Evaluating Textile Waste Severity: Applying Circular Economy Principles to Rank Post-Industrial, Pre-Consumer, and Post-Consumer Waste

Rabiya Faheem
Department of Operational Research
University of Delhi
Delhi, India
rabiyafaheem95@gmail.com

Rubina Mittal
Keshav Mahavidyalaya
University of Delhi
Delhi, India
drmittal@keshav.du.ac.in

Akansha Jain
Department of Operations
Fortune Institute of International Business
New Delhi, India
akansha.jain@fiib.ed

Abstract— **Fast fashion has become a worldwide trend, leading to a significant increase in textile waste due to the mass production of clothing. The prevailing culture of 'buy-and-discard' has intensified the volume of textiles ending up in landfills and incinerators, exacerbating the problem. The traditional linear model is proving to be unsustainable. In response to this issue, the textile industry is seeking more circular and sustainable approaches for effective waste management. Three types of textile waste exist: post-industrial waste from production processes, pre-consumer waste from damaged or unsaleable stock, and post-consumer waste from discarded garments. This study aims to examine the severity of textile waste by identifying which of the three forms—post-industrial, pre-consumer, or post-consumer—poses the greatest hazard. This will be done by analyzing the quantities of wastes generated, collected, landfilled, reduced, reused, and recycled, as well as the associated carbon footprint. Results show that post-consumer waste is the most severe waste as per the criteria considered in the study. Post-consumer waste in the textile industry will be crucial in the future, especially if the rate of collection and recycling of discarded clothing are not increased.**

Keywords— Textile wastes, Post-industrial waste, Pre-consumer waste, Post-consumer waste, Circular Economy (CE), Analytic Hierarchy Process (AHP).

I. INTRODUCTION

The emergence of fast fashion has had a profound impact on the worldwide textile sector, resulting in a notable surge in both clothing production and its consumption. This trend, characterized by the fast change of fashion trend and the availability of inexpensive garments, has exacerbated the issue of textile waste. The pervasive "buy-and-discard" culture has resulted in vast amounts of clothing being discarded after only brief use, with most of this waste ending up in landfills or incinerators. The traditional linear model of textile manufacturing, which follows a "take-make-dispose" approach, is proving to be unsustainable as it continues to contribute to growing environmental challenges. Textile waste is not only a matter of volume but also of its environmental impact. Textile waste can be categorized into three distinct types based on its origin: post-industrial, pre-consumer, and post-consumer waste. Post-industrial waste arises during the manufacturing process and includes offcuts, trimmings, and other remnants discarded before the product reaches the market. Pre-consumer waste comes from damaged or unsellable stock, such as garments that are rejected due to quality issues or remain unsold. Post-consumer waste is generated when consumers discard clothing, frequently driven by the swift turnover of fashion trends.

The fashion industry is projected to generate 60% more waste by 2030, resulting in 148 million tons of waste globally [5]. This staggering increase underscores the urgent need for the industry to shift from a linear model to a more sustainable, circular economy (CE). A circular strategy places a strong emphasis on cutting waste, optimizing the use of resources, and closing the loop by recycling and reusing resources [12]. However, this transition is challenging, particularly in expanding recycling capacities and optimizing the use of renewable resources. One of the critical issues in waste management is the environmental impact of decomposed clothes in landfills. According to Yacout and Hassouna [25], decomposed textiles contribute to soil erosion, groundwater contamination, and the release of greenhouse gases (GHGs), all of which have detrimental effects on ecosystems. Notwithstanding these concerns, the amount of material recycled into new apparel is now less than 1%, costing more than $100 billion in lost resources yearly. This highlights the inefficiency of current waste management practices and the significant opportunity to reclaim and repurpose textile materials. Concerning repurposing, data shows that just 5% of post-consumer textile waste is non-usable waste, with 45% of it being recycled as old apparel, 30% as industrial rags, and 20% biodegrading after landfilling. The aforementioned statistics indicate that employing more efficient recycling and repurposing techniques might significantly decrease the quantity of waste that finds its way into landfills and incinerators [22].

The textile industry is currently facing the issue of implementing sustainable approaches that handle every phase of the clothing lifecycle, from manufacture to post-consumer dumping. Reducing the industry's environmental footprint requires a multifaceted approach that includes improving recycling technologies, increasing the use of renewable resources, and encouraging consumers to adopt more sustainable consumption habits. Given the scale of the problem, it is essential to identify which category of textile waste—post-industrial, pre-consumer, or post-consumer—poses the greatest environmental hazard. This study seeks to address this by examining the amount of waste created in each category, the efficacy of waste collection and management systems, and the overall environmental impact, particularly in terms of carbon footprint. By identifying the most hazardous waste types, the study intends to improve waste management procedures and aid the textile industry's shifting to CE.

Therefore, the present study's research aims are as follows:

(1) Identifying sustainable and circular criteria for prioritizing three forms of textile industry clothing waste, with the goal of reducing, reusing, and recycling textile waste for CE implementation.

(2) Prioritizing the most severe waste out of the three textile wastes using Analytic Hierarchy Process (AHP) methodology.

ISBN : 978-81-978522-2-0

In conclusion, the textile industry is at a critical juncture. The traditional linear model must evolve towards more sustainable practices, particularly in waste management. Addressing waste generation at all stages—manufacturing, pre-consumer, and post-consumer—is critical to lowering the industry's environmental effect and assuring a sustainable future. This study seeks to give a detailed analysis of textile waste, as well as insights on how the industry may better manage and minimize waste in the coming years. The rest of the paper is arranged as follows. Sections II contain a literature assessment of recent studies on textile waste, as well as information on research gaps and contributions. Section III describes the methodology used to prioritize the most severe waste based on the criteria outlined in the research, followed by the result and discussion in section IV. Section V summarizes the findings and their relevance to the textile industry, as well as suggestions for further study.

II. LITERATURE REWIEW

Fast fashion has become more and more popular, and this has led to a significant amount of textile waste due to changing consumer habits and rising demand [11, 12, 22]. Three categories have been established for textile waste — pre-consumer, post-consumer, and post-industrial wastes. Managing textile waste is particularly challenging. Sinha [18] addressed the issue of post-consumer waste in Sri Lanka, highlighting that the country, like many developing nations, suffers from inadequate handling of solid waste and lacks the requisite collection and recycling systems for post-consumer textiles. The challenges include a lack of separation of post-consumer waste at the source, insufficient recycling technologies, and a public perception that undervalues post-consumer waste, all of which impede market creation and the achievement of sustainable consumption and production goals by 2030. However, there are chances to start new businesses that collect, sort, and clean post-consumer waste, to aware the people about the adverse effects that textile waste does to the environment, and to enact effective post-consumer waste policies. Haq and Alam [8] investigate an innovative way for achieving circular fashion by using the CE's 'reuse' concept to handle pre-consumer trash from the garment industry's cutting department in a sustainable manner. The study focuses on a particular product (boys' t-shirts) with the goal of tracking, collecting, classifying, and estimating the waste from reusable cutting that is produced at a facility in Dhaka, Bangladesh. This study's approach illustrates the smallest loop of the CE, with processes including collecting, sorting, redesigning, recutting, and sewing. The study found that directly using pre-consumer waste from cutting sections is more environmentally and economically sustainable than recycling, landfilling, or incineration.

Asia is home to the world's largest textile and apparel exporters, ranging from China and India to Southeast Asia. The industry generates industrial and post-consumer wastes. In the case of industrial waste, material is wasted at each stage of the manufacturing process. Worn clothes is commonly disposed of in landfills, open-air dumps, or incineration facilities as post-consumer waste. According to the Wealth in Waste [24] study, India generates more than 7,793 ktons of textile waste per year, accounting for 8.5% of the global total. Only a small amount of this waste reaches high-end global supply chains (SCs) due to visibility and quality issues, whereas 59% is recycled and reused in the textile industry. The remaining 41% is either downcycled (19%), incinerated (5%) or dumped as waste in a landfill (17%) [6, 24]. A significant amount of industrial textile waste is dumped in landfills because there is insufficient infrastructure and technology for recycling [14]. The problem of recycling or reusing leftovers arises from the habit of garment manufacturing companies combining all of their textile cuts.

Yalcin-Enis [26] examine the challenges posed by textile waste and the strategies for managing this waste from multiple perspectives. The preferred hierarchy of waste management strategies, from most to least sustainable, includes reduction, reuse, recycling, energy recovery, and waste disposal. Kamble and Behera [9] highlight several challenges in textile waste management, critically evaluate the use of upcycling techniques, and explore ways to use textile waste to generate upcycled items. Chowdhury [4] discusses the challenges that the textile industry encountered when implementing smart waste management systems. These challenges are primarily caused by the industry's complicated structure, which involves multiple stakeholders, varying consumer behaviour, and a lack of robust standards, particularly in the context of emerging economies. The results indicate that the most crucial phase in implementing smart waste management systems is effective waste recovery monitoring and its management.

Typical clothing materials including cotton, wool, polyester, polyamide 6 6, and acrylic may be recycled using a variety of techniques, including mechanical, chemical, and biological approaches. In a review of the literature, Baloyi [2] emphasized recent advancements in recycling technology, including improved sorting methods, innovative chemical processing, and evolving biochemical processes. The assessment also emphasizes initiatives by several organizations and firms to facilitate and commercialize the technology. Several ways for efficiently sorting and identifying textile waste are also addressed. According to the reviewed research, the majority of recycling systems were tested on post-industrial textile waste, which is typically homogeneous in terms of colours and fibers. Additionally, it suggested that post-consumer textiles may be recycled chemically and biologically, potentially turning waste into useful items. A review study on the prospects and challenges of post-consumer waste was carried out by Shahid [18]. These included the need for more clothing recycling, reuse, advanced recycling technologies, socioeconomic benefits, CE initiatives, production of bioenergy, strict laws, and innovative business prospects. Concerns including the inability to recycle, inadequate infrastructure, declining economic feasibility, and declining final product quality are addressed. Using best practices including sufficient identification, segregation, and disinfection to get over contamination issues. Rossi [16] distinguish between two distinct collecting streams as they investigate the opportunities and challenges associated with recycling independently collected post-consumer textiles. The objective is to assess the massive quantities of used clothing that might be collected separately via a second stream that isn't reusable and might be useful for material recycling.

It also aims to look into different possibilities for appropriate textile-to-textile recycling technologies and their benefits and drawbacks.

Although the literature contains numerous studies on textile waste generated by the industry, there remains a notable gap in the examination of how sustainability and CE principles can be employed to rank the severity of different types of textile waste. Either post-industrial, pre-consumer, or post-consumer textile waste is considered to constitute the biggest environmental concern, but the application of these concepts to this task has not been well investigated in previous study. In order to bridge this gap, this study uses the frameworks of sustainability and CE to identify which of all three types of textile waste is the most hazardous. The research will evaluate the quantities of waste generated, collected, landfilled, reduced, reused, and recycled for each category, as well as their associated carbon footprints. This study's significant contributions include:

1) The study adds to the literature by defining sustainable and circular criteria like percentage of waste generated, collected, landfilled, reduced/ reused/ recycled of each type of waste and the amount of carbon emission.
2) The prioritization of the most severe waste out of the three textile industry clothing wastes using AHP methodology aiming to reduce, reuse and recycle the textile waste for CE implementation in the textile industry.

III. RESEARCH METHODOLOGY

Saaty [17] developed the AHP, an effective and efficient technique for managing the multi-criteria, qualitative, and quantitative components of decision-making behaviour. It serves as a decision-making tool by comparing distinct alternatives pairwise using various criteria. AHP is very good in ensuring the consistency of decision makers' (DMs) judgments, setting it apart from many other multi-criteria decision-making (MCDM) methods. TABLE I provides information on the DMs' roles and years of experience.

TABLE I. DETAILS OF THE DMS INVOLVED IN TEXTILE WASTE SC

S. No.	Experts	Work Experience
1	Waste Supplier	9
2	Procurement Manager	5
3	Collection Facility Manager	6
4	Sorting Facility Manager	7
5	Recycling Facility Manager	10

The steps of the AHP are explained below:

Step 1: Problem identification as shown in Fig. 1.

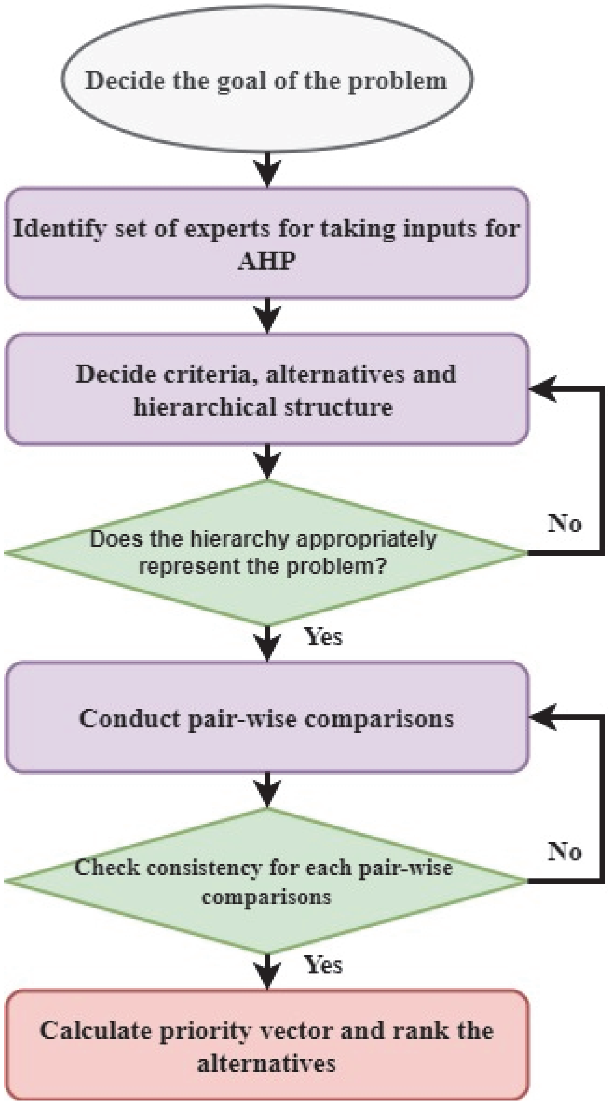

Fig. 1. Flow chart of AHP

- Identification of the criteria and alternatives (wastes) as given in TABLE II and III.

ISBN : 978-81-978522-2-0

TABLE II. CRITERIA FOR PRIORITIZING WASTES

S. No.	Criteria (Ci)	Description
1	Percentage of waste (C1)	Any wasted or rejected textile product or material that is no longer fit for its intended use. It is gathered from diverse sources and divided into three primary categories: pre-consumer, post-industrial, and post-consumer wastes.
2	Percentage of collection (C2)	Large-scale waste collectors, or chindiwalas, collect the waste produced at the manufacturing facilities and then transfer it to waste aggregators. Post-consumer textile waste is mostly collected from houses through cloth waste collection drives and sent to collection facilities. Following collection, the waste is either sold to various recyclers or transferred to recycling facilities.
3	Percentage of landfill (C3)	The decomposition of textile waste might take more than 200 years in open-air dumps or landfills. Because of gas and chemical leachates, the decomposition process can contaminate the groundwater, soil, and air. Textiles have the potential to produce greenhouse gas emissions and block gutters, leading to water-borne illnesses and flooding.
4	Percentage of reduce/reuse/recycling (C4)	Utilizing minimum packaging, and purchase long-lasting things rather than throwaway ones. Repurpose used clothing, borrow or rent it, or host a garment exchange event. Composting, chemical processing, and mechanical processing are the three methods available for recycling textiles.
5	Carbon emission (C5)	The degradation of synthetic textile waste is a protracted process that poses a significant threat to the ecosystem. This is because the waste generates GHGs, which in turn contribute to carbon emissions and environmental damage.

TABLE III. TYPES OF WASTES

S. No.	Alternatives (W_k)	Description	References
1	Post-industrial waste (W1)	Waste produced by the textile industry when textile items are being manufactured or produced.	[7], [13]
2	Pre-consumer waste (W2)	Waste includes items like clothing or household products that are defective, unsold in stores, or returned without being used.	[1], [8]
3	Post-consumer waste (W3)	Waste encompasses textiles that individuals discard after prolonged use, including old garments, and various household textile products. These items have undergone multiple wearing, uses, and washes, leading them to the	[6], [15], [16], [18], [19], [20]

- Create a hierarchical structure of criteria and wastes, beginning with the main aim, then criteria, and finally wastes, as illustrated in Fig. 2.

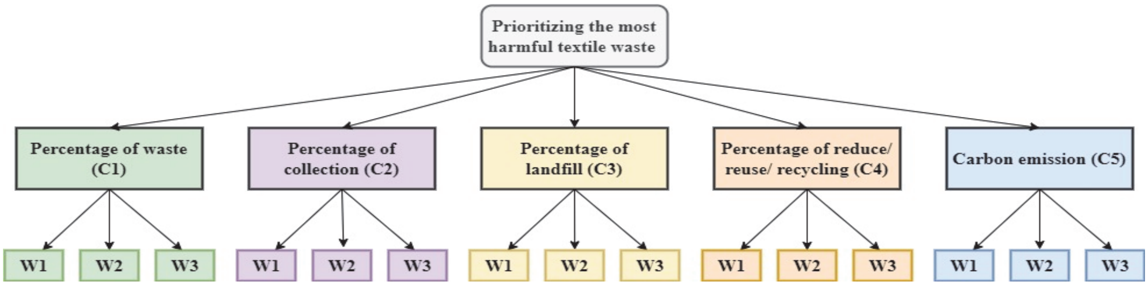

Fig. 2. Hierarchical Structure

Step 2:

Establishing a pairwise comparison matrix: Using a nine-point Saaty [17] scale provided in TABLE IV, the DMs determine the pairwise comparison between criterion C_i and criterion C_j through group decision-making. This yields a pairwise comparison matrix $A = [a_{ij}]_{n\times n}$. There are n criteria to be compared and $a_{ij} = \frac{1}{a_{ji}}\ \forall i, j = 1,2, \dots, n$.

TABLE IV. NUMERICAL SCALE

Intensity of Importance of C_i over C_j (value of a_{ij})	Definition
1	Both criteria are equally important.
3	One criterion is moderately more important than the other.
5	Strong importance given to one criterion over another
7	Very important criterion compared to other
9	Extreme importance given to one criterion over another
2, 4, 6, 8	Values in between two adjacent judgements

The $n \times n$ pair-wise judgment matrix A is obtained as given in “(1)” (TABLE V):

$$A = [a_{ij}] = \begin{bmatrix} a_{11} & a_{12} \dots & a_{1n} \\ a_{21} & a_{22} \dots & a_{2n} \\ \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} \dots & a_{nn} \end{bmatrix} \tag{1}$$

Priority Vector: The geometric mean (GM) of the rows in the aforementioned matrix A is normalized

ISBN : 978-81-978522-2-0

to produce the priority vector w, which stands for the weights of each criterion. Weights are computed by combining the GM approach with Saaty's λ-max technique [2].

Given a positive reciprocal matrix A, first find the row geometric mean i.e., r_i , then normal row geometric mean i.e., w_i as shown in "(2)" and "(3)".

$$r_i = \left(\prod_{j=1}^{n} a_{ij}\right)^{1/n} \quad i = 1,2,\dots,n \tag{2}$$

$$w_i = \frac{r_i}{(r_1+r_2+\cdots r_n)} \quad i = 1,2,\dots,n \tag{3}$$

Matrix consistency check: To determine if the DMs' assessments are consistent, the pairwise comparison matrix's consistency is examined. This is accomplished by calculating the consistency ratio (CR) and consistency index (CI) of each pair-wise comparison matrix, as shown in "(4)," "(5)," and "(6)."

$$CI. = \frac{(\lambda_{max} - n)}{(n-1)} \tag{4}$$

where λ_{max} is the principal eigenvalue of matrix A and n is the order of A.

$$\lambda_{max} = \sum_{i=1}^{n}\left(w_i + \sum_{j=1}^{n} a_{ij}\right) \tag{5}$$

$$CR = \frac{CI}{RI} \tag{6}$$

where RI is the random index corresponding to matrix size (n). The pairwise comparison matrix is considered consistent when the value of $CR \leq 0.1$.

TABLE V. PAIR-WISE COMPARISON MATRIX OF CRITERIA

Criteria	C1	C2	C3	C4	C5	r_i	w_i	$\left(w_i + \sum_{j=1}^{n} a_{ij}\right)$
Percentage of waste (C1)	1	3	7	5	8	3.8446	0.5013	2.7478
Percentage of collection (C2)	0.3333	1	5	7	5	2.2552	0.2941	1.5956
Percentage of landfill (C3)	0.1429	0.2	1	4	3	0.8073	0.1053	0.5894
Percentage of reduce/ reuse/ recycling (C4)	0.2	0.1428	0.2500	1	2	0.4275	0.0558	0.3115
Carbon emission (C5)	0.1250	0.2000	0.3333	0.5	1	0.3342	0.0436	0.2280
					$\sum_{i=1}^{n} r_i$	7.6688	λ_{max}	5.4724

CI = 0.1181 and CR = 0.1064

Pair-wise comparison of wastes on the basis of criteria are given in TABLES VI, VII, VIII, IX and X.

TABLE VI. PERCENTAGE OF WASTE (C1)

W_K	W1	W2	W3	r_i	w_i	$(w_i + \sum_{j=1}^{n} a_{ij})$
Post-industrial waste (W1)	1	0.2000	0.1250	0.2924	0.0643	0.1991
Pre-consumer waste (W2)	5	1	0.2500	1.0772	0.2370	0.7334
Post-consumer waste (W3)	8	4	1	3.1748	0.6986	2.1615
			$\sum_{i=1}^{n} r_i$	4.5444	λ_{max}	3.0940

CI = 0.0470 and CR = 0.0904

TABLE VII. PERCENTAGE OF COLLECTION (C2)

W_K	W1	W2	W3	r_i	w_i	$(w_i + \sum_{j=1}^{n} a_{ij})$
Post-industrial waste (W1)	1	0.1667	0.1111	0.2646	0.0585	0.1786
Pre-consumer waste (W2)	6	1	0.3333	1.2599	0.2785	0.8503
Post-consumer waste (W3)	9	3	1	3.0000	0.6631	2.0247
			$\sum_{i=1}^{n} r_i$	4.5245	λ_{max}	3.0536

CI = 0.0268 and CR = 0.0516

TABLE VIII. PERCENTAGE OF LANDFILL (C3)

W_K	W1	W2	W3	r_i	w_i	$(w_i + \sum_{j=1}^{n} a_{ij})$
Post-industrial waste (W1)	1	0.25	0.1250	0.3150	0.0675	0.2090
Pre-consumer waste (W2)	4	1	0.2	0.9283	0.1991	0.6159
Post-consumer waste (W3)	8	5	1	3.4200	0.7334	2.2691
			$\sum_{i=1}^{n} r_i$	4.6632	λ_{max}	3.0940

CI = 0.0470 and CR = 0.0904

TABLE IX. PERCENTAGE OF REDUCE/ REUSE/ RECYCLING (C4)

W_K	W1	W2	W3	r_i	w_i	$\left(w_i + \sum_{j=1}^{n} a_{ij}\right)$
Post-industrial waste (W1)	1	0.5000	0.1111	0.3816	0.0738	0.2241
Pre-consumer waste (W2)	2	1	0.1250	0.6300	0.1218	0.3699
Post-consumer waste (W3)	9	8	1	4.1602	0.8044	2.4429
			$\sum_{i=1}^{n} r_i$	5.1717	λ_{max}	3.0369

CI = 0.0184 and CR = 0.0355

TABLE X. CARBON EMISSION (C5)

W_K	W1	W2	W3	r_i	w_i	$\left(w_i + \sum_{j=1}^{n} a_{ij}\right)$
Post-industrial waste (W1)	1	0.5	0.1429	0.4149	0.0905	0.2745
Pre-consumer waste (W2)	2	1	0.1667	0.6934	0.1512	0.4586
Post-consumer waste (W3)	7	6	1	3.4760	0.7582	2.2993
			$\sum_{i=1}^{n} r_i$	4.5843	λ_{max}	3.0324

CI = 0.0162 and CR = 0.0311

Step 4: Using the weights determined from each pair-wise comparison, the normalized weights of the wastes and criteria are computed. The scores for each waste are then obtained by multiplying the weights of each waste by the corresponding criterion (TABLE XI). Based on these results, the waste with the highest score is recommended to the DM (TABLE XII).

Step 5:

TABLE XI. NORMALIZED WEIGHTS OF EACH WASTE FOR EACH CRITERION

Normalized C_i/W_k weights	W1	W2	W3
Percentage of waste (C1)	0.0323	0.1188	0.3502
Percentage of collection (C2)	0.0172	0.0819	0.1950
Percentage of landfill (C3)	0.0071	0.0210	0.0772
Percentage of reduce/ reuse/ recycling (C4)	0.0041	0.0068	0.0448
Carbon emission (C5)	0.0039	0.0066	0.0330
Total	0.0646	0.2351	0.7003

ISBN : 978-81-978522-2-0

TABLE XII. FINAL RANKING OF WASTE

W_K	Final weights	Rank
Post-industrial waste (W1)	0.0646	3
Pre-consumer waste (W2)	0.2351	2
Post-consumer waste (W3)	0.7003	1

IV. RESULTS AND DISCUSSIONS

The study utilized the AHP to rank the severity of three forms of textile waste—post-industrial, pre-consumer, and post-consumer—based on a set of criteria including the quantity generated, collected, landfilled, reduced, reused, recycled, and associated carbon footprint. The final ranking of these waste categories, determined by their weighted scores, is post-consumer waste: 0.7003, pre-consumer waste: 0.2351 and post-industrial waste: 0.0646. These results indicate that post-consumer waste is identified as the most severe form of textile waste, followed by pre-consumer waste and post-industrial waste. This ranking reflects several key aspects of textile waste management:

- Volume and Disposal: Post-consumer waste, which consists of discarded clothing by consumers, represents a substantial portion of textile waste. The high ranking of this category is largely attributed to its large volume and the challenges associated with its disposal. As the primary endpoint of the textile lifecycle, post-consumer waste accumulates in landfills and incineration facilities, contributing significantly to environmental issues such as soil contamination, groundwater pollution, and GHG emissions. The high weight of 0.7003 in the final ranking reflects the significant environmental footprint of this waste category.
- Recycling and Reuse Challenges: Despite efforts to promote recycling and repurposing, post-consumer waste remains challenging to manage. The fact that this category has the highest weight emphasizes the need for improved recycling infrastructure and consumer education to increase the rates of textile recycling and repurposing. The study's findings align with existing research that highlights the inefficiencies in current recycling practices and the potential for greater resource recovery [21].

Pre-consumer waste, with a weight of 0.2351, ranks second in terms of severity. This category includes waste from damaged or unsellable stock before reaching consumers. While it represents a smaller volume compared to post-consumer waste, pre-consumer waste still poses significant challenges in terms of resource management and waste reduction. Post-industrial waste, with the lowest weight of 0.0646, is ranked third. This category includes manufacturing remnants and offcuts. Although it constitutes a smaller portion of overall textile waste, it remains an important aspect of waste management. The relatively low weight in the ranking suggests that while post-industrial waste is manageable compared to other categories, there is still a need for improved practices in reducing and recycling manufacturing waste. Research by La Mantia and Morreale [11] supports the need for better waste recovery techniques in manufacturing processes.

The outcomes of this study underline the urgency of addressing post-consumer waste within the context of CE. The high environmental impact associated with post-consumer waste necessitates a shift towards more sustainable practices, including enhanced recycling technologies, greater emphasis on waste reduction at the consumer level, and the promotion of second-hand and repurposed textiles.

V. CONCLUSION

This study fills a significant gap in the literature by evaluating the severity of textile waste categories through the lens of sustainability and CE principles. Utilizing AHP, we have ranked post-consumer, pre-consumer, and post-industrial textile waste based on percentages of waste (C1), collection (C2), landfill (C3), reduce/reuse/recycle (C4), and carbon emissions (C5). The findings indicate that post-consumer waste is the most severe form of textile waste, with a weight of 0.7003, highlighting its significant contribution to environmental degradation. This category's high ranking underscores the urgent need for improved recycling infrastructure and enhanced consumer awareness to better manage and repurpose discarded clothing. Post-consumer waste's substantial volume and the difficulties associated with its disposal emphasize the necessity of adopting more sustainable practices to mitigate its impact. Pre-consumer waste, with a weight of 0.2351, follows as the second most severe category. Although it represents a smaller portion of the total waste, it still poses significant challenges that need addressing through better inventory management and quality control measures. Post-industrial waste, ranked third with a weight of 0.0646, is the least severe among the three categories but remains a critical aspect of textile waste management. Improvements in manufacturing processes and waste recovery techniques are essential to manage this type of waste effectively. The study's insights provide a foundation for the textile industry to focus its efforts on the most impactful areas. By prioritizing post-consumer waste management, enhancing recycling technologies, and promoting CE practices, the industry can make significant strides towards sustainability. The application of AHP has proven valuable in identifying and ranking waste categories, offering actionable guidance for policy and practice. In conclusion, addressing textile waste through a CE framework is vital for reducing the industry's environmental footprint. This study's results underscore the need for targeted interventions to manage textile waste more effectively, assuring the industry's long-term sustainability. The insights gained through this study will be crucial in directing initiatives to enhance waste management procedures and move towards a more sustainable textile industry as the demand for clothing rises.

ACKNOWLEDGMENT

The first author Rabiya Faheem is supported by the DST-INSPIRE Fellowship (DST/INSPIRE Fellowship/IF190736).

REFERENCES

[1] Azad, A. K., Haq, U. N., Khairul Akter, M. M., & Uddin, M. A. (2024). Recycling Practices of Pre-Consumer Waste Generated from Textile Industry. In *Sustainable Manufacturing Practices in the Textiles and Fashion Sector* (pp. 301-324). Cham: Springer Nature Switzerland. DOI:10.1007/978-3-031-51362-6_12

[2] Baloyi, R. B., Gbadeyan, O. J., Sithole, B., & Chunilall, V. (2024). Recent advances in recycling technologies for waste textile fabrics: A review. *Textile Research Journal*, *94*(3-4),

508-529.
DOI:10.1177/00405175231210239

[3] Buckley, J. J. (1985). Fuzzy hierarchical analysis. *Fuzzy sets and systems*, *17*(3), 233-247. DOI:10.1016/0165-0114(85)90090-9

[4] Chowdhury, N. R., Paul, S. K., Sarker, T., & Shi, Y. (2023). Implementing smart waste management system for a sustainable circular economy in the textile industry. *International Journal of Production Economics*, *262*, 108876. DOI:10.1016/j.ijpe.2023.108876

[5] Climate Seed (2022). “Textile Industry: Environmental Impact and Regulations”, Aug. 2024. [Online]. Available: https://climateseed.com/blog/secteur-du-textile-impact-environnemental-et-reglementation

[6] DeVoy, J. E., Congiusta, E., Lundberg, D. J., Findeisen, S., & Bhattacharya, S. (2021). Post-Consumer textile waste and disposal: Differences by socioeconomic, demographic, and retail factors. *Waste Management*, *136*, 303-309. DOI:10.1016/j.wasman.2021.10.009

[7] Dissanayake, D. G. K., & Weerasinghe, D. (2021). Managing post-industrial textile waste: Current status and prospects for Sri Lanka. *The journal of the textile institute*, *112*(11), 1804-1810. DOI:10.1080/00405000.2020.1845461

[8] Haq, U. N., & Alam, S. R. (2023). Implementing circular economy principles in the apparel production process: Reusing pre-consumer waste for sustainability of environment and economy. *Cleaner Waste Systems*, *6*, 100108. DOI:10.1016/j.clwas.2023.100108

[9] Kamble, Z., & Behera, B. K. (2021). Upcycling textile wastes: challenges and innovations. *Textile Progress*, *53*(2), 65-122. DOI:10.1080/00405167.2021.1986965

[10] La Mantia, F. P., & Morreale, M. (2011). Green composites: A brief review. *Composites Part A: Applied Science and Manufacturing*, *42*(6), 579-588. DOI:10.1016/j.compositesa.2011.01.017

[11] Marshall, R. E., & Farahbakhsh, K. (2013). Systems approaches to integrated solid waste management in developing countries. *Waste management*, *33*(4), 988-1003. DOI:10.1016/j.wasman.2012.12.023

[12] Niinimäki, K., Peters, G., Dahlbo, H., Perry, P., Rissanen, T., & Gwilt, A. (2020). The environmental price of fast fashion. *Nature Reviews Earth & Environment*, *1*(4), 189-200. DOI:10.1038/s43017-020-0039-9

[13] Picvisa (2024). “The management of post-industrial waste in the textile industry is moving towards a circular economy”, August 2024. [0nline]. Available: https://picvisa.com/waste-management-industrial-post-industrial-waste/

[14] Rapsikevičienė, J., Gurauskienė, I., & Jučienė, A. (2019). Model of industrial textile waste management. *Environmental Research, Engineering and Management*, *75*(1), 43-55. DOI:10.5755/j01.erem.75.1.21703

[15] Riba, J. R., Cantero, R., Canals, T., & Puig, R. (2020). Circular economy of post-consumer

textile waste: Classification through infrared spectroscopy. *Journal of Cleaner Production*, *272*, 123011.
DOI:10.1016/j.jclepro.2020.123011

[16] Rossi, V., Damgaard, A., & Logan, H. M. (2024). *Recycling potential of separately collected post-consumer textile waste*. Danish Environmental Protection Agency. Miljoeprojekter No. 2266 https://mst.dk/publikationer/2024/juni/recycling-potential-of-separately-collected-post-consumer-textile-waste

[17] Saaty, T. (1980, November). The analytic hierarchy process (AHP) for decision making. In *Kobe, Japan* (Vol. 1, p. 69).

[18] Shahid, M. A., Hossain, M. T., Habib, M. A., Islam, S., Sharna, K., Hossain, I., & Limon, M. G. M. (2024). Prospects and challenges of recycling and reusing post-consumer garments: a review. *Cleaner Engineering and Technology*, *19*, 100744.
DOI:10.1016/j.clet.2024.100744

[19] Sinha, P., Dissanayke, D. G. K., Abeysooriya, R. P., & Bulathgama, B. H. N. (2022). Addressing post-consumer textile waste in developing economies. *The Journal of The Textile Institute*, *113*(9), 1887-1907.
DOI:10.1080/00405000.2021.1954428

[20] Stanescu, M. D. (2021). State of the art of post-consumer textile waste upcycling to reach the zero waste milestone. *Environmental Science and Pollution Research*, *28*(12), 14253-14270.
DOI:10.1007/s11356-021-12416-9

[21] The Business Standard (2024). “Global fashion industry can reach 80% circularity by 2030: Report”, August 2024. [0nline]. Available: https://www.tbsnews.net/world/global-economy/global-fashion-industry-can-reach-80-circularity-2030-report-333193

[22] Ütebay, B., Çelik, P., & Çay, A. (2020). Textile wastes: Status and perspectives. *Waste in textile and leather sectors*, 39-52.

[23] Waste & Recycling (2024). “Assessing India's Readiness in EPR for Textile Waste”, August 2024. [0nline]. Available: https://www.wasterecyclingmea.com/top-stories/assessing-india-s-readiness-in-epr-for-textile-waste

[24] Wealth in Waste report (2022). “India’s potential to bring textile waste back into apparel supply chain”, August 2024. [0nline]. Available: https://reverseresources.net/elementor-3373/

[25] Yacout, D. M., & Hassouna, M. S. (2016). Identifying potential environmental impacts of waste handling strategies in textile industry. *Environmental monitoring and assessment*, *188*, 1-13.
DOI:10.1007/s10661-016-5443-8

[26] Yalcin-Enis, I., Kucukali-Ozturk, M., & Sezgin, H. (2019). Risks and management of textile waste. *Nanoscience and biotechnology for environmental applications*, 29-53.
DOI:10.1007/978-3-319-97922-9_2