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MECHANICAL VS. SOLVENT-BASED RECYCLING TECHNOLOGIES FOR ROVING WASTE: A COMPARATIVE REVIEW

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Abstract: The textile industry's transition toward a circular economy necessitates effective recycling of pre-consumer waste streams, particularly roving waste generated during spinning. This review provides a comparative analysis of mechanical and solvent-based recycling technologies for processing roving waste, evaluating their principles, efficiencies, and suitability for fiber recovery. Drawing on recent literature (2019–2025) and industrial case studies, including data from Uzbek spinning mills, the paper examines the strengths and limitations of each approach. Mechanical recycling, while cost-effective and widely adopted, often compromises fiber length and quality. In contrast, solvent-based regeneration offers the potential to produce fibers with virgin-like properties but faces challenges related to cost and solvent recovery. The comparative techno-economic assessment reveals that mechanical processes have lower immediate costs, whereas advanced solvent-based methods may yield higher-value end products, albeit with greater capital investment. The review concludes by identifying research gaps and proposing pathways for integrating these technologies to enhance material recovery and support sustainable textile manufacturing.

Keywords: Roving waste, mechanical recycling, solvent-based regeneration, textile waste, comparative analysis, fiber recovery, circular economy, spinning waste, recycling technologies, sustainable textiles.

Introduction

The textile industry is a major contributor to industrial waste worldwide, with spinning processes producing significant pre-consumer waste, including roving waste. Roving waste, generated during roving and spinning frame operations, represents valuable fibrous material that can be recycled or valorized if appropriate technologies are applied [1,2]. Despite its potential, roving waste is often under-researched compared to other waste streams, contributing to inefficiencies and environmental burdens.

Key points in this section:

1. Textile industry waste is increasing due to global production volume growth [4].
2. Roving waste emerges primarily during the drafting and twisting stages in spinning mills [1].
3. Recycling of roving waste supports circular economy goals and resource conservation [4].

Methods

This review synthesizes current research on roving waste generation, characterization, and processing technologies. Peer-reviewed journal articles, industrial case studies, and recent textile recycling reviews were analyzed.

The methodology involved:

1. Literature Survey: Systematic review of research articles from 2019–2025 on textile waste and roving waste processing [3, 4, 5, 7].
2. Inclusion Criteria: Studies involving spinning waste, recycling technologies, and circular economy integration.
3. Classification: Technologies were categorized into mechanical recycling, solvent-based regeneration, and digital/innovative pre-sorting methods.

Results

-Roving waste accounts for approximately 3.5–5.2% of total spinning output, as documented in detailed audits conducted at multiple spinning facilities, including mills in Uzbekistan [1].

-Primary causes of roving waste formation include mechanical inefficiencies, operator handling, and raw material variability.

-Roving waste contains relatively long staple fibers suited to reuse, though fiber quality degrades with repeated mechanical opening.

Mechanical Recycling: The most mature technology involves fiber opening, cleaning, carding, and rewinding to produce reusable slivers or yarns. Mechanical recycling remains dominant due to technological maturity and relatively low cost, though it may reduce fiber length and quality [8, 9].

Solvent-Based Regeneration: Advanced dissolution and regenerative systems can selectively process cellulosic waste into new fibers, potentially matching virgin fiber qualities. Such approaches show promise in producing regenerated textiles with improved properties, though industrial deployment remains limited by cost and solvent recovery challenges [5, 7].

Quantitative Findings and Comparisons

Life cycle and techno-economic evaluations reveal that mechanical processes consume less energy and preserve fiber integrity but may lag in material recovery quality compared with solvent-based methods [6].

Balancing environmental and economic metrics shows mechanical recycling has lower immediate costs, whereas advanced technologies may yield higher revenue but require larger capital investment.

Discussion

Sustainability Impact: Recycling roving waste reduces reliance on virgin materials and supports environmental sustainability targets. Multiple studies highlight the importance of integrating circular economy frameworks to reduce landfill and resource depletion [4].

Industrial Technology Gaps: Mechanical recycling is widely applied, but innovation is needed for high-quality regenerated fibers. Solvent-based systems show potential but require improvements in cost efficiency and solvent management [5,7].

Uzbekiston Contributions: In our previous research work, we quantitatively evaluates roving waste at Uzbek spinning mills, establishing baseline data for waste reduction strategies [1]. Additionally, utilization frameworks for cotton roving waste were outlined as part of national efforts to improve textile sustainability [2].

Applications of Recycled Roving Waste

Recycled roving fibers can be used to produce:

1. Lower-count yarns suitable for non-woven and industrial textiles.
2. Blends for denim and home textile products.
3. Value-added recycled cotton components in garments.

These applications contribute to sustainability while opening economic opportunities within textile value chains [3, 6].

Conclusion

Roving waste represents a critical yet under-exploited resource within textile manufacturing. Current recycling technologies range from established mechanical processes to advanced solvent regeneration and digital pre-sorting. While mechanical recycling dominates due to maturity and cost, innovations in solvent systems and digital technologies offer promising pathways for enhanced material recovery. Research contributions from Uzbekistan and other regions provide valuable empirical data that can support improved waste management and integration of circular economy principles in textile production.

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