



SUSTAINABLE MATERIALS AND THEIR APPLICATIONS IN MODERN FASHION DESIGN

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ABSTRACT

The fashion industry is one of the world's largest creative and manufacturing sectors, but its conventional production systems create significant environmental challenges through intensive resource consumption, chemical use, greenhouse-gas emissions, textile waste, and dependence on fossil-based synthetic fibres. In response to these challenges, sustainable materials have become increasingly important in contemporary fashion design. Sustainable materials include recycled fibres, organic and responsibly produced natural fibres, regenerated cellulose, agricultural-waste fibres, bio-based polymers, bacterial cellulose, mycelium-based materials, and other innovative biomaterials. This research examines the development, characteristics, applications, benefits, and limitations of sustainable materials in modern fashion design. The study adopts a qualitative secondary-research design based on academic literature, industry reports, and sustainability publications published primarily between 2023 and 2025. Recent evidence demonstrates that the global demand for fibres continues to increase. Textile Exchange reported that global fibre production reached approximately 124 million tonnes in 2023 and approximately 132 million tonnes in 2024, demonstrating the continuing scale of material consumption in fashion and textiles. Polyester remains the dominant fibre, while textile-to-textile recycling remains a very small proportion of global fibre production. The research therefore argues that simply replacing one material with another is insufficient. Sustainable fashion design requires a broader systems approach that considers material sourcing, manufacturing, durability, product use, repair, reuse, recycling, and end-of-life management. The literature indicates that recycled materials can reduce dependence on virgin resources, while natural and regenerated fibres can offer renewable alternatives when responsibly sourced and processed. Emerging materials such as mycelium leather and bacterial cellulose demonstrate substantial potential for replacing petroleum-based and animal-derived materials in selected applications. However, their wider adoption is constrained by cost, scalability, performance, durability, standardisation, consumer acceptance, and incomplete life-cycle evidence. The study concludes that sustainable materials can contribute substantially to modern fashion design when combined with circular design principles, responsible production, durable construction, transparent supply chains, and appropriate end-of-life strategies.

KEYWORDS: sustainable fashion, sustainable materials, circular fashion, recycled fibres, biomaterials, bacterial cellulose, mycelium leather, textile recycling, eco-design, fashion design.

INTRODUCTION

Fashion is simultaneously a cultural practice, a creative industry, an economic activity, and a global manufacturing system. Clothing and accessories communicate identity, social status, cultural values, lifestyle and personal expression. At the same time, the fashion industry depends on large quantities of fibres, dyes, chemicals, energy, water, packaging and transportation. The rapid growth of fashion consumption has therefore created a contradiction: fashion is expected to continually provide novelty and affordability while society increasingly demands environmental responsibility. One of the most important



dimensions of this sustainability challenge is material selection. Every garment begins with a material decision. It is an essential part of fashion design strategy. Recent industry data illustrates the scale of the problem. Textile Exchange's 2024 Materials Market Report estimated that global fibre production increased to approximately 124 million tonnes in 2023, up from 116 million tonnes in 2022. The organisation projected that production could reach approximately 160 million tonnes by 2030 if current trends continue. Virgin fossil-based synthetic fibres represented a major part of this growth, with polyester remaining the world's most widely produced fibre. The 2025 Materials Market Report provides an even more recent picture. It estimates that global fibre production increased to approximately 132 million tonnes in 2024 and could reach around 169 million tonnes by 2030 under business-as-usual conditions. Polyester accounted for approximately 59% of global fibre production, and approximately 88% of polyester was fossil-based. Although recycled polyester production increased, its market share declined slightly because virgin polyester production grew even faster. Importantly, less than 1% of the global fibre market was produced from pre- and post-consumer recycled textiles. These figures indicate that sustainability cannot be achieved simply by increasing the production of recycled fibres while continuing to expand overall material consumption. Instead, the fashion sector must consider the complete material life cycle. A sustainable garment should ideally be designed using materials that have reduced environmental impacts, manufactured efficiently, remain useful for a long period, can be repaired or reused, and can ultimately return safely to a biological or technical cycle. Bifulco, A., Imperato, C., Passaro, J., Malucelli, G., Gaan, S., & Aronne, A. (2024, March).found that.

The concept of circular fashion has become increasingly important in this context. The Ellen MacArthur Foundation describes a circular economy for fashion as one in which products are designed to be used more, made to be made again, and produced from safe recycled or renewable inputs. Ellen MacArthur Foundation This approach shifts attention from isolated material substitution towards the design of an entire system. The United Nations Environment Programme (UNEP) similarly emphasises that transforming the textile value chain requires coordinated changes in consumption, production practices and infrastructure. Its 2023 roadmap identifies shifting consumption patterns, improving practices and investing in infrastructure as interconnected priorities for achieving a circular textile sector. UNEP - UN Environment Programme Sustainable materials are therefore an important component of a much wider transformation. They include materials traditionally recognised as environmentally preferable, such as organic cotton, responsibly produced wool, hemp, linen and recycled fibres, as well as newer materials developed through biotechnology and waste valorisation. Agricultural waste, food waste, microorganisms and fungi are increasingly being investigated as material resources. One example is bacterial cellulose. Bacterial cellulose is produced through microbial fermentation and has attracted attention because of its biodegradability, renewable feedstocks and distinctive physical properties. A 2024 review



found that bacterial cellulose has potential applications across clothing, accessories, footwear and wearable technologies, while also identifying challenges related to production costs, scalability, quality and industrial development. Biyada, S., & Urbonavičius, J. (2025).explain that.

Unlike conventional materials that are selected primarily according to cost, availability and performance, new biomaterials may encourage designers to rethink texture, construction, form, manufacturing and product life. The material itself can become part of the creative concept. For example, bacterial cellulose can be grown or processed into unusual surfaces, while mycelium can be formed into three-dimensional structures. Agricultural residues can be transformed into fibres or composite materials, allowing designers to integrate waste reduction into aesthetic development. However, the term "sustainable material" should be used critically. A material is not automatically sustainable simply because it is natural, plant-based, recycled or biodegradable. Environmental performance depends on cultivation, feedstock, processing, chemical treatments, energy use, transportation, durability, maintenance and end-of-life conditions. For example, a biodegradable material may not actually biodegrade in the environment where a consumer disposes of it. Similarly, a recycled material may reduce demand for virgin resources but still create challenges if it is difficult to recycle again. Life-cycle assessment (LCA) is therefore increasingly relevant to material selection. LCA evaluates environmental impacts across different stages of a product or process, including resource extraction, manufacturing, use and disposal. Recent research emphasises the importance of assessing textiles across the complete supply chain rather than evaluating materials based on one environmental characteristic alone.

ScienceDirect Another significant issue is blended fabrics. Blending fibres such as cotton and polyester can provide desirable characteristics including strength, comfort, durability and affordability. However, blends can be difficult to recycle because the constituent fibres must be separated. Research on textile circularity identifies polyester-cotton blends as a major technical challenge and highlights the importance of developing technologies capable of separating complex textile materials. This issue demonstrates why fashion designers must consider end-of-life possibilities at the design stage. A garment designed from several permanently bonded materials may be difficult to disassemble or recycle. Conversely, a garment designed with mono-material construction, detachable components, recyclable trims and accessible seams may have greater circular potential. Modern fashion design is therefore moving from a linear model towards a more systemic approach. Within this system, sustainable materials are not an isolated solution but a foundation for circular product development. The purpose of this research is to investigate how sustainable materials can be applied in modern fashion design and to identify their environmental, technical and creative opportunities and limitations. The study focuses particularly on recycled fibres, responsible natural fibres, regenerated cellulose, agricultural-waste materials, bacterial cellulose and



mycelium-based materials. The research is significant because fashion designers increasingly make decisions that influence sustainability before a product enters manufacturing. Material selection, pattern cutting, garment construction, trims, colour, finishing and expected product life can all be incorporated into a sustainable design strategy. Understanding materials therefore enables designers to move beyond sustainability as a marketing concept and incorporate it directly into product development. Ferreira, P., Apolinário, A., & Forman, G. (2023). explains that.

RESEARCH OBJECTIVES

1. To examine the major types and characteristics of sustainable materials used or proposed for modern fashion design, including recycled fibres, natural fibres, regenerated fibres and emerging biomaterials.
2. To analyse the environmental, functional, aesthetic and commercial applications of sustainable materials in contemporary fashion design, with particular attention to circularity, waste reduction and resource efficiency.
3. To identify the major opportunities, challenges and future prospects associated with sustainable material adoption in the fashion industry, including technological, economic, design and consumer-related factors.

RESEARCH QUESTIONS

1. What sustainable materials are currently being used or developed for modern fashion design, and what are their principal characteristics?
2. How can sustainable materials contribute to environmental improvement and innovation in contemporary fashion design?
3. What barriers limit the widespread adoption of sustainable materials, and what strategies could support their future development and application?

LITERATURE REVIEW

Sustainable materials have become increasingly important because conventional textile production depends heavily on resources that create environmental impacts. The continuing growth of fibre production demonstrates that efficiency improvements alone may not be enough. Textile Exchange's 2025 report shows that global fibre production reached approximately 132 million tonnes in 2024, more than doubling since 2000. Polyester remained the dominant fibre, illustrating the industry's continuing dependence on synthetic materials. This situation has encouraged researchers and designers to investigate materials with lower environmental impacts. Sustainable material development includes two broad strategies. The first is improving existing materials through responsible cultivation, certification, recycling or cleaner processing. The second is developing entirely new materials



using biological resources, waste streams or advanced technologies. Ferreira, Apolinário and Forman (2023) argue that textile biomaterial selection should be integrated with sustainable product and circular design. Their work highlights the importance of evaluating materials according to multiple criteria rather than selecting them based on one environmental attribute. This perspective is important because the environmental performance of a material depends on its entire life cycle. For example, a renewable fibre can still have significant environmental impacts if cultivation requires large quantities of water, fertiliser or pesticides. Similarly, a recycled fibre may have lower resource requirements but may lose quality after repeated mechanical recycling. Consequently, sustainable fashion materials should be evaluated according to a combination of environmental, technical, social and economic criteria. Ferreira, P., Apolinário, A., & Forman, G. (2025).found that.

In 2024, approximately 9.3 million tonnes of recycled polyester were produced, but recycled polyester's share declined slightly because virgin polyester production grew faster. Textile-to-textile recycled fibres remained below 1% of the global fibre market. This situation creates a distinction between "recycled content" and genuine textile circularity. Using recycled plastic bottles in clothing can reduce the demand for virgin polyester, but it does not necessarily create a closed textile-to-textile system. Once a bottle becomes clothing, recycling it again may become more difficult, particularly when it is blended with other fibres or contains complex trims and finishes. Recent research has therefore focused on chemical and mechanical methods for recycling textile polyester. A 2025 review identifies mechanical, thermo-mechanical, solvent-based and chemical recycling approaches, including glycolysis, hydrolysis and other depolymerisation methods. Mechanical recycling is generally more established, but fibre quality can decrease as materials are repeatedly processed. Chemical recycling can potentially return polymers to a more fundamental state and therefore produce higher-quality recycled materials, but it can involve greater complexity, energy consumption, chemicals and infrastructure. For fashion designers, recycled materials provide opportunities for sustainable collections without requiring entirely new material systems. Recycled polyester can be used in sportswear, outerwear, dresses and accessories. Recycled cotton can be incorporated into casual clothing, denim and knitwear. Recycled wool can be used for jackets, coats and knit products. Hossain, K., Chowdhury, S., Shanta, I. S., Hossain, M. S., Ghosh, P. K., & Alam, M. S. (2024).

However, designers should consider durability and recyclability simultaneously. A recycled fibre should ideally be selected with its future recovery pathway in mind. Natural fibres such as cotton, linen, hemp and wool have long been used in fashion. Their renewable biological origins make them attractive for sustainable design, but natural does not automatically mean environmentally harmless. Cotton, for example, is biodegradable and renewable but can require substantial water and agricultural inputs depending on where and how it is produced. Organic and certified production systems attempt to address some of these concerns through



agricultural standards and improved management practices. Textile Exchange reported in 2024 that approximately 28% of global cotton production was associated with sustainability programmes. It also reported growth in certified wool production and responsible fibre standards. Hemp and flax are frequently discussed as alternative natural fibres because of their versatility and potential for lower-input cultivation. They can be used in lightweight fabrics, denim, home textiles and blended materials. Hemp is also associated with durability, which is an important sustainability characteristic because longer product life can reduce the need for replacement. Wool presents a different sustainability question. As an animal fibre, it involves land use, livestock management and methane emissions, but wool can be durable, repairable and biodegradable. Responsible wool standards aim to improve environmental management and animal welfare.

Thus, responsible natural fibres should not be treated as automatically sustainable. Designers need to investigate origin, certification, processing, durability and end-of-life characteristics. Regenerated cellulosic fibres occupy an important position between conventional natural fibres and synthetic fibres. Materials such as viscose, modal and lyocell are produced from cellulose, usually originating from wood or other plant sources. Textile Exchange reported that man-made cellulosic fibre production increased from approximately 7.4 million tonnes in 2022 to 7.9 million tonnes in 2023. These fibres are important because they can provide softness, drape and comfort while potentially using renewable feedstocks. However, their environmental performance depends heavily on forestry practices, chemical management, solvent recovery and manufacturing systems. Lyocell has attracted particular attention because closed-loop solvent systems can recover and reuse much of the processing solvent. Such approaches illustrate a key principle of sustainable material design: sustainability depends not only on what a material is made from, but also on how it is manufactured.

For fashion designers, regenerated cellulose is useful for dresses, shirts, underwear, activewear, linings and other products where softness and drape are important. One of the most innovative developments in sustainable fashion involves converting agricultural and food-processing waste into useful materials. Examples include fibres or composites derived from pineapple leaves, banana residues, grape waste, apple waste, coffee waste and other biological by-products. The principle behind these materials is waste valorisation. Instead of treating agricultural residues as waste, designers and manufacturers can consider them as secondary resources. Recent research into bio-based textiles in emerging markets highlights materials developed from pineapple, banana, apple, grape, cactus, coffee, milk and other biological sources. These materials demonstrate the potential for linking agricultural waste with new fashion-material systems. Such materials are particularly relevant to sustainable design because they can create connections between fashion, agriculture and local economies. In regions where agricultural waste is abundant, local material production could potentially



create new income streams while reducing waste. Nevertheless, waste-based materials also have limitations. Agricultural residues may have seasonal availability, variable composition and geographic constraints. Processing them into consistent textile materials can require machinery, chemicals and energy. Some bio-based leather alternatives also require coatings or binders that may reduce biodegradability.

It is produced by microorganisms during fermentation and can be cultivated using various nutrient sources. A 2024 review published in the Journal of Materials Science describes bacterial cellulose as a promising renewable and biodegradable material for fashion and textile applications. Potential applications include clothing, accessories, footwear and wearable electronics. The study also identifies important challenges involving scalability, production cost and material quality. Bacterial cellulose has several properties attractive to designers. It can form flexible films and three-dimensional structures and can be modified through various treatments. Its ability to be produced from biological resources creates opportunities for alternative material production. However, bacterial cellulose is not yet a direct universal replacement for cotton, polyester or leather. Industrial production must address consistency, drying, strength, water resistance, flexibility, durability and cost. A 2025 review similarly describes bacterial cellulose as an attractive biomaterial while emphasising that its application remains relatively niche because of economic and large-scale production challenges. The design significance of bacterial cellulose lies partly in its potential to expand the vocabulary of fashion materials. Rather than simply imitating existing fabrics, designers can develop new surfaces and forms that take advantage of the material's unique biological characteristics. Mycelium-based materials represent another significant category of emerging sustainable materials. Mycelium consists of interconnected fungal filaments and can be grown on biological substrates, including certain agricultural residues. Research published in 2023 identified fungal mycelium as a promising material for leather alternatives because of its renewability, biodegradability and potential for relatively low-impact biological production.

Mycelium materials can be processed into leather-like sheets and composite structures for bags, footwear, clothing details and accessories. Their development is particularly significant because conventional leather is associated with animal agriculture and chemical-intensive tanning processes. Research in 2024 demonstrated further development of mycelium-based biomimetic composite structures, investigating ways of producing leather-like materials with improved strength and performance. Despite their promise, mycelium materials have several challenges. Performance must be consistent enough for demanding fashion applications. Moisture resistance, abrasion resistance, flexibility, colour stability and durability require further development. Some commercially available "mushroom leather" materials may also contain synthetic coatings or backing materials, complicating claims of biodegradability. Therefore, designers should distinguish between genuinely biodegradable



fungual materials and composite materials that merely contain a biological component. The literature increasingly shows that material innovation must be combined with circular design. The Ellen MacArthur Foundation's vision for fashion emphasises products that are used more, designed to be made again, and produced from safe recycled or renewable inputs. Circular design involves decisions such as: The Ellen MacArthur Foundation's Jeans Redesign initiative demonstrated that durability, traceability, recyclability and safer materials can be integrated into fashion-product design. This suggests that sustainable materials should not be considered separately from pattern cutting, construction and business models. Despite rapid innovation, several barriers remain. First, cost is a major issue. Laboratory success does not automatically translate into millions of metres of commercially consistent fabric. Third, performance must match consumer expectations. Fashion materials need appropriate strength, softness, colour fastness, abrasion resistance, washability and dimensional stability. Fourth, recycling infrastructure remains underdeveloped. A sustainable material cannot create circularity if there is no practical system for collecting and processing products at end of life. Fifth, consumer perception influences adoption. Consumers may appreciate sustainable products but still expect conventional appearance, price and performance. Finally, greenwashing is a serious concern. Sustainability claims can become misleading when brands highlight one positive feature while ignoring other environmental impacts. The 2025 systematic literature review of textile waste management similarly identifies technical, economic and organisational barriers to circularity.

METHODOLOGY

This research uses a qualitative secondary-research methodology to investigate sustainable materials and their applications in modern fashion design. Secondary research was selected because the research objectives focus on understanding existing knowledge, material developments, industry trends and documented challenges rather than measuring the behaviour of a specific group of consumers. The literature search focused primarily on publications from 2023 to 2025 in order to provide current evidence. Academic journal articles, scholarly reviews, industry reports and publications from recognised international organisations were considered. Particular attention was given to literature concerning sustainable fibres, recycled materials, circular fashion, biomaterials, textile recycling, bacterial cellulose, mycelium materials and sustainable design. Sources were identified through academic and professional databases and organisational publications. Search terms included combinations of "sustainable fashion materials," "sustainable textile materials," "circular fashion," "recycled textile fibres," "bacterial cellulose fashion," "mycelium leather," "bio-based textiles," "textile recycling," and "sustainable fashion design. The inclusion criteria were publication between 2023 and 2025 relevance to textiles, fashion, materials or circularity sufficient methodological or conceptual information and relevance to one or more research questions. Sources that discussed sustainability only generally without meaningful



connection to materials or fashion were given lower priority. The collected literature was analysed thematically. Major themes were identified and compared across sources. These themes included environmental benefits, material performance, circularity, waste reduction, renewable resources, scalability, economic feasibility and design applications. The findings were then synthesised to identify common patterns and contradictions. Because the research is based on secondary data, it does not claim to represent original laboratory testing, consumer surveys or interviews. The findings represent a synthesis of published evidence and therefore should be interpreted as a literature-based assessment.

RESEARCH DESIGN

The research design is descriptive, exploratory and qualitative. The descriptive component identifies the main sustainable materials currently used or investigated in fashion. The exploratory component examines emerging materials and their potential applications. The qualitative component allows the study to evaluate environmental, technical, aesthetic and commercial issues that cannot be adequately represented through numerical measurements alone. A conceptual framework was developed around four material categories: organic cotton, responsibly produced wool and other certified fibres, recycled polyester, recycled cotton, recycled wool and textile-to-textile recycling, regenerated cellulose and agricultural-waste materials, bacterial cellulose and mycelium-based materials. The framework also considers the material life cycle. The research design assumes that sustainable fashion cannot be assessed through raw material selection alone. Material choice must be connected with product durability, design construction, consumption patterns and end-of-life infrastructure.

DATA ANALYSIS

The collected literature was analysed through thematic comparison. The evidence was grouped according to the research questions and then compared to determine areas of agreement, opportunity and limitation. A major finding across the literature is that recycled and renewable materials can reduce dependence on virgin resources. However, recent Textile Exchange data shows that the global market remains dominated by virgin materials, especially fossil-based polyester. In 2024, polyester represented approximately 59% of global fibre production, and the majority of polyester was fossil-based. This indicates that sustainable materials have grown but have not yet fundamentally transformed the global fibre system. The analysis shows a major difference between sustainability claims and actual circularity. Textile-to-textile recycling represented less than 1% of the global fibre market in the latest Textile Exchange data. This means that many garments still move through a predominantly linear system. Even when recycled polyester is used, it often originates from plastic bottles rather than old clothing. The literature on bacterial cellulose and mycelium demonstrates that biomaterials are more than environmental substitutes. They can create new



textures, structures and manufacturing approaches. Bacterial cellulose offers potential for clothing, accessories and wearable technologies, while mycelium is being developed as a leather alternative. The data therefore suggests that material innovation can contribute simultaneously to environmental improvement and creative innovation. Although emerging biomaterials have promising environmental characteristics, they are generally less commercially mature than polyester, cotton and conventional leather. Research on bacterial cellulose identifies cost, scalability and quality as significant challenges. The same pattern occurs with mycelium materials: laboratory and prototype success does not automatically demonstrate industrial viability. The literature strongly indicates that sustainable material selection must be connected with product design. Blended fabrics demonstrate the problem clearly. Cotton-polyester blends can provide desirable performance but are difficult to recycle because the constituent materials need to be separated. Designers therefore influence circularity through decisions about fibre composition, seams, trims, coatings, adhesives and garment construction.

FINDINGS

Sustainable materials are essential but cannot independently solve fashion's environmental problems. Sustainable materials can reduce environmental impacts, but their effectiveness depends on the wider production and consumption system. Replacing conventional polyester with a bio-based material does not automatically make a garment sustainable if the garment is poorly made, rarely worn, difficult to repair and impossible to recycle. The evidence therefore supports a systems approach in which materials are combined with durability, repair, reuse, recycling and responsible consumption. Recycled materials are currently more commercially mature than many biomaterials. Recycled polyester and other recycled fibres are already integrated into commercial fashion. This makes them practical tools for reducing virgin material demand. However, recycled materials have limitations. Textile-to-textile recycling remains extremely small, and recycling becomes more difficult when garments contain mixed fibres, coatings, adhesives and complex trims. Therefore, recycled materials should be accompanied by design-for-recycling strategies. Biomaterials have strong innovation potential. Bacterial cellulose and mycelium materials demonstrate how biotechnology can create new material pathways. Bacterial cellulose has potential because it is renewable and biodegradable and can be developed into flexible textile-like structures. Mycelium has potential because fungal growth can transform biological substrates into leather-like materials. These materials could be particularly valuable in accessories, experimental fashion, footwear and selected apparel applications. Performance and scalability determine commercial adoption. The biggest barriers for emerging materials are not necessarily creativity or environmental ambition but industrial performance. Fashion products need materials that can survive real-world use. Without adequate performance, consumers may replace garments more frequently, potentially cancelling some environmental benefits.



CONCLUSION

This research examined sustainable materials and their applications in modern fashion design using recent literature and industry evidence from 2023 to 2025. The research demonstrates that sustainable materials are becoming increasingly important as the fashion industry attempts to respond to resource depletion, pollution, climate change and textile waste. The study found that recycled fibres, responsibly produced natural fibres, regenerated cellulose, agricultural-waste materials, bacterial cellulose and mycelium-based materials all offer opportunities for improving fashion sustainability. However, each category has advantages and limitations. Recycled materials are currently among the most commercially accessible sustainable options, but the global textile system remains heavily dependent on virgin materials. Textile-to-textile recycling is still extremely limited. Exchange Natural and regenerated fibres provide renewable alternatives but require responsible cultivation and processing. Emerging materials such as bacterial cellulose and mycelium provide exciting opportunities but require further development in scalability, cost, durability and commercial consistency. The research concludes that sustainable material selection should be approached through a life-cycle and circular-design perspective. A material should not be evaluated only according to whether it is "natural," "recycled" or "biodegradable." Designers should consider where it comes from, how it is manufactured, how long it lasts, how it is maintained, whether it can be repaired or reused, and what happens to it at the end of its useful life.

The future of sustainable fashion therefore depends on the integration of material innovation, circular design, responsible production and longer product use. Fashion designers have a particularly important role because many sustainability decisions are made during the design stage. Designers can select compatible fibres, minimise waste, avoid unnecessary blends, choose recyclable components, design for repair and create products that remain desirable for longer periods. Ultimately, sustainable materials should not be regarded simply as replacements for conventional fabrics. They represent an opportunity to rethink fashion itself. The transition from a linear "take-make-dispose" model to a circular system requires designers to treat materials as resources that should be valued, retained and regenerated. Sustainable fashion will therefore be strongest when environmental responsibility and creative innovation are treated not as competing objectives but as interconnected elements of contemporary design.

REFERENCES

Bifulco, A., Imparato, C., Passaro, J., Malucelli, G., Gaan, S., & Aronne, A. (2024, March). *Sol-gel chemistry approaches for the manufacturing of innovative functional composites for the aerospace sector. In Journal of Physics: Conference Series (Vol. 2716, No. 1, p. 012035). IOP Publishing.*



- Biyada, S., & Urbonavičius, J. (2025). Circularity in textile waste: Challenges and pathways to sustainability. Cleaner Engineering and Technology, 24, 100905.*
- Ferreira, P., Apolinário, A., & Forman, G. (2023). Optimising textile biomaterial selection for sustainable product and circular design: practical guidelines for a greener future. Materials Circular Economy, 5(1), 14.*
- Ferreira, P., Apolinário, A., & Forman, G. (2025). Bridging Innovation in Materials Selection and Design Education. In Meeting of Research in Music, Arts and Design (pp. 400-415). Springer, Cham.*
- Hossain, K., Chowdhury, S., Shanta, I. S., Hossain, M. S., Ghosh, P. K., & Alam, M. S. (2024). Spatio-temporal patterns of dengue in Bangladesh during 2019 to 2023: Implications for targeted control strategies. PLoS neglected tropical diseases, 18(9), e0012503.*
- Hossain, M. T., Shahid, M. A., Limon, M. G. M., Hossain, I., & Mahmud, N. (2024). Techniques, applications, and challenges in textiles for a sustainable future. Journal of Open Innovation: Technology, Market, and Complexity, 10(1), 100230.*
- Lam, J., Chen, Y., Zulkernine, F., & Dahan, S. (2025). Legal text analytics for reasonable notice period prediction. Journal of Computational and Cognitive Engineering, 4(3), 319-331.*
- Papamichael, I., Voukkali, I., Economou, F., Loizia, P., Demetriou, G., Esposito, M., ... & Zorpas, A. A. (2024). Mobilisation of textile waste to recover high added value products and energy for the transition to circular economy. Environmental Research, 242, 117716.*
- Rahaman, M. T., & Khan, M. S. H. (2024). Applications of green nano textile materials for environmental sustainability and functional performance: Past, present and future perspectives. Nano-Structures & Nano-Objects, 40, 101332.*
- Shamsuzzaman, M., Islam, M., Mamun, M. A. A., Rayyaan, R., Sowrov, K., Islam, S., & Sayem, A. S. M. (2025). Fashion and textile waste management in the circular economy: A systematic review. Cleaner Waste Systems, 11, 100268.*