



TEXTILE WASTE RECYCLING IN THE CONTEXT OF CIRCULAR ECONOMY: A BIBLIOMETRIC AND VISUAL ANALYSIS USING WEB OF SCIENCE AND VOSVIEWER

POPA Alexandru¹, BUCEVSCHI Adina¹, PUSTIANU Monica¹

¹ Aurel Vlaicu University of Arad, Faculty of Engineering, Department of Automation, Industrial Engineering, Textiles and Transport, 77 Revolutiei Bd., 310130, Arad, Romania

Corresponding author: Popa, Alexandru, E-mail: alexpopaarad@yahoo.com

Abstract: *The rapid growth of the global textile industry has led to a significant increase in textile waste, raising major environmental concerns and intensifying the need for sustainable waste management strategies. Textile waste recycling has emerged as a key component of the circular economy, aiming to reduce resource consumption, minimize environmental impact, and promote sustainable production and consumption patterns. This study provides a comprehensive bibliometric and historical analysis of research on textile waste recycling using data extracted from the Web of Science database. The analysis covers the period 2000–2025 and employs VOSviewer to map scientific knowledge structures and identify research trends. The results highlight a significant increase in publications over the last decade, reflecting growing academic and industrial interest in sustainable textile practices. Key research clusters are identified, including mechanical recycling, chemical recycling technologies, circular economy frameworks, and waste management strategies. The study also reveals the most influential authors, countries, and journals contributing to this field. Furthermore, the historical evolution of research themes is examined, providing insights into emerging directions such as fiber regeneration and sustainable materials innovation. The findings contribute to a better understanding of the intellectual structure of textile waste recycling research and offer valuable guidance for future studies and policy development.*

Key words: *textile waste, recycling, circular economy, bibliometric analysis, sustainability, VOSviewer, Web of Science*

1. INTRODUCTION

The textile industry is one of the largest contributors to global environmental pollution, due to intensive resource consumption, chemical use, and large volumes of post-consumer waste [1], [2]. The rapid expansion of fast fashion has significantly accelerated textile production cycles, leading to increased waste generation and environmental degradation [3].

Traditional linear production models based on “take–make–dispose” are no longer sustainable. As a result, the transition toward circular economy principles has become essential in addressing the environmental challenges associated with textile waste [4]. The circular economy promotes material reuse, recycling, and regeneration, aiming to reduce waste and improve resource efficiency.



Textile waste [5], [6] recycling plays a crucial role in this transition, offering opportunities to recover materials and reduce environmental impacts. However, the growing volume of scientific literature in this field makes it difficult to identify key trends and research directions. Therefore, bibliometric analysis provides a systematic approach to understanding the structure and evolution of research in textile waste recycling.

2. LITERATURE REVIEW

Textile waste has become a critical global environmental issue due to increasing consumption and reduced product lifespans [3]. Large quantities of textile products are disposed of in landfills or incinerated, leading to environmental problems such as greenhouse gas emissions, water pollution, and microplastic contamination [7].

Recycling technologies are generally classified into mechanical and chemical processes. Mechanical recycling involves shredding and reprocessing fibers, but often results in reduced material quality [8]. In contrast, chemical recycling enables the recovery of high-quality raw materials, particularly for synthetic fibers such as polyester [9].

The concept of circular economy has gained increasing attention in textile research, promoting sustainable production and consumption systems [4], [10]. Strategies such as product redesign, recycling-friendly materials, and closed-loop systems are essential for achieving sustainability in the textile sector [11].

Environmental assessment tools such as life cycle assessment (LCA) are widely used to evaluate the impact of textile recycling processes [7], [12], [13]. These methods allow for a comprehensive analysis of environmental performance across the entire lifecycle of textile products.

Despite significant progress, challenges remain in the recycling of blended fibers and the implementation of large-scale recycling systems [14], [15]. Recent research emphasizes the need for innovative technologies and integrated approaches to improve efficiency and sustainability [16].

3. METHODOLOGY

The bibliometric analysis was conducted using the Web of Science Core Collection database, which provides high-quality and peer-reviewed scientific publications. A total of 883 articles published between 2000 and 2025 were selected, considering only English-language articles.

The search query included terms related to textile waste, recycling, and circular economy. The bibliographic data were exported as plain text files and analyzed using VOSviewer, a specialized tool for constructing and visualizing bibliometric networks.

The analysis focused on keyword co-occurrence, enabling the identification of thematic clusters and relationships between research topics. A minimum occurrence threshold was applied to ensure the relevance of selected keywords.

4. RESULTS: CLUSTER ANALYSIS

The VOSviewer network visualization illustrates the relationships between keywords in textile waste recycling research. The analysis identifies three main clusters, representing distinct research directions.

Cluster 1: Material Composition and Recycling Technologies

This cluster focuses on material properties and recycling processes, including keywords such as fibers, cotton, polyester, and depolymerization [17], [18]. These terms reflect research on

fiber recovery and material degradation, as well as mechanical and chemical recycling methods [8], [15].

The presence of both natural and synthetic fibers highlights the complexity of textile waste streams and the need for advanced recycling technologies [16]. The inclusion of depolymerization indicates the growing importance of chemical recycling technologies, particularly for synthetic materials [19], [20], [21].

This cluster suggests a strong research focus on: fiber recovery and material degradation processes, mechanical and chemical recycling methods, optimization of material properties after recycling .

Overall, it represents the technological foundation of textile waste recycling, where engineering and material science intersect to improve recycling efficiency and product quality.

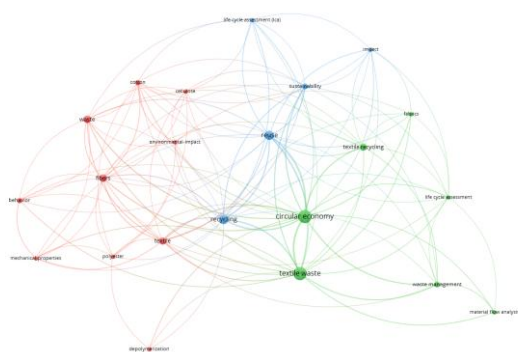


Fig. 1: Keyword Co-occurrence Network

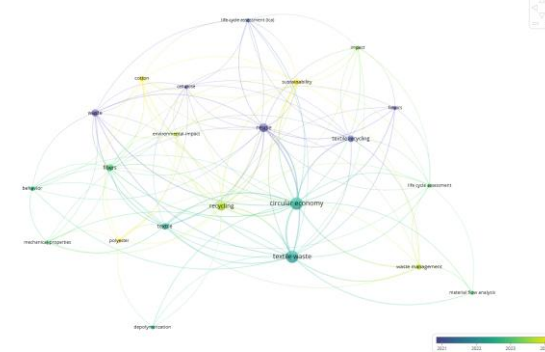


Fig. 2: Overlay Visualization (Historical Trends)

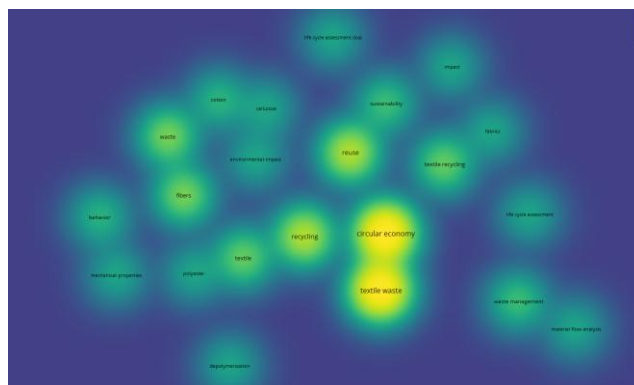


Fig. 3: Density visualization of keyword co-occurrence in textile waste recycling research (VOSviewer)

Cluster 2: Circular Economy and Waste Management

This cluster is centered on systemic approaches to textile waste management, including circular economy, textile waste, and waste management. The prominence of these terms reflects the increasing importance of sustainability frameworks and resource efficiency strategies [4], [11]. The inclusion of material flow analysis indicates the growing use of quantitative tools to optimize waste management systems [19]. This cluster reflects: closed-loop production systems, resource efficiency strategies, policy-oriented approaches to waste management .



The strong interconnection between textile waste and circular economy suggests that current research is increasingly focused on transforming waste into valuable resources within sustainable systems.

Cluster 3: Sustainability and Environmental Assessment

This cluster emphasizes environmental evaluation, including keywords such as sustainability, life cycle assessment, and environmental impact. [22], [23]. [24]. These concepts reflect the shift toward assessing the environmental performance of recycling systems [7], [2]. The increasing importance of LCA highlights the need for evidence-based approaches in sustainable textile management.

Density Analysis

The density visualization reveals that the most prominent research areas are concentrated around circular economy, textile waste, recycling, and reuse. These high-density regions indicate the core focus of current research.

Emerging topics such as life cycle assessment and environmental impact show moderate density, suggesting growing interest in sustainability evaluation. Lower-density areas represent specialized or developing topics, such as material properties and advanced recycling methods. This cluster demonstrates a shift toward: environmental performance assessment, sustainability metrics and indicators, integrated evaluation of recycling systems. It represents the analytical and evaluative dimension of textile waste research, linking environmental science with industrial practices.

4. RESULTS: DISCUSSION

The bibliometric analysis reveals not only the thematic structure of textile waste recycling research, but also a clear maturation of the field from isolated technical solutions toward integrated sustainability-oriented systems.

The first cluster, centered on material composition and recycling technologies, reflects the technological foundation of this research domain. The strong presence of keywords such as cotton, polyester, fibers, and depolymerization indicates an increasing scientific interest in overcoming one of the most critical technical barriers in textile recycling, namely the separation and recovery of mixed-fiber materials [8], [15], [17], [18]. The growing relevance of chemical recycling methods, particularly depolymerization, suggests a transition toward higher-value material recovery and improved resource efficiency [9], [16], [19]. From an industrial perspective, these findings highlight the necessity of investing in advanced recycling infrastructure capable of processing increasingly complex textile waste streams.

The second cluster, associated with circular economy and waste management, demonstrates that textile recycling is no longer perceived solely as end-of-life treatment strategy, but increasingly as a systemic component of sustainable production and consumption models [4],[10],[11]. The prominence of circular economy as a central keyword suggests that the research community increasingly recognizes recycling as part of broader value-chain redesign and closed-loop production systems [21], [25]. From a policy perspective, these findings support the implementation of regulatory instruments such as extended producer responsibility, eco-design requirements, and material traceability frameworks aimed at accelerating circular textile ecosystems [26], [27].

The third cluster, focused on sustainability and environmental assessment, reflects the growing importance of evidence-based decision-making in textile waste management. The increasing occurrence of keywords such as life cycle assessment and environmental impact indicates that both researchers and industrial stakeholders are increasingly concerned not only with recycling



efficiency, but also with measurable environmental performance [7], [12], [13], [22]. This trend confirms the growing role of environmental assessment tools in supporting sustainable material selection, process optimization, and strategic decision-making [23], [24].

Importantly, the interaction between these three clusters suggests that textile waste recycling research is evolving toward convergence between technological innovation, environmental accountability, and systemic circularity. This evolution reflects the transition from traditional recycling approaches focused mainly on waste reduction toward integrated strategies [4], [7], [25].

However, the bibliometric analysis also reveals several emerging research gaps. Despite the growing interest in chemical recycling and circular economy frameworks, keywords related to digital technologies such as artificial intelligence, blockchain, digital twins, and smart waste management systems remain relatively underrepresented. This suggests that the digital transformation of textile recycling processes remains insufficiently explored. Furthermore, the relatively limited presence of socio-economic and policy-related terms indicates that non-technical dimensions of circular textile systems require further investigation.

Future research should therefore prioritize interdisciplinary approaches that integrate advanced recycling technologies, environmental assessment methods, digital innovation, supply-chain transparency, and supportive policy frameworks. Such integration may significantly accelerate the transition toward sustainable textile production and consumption systems.

5. CONCLUSIONS

This study provides a comprehensive bibliometric and visual analysis of research on textile waste recycling in the context of the circular economy, based on scientific publications indexed in the Clarivate Web of Science database between 2000 and 2025. The results reveal three dominant research directions: recycling technologies and material recovery, circular economy and waste management strategies, and sustainability assessment through environmental evaluation tools.

The field has evolved from predominantly technical studies focused on fiber recovery toward more integrated approaches that combine technological innovation, environmental accountability, and systemic circularity. The increasing prominence of concepts such as life cycle assessment, resource efficiency, and circular economy indicates a growing emphasis on evidence-based and multidisciplinary solutions.

From an industrial perspective, the results highlight the urgent need for scalable recycling infrastructures, improved sorting and separation technologies, and greater integration of digital solutions for waste tracking and process optimization.

The analysis also identifies important research gaps, particularly in the integration of digital technologies such as artificial intelligence, blockchain, and smart waste management systems, as well as in the socio-economic evaluation of circular textile systems. Addressing these gaps may significantly accelerate the transition toward sustainable textile production and consumption.

Overall, this study contributes not only to mapping the intellectual structure of textile waste recycling research, but also to identifying strategic directions for future scientific investigation, industrial implementation, and policy development within circular textile ecosystems.

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