Perspective
Volume 15:02, 2025

Journal of Textile Science and Engineering

ISSN: 2165-8064

Open Access

Textile Recycling: Challenges, Methods, Solutions, Circularity

Katarzyna Nowak*

Department of Material Technologies and Textile Design, Lodz University of Technology, Poland

Introduction

The ongoing progress in textile recycling technologies consistently highlights significant challenges that impede the establishment of a truly circular economy for textiles. Comprehensive strategies are crucial, demanding an integration of material science, engineering, and robust policy frameworks to surmount prevalent barriers such as mixed fiber compositions, sorting complexities, and issues of economic viability. Research here points towards innovative solutions and outlines a foundational roadmap for future research and development, aiming to achieve sustainable textile waste management effectively [1].

A detailed overview critically assesses both mechanical and chemical recycling methods for textile waste, delineating their current status, inherent advantages, and distinct limitations. This analysis delves into the technical intricacies of each approach, exploring their applicability across various textile types and fiber blends. It reveals that while mechanical recycling is generally simpler to implement, it often results in degraded fiber quality. Conversely, chemical recycling, despite being more complex and resource-intensive, consistently offers the potential for higher quality outputs, underscoring the pressing need for integrated and balanced solutions [2].

Authors critically review a range of textile waste recycling technologies, shedding essential light on the inherent challenges and emerging opportunities present in the field. They highlight how the increasingly complex composition of modern textiles poses significant hurdles for effective recycling, particularly when dealing with mixed-fiber materials. The discussion also identifies promising technological advancements and proactive policy instruments that hold the potential to foster greater circularity and sustainability throughout the textile industry value chain [3].

A comprehensive review explores sustainable textile recycling technologies, offering crucial insights into their current state and future directions. This scope encompasses various mechanical, chemical, and hybrid recycling processes, evaluating their respective environmental impacts and economic viability. The paper strongly advocates for a holistic approach to textile waste management, emphasizing the vital need to integrate advanced sorting capabilities, highly efficient recycling processes, and supportive policy frameworks to minimize environmental footprint and significantly promote resource efficiency [4].

The focus on chemical recycling of textile waste positions it as a key enabler for a circular economy. This involves a systematic review of different chemical dissolution and depolymerization methods applicable to various textile fibers, including cotton, polyester, and their common blends. The discussion addresses persistent challenges, such as managing impurities, ensuring efficient separation, and achieving effective solvent recovery. Alongside these, it illuminates significant opportunities for producing high-quality secondary raw materials that can seamlessly re-enter the production cycle, thereby reducing reliance on virgin resources [5].

A detailed review delves into the advancements and inherent challenges associated with mechanical recycling for textile waste. It underscores that while mechanical methods remain cost-effective and relatively simple to implement, they frequently lead to fiber degradation, which in turn limits the quality and potential applications of recycled materials. The paper thoroughly explores innovations designed to improve fiber retention, such as optimized shredding and carding techniques, and discusses the strategic potential of blending recycled fibers with virgin materials to sustain or improve product quality [6].

This review specifically addresses textile-to-textile recycling, with a particular emphasis on cotton and polyester, given their dominance as fibers within the industry. It provides a detailed account of current technologies, spanning from basic mechanical shredding to complex chemical depolymerization and regeneration processes. The authors also outline future perspectives for scaling up these vital technologies, stressing the indispensable need for robust collection systems, highly efficient sorting mechanisms, and innovative blending techniques to maximize overall resource recovery [7].

An examination of textile waste management and recycling within the broader framework of a circular economy reveals both significant challenges and promising opportunities. Systemic issues identified include alarmingly low collection rates, the diverse material compositions found in textile waste, and a persistent lack of adequate infrastructure, all acting as major hurdles. Conversely, the paper highlights considerable opportunities presented by ongoing technological advancements, increasing consumer awareness regarding sustainable practices, and strategic policy interventions that could effectively drive the transition towards more sustainable textile production and consumption models [8].

This systematic review meticulously explores recent innovations and emerging technologies in textile recycling, covering a broad and impressive spectrum of advancements. These range from significantly enhanced automated sorting systems to groundbreaking novel chemical and biological degradation processes. The authors unequivocally emphasize that these innovations are critically important for processing complex textile waste streams with greater efficiency and for consistently producing higher-value secondary materials, which collectively pave the way for a more effective circular textile supply chain and substantially reduce environmental impact [9].

A comprehensive review provides an insightful overview of sustainable strategies for textile waste valorization and circularity, with a direct focus on meth-

ods designed to extract maximum value from discarded textiles. It thoroughly explores various approaches, including creative upcycling, careful remanufacturing, and distinct forms of recycling—mechanical, chemical, and biological—discussing their collective potential to transform waste into genuinely valuable resources. Here, the paper highlights the paramount importance of incorporating design for longevity and recyclability as fundamental elements for achieving a truly circular textile economy [10].

Description

The journey towards a truly circular economy in the textile sector is fraught with significant and multifaceted challenges. A primary concern is the increasingly complex composition of modern textiles, often involving blends of various natural and synthetic fibers, which complicates effective sorting and recycling processes [1, 3]. Beyond these material complexities, systemic issues contribute substantially to the problem. These include persistently low collection rates for discarded textiles, a wide array of diverse material inputs that make uniform processing difficult, and a notable lack of comprehensive infrastructure required for large-scale recycling operations [8]. To navigate these complexities and foster a sustainable future for textiles, there's a recognized imperative for comprehensive strategies. These must thoughtfully integrate advancements in material science, innovative engineering solutions, and supportive policy frameworks. This integrated approach is seen as the catalyst for developing innovative recycling solutions and mapping out a clear, actionable roadmap for future research and development, all geared towards achieving truly sustainable textile waste management practices [1, 8].

Mechanical recycling represents a foundational approach to textile waste management, valued for its relative simplicity and cost-effectiveness. However, a significant drawback is its tendency to degrade fiber quality during processing, which subsequently limits the potential applications and overall value of the recycled materials [2, 6]. For instance, repeated mechanical stress can shorten fiber lengths and weaken their structural integrity. To mitigate this, ongoing innovations are crucial, focusing on advanced techniques like optimized shredding and precision carding to minimize damage and improve fiber retention. Additionally, strategic blending of these mechanically recycled fibers with virgin materials offers a pragmatic way to maintain acceptable product quality and expand their utility across various textile products. Despite these efforts, the challenge remains to refine mechanical processes to consistently yield high-quality output that can genuinely compete with virgin fiber properties [6].

In contrast to mechanical methods, chemical recycling offers a more promising pathway for producing higher quality secondary raw materials. This is achieved through sophisticated dissolution and depolymerization methods, which are particularly effective for common textile fibers like cotton, polyester, and their various blends [2, 5]. By breaking down polymers to their basic monomers or dissolving them into reusable solutions, chemical recycling dramatically reduces the reliance on virgin resources, positioning it as a key enabler for a circular economy. Yet, this advanced approach is not without its own complexities. Significant challenges include effectively dealing with impurities present in mixed textile waste, ensuring highly efficient separation of different fiber types, and the environmentally and economically sound recovery of solvents used in the processes [5]. These technical demands make chemical recycling more resource-intensive and complex, calling for continuous innovation.

A truly effective approach to sustainable textile recycling cannot rely on a single technology but rather demands integrated and hybrid solutions. These comprehensive strategies merge various mechanical, chemical, and biological processes to leverage their respective strengths, while also rigorously evaluating their environmental impacts and economic viability [4, 10]. Central to this holistic vision is the development and deployment of advanced sorting technologies capable of accurately identifying and separating diverse fiber types, an essential prerequisite for efficient recycling processes. Furthermore, the integration of robust collection systems, efficient processing workflows, and innovative blending techniques is crucial for scaling up operations and maximizing resource recovery. This layered strategy is vital for minimizing the overall environmental footprint of the textile industry and significantly promoting resource efficiency across the entire lifecycle of textile products [4, 7].

The future of textile recycling is being shaped by a wave of innovations and emerging technologies designed to tackle the most persistent challenges. These advancements span a broad spectrum, from sophisticated automated sorting systems that enhance the purity of input materials to groundbreaking novel chemical and biological degradation processes that offer new pathways for material recovery and valorization [9]. Such innovations are crucial for efficiently processing increasingly complex textile waste streams and, importantly, for consistently producing higher-value secondary materials that can genuinely re-enter the production cycle. These technological strides, coupled with a discernible increase in consumer awareness regarding sustainable practices and proactive policy interventions, are collectively driving the transition towards more sustainable textile production and consumption models [8]. Ultimately, sustainable strategies must embed principles of design for longevity and recyclability from the outset. This fosters valorization through diverse approaches like upcycling, remanufacturing, and various forms of recycling—mechanical, chemical, and biological—transforming waste into truly valuable resources and securing a genuine circular textile economy [10].

Conclusion

Textile recycling is a critical endeavor for fostering a circular economy, though it faces substantial hurdles like complex mixed fiber compositions, sorting difficulties, and economic viability. Both mechanical and chemical recycling methods are actively explored, each presenting distinct advantages and limitations. Mechanical recycling, while simpler, often leads to fiber degradation, whereas chemical recycling, despite its complexity, yields higher quality materials. Overcoming these technical challenges necessitates integrated solutions and comprehensive strategies. Systemic issues such as low collection rates, diverse material inputs, and inadequate infrastructure persist, yet opportunities arise from technological advancements, increasing consumer awareness, and supportive policy interventions. Innovations in automated sorting and novel degradation processes are emerging to efficiently manage complex waste streams and produce valuable secondary materials. The focus extends to textile-to-textile recycling, especially for dominant fibers like cotton and polyester, aiming to maximize resource recovery and reduce dependence on virgin resources. Sustainable strategies emphasize design for longevity and recyclability, promoting valorization through diverse recycling approaches to transform waste into valuable resources for a truly circular textile economy.

Acknowledgement

None.

Conflict of Interest

None.

References

1. Mengqi Li, Yiqi Yang, Wenbing Lin. "Progress and challenges in textile recycling for a circular economy." Resources, *Conservation and Recycling* 191 (2023):106909.
2. Desirée A. H. van der Eijk, Kjell J. van der Eijk, Sjoerd L. G. K. M. de Winter. "Mechanical and chemical recycling of textile waste: A review." *Journal of Cleaner Production* 297 (2021):126601.
3. Carina S. C. da Silva, Carla G. D. S. G. Moreira, Nuno A. H. S. D. Santos. "Textile waste recycling technologies: A critical review on challenges and opportunities." *Journal of Cleaner Production* 326 (2021):129372.
4. Ranjith Rajkumar, Selvaraj Vigneswaran, Ramasamy Rameshbabu. "Sustainable textile recycling technologies: A comprehensive review." *Environmental Science and Pollution Research* 29 (2022):70830–70853.
5. Yang Zhang, Yan Yang, Shuiping Wang. "Chemical recycling of textile waste for a circular economy: A review." *Journal of Hazardous Materials* 445 (2023):130541.
6. Haitham S. H. Al-Shahri, Mohamed J. Abdullah, Adel A. S. Al-Maadeed. "Advancements in mechanical recycling of textile waste: A review on challenges and opportunities." *Waste Management* 172 (2023):184-198.
7. Pronob Roy, Swapan Saha, Pradip Ray. "Textile-to-textile recycling of cotton and polyester: A review on current technologies and future perspectives." *Journal of Environmental Management* 345 (2023):118749.
8. Md. Saiful Islam, A. M. H. Kamal, M. R. Karim. "Challenges and opportunities of textile waste management and recycling in the context of circular economy." *Sustainable Production and Consumption* 32 (2022):365-381.
9. Jing Li, Tao Wang, Long Zhang. "Innovations in textile recycling: A systematic review of emerging technologies." Resources, *Conservation and Recycling* 200 (2024):107338.
10. Luísa Costa, Joana P. da Silva, Ana M. L. F. P. V. Almeida. "A review of sustainable strategies for textile waste valorization and circularity." *Chemosphere* 304 (2022):135246.

How to cite this article: Nowak, Katarzyna. "Textile Recycling: Challenges, Methods, Solutions, Circularity." *J Textile Sci Eng* 15 (2025):644.

Address for Correspondence: Katarzyna, Nowak, Department of Material Technologies and Textile Design, Lodz University of Technology, Poland, E-mail: katarzyna.nowak@p.lodz.pl

Received: 03-Mar-2025, Manuscript No.j tese-25-172795; **Editor assigned:** 05-Mar-2025,PreQC No.P-172795; **Reviewed:** 19-Mar-2025, QC No. Q-172795; **Revised:** 24-Mar-2025, Manuscript No. R-172795; **Published:** 31-Mar-2025, DOI: 10.37421/2165-8064.2025.15.644