ITFP-GH
Institute of Textiles and Fashion Professionals - Ghana

Fashion and Textiles Review
Volume 7, (2026), Pages 47-66
ISSN: 2665-0983 (ONLINE)
Journal homepage: https://journal.itfpgh.com/ftr/index



ORIGINAL ARTICLE
DOI: https://doi.org/10.35738/ftr.v7.2024.13

Waste Management Strategies Employed by Selected Textile Firms in Ghana

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Abstract

Purpose: This study investigated the management strategies employed by the large textile firms in Ghana.

Methodology/Design: This qualitative study examined waste management strategies and sustainability practices in Ghana's large textile industry through descriptive observation and multiple case studies, assessing both operational techniques and their environmental impacts. Data was collected through structured interviews and systematic observations from a purposive sample of 25 participants, including managers and supervisors, then analysed using NVivo software to identify key themes and patterns in waste reduction efforts. The methodology provided in-depth insights into current practices and their effectiveness in minimising ecological harm within the sector.

Findings: The study found that most strategies adopted by the firms not only have significant environmental benefits but are also not cost-effective. Additionally, it highlighted the ongoing efforts made by these firms to minimise losses and enhance sustainability.

Practical and Social Implications: The results of the study proved that the textile industry in Ghana is practising waste reduction principles such as recycling, reuse and recovery of materials to minimise environmental pollution caused by the disposal of waste. However, such practices are not cost-effective and need the support of the government and investors to assist them in improving on such sustainable measures. The study recommends that the large textile firms partner with the small-scale textile industry to repurpose their fabric waste. This will ensure a closed-loop circular economy, which leads to job creation.

Originality: The textile industry is one of the major contributors to greenhouse gas emissions due to the activities involved in its manufacture. As a result, the global textile industry is prioritising waste management strategies to salvage the situation. Therefore, an investigation of the efforts being made by the Ghanaian textile industry to combat environmental pollution caused by their activities is necessary. Additionally, it contributes empirical knowledge to the waste management conversation.

Keywords
Waste management, textile waste, strategies, textile industry, production, sustainable measures.

1 | INTRODUCTION

The textile industry is ranked second as the most polluting industry in the world in terms of waste generation and the release of large amounts of toxic substances to the environment. Both production and consumption are contributors to this problem. Most stakeholders in the textile industry focus on a sustainable production and consumption model in fashion with regard to used garment waste. However, the textile industry produces a significant amount of waste at every stage of production (Domina & Koch, 1997). Global consumption of goods and services has brought immense pressure on the environment,

Received: November 25, 2024. **Revised:** May 16, 2025. **Accepted:** August 14, 2025

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DOI: https://doi.org/10.35738/ftr.v7.2024.13

accounting for about 60% greenhouse gas emissions and 50–80% of the total resource use (Ivanova et al., 2016). Natural resource consumption has advanced considerably with little regard for environmental degradation as a result, especially in industrialised countries (Zafar et al., 2020). Global warming, caused by rising carbon dioxide levels in the atmosphere due to fossil fuel combustion, natural resource depletion, toxic waste disposal, and increased air, water, and soil pollution from agriculture and industry are all becoming global issues that require concerted international action to address the consequences of this reckless attitude toward the natural environment have only just started to be understood by the globe. Therefore, it is now vital for everyone to actively participate in fixing these problems. Every industrial sector and its leading companies are increasingly being held responsible for their impact on environmental and human health (Allwood et al., 2006). The textile sector is a vital one that makes a substantial contribution to both society and the global economy. Millions of people worldwide work in this sector, with approximately $2.4 trillion in revenue in 2019. The textile and apparel (T&A) business is the third-largest industrial sector globally. Across the whole value chain, more than 300 million people are employed, including fibre producers, designers, manufacturers, retailers, content suppliers, and many more (Ahiable & Triki, 2021). Fibre harvesting, washing, spinning, fabric formation, dyeing and processing with various treatments are all part of the textile industry's production process. Each deed has an adverse effect on the ecosystem (Torstensson, 2011).

The textile industry causes a massive amount of pollution, contributing up to 10 per cent of global greenhouse gas (GHG) emissions. The industry also generates a huge amount of waste, with clothing either being dumped in landfill or shipped to lower-income countries to be sold, causing environmental, economic and social damage. Textile waste falls into two categories: post-production (fabric cut-offs, defects) and post-consumer (discarded garments) (Domina & Koch, 1997), with both types posing substantial financial and ecological challenges (Wang, 2006). While waste generation rates vary globally, ranging from 0.47 kg/person/day in Ghana compared to 1.22 kg in developed nations (Miezah et al., 2015) disposal methods such as uncontrolled landfilling create universal environmental hazards through methane emissions and soil contamination (Lissah et al., 2021). In Ghana, the textile industry plays a crucial economic role but struggles with inefficient waste management systems, leading to severe environmental degradation. The country’s textile waste, though lower in per capita terms, is exacerbated by limited recycling infrastructure and reliance on informal disposal methods (Lissah et al., 2021). With the sector contributing to employment and export earnings, there is a growing need to reconcile industrial growth with sustainable practices. While sustainable waste management has become imperative globally (Torstensson, 2011), research gaps persist regarding specific strategies employed by Ghana's textile industry, particularly in balancing economic development with circular economy principles to reduce waste and carbon emissions (Gardetti & Torres, 2013). Addressing these gaps is critical for policy formulation and industry practices that align with both local economic priorities and global sustainability goals.

1.1| Theories Underpinning the Study

The waste hierarchy framework and circular economy principles conceptualise waste as a valuable resource (Wilson, 2007), with European regulations formalising this approach through a prioritised waste management strategy (Golomeova et al., 2013). This system has long informed textile waste management, dating back to 18th-century innovations like the rag grinder during Britain's Industrial Revolution. The urgent need for textile recycling persists today, particularly given the substantial water footprint of clothing production, which requires 2,720 litres for a single cotton T-shirt and nearly 11,000 litres for jeans (Gardetti & Torres, 2013). Figure 1 represents these waste hierarchy priorities, demonstrating how sustainable design principles can systematically reduce textile waste through prevention, reuse, and recycling before considering disposal options.



Figure 1. Waste Hierarchy as in Waste Framework Directive (European Union., 2008)

DOI: https://doi.org/10.35738/ftr.v7.2024.13

The 'waste hierarchy,' according to the European Union. (2008), consists of five steps: prevention, preparation for reuse, recycling, other recovery (e.g. energy recovery), and disposal. The 'waste hierarchy,' which advises a priority order from the most desirable option of 'prevention' at the top to the least chosen option of 'disposal' at the bottom, has a considerable influence on current waste management methods. For instance, Modern waste management combines policy-driven approaches like the EU's Circular Economy Action Plan and EPR laws (OECD, 2016) with municipal solutions such as single-stream recycling and waste-to-energy (World Bank, 2022), while corporations adopt circular models like take-back schemes (Ellen MacArthur Foundation, 2023). Persistent challenges like low recycling rates and infrastructure gaps are driving innovations in AI sorting and chemical recycling. (UNEP, 2023). Other academics have suggested that the current 'waste hierarchy' is effective at avoiding landfill disposal but ineffective at reducing natural resource use and environmental impact (Van Ewijk & Stegemann, 2016; Price & Joseph, 2000). While the waste hierarchy effectively diverts waste from landfills, scholars argue it inadequately addresses resource depletion and systemic environmental impacts. Rasmussen and Vigsoe (2005) criticise its downstream focus for ignoring upstream resource extraction, perpetuating linear consumption, while Korhonen et al. (2018) highlight how recycling often downgrades materials ("downcycling"), necessitating virgin resources and failing to decouple growth from resource use. Gregson et al. (2015) further note its neglect of production-phase impacts (e.g., textile dye pollution), with UNEP (2023) showing tripled global resource use since 1970 despite recycling gains, underscoring the hierarchy's inability to achieve absolute dematerialisation without complementary upstream interventions.

In the realm of waste control, determining a consistent definition of "waste" has been a long-debated topic. 'Waste' is defined as "any material or thing that the holder discards, intends to discard, or is obligated to waste" (European Union., 2008). Waste is generally viewed as something to be dumped, although it is frequently repurposed when its value is recognised. While the Waste Framework Directive's interpretation focuses on the holder's intention, critics argue this anthropocentric view fails to account for material flows in natural systems (Liboiron, 2021). Some scholars suggest waste should be understood relationally rather than through discard intentions, as materials may be valuable to some while being waste to others (Gregson et al., 2015). This debate has significant policy implications, as narrow legal definitions may exclude important waste streams from regulation (Silva et al., 2016). The European Environment Agency (2019) notes that approximately 60% of what is currently classified as waste could potentially be reintegrated into production cycles, suggesting definitions may need to evolve alongside circular economy principles. Some researchers, on the other hand, consider waste to be a resource. The resource value of 'waste,' for example, has enabled individuals in developing nations to make a living with a current trend that is progressively transitioning from the concept of end-of-pipe waste management to a more comprehensive approach of resource management (Wilson, 2007). Similarly, Zamani (2014) discusses how holistic 'zero waste' management systems can reroute 'resources' that are transformed into 'waste' as a result of human consumption activities back into the production process. Contemporary theories, such as closed-loop or circular materials economies, which support the notion of a 'resource-based' paradigm rather than a 'waste-based' paradigm, have advocated the necessity of focusing on 'waste as resource.' (Wilson, 2007). While traditional definitions view waste as valueless (European Union., 2008), emerging circular economy paradigms conceptualise it as a resource (Ellen MacArthur Foundation, 2015), evidenced by innovations like Ambercycle's textile recycling and global reuse initiatives. This shift is particularly impactful in developing economies, where waste-based livelihoods prevail (Wilson, 2007), suggesting that Ghana's textile industry could achieve socio-environmental sustainability by adopting such circular strategies alongside improved waste categorisation and valorisation approaches (Gregson et al., 2015; Zamani, 2014).

2 | METHODOLOGY

This study employed a qualitative research approach using multiple case studies to examine textile waste management strategies in Ghana's large textile firms (Creswell & Poth, 2018). The methodology combined semi-structured interviews with 25 managers and supervisors from three major textile companies (Volta Star Textile Ltd., Akosombo Industrial Company Ltd., and TexStyle Ghana Ltd.) and descriptive observational techniques (Schmuck, 1997; Syed, 2016), allowing for in-depth analysis of environmental, social, and economic impacts. Purposive sampling ensured the selection of knowledgeable participants representing 59.5% (25) of the target population (100%, n=42), following Cohen et al. (2002) recommendation for quality research. The multiple case study design (Merriam, 1998) enabled comparative analysis of firm-specific waste management practices while maintaining methodological

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rigour through NVivo-assisted data coding and analysis. The research design specifically addressed the contextual challenges of textile waste management in developing economies such as the Ghanaian textile firms (Asiedu et al., 2020; Ellen MacArthur Foundation, 2021) by capturing subjective experiences through descriptive research (Bradshaw et al., 2017). Focused on operational-level perspectives from eight (8) VSTL, eight (7) AICL and ten (10) TSGL participants, the study combined verbal accounts with observational data to triangulate findings about current waste generation patterns and management strategies. This approach aligned with Muthu (2017) framework for assessing industrial sustainability while accommodating the unique operational realities of each case study firm through flexible, context-sensitive data collection methods. Geographically, the study was conducted at three major regions in Ghana: the Volta Region, the Eastern Region and the Greater Accra Region.

3 | FINDINGS AND DISCUSSION

3.1| Demographic Profile of Interview Respondents

The demographic characteristics of the study participants are shown in Table 1. The study's participant demographics revealed a significant gender disparity in Ghana's textile manufacturing sector, with males comprising 88% (n=22) of respondents and females only 12% (n=3). This aligns with global trends showing male dominance in industrial manufacturing roles (ILO, 2025). The workforce demonstrated substantial experience, with 52% (n=13) having 11-20 years of service, suggesting high institutional knowledge retention. Educational attainment was notably high, with 60% (n=15) holding master's degrees and 40% (n=10) bachelor's degrees, reflecting the technical demands of modern textile production. The majority (56%, n=14) fell within the 41-50 age bracket, indicating a mature workforce composition typical of Ghana's industrial sectors.

Table 1. Demographics of Respondents

Variable		Frequency	Percentage
Gender	Male	22	88%
	Female	3	12%
Age groups	20-40	4	16%
	41-50	14	56%
	51-60	7	28%
Level of education	1st Degree	10	40%
	Masters	15	60%
Years in service	1-5 years	2	8%
	6-10 years	5	20%
	11-20 years	13	52%
	21-30 years	3	12%
	above 30 years	2	8%
Total number of respondents		25	100%

Source: Field Research 2023

3.2| Overview of Waste Generated at the Textile Firms

The study examined waste production across different stages of textile manufacturing, categorising waste types according to raw materials used and final products. As illustrated in Figure 2, the matrix coding chart, waste generation occurs at multiple production levels, with distinct waste types emerging at each stage. This finding corroborates Torstensson (2011) assertion that the textile sector ranks among the most waste-intensive industries.

DOI: https://doi.org/10.35738/ftr.v7.2024.13

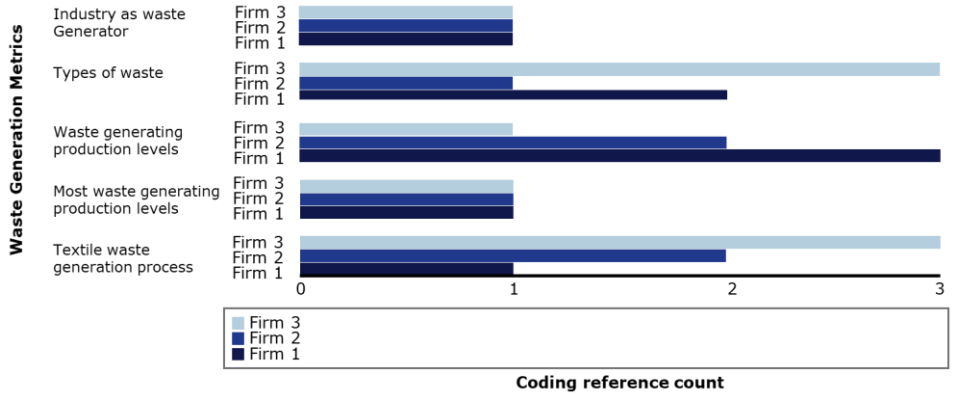


Figure 2. Matrix Coding Chart of Waste Generation in the Textile Industry
Source: Field Research (2024)

The study confirms that textile manufacturing inherently generates waste across all production stages, as unanimously evidenced by selected firms (coding value = 1). Through interviews with selected firms, the study identified: (1) distinct waste generation patterns, (2) specific waste varieties, and (3) their production-level origins. These findings align with established industrial waste literature while providing contextual data from Ghana's textile sector, bridging theoretical frameworks with practical case evidence. The systematic documentation of participant responses offers valuable insights for developing targeted waste management strategies.

3.2.1| Waste Generation in the Textile Industry: A Universal Challenge

The findings demonstrate precise alignment between empirical data and established literature on textile waste generation. TSGL's (Texstyle Ghana Limited) assertion that "the process involves everything that affects the environment, water, energy, chemicals" substantiates Torstensson (2011) characterisation of the textile industry as particularly waste-intensive due to its substantial resource demands. Furthermore, the variation in waste profiles across firms - from AICL's (Akosombo Industrial Company Limited) screen printing residues to VSTL's (Volta Star Textile Limited) spinning and weaving by-products - empirically validates Domina and Koch (1997) theoretical framework that waste composition is fundamentally process-dependent. This process-specific differentiation of waste streams underscores the need for tailored waste management approaches across different textile manufacturing operations.

3.2.2| Types of Waste: Firm-Specific Variations

The waste profiles documented across the selected firms demonstrate how production specialisation leads to distinct waste generation patterns:

Hazardous Waste in Printing Operations (Firm 1) Akosombo Industrial Company Ltd.

Firm 1's (AICL) report on Residual Fuel Oil (RFO), wastewater, and used screens as hazardous waste, corresponds with Dong et al. (2025) review on the effect of textile printing waste on both the ecological environment and human health. This alignment suggests that, despite geographical differences, certain textile processes generate consistent waste types globally. However, the persistence of these hazardous wastes in Firm 1's operations indicates potential gaps in adopting cleaner production technologies that have been successfully implemented elsewhere (Tang, 2023).

Waste in Spinning/Weaving (Firm 2) Volta Star Textile Ltd.

Firm 2 (VSTL) had relatively limited waste diversity, consisting mainly of spinning and weaving offcuts. This finding challenges the assumption that all textile subsectors are equally waste-intensive and suggests opportunities for waste minimisation through production specialisation.

Startup Waste in Design Production (Firm 3) TexStyle Ghana Ltd.

Firm 3's significant start-up waste from design trials (100-yard wastage per new pattern) and wastewater from pre-treatment empirically validate Harane and Adivarekar (2016) findings about sustainable reuse and recycling of wastewater in a scouring and bleaching bath three times to curb water consumption in textile wet processing. A research by Bisht et al. (2025) highlighted how technological innovation such as digital printing has reshaped the textile industry with benefits which include reduced

DOI: https://doi.org/10.35738/ftr.v7.2024.13

usage of water, energy and waste generation. This suggests an important trade-off between product customisation and waste generation that deserves further exploration in the Ghanaian context. Recent work by Angelova (2025) proposes digital prototyping as a potential solution, though its feasibility for firms like Firm 3 remains uncertain given capital constraints.

3.2.3| Production-Level Waste

The findings from Ghanaian textile firms reveal significant waste generation at specific production stages, which align with and contribute to existing literature on textile waste management. These production-level wastes demonstrate both universal challenges in textile manufacturing and context-specific issues faced by Ghanaian firms.

Printing Waste (Firm 1)

The interview data from Firm 1 (AICL) highlights printing as a major waste generation point, particularly due to power outages, causing 10-15 metres of fabric waste per incident. This finding strongly supports Yasmeen et al. (2022) research on the negative impact of the energy crisis on a firm's productivity, which identified unreliable infrastructure as a key contributor to production waste. The current study adds empirical evidence from industry practitioners, showing how sudden power interruptions disrupt quality control processes, leading to substantial material losses. This challenge appears particularly acute in developing country contexts where energy infrastructure is less stable compared to global counterparts.

Spinning and Weaving Waste (Firm 2)

Firm 2 (VSTL) reported experience with waste generation during spinning (particularly in the blowing stage) and weaving operations. This aligns with Domina and Koch (1997) foundational work on textile waste categorisation. The observed fibre loss during early-stage processing and beam cutting echoes their findings about inherent waste in yarn preparation and loom operations. However, Firm 2 also reported a reduction in waste levels over time, which suggests possible improvements in production efficiency that may not be reflected in existing literature. This presents an opportunity for future research to document successful waste reduction strategies in spinning operations within African contexts.

Start-up Waste (Firm 3)

Firm 3 (TSGL) reported a significant startup waste (particularly loss of 100 yards during design trials for new patterns). This provides empirical validation for Angelova (2025) research about digital prototyping in textile operations to reduce waste. This finding underscores the tension between quality assurance and waste generation in small-batch production environments. While such startup waste may be technically "unavoidable," as participants described, its magnitude suggests potential for improvement through digital prototyping technologies or lean manufacturing techniques not currently widely adopted in Ghana.

3.3| Types of Raw Materials

The types of raw materials used by the firms play a significant role in the kind of waste generated by the various firms. Table 2 shows the type of raw materials used by the selected firms. The analysis of raw material usage among Ghanaian textile firms reveals distinct production specialisations and inter-firm dependencies, which align with broader literature on textile supply chains in developing economies. The data highlights how firm-specific product lines influence raw material selection and create symbiotic relationships between manufacturers.

Table 2: Raw Materials used by The Firms

Akosombo Industrial Company Limited (AICL)	Volta Star Textile Limited (VSTL)	TexStyle Ghana Limited (TSGL)
Greybaft	cotton	Greybaft
Wax	Cassava-based starch	Dyes
Dyes		Chemicals
Chemicals		

Source: Field Research (2023)

DOI: https://doi.org/10.35738/ftr.v7.2024.13

Table 2 indicates that AICL remains the only firm using wax as a raw material, as it continues to produce authentic wax prints. This finding aligns with historical studies on Ghana's textile industry, which identify wax print manufacturing as a specialised and increasingly rare segment of African textile production (Gharte & Essel, 2023). The decline of wax production in TSGL reflects broader industry trends where high production costs and competition from cheap imports have made traditional wax printing economically challenging (Amponsah et al., 2020). Some firms shift to faux-wax (machine-printed imitation wax) to remain competitive, eliminating the need for actual wax. This supports the argument that real wax production is becoming a niche market, sustained only by firms like AICL that maintain traditional techniques. VSTL stands out for its use of cassava-based starch and cotton, which are key inputs for producing greybaft (unbleached cotton fabric). This observation corroborates Temesgen et al. (2019), who note that cassava starch performs better as a sizing agent to strengthen yarn before weaving as compared to other starches. The use of cassava starch (a locally available bioresource) suggests potential for reduced import dependency, as highlighted by Yalcin-Enis et al. (2016). Cotton (though imported mainly due to Ghana's limited cotton farming) remains essential for base fabric production. VSTL's role as a grey baft supplier to AICL and TSGL (who further process it into printed fabrics) demonstrates a vertical supply chain linkage within Ghana's textile sector. This aligns with Domina and Koch's (1997) assertion that textile waste and raw material flows are often inter-firm, with one company's output becoming another's input. The raw material variations among AICL, TSGL, and VSTL reflect diverse production strategies shaped by market demands, cost factors, and local resource availability. While AICL preserves traditional wax printing, VSTL supplies foundational greybaft, and TSGL adapts to market shifts by abandoning wax. These dynamics highlight:

- The decline of authentic wax production in favour of more cost-effective methods.
- The potential for localised, bio-based inputs (e.g., cassava starch) to enhance sustainability.
- The need for stronger circular supply chains to reduce waste and import reliance.

3.4| Waste Generated by Firm 1 (AICL)

As depicted in Figure 4, the main raw material used by the firm is grey fabric, which is imported from China due to the closure of its spinning section. This shutdown resulted from obsolete machinery, high production costs, and the non-availability of domestic cotton (Production Manager, Personal communication, April 2023). The cost of importing grey fabric is significantly lower than in-house production, making it the preferred option. Waste generation begins at the pre-treatment stage, where liquid effluent is produced during washing processes to remove impurities from the grey fabric before printing and dyeing. Similar effluent is generated during screen washing and post-printing fabric washing. These waste streams are treated in an on-site recycling plant to ensure environmental safety before disposal, a practice aligned with EU Best Available Techniques (BAT) guidelines for textile effluent management (Roth et al., 2023).

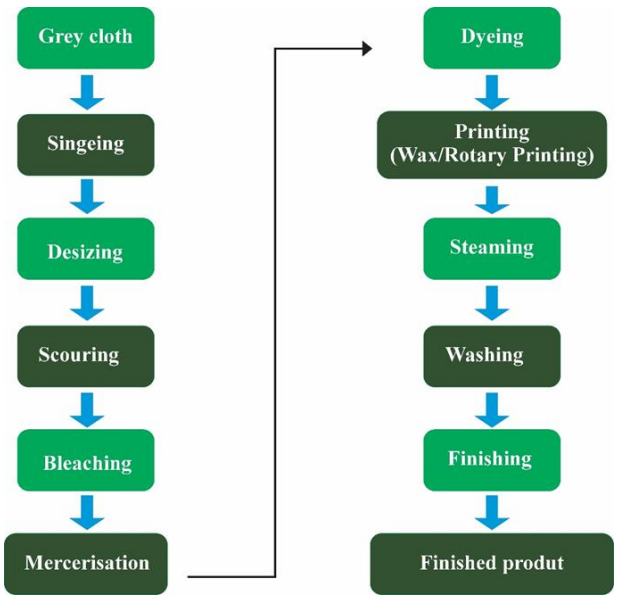


Figure 4. Production flow chart of AICL
Source: Field Research (2023)

DOI: https://doi.org/10.35738/ftr.v7.2024.13

At the printing stage, approximately 50–100 yards of fabric are wasted during setup (known as "ferns") or due to power outages that cause abrupt machine stoppages and defects. While these defective fabrics are classified as waste, the firm mitigates losses by selling them at discounted prices or overdyeing them in darker shades for repurposing as funeral cloth. Additionally, used printing screens become waste after repeated use and are returned to manufacturers for recycling. In exchange, the firm receives new screens, exemplifying a closed-loop recycling system advocated by the Ellen MacArthur Foundation (2017). This practice not only reduces waste but also aligns with global efforts to promote circular economy principles in textile production (Chen et al., 2021). Table 3 shows the categories of waste generated at AICL.

Table 3. Waste Generated at AICL

Types of waste	Percentage of waste over production
Residual Fuel Oil	30
Printed fabric	2.3
Waste water	5
Used screens	1

Source: Field Research (2023)

3.5| Waste Generated by Firm 2 (VSTL)

3.5.1| Production Process Chart of VSTL

The waste profile at VSTL exemplifies systemic challenges in cotton textile production, where material losses occur at nearly every processing stage. While some waste is inevitable, the scale and diversity of waste streams from invisible dust to sizable yarn cuts reveal opportunities for process optimisation and circular economy integration. VSTL reports short fibres from baling and invisible dust waste, which aligns with industry norms. Similarly, improper cops and knotting waste, often attributed to machine inefficiencies, might be reduced through machine modifications and the adoption of new practices, as demonstrated by Ghosh et al. (2014) in their innovative approaches to reducing knotting waste. The 25-yard unsized yarn waste per beam at VSTL mirrors findings in the EU's Best Available Techniques report in 2013, which identifies sizing as a "critical loss hotspot" (Sandin & Peters, 2018), counter that such waste could be minimized by dynamic beam synchronisation (reducing uneven exhaustion), reusing unsized yarns in non-woven applications (e.g., padding or composites). Meanwhile, weaving faults (3–7% material loss) are often treated as unavoidable. VSTL's entangled yarns and partial pirn waste are typically discarded. This contrasts with the Ellen MacArthur Foundation (2017) advocacy for "designing out waste" by standardising pirn sizes to reduce leftovers. While VSTL's practices align with conventional textile production, they lag behind the 2020 EU Circular Economy Action Plan targets, which mandate "zero process waste to landfill" by 2030. The production process chart of VSTL is indicated in Figure 5.

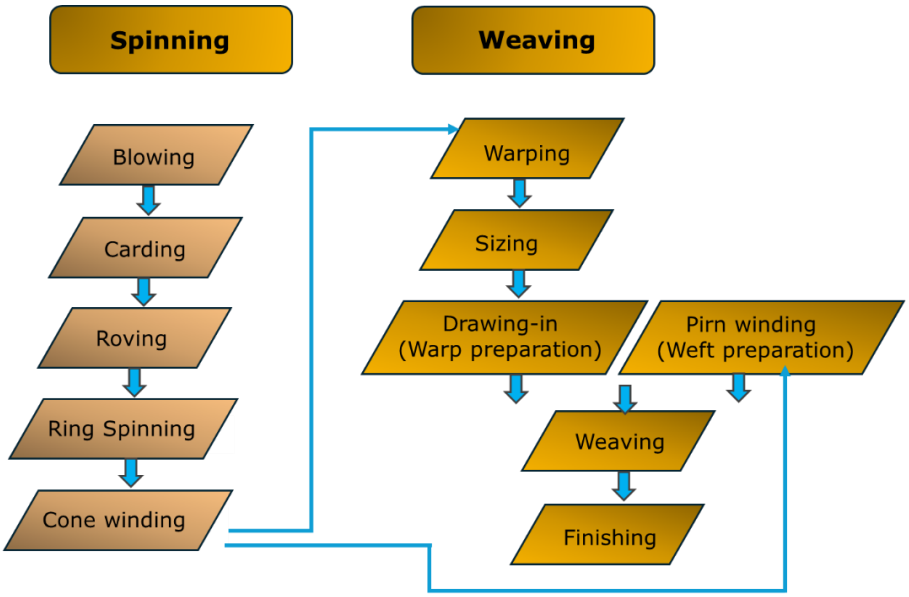


Figure 5. Flow chart of spinning and weaving, VSTL
Source: Field Research 2023

DOI: https://doi.org/10.35738/ftr.v7.2024.13

3.5.2| Categories of Waste from Spinning and Weaving Sections

At VSTL, waste generated is categorised into two major groupings. These are known as non-usable waste and usable waste. Non-useable waste, as the name suggests, is very short fibres and dust particles that are collected from the filters of machines and cannot be reused. Apart from being very short, they are mixed with dust particles and therefore appear dirty. Sweepings from the factory floor also fall under this category. Table 4 shows the types of non-usable waste. Usable waste, on the other hand, refers to waste that can be reused or recycled. These are short fibres collected from various cleaning sections in the production line. These wastes are graded according to their level of purity. The various grades are shown in Table 5.

Table 4. Non-usable Waste

1		**Micro Dust** This type of waste comes in the form of very short fibres and dust particles, which are collected from the filter machines installed on the blowing and carding machines. These wastes are classified as unhealthy for reuse and therefore are burnt.
2		**Sweepings** These are short fibres which accidentally fall on the floor in the course of production. These are always swept together with dust and other waste and burnt.

Source: Field research (2023)

Table 5. Re-usable Waste

1		**Grade one Waste Cotton** These wastes are generated as a result of clogging due to machine breakdown. They come in the form of dusted, clean mat and carding as well as portions of the lint cotton which may have defects. This waste is sold to the pillow-making industry.
2		**Waste From Drum Filter** These kinds of waste are collected from several cleaning sessions in carding. The fibres are collected together and filtered. The waste is classified as grade two waste and used by the pillow industry.
3		**Waste From Waste Extractor in the Blow Room** These are waste from the cleaning points in the blowing line of machines. These wastes are classified as grade three waste because most of the impurities in the cotton are removed at the blow room stage. While the micro dust and short fibres are unhealthy for use by the pillow industry, they are also burnt.

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4		**The Recyclable waste cotton** These are slivers that are broken off by the operators during piecing or faulty slivers; roving waste and ring spinning and also pneumatic waste from ring spinning. These are reusable waste which are put back into the production process again.
5		**Waste from sized Beams** This waste is generated from sized beams that were not completely exhausted during weaving.
6		**Unsized Beam cut** During sizing, some warp sheets (seven beams) are pieced together through the sizing process. At the point of exhaustion, not all the beams get exhausted and therefore are cut as yarn waste. This waste is sold out to bead-making industry for threading beads.
7		**Defective cones** These wastes are generated from yarns that were not properly wound onto cones and are not good enough for weaving. This comes as a result of mechanical faults (machine breakdown), or when the cones are not properly such yarns when used for weaving, will cause yarn breakages in the weaving process or unevenness in the woven fabric. These are sold to *kente* weavers who take their time to unravel these yarns and wind them onto bobbins as weft yarns for weaving.
8		**Entangled Waste** Entangled warp ends are caused by fluffs falling on the warp, broken warp ends entangled to adjacent ends, knots with a long tail also result in entanglement, snarls in yarn getting entangled, too much hairiness in yarns, weak picking, faulty shuttle checking, gear wheels slipping due to broken teeth, loose stop rod finger, and uneven joint of the flat belt are causes of entangled wastes
9		**Rags, Tabs and Net-fin** These are generated at finishing, where the woven cloth is inspected to get rid of faults. These defects are cut off from the woven fabric. They come as a result of knotting (that is, tying new ends to exhausted ends on the loom to continue weaving), yarn breakage, loss of yarns etc. and are classified as rags, tabs and net

Source: Field Research 2023

VSTL's binary classification of waste into *non-usable* and *usable* categories reflects common industry practice, but warrants critical examination through contemporary waste management literature. The classification of short fibres and floor sweepings as non-recyclable aligns with Celep et al. (2022) observation about limitations in fibre recycling, which has led to the development of new sustainable fibres as alternatives to natural fibres. However, this perspective is increasingly contested; Sandin and Peters (2018) demonstrated that even heavily contaminated fibres can serve as raw material for acoustic insulation panels after sterilisation. VSTL's practice of grading usable waste by purity level aligns with the recommendation for waste-stream valorisation. This approach shows awareness of quality hierarchy, higher-grade waste can re-enter spinning, while lower-grade suits nonwovens (Ellen MacArthur

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Foundation, 2021). Grading enables price differentiation by highlighting the role grading and classification play in the cotton marketing of cotton fibres. However, Muthu (2017) warns that internal grading systems often underestimate upcycling potential due to a lack of external market knowledge and overemphasis on textile-specific reuse. The binary system reveals three limitations identified in the literature:

- Overlooks potential for biological valorisation (composting) of "non-usable" waste (European Commission, 2022)
- Fails to address root causes of contamination (Hasanbeigi et al., 2015)
- Does not account for emerging markets in recycled materials (Manteco., 2023)

3.6| Waste generation by Firm 3 (TSGL)

The production process at TSGL comes in three folds: pre-treatment, printing, finishing and making –up. At every section of production, waste is generated (Figure 6).

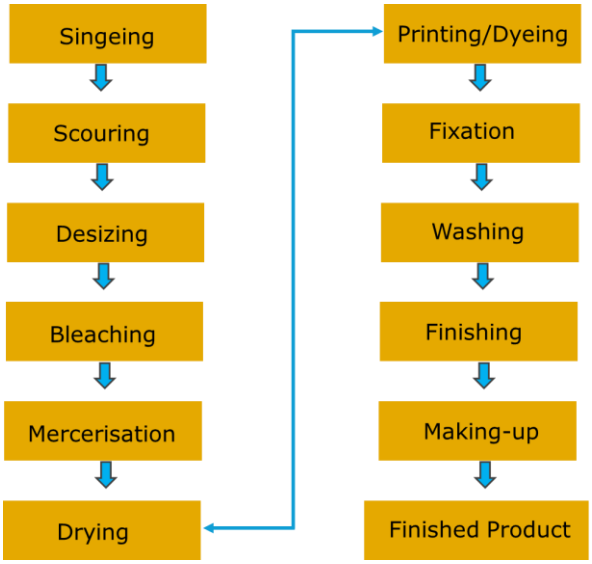


Figure 6. Flow Chart of Production Processes at TSGL
Source: Field Research (2024)

3.6.1| Pre-treatment

TSGL obtain their raw material, which is grey cloth, from VSTL and imports some from China, Pakistan, Thailand, and India. TSGL's reliance on imported grey fabric from multiple Asian countries reflects globalised textile supply chains, which are often critiqued for their environmental footprint (Niinimäki et al., 2020). While this strategy may reduce costs, studies suggest that localised sourcing could lower carbon emissions (Onyido, 2014). The company's rigorous quality inspections (checking weight, strength, and dimensions) align with industry best practices (BS EN 1773:2021), but researchers argue that incorporating sustainability metrics (e.g., water footprint of sourced fabrics) could enhance environmental accountability (Ercin & Mathews, 2017). TSGL's pre-treatment sequence, singeing, desizing, scouring, bleaching, and mercerisation, follows conventional industry protocols but generates significant waste streams.

- **Singeing**: While effective for fabric smoothness, this process releases particulate matter (PM2.5–PM10), contributing to workplace air pollution (Roth et al., 2023).
- **Enzymatic Desizing**: TSGL's use of α-amylase is commendable, as enzymatic methods reduce water and energy use compared to oxidative desizing. However, the resulting effluent still contains high chemical oxygen demand (COD) from starch hydrolysis. Closed-loop water recycling systems, as piloted in German textile mills, could mitigate this (Lu et al., 2010).
- **Scouring & Bleaching**: The combined use of caustic soda and hydrogen peroxide is effective but generates highly alkaline wastewater (pH 11–12) with dissolved organics (Choudhury, 2017). Recent advances in bio-scouring (using pectinase enzymes) could reduce alkali use by 50% (Baloyi et al., 2024), though scalability remains a challenge.
- **Mercerisation**: While this process enhances dye uptake and fabric strength, the spent NaOH liquor (200–250 g/L) poses disposal challenges. Neutralisation with waste CO_2 (from flue gases) is being explored as a circular solution (Thabit et al., 2023).

Fashion and Textiles Review, **2026**, Volume 7, Pages 47-66, https://doi.org/10.35738/ftr.v7.2024.13

DOI: https://doi.org/10.35738/ftr.v7.2024.13

While TSGL's methods are industry-standard, incremental innovations could significantly reduce environmental impact without compromising quality. The composite effluent from pre-treatment, characterised by high pH, COD, and heavy metals (Greenwood, 1987), represents a critical sustainability hurdle. TSGL's current treatment (Safety Manager of TSGL, Personal communication, 2024) likely involves neutralisation and biological treatment, but studies suggest additional steps could enhance efficiency: Ozone or UV/H_2O_2 treatments can degrade persistent organic pollutants (Ogunbiyi et al., 2025). Nanofiltration systems recover up to 90% of water for reuse (Koyuncu et al., 2000). High operational costs limit adoption in developing economies (Othman et al., 2021).

3.6.2| Printing

The company has stopped printing with real wax because they are unfriendly to the environment due to its synthetic nature. They now print imitation wax with reactive dyes on their Duplex printing machines. Both wax and fancy products are printed with the rotary screen printing machines. Waste generated in this section is known as start-up waste, which is generated at the initial printing stage. TSGL's shift from synthetic wax printing to reactive dyes reflects growing industry recognition of synthetic waxes' environmental hazards. Traditional wax printing compounds have been shown to release volatile organic compounds (VOCs) during application and removal, contributing to workplace air pollution and ozone formation (Roth et al., 2023). It also generates difficult-to-treat wastewater containing persistent hydrocarbon residues (Manickam & Vijay, 2021). The adoption of reactive dyes on Duplex machines represents a significant environmental improvement, as demonstrated by 40% reduction in CO_2 emissions per metre printed, primarily through elimination of wax removal steps (Muthu, 2017), 25-30% decrease in water consumption by avoiding wax wash-off cycles (Ellen MacArthur Foundation, 2021) Improved biodegradability of printing effluents, though challenges remain regarding salt content (Choudhury, 2017). However, this transition presents new technical challenges: Colour matching difficulties due to different dye-fibre interactions compared to wax and higher skill requirements for operators to achieve consistent print quality. The persistence of start-up waste (50-100 yards per run) despite technological changes highlights systemic inefficiencies in textile printing operations. The textile industry averages 3-5% material loss during printing initiation (Manteco., 2023).

3.6.3| Finishing

The finishing stage in textile manufacturing plays a crucial role in enhancing fabric quality, appearance, and marketability. As observed at TSGL, calendaring rollers are employed to improve fabric aesthetics by fixing dyes and imparting a smooth, glossy finish. This mechanical finishing process not only enhances the fabric's visual appeal but also contributes to its durability and hand feel (Gulrajani, 2013). Following calendaring, the fabric undergoes a rigorous inspection to ensure compliance with industry standards. Any defective fabrics, particularly institutional prints that fail to meet specifications, are discarded as waste (Saville, 1999). This quality control step is essential in minimising defects and maintaining brand reputation in competitive markets (Schwartz, 2019). The final steps in this section include cutting, folding, and labelling, which prepare the fabric for distribution and marketing. Proper labelling ensures traceability and compliance with regulatory requirements (Kadolph, 2016). Efficient finishing processes not only enhance product value but also reduce waste, aligning with sustainable textile production practices (Fletcher & Grose, 2012).

3.7| Waste Management Strategies (AICL)

AICL generates diverse waste streams across its production processes, as outlined in Table 4. These waste categories; ranging from fabric waste to effluents, reflect the firm's material inputs and manufacturing operations.

Table 6. Waste Management Measures (AICL)

Waste Type	Categories of Waste	Management Strategies
Printed fabrics	ATL brands (wax and fancy) fabric waste	Sold as low-grade
	Institutional waste	Used to generate energy for Biomass
Wastewater		Recycled
Used screens		Stripped for reuse
Wax		Recover, recycle and reuse

Source: Field Research (2023)

DOI: https://doi.org/10.35738/ftr.v7.2024.13

The textile industry generates significant waste, but innovative firms are adopting sustainable practices to minimise environmental impact. In the case of AICL, defective fabrics, particularly those from printing sessions, are often re-dyed in darker shades and repurposed as funeral cloth, sold at discounted prices (Allwood et al., 2006). This approach aligns with the circular economy model, which reduces waste through reuse and recycling (Ellen MacArthur Foundation, 2017). For fabrics that are too damaged for reuse, such as institutional prints, the firm utilises them as biomass feedstock, converting waste into energy (Blackburn, 2009). Additionally, wastewater from washing is treated and reused, reducing freshwater consumption; a critical step in sustainable textile production (Babu et al., 2007). To further enhance efficiency, the firm has invested in screen-engraving and stripping machines, which optimise printing processes and reduce material waste (Shamey & Zhao, 2013). These technological upgrades contribute to waste minimisation and profit maximisation, demonstrating how modern machinery can enhance sustainability (Muthu, 2017). The firm's wax recovery system is another key sustainability measure. Unlike conventional paraffin wax, which is petroleum-based and environmentally harmful, the firm uses wood rosin wax, a natural alternative derived from tree bark (Factory Manager of AICL, Personal Communication, April 2023). The recovery plant processes used wax, strengthening it with additives for reuse, thereby minimising raw material consumption. This closed-loop system exemplifies industrial best practices in waste management (Sandin & Peters, 2018).

3.8| Waste Management Strategies (VSTL)

VSTL's production processes generate multiple waste streams, primarily consisting of fibre, yarn, and fabric waste. These materials arise at different stages of manufacturing, from raw material processing to finished textile production. Table 6 outlines the specific waste categories and the strategies VSTL employs to manage them, reflecting the firm's emphasis on external partnerships and community-based recycling as key waste-reduction approaches.

Table 6. Waste Management Measures (VSTL)

Types of waste	Categories of waste	Management strategies
Production Waste	Non-usable waste (short fibres)	Burning
	Usable waste (short fibres)	Sold at a cheaper price to pillow makers in the community.
	Recycled waste (Clean fibres)	Re-utilised in the manufacturing process
	Usable Yarn waste	Sold to bead makers
	Fabric waste	Sold out as a lower grade

Source: Field Research (2023)

While many textile firms are adopting advanced recycling technologies to repurpose production waste, VSTL currently does not directly reuse short fibres and waste yarns. Instead, these materials are sold at low cost to local women who use them for pillow making, supporting small-scale entrepreneurship (Hawley, 2006). The company views this as part of its corporate social responsibility (CSR), ensuring that waste benefits the community rather than being discarded (Carroll & Shabana, 2010). This practice aligns with the social sustainability model, where businesses contribute to local economic development (Dyllick & Hockerts, 2002). Beyond pillow production, waste cotton is purchased by mushroom farmers for cultivation, while waste yarns are used by bead makers for threading. Additionally, scrap fabrics are repurposed for tie-dye/batik, *fugu* (traditional smock) production, and linings for shoes and bags, demonstrating the versatility of textile waste in informal economies (Birtwistle & Moore, 2007). Such practices reflect a community-based circular economy, where waste finds new life through artisanal and agricultural applications (Ghisellini et al., 2016). However, VSTL acknowledges that selling waste rather than recycling it internally is not the most efficient long-term strategy. The firm plans to invest in new recycling technologies to minimise waste generation in the production line (Production Manager, Personal Communication, April 2023). This shift would align with global best practices in textile waste valorisation, where companies integrate mechanical and chemical recycling to recover fibres (Sandin & Peters, 2018). Until then, the firm continues balancing economic sustainability (future efficiency improvements) with social sustainability (current community support) (Seuring & Müller, 2008).

DOI: https://doi.org/10.35738/ftr.v7.2024.13

3.9| Waste Management Strategies (TSGL)

TSGL produces various waste materials, including fabric scraps, defective items, and production by-products throughout its manufacturing process. As shown in Table 7, the company employs an integrated lean and circular economy strategy, which includes recycling 50% of its wastewater back into production.

Table 7. Waste Management Strategies (TSGL)

Types of Waste	Categories	Management strategies
Post–production waste	Start–up waste	Washed and sold to tie-dye and batik makers
	Re-sampling waste	Burning
	Institutional waste	Burning
	GTP (brand) fabric waste	Sold as low-grade

Source: Field Research (2024)

Textile manufacturing inevitably generates operational waste, and TSGL faces several forms, including start-up waste, design errors (particularly in institutional fabrics), resampling waste, and production mistakes. Such waste streams are common in textile production and present both environmental and economic challenges (Muthu, 2014). To mitigate waste, TSGL redesigns some defective fabrics by overdyeing them in darker shades and repurposing them as packaging bags for its retail outlets. This approach aligns with upcycling principles, where waste materials are transformed into higher-value products (Han et al., 2015). However, institutional fabrics with proprietary logos and branding are burnt to prevent legal risks from unauthorised use (Safety Manager of TSGL, Personal Communication, 2024). This practice, while necessary for intellectual property protection, contributes significantly to the firm's annual waste burden. The burning of institutional waste raises sustainability concerns, as burning textiles releases greenhouse gases and toxic pollutants (Roth et al., 2023). Alternative solutions, such as mechanical shredding or chemical recycling, could help TSGL reduce its environmental footprint while still safeguarding institutional branding (Sandin & Peters, 2018). TSGL uses 50% of its recycled wastewater back into production (World Bank, 2019). This approach prioritises waste minimisation at the source, material recovery, and sustainable reprocessing, aligning with TSGL's commitment to operational efficiency and environmental sustainability.

4 | ASSESSMENT OF WASTE MANAGEMENT STRATEGIES BY THE FIRMS

The waste management strategies employed by the firms were generally looked at in three (3) dimensions: waste reduction measures, waste management challenges and future perspectives of overcoming waste by the industry.

4.1| Waste Reduction Measures

The textile industry in Ghana currently operates on a linear production model (McQuillan, 2014), leading to significant waste generation through raw material extraction and manufacturing processes. While all three studied firms implement waste reduction strategies, their approaches differ based on production methods (Domina & Koch, 1997). AICL and TSGL, which produce printed fabrics, share similar waste streams but employ distinct management techniques, whereas VSTL's greybraft production generates different waste types. Common practices include selling reusable waste and incinerating hazardous materials (Domina & Koch, 1997), along with wastewater recycling - though only TSGL reuses 50% of its recycled water (Safety Manager of TSGL, Personal Communication, 2023). TSGL stands out for its eco-friendly bleaching process using hydrogen peroxide instead of hypochlorite (Kabir et al., 2019) and caustic soda recovery, while AICL leads in biodegradable wax recovery (Production Manager of AICL, Personal Communication, 2023). VSTL recycles fibrous waste back into production, demonstrating sector-wide efforts to align with SDG target 3.9.1 for pollution reduction (UNDP, 2015).

Despite these initiatives, challenges persist in fully transitioning from linear to circular systems. The industry's partial adoption of circular practices reveals gaps in optimisation, particularly in water reuse and recycling rates. While specialised solutions like AICL's wax recovery and TSGL's chemical management show potential for broader application (Production Manager of AICL, Personal Communication, 2023), financial and technical barriers hinder comprehensive waste reduction. These

DOI: https://doi.org/10.35738/ftr.v7.2024.13

findings underscore the need for standardised circular practices and policy support to overcome limitations in Ghana's textile waste management, particularly in addressing the high water consumption characteristic of the global textile industry (Kabir et al., 2019).

4.2| Waste Management Challenges

One major challenge expressed by all the firms is the cost involved in waste management. The cost of running a plant, chemicals and energy consumption, among other factors, put some pressure on the firms' revenue (Safety Manager of AICL, Personal Communication, 2023). TSGL uses hydrogen peroxide to bleach cotton because of its environmental friendliness. However, the output of it is not favourable in terms of whiteness. Yet, their commitment to environmental safety is paramount (Safety Manager of TSGL, Personal Communication, 2024). As espoused by Pensupa et al. (2017), the efficient management of textile waste is faced with multiple challenges. Nonetheless, effective management of waste could yield positive environmental, economic and social impacts. Despite the challenges faced by the firms, they are working towards continuous improvement to ensure sustainable waste management measures that reduce waste.

4.3| Future Perspective of Overcoming Waste

The study findings reveal that textile firms in Ghana have implemented strategic plans to minimise waste generation. TSGL plans to adopt advanced technologies such as digital printing machines and spectrometers for precise colour testing, which will significantly reduce start-up and sampling waste (Production Manager of TSGL, Personal Communication, 2024). Additionally, the firm is exploring Single Minute Exchange Die (SMED) technology to minimise costly machine downtime during changeovers - an approach widely recognised for improving efficiency in manufacturing industries (King, 2009; McIntosh et al., 2007). Similarly, AICL is focusing on energy-efficient equipment to optimise costs, while VSTL aims to invest in modern spinning technologies, such as Rieter machines, to enhance yarn quality while reducing waste (Factory Manager of ATL, Personal Communication, 2023). These technological investments demonstrate the industry's commitment to adopting global best practices for sustainable production. However, the high cost of modern equipment presents a significant challenge for Ghana's textile industry. As one of the world's most established sectors, contributing substantially to global GDP and employment, the textile industry requires substantial investment to maintain competitiveness. The current technological revolution in textiles demands that Ghanaian policymakers and investors prioritise support for local firms through financial incentives and infrastructure development. Such interventions would not only modernise production processes but also create valuable employment opportunities, helping revitalise this crucial sector of Ghana's economy while promoting sustainable manufacturing practices.

5 | CONCLUSION AND RECOMMENDATIONS

This study highlights that while textile firms are actively pursuing waste reduction, their approaches differ in scope and effectiveness. TSGL's multi-faceted strategies serve as an industry benchmark, whereas AICL and VSTL show potential but require further innovation. Key challenges, financial constraints, social considerations, and technological gaps must be addressed to advance sustainable waste management. To drive progress, Ghana's textile industry should adopt integrated strategies, including lean manufacturing, circular economy practices, and waste-to-product innovations, alongside increased investment in R&D for advanced recycling technologies. Policymakers play a pivotal role by introducing financial incentives, stricter waste regulations, and fostering industry-academia collaborations. Such as supporting joint facilities where universities, startups, and manufacturers co-develop and pilot textile technologies, and co-creating programmes with technical institutions that focus on circular economy principles and sustainable production. Ghana's informal textile sector, such as bead makers, tie-dye/batik makers and upcyclers, is already practising circular principles through reuse, repair and low-waste production. In order to fully harness their potential, policymakers can provide small-scale funding and equipment to informal artisans for scaling sustainable practices, integrate informal actors into national circular economy plans and sustainability certifications and partner with NGOs and universities to offer design, business, and digital skills training tailored to informal producers. Future research should prioritise longitudinal studies to assess the long-term economic and environmental

DOI: https://doi.org/10.35738/ftr.v7.2024.13

impacts of these strategies, as well as regional comparisons to refine best practices. By combining technological advancement, policy support, and cross-sector partnerships, the industry can move closer to a zero-waste, sustainable future that balances economic, environmental, and social priorities.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this study due to the qualitative nature of the research and ethical restrictions on participant data.

ACKNOWLEDGEMENTS

The researchers express their profound gratitude to the management and staff of Tex Style Ghana Limited, Akosombo Industrial Company Limited and Volta Star Textile Limited for their immense assistance and grant of access to collect data for this study. We are also highly indebted to all the managers and supervisors of the various textile firms who participated as respondents to the study.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest. No conflict of interest was recorded by the authors.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this work, the author(s) used Microsoft 365 Copilot in order to assist with editing. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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