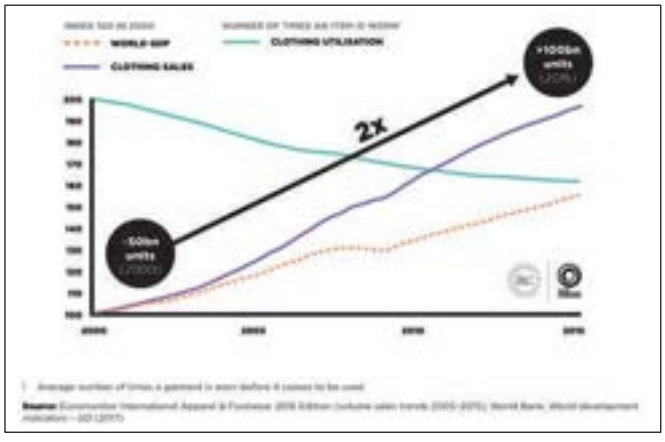
By highlighting the potential of circular design in traditional Indian textiles, this research contributes to the broader discourse on sustainable fashion. It offers a valuable perspective on how cultural heritage can help form innovative solutions to contemporary environmental challenges. Moreover, it provides insights into the potential for revitalizing traditional textile industries while promoting sustainable livelihoods and preserving cultural diversity

Introduction

TRADITIONALLY the fashion cycle moved at a much slower pace, with seasons dictating the release of new collections. Designers would meticulously craft their designs. Production was a lengthy process, involving skilled artisans and intricate techniques. As a result, fashion trends had a longer lifespan, and garments were considered investments, meant to be cherished for years. In contrast, fast fashion has revolutionized the industry with its rapid turnaround time. Trends are identified quickly and designs are translated into garments at breakneck speed. This allows brands to capitalize on the latest trends and offer them to consumers almost immediately. This unsustainable, rapid turnover of new styles and the increased number of collections offered per year is primarily due to this phenomenon. The lower

prices associated with fast fashion is another contributing factor, enabling the consumers to make a quicker, impulse-based purchase.

This disruption translated into global apparel market witnessing an unprecedented surge in recent decades, driven by factors such as flourishing economic growth, faster than ever globalization and changing consumer preferences. This rapid expansion has, however, come at a significant environmental cost, with the textile industry emerging as a major contributor to significant waste and pollution. Ellen MacArthur Foundation (2019) report states, "Clothing represents more than 60% of the total textiles used and in the last 15 years, clothing production has approximately doubled, driven by a growing middle-class population across the globe and increased per capita sales in mature economies. At the same time, clothing use has declined by almost 40%."



A large part of the problem is that the fashion industry currently follows a largely linear model. Vast quantities of non-renewable resources are mined to create apparel products that are frequently discarded after brief/ negligible use. It's estimated that over half of fast fashion garments end up in landfills or are incinerated within a year of their lifecycle. According to the Ellen MacArthur Foundation (2017), over 150 million tonnes of clothing waste are estimated to end up in landfills by 2050 if current consumption patterns continue. Every second, one truckload of clothing is landfilled or burned. This is an alarming situation.

"This consumer inclination of using garments forever shorter periods before throwing them away contributes the most to unsustainable patterns of overproduction and overconsumption. Such trends entice consumers to keep on buying clothing of inferior quality and lower price, produced rapidly in response to keep up with the latest fashion trends. This growing demand for cheap textiles is fuelling the inefficient use of non-renewable resources, including the production of synthetic fibres from fossil-fuels." Kapoor (2022). The linear system not only wastes economic resources, but also puts pressure on the environment and natural resources. It depletes resources, pollutes ecosystems and creates significant negative societal impacts at local, regional as well as global scales. This alarming statistic underscores the urgent need for sustainable fashion practices that can mitigate the negative impacts of the industry.

Literature Review

Circular Design, is a design philosophy that aims to create products and systems that minimize waste and pollution, promote resource conservation and regenerate natural systems. Instead of a linear "take-make-dispose" model, it adopts a circular approach where materials and products are continuously reused, recycled or repurposed expanding their life cycle (Ref. Figure 2). Circular designers consider all stages of a product's life cycle and ensure that it is sustainable from the manufacturing stage to its end of life disposal. By prioritizing durability, repairability, recyclability and reuse, circular design seeks to create products that have a minimal environmental impact throughout their entire lifecycle.

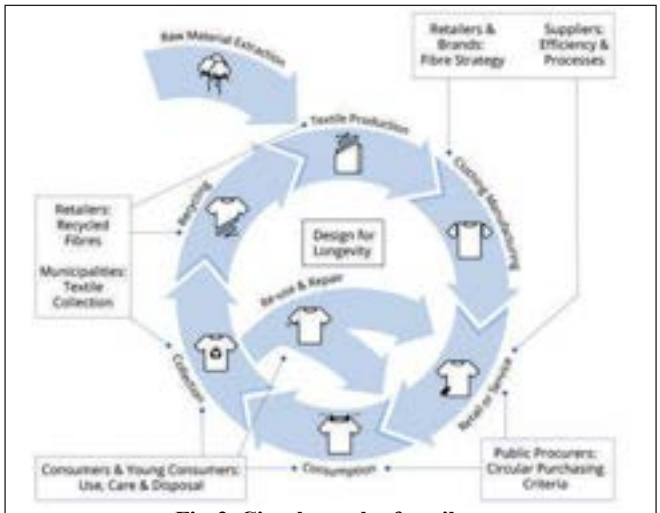


Fig. 2: Circular cycle of textiles. (Ellen Macarthur Foundation, 2017)

The Three Principles of Circular Design, as mentioned in the Interaction Design Foundation (2024), are:

1. Eliminate waste and pollution, including toxic substances that harm the soil and water and reduce emissions. This principle emphasizes the need to redesign products and systems to minimize waste as well as harmful emissions throughout their lifecycle.
2. Circulate products and materials at their highest value for as long as possible through strategies like repair, reuse, and recycling. A recycled product must be energy-efficient in the recycling process. Furthermore, recycling should not result in a substantially inferior product.
3. Regenerate natural systems by returning natural resources to the earth. This helps to restore and revitalize ecosystems, minimize the extraction of virgin resources, and promote a more sustainable future.

This approach aims to minimize waste and pollution while maximizing resource efficiency throughout the product lifecycle. By adopting circular principles, fashion brands can reduce their reliance on virgin materials, minimize waste generation, and

create products that are designed for longevity and reuse. Circular design has gained significant traction in recent years, with many companies recognizing its potential to drive both environmental sustainability and business innovation.

"By moving to a circular system, the industry can unlock a USD 560 billion economic opportunity. Realising this opportunity requires new business models and collaboration across the value chain (e.g. production, marketing, and after-sales care), to keep safe materials in use" Ellen Macarthur Foundation (2019).

While circular design offers a viable path towards a more sustainable fashion industry, it is essential to explore diverse cultural and historical contexts to identify potential solutions. Indian design ethos, with its rich heritage and deep-rooted traditions, provides a valuable perspective on circularity and sustainability. For centuries, Indian societies have embodied principles of circularity, incorporating practices that promote resource conservation as well as waste reduction. These practices often passed down through generations, have been integral to the sustainable livelihoods of Indian artisans and communities. They not only contribute to environmental protection but also promote economic and social benefits within the society.

The concept of circularity in Indian design is deeply intertwined with the cultural and philosophical values that have shaped the region's textile traditions. Traditional Indian textiles often employ natural materials such as cotton, silk and wool, which are renewable and biodegradable. Furthermore, the production processes, involved in creating these 'Khadi' textiles incorporate sustainable practices, such as hand-spinning and weaving, natural dyeing and using traditional hand-embroidery techniques for surface ornamentation when needed. These practices not only preserve the cultural heritage of Indian design but also contribute to the overall sustainability of the textile industry and the artisans.

The principles of circularity can be observed in various aspects of Indian design, from the choice of materials to the production techniques and end-of-life considerations. Indian apparel and textiles have a long history of sustainability, often incorporating practices that minimize waste and pollution. By exploring the cultural and historical context of Indian design, we can identify key elements of circularity and develop strategies for integrating these principles into contemporary fashion practices. Here are some key examples:

- **Natural Fibers:** Traditional fabrics like cotton, silk and jute are often derived from natural sources, reducing the environmental impact when compared to synthetic materials.
- **Handloom Weaving:** Handloom weaving is a labor-intensive process that often involves traditional techniques passed down through generations. It is generally more sustainable than mass production methods.
- **Natural Dyes:** Many traditional dyes are made from natural sources, such as plants and minerals. These dyes, like 'Indigo' are often renewable and have a lower environmental impact than synthetic dyes.
- **Recycling and Upcycling:** Traditional crafts often involve reusing and recycling fabric scraps, creating new products like quilts, bags and home decor items.

Traditional Indian garments are often designed to be versatile and adaptable as well, allowing them to be worn in different seasons and for various occasions. The saree, one of the world's oldest and perhaps most versatile unstitched garments, is a cornerstone of Indian history and fashion heritage. The exact number of ways to drape a sari is difficult to pinpoint with accuracy. Each region in India has its own traditional draping style, often tied to cultural significance or practical considerations with respect to that area. While there are countless documented styles, new variations continue to emerge, adapting to cultural shifts, fashion trends, and individual preferences. This adaptability reduces the need for frequent purchases and contributes to the longevity of the garments. Additionally, many traditional textiles are known for their durability and resistance to wear and tear, ensuring that they can be enjoyed for many years to come and are often passed down to the younger generations as treasured heirlooms.

Methodology

In order to investigate the potential of circular design in modernizing traditional Indian circular ethos, this research employed a mixed-methods approach that combined quantitative and qualitative research techniques. This approach allowed for a comprehensive exploration of the subject matter, capturing both quantitative data and qualitative insights.

Quantitative Research

A key component of the quantitative research was the development and administration of a structured questionnaire. The questionnaire was designed to gather demographic information about the participants, as well as their perceptions of traditional Indian textiles and sustainability. Questions were included to assess participants' knowledge of apparel production processes, their attitudes towards sustainable fashion and their willingness to adopt sustainable practices.

The two age groups for the conducted study were chosen based on research. The younger generations are heavily into the aspirational lifestyle and consider material success as a reflection of social prestige. Consumers in this segment are one of the largest consumers of fast fashion in India. According to a survey conducted by Business Today (2021), customers in the age group of 18-30 drove the demand for online fashion, with 71 per cent of them spending heavily in the category. This is one of the age groups under focus for this research.

A questionnaire was distributed to a sample of older individuals from traditional Indian communities as well. This second category is the age group between 40-60 year, who have

been around long enough to see these remarkable changes come across our societies. They are well established in their family lives, with kids (if any) belonging to the category mentioned above and have parents belonging to the post-independence era, wherein being thrifty and therefore sustainable, was a matter of survival and not just a choice for them. These individuals were selected based on their familiarity with traditional textile traditions and their potential to provide valuable insights into the historical and cultural context of Indian design. The data collected through the questionnaire was analyzed to identify inherent patterns and trends.

Qualitative Research

In addition to the quantitative research, informal interviews were conducted with a subset of older individuals from traditional Indian communities. These interviews provided an opportunity to delve deeper into the participants' experiences and perspectives. The interviews focused on exploring the participants' knowledge of traditional textile production processes, their understanding of circularity and sustainability and their experiences with incorporating circular principles into their daily lives and into the future generations.

To gain a broader understanding of the subject matter, the research also included a comparison between the perspectives of older individuals and younger Generation Z. This comparison was conducted through a combination of questionnaires from both groups. The goal was to identify similarities and differences in their attitudes toward traditional textiles, circular design and sustainability.

In order to complement the quantitative and qualitative research, this process also involved an in-depth study of traditional apparel production processes, material usage and techniques. This research was conducted through a combination of literature reviews and interviews with experts in the field of Indian textiles.

Literature reviews were conducted to gather information on the historical and contemporary practices of traditional textile production in India. This included examining scholarly articles, books and other published materials that discussed the use of different materials, production techniques, and design elements in traditional Indian textiles. The Author's extensive experience as a designer offers firsthand insights into the production processes, material usage and design techniques employed in the creation of traditional Indian textiles.

A Case study was also conducted, on the brand "Button Masala". This Involved semi-structured interview with the Designer, Anuj Sharma, and provided valuable insights into the historical and cultural significance of traditional textiles, his contribution to the sustainability, as well as the challenges and opportunities facing the industry today. The potential of circular design, especially modular designing and its potential in modernizing the industry was also discussed.

Results & Discussion

- A questionnaire was floated across to respondents between the age groups of 18-30 years. A total of 37 responses were received. The responses to the question on their understanding of sustainability provides a broad understanding of the concept in their peer group. This was an open-ended question and the responses focussed primarily on the following:
  - **Reduce, Reuse, Recycle:** This classic mantra is a core principle of the circular economy, emphasizing the minimization of waste and the maximization of resource use.
  - **Using products in a sustainable way that doesn't harm nature:** This implies a focus on minimizing waste and pollution, which aligns with the principles of circular economy.
  - **Less wastage and more usage:** This directly relates to the circular economy's goal of keeping resources in use for as long as possible.
  - **Products that have been recycled:** Recycled/ upcycled products are a direct example of circularity, as they extend the life cycle of materials.

Although the responses don't explicitly discuss circularity, they do highlight several key principles of the circular economy, such as: waste reduction, resource efficiency, and product longevity. These principles are essential for creating a more sustainable and resilient future.

- When it comes to the older age group of 40+ years, the respondent's understanding of sustainability expands on the previous group's responses. While they still emphasize minimizing environmental impact (phrases like "not to harm the environment" and "eco-friendly" were used), a stronger focus on circularity emerges:
  - **Circularity:** Several responses directly mention circularity, highlighting the importance of product life cycles and minimizing waste.
  - **Reduce, Reuse, Recycle:** This mantra features prominently again, showcasing a practical approach to circularity.
  - **Lesser wastage and reusability:** These phrases directly contribute to the concept of extending resource use through reuse and minimizing discards

This age group demonstrates a deeper understanding of sustainability, encompassing resource conservation, and responsible consumption and emphasises extending the lifespan of products. They recognize the importance of innovation and research in furthering circular practices for a more sustainable future.

- When asked if they were into recycling, over half the respondents (57.1%) in the 18-30 age segment, said they recycle their clothing. This recycling involves a variety of creative approaches. Many people repurpose old clothes for cleaning purposes (dusters, rags), while others upcycle them

into new garments (shorts from old/ torn jeans, bags from t-shirts). Some even find uses for clothes beyond garments, like making doormats or shirts for their pets. By extending the lifespan of their clothing and minimizing textile waste, these individuals are actively contributing to a more circular fashion economy. This highlights a growing awareness of the importance of sustainable practices and a desire to reduce the environmental impact of clothing consumption.

- On being asked about their shopping habits, only 33% of the respondents confirmed to have shopped from sustainable brands.
- Once made aware of the clothing industry's environmental impact, respondents prioritize factors that promote a more circular approach to fashion. Durability and versatility are key, with many focusing on garments that can be worn for a long time and easily paired with other outfits. Key considerations included purchasing high-quality, versatile garments that could be worn for extended periods. This aligns with the circular economy's goal of extending product lifespans. Sustainability was also a major factor, with consumers seeking eco-friendly materials and researching brand practices. By focusing on durability, versatility, and sustainability, these shoppers are actively contributing to a more circular fashion system, reducing waste and minimizing the industry's environmental impact.
- When asked if their elders had any sustainable habits, the 40+ age group, 96.7% responded affirmatively. The main fact that emerged was that the concept of sustainability wasn't a new trend for many respondents' older family members. Their practices exemplified core circularity principles. Many reused clothing for various purposes, like turning old clothes into cleaning cloths, bags, or even new garments (e.g., quilts from saris). Passing down clothes within families from older to younger siblings maximized their use. Resourcefulness was another theme – respondents mentioned elders using items for extended periods, minimizing waste. These examples highlight a strong emphasis on maximizing product lifespan and reducing consumption, demonstrating a long-standing awareness of sustainable practices. This highlights our traditional circular/ sustainable roots.

Case Study

Anuj Sharma's innovative "Button Masala" technique offers a circular and sustainable approach to apparel design. Simply by replacing traditional sewing techniques with a simple system of buttons and rubber bands, he creates a sustainable method that is both efficient and environmentally friendly. This concept's unique technique allows for easy recycling and repurposing of materials, as products can be disassembled and reassembled with minimal effort. This not only reduces waste but also empowers individuals to create personalized items while reducing consumption and contributing to a more sustainable future.

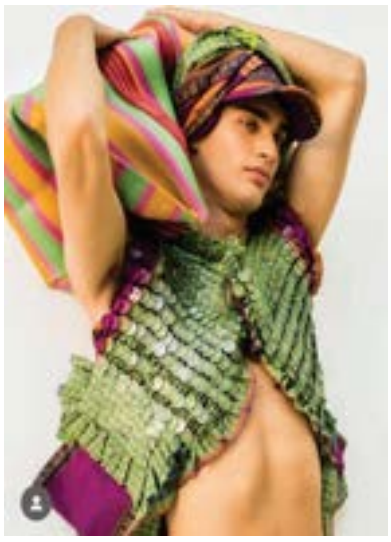
During the interview, some key factors became apparent: His brand operates on a simple, manageable system. Without the need for pattern cutting or large-scale production, he maintains a small studio environment. He sources fabrics ethically (Ref. Picture: 1), often purchasing from craftsmen and hand looms during his travels. He believes that while most Indian textiles can be considered circular and astute, the key lies in how they are treated and transformed. By avoiding traditional cutting and sewing methods, he utilizes fabrics more efficiently, promoting sustainability and circularity in his designs. This approach allows him to produce a limited quantity of pieces, ensuring a personal and sustainable production process.

Pic 1: Button Masala top created from Ajrakh fabric sourced from Kutch. Source: Button Masala

He understands sustainability as a holistic approach that extends beyond just creating sustainable garments. It involves sustaining the business, the designer, and all elements of the production chain, including the craftsmen involved. Circularity, on the other hand, is about creating products that can be used for longer and have minimal waste. While sustainability isn't a conscious concern for him, it is deeply ingrained in his design process. His company prioritizes small-scale production, zero-waste practices and ethical treatment of his minimal team of workers, making sustainability a natural part of his business operations as well.

His successful business model shows that increasing production is not the only way to increase revenue. We need to decouple revenue from production and resource use to create a circular economy for fashion. This is where modular design comes into the picture. Whether we call it "multi-functional" "convertible" or "adaptable" modular fashion refers to apparel products or accessories that can be changed or adjusted for different purposes. Modular garments are designed to be disassembled into separate parts and reassembled as needed. This is often accomplished using various fasteners like buttons, zippers, snaps or Velcro. These fasteners allow for the attachment

Pic 2: Gigi in his creation using Button Masala technique
Source: Button Masala



Pic 3: Gigi in his creation using Button Masala technique.
Source: Button Masala

or removal of optional features like collars, hoods, or pockets, transforming a garment into something different. Button masala uses normal rubber bands and buttons/ sequins/ beads to create the different variations in apparel design.

His brand prioritizes sustainability and ethics in all aspects of its operations. He's been recognized as one of the most sustainable fashion brands due to his system-based approach, which eliminates the need for machinery, tools, and excessive energy consumption. By focusing on soft fabrics and empowering customers to alter garments themselves, he reduces the need for frequent purchases. This not only promotes sustainability but also minimizes his environmental impact. He teaches his techniques via workshops across the world and encourages the participants into giving their own spin to the process (Ref. Pic 2&3). He believes that by fostering collaboration and learning from each other, the global community can accelerate the transition to a sustainable fashion future.

Discussion & Recommendations

The research presented in this paper offers a valuable contribution to the broader discourse on sustainable fashion. By highlighting the potential of circular design in traditional Indian textiles, the study sheds light on a promising approach to addressing the environmental challenges faced by the fashion industry.

One of the key contributions of this research is its emphasis on the importance of cultural heritage in driving sustainable solutions. Traditional Indian textiles embody principles of circularity and sustainability, demonstrating how cultural practices can offer valuable insights and inspiration for contemporary design. By examining the historical and cultural context of Indian design, the study reveals the potential for leveraging traditional knowledge and techniques to create more sustainable and environmentally friendly fashion products. We can start to foster a more sustainable fashion industry by focusing on the following resources:

Prioritizing Circularity and Use of Natural Materials

- Increase Market Share of Locally-Sourced Natural Fibers: Promoting indigenous fibers like cotton, jute and silk can reduce the carbon footprint associated with long-distance transportation and support local economies.
- Increase Market Share of Recycled Natural/Synthetic Fibers: Recycling textile waste and transforming it into new garments minimizes waste and conserves resources.
- Produce Natural Fibers Sustainably: Implementing sustainable farming practices, such as organic cultivation and water-efficient irrigation will be invaluable in conserving resources and increasing output.

Enhancing Durability and Embracing Slow Fashion

- Increase Garment Durability: Simply by focusing on quality craftsmanship, robust construction and timeless designs, the lifespan of garments can be extended and will reduce the need for frequent replacements.
- Embrace Slow Fashion: By prioritizing quality over quantity, slow fashion encourages mindful consumption and reduces the demand for fast fashion's instant gratification and discard.

Advancing Circular Design and Manufacturing

- Design for Durability and Recyclability: By designing garments that can be easily repaired, reused and recycled, we can extend their lifecycle and minimize waste.
- Implement Closed-Loop Systems: By recovering and repurposing materials at the end of their life, we can create a truly circular fashion system.

In addition, collaborative efforts and modular fashion are emerging as powerful tools in the pursuit of a sustainable future. By fostering partnerships between designers, manufacturers and consumers, collaborative efforts can drive innovation, reduce waste and promote ethical practices. Modular fashion, characterized by interchangeable components and customizable designs, offers a solution to the fast-fashion model's unsustainable practices. By extending the lifespan of garments and reducing the need for constant replenishment, modular fashion can significantly decrease the environmental impact of the fashion industry. Modular design principles can also be applied to any brand to improve customer retention. By allowing for individual component repairs or replacements, modular garments can reduce waste and extend the garment's lifespan.

"The current fashion system (design-produce-marketization) may see a revolution through the emergence of modular fashion, as it provides possibilities for designing, manufacturing and marketing garments in a manner of individual garment modules instead of a whole piece of ready-to-wear. Thus, modular fashion can be seen as a new concept that features modularity throughout a product's lifecycle." X. Zhang, Et al (2024). As these collaborative efforts and modular fashion practices gain momentum, they have the potential to revolutionize the way we produce, consume, and perceive clothing, ultimately paving the way for a more sustainable and equitable fashion landscape.

Furthermore, the research highlights the potential for revitalizing traditional textile industries through the adoption of circular design principles. By incorporating circular practices into modern fashion, traditional textile artisans can gain access to new markets and opportunities, at the same time also contributing to the overall sustainability of the fashion industry. This can help to preserve cultural heritage and promote economic development in rural communities.

The findings of this research also have important implications for future research and practice. One area for further exploration is the potential for collaborations between traditional artisans and modern designers. By combining traditional knowledge and techniques with contemporary design sensibilities, it may be possible to create innovative and sustainable fashion products that appeal to a wider audience.

Another area for future research is the investigation of the economic and social impacts of circular design in the fashion industry. While the environmental benefits of circular design are well-documented, it is important to also consider the economic and social implications of this approach. For example, circular design may lead to job creation, increased economic activity and improved livelihoods for those involved in the textile industry.

Finally, the research emphasizes the need to promote awareness and adoption of sustainable fashion practices. This can be achieved through a variety of strategies, including education, advocacy, and policy initiatives. By raising awareness of the environmental and social impacts of the fashion industry and promoting the benefits of circular design, it is possible to encourage consumers and businesses to adopt more sustainable practices.

Conclusion

The research presented in this paper has demonstrated the significant potential of circularity and sustainability in traditional Indian textiles. By examining the historical and cultural context of Indian design, we have identified key elements of circularity that have been embedded in these traditions for centuries. These principles, including the use of natural materials, sustainable production practices and a focus on longevity and durability, offer valuable insights for contemporary fashion designers and businesses.

This study has also highlighted the importance of revitalizing traditional textile industries as a means of promoting sustainability and economic development. By incorporating circular design principles into modern fashion, traditional textile artisans can gain access to new markets and opportunities, while also contributing to the overall sustainability of the fashion industry. This can help to preserve cultural heritage and promote economic development in rural communities.

Moreover, the research has emphasized the need for a more sustainable and equitable fashion industry. The current model of fast fashion, which is characterized by low-quality products, excessive consumption, and significant environmental impacts, is unsustainable and harmful to both people and the planet. By adopting circular design principles and supporting traditional textile industries, we can move towards a more sustainable and equitable fashion system.

In conclusion, the research presented in this paper provides compelling evidence for the importance of circularity and sustainability in traditional Indian textiles. By embracing these principles, we can create a more sustainable and equitable fashion industry that benefits both people and the planet. As we continue to face the challenges of climate change and resource depletion, it is imperative that we adopt innovative and sustainable approaches to fashion design and production. Traditional Indian textiles & apparel offer a rich source of inspiration and guidance for this endeavour towards a more sustainable and equitable fashion industry.

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Advancing a more circular economy through the use of bio-based materials

Dr Akshay Kumar Sardana
Covation Biomaterials LLC

Abstract

For several decades, scientists at Covation Biomaterials (formerly DuPont Biomaterials) have been working to deliver innovative materials which are not only from bio-based sustainable sources but have unique performance advantages. Additionally, these innovative materials could easily be converted into various end use applications, such as value-added conventional /technical textiles, carpets, shoes and non-wovens with minimized footprints and the ability to be mechanically recycled without harming our beautiful planet. Available commercially for more than two decades, Sorona polymer is now being widely adopted by many customers globally in numerous applications primarily in textiles.
In the simplest of terms, fibres, garments and carpets made with Sorona(R) polymer are more sustainable as they are produced through a biobased process that was formerly a chemical one.
In addition to its bio-based attributes, products made with Sorona (r) polymer enable exceptional performance properties including stretch and recovery, chemical resistance and more. These properties allow customers to keep clothing and shoes longer, reducing garment waste and advancing a more circular economy.

Covation Biomaterials LLC Overview

COVATION Biomaterials was formerly a part of DuPont until its acquisition by the Chinese conglomerate, Huafon Group, in June 2021. Headquartered in the US, the company has around 220 employees across 15 countries, including offices and labs in Gurgaon, India. The company specialises in producing BIO PDO (1,3 Propanediol) and Sorona, high-performance chemicals and polymers made from corn sugar through a fermentation process. Company has three branded Bio based Products.

Sorona - a unique biobased synthetic fiber which is in commercial use for more than 20 years. Sorona can be used in all types of fabrics which provide exceptional softness, long lasting stretchability, dimensional stability, colour brilliance and many other unique attributes to the fabrics. These Sorona-based fabrics can be recycled as traditional polyester based fabrics. Sorona applications spans in traditional textiles, technical textiles, automative and nonwoven as well.

Next branded product which is 100% plant-based product- Susterra, a pure 100% plant-based, petroleum-free diol. Susterra propanediol is the building block that delivers high performance in a variety of applications, from polyurethanes and unsaturated polyester resins to heat-transfer fluids. Susterra brings sustainability to many footwears, gear, apparel and synthetic material application.

Next branded product is 100% plant-based product- Zemea, a propane diol. Zemea helps companies fulfil their sustainability goals without compromising on quality. Naturally derived, and sustainable, Zemea brings opportunities for formulators across many applications the ability to reduce or eliminate the need for petroleum-based glycols. Zemea is mainly used in health care and cosmetics application.

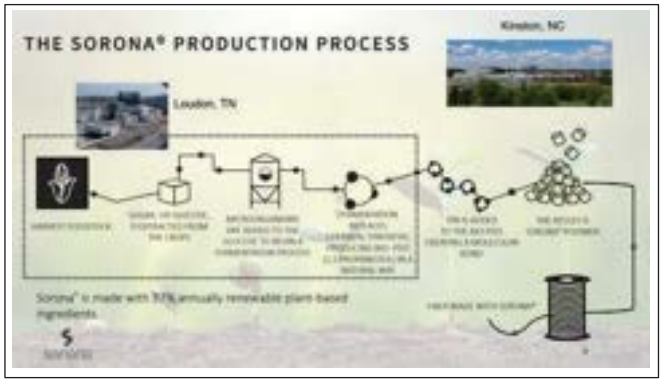
Further, CovationBio sustainability priorities align with the following four United Nations Sustainable Development Goals (SDGs):

- Decent Work & Economic Growth
- Responsible Consumption & Production
- Climate Action
- Life on Land

Sorona Polymer for Textiles

Sorona is CovationBio's brand of Triexta, chemically known

as polytrimethylene Terephthalate (PTT) named and commercialized in 2000. Sorona is made by combining plant based 1, 3 propane diol and terephthalic acid. The below picture schematically demonstrates the process of Sorona production. Overall, Sorona Polymer production uses less energy and emits less greenhouse gas compared to other synthetic polymers (Nylon, PET) produced using non- renewable resource.



Sorona polymer can be spun into 100% homo- fiber and -filament and also co-extruded with PET polymer which is known as bicomponent- fiber and -filament. Sorona based fiber/filament can be blended with any other synthetic and natural fiber easily to produce fabric of customer's choice. Sorona can be dyed with disperse dyes at significantly lower temperature compared to regular PET.

Unique Properties of Sorona

Sorona, certified biobased polymer, offers a range of unique properties that set it apart from traditional materials like PET, PBT, and nylon. It excels in softness, smooth feel, resiliency, fade resistance, wrinkle resistance, easy care, low temperature dyeing with brilliant colors, breathable insulation, chemical and UV resistance. These characteristics make Sorona suitable for various applications such as sportswear, shirting, bottoms, denim, faux fur, footwear, insulation, and more.

Further, company have "The Common Thread-the fabric certification Program", where Sorona fabrics are tested for Sorona type/ content and performance through third party certified labs, to which any fabric mill/brand can enrol and get certified their fabrics. The transparency and traceability of this program ensures that your choice to partner with Sorona is meaningful and impactful, today and in the future. Based on type of Sorona uses and fabric performance, the fabrics can be tested and qualified for five different fabric sub brands as depicted in above picture.

Applications and Collaborations in India

In India and South Asia, CovationBio have collaborated with many partners to create innovative fabrics and yarns using Sorona. They have worked with linen manufacturers, yarn spinners, fabric mills, Saree companies, and denim brands to develop fabrics with improved softness, stretch, recovery, and durability. Their collaborations have resulted in successful adoptions and positive market feedback.

Industry Trends and Sustainability

The textile industry is experiencing a significant shift towards sustainability driven by consumer demand. Brands are actively seeking sustainable solutions, aiming to reduce waste, promote durability, and incorporate more plant-based materials. Consumers are embracing athleisure and functional clothing, which has led to a growing demand for comfortable and stretchable fabrics like Sorona.

Conclusion

The future of biomaterials is promising, driven by the growing focus on sustainability and the demand for high-performance, eco-friendly solutions. Covation Biomaterials remains committed for providing innovative products like Sorona and BIO PDO to cater to these evolving needs. They are dedicated for supporting customers, collaborating with partners, and contributing to a more sustainable future for the textile industry.

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Sustainability meets performance: Designing eco-friendly sports shoes for amateur athletes

Sweta Kumari & Manpreet Manshahia
Footwear Design and Development Institute (FDDI), Sector-24, Noida, India
Amity University, Sector 125, Noida, UP, India

Abstract

The increasing awareness of environmental sustainability has driven significant advancements in the design and production of sports footwear, particularly in developing eco-friendly shoes for amateur athletes. This paper explores the intersection of sustainability and performance, focusing on how sports shoes can be designed to meet the ecological responsibility demands of today's consumers without sacrificing athletic performance. Key design principles include using vegan materials, ethical sourcing, and emotionally durable designs that encourage longevity. Innovations such as 3D printing and advanced knitting technologies are revolutionizing production, enabling more sustainable processes. A user-centric approach ensures these sustainable shoes meet performance needs while incorporating end-of-life solutions like recycling programs. The findings from this study suggest that, despite challenges, it is possible to create sports shoes that are both sustainable and high-performing, contributing to a more environmentally responsible sports industry. Ultimately, sustainable athletic footwear is not just a trend but a commitment to both personal performance and global sustainability.

Keywords: *Sustainable footwear, eco-friendly design, amateur athletes, 3D printing, recyclable materials.*

Introduction

THE sports footwear industry traditionally focused on maximizing athletic performance, is undergoing a significant transformation as environmental sustainability becomes an increasingly urgent concern. Valued at USD 127.3 billion in 2021(Athletic Footwear Industry Statistics [Fresh Research] Gitnux, n.d.), the market for sports footwear is expected to grow steadily, driven by increasing consumer awareness of health and fitness(Young et al., 2013). As part of this evolution, there is a rising demand for sports shoes that harmonize high performance with eco-friendly design, especially among amateur athletes(Physiology of Sports - Google Books, n.d.). These individuals, who participate in sports out of passion rather than financial gain, represent the grassroots of athletic culture, bringing fresh perspectives and untapped potential to the field. As awareness of the environmental impact of traditional shoe materials increases, the industry faces the challenge of developing innovative solutions that do not compromise the planet's well-being. This paper explores the intersection of sustainability and performance in the design and production of sports shoes tailored for amateur athletes, examining how the industry can reconcile the demands of athletic performance with the imperative of sustainability. It focuses on key design principles such as the use of vegan materials, ethical sourcing, and advanced manufacturing techniques like 3D printing and knitting technologies. Additionally, the importance of a user-centric approach is highlighted, ensuring that eco-friendly sports shoes meet the performance needs of athletes while incorporating sustainable end-of-life solutions like recycling programs.

Literature Review

The design of athletic shoes has evolved significantly, focusing not only on enhancing sports performance but also on providing optimal foot protection(Frederick, 1986). Ergonomics plays a crucial role in this evolution, considering factors such as human anatomy, psychology, and physiology to ensure that footwear aligns with the needs of the wearer. Sports shoe design, rooted in physical ergonomics, takes into account human anthropometric, physiological, anatomical, and biomechanical factors, contributing to improved performance, safety, and

comfort(Ergonomics/Anthropometrics and Feet, n.d.; Herbaut et al., 2016). Customization for specific sports and foot types is essential in maximizing these benefits, as ergonomic considerations such as gait patterns, arch types, and joint dynamics significantly influence sports performance and shoe wear patterns(Miyake et al., 2021; Sawangphol et al., 2023).

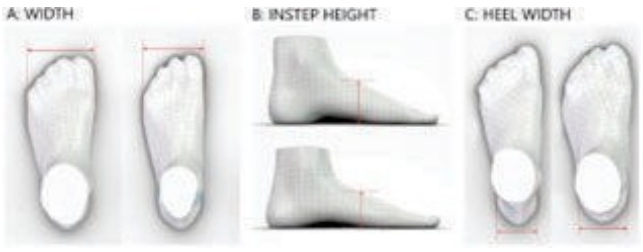

Fig.1: 3D scans demonstrating dispersion of feet (Jurca et al., n.d.)

Fig. 2: Different types of arches (Foot.Jpg (998×665), n.d.)

Simultaneously, the rising demand for sustainable sports footwear has spurred extensive research into the use of recycled and renewable materials(A Sustainable Approach to Footwear Manufacture, n.d.; What Makes a Shoe Sustainable?, n.d.), as well as innovative manufacturing processes. Materials like recycled polyester, natural rubber, and plant-based leathers have been highlighted for their lower carbon footprint, making them key components in eco-friendly footwear design. Innovations in 3D printing, such as Carbon's Digital Light Synthesis and customizable lattice structures, have revolutionized the industry by enabling the production of intricate shoe components with minimal waste(Reddy Bathula, 2017; Ukobitz & Faullant, 2021). These advances not only reduce material waste but also support localized production, thereby minimizing the environmental impact(15 Best Sustainable Running Shoe Brands for 2024, n.d.; Green Steps Ahead: Top Sustainable Sneakers & Eco-Friendly Shoes — Sustainable Review, n.d.; Sustainable Footwear Market Size, Share, Trends | Forecast 2032, n.d.).

The adoption of circular economy principles further enhances sustainability in sports footwear design. Brands like On Running and VEJA are leading the way by using innovative materials and implementing recycling programs that allow for the easy disassembly and recycling of shoes(Cook, 2019a, 2019b). Despite these advancements, a gap remains in addressing the specific needs of amateur athletes(Piermattéo et al., 2020), who often lack access to high-performance, eco-friendly footwear. This highlights the importance of sustainable design strategies that cater to the performance requirements of amateur athletes, ensuring that the pursuit of sustainability does not come at the expense of athletic performance(15 Best Sustainable Running Shoe Brands for 2024, n.d.; Sustainable Footwear Market Size, Share, Trends | Forecast 2032, n.d.).

Methodology

The methodology for this study employed a mixed-methods approach, integrating qualitative and quantitative research to design and assess eco-friendly sports shoes tailored for amateur athletes. It began with a comprehensive literature review that identified sustainable materials, such as recycled polyester, natural rubber, and plant-based alternatives, and explored circular design principles like recyclability and biodegradability.

A survey of amateur athletes aged 12-16 followed, focusing on their priorities in footwear, including performance, durability, comfort, and environmental impact. The survey data informed the development of three hypotheses about design elements and their influence on factors like gender and design features, highlighting design plays a vital and sustainability is important factor while selecting sports shoe for amateur athletes.

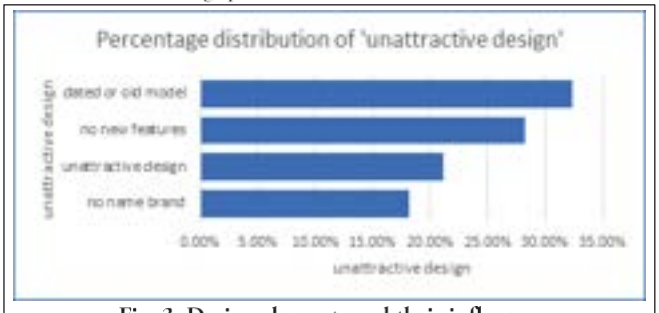

Fig. 3: Design elements and their influence

Features		Percentage
Avant Garde design		32.00%
Sustainable/recycled fashion		30.00%
Minimalism design		28.00%
Reto look		10.00%
Grand Total		**100.00%**

Fig. 4: Design elements and their influence in the percentage

Material Selection

The selection of materials for the shoe upper was guided by the distinctive physical characteristics of sustainable materials used in the construction of sports shoes by analyzing their features and benefit(Every Step Counts: How The Footwear Industry Is Becoming More Sustainable, N.D.; (Pdf) A Sustainable Materials For Footwear Industry: Designing Biodegradable Shoes, N.D.)s. (See Table 1)

Prototype Development Process

The iterative prototype development involved response from

Table 1: Sustainable Materials for Footwear Industry			
Material	**Description**	**Benefits**	**Application**
Recycled Polyester	Made from post-consumer plastic bottles or recycled Polyester garments. Reduces virgin production.	- **Environmental Impact:** Minimizes resource extraction and landfill waste. - **Performance:** Durable, moisture-wicking, and breathable.	Shoe uppers, linings, and laces
Natural Rubber	Derived from latex harvested from rubber trees.	- Sustainability: Rubber trees are renewable. - Biodegradability: Breaks down more easily than synthetic rubber. - Traction: Excellent grip.	Outsoles and midsoles
Plant-Based Alternatives	- **Hemp:** Strong, lightweight, and biodegradable. - **Cork:** Sustainable, shock-absorbing, moisture-resistant. - **Piñatex** (Pineapple Leather): Cruelty-free alternative to leather.	- **Eco-Friendly:** Reduces reliance on petroleum-based synthetics. - **Renewable:** Hemp and cork are rapidly renewable.	Varies based on the material

amateur athletes and trainers, upgrading the design. Following J.F. Boles' framework, four essential steps were employed: problem generation needs assessment, prototype development, and evaluation. The prototypes were constructed using sustainable materials, enduring international specifications, and aligning with international trends in athletic shoe manufacturing. The study then progressed to developing and designing a virtual prototype eco-friendly sports shoe, utilizing advanced manufacturing techniques like 3D printing and waterless dyeing to minimize waste. incorporating biomimicry principles for enhanced efficiency.

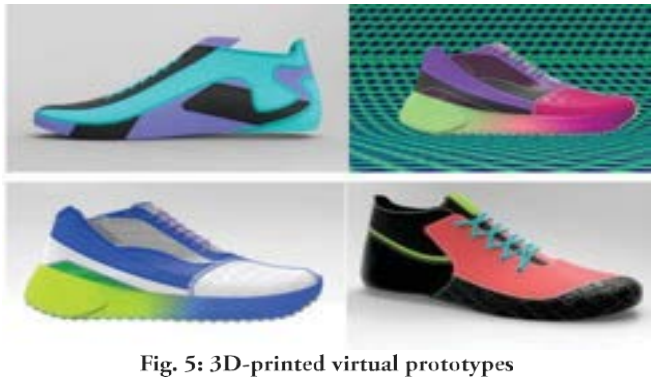

Fig. 5: 3D-printed virtual prototypes

Finally, consumer education was emphasized, with transparent communication about materials and production processes, highlighting the benefits of sustainable footwear and encouraging responsible disposal and recycling practices. This methodology aimed to balance performance excellence with ecological responsibility in sports footwear design for amateur athletes.

Results and Discussions

This study reveals a strong interest among amateur athletes in sustainable sports footwear, provided that performance is not compromised. The literature review and survey results indicate that while performance remains the top priority, a significant number of respondents are willing to pay a premium for eco-friendly options. The prototype development phase demonstrated that it is feasible to create a sports shoe that effectively balances sustainability and performance. Utilizing recycled polyester for the upper, natural rubber for the sole, and water-based adhesives resulted in a prototype with a significantly reduced environmental footprint. Performance testing confirmed that the prototype met essential requirements for comfort, durability, and support, making it a viable option for amateur athletes. However, challenges were identified, particularly in the areas of cost and scalability. Sustainable materials often come at a higher price, which can be a barrier for many consumers. Additionally, scaling up production while maintaining sustainable practices poses logistical challenges that need to be addressed. The integration of 3D printing in the production process offers promising solutions by reducing waste through precise material usage, enabling localized production, and allowing for customization, which leads to fewer returns and reduced waste. The study also highlights the importance of design features in influencing amateur athletes' preferences and psychological well-being. The prototypes, designed with innovative materials, ergonomic features, and vibrant colors, addressed the specific needs of amateur athletes. The psychological effects of color on athletes were also emphasized, with colors like red, yellow, and orange being particularly effective in eliciting strong emotions and enhancing performance. These colors can increase enthusiasm, focus, and energy, making them ideal choices for sports footwear aimed at boosting endurance and vigor. Surface decoration techniques like quilting and embellishments further improved comfort and aesthetics by providing targeted cushioning and visual appeal. Overall, the study illustrates the potential for creating sustainable sports footwear that meets the needs of amateur athletes without sacrificing performance or style.

Conclusions

The article emphasizes the importance of collaboration among designers, manufacturers, and consumers to drive sustainable innovation in sports footwear. By prioritizing both performance and eco-friendliness, we can create a positive impact on athletes, the environment, and the industry. The feasibility and desirability of designing eco-friendly sports shoes for amateur athletes are evident. Innovations like 3D printing and advanced knitting technologies allow us to create customized, high-performing shoes while minimizing waste. However, challenges related to cost and scalability remain. Overcoming these challenges involves optimizing production methods and finding cost-effective alternatives. Future research directions include streamlining sustainable manufacturing processes and investigating novel materials that balance performance, sustainability, and affordability. Educating athletes about the impact of their footwear choices is crucial. Ultimately, prioritizing both performance and eco-friendliness benefits athletes, the environment, and the industry, setting a positive precedent for responsible design. Sustainable sports footwear is a collective responsibility, and fostering collaboration and innovation will lead us toward a future where every athlete's performance is powered by eco-conscious choices.

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Unlocking the power of Indian wool: A sustainable path to achieving Sustainable Development Goals (SDGs)

Vinod Kadam
ICAR-Central Sheep and Wool Research Institute, Avikanagar, Rajasthan 304501, India

Abstract

United Nations adopted 17 interconnected Sustainable Development Goals (SDGs) to address various global challenges. While every sector attempts to contribute, the Indian wool sector can contribute to attaining several SDGs with its diverse applications in textiles, agriculture, construction, and environmental sustainability. Wool promotes responsible consumption (SDG 12), sustainable agriculture (SDG 15), and climate action (SDG 13) through biodegradable products, regenerative farming practices, and carbon sequestration. In textiles, Indian wool is used to create eco-friendly garments, carpets, and handicrafts, preserving traditional crafts while supporting rural economies. The wool industry also contributes to economic growth (SDG 8) by creating farming, processing, and manufacturing jobs. The product diversification of indigenous wool provides avenues of value addition and contributes to SDGs. Wool's use in agriculture as mulch and compost enhances soil health and reduces reliance on synthetic fertilizers, fostering sustainable farming practices. In construction, wool-based insulation materials help reduce energy consumption and promote green architecture. Beyond its versatile uses, wool's ability to be recycled and its minimal environmental footprint make it a valuable player in the circular economy. By tapping into the potential of Indian wool, we can create a more sustainable, resilient, and inclusive future. With continued innovation, Indian wool offers a pathway to environmental sustainability and economic development.

Keywords: *Sheep, Coarse wool, Environmental Sustainability, Renewable Resources, Eco-friendly Textiles, Diversified applications*

Introduction

The Sustainable Development Goals (SDGs), adopted by the United Nations in 2015, are a universal call to action aimed at eradicating poverty, protecting the planet, and ensuring peace and prosperity for all by 2030. Comprising 17 interconnected goals, they address global challenges such as inequality, climate change, environmental degradation, and access to quality education and healthcare [1]. The SDGs emphasize inclusivity and sustainability, urging collaboration among governments, businesses, civil society, and individuals to create a more equitable and resilient world. Key goals include ensuring clean energy, sustainable cities, responsible consumption, and partnerships for implementation. The SDGs provide a roadmap for balancing human progress with planetary health by integrating economic growth, social inclusion, and environmental protection [1,2]

Wool fiber, nature's gift to sheep, is significant in advancing various Sustainable Development Goals (SDGs) thanks to its natural, renewable, and biodegradable qualities. As a natural fiber, wool is fully biodegradable, meaning it decomposes without leaving harmful residues, contributing to SDG 12 (Responsible Consumption and Production) by reducing the environmental impact of waste. Wool production also promotes sustainable farming practices, as sheep are often raised in harmony with the land, grazing on pastures that help maintain healthy ecosystems and biodiversity, supporting SDG 15 (Life on Land).

Wool is a renewable resource, as sheep can be sheared annually, making it a sustainable alternative to synthetic fibers made from fossil fuels. The wool industry also supports rural economies by creating farming, processing, and manufacturing jobs, directly contributing to SDG 1 (No Poverty) and SDG 8 (Decent Work and Economic Growth). Wool is used in a wide variety of products, from clothing to insulation materials, helping

to create sustainable consumer goods, aligning with SDG 9 (Industry, Innovation, and Infrastructure) by promoting eco-friendly materials in manufacturing.

Additionally, wool's natural properties—such as its insulating, moisture-wicking, and flame-retardant qualities—make it valuable for creating energy-efficient clothing and building materials. By promoting the use of wool in these contexts, we can contribute to SDG 7 (Affordable and Clean Energy) and SDG 11 (Sustainable Cities and Communities). Finally, wool farming practices can be integrated into regenerative agriculture, which enhances soil health and helps sequester carbon, directly supporting SDG 13 (Climate Action) and the broader effort to mitigate climate change. With growing concerns over environmental sustainability and the need for eco-friendly alternatives to synthetic fibers, Indian wool has found increasing importance in sustainable development practices. This write-up delves into the diversified uses of Indian wool, emphasizing its role in promoting sustainability in textiles, agriculture, construction, and handicrafts.

Indian wool

India's wool industry is characterized by significant diversity in quality and production, yet it faces numerous challenges. The country produces approximately 40-45 million kilograms of wool annually, with Rajasthan, Jammu & Kashmir, Himachal Pradesh, and Karnataka being the major contributors [3, 4]. Indian wool is predominantly coarse (more than 35 µm), suitable for carpets and industrial uses, while fine wool (≤ 25 µm), essential for apparel, is limited [4-6]. This disparity arises from the dominance of mutton-purpose sheep breeds, which produce coarse wool, and the relatively low population of fine-wool breeds like Gaddi and Kashmir Merino. Consequently, India imports a substantial quantity of fine wool from countries like Australia and New Zealand to meet domestic demands for high-quality textiles.

The challenges facing the Indian wool sector include low productivity, poor genetic quality of indigenous breeds, inadequate marketing infrastructure, and a fragmented supply chain. Climatic changes, disease outbreaks, and limited availability of grazing land further constrain wool production [7]. Additionally, the traditional wool-processing industry suffers from outdated technology and a lack of skilled labor, affecting quality and competitiveness. Addressing these issues requires a multi-pronged strategy, including genetic improvement of sheep, enhanced pasture management, modernization of processing facilities, and integration of wool producers into organized supply chains. Diversification of Indian wool into various applications can open a plethora of avenues [6]. With targeted interventions and sustainable practices, India can tap into its potential to become a significant player in the global wool market.

Diversification of Indian wool

Fig. 1 shows the new application areas that gain researchers' interest in utilizing the unique properties of coarse Indigenous wool and its potential to contribute to various industries and address contemporary challenges. Such diversification can contribute to attaining SDGs by developing a sustainable value chain of unconventional products that are helpful to society.

Fig. 1: Diversified application areas of indigenous wool

Wool in Textiles, Fashion and Handicrafts

The Indian textile industry is one of the largest in the world, with wool playing a pivotal role in its growth. Indigenous fine wool is being used to manufacture apparel and garments. Indian wool is used extensively in producing clothing such as sweaters, shawls, coats, and suits [5]. Traditional woolen garments like the Pashmina shawl from Kashmir and woolen sarees reflect the rich heritage of India's wool craft. The fabric is known for its warmth, comfort, and softness, making it ideal for cold climates.

As synthetic fibers such as polyester contribute significantly to environmental degradation, the demand for natural fibers like wool is rising. Wool is biodegradable, and its production has a smaller carbon footprint than synthetic alternatives [8]. Designers and manufacturers are increasingly experimenting with wool blends and sustainable fashion to create eco-friendly collections. Indian wool is also used in innovative textile projects, such as biodegradable insulation materials and sustainable fashion lines promoting eco-conscious lifestyles.

Indian wool is valuable in the fashion and textile sectors and has deep roots in traditional crafts. Local artisans, especially in Kashmir and Rajasthan, have used wool for centuries to create beautiful, handcrafted products. Pashmina wool, known for its softness and fine texture, is handwoven into shawls and scarves. The production of Pashmina supports local economies, as it employs many artisans and their families. The value chain from sheep herding to the final product promotes rural development

and ensures the preservation of traditional handicraft techniques[9].

Woolen carpets, especially from Kashmir and Uttar Pradesh, have been highly regarded worldwide. This recognition is attributed to the lustre property of Indian breeds Magra in Rajasthan and excellent resilience in medium-grade wool owing to intermittent hollow space at the center of the fiber surface. Hand-knotted carpets are known for their durability, intricate designs, and luxurious feel. The wool used in carpets is sourced from various regions, supporting local shepherds and artisans. The wool industry thus contributes to preserving ancient craft techniques while promoting sustainable rural employment.

Wool felt, an ancient craft in India, is used to make bags, footwear, mats, and decorative items. These products are eco-friendly and help empower rural women artisans by providing them with a livelihood that preserves cultural heritage[9].

Wool in Agricultural Practices

Beyond its uses in textiles and handicrafts, Indian wool has significant potential in agricultural practices. It can contribute to sustainable farming and soil health. Wool can be used as mulch, plant-protecting sapling bags, and wool compost[6,10].

Wool is an excellent material for use as mulch in agricultural fields. It is biodegradable, providing long-term benefits by decomposing into the soil and enriching it with nutrients. Wool mulch retains moisture, reduces soil erosion, and suppresses weed growth, thus enhancing crop yield in dry regions[11]. Wool is also used to create sustainable compost. Its slow decomposition process helps improve soil structure, enhance water retention, and add organic matter. Using wool compost reduces the need for synthetic fertilizers, thus contributing to sustainable farming practices. Wool can be used as a natural plant protector. Such bags can replace plastic bags, improve soil fertility, and ensure better plant growth[12]. This eco-friendly alternative reduces the need for chemical pesticides and fertilizers, which harm the environment.

Wool in Construction and Insulation

As the demand for eco-friendly construction materials rises, wool has emerged as a sustainable option for building insulation[10, 13]. Using wool in construction helps reduce the environmental footprint and contributes to energy efficiency. Wool can typically be used for insulation and soundproofing in construction and building applications. Wool is increasingly used as a natural insulation material in the construction industry. Its thermal properties help in reducing heating and cooling costs in buildings. Indian Wool has recently experimented with eco-friendly home insulation products that maintain a comfortable indoor temperature, reducing reliance on energy-intensive cooling and heating systems.

Wool is also effective in soundproofing. It absorbs sound better than synthetic alternatives, reducing noise in buildings and other spaces. Using wool in soundproofing minimizes the need for chemical-based insulation materials, which can harm health and the environment. The growing trend of green architecture, which focuses on environmentally sustainable construction, has increased demand for wood-based materials. Wool carpets, wool-based insulation panels, and even wool cement are now used to construct sustainable buildings that align with eco-friendly building standards.

Wool in Environmental Sustainability and Carbon Sequestration

Wool, a natural fiber, is vital in combating climate change. Its sustainable production and biodegradability contribute to its positive environmental impact in three ways: carbon sequestration, sustainable land management, and wool recycling. Sheep, which produce wool, contribute to carbon sequestration[7]. Their grazing helps maintain grasslands, which act as carbon sinks by absorbing carbon dioxide from the atmosphere. Unlike synthetic fibers, biodegradable wool does not contribute to microplastic pollution.

Sustainable sheep farming ensures the responsible management of grazing lands. When combined with proper pasture management techniques, it can promote biodiversity and protect natural ecosystems. Wool and wool products can be reused and recycled multiple times. Waste wool is often processed into new products such as insulation materials, upholstery, and mattresses. This reduces waste and lowers the need to extract raw materials, making it a key player in the circular economy[8].

Conclusion

Indian wool offers a wide range of diversified uses that contribute significantly to sustainable development. From textiles to agriculture, handicrafts, construction, and environmental sustainability, wool provides an eco-friendly alternative to many synthetic materials. Promoting the use of Indian wool in various industries has the potential to drive economic growth while reducing environmental impacts. With continued innovation, research, and market development, Indian wool can be more prominent in supporting sustainability and creating a greener, more sustainable future. In summary, wool's role in sustainable development is multifaceted. It promotes environmental stewardship, economic growth, and social well-being while offering a renewable, biodegradable alternative to synthetic materials.

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Beyond the bandage: The environmental impact of medical textiles

Chirag R. Gajjar
Ph.D. NC State University, USA (alumni)

Abstract

Medical textiles are integral to modern healthcare, serving applications in wound care, implantable devices, personal protection, and hygiene. Amid increasing reliance on medical textiles, sustainability has become a pressing concern due to environmental challenges and the healthcare industry's significant carbon footprint. This paper explores the need for sustainability in the field of medical textiles, with the focus on adult incontinence products, emphasizing eco-friendly practices in material selection, lifecycle analysis, and recycling opportunities to reduce ecological impact. Key topics include the use of biodegradable polymers, recycled fibers, and natural alternatives. This paper addresses the challenges and opportunities in creating eco-friendly adult diapers that meet the rigorous performance, safety, and regulatory standards required in healthcare.

Lifecycle assessments (LCA) will illustrate opportunities for designing recyclable and reusable adult diapers while integrating circular economy principles. The paper also addresses barriers to sustainable adoption, including regulatory constraints, cost, and material performance trade-offs. By balancing innovation with environmental responsibility, the medical textile industry can lead the way toward a more sustainable and effective healthcare future.

Introduction

MEDICAL textiles are a specialized segment of technical textiles designed to cater to the unique demands of the healthcare and medical sectors. These textiles are integral to improving patient outcomes, providing hygiene, and enhancing comfort across various applications. Products such as wound dressings, surgical implants, and personal protective equipment (PPE) exemplify the versatility and significance of medical textiles. Their use extends to implantable devices, compression garments, and even wearable technologies, underscoring their role in advancing modern medicine.

Based on the definition given by the United States Food and Drugs Administration (US FDA) [1], a medical device is "an instrument, apparatus, implement, machine, contrivance, implant, in vitro reagent, or other similar or related article, including a component part or accessory intended for use in the diagnosis of disease or other conditions, or in the cure, mitigation, treatment, or prevention of disease. It does not achieve its primary intended purposes through chemical action within or on the body." On the other hand, if a medical device or any of its component consists of fiber, yarn/filament, woven/knitted fabric, braided structure or nonwoven substrate it can be considered as a medical textile. Medical textiles are further classified as Bio-Textile (or Biomedical Textiles) which are the structures composed of textile fibers designed for use in specific biological environments where their performance depends on biocompatibility and biostability with cells and biological fluids[2]. Bio-textiles include devices implanted in the body, such as surgical sutures, hernia repair fabrics, arterial grafts, artificial skin, and parts of artificial hearts. Medical textiles, on the other hand, include everything from bandages, wound dressings, and splints to orthotic devices and clothing used for rehabilitation. Hospital linens, barrier fabrics, protective clothing, and operating room scrubs are also medical textile products. US FDA classifies medical devices into Class I, Class II and Class III devices, based on the risk to the patient, Class III being highest risk (Figure 1). Accordingly, Class II and Class III device go through more rigorous testing and scrutiny before the approval by US FDA.

Fig. 1: Different Classes of Medical Textiles

The combination of innovative materials and sophisticated manufacturing processes has enabled medical textiles to meet stringent requirements for biocompatibility, sterility, and functionality. However, this sector also faces pressing challenges related to environmental sustainability. Many medical textiles rely on synthetic, non-biodegradable materials and are predominantly single use, leading to significant waste generation. Moreover, their production processes often involve high energy consumption and resource use, contributing to their environmental footprint.

While the field of medical textiles has a wide spectrum of end-use devices, this paper focuses on adult incontinence products. This paper examines the dual challenge of maintaining the high-performance standards of adult diapers while addressing their environmental impact. By exploring innovative materials, lifecycle design principles, and regulatory measures, it aims to present a path forward for achieving sustainability in this critical industry.

Adult Incontinence Products

Adult Incontinence Products, also known as Absorbent Hygiene Products (AHPs) is a category name for adult diapers and incontinence pads. The basic design of an adult diaper consists of four main components as shown in Figure 2[3].

The top sheet is a polypropylene (PP) nonwoven film with a primary function to transfer liquid excreta to internal layers while remaining relatively dry. The acquisition system consists of an acquisition and distribution layer (ADL). ADL comprises of modified cellulose patch and a super-absorbent polymer (SAP). SAPs are synthetic materials capable of absorbing and retaining liquids up to 1000 times relative to its mass. Sodium Polyacrylate is the most common type of SAP used in disposable diapers[4]. The absorbent core is the innermost layer of the diaper and is composed of blend of SAP and cellulose fluff. The primary function of the absorbent core is to retain and lock-in the excreta fluids. The bottom layer of the diaper is a water-resistant low-density polyethylene (LDPE) film intended to prevent the leakage of liquids from the diaper to the outer clothing. A typical composition of a disposable diaper according to EDANA standards is shown in Table 1.

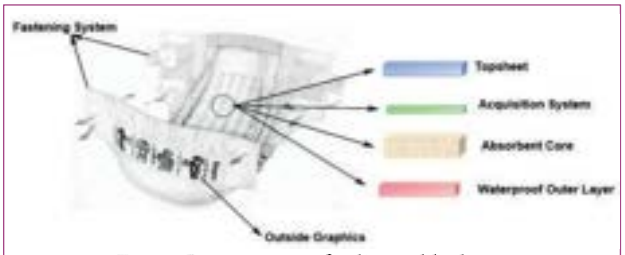

Fig. 2: Construction of a disposable diaper

Table 1: Composition of a disposable diaper

	EDANA, 2007
Fluff Pulp	35%
SAP	33%
PP	17%
LDPE	6%
Tapes, Elastics, and Adhesives	9%

Environmental Impact of Disposable Diapers

While the adult diapers are very helpful in maintaining hygiene and providing nursing care for the elderly population, disposing of adult diapers and incontinence products poses significant environmental challenges due to their composition, widespread use, and lack of recycling systems. Key challenges include:

High Volume of Waste

The global demand for adult diapers and incontinence products has surged due to factors such as aging populations, increased awareness about incontinence care, and higher living standards. Over 60 billion disposable diapers and other adult incontinence products are used annually worldwide. This number is expected to increase in the coming years due to increasing aging populations and chronic health conditions. India is also witnessing a rise in the use of adult diapers and incontinence products due to an aging population, chronic health conditions, increasing urbanization, and improved healthcare access. It is estimated that 2 billion adult diapers are used annually in India, and this number is increasing. Disposable diapers (infant and adult) contribute 2-5% of municipal solid waste in urban areas like Mumbai, Delhi, and Bangalore. India's population aged 60 and above is projected to reach 319 million by 2050, increasing the demand for incontinence care products. Improved diagnosis and treatment for conditions like urinary incontinence, diabetes, and prostate issues are driving the adoption of adult diapers.

Non-Biodegradable Components

Disposable diapers contain plastics, synthetic fibers, and

superabsorbent polymers (SAPs), which are non-biodegradable. Moreover, the combination of organic waste (urine and feces) and synthetic materials makes separation and recycling complex and costly. Disposal in landfills is the most common approach leading to long-term environmental persistence, with decomposition taking hundreds of years.

Limited Recycling Options

AHPs consist of complex materials such as plastics, cellulose, and superabsorbent polymers, which are difficult to separate effectively. Existing technologies for recycling AHPs often struggle to achieve the purity needed for secondary material recovery, leading to inefficient processes and limited market applications for recycled products[5]. Additionally, hygiene concerns related to handling used AHPs introduce logistical and health risks, requiring robust sanitization steps that increase processing costs and complexity[6].

Economic viability is another hurdle, as recycling AHPs competes with cheaper landfilling and incineration options. Innovative methods like SAP recovery can reduce environmental impacts significantly but remain underutilized due to high operational costs and energy demands. Many waste management systems lack infrastructure for AHP collection and segregation, particularly in low-income areas.

In India, specific challenges include a lack of effective waste segregation and recycling infrastructure, which leads to significant quantities of these products ending up in landfills or open dumps. This not only poses environmental risks but also impacts sanitation and public health.

Greenhouse Gas Emission

Life Cycle Assessments (LCA) have identified key environmental hotspots, including the energy-intensive production of materials like superabsorbent polymers and polypropylene, which are major contributors to carbon and ecological footprints[7]. In addition, the disposition of adult diapers is another major contributor of greenhouse gases. For example, when disposed of in landfills, decomposition of organic components releases methane. Incineration, another common disposal method, emits toxic pollutants and CO_2. Figure 3 shows environmental hotspots during the product lifecycle for AHPs.

Water Contamination Risks

In India, specific challenges include a lack of effective waste segregation and recycling infrastructure, which leads to significant quantities of these products ending up in landfills or open dumps. This not only poses environmental risks but also impacts sanitation and public health. Improper disposal or leakage in landfills can lead to the leaching of chemicals and pollutants into groundwater, thereby posing water contamination risks.

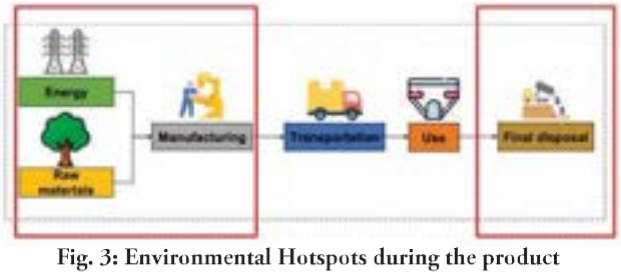

Fig. 3: Environmental Hotspots during the product lifecycle for AHPs

Potential Solutions

Biodegradable Materials

In one study, reusable menstrual products, such as washable pads, outperformed disposable AHPs in LCA studies conducted in India, achieving up to 99% lower environmental impact scores[8]. These results underscore the importance of promoting reusable options to mitigate environmental impact. There are numerous biodegradable linear aliphatic polyester polymers that could be used as alternative materials. Although more costly, use of biodegradable materials like polylactic acid (PLA) fibers and compostable SAPs should be encouraged.

Recycling Innovations

Emerging innovations in recycling AHPs should focus on reducing their environmental burden by transforming waste into valuable resources. Advanced recycling techniques include processes that separate and recover materials like plastics and cellulose. One notable approach is mechanical-thermal treatment, converting AHP waste into fluff material, which holds potential for energy recovery if integrated with improved processes. Biological recycling methods, which utilize microbial decomposition, are gaining attention for their ability to handle organic components in a more sustainable manner. Studies reveal that recycling processes can result in net environmental benefits, reducing CO_2 emissions and conserving energy compared to traditional landfill and incineration methods [9]. Additionally, novel applications of recycled superabsorbent materials have emerged, such as their use as additives in self-compacting concrete to improve material properties and sustainability [10].

Education and Awareness

Media campaigns should be initiated to promote awareness about the environmental impact of disposable incontinence products and to encouraging consumers and caregivers to adopt reusable alternatives and eco-friendly disposal practices. Efforts should also be made to train waste-pickers for the segregation and hygienic disposal of adult diapers. Local municipal corporations should install collection bins in healthcare facilities and residential areas.

Policy Interventions

Government regulations should promote sustainable designs, reduced use of plastics, and subsidized waste management

initiatives. Local governments should consider regulations requiring manufacturers to take responsibility for post-consumer waste management (Extended Producer Responsibility - EPR).

Conclusion

This paper reviews the environmental impact of adult absorbent hygiene products. Life Cycle Assessments (LCAs) for absorbent hygiene products (AHPs) in India reveal significant environmental challenges and opportunities for sustainable waste management. Studies highlight that production and end-of-life stages contribute substantially to environmental impacts, particularly through greenhouse gas emissions and material resource depletion. Incineration, landfill, and recycling are commonly evaluated disposal pathways, with recycling emerging as a promising alternative due to its potential to recover valuable materials like plastics and cellulose. However, these methods face technical and economic challenges in India due to inadequate infrastructure and waste segregation systems. Comprehensive LCAs of AHPs emphasize the need for integrated waste management strategies, combining recycling technologies, behavioural interventions, and policy reforms. Strategies such as extended producer responsibility and incentivizing the use of biodegradable materials could further reduce environmental impacts. Moreover, public awareness campaigns and infrastructure development are critical to overcoming challenges specific to India, including mixed waste streams and informal disposal practices.

With the increasing demand for adult incontinence products, sustainable practices are not just an option; they are a responsibility!

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Design and development of smart zonal sports apparels & accessories

Yamini Jhanji[1], **GK Tyagi**[2] **& Priti Sheoran**[3]
[1]*Associate Professor, Department of Textile Technology*
[2]*Professor & Director, The Technological Institute of Textile & Sciences, Bhiwani, Haryana, India, 127021.*
[3]*Assistant Manager, Pearl Global Industries Limited, Gurgaon.*

Abstract

Sportswear is an emerging domain of technical textiles that has witnessed humongous growth in the recent times owing to acceptance of the clothing category both as professional and leisure wear. Sport-specific clothing is worn for enhanced performance, comfort and safety aspects. A considerable amount of research and innovation is involved in design and development of sportswear owing to a myriad of functional and performance requirements that sports person seek in their attire. Furthermore, the requirements vary as per the sportsperson's level of physical activity, ambient conditions and specific sport. Accordingly, the sportswear can be categorized into performance, basic, leisurewear and fashion clothing. Performance wear is technology-driven sportswear category that enhances the functional attributes associated with clothing. The clothing category is intended for sportspersons involved in rigorous physical activity and is generally custom made in smaller quantities owing to their exorbitant prices. Contrastingly, basic sportswear is designed with a prime focus on aesthetics, silhouette and affordability rather than performance, primarily intended for the mass public. Sports leisurewear, a cheaper replica of performance sportswear is preferred by millennials who indulge in leisure or light physical activities indoors. Undoubtedly, the varied categories of sportswear clothing should exhibit the primary requirement of being lightweight, comfortable, breathability and agility to the wearer. Thermo- physiological comfort involving consideration of heat, moisture vapour and liquid moisture transmission is of utmost importance while designing sportswear for particular sports. The agility to wearer, light weight, durability, anti-odour, antimicrobial and antistatic properties are some other crucial aspects considered while designing sportswear. The design and development of sportswear with optimum, desirable, sport specific property thus involves considerable brain storming and research as far as selection of appropriate raw materials, ergonomics, sizing and incorporation of smart features to monitor physiological parameters of sportspersons are concerned.

A myriad of innovative fibres, yarns and fabric structures are thus being explored for engineering sports textiles. The trend of wearables around arms or legs worn by sportspersons to monitor their fitness and other health parameters is bygone with the inception of smart sportswear that behaves intelligently and can monitor sportsperson's physiological parameters owing to high performance, smart fibres and yarns like optical fibres, conductive yarns, thermo-chromic materials, shape-memory materials, that impart smart functionality to the fabric. Furthermore, introducing some salient smart features like GPS, music playing, phone charging, monitoring sportsperson's physiological parameters, stress relaxation and intensity of activity or workout are hailed and readily accepted by sportspersons who prefer performance clothing laced with technology. Sportswear is not just crucial for athletes and sports persons but this clothing segment has become an integral and inseparable part of users' routine activities like morning walk, jogging, yoga, stretching exercises and daily fitness activities owing to comfort, easy care properties and enticing aesthetic appeal of sports clothing.

The present study was undertaken to design and develop smart zonal sportswear and accessories intended for low to dynamic physical activities (such as tennis, and badminton). The developed prototypes were subjectively evaluated by wearers in dynamic conditions to rate the effectiveness of the ensembles. The subjective evaluation of the prototypes suggested that although wearers did not hesitate to wear a sensor embedded clothing however, they were wary of the frequent need of sensor detachment during garment washing. Likewise, the subjects approved the concept of unconventional styling in sportswear but at the same time suggested further aesthetic appreciation of designed ensembles.

Keywords: *Aesthetics, Design, Clothing, Comfort Sports, Leisure, Moisture, Performance, Sensor, Smart, Thermal.*

Introduction

SPORTSWEAR is defined as the clothing worn by the sportsperson while playing different sports. Sport-specific clothing is worn for practical, comfort or safety reasons. Sportswear is one of the most promising and fastest-growing segments of technical textiles. A considerable amount of research and innovation is involved in the design and development of sportswear owing to a range of functional and performance requirements that sportspersons seek in their attire. Furthermore, the requirements vary as per the sportsperson's level of physical activity, ambient conditions and specific sport. Accordingly, the sportswear can be categorized into performance, basic, leisurewear and fashion clothing. Performance wear is technology-driven sportswear category that enhances the functional attributes associated with clothing. The clothing category is intended for sportspersons involved in rigorous physical activity and is generally custom made in smaller quantities which accounts for their exorbitant prices. Contrastingly, the basic sportswear is designed with prime focus on aesthetics and silhouette rather than performance, caters to the demands of mass public and are available at lower price points. Sports leisurewear, a cheaper replica of performance sportswear is preferred by millennials who indulge in leisure or light physical activities indoors [1]. Undoubtedly, the varied categories of sportswear clothing should exhibit the primary requirement of being light weight, comfortable, breathability and providing ease of movement for wearer. Thermo-physiological comfort involving consideration of heat, moisture vapour and liquid moisture transmission is of utmost importance while designing sportswear for particular sports. The agility to wearer, light weight, durability, anti-odour, antimicrobial and antistatic properties are some other crucial aspects considered while designing sportswear [2-4]. The design and development of sportswear with optimum, desirable, sport specific property thus involves considerable brain storming and research as far as selection of appropriate raw materials, ergonomics, sizing and incorporation of smart features to monitor physiological parameters of sportspersons are concerned. A myriad of innovative fibres, yarns and fabric structures are thus being explored for engineering sports textiles. The trend of wearables around arms or legs worn by sportsperson to monitor their fitness and other health parameters is bygone with inception of smart sportswear that behave intelligently and can monitor sportsperson's physiological parameters owing to high performance, smart fibres and yarns like optical fibres, conductive yarns, thermo-chromic materials, shape memory materials, that impart smart functionality to fabric[5]. Furthermore, introducing some salient smart features like GPS, music playing, phone charging, monitoring sportsperson's physiological parameters, stress relaxation and intensity of activity or workout are hailed and readily accepted by sportspersons who prefer performance clothing laced with technology. Sportswear is not just crucial for athletes and sports person but this clothing segment has become an integral and inseparable part of users' routine activities like morning walks, jogging, yoga, stretching exercises and daily fitness activities owing to comfort, easy care properties and enticing aesthetic appeal of sports clothing [6-9].

Desirable properties in Sportswear

The requirements for an active sportswear can be as classified in two groups, namely

- Functional- light weight, low fluid resistance, high tenacity, stretchability, thermal regulation, UV protection, vapour permeability, and sweat absorption and release
- Aesthetics- softness, surface texture, handle, luster, colour, and comfort.

Apart from these general requirements, sportswear has to perform other functional activity related to a specific sport.

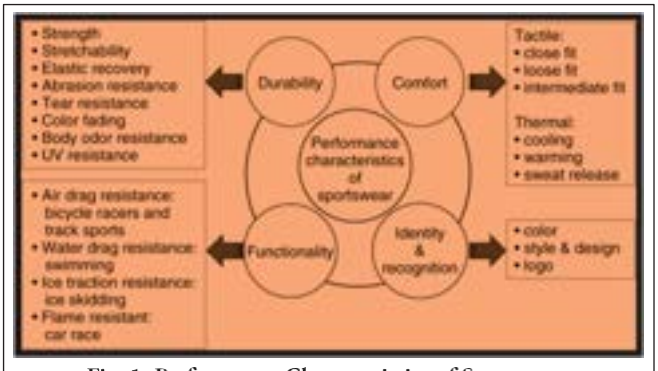

Fig. 1: Performance Characteristics of Sportswear

Comfort properties

Comfort is the one of the most important properties of sportswear. The sportsperson's performance is highly dependent on the comfort of clothing. For outdoor activities the clothing should protect the wearer from external elements such as wind, sun, rain and snow. At the same time, it should maintain the heat balance between the excess heat produced by the wearer and the capacity of the clothing to dissipate body heat and perspiration. The human body has an operating temperature of 37°C which should be maintained under all circumstances for proper comfort. To prevent excess température rise, the heat must be dissipated outward simultaneously. The human body can excrete half a liter or a whole liter of perspiration per hour provided that this process is not impeded by the relative humidity of its environment & clothing. Comfort is difficult to define since it covers both subjective considerations and quantifiable data.

Clothing comfort encompasses

- Thermo-physiological comfort: This form of comfort is related to thermal balance i.e. the rate of loss of heat from the body should be equal to the rate at which it is being generated. If the rate is imbalanced, it can cause discomfort.
- Sensorial/tactile comfort: The sensorial comfort is related to how the person feels when clothing is worn next to the skin.

Wet feeling can be a major source of sensorial discomfort in situations of profuse sweating. If the skin is wet and the sweat is not released by the clothing then an unpleasant feeling with wetness will occur. Also, the clothing which is next-to-skin will stick to body which will hinder the movement of sports person.

- Mobility: In sports a lot of body movement occurs. The sportswear must have sufficient amount of mobility so that wearer can be able to move freely. Too much volume, too much weight or too much stiffness of fabric will reduce the mobility and lead to discomfort. The clothing should have low stretchability and fluid resistance.
- Psychological comfort: The feeling of the wearer that he or she is dressed in a style means the psychological comfort. This is related with aesthetic appeal. From top-level professional sport person to amateurs, all demand psychological comfort to some extent along with other three comforts [10-12].

Wicking

Wicking is the transport of moisture through a fabric. Moisture can pass between fibres, yarns and through the fibre itself. The ability for moisture to pass through a fabric will depend on the fabric construction and the fibre type. Synthetic fibres tend to dry quickly and are the most commonly used fibre in athletic wear now. The moisture is transported via capillary action. Moisture management in textiles is a challenge during physical activities that need to be addressed to ensure maximum comfort to the sportsman. The sports garments worn as second skin should have good, transmission, sweat absorption and desorption properties. The synthetic fibres are preferred over the natural fibres as they do not retain moisture and keep the garment dry and lighter in wet condition. Due to lower liquid absorbency wet synthetic fibres dried faster [13-15].

Breathability

When high intensity exercise takes place, sweating will occur to evaporate heat off the skin. If clothing is not breathable than there is nowhere for the moisture to escape. This causes moisture to build up inside the garment and on the skin resulting in the body getting hotter. Another consequence is when exercise decreases and heat stops being generated from the body, the moisture (which is less insulating than still air) will then increase heat loss rapidly, especially in a cold environment. From this we can conclude that clothing needs to prevent rain and wind from getting in but at the same time allow moisture from the inside to escape out. This process is known as water vapour transmission and fabrics which are able to do this are known as waterproof breathable fabrics. It can be produced by three technologies, such as High-density fabric, Coated fabrics, Film laminate [16-18].

Smart materials

Smart materials possess the capability of responding to external stimulus such as change in the ambient conditions from mechanical, thermal, chemical, electrical or magnetic sources. Figure 2 shows the different components of smart clothing like sensors, actuators, controlling unit and the mode of responding to external stimulus.

Sensors: are used to sense the stimulation in external environment and send it further for reaction. Actuators: collect the sensed signal directly or from a central control unit; together with the sensors. Controlling Unit: is analogous to human brain with cognition, reasoning and activating capacities. [4]

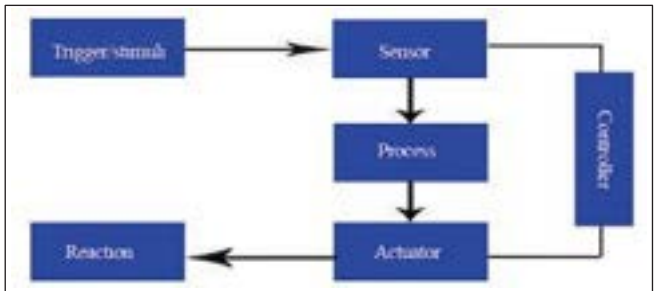

Fig. 2: Different components of smart clothing

Innovative approaches for smart sportswear designing

A major challenge in designing smart sportswear is engineering smartness without compromising the inherent textile characteristics like handle, softness, light weight, washability, easy care properties, durability and comfort. Therefore, the conventional approach of designing smart sportswear by integration of external sensors, light emitting elements, electronic circuitry and batteries have gradually undergone transformation with the inclusion of high performance and smart fibres, yarns, fabric structures and innovative printing and finishing technologies. Figure 3 shows the innovative fibres, yarns and fabric structures used for sportswear development. The technological innovations at the fibre, yarn, fabric and finishing stage are discussed in the following section.

Hygra is a preferred choice for designing active sportswear owing to its superior antistatic properties and exceptionally high-water absorbing ability that is crucial to maintain dry

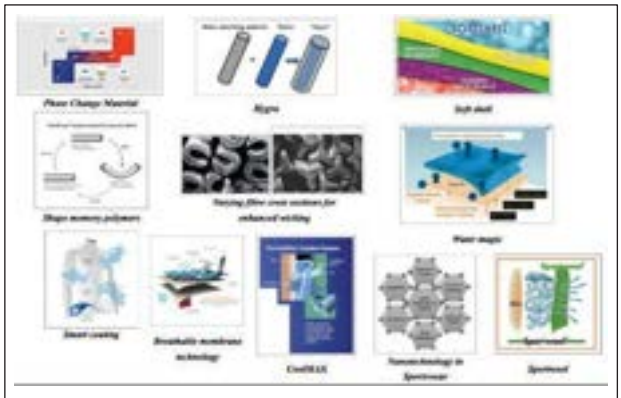

Fig. 3:Innovative Sportswear fibres, yarns and fabrics

microclimate for the sports person. The water absorbing ability of the fibre is attributed to the core-sheath filament composed of fibre made of water absorbing polymer and nylon. The water absorbing polymer can absorb 35 times its own weight of water and provide rapid dry ability of sports clothing while strength and dimensional stability is ensured by the core composed of nylon fibre.

Dryarn, a recyclable microfiber results in light weight, antibacterial, comfortable, soft handle and quick drying fabric with excellent thermal regulation and thus is suitable for smart sportswear [5,6].

Killat N is suitable for active and performance wear owing to its rapid liquid transmission property by capillary wicking. The bi-component filament yarn is composed of soluble polyester copolymer core and nylon sheath. The water absorbency and heat retention characteristics are provided by nylon in sheath while capillary action for liquid transmission and creation of air pocket is due to hollow core produced by alkali dissolving of polyester copolymer core [6,7].

Triactor features Y shaped cross section thereby increasing the channels for capillary wicking and thus the fabric composed of this polyester variant exhibits faster release of perspiration.

Coolmax is another popular fibre generally used for sportswear owing to improved wicking capability and moisture vapour permeability that the double scalloped fibre exhibits.

Soft shell fabric features three layers namely the upper, middle and innermost layer. The upper layer is water repellent polyester, middle layer, the breathable membrane and innermost layer of micro fleece that provides good thermal insulation. The fabric is designed to impart wind and weather resistance, good breathability and freedom of movement along with maximum wearer comfort in different environmental conditions [8,9].

Naiva fabric is another specialty fabric suitable for mountaineering and active sportswear exhibiting good moisture permeability, light weight and soft feel. The fabric is composed of 55% Eval and 45% nylon, with Eval being copolymer resin of ethylene vinyl-alcohol [8,9].

Field Sensor is a high-performance multilayered fabric composed of coarser denier yarn in outer layer and inner layer of fine denier hydrophobic polyester. The variation of yarn coarseness in inner and outer layer of fabric results in quick sweat evaporation from fabric surface [8,9].

Phase change materials also referred to as latent heat storage materials find application in sportswear and cold weather clothing owing to their salient characteristic of changing their phase in response to external ambient conditions of variable temperature. The PCM can be applied to textile substrates as microcapsules that liquify and store heat energy at elevated temperatures whereas the paraffin solidifies and releases the stored heat as the temperature drops down [10].

Shape memory polymers in response to external ambient conditions like temperature, pH and chemical can respond and adapt by changing their shape and memorizing the previous shape. The materials find application in smart sportswear and winter wear for achieving enhanced thermal insulation [11,12].

Membrane technology utilizes a thin polymeric membrane films of thickness of the order of 10 microns that can be coated on a textile substrate to render it waterproof, windproof and breathable. Micro porous and hydrophilic membrane are generally utilized for imparting water proofing and breathability in smart sportswear.

Smart coatings are effective in reducing the air drag to which cyclists, sprinters and swimmers are exposed to as they indulge in high-speed performance sports. The state of art biometric swimsuit Fastskin® is inspired from shark's skin which features specially articulated scales on its surface intended to reduce the drag through water [13-15].

Nano materials for smart sportswear Nano materials namely carbon nano fibres, nano clay, silver nano particles, nano nickel and carbon nanoparticles are increasingly finding application in smart sportswear as the nano finished textiles exhibit several salient features like UV, wind and water resistance, self-cleaning and antimicrobial properties [16-18]. One such state-of-the-art swim wear modified with nanoparticles is capable of reducing the absorption by 2% of fabric weight [19].

Water magic, a three-layered knitted fabric composed of 67% polyester and 33% nylon ultra-fine microfibre features innumerable random and minute pores that quickly transport perspiration from the wearer's skin to outer layer and thus provide dry, comfortable feel to the sportsperson [20-21].

Sportwool® by Woolmark is composed lightweight, machine washable fine merino wool and polyester exterior. The exceptionally high thermal insulation, UV protection and rapid sweat dissipation makes the fabric suitable for cold weather clothing and sportswear.

Fig. 4: Smart sportswear to monitor sports person's physiological parameters

Smart sportswear for health and well-being monitoring

The unique and smart features offered by smart sportswear

make them suitable for a range of performance and functional based applications as enlisted below:

Performance and data analysis

An important aspect of sportswear encompasses maximizing human performance, improving and monitoring sports person's performance. Watches or strap bands equipped with sensors are capable of recording a range of wearer's physiological data such as distance covered, steps taken, calories burnt, speed of the activity and body temperature etc. The integrated sensors in the wearer's clothing are capable of monitoring health related parameters and in turn recording temperature, sweat and muscle movement and even the athlete's emotional response. The real time data recorded can be viewed or even retrieved for later use to track a sportsperson's performance. The data can be systematically analyzed to guide the sportsperson to improve and work on their technique, fitness level and even to avoid injuries[6].

Health monitoring

The smart sportswear ensemble is increasingly being incorporated with sensors exhibiting the capability of measuring body functions and biomechanics such as heart rate, breathing, lung capacity and perspiration or the muscle and joint movement. Smart sportswear so designed with integrated sensors can portray several salient and smart features like timely monitoring of any health ailment, reduction or elimination of injuries and prediction of injuries before hands as a result of Artificial Intelligence based analytics [6,7]. Several sportswear brands are offering technology laced, wearable sensors that cannot just monitor sportsperson's health related parameters but can serve as their personal coaches by providing data pertaining to workout patterns, intensity and speed of activity so that athletes can improvise based on the obtained data (Figure 5).

Fig. 5:Engineering Smartness into sports apparels & accessories

Materials & Methods

Materials

Polyester & Polyester spandex blended fabrics of varying aerial density, stitch density, thickness and structures namely Interlock, Mesh & Single jersey structures were used for preparation of sportswear attires. The fabric samples were procured from VPL Polytex, Ludhiana. The five knit structures were used for the development of sportswear apparels and accessories. The developed sportswear were integrated with solar panels, vibrator, wires, silica gel bands, with the components procured online.

Methods

The procured fabric samples were tested for their physical properties (course and wale density, stitch density, aerial density, bulk density, fabric porosity, loop length and tightness factor). Structured and semi structured questionnaires were designed for subjective evaluation of sportwear prototypes. The subjects chosen for the study primarily comprised of teenagers and sports enthusiasts aged 13-28 years who had penchant for performance sports or any light physical activity (Figure 6)

The product development process involved procurement of sportswear fabrics from fabric suppliers supplying to major sportswear brand, conducting market surveys and subjective trials to garner information pertaining to consumers requirements in terms of styling, design elements and aesthetic appreciation of sports attire and development of mood board and story board thereof. Subsequently flat sketches were prepared based on obtained feedback from subjects related to stylization and designing attributes of the subjects. The protyping phase involved development of virtual and physical prototypes followed by integration of smart gadgets thereof (Figure 7 & 8). Eventually, the developed protypes were subjectively evaluated by wear trials wherein dedicated subjects were expected to doff and donn the developed sports apparel and accessory and performance light to moderate physical activity. The subjects were free to choose the activity as per their convenience and liking. The wear trails were followed by feedback obtained through structured questionnaire filled by subjects pertaining to comfort, stylization and design attributes of developed sports prototypes.

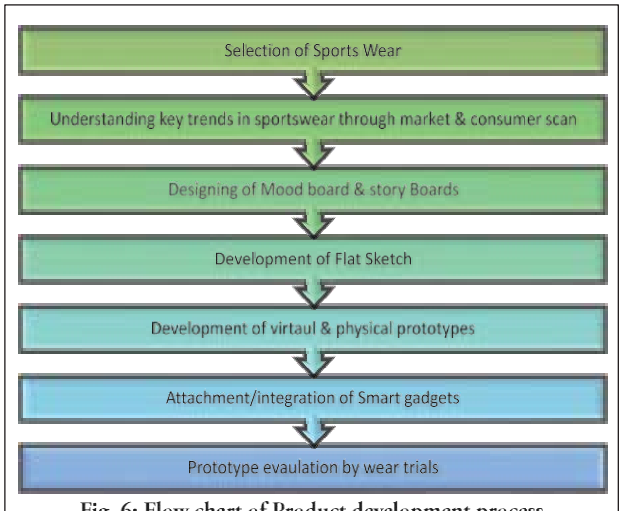

Fig. 6: Flow chart of Product development process

Fig. 7: Mood board & Story board for Smart zonal sportswear design & development

Fig. 8: Flat Sketches for sportswear apparels & accessories

Development of Sports wear

The procured sportswear fabrics were utilized for development of physical prototypes. The pattern making was followed by assembling the individual components of respective apparels and accessories to obtain the final three-dimensional ensembles. The garment components were stitched on JUKI machine (MF-7723) in New ADC Lab in TIT&S College, Bhiwani. Figures 9 and 10 shows the virtual and physical prototypes developed for the study.

Solor panels, vibrator, knee band, wrist band, elbow band with silica gel were subsequently attached to the developed sports attire and accessories.

Solar Panel Integration

It was intended to further enhance the functionality of designed sportswear. Henceforth, solar panels were integrated in developed t-shirt which served as energy harvesting device and could assist the sportsperson to charge their gardget, specifically a mobile while on the move or involved in any activity. A complete set of sports uniform including T-Shirt, Shorts & base ball cap was designed.

Vibrator Attachment

The vibrator that are integrated into the wrist band was reused & taken from the damageded mobile phone attached with a battery taken from a damaged headphone. To increase the frequency of the vibration more vibrator could be attached. Thes wrist band prototype was developed with two vibrators attached on a elastic with battery and a switch.

Neoprene Elbow Band

Neoprene elbow band was designed to support the elbow of sports person in the event of any unprecedented injury. The elbow band was designed from neoprene fabric and the upper layer of the band was covered with 100% interlock fabric.

Socks with Silica gel heel

The socks were constructed with 90/10 Polyester Lycra blend to impart stretchability to the wearer. A silica gel constructed heel was attached within the socks in heel turn area thereby relieving the sports person from pain due to sprain or injury.

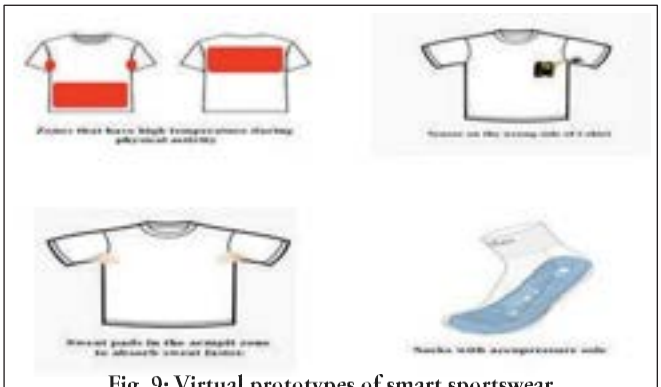

Fig. 9: Virtual prototypes of smart sportswear

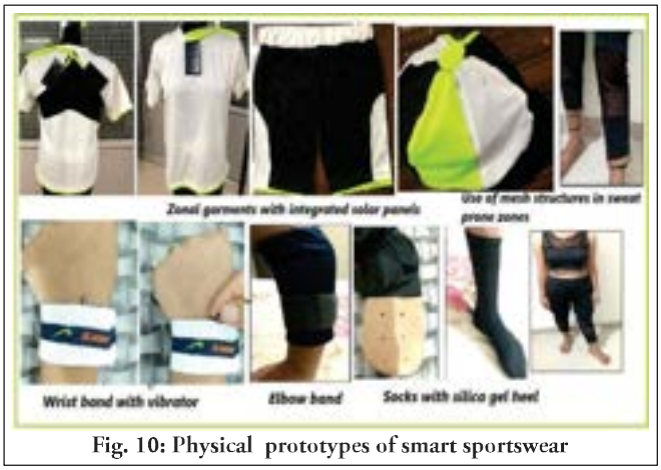

Fig. 10: Physical prototypes of smart sportswear

Zonal Garment

The zonal garment prototypes were constructed on Single needle lockstitch machine and finally finished with serger machine.

Results & Discussion

81% respondents gave precedence to comfort in their sportswear attire with just 9% concerned about the durability of the sportswear (Figure 11). The subjects preferred wrist bands, knee and elbow bands as the next to skin accessory when indulging in light physical activity. Almost equal number of subjects preferred 100% cotton and polyester/cotton based next to skin clothing while only a small percentage of the subjects gave consideration to price over fabric type while choosing sports attire. The subjects were aware and responded that lightweight, stretchability, agility to wearer are most sought out attributes for their summer merchandise. 53% respondents approved of sportswear with some pain relief features engineered into it. A solar panel attached to sports attire for energy harvesting was well received concept by almost 40% respondents who believed that the feature could enable charging their electronic gadgets while walking, jogging or in any such situation when they do not have access to charging point. 46% respondents were of the view that zonal garments were effective in sweat dissipation and goo percentage of respondents namely 22% found the attire comfortable. A vibrator attached in sports accessories (wrist band) as a pain relief concept was well received by almost 46% of the respondents. Silica gel inclusion in sports socks for therapeutic relief was regarded an interesting concept by 68% subjects while 8% were wary of increased weight as a result of its inclusion in the socks. 62% respondents found the concept of elbow band interesting that could offer some pain relief to sportsperson against muscle sprains.

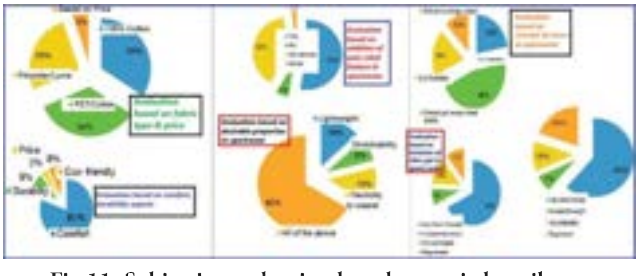

Fig.11: Subjective evaluation based on varied attributes of developed sportswear

Conclusions

The functional & design features of smart sportswear were studied. The consumer & market scan were the basis of virtual & physical smart sportswear design & development. The result of subjective trials suggested that 81% respondents gave precedence to comfort in their sports attire with just 9% concerned about the durability of the sportswear. The subjects preferred wrist bands, knee and elbow bands as the next to skin accessory when indulging in light physical activity. Almost equal number of subjects preferred 100% cotton and polyester/cotton based next to skin clothing while only a small percentage of the subjects gave consideration to price over fabric type while choosing sports attire. The subjects were aware and responded that lightweight, stretchability, agility to wearer are most sought out attributes for their summer sports merchandise.

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Sustainability in textiles and clothing: A call for responsibility, awareness, and action

Nirbhay Rana*
Assistant Professor, IILM University Gurugram

IT is an honor to contribute to the NISTI-IIT Delhi Conference on Sustainability in Textiles and Clothing, an initiative that exemplifies the power of collective thought in revolutionizing the textiles and clothing industry toward a sustainable future. This gathering is not just a meeting of minds but a platform to catalyze transformative change, pushing the boundaries of innovation, responsibility, and awareness in one of the world's most resource-intensive industries. As an educator and advocate for sustainability, I firmly believe that this platform provides a unique opportunity to inspire meaningful change. The very essence of this conference aligns with my personal and professional mission: to promote awareness, responsibility, and action for sustainability across all dimensions of society.

The Dichotomy of the Industry

The textile and clothing industry is both a vibrant driver of cultural expression and a significant contributor to economic growth. Yet, it is also one of the largest consumers of natural resources and a major source of pollution. This dichotomy demands urgent attention. Events like this conference are pivotal in addressing these challenges by fostering innovative solutions, best practices, and actionable strategies to minimize the industry's environmental footprint. Through initiatives like this, NISTI-IIT Delhi is setting a benchmark for how collective action can lead to systemic change.

Sustainability in Education: The Foundation of Change

Education is the cornerstone of any sustainable movement. The challenges we face today—climate change, resource depletion, and waste mismanagement—cannot be resolved without raising awareness and instilling responsibility among future generations. This conference provides an ideal platform to highlight the importance of integrating sustainability into education, not just for fashion students but across all disciplines.

Clothing is universal, and its impact on the planet is something every individual should understand. By embedding sustainability into curriculums across fields of study, we can cultivate a generation that values ethical practices and is equipped to make informed, responsible choices. Incorporating modules on sustainable practices, life cycle assessments, and the environmental impacts of textiles can help students view sustainability as a core value rather than an afterthought.

Responsibility and Traceability: A Pathway Forward

The principles of responsibility and traceability are vital for advancing sustainability in the textiles and clothing industry. Responsibility begins with acknowledging the environmental and social footprint of every stage in a garment's lifecycle—from sourcing raw materials to its eventual disposal. Traceability provides the tools and transparency necessary to monitor and manage this journey effectively.

By adopting advanced digital tools such as blockchain and AI, the industry can enhance traceability, enabling stakeholders to make more ethical and environmentally sound decisions. These principles foster trust, accountability, and ethical standards, creating a transparent and equitable system that benefits both people and the planet. This dual focus ensures that sustainability moves beyond being an aspirational ideal to becoming a tangible reality.

Closing the Loop: A Circular Vision for Sustainability in Textiles and Clothing

The textile and clothing industry stands at a critical crossroads. As one of the most resource-intensive industries globally, its traditional linear model—"take, make, dispose"—has led to unsustainable levels of waste, environmental degradation, and social inequity. To address these challenges, we must fundamentally shift towards a circular model that closes the loop and reimagines the lifecycle of textiles and clothing.

* Nirbhay Rana and FRSA London is also the Author of Threaded Harmony: A Sustainable approach to fashion, Emerald Publishing

Circularity in fashion is not just a trend but a necessity for the industry's survival and for the planet's health. It demands that we transition from a model of overproduction and overconsumption to one that prioritizes longevity, resource efficiency, and waste minimization. This vision is not only achievable but also imperative.

Adopting Circular Models: Key Practices

1. **Swapping and Sharing:** In a world where over 92 million tonnes of textile waste are generated annually, encouraging swapping and sharing clothing is a powerful tool to reduce demand for new production. Platforms facilitating clothing exchanges, rentals, and peer-to-peer sharing extend the lifespan of garments, reduce environmental impact, and foster a culture of mindful consumption.
2. **Recycling and Upcycling:** Recycling textiles into new fabrics and upcycling discarded materials into high-value products are critical practices for closing the loop. However, innovation in recycling technology is essential to achieve scalability and efficiency. For instance, advancements in chemical recycling can break down blended fabrics into reusable fibers, overcoming a significant barrier in current recycling efforts.

Upcycling, on the other hand, adds creative and economic value to what would otherwise be considered waste. It promotes resourcefulness and transforms pre-loved clothing into unique, desirable items, offering a compelling solution to fast fashion's relentless cycle.

3. **Designing for Circularity:** Sustainability must begin at the design stage. Designers have the power to create garments that are durable, modular, and easy to disassemble for recycling. By embracing zero-waste design techniques, biodegradable materials, and multifunctional garments, the industry can significantly reduce its ecological footprint.

Circular Fashion: A Shared Responsibility

The journey toward a circular economy requires collective action. It calls for:

- **Brands and Manufacturers:** To prioritize ethical sourcing, transparent supply chains, and closed-loop production systems. Leading brands are already piloting initiatives where consumers can return used garments for recycling or upcycling. Scaling such programs is essential.
- **Consumers:** To rethink their relationship with clothing. Embracing swapping, upcycling, and responsible purchasing can shift consumer culture from disposability to sustainability.
- **Governments and Policymakers:** To support the transition through regulations, incentives, and infrastructure. Policies promoting extended producer responsibility (EPR) can encourage brands to take accountability for their products' end-of-life impact.

Closing the Loop: Beyond Environmental Benefits

The shift to circularity transcends environmental gains; it also addresses pressing social and economic challenges. By fostering local recycling industries and upcycling businesses, we can create green jobs and empower communities. Additionally, reducing reliance on virgin materials like cotton and polyester—both of which have high water and energy demands—eases pressure on finite natural resources.

The Role of Collaborative Platforms like NISTI-IIT Delhi

NISTI-IIT Delhi's initiative to bring together diverse stakeholders under one roof is both timely and impactful. The multidisciplinary nature of this conference ensures that proposed solutions are holistic, addressing not just the symptoms but the root causes of unsustainability in textiles and clothing.

The decision to publish the proceedings in a special issue of COLOURAGE further amplifies the reach and significance of this initiative. By documenting and disseminating the insights shared here, the conference extends its impact beyond immediate participants, inspiring action across a broader audience.

My Contribution and Commitment

As the author of Threaded Harmony: A Sustainable Approach To Fashion, I am passionate about advocating for sustainable practices within the industry. My work explores how circular fashion models can mitigate the environmental impact of clothing production and consumption. These models emphasize designing for durability, promoting reuse and recycling, and minimizing waste—a vision that aligns closely with the themes of this conference.

Equally, I stress the importance of education in achieving these goals. By equipping students with the knowledge and tools to embrace sustainability, we are not only shaping responsible professionals but also empowering individuals who can drive change in their communities and industries.

A Vision for the Future

This conference serves as a powerful reminder of what can be achieved through collaboration and shared purpose. It is a call to action for educators, industry leaders, policymakers, and consumers to take responsibility for their role in creating a sustainable future.

As we engage in discussions, share insights, and explore innovations, let us commit to turning these ideas into action. Together, we can make sustainability the cornerstone of the textiles and clothing industry, contributing to the well-being of our planet and its people.

Closing Thoughts

The NISTI-IIT Delhi Conference is more than an event; it is a movement—a collective endeavor to redefine the future of textiles and clothing. Let us use this platform to inspire, innovate, and act, ensuring that sustainability becomes the guiding principle of our industry and our lives. ■

NISTI-IIT Delhi Conference on Sustainability in Textiles

THE NISTI-IIT Delhi Conference on Sustainability in Textiles, held on 14th December 2024, brought together a distinguished group of professionals, scholars, and industry leaders to explore the critical intersection of sustainability and the textile industry. The event was organized jointly by NISTI (North India Section of the Textile Institute) and the Department of Textile and Fibre Engineering, IIT Delhi, with a focus on advancing sustainable practices, technological innovations, and circular economy principles within the textile sector.

The conference commenced with the reception of the Chief Guest, Ms. Roop Rashi, IA & AS, the Textile Commissioner, who was warmly welcomed by Dr. RA Lal, Chairman of NISTI, Prof. R. Alagirusamy, Head of the Department of Textile and Fibre Engineering at IIT Delhi, Dr. Vijay Yadav, Hon. Secretary of NISTI, and other key figures. The gathering was a fitting start to the conference, setting the stage for insightful discussions and knowledge exchange on sustainability.

Lighting of the lamp

The conference also featured a performance of Saraswati Vandana by the students of JS Institute of Design, adding a cultural touch to the event. The traditional prayer, invoking blessings for knowledge and wisdom, resonated with the themes of the conference, emphasizing the importance of education and research in driving sustainable practices.

The formal inauguration of the conference was led by the

Ms. Roop Rashi

Chief Guest, Ms. Roop Rashi, who delivered an inspiring speech emphasizing the importance of sustainability in the textile industry. She spoke on the role of government policies in shaping a sustainable future for textiles, underlining the need for innovation, collaboration, and the adoption of eco-friendly practices across the entire supply chain. Ms. Roop Rashi highlighted the ongoing efforts of the Ministry of Textiles to integrate sustainability into textile manufacturing processes and the importance of a collective industry response to the global environmental challenges. Her address set the tone for the conference, calling for an industry-wide shift towards responsible practices that balance economic growth with environmental stewardship.

Dr. RA Lal

Following the inauguration, Dr. RA Lal, Chairman of NISTI, delivered a welcoming address. He acknowledged the significance of the event, noting that the discussions would contribute towards finding actionable solutions for a sustainable textile industry. Dr. Lal spoke about the growing need for collaboration between industry stakeholders, policymakers, and academia to drive sustainability initiatives. He also emphasized the pivotal role of NISTI in promoting knowledge exchange and fostering innovation in the textile sector.

Prof. R. Alagirusamy

The first of the Guest of Honour address was delivered by Prof. R. Alagirusamy, Head of the Department of Textile and Fibre Engineering at IIT Delhi. Prof. Alagirusamy focused on the role of academic institutions in advancing sustainable textile practices. He discussed the importance of research in developing new materials, production methods, and technologies that minimize environmental impact. Prof. Alagirusamy also highlighted the department's efforts to contribute to sustainable solutions, noting that students and faculty are continuously engaged in research that aims to create a greener and more sustainable textile industry. He stressed that academia's role is critical in developing future leaders who will drive the industry towards more sustainable practices.

Mr. Anil Jain, Chairman of Jain Cord Industries Limited, was the other Guest of Honour. Mr. Jain discussed the practical


Anil Jain

challenges and opportunities within the textile manufacturing sector when it comes to sustainability. He shared insights on how Jain Cord Industries has integrated sustainable practices in its operations, from material sourcing to production processes. Mr. Jain also addressed the evolving consumer demand for environmentally responsible products, emphasizing that manufacturers must align their operations with these changing market trends to remain competitive. His speech underscored the importance of innovation, efficiency, and transparency in meeting sustainability goals.


R K Vij

Mr. R K Vij, Secretary General of PTAIA, in his speech focused on the role of industry associations in promoting sustainability within the textile sector. Mr. Vij spoke about the initiatives taken by PTAIA to support members in adopting sustainable practices, providing resources, and facilitating industry-wide collaborations. He also highlighted the need for a unified approach to sustainability, urging stakeholders to work together to overcome barriers and drive meaningful change across the entire textile value chain.

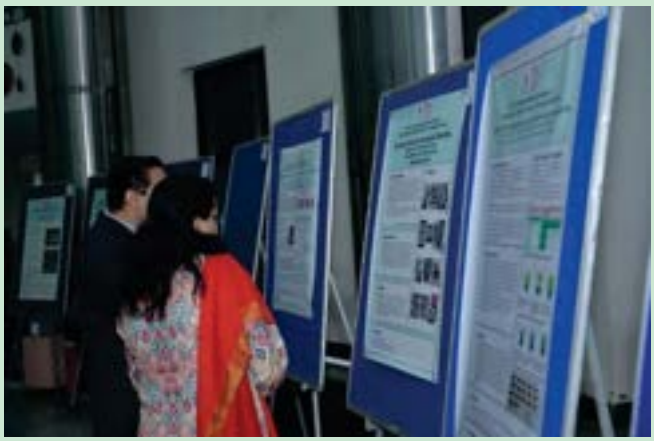

Dr. Abhijit Majumdar

The summing up of the conference proceedings was carried out by Dr. Abhijit Majumdar, who reflected on the major themes and discussions of the day. Dr. Majumdar emphasized the key takeaways from the sessions, calling for greater focus on circular economy models, waste reduction, and the adoption of new technologies that promote sustainability. He also noted the importance of collaboration between academia, industry, and government in achieving the collective goal of a sustainable textile industry. Dr. Majumdar's summing up provided a comprehensive overview of the conference discussions and outlined the key steps forward for the industry.


Dr. Vijay Yadav

Dr. Vijay Yadav, Hon. Secretary of NISTI, delivered the Vote of Thanks, expressing gratitude to all attendees for their active participation. He acknowledged the hard work of the organizing committee and the invaluable contributions of the experts and delegates who shared their insights. Dr. Yadav emphasized that the conference had successfully facilitated important discussions on sustainable practices and hoped that the ideas shared would inspire actionable outcomes that contribute to a greener and more sustainable textile industry.

One of the significant segments of the conference was the


Poster presentation session

student poster presentation session, where students from various institutions showcased their research on sustainability in textiles. The posters covered a wide range of topics, including circular textiles, sustainable dyeing technologies, eco-friendly materials, and waste management practices. An expert panel evaluated the presentations, providing constructive feedback and encouraging the students to pursue further research in these areas. The panel members were impressed by the creativity and innovation

Lifetime Achievement Awards


Prof. V K Kothari


Dr. Sailen Chaudhury


Prof. Vinod Shanbhag


Mr. Vijay Bhalla


Dr. Kuldip Sharma


Prof. (Dr.) Kushal Sen

demonstrated in the student posters, reaffirming the importance of nurturing young talent in the pursuit of sustainability.

A highlight of the event was the honouring of following industry legends with Lifetime Achievement Awards:

1. Prof. V K Kothari
2. Dr. Sailen Chaudhury
3. Prof. Vinod Shanbhag
4. Mr. Vijay Bhalla
5. Dr. Kuldip Sharma

These awards recognized the outstanding contributions of individuals who have made significant strides in promoting sustainability within the textile sector. The ceremony was an emotional moment for all, as the pioneers were acknowledged for their dedication, hard work, and vision in driving positive change in the industry.

The conference also took the opportunity to honour its sponsors and individual financial contributors, acknowledging their critical support in making the event a success. Their contributions were essential in bringing together experts and stakeholders from across the textile industry, allowing for the fruitful exchange of ideas and experiences that helped further the cause of sustainability.

Covation Biomaterials and the JS Institute of Design had product displays at the conference, showcasing their innovative solutions for sustainable textiles. Covation Biomaterials presented their cutting-edge eco-friendly materials, while the JS Institute of Design showcased collections that incorporated sustainable fashion practices. These product displays offered a firsthand look at how innovation is being applied to create a more sustainable future for the textile industry.

The conference featured a series of insightful technical sessions, with each session exploring diverse aspects of sustainability in the textile industry.

Technical Session 1 was chaired by Prof. R. Alagirusamy, Head of the Department of Textile and Fibre Engineering at IIT Delhi, who underscored the importance of innovation and collaboration in addressing the environmental challenges faced by the textile industry. Dr. Arun K. Patra, Professor and Head of Textile Chemistry at U.P. Textile Technology Institute, Kanpur, presented on "Chemical Management in Wet Processing – The Sustainable Way," exploring sustainable practices in chemical usage within textile wet processing. Representatives from Trident, Mr. Amit Ghosal and Ms. Ayushi Purohit, shared their organization's initiatives in energy efficiency, waste management, and resource conservation. Mr. V. R. Sai Ganesh, Chief Operating Officer of Zydex Group, Vadodara, introduced the concept of chemical-free and organic cotton farming through Zydex's bio-fertilizer technology, which improves soil quality, reduces water consumption, and enhances traceability. Ms. Pooja Kapoor, Founder and Creative Director of Pooja Kapoor Womenswear, discussed circularity and sustainability in traditional Indian apparel, proposing frameworks for adapting traditional circular design practices to contemporary fashion markets. This session highlighted the need for responsible chemical management, bio-farming technologies, and integrating circular design principles into modern fashion.

Technical Session 2, chaired by Prof. Mangala Joshi, Professor at IIT Delhi, provided valuable insights into bio-based materials, sustainable footwear design, and the potential of Indian wool in driving sustainability. Shri Akshay Sardana, Director & Head of Huafon India Pvt. Ltd., presented innovations in bio-based materials, specifically the Sorona® polymer, a bio-based material with significant applications in textiles. Dr. Manpreet Mansahia from Amity University focused on sustainable materials and innovative production techniques for eco-friendly sports footwear, proposing circular economy practices in footwear production. Dr. Vinod Kadam, Senior Scientist at ICAR-Central Sheep and Wool Research Institute, introduced the untapped potential of Indian wool in achieving sustainable development goals, highlighting its versatility in textiles and agro-textiles. This session emphasized collaboration between research, industry, and academia to address challenges and promote sustainability in the textile sector.

Technical Session 3, chaired by Shri Kamal Misra, Partner at Sterling Sales Pvt. Ltd., brought attention to the intersections of technology, functionality, and sustainability. Dr. Chirag R. Gajjar, Principal R&D Engineer at Medtronic, shared his insights into the transformative potential of medical textiles, particularly in wound care and implantable devices. Dr. Yamini Jhanji and Dr. G.K. Tyagi from TIT&S, Bhiwani, discussed innovations in sportswear, exploring advancements in smart sportswear designed to monitor physiological parameters, using advanced fibers and technologies like conductive yarns and sensors. Ms. Priyanka Priyadarshini from Aditya Birla Group presented on the innovative use of Liva fibers in handloom textiles, promoting eco-friendly practices through the

Panel discussion

Student volunteers

integration of natural dyes. This session showcased advancements in medical textiles, sportswear, and sustainable handlooms, with a focus on balancing technological innovation and environmental responsibility.

Prof. A. K. Patra, under interaction with audience

The conference also featured an engaging panel discussion with prominent experts in the field. Mr. Nirbhay Rana, Assistant Professor at IILM University, discussed bridging the gap between sustainability ideals and industry practices, while Mr. Shailesh Kaushik, a techno-commercial professional with over 38 years of experience, shared insights into sustainable

Recognizing the Dedication of Our Organizing Team and Volunteers!

View of the audience

composites and technical textiles. Mr. Madhav Bhatt, a textile technologist from Bhatt Bros, Ahmedabad, spoke about the potential of seawater-based processes for textile dyeing. Prof. Nien Siao, Dean of JS Institute of Design, New Delhi, discussed integrating Sustainable Development Goals into design education. Shri Kishore Motwani, a seasoned engineer with expertise in textile manufacturing, shared his extensive experience in setting up global textile projects. Dr. Garima Singh, a textile scientist focusing on sustainable innovations, emphasized preserving traditional Indian fabrics while innovating for the future. The panellists brought a wealth of knowledge and expertise to the conference, contributing to dynamic discussions on the future of sustainability in textiles.

In conclusion, the NISTI-IIT Delhi Conference on Sustainability in Textiles successfully brought together leading experts, researchers, and industry professionals to discuss and promote sustainable practices in the textile industry. The event provided a platform for fruitful discussions, collaboration, and the sharing of ideas and innovations that will contribute to a more sustainable and responsible textile sector. The conference ended with a collective commitment to driving positive change, with all participants expressing their dedication to continuing the journey towards sustainability in textiles.

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The Textile Institute
NISTI (Regd.)

Regd. No. S/58201/2007 dt 23/03/2007

Section of Textile Institute, UK

NISTI Outreach Drive for Textile Fraternity

NISTI's Brief Background

Historically, NISTI's association with Textile Institute, in India's perspective, goes back to 1910 when Sir Dorabjee Tata served on the Board of the Textile Institute, Manchester while it was set up under a Royal Charter.

NISTI has revamped its role of positively influencing the Textile Ecosystem, especially the industry Academia interface and Technological Up-gradation and Innovation. It has a 28 members Executive Council (EC) with stalwarts of Industry and a Patrons' Think-Tank of 66 members. The EC has members from, Confederation of Indian Textile Industry (CITI), IIT Delhi, NIFT, PEARL Academy, TIT&S Bhiwani, PIET Panipat, NSUT etc and eminent Past Chairmen like Prof VK Kothari, Dr Sailen Chaudhuri, Dr Kuldip Sharma, Dr Vinod Shanbhag, and Shri. Vijay Bhalla among others.

NISTI is a Technology Think-Tank for Textile Industry and a section of the Textile Institute (TI), Manchester set up in 1989 by the then Director, IIT Delhi, a group of IIT Delhi professors, Professors from Shriram Institute and Textile Industry stalwarts from leading institutes in India. Lately in 2007 NISTI transformed itself into an Association of Persons registered under the Registration of Societies Act 1860 and rechristened as NISTI (Regd) or NORTH INDIA SECTION OF THE TEXTILE INSTITUTE (REGISTERED).

The NISTI's Executive Council and its membership have some outstanding experts in Textile Technology, especially in the areas of Design, Management, Art, Economics, Education, Engineering, Fashion, Marketing, Research, Retailing, Science, Sustainability, Technical and Medical Textiles. Thus, NISTI brings together professionals who work in setting professional standards, advancing knowledge and industrial practices; exchange of ideas; and building a social community promoting harmonious relationship among its stake holders. NISTI also works for finding professional talent for the textile industry; infusing textile education and training; recognizing excellence of industry /academic organizations and promotes knowledge.

NISTI has its own outreach drive (https://nistiregd.in/nisti-registration/) and is open for anyone to join as Patrons/Associates/Industry Associates/Young Change makers/Institutional Partners.

NISTI allows joining as Patrons/Associates/Industry Associates/Young Change makers/Institutional Partners, through https://nistiregd.in/nisti-registration/. Patrons may join through given link or fill-in the form overleaf and submit to us by post or email at secy@nistiregd.in

REGISTRATION FORM FOR PATRONS

Personal Details

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Email:

Phone (Preferably WhatsApp No):

Gender:

Date of Birth:

Aadhaar Number:

Address with Pin Code:

Education Qualifications:

Experience (in years):

Professional Details

Professional Qualifications:

Reference

Name:

Email ID:

WhatsApp Number:

This form may be filled by the Patrons. For other position please

visit the Link at https://nistiregd.in/nisti-registration/

Please send Copy of this filled up Form on Email to secy@nistiregd.in

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