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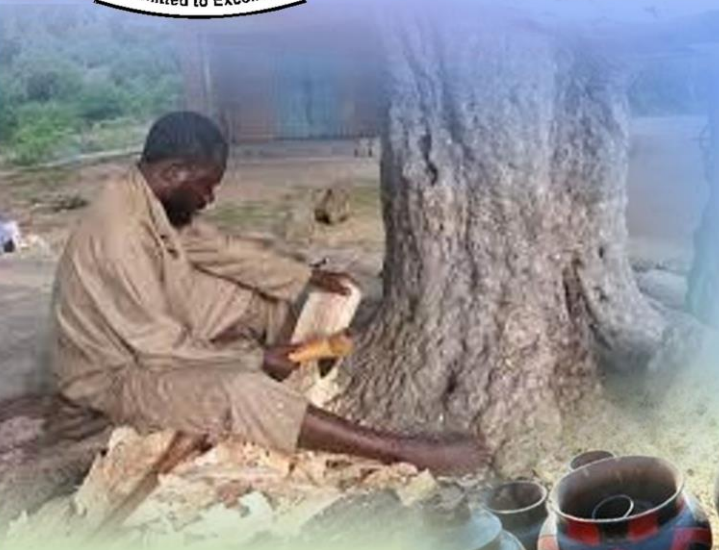

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Fabrics of the Future: Economics, Environment and Equity as Calls for Critical Thinking

EMILY MOTSI[1] AND FLORENCE SEBELE[2]

Abstract

This article explores the general future position of the textile fabric sector on how it can contribute to sustainable production and consumption of fabrics in the coming decades. Using a futures studies perspective, the article examines the drivers, practices and barriers impacting the fabric production and consumption landscape at global and local levels. Findings identified textile innovations as key drivers positively revolutionising the next generation of fabrics though barriers hinder their uptake in emerging economies; practices within the global fabric production industry continue to show a heavy reliance on non-renewable resources and linear economy models that result in the depletion of natural resources and excessive accumulation of fabric waste. The "throw-away" culture and "fast fashion business model" are two drivers fuelling over and wasteful consumption of clothes, with fast fashion negatively contributing to unjust systems of production and consumption.

Keywords: sustainable production and consumption, inclusive circular economy, futures studies, sustainable development.

INTRODUCTION

Textile fabrics have long been a vital part of daily life and society. The largest area of fabric used is apparel which accounts for approximately 60% of the global demand for fibres, with household/interior and technical textiles taking up 20% each of the global demand for fibres (Mackenzie, 2016). Before the introduction of synthetics, the textile industry relied on four bio-based fibres i.e. flax, cotton, silk and wool. Synthetic fabrics were a later innovation developed to overcome some of the

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inherent limitations of natural fibres such as the excessive wrinkling of cotton and linen, shrinkage and irritation of wool. Synthetic materials were valued for their better desirable performance properties such as greater tensile strength, abrasion and wrinkle resistance, colourfastness, as well as lower cost. The discovery of in the 20th century of novel technologies led to the development of fabrics with impressive performance characteristics and functionality, thus providing added value to textile fabrics. This new generation of fabric, which includes 'smart textiles', was developed through a convergence of different disciplines such as polymer science, electronics and computing science. In the 21st century fabric, manufacturers continue to respond to consumer demands for fabrics with enhanced functionality and performance. This has resulted in the development of the next generation of 'smart and e-textiles' for millennials that are functional and responsive.

Despite the remarkable achievements of this earlier generation of fabrics, today there is growing concern over increasing pressure on resources, negative environmental and social impact and climate change effects brought about by the production and consumption of textile fabrics (Steffen *et al.*, 2015; UNEP, 2020). The textile industry is important to economic and social development in emerging and mature economies. The global significance of the industry is seen in its contribution to high employment levels, the generation of foreign exchange revenue and the design of products crucial for human well-being (UNEP, 2020). The textile industry also facilitates access by developing and emerging economies to the global supply chains and export market (ILO, 2019). However, the industry is bedevilled by criticism of being a resource-intensive and inefficient system utilising a linear textile value chain offering limited potential for re-use, re-purposing and recycling of textile materials (UNEP, 2020).

CONCEPTUAL FRAMEWORK

The transitioning of the textile industry to a more sustainable circular economic system has become more desirable as reflected in the discourse regarding prospects of fabric production and consumption. Two concepts, "sustainability" and "circularity" are thus explored to understand their

relationship and significance in addressing the environmental, economic and social challenges of current fabric production and consumption practices.

SUSTAINABILITY IN FABRIC PRODUCTION

The concept of sustainable business provides insights into what can be done in producing fabrics for the future without harming its environment . It is befitting that before we delve into this concept, we conceptualise and contextualise sustainability in the context of the textile industry. For instance, as defined by Fletcher (2009), a sustainable product is produced in such a way that it has the lowest possible adverse effects on the environment by utilising resources such as water and energy most effectively. This definition is further expounded by Hethorn and Ulasewicz (2008), who view sustainability in the context of fashion as the development and use of a thing or process, without harming people or the planet and once put into action, can enhance the well-being of the people who interact with it. In this article, we adopt and adapt Gardetti and Torre's (2012)'s definition of sustainability in producing fabrics for the future as reducing water use and wastage across the supply chain, reduction in chemical pollution and minimising the use of non-renewable sources without any anti-social means. The textile industry is subject to severe ecological problems in most of the phases of the supply chain. Sustainability issues concerning the textile supply chain are related to energy efficiency, water management, waste management and logistics from raw material procurement to textile production until fabric finishing. As per Chen and Burns (2006) assessment, the full environmental impact of any textile product may be broken down into those associated with its production (renewability of raw materials and chemicals released during production and processing), maintenance (quality and nature of chemicals used for laundering and dry cleaning) and eventual disposal (products recyclability and biodegradability). This indicates that making the production process sustainable can help to reduce resource consumption, waste generation and other associated costs for textile firms.

Scientific literature in the field of design research claims that designers play an important role in sustainable transitions. To

mediate this transition, the role of the designer has become more diverse as they find themselves filling multiple roles as creators, researchers, facilitators and process managers in the product design process (Atkinson, 2011). According to Ramani *et al.* (2010), product design is one of the most important sectors influencing global sustainability, as almost all the products consumed by people are outputs of the product development process. Charter and Tischner (2001) estimated that the product design and development phase carry approximately 80% or even more of the environmental and social impacts of the product, including the manufacturing, use and disposal phases. As Niinimäki, (2011) observes, decisions made during the design process tend to affect the environmental impact of the product during its whole life cycle. Designers are, therefore, key to sustainable product development through eco-design (Luttropp and Lagerstedt, 2006). Furthermore, Luttropp, (2006) emphasises that environmentally driven demands must enter the early phases of design and be included in the specifications as early design decisions can have a very significant impact on sustainability.

CIRCULARITY IN THE TEXTILE VALUE CHAIN

The circular economy (CE) is applied in diverse fields and is an extensively researched topic that is also widely discussed outside academia. The CE has been presented in literature as a solution to sustainability challenges brought on by the linear economy (Marjamma and Makela, 2022). A systemic shift to a CE is a process receiving a lot of attention in business, manufacturing, agendas of policy-makers as well as the textile industry (Brennam *et al.*, 2015; Kirchherr *et al.*, 2017). The concept of CE has been criticised in literature for having significantly varying definitions with a systematic and comprehensive study by Kirchherr *et al.* (2017) identifying 114 CE definitions. The most prominent definition has been developed by the Ellen MacArthur Foundation describing a circular economy as an 'industrial economy that is restorative and regenerative by intention and design', (2013b:14). This definition focuses on three principles which relate to the elimination of wastage and pollution through reduction (resource use is minimised), re-use (of products and components is maximised) and recycling (raw materials are re-

used); circulation of materials and products in a long-lasting and high-quality way and emphasising the restoration of the natural system while creating conditions for regeneration. Of the three principles, 'reduce by design' is the overall principle upon which circularity is built (UNEP, 2020). Embedded into the early stage of a product's design, 'reduce by design aims at reducing the number of raw materials and hazardous chemicals used during production and use (*ibid.*).

Circularity's underlying objective is that of maintaining the value of materials as they move and keeping them for the longest possible time within the textile value chain (*ibid.*). As UNEP (*ibid.*) explain, this reduces the use of natural resources and the environmental impacts of the economic activity of the textile industry, while enabling improvements in human and ecosystem well-being. To achieve this, three elements are emphasised, closed material cycles (a system of closed loops where raw materials, components or products lose as little value as possible by not having wastage and having every residual stream turned into a new product), use of renewable energy (the circular economy must be fed by renewable energy sources that, just like raw materials, components and products, should last as long as possible) and systems thinking (the system is viewed as a network with several actors where the individual actions of one have short-term or long-term consequences on others (Ellen MacArthur Foundation 2015a; Korhonen *et al.*, 2018).

A circular economy challenges innovative solutions that result in the generation of new insights and interdisciplinary cooperation between designers, producers and recyclers (Kraaijenhagen *et al.* 2016). The production of new innovative fibres is essential in the new circular textile economy, particularly those fibres that can be used for longer or re-used or those that do not shed microplastics (PACE, 2020). Replacing fossil-based synthetics with biosynthetic and using biofabrication to produce natural biofabrics, has the potential to limit global warming. Biosynthetic are made from a variety of biomass feedstock with the most common source being high-sugar or starch-containing crops such as corn, sugar beets and sugar cane. The extraction of sugars from lignocellulosic plants

(e.g. timbers and elephant grass) is currently being explored as future feedstock for biosynthetic. Concerns have, however, been raised over the use of food crops for biosynthetic and how this may impact food security (Textile Exchange, 2022). Biofabrication technologies are evolving and extending into applications in textile fabrics where living organisms such as yeast or bacteria are used to produce natural-based biofabrics. For example, a yeast cell may be used to produce silk protein (fabricated silk) or a bacterial cell might be used to produce biofabricated cellulose (Biofabricate-Fashion for Good, 2020). Examples of successful innovations utilising secondary material for the production of plastic-based fibres include NuCyl Envrn, a fibre made from discarded clothing and Repreve Unifi, a high-performance fibre made from plastic bottles (https//www.evrnu.com/nucyl; https//www.repreve.com).

To accelerate the transition to a circular economy in the textile industry, several action points have been suggested in the literature. For example, UNEP (2020) calls for a life-cycle thinking approach that enables the identification of strategic intervention points along the textile value chain and the engagement of all stakeholders in the processes in the textile value chain. Schroder (2020) calls for circularity that is socially inclusive and is concerned about the well-being of everyone and is aimed at a just transition that potentially reduces inequalities within and between countries, communities and sectors as they mediate the systemic process to a CE. PACE (2020) proposes several action points, which include supporting and incentivising the design of textile products that last long and have built-in recyclability features, encouraging the sustainable production of virgin natural fibres (e.g. cotton) through the use of regenerative agricultural techniques, making the recycled fibre market competitive so that the practice can be adopted on a significant scale and integrating and advancing decent work in the transition to a circular textile economy.

LITERATURE REVIEW

To envision a future for fabrics an exploration of the current status of fibre and fabric production is necessary to build a case for transformation. This section of the literature review sought to establish the positive and negative features of fibre and fabric

production documented in the literature to determine the trajectory proposed for the future. Two points pursued in detail in the review of current developments in the global textile fabric production landscape are; first, the production of fabrics has been influenced mainly by the linear economic system, globalisation and innovations with consumption of fabrics being accelerated by fashion trends such as 'fast fashion'; secondly, there are widespread economic, environmental and social costs involved in textile fibre and fabric production.

CURRENT DEVELOPMENTS IN THE GLOBAL TEXTILE FABRIC PRODUCTION LANDSCAPE

The current system for producing textile products is made up of five broad areas of activities which encompass fibre production, yarn and fabric production, textile production, consumption (distribution, retail and use) and end-life. The system is usually graphically depicted and described as a linear production and consumption system. It is often labelled as a 'take-make-dispose' model where the focus of operations is on resource extraction, production of goods and disposal of post-consumer waste (Ellen MacArthur, 2017; UNEP, 2020; Mellick *et al.*, 2021). Value in this economic system is created by producing and selling many products as compared to the circular economy where value is created through value preservation. As an economic model, there is growing consensus that its production and consumption practices are unsustainable, leading to environmental destruction and social inequality and causing long-term economic instability (Korhonen et. al, 2018; Millar et. al, 2019). The linear model is considered inefficient in the way it handles raw materials as the value of the material is not fully exploited but is lost after use and does not circulate in the system long enough for it to offer its highest possible value (UNEP, 2020). The model has also been criticised for resulting in high levels of textile waste due to overproduction (Mellick *et al*, 2021).

The current model of production and consumption of textiles fabrics and clothing is greatly influenced by globalisation. Globalisation has brought changes in where and how textile products are manufactured and consumed (ILO, 2019; EPRS, 2020). Textiles and clothing supply chains have gone

international due to the rise of globalisation and the growth of the global economy. This has caused the cultivation of fibres, the manufacturing of textiles and the construction of garments to shift to areas with cheaper labour (Bick *et al.*, 2018). Several countries in Asia have experienced rapid growth in their textile and clothing industries through the offshoring and outsourcing model that emerged with the trade liberalisation system and the end of the textile quota system (ILO, 2019). Inexpensive clothing becomes available to consumers in the global north because prices are kept down by outsourcing production to low and middle-income countries (Bick *et al.*, 2018; EPRS, 2020). Uneven distribution of environmental consequences has resulted due to the globalisation of the textile and fashion system as developing countries (who produce the textiles and clothing) are bearing the burden for the developed countries (who consume them) (Carbon Trust, 2011).

Textile fabric consumption has accelerated due to such global trends as 'fast fashion'. The key features of fast fashion are high production, low cost, trend-led fashion and availability of the latest fashion styles to all classes of consumers (Anguelov, 2015; Remy *et al.*, 2016; Bick *et al.*, 2018; Niinimaki, 2018). Fast fashion has emerged as a leading business model, through which large quantities of inexpensive clothing are sold with their widely available of-the-moment garments changing the way people buy and dispose of clothing (Anguelov, 2015; Remy *et al.*, 2016; Niinimaki, 2018). This has caused garment consumption to skyrocket, resulting in millions of tonnes of textile waste being disposed of in landfills and unregulated settings (Chen *et al.*, 2012). Much of this waste also inevitably ends up in second-hand clothing markets in low and middle-income countries (Bick *et al.*, 2018) As Chae and Hinestroza (2020) point out, growth in consumption dictates the amount of energy used in production, the number of materials in circulation and handling means of materials during usage. In addition, threats to access to safe and decent work are a possibility as workers face pressure to meet production timelines and expected high outputs.

The profound transformation in the global textile sector in the last two decades has been reported in literature (Fashion for

Good, 2020; EURATEX, 2014; Textile Exchange, 2022). This has resulted in the development of a diverse range of fibres and textile fabrics, technologies and an increased number of areas for applications for both conventional and technical textiles. The EURATEX (2014) study notes that this growth and development was spurred by a strong push for collaborative research and innovation activities by research centres, universities, the textile industry and consumers. Impressive performance characteristics have been engineered in modern fabrics to meet the demands of various applications and contexts. These performance gains have, however, come with serious costs to the environment and people as several major drawbacks in fibre and fabric production have been highlighted in the literature (Ellen MacArthur Foundation, 2017; Global Fashion Agenda & Boston Consulting Group, 2017; UNEP, 2020).

Textile production (the process by which natural fibres and synthetic fibres are made) is the first step in the global textile supply chain. Literature generally confirms that the textile production stage and use stage contribute the highest impact for different impact categories i.e. economic, environmental and social (Moazzem *et al.*, 2021). Production of fibres has been identified as having a negative environmental impact due to its intensive use of natural and fossil-derived resources. Cellulose fibres such as cotton use high volumes of fertilizer, pesticides and water during farming (De Felice *et al.*, 2013; Gassert *et al.*, 2013; FAOSTAT, 2016). Production of polyester is heavily reliant on a non-renewable resource such as oil. Impact on land use is another issue raised in the literature, particularly the concerns over the high land footprint, habitat loss and soil degradation emanating mainly from cotton cultivation (UNEP, 2020). The land is a critical resource for the production of food and the concern is that the world's growing population finds itself in competition for arable land and water resources with cotton and wool farming (Ellen MacArthur Foundation, 2017).

Concerns have been documented in literature over how fibre production and fabric wet processing activities (sizing, scouring, bleaching, dyeing and printing) impact negatively the quality of the ecosystem (UNEP, 2020). The high use of toxic agricultural and fabric processing chemicals is reported as posing a

significant threat to environmental quality (Rehman *et al.*, 2022). Toxic effluent generated from fabric wet processing activities is discharged into local rivers and dams, thereby posing a risk to flora and fauna (Shahid and Mohammed, 2013). The impact of the global apparel value chain on the climate is quite substantial with textile production accounting for significant greenhouse gas emissions (IAE, 2016; Das *et al.*, 2021). The burning of coal to generate electricity and heat during fabric treatment and finishing processes lead to the emission of greenhouse gases that have a severe impact on the climate. An evaluation of the climate impact across the global apparel value chain has shown that the energy-intensive wet processing stage involving the dyeing and finishing of fabrics constitutes the highest contribution to climate change (Quantis, 2018; UNEP, 2020).

The textile value chain also has multiple negative social impacts. Key social issues of concern constantly raised in literature are the working conditions, occupational safety and health of workers and infringement of workers' fundamental rights and principles at work (ILO, 2019; UNEP, 2020). Many textile workers face dangerous working environments due to the hazardous chemicals they encounter during fabric production. Most of the chemicals used in fabric processing and finishing are highly toxic and are known to harm health (Niceforo, 2021). Exposure of workers to unsafe workspaces was brought to global attention by the collapse of the Rana Plaza factory in Bangladesh on 24 April 2013 (ILO, 2019). This event, described by the Clean Clothes Campaign as “the worst ever industrial accident to hit the garment industry” raised global attention to the appalling working conditions of many workers in the textiles industry (Clean Clothes Campaign, 2016). However, as noted earlier by Taplin (2014), such disasters have not demonstrably changed safety standards for workers in low- and middle-income countries. Growing concerns over labour rights abuses continue to bedevil the textile industry, particularly in countries with ineffective implementation and enforcement of national labour laws or fundamental principles and rights at work and other international standards (ILO, 2019). Issues regarding long working hours and low pay with some evidence of unacceptable

working conditions such as child labour and modern-day slavery have brought global attention to unsafe and undignified work textile workers are subjected to (SOMO 2014; ILO, 2019).

The economic concerns that are raised in literature are generally linked to the linear economic model. The key economic impact on textile fibre production is that it jeopardises the supply of materials through fluctuations in raw material prices, scarcity of materials, geopolitical dependence on different materials and increased demand (European Commission, 2014; Circle Economy, 2018;). Volatility in raw material prices has been experienced over time, creating risks in the textile supply chain (Koszewska, 2018). The geopolitical interconnectedness of products due to the increase in trade on the international markets has been rising over time. It is now a commonplace phenomenon for the scarcity of one raw material to have a widespread effect on the prices and availability of many more goods (European Commission, 2014). The demand for textile fibre raw materials is likely to increase as the global population increases. The growth in the upper middle class in emerging economies and the expanding demand for quality products are expected to increase the demand for textiles in the future. This growing demand has adverse effects on the environment and people since this is expected to boost the demand for textile chemicals (Ahmed *et al.*, 2022). Because cotton is competing with food crops for limited arable land, the large majority of additional fibre will have to be met by man-made fibres.

THE IMPETUS FOR THE TRANSFORMATION OF FABRIC PRODUCTION (THREATENING FUTURE)

A future that threatens the environment, businesses and people if the current unsustainable practices of producing fabrics continue, is what is envisioned in some of the literature. For example, Ellen MacArthur (2017) cautions that if things continue on this path, the negative environmental impacts such as greenhouse gas emissions and pollution of the world's oceans (through plastic microfibres), could become unmanageable. In addition, the potential risk of business disruption is envisioned when inputs into fibre and fabric production, such as fossil feedstock and water, become difficult

to source due to scarcity. Fabric waste, increasingly accumulating in landfills throughout the world, would also become a serious global challenge to manage. Businesses with branded products that fail to respond to the call to find solutions to the negative environmental and societal impacts run the potential risk of tarnishing the reputation of their brand.

Maintaining current approaches also raises economic risks for the textile/fashion industry as there can be a potential decline in earnings, leading to a reduction in profits and threats to the viability of the industry (Global Fashion Agenda and Boston Consulting Group, 2017). Global trends, such as fast fashion that fuel overconsumption of textile products, need to be controlled and cannot be let to continue at the current pace as it poses a negative impact on the environment, resources and people involved (Moorhouse and Moorhouse, 2017; Chen *et al.*, 2021). The multiple environmental, economic and social concerns raised concerning the linear economic model have fuelled calls by governments, businesses, civil society and other actors for a systemic change as continued use of this model and approaches is viewed as leading to potentially catastrophic consequences in the future (Ellen MacArthur Foundation, 2017).

FUTURE VISIONING (PROBABLE FUTURE) REGARDING PRODUCTION AND CONSUMPTION OF FABRICS IN THE NEW MILLENNIAL AND BEYOND

Recognising the challenges of unsustainable production and consumption practices in a linear economic system, scholars, researchers, business leaders, NGOs, the textile industry and global governments have supported the vision for a transition to a circular economy as a pathway towards sustainability in textile/clothing production. One of the key publications that set the tone for this new vision for the textile industry is the Ellen MacArthur Foundation (2017) report. The report outlines a future in textile production and consumption that is based on the principles of a circular economy. Other significant publications such as the UNEP (2020),) Chen *et al.* (2021) and PACE (2021) also present a similar vision which proposes a move towards the production of sustainable and circular textiles. According to Ellen MacArthur Foundation (2017), the

core vision of a CE is for the development of a textile and clothing system that is restorative and regenerative by design and is beneficial to business, the environment and society). Similar sentiments are expressed by PACE (2020) as they consider circularity as an important pathway to achieving planetary and human well-being as described by the UN Sustainable Development Goals (SDGs).

The aim for fabrics of the future can be condensed into two key processes, the first relates to the development of sustainable fibres and fabrics and, second, getting fibres back into the circular loop. To reach a CE, a shift towards the use of renewable resources and energy sources is essential for textile production inputs/materials (Ellen MacArthur Foundation, 2017; UNEP, 2020). Strategies that are recommended include the use of renewable feedstock or secondary/recycled materials for the production of plastic and bio-based fibres (*ibid.*). Renewable feedstock using bio-based feedstock is gaining traction in a move to find alternatives to traditional materials such as polyester and cotton through the adoption of innovations such as biosynthetic and biofabrication. Biofabricate and Fashion for Good (2020) observe that the increasing demand for fabrics with reduced negative environmental and social impact, along with ethical concerns from consumers, is driving innovations in the search for these sustainable alternatives. As the Textile Exchange (2022) notes, biosynthetic and biofabrication technologies are thus part of a broader sustainability journey towards a regenerative and circular future. Besides renewable resources inputs, renewable energy sources are also vital in the new textile economy. The use of renewable energy sources limits global warming and reduces dependence on fossil fuel energy sources and, this, in turn, creates a resilient system, a key element in sustainability (Ellen MacArthur Foundation, 2017; Textile Exchange, 2022).

In a new circular textile economy, material inputs are expected to be safe and healthy for both workers and consumers to allow them to cycle in the system and avoid impacts during production, use and after use (Ellen MacArthur Foundation, 2017; PACE, 2020). This means substances that cause harm to health and the environment are eliminated. Action required

includes scaling up the use of existing alternative technologies to create safe material cycles and the development of new materials and production processes that prevent the release of microfibres (Ellen MacArthur Foundation, 2017). Innovations are thus being developed to devise alternatives to conventional wet processes through the creation of fabric technologies with minimal adverse impacts on the user and environment (Rahman *et al.*, 2020). Consequently, bio-based processing or green chemistry has created a new approach utilising biotechnological advances in the development of alternative green and biodegradable chemicals usable as wetting, washing and finishing agents (Gulzar *et al.*, 2019).

The use and after-use phase have special consideration in the new circular textile economy as it enables the principle of the closed loop to function where materials circulate in the system and considerations are made for the two cycles of the circular economy, i.e. the biological cycle and the technological cycle. During the use phase, textile products must be kept in use for longer in the cycle through repeated use of clothing items and avoiding premature disposal of clothes. The fast fashion model tends to encourage consumers to view clothing as disposable (Bick *et al.*, 2018). Ways of reducing this wasteful nature cited by the Ellen MacArthur Foundation (2017) and PACE (2020) is through increasing the number of times clothing is worn and discouraging the premature disposal of clothes. This is viewed as the best way to capture value, reduce pressure on resources and decrease negative impacts such as excessive pollution (*ibid.*). In the after-use phase, the textile is expected to be recyclable and recycled at end of use with upcycling being prioritised over downcycling (*bid.*). Two upcycling initiatives currently in use include mechanical recycling where fabrics are deconstructed into fibres that can be used to make new yarn and chemical recycling which uses chemicals to dissolve natural and synthetic fibres and use them as new feedstock (PACE, 2020).

Transitioning to a circular economy for textiles is cited in the literature as having a positive impact on the economy, environment and people (Ellen MacArthur Foundation, 2017; PACE, 2020). Ensuring that textile inputs are safe, recycled or

renewable, may result in lower resource use through shifting from using virgin cotton as well as reducing greenhouse emissions by shifting from high carbon footprint textiles such as cotton and wool to recycled materials (Global Fashion Agenda and Boston Consulting Group, 2017). A healthy environment and biodiversity are the benefits of moving towards the use of safe materials and the elimination of toxic chemicals in textile fibre production and fabric processing. Safe and decent work for workers can be achieved by reducing exposure to toxic substances (Schroder, 2020). Sodjuniu *et al.* (2015) note that switching to renewable inputs through the growing of cotton using regenerative agriculture may lead to more jobs and increased economic independence for women.

Moving to a circular economy in textiles is approached and integrated differently across the globe due to the different contexts countries are operating in. ILO (2019) reiterate that any strategies, actions and policies to advance circularity must consider the realities of each country and be aligned with the priorities of the SDGs. Most research and ideation about the new circular economy models take place in and for developed country contexts (Kirchherr and van Santen, 2019).

METHODOLOGY

To explore the broad topics of sustainable fabric production and consumption, a narrative approach was adopted. Academic writing, studies and reports from global community leaders and business groups (working together to drive the agenda and transitioning to a circular economy in textiles) were examined. Patterns and themes emerging from the literature review were identified, analyzed and reported using contentment analysis. The content analysis was useful in synthesizing the negative environmental, economic and social impact on the current global textile fabric production landscape, the factors driving the thinking around changing how textile fabrics are produced and consumed and future visioning for the production of textile fabrics in the years to come.

RESULTS

The findings synthesized from the narrative review are presented in this section. The findings relate to the following

aspects, similarities and differences between sustainability and circularity, the role of innovation in sustainable fabric production, the negative environmental, economic and social impact of fibre production and fabric processing and the future vision of transitioning the textile industry to the circular economy.

Relationship Between Sustainability and Circularity

There is a close connection between sustainability and circularity even though they are different concepts (Walker *et al.*, 2022). Sustainability is broader and focuses on the three pillars undergirding sustainable development relating to the environment, economy and people while circularity is concerned with maintaining resources in cycles. Circularity is a pathway to achieving sustainability in the textile industry, particularly in addressing the environmental and economic concerns of the textile value chain. However, discussions on circularity tend to focus less on social opportunities and consequences of transitioning. Adoption of a circular economy in textiles is also a pathway to the attainment of SDGs, particularly SDG 6 (clean water), SDG7 (affordable and clean energy, SDG 12 (responsible consumption and production) and SDG15 (life on land).

Negative Environmental, Economic and Social Impact of Fibre Production and Fabric Processing

The current production of fabrics is not sustainable and the problems arising from this expanding industry are threefold: pollution, anti-social and higher prevalence of inequality. The worldwide textile fabric sector results in material depletion, toxic emissions and socio-economic exploitation. The leading environmental snags allied with this industry comprise water body pollution instigated through the absolution of unprocessed emissions. During production, the fabric passes through numerous processes and chemical operations like bleaching, de-sizing, dyeing, printing and other finishing methods desired in quality fabric production. This results in environmental degradation as it is unlikely that the effluent is treated before disposal. The cotton production processes similarly generate air pollution in the course of spinning and weaving. It can then be seen that during fabric production, there is heavy pollution and depletion of non-renewable resources. The social ills of the

textile industry include long working hours and low pay with some evidence of unacceptable working conditions such as child labour and modern-day slavery. The economic concerns against textile fabric production are generally linked to the linear economic model adopted in the textile industry which results in volatility in raw material prices, scarcity of raw materials and increased demand for specific raw materials.

TRANSITIONING TO A CIRCULAR TEXTILE ECONOMY

Transitioning to a circular textile economy is envisioned as the preferable future for textile fabric production because of its several economic and ecological benefits. It is being regarded as a substitute for the linear economy currently prevalent as a textile manufacturing model across the globe. The take-make-dispose mentality of the linear economic model assuming that natural resources are infinite, is being replaced by the reduce-re-use-recycle approach that aims at displacing production and keeping resources in the textile loop for longer. As noted in the literature, moving to a CE is a complex task that takes several years and requires a shift in attitudes and mindsets of manufacturers, businesses and consumers. Most countries in the Global South have large-scale textile industries still basically operating on a linear economic model and require a lot of support in establishing circular economy practices and policies in their manufacturing systems.

DISCUSSION

Notwithstanding that the textile industry contributes immensely to the national economy, it is, on the other hand, considered the most ecologically and socially harmful the world over. The eco-problems in the textile industry occur during fabric production processes and are carried forward right to the finished product. Fabrics produced should have the lowest possible adverse effect on the environment, respect the social elements of fair trade and the human rights of the people involved and be able to compete effectively on the global marketplace against less sustainable products. The present system in the textile and clothing industry is based on fast cycles of fashion trends that aim to continuously produce new consumer needs and products. Product lifecycles are shortening and companies want to substitute their products at an increasing pace. To date, the

fast fashion concept continues to dominate in Europe and the United States and has been introduced over the past decade in emergent economies in the Middle and the Far East.

The textile and apparel supply chain is not optimised to prioritise sustainability. There are multiple barriers embedded within the supply chain which makes it difficult for the industry to adopt more environmentally friendly practices, the first and foremost among them being financial and technological barriers. The cost of raw materials is a massive burden for apparel manufacturers, especially in countries where they have to import raw materials. The high costs combined with problems like inflation make it difficult for them to afford sustainable practices. Here, lack of adequate infrastructure and skill also adds to the problems. In developing countries, most small and medium enterprise (SMEs) (who form a large section of the informal textile industry) do not have access to advanced technology that aids sustainable production. For instance, to convert plastic bottles to fibre for clothes, one needs certain infrastructures to be in place. To reduce the use of non-renewable energy, one must switch to solar or wind power, which again demands infrastructure. The same holds when it comes to processing toxic chemicals. Added to this, is the lack of skilled labour needed to adopt new technologies to local conditions.

The circular economy introduced the body of ideas of thinking in material loops, either biological or technical cycles, including design for a long lifespan, disassembly and/or recycling as well as advocating for use of renewable inputs and energy sources in the textile industry. The CE has been inspiring many textile companies and designers worldwide, promoting clothing collection schemes and accelerating the development of textiles made from recycled materials, produced from both chemical (mainly PET-recycling, e.g. Eco-fi) and natural origin (cotton recycling, e.g. sacellum). Simultaneously, the development of modern technology has been stimulating the textile industry (both researchers and designers) to create technologically advanced and complex systems and products and creation of fabric technologies utilising green chemistry principles. While in the Global North, eco-consciousness has assumed centre stage,

in countries in the Global South, the awareness is still limited. At the same time, the demand for sustainable products is limited at the moment in our domestic markets, while consumers in countries in the Global North are driving demand for sustainably produced textile fabrics and products and are pushing textile fabric manufacturers to adopt environmentally friendly and ethical production practices and policies.

Designers and consumers may be identified as potential actors who can contribute to the transition towards a more sustainable fabric production industry, hence the call for the development of sustainable thinking in the production of fabrics. Much more recently the textile fabric industry is quickly adopting and exploring new technology and materials that are available to create fabrics that are dynamic and support the three Es of sustainability. Whilst in developed countries, there is this keen interest in advanced and smart fabrics, the growing social inequity prevalent in developing countries fails to reap this benefit. What is ideally needed is a radical new approach to defining ethical consumption in the field of fabric production in developing countries so that this market also booms.

CONCLUSION AND RECOMMENDATIONS

The current production of fabrics is not sustainable and the problems arising from this expanding industry are threefold: pollution, anti-social and higher prevalence of inequality. For any product to be considered sustainable, it needs not only to be profitable, but also to take into consideration environmental and social impact during its lifetime. Strategies and actions that effectively contribute toward a more sustainable fabric production industry are those that consider the ecological, social and economic impact of fabric production in a way that will not compromise the needs of future generations. A promising strategy gaining momentum and being prioritised globally is the transition to the circular economy. The CE appears to offer a credible pathway to sustainable production and consumption of textile fabrics now and in the future. It will help create solutions for challenges such as resource depletion or scarcity, pollution and socio-economic exploitation in the

textile sector. Industry, researchers, policy-makers and consumers, have a role to play in promoting sustainable circular production and ethical consumption of fabrics equitably.

A sustainable transition to a circular economy can be accelerated in textile industries using designing distributed production systems in combination with (digital) AM technologies. A distributed production system holds promising results for the development of a sustainable production and consumption system for textile fabric production in the future. The shift from mass production in large factories towards localised small-scale manufacturing might bring positive as well as negative effects. An example of a positive effect is the opportunity for entrepreneurial SMEs to think of new business models that might better serve the customer, whereas a negative effect could be the shift of production back to highly developed countries, reducing employment opportunities in the developing world.

Communication and research are essential components of the CE transition. The unsustainable linear textile industry can be transformed into a sustainable and circular industry providing textile fabric designers with the correct information to promote the implementation of scientific Life Cycle Assessment (LCA) research and results in textile design practice. Therefore, designers (and other stakeholders) must be educated in (i) life cycle thinking, (ii) eco-design, and (iii) LCA. LCA experts/researchers must continue improving the LCA methodology (although the main building blocks are there) and producing up-to-date LCA research and (open) LCI data (of textile products). The remaining LCA issues, which could be a topic of further research are, for example, water use and land use over the textile's lifecycle; toxicity of textile materials (e.g. elastane) and additives over the textile's lifecycle.

The possible execution of the recommendations to textile fabric manufacturing companies and SMEs to transition to sustainable and circular textile production is closely linked to the political environment in which companies (and the designers) operate. It is the institutional landscape, shaped by

policy-makers, which allows the companies to act. Policy-makers at all levels need to develop an independent vision of the future direction of the textile industry and set the rules for sustainable and circular transformation. Moving this discussion to a European and Dutch level, it is observed that the (textile) research community and the textile industry are supported by many funding programmes that include sustainable development in general and, more specifically, innovative textile research focusing on stimulating research based on 'hypes' (such as 'smart textiles', 'the bio-based economy' and 'bio-based materials' and the circular economy). Such support for research and wider uptake of circular economy principles and visions in developing countries, requires partnerships and collaboration with countries in the Global North to ensure equity in the development of sustainable, low-carbon, resource efficient and competitive economy for all.

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