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Global and Regional Perspectives on Textile Waste: A Review of India and Maharashtra in the International Context

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Abstract: *The global textile industry is currently grappling with a monumental waste crisis, generating approximately 92 million tons of waste annually. India, a critical node in the global supply chain, contributes significantly to this volume, generating an estimated 7,073 kilotons per annum (kTPA). This review examines the multifaceted textile waste value chain in India, categorizing waste into pre-consumer (42%) and post-consumer (58%) streams. It highlights the unique role of the informal sector and regional clusters specifically the aggregation dynamics in Maharashtra versus the processing capabilities of Panipat. Internationally, the landscape is shifting toward mandatory Extended Producer Responsibility (EPR) and digital traceability, particularly in the EU and USA. This paper explores the transition from mechanical to chemical recycling and evaluates the emerging potential for industrial symbiosis, such as the integration of textile fibers with industrial by-products like fly ash for "Green Tile" construction. Ultimately, the study concludes that by formalizing recovery networks and localizing high-value engineering applications, India and Maharashtra in particular can transform an environmental liability into a cornerstone of a circular, low-emission economy.*

Keywords: *Textile Waste, Sustainable Green Tile, Industrial waste.*

1. INTRODUCTION: The Scale of the Challenge

Textile waste management is transitioning from a localized environmental concern to a globally regulated industrial priority. This paper reviews the textile waste value chain in India, with a deep dive into the **Maharashtra** regional ecosystem, and evaluates how these systems align with international circularity standards and policy trends from the EU, Japan, and the United States. **Global Policy Landscape** -International directives are increasingly shifting from voluntary guidelines to mandatory regulations that impact global trade.(1)

1. **European Union (EU):** The *EU Strategy for Sustainable and Circular Textiles* and the *Ecodesign for Sustainable Products Regulation* are setting high bars for durability and recycled content.
2. **The Netherlands & France:** These nations have implemented **Extended Producer Responsibility (EPR)** decrees, mandating that producers take financial and physical responsibility for end-of-life textiles.
3. **United States:** State-level actions like the *California Responsible Textile Recovery Act* and the *New York Fashion Act* are targeting large-scale waste diversion.
4. **East Asia: Japan's** *Circular Economy Vision 2020* and **China's** *Implementation Opinions* focus on integrating digital technologies and high-value chemical recycling into the industrial base. (12)

1.1 Textile Waste in India: A Path Toward Circularity

India generates approximately 7,073 kilotons per annum (kTPA) of textile waste, split between pre-consumer (42%) and post-consumer (58%) streams. India's textile industry, a 157 billion sector contributing 2% to the national GDP, is at a decisive crossroads .While the nation has ancient traditions of resource stewardship such as *godhadi* and *rafugari* modern industrialization has necessitated a more structured approach to waste management. Currently, more than 70% of total textile waste in India is recovered for recycling, upcycling, or downcycling This paper reviews the current state of India's textile waste ecosystem, analyzing the recovery mechanisms, environmental impacts, and the technological pathways essential for transitioning from a linear "take-make-dispose" model to a circular economy.(4)

1.2. Regional Analysis: The Maharashtra (Mumbai-Sion) Ecosystem

Maharashtra is a critical node in India's textile economy, but it currently lacks the centralized processing infrastructure seen in international hubs or Northern India. As a major garmenting and retail center, Mumbai generates significant pre-consumer and post-consumer waste.

1. **Local Sorting:** In clusters like **Sion**, basic material-wise sorting occurs on the ground.
2. **Logistical Flow:** Unlike the integrated "closed-loop" systems seen in the EU, Mumbai's waste is often "leaked" to informal markets or transported over 1,000 km to **Panipat** for actual recycling.
3. **Urban Recovery:** In Mumbai and Navi Mumbai (Turbhe, Panvel), formal channels like Municipal Corporations and NGOs are beginning to map waste generation through formal Material Recovery Facilities (MRFs).(12)

1.3. Comparison of International and Regional Models

Feature	International (EU/Japan)	India (Panipat Hub)	Maharashtra (Mumbai/Sion)
Primary Driver	EPR Regulations & Legislation	Market Demand for Shoddy Yarn	Aggregation & Garmenting Waste
Recycling Tech	Scaling Chemical Recycling	Established Mechanical Recycling	Sorting & Trans-shipment
Involvement	Formal Retailer Take-back	55% Informal (Waghri) Recovery	Mixed Formal/Informal Aggregation
Infrastructure	Automated Sorting Plants	Large-scale Shredding/Blanket Units	Small-scale Manual Sorting (Sion)

Table 1- Comparison of International and Regional Models

1.4. Synthesis: Aligning Maharashtra with Global Standards

For Maharashtra to evolve from an aggregation point to a circular leader, the report suggests several interventions that mirror global best practices:

1. **Industrial Symbiosis:** Following the model of "Circular Economy Industrial Parks" seen in China and Japan, Maharashtra should deploy cluster-level recycling facilities to process waste at the source (e.g., in Mumbai) rather than transporting it to Panipat.
2. **Digital Traceability:** Adopting international standards like **ISO 14001** and digital product passports to ensure that waste from Mumbai meets the stringent import requirements of the EU and USA.
3. **Formalizing the Informal:** Integrating the highly efficient informal collectors (like those in Sion) into a formal framework, similar to successful "social upliftment" models in Brazil's *Meias do Bem* program.

2. The Linear Fashion Model and Waste Crisis

The global clothing industry operates on a predominantly **linear pattern** ("take-make-dispose"). Driven by "fast fashion," more than half of manufactured garments are discarded within a single year. This results in the massive exploitation of non-renewable resources for products with short lifespans, which are ultimately landfilled or incinerated.

2.1 Economic and Environmental Impact

1. **Scale of Waste:** Approximately 92 million tons of textile waste are produced annually from a consumption of 53 million tons of fiber. By 2030, global textile waste is projected to increase by 60%, reaching 148 million tons per year.
2. **Financial Loss:** Roughly 73% of fibers are wasted, representing an annual loss of over **USD 100 billion** in raw materials. Conversely, addressing environmental and societal impacts could boost the global economy by **USD 192 billion** by 2030.
3. **Pollution:** The industry is a major polluter; for example, in Cambodia, the fashion sector is responsible for 60% of water pollution and 34% of chemical pollution. It also contributes significantly to CO_2 emissions through manufacturing and global supply chains.(8)

3. Classification of Textile Waste

Waste is generated at every stage spinning, weaving, dyeing, and finishing and is categorized into three main types:

1. **Pre-consumer Waste (2,971 kTPA)-** "Clean waste" from the production process (yarn waste, fabric scraps, cutting waste). Between 10% and 20% of textiles are lost during manufacturing.
2. **Post-industrial Waste:** Virgin or clean waste released without being processed into a final product
3. **Post-consumer Waste (4,102 kTPA)-** Discarded garments and textiles no longer used by the consumer. This is the largest and most complex stream due to mixtures of fibers and contaminants. Over 50% is recovered by informal networks (e.g., the *Waghri* community), sustaining 4-4.5 million livelihoods They are hard to recycle because they are often dirty and made of a mix of materials (like cotton mixed with polyester, metal zips, or plastic buttons). (4)

4. The Challenge of Recycling

While biodegradable fibers (fibers, yarns, scraps) can potentially be converted into biofertilizers or biogas, the modern garment industry presents significant hurdles. Most garments are a complex blend of natural and synthetic fibers combined with non-textile components like metal zips, acrylic buttons, and snaps, making them extremely difficult to degrade or recycle efficiently. current fashion industry follows a "linear" pattern, which can be described as **take-make-waste**. We extract massive amounts of natural resources to make clothes that are often worn for a very short time and then thrown away.(7) Here is a simple breakdown of the current situation:

4.1. The Problem of "Fast Fashion"

Because people are buying more clothes and keeping them for less time, waste is exploding. It is estimated that more than half of all "fast fashion" items are discarded in less than a year. By 2030, the world could be producing **148 million tons of textile waste** every year.

4.2. Huge Economic Loss

When we burn or bury old clothes in landfills, we aren't just hurting the planet; we are throwing away money. Every year, about **100 billion** worth of raw materials are wasted. In countries like Bangladesh, nearly half of the waste produced by factories is **100% recyclable cotton**, yet much of it is lost.

4.3. Environmental Damage

The textile industry is one of the world's biggest polluters:

1. **Water & Chemicals:** In some countries, the fashion sector is responsible for up to 60% of water pollution and 34% of chemical pollution.
2. **Emissions:** The process of making, transporting, and disposing of clothes releases massive amounts of CO_2.(9)

4.4. Comparative Environmental Impact (Life Cycle Assessment)

A Life Cycle Assessment (LCA) within the report demonstrates the measurable environmental gains from utilizing recycled materials over virgin inputs:

Fiber Type	Recycled Content Strategy	Key Impact Findings
Cotton	25% Recycled / 75% Virgin	Reduced water and pesticide use compared to 100% virgin cotton.
Viscose	100% Recycled	Significant reduction in forestry-related impacts and chemical processing.
Polyester	100% Recycled (r PET)	Lower carbon emissions by diverting plastic waste from landfills.

Table. 2 Comparative Environmental Impact

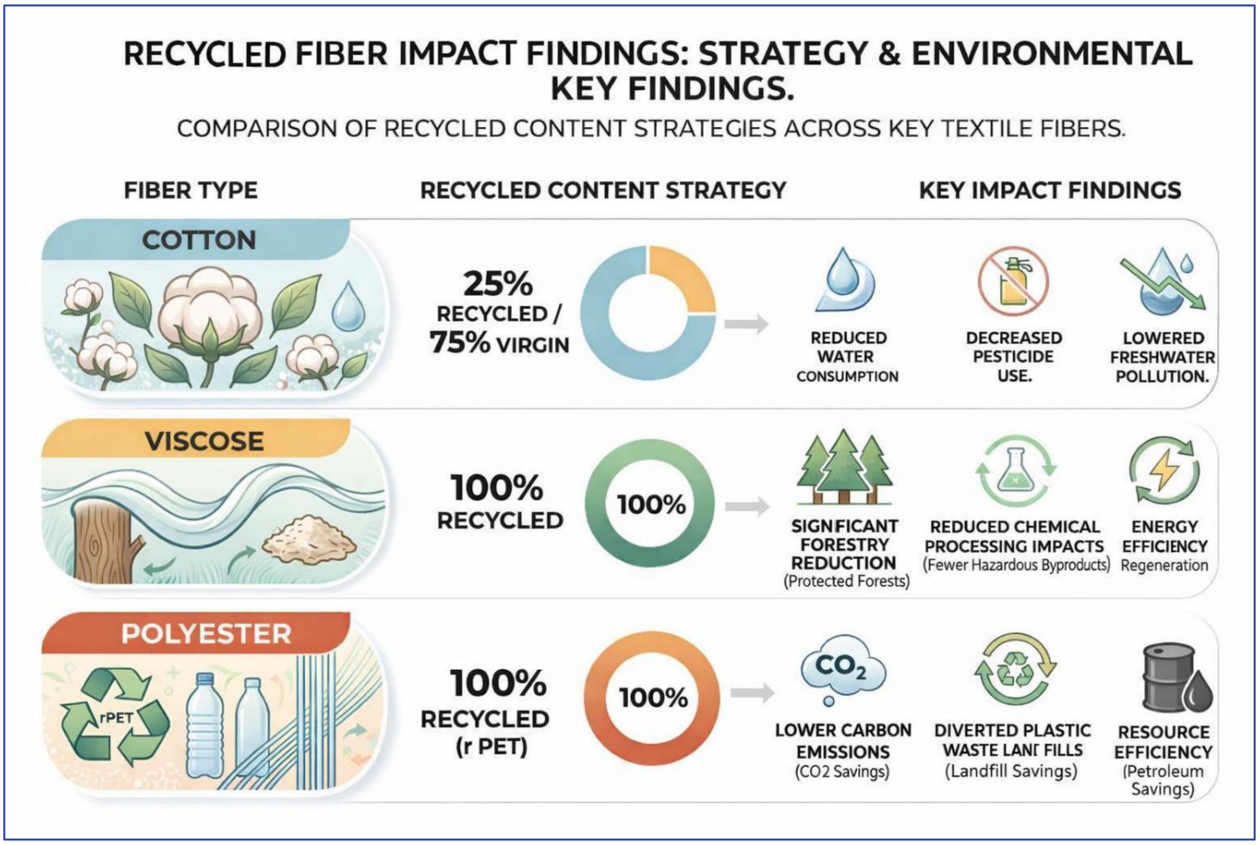

Fig1 **Comparative Environmental Impact**

5. Technological Pathways for Valorization

The study proposes a hybrid recycling ecosystem to address diverse waste streams:

1. **Mechanical Recycling:** The most established method in India, used for physical breakdown of fibers into lower-grade yarn (mats, wipers).
2. **Chemical Recycling:** Breaking fibers down at the molecular level to regenerate high-quality "virgin-like" fibers. Current penetration in India is low, with emerging technologies like *Worn Again* and *Circulose* pulp.
3. **Thermo-Chemical Processes:** Utilizing complex, unrecyclable waste for energy recovery or conversion into fuels and chemicals. (12)

6. Regional Clusters and Industrial Hubs

1. **Panipat:** Acts as the centralized hub for processing textile waste from across India.

2. **Ludhiana:** A major pre-consumer waste cluster, producing 3,600 tons of fabric daily, with 10-20% generated as "clip waste".
3. **Mumbai & Saharanpur:** Identified as prominent garmenting waste clusters. (8)

7 . Policy and Economic Gaps

The transition is hindered by several "bottlenecks":

1. **Lack of HSN Codes:** The absence of a specific HSN code for recycled or upcycled products limits formal trade and export incentives.
2. **Regulatory Frameworks:** Unlike the EU, which mandates recycled content by 2025, India's current policy landscape for textile waste is fragmented.
3. **Perception:** There is a need for branding strategies to position recycled textiles as equal or superior to virgin fabrics.(10)

8. The Opportunity

While the current system is damaging, there is hope. Solid textile waste contains fibers that can be recycled into new materials, turned into **bio-fertilizers**, or even used to create high-value engineering and industrial symbiosis. If the industry tackled these environmental and social issues, it could add nearly **192 billion** to the global economy by 2030. Based on recent industrial mapping and emerging technological trends, the future scope for textile recycling in Maharashtra is shifting from simple aggregation to high-value engineering and industrial symbiosis.

The following areas represent the most significant growth opportunities for the state:

8.1. Integration into "Green" Construction Materials

Maharashtra has a unique opportunity to lead in the development of low-carbon building materials by combining textile waste with other industrial by-products.

1. **Composite Development:** There is significant potential for projects that utilize textile fibers specifically from the garmenting clusters in Mumbai and Nagpur as reinforcement in cementitious or geopolymer matrices.(15)
2. **Fly Ash Valorization:** Given the presence of thermal power plants in regions like Vidarbha, the synthesis of "Green Tiles" or bricks using fly ash and textile waste offers a durable, low-emission alternative to traditional fired-clay products.(9)
3. **Thermal & Acoustic Insulation:** With the rise of sustainable architecture in Pune and Mumbai, there is a growing market for insulation panels made from shredded post-consumer cotton and polyester waste.(8)

8.2. Localization of the Value Chain (The "At-Source" Model)

Currently, a large percentage of Maharashtra's textile waste is transported over 1,000 km to Panipat for processing. The future scope lies in shortening this logistics chain:

1. **Mini-Recycling Clusters:** Establishing localized mechanical recycling units in garmenting hubs (like Sion or Bhiwandi) can reduce the carbon footprint of transport and create local employment.
2. **Automated Sorting Facilities:** Moving from manual sorting to AI-based automated sorting will allow the state to meet international standards for fiber purity, making the output more attractive for chemical recycling.

8.3. Circular Economy Industrial Parks

The Maharashtra Industrial Development Corporation (MIDC) is well-positioned to foster "Industrial Symbiosis," where the waste of one industry becomes the raw material for another.

1. **Textile-to-Chemical Pathways:** Future investments are likely to flow into chemical recycling plants that can break down poly-cotton blends—common in Mumbai's waste stream—into high-quality regenerated cellulose and polyester monomers.

2. **Public-Private Partnerships:** Collaborative models involving academic institutions and local startups can accelerate the transition from lab-scale research to commercialized "zero-waste" products.(8)

8.4. Policy-Driven Formalization

As global regulations like the EU's "Digital Product Passports" come into effect, Maharashtra's informal recovery networks (such as the *Waghri* community) will likely see a push toward formalization.

1. **Traceability Systems:** Implementing digital tracking for waste from the point of collection in urban centers to the final recycled product will be essential for participating in the global "Green Trade" economy.
2. **Standardization:** Developing state-level standards for recycled textile products will help overcome the "perception gap," positioning recycled materials as high-performance alternatives rather than "downcycled" goods.(15.11)

8.5. Entrepreneurship and Incubation

With a robust ecosystem of incubation cells and academic research centers, the state is an ideal testing ground for "Skill-to-Startup" initiatives focused on textile valorization. The focus is shifting toward creating entrepreneurial ventures that specialize in niche applications, such as textile-reinforced polymers for the automotive sector (centered in the Pune-Chakan belt) or sustainable geotextiles for infrastructure projects.(13)

9. Conclusion

The mapping of India's textile waste ecosystem reveals a sector at a decisive turning point. While the nation demonstrates a high recovery rate of over 70%, much of this remains "downcycling" or is hindered by high logistical costs and a lack of standardized sorting infrastructure. The regional analysis of Maharashtra underscores a significant opportunity: transitioning from a mere aggregation and sorting hub (as seen in the Mumbai-Sion clusters) to a center for high-value valorization.

Future progress depends on three critical pillars:

1. **Technological Innovation:** Moving beyond traditional mechanical shredding toward advanced chemical recycling and the development of composite materials—such as geopolymer tiles reinforced with textile waste—to meet the rising demand for sustainable construction.
2. **Strategic Localization:** Establishing decentralized recycling facilities near generation hubs in Maharashtra to reduce the carbon footprint and logistical overhead of transporting materials to Northern Indian hubs.
3. **Global Alignment:** Adopting digital traceability and formalizing the informal recovery networks to comply with emerging international regulations like the EU's Ecodesign mandates. (10)

In conclusion, the shift toward a circular textile economy is no longer an optional environmental goal but a mechanical necessity for global industrial competitiveness. By leveraging its robust informal networks and integrating textile waste into diverse sectors like building materials and green technology, Maharashtra can serve as a scalable model for circularity on an international stage.

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