

Post-Consumer Textile Waste Management Practices and Challenges in India: A Systematic Literature Review

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ABSTRACT

Purpose: This review systematically maps the scholarly articles on waste management practices in the textile sector in light of consumer-disposed textiles and the adoption of the circular economy. It emphasizes the significance of scholarly research to the existing knowledge on waste management practices in the context of India's textile sector. **Materials and Methods:** A thorough Systematic Literature Review (SLR) was employed, which included an analysis of the content of 58 papers published in academic journals in the last 6 years. **Findings:** The integration of textile waste management methods/practices in this review depicts the varied and challenging domain of waste management in the textile industry. Conversely, there are very limited studies conducted in developing economies, where most textile manufacturing occurs. **Research Limitations:** The study includes literature from selected databases published between 2015 and 2021. More comprehensive research coverage and continuous evaluation of the health and status of the textile industry are required for valuable insights to effectively adopt circular economy practices from the perspective of developing countries like India.

Keywords: Post-consumer textile waste management, Waste management, Textile waste, Developing economies, Circular economy, Systematic review.

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INTRODUCTION

Environmental Concerns and the Clothing Industry

Clothing and fashion ingestion have grown in the twenty-first century. Profoundly due to various effects on global population expansion, overall upgrade in standard of living, and the upsurge of fast fashion.^[1-3] With technological improvements, globalisation, and changing customer demands, the garment business has seen incredible expansion and transformation over the last few decades.^[4] However, because of the industry's substantial resource use and the manufacturing of vast volumes of textile waste, its rise has also raised environmental issues.^[5] The clothing industry's environmental effect extends beyond the manufacturing phase, including the full textile lifecycle, from beginning with raw material extraction to final disposal.^[6] This has increased public awareness of the importance of sustainable methods in the textile and garment industries.

Textile Waste and the Linear Economy Model^[7]

In light of how we create and consume products, professionals have significantly increased the demand for global ecological sustainability.^[8] For a considerable time, buyers and suppliers have followed the Linear Economy's (LE) take-make-use-waste model, wherein massive volumes of finite resources are retrieved to create goods that are employed several times by buyers before being discarded in dump sites, generating wastages.^[9] Consequently, textile waste accumulates in landfills, decaying slowly and emitting dangerous toxins into the environment.^[10] This linear model is founded on a manufacturing mindset that believes resources are limitless. Industries have constantly retrieved resources from the world by embracing this outlook and economy without any strategies for reusing or rejuvenating the natural sources from where the materials have been derived.^[11] Approximately 80% of raw materials are discarded after a single use, experiencing severe adverse effects on the environment, economy, and society,^[12] depletion of natural resources, vegetation cover loss, shifts in global temperature, and economic fallout from global weather catastrophe are all threats to human wellness and well-being.

Global Circular Economy Measures

In response to the environmental problems created by the linear economy,^[13] theorists have proposed new business models that could comply with textile waste management concerning these resources to one's complete capability; such practices



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are incorporated into circular production models.^[14] In brief, the concept of a circular economy has gained popularity as an environmentally sound alternative. Circular practices increase the volume of resource utilisation while limiting environmental effects throughout the manufacturing and consumption phases.^[15] As per the circular economy, the primary focus on textile management of waste should be on maximising garment usage, reducing consumption, and emphasising recycling resources. The textile and garment sector may dramatically minimise its environmental impact and enhance resource efficiency by adopting a circular strategy^[16,17] Since textile waste accounts for a comparatively tiny proportion of total waste, its effect on our well-being and our surroundings is significant and growing owing to the existing manufacturing framework. As a result, because the clothing industry functions in a linear fashion, struggling with environmental, social, and financial constraints, the Circular Economy (CE) can serve as a recuperative and reformative framework, attempting to keep goods, constituents, and materials at one's maximum degree of utility and value.

The Challenges of the Indian Textile Industry

India is a significant player in the global textile business and is one of the top manufacturers and exporters of textiles and clothing.^[18] While the sector contributes considerably to the country's economic growth and jobs, it has various issues in handling post-consumer textile waste.^[19] The particular challenges of the Indian textile industry, such as the wide range of textiles produced, the prevalence of unorganised sectors, and insufficient waste treatment facilities, add to the difficulty of solving textile waste concerns.^[20]

LITERATURE REVIEW

According to a report by Quantis, the textile sector ranks second after the oil industry in terms of pollution, accounting for around 1.2 billion tonnes of greenhouse gas (GHG) emissions each year. Every year, tonnes of clothing are produced, used, and discarded. Moreover, the textile and garment industry is also a significant source of plastic microfibres in the seas and is expected to consume up to 25% of the world's carbon budget by 2050. Hence, transitioning from a linear to a circular economy is the need of the hour. In addition, textile waste management is a crucial component of the circular economy for textiles.

PCTW Management in India^[21]

India positions 6th on the planet in material and attire trades. The material and attire area in the nation is the second area that does the most work after farming, providing direct employment to 45 million people and 100 million people from related areas. India's domestic apparel and fashion industry contributes 5% to the nation's GDP, 7% of modern results in esteem terms, and 12% of the nation's product profit.

Nowadays,^[22] the brief life spans of clothing items led to fast fashion cycles and a higher purchasing majority of customers of India live in metropolitan areas that create substantial quantities of (PCTW) in the form of worn clothes or possibly even Second-Hand Clothing (SHC).^[23] India is likewise perhaps the biggest beneficiary of worldwide post-customer textile waste, with a significant volume of more than €100m, of disposing of material imported and manually sorted in different hubs. Because the bulk of this post-consumer textile waste is generated domestically, its management is challenging; industrial waste is easier to recycle than residential waste.

The literature highlights the pressing need for sustainable solutions in the Indian textile and apparel industry.^[24,25] Initiatives and practices geared towards sustainability, circular economy, and reverse logistics are emerging as potential strategies to address the challenges of textile waste and fast fashion, as discussed in the following research studies.^[26-31] Additionally, the economic viability and challenges of the second-hand clothing market are explored as a promising avenue for reducing textile waste and fostering sustainability.^[31] These studies collectively underline the importance of sustainable practices and waste management in the Indian textile and apparel industry, which is essential for the sector's long-term growth and environmental responsibility.

Recycling Processes in Textile

Mechanical Recycling Process^[32]

Mechanical recycling is a simple, easy and cost-effective method.^[33] This recycling technique is preferred for many clothes.^[34] Mechanical recycling is commonly used to recycle discarded consumer textile waste.^[35] Mechanical recycling breaks textiles into fibres through cutting, shredding, carding, or other processes. Machines progressively break down the textile and contribute to making it fibrous, and the resulting fibers are used again/utilised in the manufacturing of yarns. Subsequently, waste materials are sorted in the mechanical recycling process.^[36] Metals and labels are removed as foreign constituents. The textile is divided into fibers after trimming into smaller bits with rotary blades.

Thermal Recycling Process^[37,38]

Synthetic materials are disintegrated and realigned in thermal recycling. Thermal recycling is the preferred approach for recycling synthetic materials.^[39] Melt extrusion transforms chips and pellets procured mechanically from synthetic waste materials into fibers.

Chemical Recycling Process^[40]

Chemical recycling is the process of recycling, which includes the depolymerisation of polymers which is the method of diluting polymers.^[41,42] Chemical and biological processes are used to transform or disintegrate polymers into their monomeric building

blocks. The two forms of chemical recycling are-Monomer and Polymer. During polymer recycling, the polymer chain is often diminished. As an outcome, the recycled fibre's quality deteriorates. Original quality fibres are extracted through monomer recycling.^[43] While monomer recycling is exclusively utilised for synthetic fabrics, chemical recycling can be used for various textiles.

Downcycling^[36-39]

Downcycling tends to happen whenever the quality and monetary value of recyclable material is relatively lower than the original item. Examples of downcycling are insulation materials, upholstery textiles, etc.

Upcycling^[39]

Occurs when the recycled material's quality is comparable to or better than that of the actual product.^[44] Upcycling is the method of utilizing materials to produce more valuable items. This ecologically safe method is an essential first phase towards a zero-waste approach.^[40] Under the circular economy context, manufacturing raw materials like cotton yarns or fibers is an example of upcycling.

Open-loop Channel of Recycling^[36]

The practice of recycling an item's raw materials in a different manufacturing area is called an open-loop or linear recycling channel. Secondary items acquired through linear recycling are typically disrupted at the end of their useful life.

Closed-loop Channel of Recycling^[40]

Closed-loop Channel of Recycling refers to the reusability of recyclable textile waste materials in the textile industry.^[36] This recycling method is demonstrated by incorporating mechanically recycled pre-consumer or PCTW in textile manufacturing.

Circular Economy and India^[45]

The "circular economy" phenomenon as a waste-reduction approach has gained widespread acceptance in the commercial world. Organizations have attempted to attain "zero waste" by discovering new applications for discarded materials and closing the supply chain loop. This entails shifting the flow of materials from LE (take-create-waste) to CE (take-create-waste-new product). Moreover,^[46] a circular economy model has long been recognized for its importance, validity, and scope. But nevertheless, owing to the dominance of the linear model in academic and research contexts, it has persisted as an underresearched concept. Figure 1 depicts a layout view of the connection among resources,

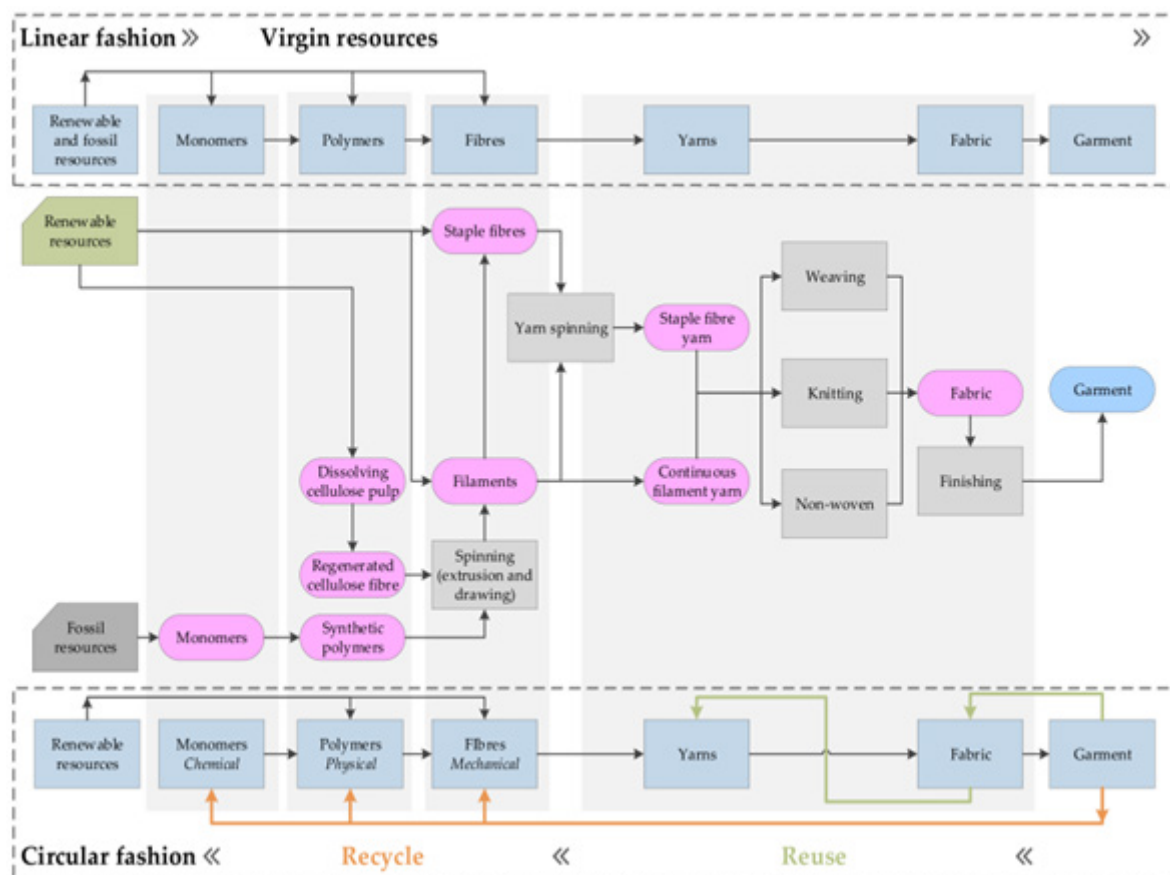


Figure 1: Linear and the circular process of recycling.^[46]

byproducts, and processes that are involved used in the textile sector.^[47] Several typical operating steps are required to create clothing from renewable or fossil resources.^[15]

India is at a crossroads in its economic growth journey. Incorporating circularity into India's economic development is imperative to counteract the adverse effects of rapid urbanisation, industrialisation, population growth, and climate change. According to the Ellen MacArthur Foundation, adopting the circular economy in India will result in an annual benefit of Rs 40 lakh crore (\$624 billion) in 2050 and a 44% reduction in GHG emissions.^[48] Following a recent Accenture research, India can unleash nearly \$500 billion in economic value by 2030 by adopting Circular Economy business models, as shown in Figure 2.

In nations like India, waste management is mostly an unorganized, diverse sector.^[46] Numerous legislations enacted by the Ministry of Forests, Ministry of Environment and Ministry of Climate Change in collaboration with state board of pollution control, state governments, and municipal corporations regulate the said sector.

Origin of the problem

From the literature study, it is evident that there is a dearth of studies in the field of post-consumer textile waste management in India broadly under the circular economy context.

The new circular economy's goals entail redesigning and reshaping the linear economy towards many more sustainable alternatives.^[49] This could possibly be concentrated on four key aspects of the textile cycle as follows; (1) resources, (2) manufacturing, (3) consumption, and (4) post-consumption.^[50] The environmentally-unfriendly characteristics of present post-consumer textile waste treatment procedures compel the discovery of various alternative strategies to handle the textile waste.^[51] Discarded waste textiles are widely regarded as a new source and a revenue prospect. Whereas,^[50] in the past decades, the recycling/reusability of PCTW goods has developed as a viable approach to solving this problem.^[52] Well-thought-out sustainable fashion projects and their implementation have the potential to considerably aid in involving the general public

in initiatives aimed at addressing climate change as well as environmental inequities. According to Bernardes *et al.*,^[53] consumers assert the absence of information about corporations distributing sustainable products and express a desire to gain more knowledge. Promotional strategies, events, and advertising schemes must concentrate on appropriate communications emphasizing sustainable items' advantages and describing why they are significantly more costly than non-sustainable items owing to greater quality and restricted availability. Most of the research concentrated on nations like the United States, China, and Europe. As a result,^[54] further research on circular fashion should be conducted in growing nations such as India, which are additionally significant contributors to global pollution and might have constraints, motivations, and efforts that vary from those previously investigated.^[55] Textile waste management study in India is mostly unexplored. In the Indian context, secondary research on textile waste management is scarce. Recent studies have shed light on various aspects of circular economy implementation, sustainable practices, and post-consumer textile waste management in the Indian context, emphasising the need for more extensive research and the development of tailored strategies to address this critical issue.^[56-64]

Research Objectives

As determined by systematic literature analysis, specific study objectives are as follows:

Objective: To identify the PCTW management practices in India.

Sub-objective:

- (i) To conduct a systematic literature review on PCTW management practices in India.
- (ii) To identify the waste management practices used in the textile industry.
- (iii) To identify the critical challenges through the literature

Research Methodology

A systematic strategy for literature analysis was used to extract data for this study.^[65] An SLR is a research method for collecting, synthesising, and reviewing the recorded study results surrounding a certain subject or issue, which helps reduce bias related to non-systematic reviews.^[53] Despite being initiated and used first in medical and healthcare research, SLR is progressively booming in the social sciences, notably in management and business disciplines.

This analysis technique was chosen since there is a lack of clarity and consensus in the PCTW management domain. For this study, current literature and empirical findings were reconstructed as transparent and reproducible, identifying areas where knowledge is still sparse and suggesting future research implications to industry practitioners by carefully examining the literature.

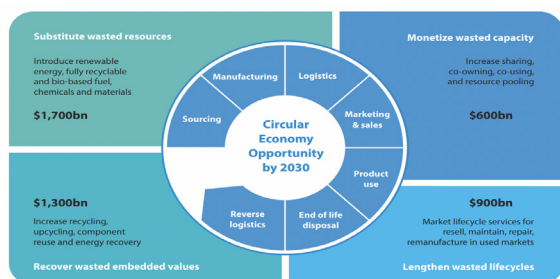


Figure 2: Potential value creation from circular business models by 2030.^[47]

Firstly, the scope of the SLR was outlined. It determines searched keywords and a range of assessment criteria depending on the proposed research questions.

Secondly, after the research plan is defined, a comprehensive literature search is conducted from 2015 to 2021 by employing both inclusion and exclusion criteria while gathering data supported by a broad corpus of available scholarly material on the topic. Academic article publications give valuable information at the moment on a wide range of issues, which is sufficient for achieving research objectives. The Scopus and Web of Science (WoS) databases were included in the inclusion criteria since they are widely regarded as the most extensive research datasets available. In both the databases, specific keywords- “textile”, “waste management”, and “post-consumer waste management” for search strings in the title, abstract, and keywords of the published articles were used. Table 1 shows the range of combinations searched and replicated in the two databases, ranging from more complex strings to simpler combinations.

Thirdly, screening and data extraction is conducted to identify the potentially relevant articles. During the third phase of the inclusion search process, 70 papers were found in WOS, and 455 papers were found in Scopus. After removing 40 duplicate papers and 427 irrelevant papers, 58 articles remained.

A total of 427 articles were excluded during the screening and data extraction process as they were deemed irrelevant to the study's research questions despite initially meeting the inclusion criteria. The specifics of why these articles were considered irrelevant may include factors such as not addressing the topic adequately, not containing substantial data or analysis related to the study, or not aligning with the objectives of the research. These exclusion criteria were applied systematically to ensure that only the most relevant, recent, and English-language articles and papers meeting the specified keyword criteria were included in the final analysis. Figure 3 depicts the data selection and extraction steps.

FINDINGS AND DISCUSSION

Outline of descriptive content analysis

The literature review indicates that various academic investigations concentrated on waste management strategies in textiles, with an increasing emphasis on transitioning from a linear to a circular economy. While demonstrating the necessity for an expanding amount of literature on this subject with practical implications.

Systematic Dimension and Methodical Aspect

Five systematic dimensions were identified in the post-initial reviewing of papers and examining components using inductive approaches to evaluate the topic and research directions. Methodical aspects were utilized to place material orders within each dimension, as depicted in Table 2. One paper may fall into multiple categories.

Systematic Dimension: Types of Paper

Methodical Aspect: Qualitative and quantitative papers (i.e., reviews, conceptual, case studies, surveys, exploratory, modelling).

In the examination of the academic landscape on Post-Consumer Textile Waste (PCTW) management within the circular economy context, it is crucial to categorize and evaluate the types of papers that contribute to our understanding of this multifaceted subject. The classification includes a wide spectrum of research methodologies, such as qualitative and quantitative approaches, encompassing literature reviews, conceptual papers, case studies, surveys, exploratory studies, and modelling. By encompassing such diverse types of papers, we are better equipped to comprehend the intricate dimensions of PCTW management, from theoretical conceptualizations to real-world applications.

Systematic Dimension: Types of Research

Methodical Aspect: Conceptual framework, CE perspective, PCTW management practices in the industry, zero waste fashion, innovation in the processes, design thinking, channels for textile reuse.

Table 1: Keyword search string and criteria.

Search String	Search Criteria
“Textile” AND “waste management” OR textile* AND “waste management” OR “Post-consumer” AND “waste management”	Date Range: 2015 to 2021 Language: English Document Type: Article, review and conference paper Database: Web of Science and Scopus Keyword Search: Keyword search in Article title, abstract and keywords.

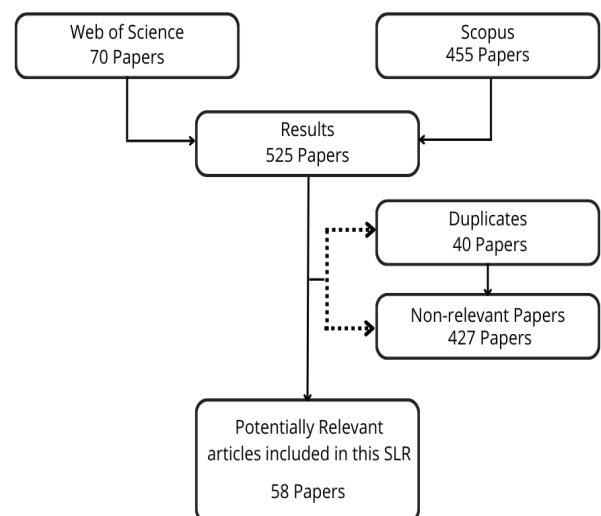


Figure 3: Systematic Literature Review Summary.

The exploration of post-consumer textile waste management reveals various dimensions within the circular economy context, encompassing the development of conceptual frameworks, Circular Economy (CE) perspectives, PCTW management practices within the industry, zero waste fashion initiatives, innovations in waste reduction processes, the application of

design thinking, and the establishment of channels for textile reuse. This comprehensive spectrum of research directions allows for a holistic view of how PCTW management is evolving, from theoretical underpinnings to practical strategies, and highlights the interplay of sustainability, innovation, and design thinking in reshaping the textile industry.

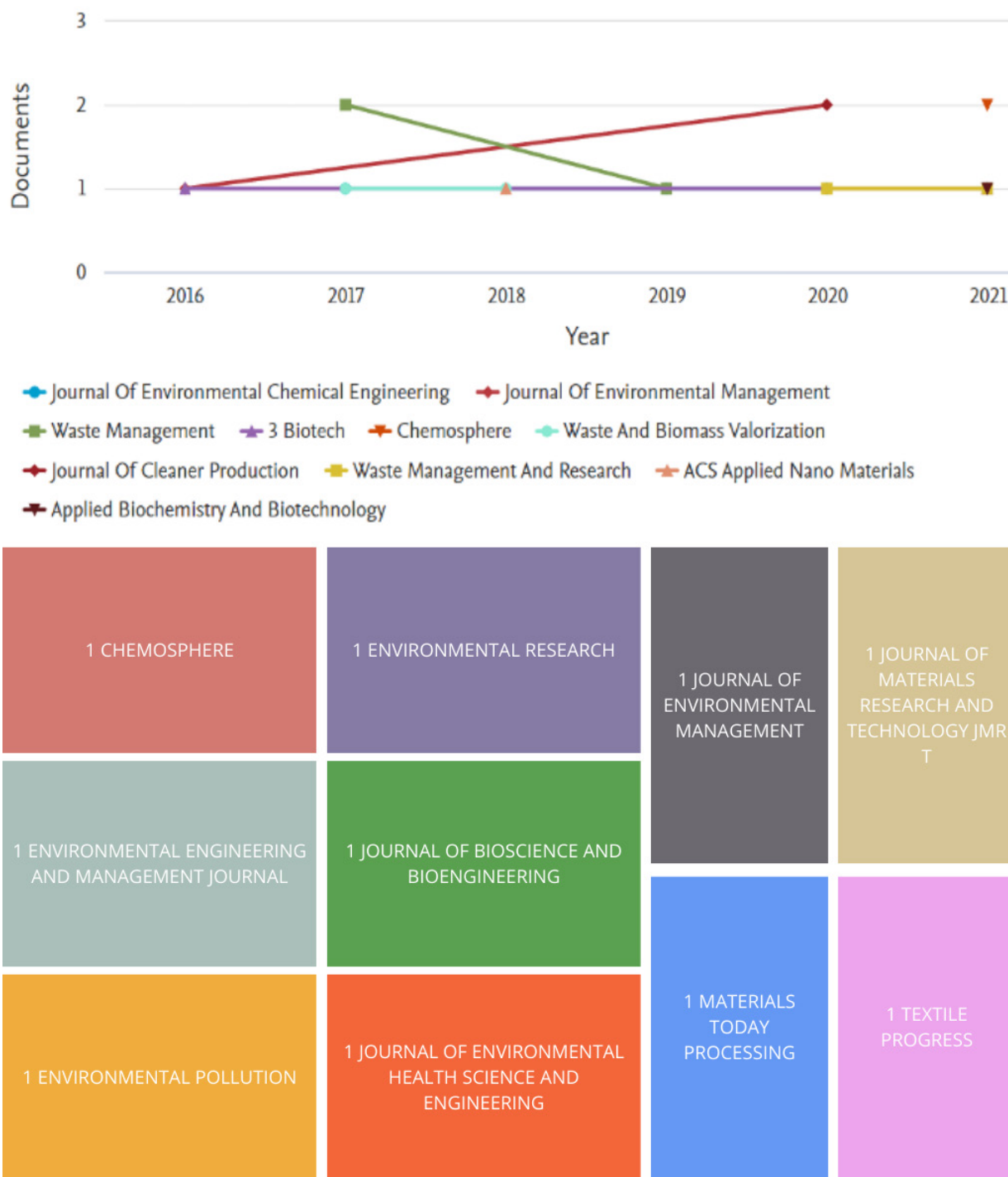


Figure 4: No. of publications on textile waste management in India from 2015–2021.

Systematic Dimension: Waste Management Practices

Methodical Aspect: Mechanical recycling, chemical recycling, incineration, decomposition, special techniques, and mixed techniques.

One of the core components of effective post-consumer textile waste management is the methodology employed in waste treatment and recycling. This dimension encompasses a range of practices, including mechanical recycling, chemical recycling, incineration, decomposition, and the utilization of special and mixed techniques. Each approach has unique implications

Table 2: Systematic dimension and methodical aspect of research papers.

Systematic Dimension	Methodical Aspect
Types of Paper	Qualitative and quantitative papers (i.e., reviews, conceptual, case studies, surveys, exploratory, modelling).
Types of Research	Conceptual framework, CE perspective, PCTW management practices in the industry, zero waste fashion, innovation in the processes, design thinking, channels for textile reuse.
Waste Management Practices	Mechanical recycling, chemical recycling, incineration, decomposition, special techniques and mixed techniques.
CE Principles (R's)	Recover, refurbish, recycle, repair, repurpose, reuse, remanufacture, reduce, rethink and refuse.
Geographical Focus	Developing nations and regions where the frequency of purchase is high.

for environmental sustainability, resource conservation, and economic viability, making it essential to scrutinize the merits and limitations of these techniques to devise the most effective strategies for PCTW management.

Systematic Dimension: CE Principles (R's)

Methodical Aspect: Recover, refurbish, recycle, repair, repurpose, reuse, remanufacture, reduce, rethink, refuse.

The principles of the circular economy, often encapsulated by the "R's," offer a structured framework for sustainable waste management. In the context of post-consumer textile waste, these principles comprise a roadmap for action. They include strategies such as recovering valuable materials, refurbishing products, recycling textiles, repairing items, repurposing materials, reusing products, remanufacturing goods, reducing waste generation, rethinking consumption patterns, and refusing disposable and non-recyclable items. Each of these principles represents a facet of sustainability, and their integration into textile waste management practices is essential for achieving circularity in the textile industry.

Systematic Dimension: Geographical Focus

Methodical Aspect: Developing nations and regions where the frequency of purchase is high.

Geographical focus is a significant aspect of post-consumer textile waste management research. The research explores the varying dynamics of textile waste generation and management in developing nations and regions characterized by high consumption frequency. By concentrating on these specific areas, the research aims to address the distinctive challenges and opportunities faced by regions with burgeoning consumer markets and emerging economies. Understanding the geographical nuances is vital

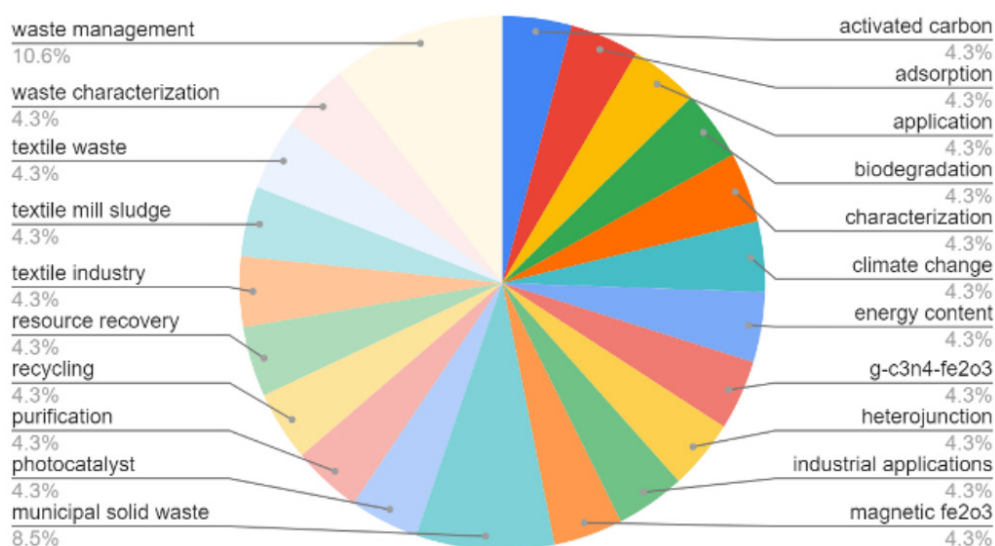


Figure 5: Number of documents in top 10 key journals-Scopus.

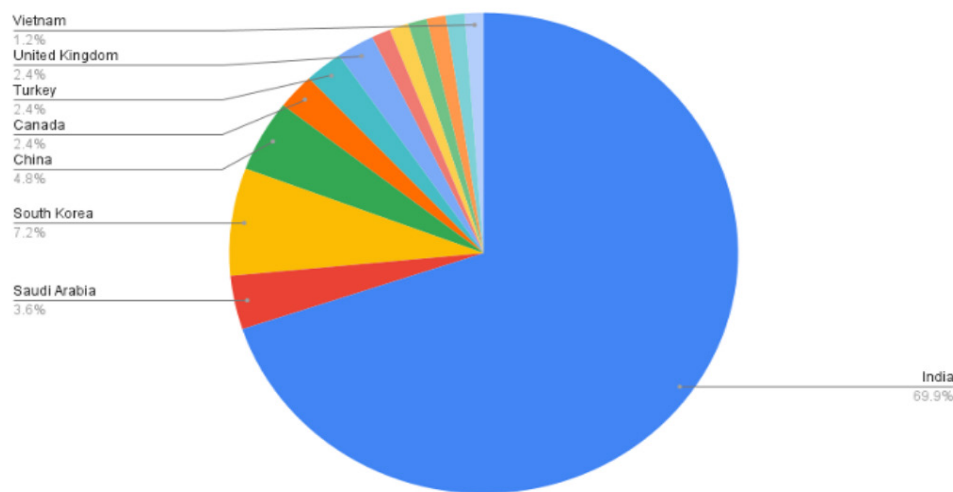


Figure 6: Prevalence of keyword similarity in selected journal articles.

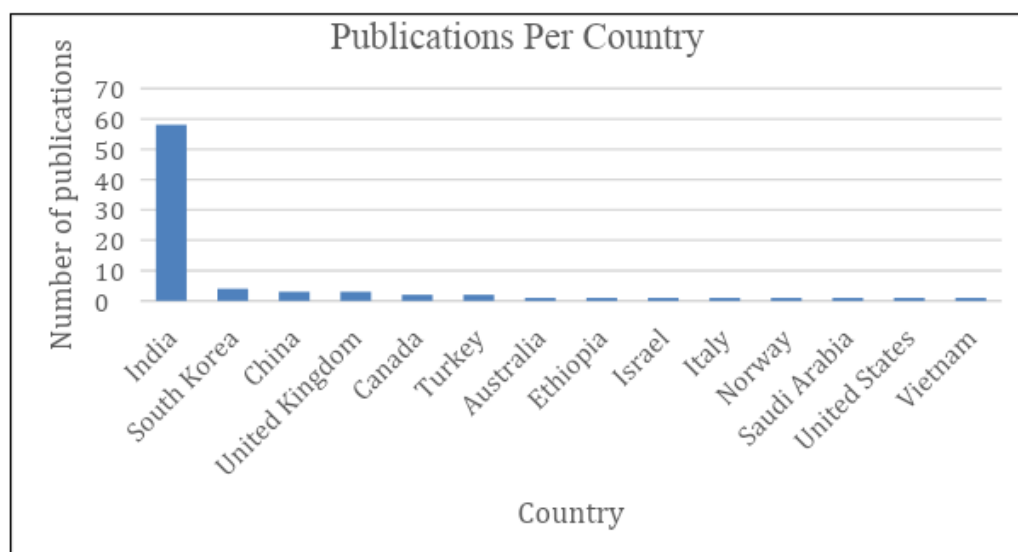


Figure 7: Number of publications per country.

in formulating targeted strategies that align with each region's cultural, economic, and environmental characteristics.

Paper distribution and Evolution

Figure 4 depicts the complete study of chosen publications and paper distributions from 2015 to 2021. Textile waste management research in India elevated from 2015 to 2018 and expedited in 2019, indicating increased academic awareness and interest in the subject. Because many research questions remain unanswered, a further upward research trend is in anticipation. Figure 5 and Table 3 depict the allocation of publications showcasing important journals' contributions to the topic.

Keywords

During this step, keywords were extracted from the selected research papers. As shown in Figure 6, keyword groups were established to demonstrate how additional topics and synonyms are connected to textile waste management methods in India.

Geographical Focus

As illustrated in Figure 7, the number of papers published for each nation is governed by the affiliation country of the first or corresponding author. This clearly depicts the increasing number of papers published on the topic in India, followed by South Korea and China.

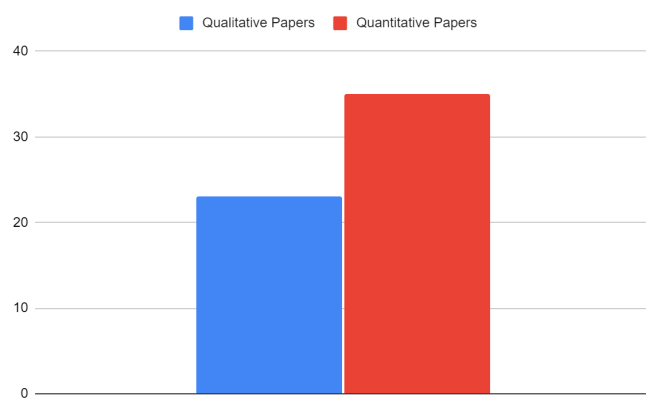


Figure 8: Research paper distribution.

Table 3: Number of documents in top 10 key journals-Web of Science.

Top 10 key Journals	Documents
Chemosphere	1
Environmental Research	1
Journal of Environmental Management	1
Journal of Materials Research and Technology JMR T	1
Environmental Engineering and Management Journal	1
Journal of Bioscience and bioengineering	1
Environmental Pollution	1
Journal of Environmental Health Science and Engineering	1
Materials Today Proceedings	1
Textile Progress	1

Types of Research Papers

Figure 8 depicts the distribution of types of research papers, with quantitative papers being the most popular method, followed by qualitative papers. Regarding the literature study for this paper, 23 papers were based on qualitative studies, while 35 were based on quantitative studies. This suggests that even after more and more empirical tests of the measures suggested in the quantitative literature, there is still a lag in the qualitative research that hinders the scalability of the post-consumer textile waste management research. For keyword occurrence set to 2 Fractional counting which is based on theoretical considerations and on the empirical analyses, we conclude that for many purposes, the fractional counting approach is preferable over the full counting one.^[66]

Waste Management Practices (because is a more relevant part of the research)

The major categories of PCTW management methods identified in the literature are:

Mechanical recycling^[67]

This recycling method includes manually tearing fabrics and ripping them into several fibers. After that, the fibers are usually mixed with other fiber types to reinforce them before being spun and woven into a new fabric.^[32] Through melt deformation, this recycling process involves the extraction of fibers from waste materials, which may be spun into yarns. As a result, to achieve high fiber tenacity and fineness, this process must be employed for virgin fibers.

Chemical recycling^[67]

This recycling method includes the application of chemical solvents to dilute textile waste fibers so that they may be removed, reclaimed, and converted into a new fabric.^[32] The dissolving method is also employed in the chemical recycling of cellulose fabrics like cotton or viscose. Simultaneously time, organic solvents use ionic liquids to disintegrate cellulosic polymers.

Physical methods^[68]

Physical processes, such as disintegrating or diluting, are used to develop fibers or polymers appropriate for reprocessing. The formation of the fibers is altered during physical recycling, but the polymer molecules that compose the fibers stay unchanged. Melt spinning or solution spinning can be employed to create a new filament after disintegrating or diluting.

Key Challenges

The critical challenges of textile waste management in India, as identified through the current literature, are the lack of an organized collection, segregation, and aggregation system, importing pre-consumer waste, the gap with recyclers and solution providers, waste flow traceability, reclaiming the lost value of discarded clothes and supply chain design.^[69,70]

CONCLUSION

Waste management practices in the textile sector emerge as a challenging and competitive area of the study. This study systematically examines the scholarly literature on PCTW practices in the textile sector in India from a CE perspective to the best of the author's knowledge. This research identified essential waste management practices that will influence the evolution of the textile sector's post-consumer textile waste management, recycling strategies, and transitioning to circular approaches.^[71-74] This could help researchers further explore, comprehend, and address a broader spectrum of PCTW practices and supplement prior work on textile waste management problems.^[75-78] It exemplifies the range of textile sector studies and summarises the study on green practices. As a result, this research concluded with a coherent depiction of waste management practices and

challenges related to various aspects of India's post-consumer textile waste management domain. Whereas, under the Indian context, this study provided a more comprehensive view of the existing waste management methods in the industry.

Implications

A few implications by integrating a diverse array of literature review, the findings could perhaps aid practitioners in building firm sustainability capabilities with clearer steps. The systematic literature analysis will assist managers in determining priorities and essential features of sustainable practices related to strategic needs, avoiding dispersing resources and investment in various directions, hence decreasing operational waste, risks, and failure costs. Subsequently, the study presents practitioners with recommendations for structuring the sustainability journey and adequately resetting natural resources to embark on opportunities and challenges, set priorities, anticipate possible vulnerable areas, and comprehend how subtleties can be avoided.

Limitations

Only PCTW management practices have been considered for this study. This review has not included aspects of waste management such as behavior change and community engagement, waste collection schemes, and waste transportation. This review is limited to consumer textile waste disposal and textile recycling methods. The findings are based on academic papers that were published between 2015 and 2021; further comprehensive coverage may give more valuable insights. The expansion of sustainable environmental practices is actively developing in the various textile industry setting, and progressing assessment of the data is necessary to allow industry specialists, regulators, and stakeholders to comprehend the sector's health and position.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

PCTW: Post-consumer textile waste; **CE:** Circular economy; **LE:** Linear economy; **SLR:** Systematic literature review.

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