Advancing Towards a Circular Economy in the Textile Industry †

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Abstract: The textile and garment manufacturing process in the textile industry produces a significant amount of waste, including fabric scraps, dyes, chemicals, as well as leftover fibers and yarns, leading to environmental pollution. The issue of fabric and garment waste is a major concern within the industry. This review provides an overview of the prevailing waste challenges in the textile sector while exploring the basics of the circular economy. The review incorporates additional findings and relevant research related to these proposals, aiming to promote sustainable solutions for waste reduction in the textile industry.

Keywords: circular economy; textile industry; garment manufacturing process; life cycle; waste reduction; sustainable solutions

1. Introduction

Circular economy means growing more materials, reducing reuse and recycling resources [1,2]. While the textile industry is a major driver of economic growth and innovation, it also leaves a significant environmental footprint in the form of waste. The multi-layered waste stream, which includes fabric residues, chemical discharges, dye impurities and residual fibers, poses significant environmental challenges [3–6]. The circular economy represents a promising framework to revolutionize the sector's prevailing linear production model [7–10]. Textile wastes, including fabric residues, chemical wastes, dye impurities and fiber residues, lead to soil degradation, water pollution and damage to aquatic ecosystems [11–13]. The textile industry's heavy dependence on natural resources such as water, land, and raw materials exacerbates resource depletion when wastes are inadequately managed [14].

2. Environmental Challenges and Impacts of Textile Waste

These problems are relevant and some work on waste prevention and reduction can be found in the literature. In study, Savini explores the contrast between the degrowth perspective, which advocates for a circular metabolism to decrease consumption and production, and the mainstream circular economy viewpoint, which views waste as a potential avenue for achieving sustainable growth [15]. Mishra et al. explore the integration of microalgae in textile wastewater treatment methods, highlighting recent progress and potential prospects [16]. Meanwhile, Di et al. investigate regional disparities and

collaborative efforts in reducing carbon emissions within China's eco-friendly, low-carbon circular economy [17]. In addition, the production and disposal of textiles consume large amounts of energy and contribute to greenhouse gas emissions and climate change. These wastes include discarded garments and production wastes such as fabric cuttings, which take up a significant amount of non-biodegradable landfill space and further strain resources [18,19]. Möslinger et al. investigate the use of a circular economy framework in urban regions to reduce greenhouse gas emissions. They analyze data from 362 cities working towards climate neutrality and emphasize the importance of strategies such as digital integration, citizen collaboration, and innovation for success in this endeavor [20]. In the study conducted by Mostaghel et al., it is highlighted that marketing within the circular economy encounters various challenges requiring attention from both managers and researchers. In response to these challenges, the study puts forth a novel marketing definition that aligns with the demands of the circular economy and expands upon the existing body of marketing theory [21]. The fast turnover of the fast fashion industry promotes a throwaway culture that undervalues clothing and contributes to social problems such as poor working conditions in some textile factories [22–24].

3. Strategies and Initiatives for Circular Economy

Economically, textile waste represents a significant loss, as valuable materials are wasted and the potential for job and revenue creation through recycling and circular economy is not realized. Inadequate textile collection, sorting and recycling infrastructure in many regions further complicates waste reduction efforts. Finally, consumer behaviors such as overconsumption and premature disposal of clothing exacerbate the textile waste problem [25–27]. Addressing these challenges requires a comprehensive, coordinated effort involving industry stakeholders, governments, consumers and environmental organizations. Remedial strategies include circular design, improved recycling infrastructure, sustainable production practices and the promotion of responsible consumption. The research conducted by Majumdar et al. is one of the first initiatives to address the barriers and strategies for building a circular supply chain in the textile and apparel industry [28]. Zaragoza-Benzal et al. reported on their research to introduce a sustainable gypsum composite material that partially replaces conventional raw materials with expanded polystyrene waste and waste textile fibers from tires. This material retains its strong mechanical properties even after rigorous moisture and drying cycles, thus complying with the principles of circular economy for sustainable construction [29]. The study by Malinverno et al. emphasizes the importance of monitoring workwear flow data for better collaboration in the textile value chain and the promotion of circular economy practices. In Switzerland, the annual consumption of workwear is estimated to be 3200 tons, corresponding to 0.4 kg per capita [30].

4. Circular Economy Principles and Suggestions

The circular economy principles are a set of strategies for sustainable resource management that emphasize resource efficiency, waste reduction, closed loop systems, and various practices such as design for longevity, reuse, recycling, and collaborative consumption [31–35]. Circular economy practices in the textile industry have gained significant attention in recent years due to their potential contribution to sustainability [36,37]. John and Mishra propose a sustainable three-layer circular economic model for the textile and fashion industry, which includes controllable waste, emissions, and wastewater [38]. Schmutz and Som identify the potential for circularity of industrial textile waste generated within Swiss companies [40]. Teixeira et al. propose a methodology for integrating circular thinking into product development processes in the textile industry [41]. Chopra et al. discuss sustainable process design for circular fashion, focusing on advances in sustainable chemistry for the valorization of textile waste [42]. In the case study authored by Govindan et al., the focus is on the transformation of the conventional circular economy into

a smart circular economy. This transformation is driven by digitization, with the ultimate aim of attaining sustainable development objectives and achieving a state of net-zero consumption [43].

5. Circularity Aspects and Approaches

Several articles deal with different aspects of circularity in the textile industry. Rossi et al. investigate circular economy indicators for organizations considering sustainability and business models [44]. A techno-economic analysis of innovative biorefineries for a cleaner management of textile waste is conducted by Farahmandpour et al. [45]. Jia et al. present a systematic literature review on circular economy in the textile and apparel industry [46]. Jäämaa and Kaipia examine the problem of collecting reusable textiles from consumers in the circular economy [47]. A concept model for waste management in the textile and apparel industry to achieve Sustainable Development Goal (SDG) 12 in Bangladesh is presented by Akter et al. Ribul et al. discuss different approaches for closed-loop bio-based recycling in the circular economy for sustainable textiles [49]. Galatti and Baruque-Ramos examine circular economy indicators for measuring social innovation in the Brazilian textile and fashion industry [50]. Chowdhury et al. present the implementation of an intelligent waste management system for a sustainable circular economy in the textile industry [51]. The orchestration of the circular economy in the textile and fashion industry to meet the challenges of the circular economy is examined by Saccani et al. Luoma et al. discuss future scenarios for the use of data in the textile circular economy [53]. The issues addressed in these studies contribute to the development of solutions for the problems of the textile industry in connection with the circular economy. The study of circular economy indicators for organizations and the implementation of an intelligent waste management system are examples of measures that can contribute to solving these problems. In addition, the techno-economic analysis of innovative biorefineries and the discussion of different approaches to recycling offer important insights and solutions for a more sustainable textile industry.

6. Conclusions

The textile industry faces significant environmental challenges due to the generation of waste throughout the manufacturing process. The circular economy offers a promising framework to address these challenges and promote sustainable solutions for waste reduction. Strategies and initiatives such as circular design, improved recycling infrastructure, and responsible consumption are necessary to transition towards a circular economy in the textile industry. Various studies have explored different aspects of circularity in the industry, including the integration of circular thinking in product development processes, the transformation into a smart circular economy, and the development of closed-loop recycling approaches.

In summary, this review highlights the need for the textile industry to move to a circular economy to address the escalating waste problem. By embracing circular economy principles and adopting innovative circular product paradigms, the sector can move beyond a linear production model and pave the way for sustainable and responsible resource management. Collaboration among industry stakeholders, policymakers and consumers is critical to driving the necessary changes toward a more environmentally and socially responsible textile sector.

Informed Consent Statement:

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