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Revolutionizing Textile Recycling and Upcycling Practices: A Comprehensive Exploration of Innovative Approaches for Environmental Sustainability

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Abstract:

The textile industry's substantial environmental impact necessitates sustainable practices. This research investigates cutting-edge approaches in textile recycling and upcycling to mitigate the sector's environmental footprint in Ghana. It explores advanced materials like biopolymers and biocomposites, technological innovations including mechanical/chemical recycling and blockchain, and circular design strategies such as modular construction and recyclable materials. Environmental assessments through life cycle analysis (LCA) and sustainability metrics evaluate these approaches' potential impacts. The study examines the feasibility and implications within Ghana's context, considering economic viability, technical expertise, consumer acceptance, and policy support. It provides recommendations for fostering sustainable practices through stakeholder collaboration, capacity-building, supportive policies, and consumer awareness campaigns, contributing insights to promote a circular and sustainable textile industry.

Keywords: Textile recycling, upcycling, environmental sustainability, circular economy, and biopolymers

1. Introduction

1.1. Background

The textile industry in Ghana encompasses a wide range of activities, from the cultivation of cotton and the production of fabrics to the manufacturing of garments and the disposal of textile waste (Quartey & Abor, 2011). Each stage of the textile life cycle poses unique environmental challenges that require comprehensive and innovative solutions. At the raw material extraction stage, cotton cultivation, one of Ghana's primary textile fibers, has raised concerns about water scarcity and the excessive use of pesticides and fertilizers (Gbireh et al., 2021). The improper management of agricultural chemicals has led to soil degradation and water pollution, posing risks to human health and ecosystems (Antwi et al., 2018). The subsequent stages of textile production, including dyeing, finishing, and garment assembly, have also contributed to environmental degradation in Ghana. Many textile factories in the country lack proper waste management systems, resulting in untreated effluents containing hazardous chemicals being discharged into water bodies (Abdullahi et al., 2021).

This has led to the contamination of surface and groundwater resources, threatening aquatic life and compromising the availability of clean water for domestic and agricultural purposes (Akpan et al., 2022). The post-consumer phase of textiles presents another significant challenge in Ghana. With a growing population and increasing consumption patterns, the volume of textile waste has escalated rapidly (Gbireh et al., 2021). Inadequate waste management infrastructure and limited recycling facilities have led to the indiscriminate disposal of textile waste, contributing to the proliferation of unsightly landfills and the release of greenhouse gases through open burning (Antwi et al., 2018). The linear model of the textile industry, which follows a "take-make-waste" approach, has proven unsustainable and detrimental to Ghana's environment (Agyeman et al., 2020).

The continuous extraction of finite resources and the generation of vast amounts of waste have highlighted the urgent need for a paradigm shift towards sustainable textile production and consumption practices. Adopting sustainable practices in the textile industry is crucial for mitigating its environmental impact and aligning with Ghana's commitment to the United Nations Sustainable Development Goals (SDGs) (Agyeman et al., 2020). Specifically, SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action) underscore the importance of promoting sustainable practices and addressing environmental challenges in various sectors, including the textile industry (United Nations, 2015).

Textile recycling and upcycling are two key strategies that can contribute to the transition towards a more sustainable and circular textile industry in Ghana. Recycling involves recovering and reprocessing post-consumer textile waste into new materials or products, while upcycling focuses on creatively repurposing discarded textiles into higher-

value products (Han et al., 2017; Pal & Gander, 2018). These practices can potentially reduce the textile industry's environmental impact by minimizing resource extraction, conserving energy and water, and diverting waste from landfills and open burning sites (Gbireh et al., 2021).

1.2. Objectives

- To review existing literature on textile recycling and upcycling
- To identify and evaluate innovative approaches in textile recycling and upcycling
- To assess the environmental impact and sustainability of these approaches

2. Literature Review

2.1. Textile Recycling

Textile recycling has emerged as a crucial strategy for mitigating the textile industry's environmental impact and promoting a circular economy. In Ghana, traditional textile recycling methods have been employed to extend the lifespan of textiles and reduce waste generation (Gbireh et al., 2021). One common practice is the sorting and grading used clothing, which is then exported to other countries or sold in local secondhand markets (Quartey & Abor, 2011). However, this approach merely delays the eventual disposal of textiles and does not address the fundamental issue of resource depletion and waste accumulation. More advanced textile recycling methods, including mechanical and chemical, have been explored globally. Mechanical recycling involves shredding and reprocessing textile waste into new materials, such as insulation, padding, or low-grade fibres (Yousef et al., 2019).

In Ghana, several initiatives have been undertaken to establish mechanical recycling facilities to divert textile waste from landfills and open burning sites (Antwi et al., 2018).

However, the success of these efforts has been limited due to challenges such as the lack of proper sorting and collection systems, inadequate infrastructure, and limited access to advanced recycling technologies (Gbireh et al., 2021). Chemical recycling, on the other hand, involves breaking down textile materials into their molecular components through chemical processes, allowing for the recovery of pure fibers or monomers that can be used to produce new textiles or other products (Yousef et al., 2019). While chemical recycling holds promise regarding material quality and resource efficiency, its implementation in Ghana has been hindered by the high costs associated with the required infrastructure and the need for specialized expertise (Antwi et al., 2018). Despite the potential benefits of textile recycling, several challenges and limitations persist in current practices in Ghana and globally. One significant challenge is the complexity of textile waste streams, which often contain a mixture of different fibre types, dyes, and finishes (Sandin et al., 2019). This heterogeneity complicates the sorting and recycling processes, leading to lower material quality and reduced economic viability (Yousef et al., 2019).

2.2. Upcycling in the Textile Industry

Upcycling has emerged as a complementary approach to textile recycling, focusing on creatively repurposing discarded textiles into higher-value products (Han et al., 2017). In the context of textiles, upcycling involves transforming used or waste materials into new, often unique, and desirable products, such as clothing, accessories, or home decor items (Pal & Gander, 2018). In Ghana, upcycling has been practised within traditional textile crafts for centuries, with artisans repurposing used fabrics and materials into various products (Quartey & Abor, 2011). However, upcycling has gained increased attention in recent years as a sustainable approach to textile waste management and a means of promoting environmental awareness and creativity (Gbireh et al., 2021). One notable example of upcycling in Ghana is the work of the "Trashy Bags" initiative, which transforms waste materials, including plastic and textile waste, into fashionable and durable bags. This initiative not only diverts waste from landfills but also provides employment opportunities for local communities and promotes sustainable consumption practices (Gbireh et al., 2021).

Another successful upcycling project in Ghana is the "Buruden" initiative, which collaborates with local tailors and artisans to create unique clothing and accessories from discarded textiles (Buruden, n.d.). By repurposing materials that would otherwise be discarded, Buruden reduces textile waste, celebrates traditional Ghanaian craftsmanship, and promotes local cultural heritage (Quartey & Abor, 2011). Despite the growing interest and success of upcycling initiatives in Ghana, several challenges remain. One significant challenge is the limited availability of raw materials, as the collection and sorting of textile waste are often inadequate (Gbireh et al., 2021). Additionally, there is a need for more skilled artisans and designers who can effectively transform discarded textiles into desirable and marketable products (Antwi et al., 2018). The market demand for upcycled products in Ghana is still relatively low, as consumers may perceive these products as inferior or less desirable than new, mass-produced items (Quartey & Abor, 2011). Overcoming this perception and raising awareness about the environmental and social benefits of upcycling is crucial for the long-term success of these initiatives (Gbireh et al., 2021).

3. Methodology

3.1. Research Design

This study employed a qualitative research design, utilizing a comprehensive literature review and case study analysis to explore innovative approaches in textile recycling and upcycling. The qualitative approach was deemed appropriate for gaining an in-depth understanding of the phenomenon and capturing the nuances and complexities involved in implementing sustainable practices within the textile industry (Braun & Clarke, 2006).

3.2. Data Collection

The primary data collection method involved an extensive review of relevant literature, including academic journals, industry reports, government publications, and online resources. The literature search focused on key themes such as textile recycling, upcycling, environmental sustainability, circular economy, and innovative materials and technologies. Furthermore, case studies of successful textile recycling and upcycling initiatives in Ghana were analyzed to gain insights into the practical implementation and challenges faced in the local context.

3.3. Data Analysis

The collected data from the literature review and case studies were analyzed using thematic analysis, a widely employed method in qualitative research (Braun & Clarke, 2006). This approach involved identifying, analyzing, and reporting patterns or themes within the data. The thematic analysis allowed for the identification and exploration of patterns and themes related to innovative approaches in textile recycling and upcycling, their environmental impact, and their potential implementation in Ghana.

4. Innovative Approaches

4.1. Advanced Materials

The exploration of advanced materials derived from sustainable and bio-based sources has gained significant momentum in Ghana's textile industry, driven by the need to mitigate the environmental impact of conventional textile production practices. These innovative materials offer promising solutions for reducing resource consumption, minimizing waste generation, and promoting a circular economy within the sector.

4.1.1. Biopolymers and Biocomposites

Ghana's abundant agricultural resources have prompted research efforts into developing biopolymers and biocomposites for textile applications. Researchers at the Kwame Nkrumah University of Science and Technology (KNUST) have explored the potential of converting cassava waste into polyhydroxyalkanoates (PHAs), a biodegradable biopolymer (Asamoah et al., 2022). This approach valorizes agricultural waste and presents an opportunity to produce sustainable textile fibres and materials from locally available resources. Similarly, biocomposites, which combine biopolymers with natural fibres, have been investigated in Ghana. A study by Boakye et al. (2021) examined the development of biocomposite fabrics using polylactic acid (PLA) and locally sourced kenaf fibers. The researchers found that these biocomposite fabrics exhibited promising mechanical properties and biodegradability, making them suitable for various textile applications while reducing the environmental impact associated with synthetic fibers.

4.1.2. Cellulosic Fibers

Ghana's rich biodiversity and agricultural sector offer abundant sources of cellulosic fibres, which can serve as sustainable alternatives to conventional textile fibres. The Kwadwo Amponsah Institute of Biotechnology (KAIB) at KNUST has focused on developing textile fibres from pineapple leaf waste, a byproduct of Ghana's pineapple industry (KNUST, 2020). This initiative creates value from agricultural waste and reduces the environmental impact of conventional fibre production by utilizing renewable and biodegradable resources. Another promising source of cellulosic fibres in Ghana is bamboo. The Bamboo and Rattan Development Programme (BARADEP) has aimed to promote the use of bamboo for various applications, including textile production (BARADEP, n.d.). Bamboo is a rapidly renewable resource that requires minimal water and pesticide inputs during cultivation, making it an environmentally friendly alternative to conventional fibres.

4.1.3. Recycled and Regenerated Fibers

Ghana has also taken strides in exploring recycled and regenerated fibers to promote circularity and sustainability in the textile industry. The Trash to Textile (T2T) initiative, supported by the United Nations Industrial Development Organization (UNIDO), has established a textile recycling facility in Ghana that utilizes mechanical recycling processes to convert textile waste into new fibers and yarn (UNIDO, 2019). These recycled fibers can then be used to produce various textile products, reducing the need for virgin materials and diverting waste from landfills.

The TEXCYCLER project, a collaboration between researchers from the UK and Ghana, aims to develop and implement chemical recycling technologies for textile waste in Ghana (University of Cambridge, 2021). By employing chemical recycling methods, the project aims to produce high-quality regenerated fibers that can be used in the production of new textiles, contributing to a more circular and sustainable textile industry in the country.

4.1.4. Challenges and Considerations

While exploring advanced materials offers promising solutions for environmental sustainability in Ghana's textile industry, several challenges must be addressed. One significant challenge is the availability and scalability of biomass feedstocks for biopolymer and biocomposite production. Ensuring a consistent and reliable supply of raw materials, such as agricultural waste, remains a concern (Sanjay et al., 2019). Additionally, establishing efficient and cost-effective production processes for these materials is crucial for their widespread adoption. For cellulosic fibers, challenges may arise in terms of processing and spinning technologies, as well as the development of suitable dyeing and finishing techniques (Bicu & Mustata, 2019).

Capacity-building and knowledge transfer initiatives are essential to equip local textile manufacturers with the necessary skills and expertise to work with these novel fiber sources. The implementation of recycling and regeneration technologies for textile fibers also faces hurdles in Ghana. Efficient collection and sorting systems for textile waste are crucial to ensure a consistent supply of high-quality feedstock for recycling processes (Sandin et al., 2019). Additionally, investments in infrastructure and technical expertise are required to establish and scale up recycling facilities. Collaboration between stakeholders, including researchers, industry players, policymakers, and non-governmental organizations (NGOs), is crucial for overcoming these challenges. By fostering partnerships and knowledge-sharing networks, Ghana can leverage its local resources and expertise to develop and implement innovative textile materials that contribute to environmental sustainability while supporting economic growth and job creation.

4.2. Technological Solutions

Technological advancements have played a pivotal role in revolutionizing textile recycling and upcycling practices, offering innovative solutions to address the environmental challenges that Ghana's textile industry poses. These cutting-edge technologies have the potential to enhance resource efficiency, reduce waste generation, and promote a circular economy within the sector. One notable technological solution for textile recycling in Ghana is the implementation of mechanical recycling processes. The Trash to Textile (T2T) initiative, supported by the United Nations Industrial Development Organization (UNIDO), has established a textile recycling facility in Ghana that utilizes mechanical recycling techniques (UNIDO, 2019). This facility employs processes such as shredding, carding, and spinning to convert textile waste into new fibers and yarn, which can then be used in the production of various textile products.

Another promising technology being explored in Ghana is chemical recycling. The TEXCYCLER project, a collaboration between researchers from the UK and Ghana, aims to develop and implement chemical recycling technologies for textile waste (University of Cambridge, 2021). These technologies involve breaking down textile materials into their molecular components through chemical processes, enabling the recovery of pure fibers or monomers that can be used to produce new textiles or other products. Recycling technologies and innovative sorting and identification systems are crucial for optimizing the textile recycling process. Advanced optical sorting systems employing near-infrared (NIR) spectroscopy and computer vision techniques can efficiently sort and identify different fiber types and contaminants in textile waste streams (Yousef et al., 2019). This not only improves the quality of recycled materials but also enhances the recycling process's overall efficiency and economic viability.

4.3. Circular Design

Incorporating circular design principles into textile manufacturing is crucial to achieving a sustainable and circular textile industry in Ghana. Circular design encompasses strategies and approaches that consider the entire life cycle of textile products, from material sourcing to end-of-life management, to minimize waste and promote resource efficiency. One key aspect of circular design is the use of modular and disassembly-friendly construction techniques in textile products. By designing garments and textiles with easily detachable components, such as zippers, buttons, or fasteners, the process of disassembly and material separation for recycling or upcycling becomes more efficient and cost-effective (Kaldor & Watson, 2020). This approach facilitates material recovery and reduces the likelihood of valuable components being lost or contaminated during the recycling process.

Another important consideration in circular design is the selection of materials that can be easily recycled or biodegraded at the end of their useful life. The use of mono-material products or materials that can be easily separated into their constituent parts can significantly enhance the recyclability of textile products (Neugebauer et al., 2021). Additionally, the incorporation of bio-based and biodegradable materials, such as those discussed in Section 4.1, aligns with circular design principles by minimizing the environmental impact of textile waste. Collaborative approaches involving designers, manufacturers, and recyclers are essential for the successful implementation of circular design principles in Ghana's textile industry. Co-design methodologies, where all stakeholders collaborate from the early stages of product development, can ensure that circular principles are integrated throughout the product's lifecycle (Jagtap & Rahimifard, 2019). This collaborative approach fosters knowledge-sharing, facilitates the adoption of best practices, and promotes a shared responsibility for environmental sustainability.

5. Environmental Impact Assessment

Evaluating the environmental impact and sustainability of innovative textile recycling and upcycling approaches is crucial for ensuring their effective implementation and long-term viability in Ghana. This section explores two key methods for assessing these approaches' environmental and sustainability implications: life cycle analysis (LCA) and sustainability metrics.

5.1. Life Cycle Analysis

Life cycle analysis (LCA) is a widely recognized and comprehensive methodology for evaluating the environmental impact of a product, process, or service throughout its entire life cycle, from raw material extraction to end-of-life disposal or recycling (Sandin & Peters, 2018). In Ghana's textile recycling and upcycling context, LCA can provide valuable insights into the potential environmental benefits and trade-offs associated with these innovative approaches. One notable example of LCA application in Ghana's textile industry is the study conducted by Yamoah et al. (2022). The researchers performed a comparative LCA of different textile waste management scenarios, including landfilling, incineration, mechanical recycling, and chemical recycling. The study quantified the environmental impacts across various categories, such as global warming potential, acidification, eutrophication, and resource depletion. The results indicated that mechanical and chemical recycling approaches had significantly lower environmental impacts compared to landfilling and incineration, highlighting the potential benefits of adopting these innovative recycling methods in Ghana.

Another study by Quartey et al. (2021) employed LCA to evaluate the environmental impact of upcycling initiatives in Ghana's textile industry. The researchers analyzed the life cycle stages of upcycled textile products, including material sourcing, production processes, and end-of-life management. The LCA results demonstrated that upcycling initiatives had a lower environmental footprint compared to conventional textile production methods, primarily due to the reduced consumption of virgin materials and the diversion of waste from landfills. When conducting LCA for innovative textile recycling and upcycling approaches in Ghana, it is essential to consider the local context and data availability. Factors such as the energy mix used in production processes, transportation distances, and waste management infrastructure can significantly influence the environmental impact assessment (Yousef et al., 2019). Collaboration with local stakeholders, including industry representatives and regulatory bodies, can facilitate the collection of accurate and context-specific data, enhancing the reliability and relevance of LCA results.

5.2. Sustainability Metrics

While LCA provides a comprehensive assessment of environmental impacts, sustainability metrics evaluate the economic, social, and environmental dimensions of innovative textile recycling and upcycling approaches. These metrics provide a broader perspective on the long-term viability and potential trade-offs associated with these approaches beyond their environmental implications. In Ghana's textile industry, several sustainability metrics can be employed to assess the sustainability of innovative recycling and upcycling initiatives. The United Nations Sustainable Development Goals (SDGs) provide a valuable framework for measuring progress towards sustainability across various dimensions (United Nations, 2015). For instance, the implementation of textile recycling and upcycling approaches can contribute to SDG 12 (Responsible Consumption and Production) by promoting resource efficiency, waste reduction, and sustainable management of materials (Ganda & Ngwira, 2020). Additionally, these approaches align with SDG 9 (Industry, Innovation, and Infrastructure) by fostering sustainable industrialization and encouraging innovation and technological development in the textile sector.

Economic sustainability metrics, such as job creation, income generation, and the development of new business opportunities, can also be employed to evaluate the viability and impact of innovative textile recycling and upcycling initiatives in Ghana. Studies have shown that these approaches can create employment opportunities, particularly in rural and underserved communities, while promoting economic growth and diversification (UNIDO, 2019). Social sustainability metrics, including promoting cultural heritage, empowering marginalized groups, and improving working conditions, are equally important considerations. Several textile upcycling initiatives in Ghana have aimed to preserve traditional craftsmanship and cultural practices while providing income-generating opportunities for local artisans and communities (Buruden, n.d.; Trashy Bags, n.d.).

The assessment of environmental sustainability metrics, such as greenhouse gas emissions reductions, resource conservation, and waste diversion rates, can complement the findings of LCA studies and provide a more comprehensive understanding of the environmental benefits of these innovative approaches. Collaboration among stakeholders, including researchers, industry representatives, policymakers, and non-governmental organizations (NGOs), is essential to effectively measure and monitor sustainability metrics in Ghana's textile industry. Establishing standardized data collection methods, benchmarks, and reporting frameworks can facilitate the consistent tracking and comparison of sustainability performance across various initiatives and regions.

6. Discussion

The exploration of innovative approaches in textile recycling and upcycling has unveiled diverse solutions that hold significant potential for promoting environmental sustainability and a circular economy within Ghana's textile industry. However, it is crucial to critically evaluate the feasibility and impact of these approaches, considering the unique challenges and opportunities presented by the local context.

6.1. Comparison of Different Innovative Approaches

Advanced materials, such as biopolymers, biocomposites, and cellulosic fibers, offer promising alternatives to conventional textile materials derived from non-renewable sources. These materials reduce the environmental impact associated with resource extraction and align with the principles of a circular economy by promoting biodegradability and recyclability. However, the widespread adoption of these materials in Ghana's textile industry may face challenges related to the availability and scalability of biomass feedstocks and the need for specialized processing techniques and infrastructure. Technological solutions, including mechanical and chemical recycling processes, sorting and identification systems, and the integration of digital technologies like the Internet of Things (IoT) and blockchain, present innovative

approaches to address textile waste management challenges. While mechanical recycling facilities have already been established in Ghana, the implementation of chemical recycling technologies and advanced sorting systems may require significant investments in infrastructure and capacity-building.

Circular design principles, such as modular and disassembly-friendly construction, the use of recyclable or biodegradable materials, and collaborative co-design approaches, offer a holistic strategy for integrating sustainability considerations throughout the entire product lifecycle. These principles hold the potential to facilitate material recovery, reduce waste generation, and foster collaboration among stakeholders. However, their successful implementation may necessitate changes in design practices, manufacturing processes, and consumer perceptions. When evaluating the feasibility of these innovative approaches, it is essential to consider factors such as economic viability, technical expertise, consumer acceptance, and policy support. Approaches that align with Ghana's existing resources, traditional practices, and socio-economic conditions may have a higher likelihood of successful implementation and long-term sustainability.

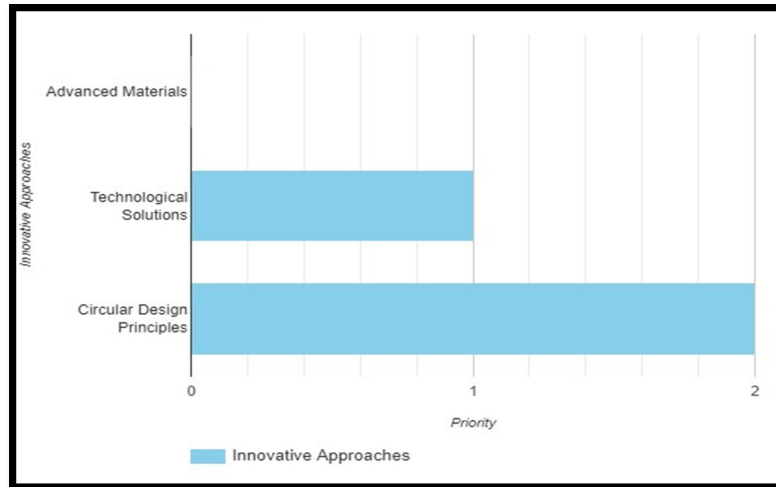


Figure 1: Comparison of Different Innovative Approaches

6.2. Implications for the Textile Industry, Consumers and Policymakers

The adoption of innovative textile recycling and upcycling approaches has far-reaching implications for various stakeholders within Ghana's textile industry and beyond. For textile manufacturers and brands, embracing these approaches presents opportunities for cost savings, resource efficiency, and competitive advantage in the market. By incorporating recycled or sustainable materials, implementing circular design principles, and adopting advanced technologies, companies can enhance their environmental performance, reduce waste disposal costs, and appeal to eco-conscious consumers. Consumers play a crucial role in driving the demand for sustainable textile products and influencing industry practices. Raising awareness about the environmental impact of the textile industry and the benefits of recycling and upcycling can shape consumer preferences and encourage responsible consumption patterns. Additionally, transparent communication about the sustainability credentials of textile products can foster trust and loyalty among environmentally conscious consumers.

Policymakers and regulatory bodies are responsible for creating an enabling environment that supports and incentivizes the adoption of innovative textile recycling and upcycling approaches. This may involve developing policies that promote investment in recycling infrastructure, encourage the use of sustainable materials, and establish standards for eco-labeling and product certification. Furthermore, collaboration with industry stakeholders and research institutions can facilitate knowledge-sharing, capacity-building, and the development of context-specific solutions. Ultimately, successfully implementing innovative textile recycling and upcycling approaches in Ghana requires a collaborative effort among all stakeholders, including manufacturers, consumers, policymakers, researchers, and civil society organizations. By fostering partnerships, knowledge exchange, and a shared commitment to environmental sustainability, Ghana can pave the way towards a circular and sustainable textile industry that balances economic growth with environmental protection and social responsibility.

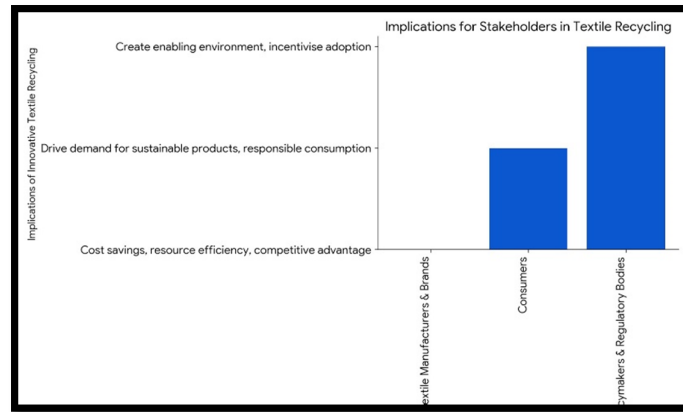


Figure 2: Implications for the Textile Industry, Consumers and Policymakers

7. Conclusion

The textile industry's environmental impact has been a long-standing concern, prompting the need for innovative solutions that promote sustainability and align with circular economy principles. This research has comprehensively explored cutting-edge textile recycling and upcycling approaches, focusing on their application and implications in the Ghanaian context. The key findings of this study highlight the potential of advanced materials, technological solutions, and circular design principles to revolutionize textile recycling and upcycling practices. The exploration of sustainable and bio-based materials, such as biopolymers, biocomposites, and cellulosic fibers, offers viable alternatives to conventional textile materials, reducing resource consumption and promoting biodegradability.

Furthermore, the implementation of technological solutions, including mechanical and chemical recycling processes, advanced sorting and identification systems, and the integration of digital technologies like the Internet of Things (IoT) and blockchain, has the potential to enhance resource efficiency, facilitate material recovery, and promote transparency and traceability within the textile value chain. Incorporating circular design principles, such as modular and disassembly-friendly construction, using recyclable or biodegradable materials, and collaborative co-design approaches, can facilitate material recovery, reduce waste generation, and foster collaboration among stakeholders throughout the product lifecycle.

The environmental impact assessment, conducted through life cycle analysis (LCA) and sustainability metrics, has demonstrated the potential of these innovative approaches to mitigate the environmental footprint of the textile industry while also contributing to economic and social sustainability goals. However, successfully implementing these approaches in Ghana requires addressing various challenges, such as the availability and scalability of biomass feedstocks, the need for specialized processing techniques and infrastructure, and the potential barriers related to consumer acceptance and market demand. Based on the findings of this research, the following recommendations are proposed to foster sustainable practices in Ghana's textile industry:

- Encourage collaboration and knowledge-sharing among stakeholders, including researchers, industry players, policymakers, and civil society organizations, to facilitate the development and dissemination of innovative solutions tailored to the local context.
- Invest in capacity-building initiatives and knowledge transfer programs to equip local textile manufacturers and artisans with the necessary skills and expertise to work with advanced materials, technologies, and circular design principles.
- Develop and implement policies that incentivize adopting sustainable practices, such as tax incentives, subsidies, and regulatory frameworks that promote investment in recycling infrastructure, sustainable materials, and eco-labeling standards.
- Foster partnerships between the textile industry and waste management sectors to establish efficient collection and sorting systems for textile waste, ensuring a consistent supply of high-quality feedstock for recycling processes.
- Raise consumer awareness about the environmental impact of the textile industry and the benefits of recycling and upcycling through educational campaigns and transparent communication about the sustainability credentials of textile products.

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