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Bioengineering Textiles at all Scales for a Long-Term Circular Economy

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Introduction

The processes used to make and process textiles give the materials desirable performance properties like stretch and moisture management. However, these processes are also a major cause of global emissions of greenhouse gases, pollution from microplastics, and toxic wastewater. Fortunately, there are green alternatives to the current textile fibers that can help us move toward a sustainable, circular materials economy. At the nano, micro and macroscales, bioengineering of fibers opens up numerous opportunities to enhance the technical performance and impact on the environment of textile materials. From biopolymer components to biofabrication strategies, we discuss recent efforts to bioengineer textiles and fibers. Green manufacturing methods, green chemistry processing of raw materials and genetic engineering of microorganisms for bio fabrication are among these. A discussion of the prospects for sustainable bio textile production in the future is informed by this overview, which focuses on the utilization of waste streams to enhance the processes' circularity and commercial viability. Material bio fabrication will be crucial in facilitating the switch from a linear economy that is harmful to the environment to a cradle-to-cradle circular economy [1].

Description

The central premise of a circular economy is that infinitely reusing our materials can make industrialization compatible with sustainable development and climate stability. It uses ecologically benign processes to close and minimize material and energy loops. Adopting circular economy strategies, such as closed-loop chemical recycling of synthetic polymers to monomers and programmed biodegradation, for instance, can lessen plastic's significant environmental impact. Currently, new polymeric materials are being developed with appropriate mechanical properties that can be easily degraded in the environment, repurposed for new uses, or completely recycled back to monomer. Since the production of both synthetic and natural textiles has a significant impact on the environment and climate, bio-based strategies for designing biodegradable materials with low carbon footprints are becoming increasingly popular in the textile industry. A variety of nonrenewable and nonrecyclable resources as well as petrochemicals are used to create synthetic textile fibers like nylon and elastane. In parallel, non-sustainable industrial agricultural practices are used to produce natural fibers like cotton and degradable polymer fibers like polylactic acid, which is made from ethanol derived from corn [2].

The tanning, dyeing, and finishing agents used to produce the aesthetic and performance properties of textiles create a linear process that is chemical, water, and energy intensive in addition to the production of raw fiber for instance, the current textile industry accounts for 20% of global waste water and 10% of global carbon emissions. Importantly, the production of some synthetic fibres results in the formation of micro plastics, and it is estimated that the textile industry is responsible for 35% of marine micro plastic pollution. Because micro plastics have been shown to disrupt endocrine signaling, accumulate throughout the food web, and have been found in the intestinal tracts of marine mammals, humans, and most recently, human placentas, this micro plastic pollution is especially harmful. Also, environment effects of the direct economy, remembering emotional aggravations or decreases for new water access and biodiversity, lopsidedly influence native networks, minorities, the old, ladies, and youngsters.

Human rights and social justice are severely impacted by these effects, as is access to education, which is essential to global sustainable development. The United Nations' Sustainable Development Goals (SDGs) include access to clean water and sanitation (SDG 6), responsible consumption and production (SDG 12), and climate action (SDG 13) if the textile industry's climate impacts are addressed. The dominant cradle-to-grave linear economy dumps the equivalent of a truckload of clothing every second, leaching toxic dyes, plasticizers, and finishing agents into groundwater and releasing potent greenhouse gases into the atmosphere despite the significant manufacturing impacts of textiles. In contrast, a circular economy integrates industrial production with end-of-life reintegration of materials through complete recycling or natural biodegradation, reduces carbon emissions, and eliminates reliance on fossil feed stocks. Healthy soil is produced as a result of this process, which has the potential to reduce 23.8 Gt of CO_2 equivalents per year worldwide and regulates the climate. Synthetic biology and bio fabrication methods lead to a textile economy that is circular. Biopolymers are made by fermenting or extracting biological building blocks from waste streams, green chemistry processing connects biopolymers to engineered fibers and bio manufacturing produces bio textiles that are biodegradable and perform well. With the extraction of non-renewable resources and the chemical, water, and energy-intensive manufacturing of non-recyclable products that end up in landfills or incinerators, current textile production follows a linear cradle-to-grave economy. As a result, new manufacturing techniques that not only produce high-performance textiles with the necessary strength, ductility, and moisture management but are also biodegradable and non-toxic to the environment's microorganisms are urgently needed. Through custom-designed organisms and bio inspired processes, synthetic biology and bio fabrication have the potential to directly transform industrial byproducts and side streams into high-value materials with numerous applications. Bio-utilization of rapidly renewable biopolymers, like fungal mycelium, can be used to create alternative leathers and fabrics, and genetically modified microbes can produce collagen fibers for leather biofabrication. In addition, numerous biofabrication technologies, such as green electrospinning and 3D printing, in conjunction with microbial fermentation present significant opportunities for biotextiles with a closed-loop life cycle and minimal waste during production. Importantly, it is anticipated that biofabrication processes and biomaterial products will be able to reduce greenhouse gas emissions by 1 to 2.5 billion tons annually by 2030 [3-5].

Conclusion

If bioengineering is used to disrupt conventional textile manufacturing, which currently accounts for 25% of the global carbon budget by 2050, greater climate change offsets may be achieved. Research into more environmentally friendly, bio-based textiles has been sparked by the enormous environmental

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impact of conventional textile manufacturing and the potential to engineer a variety of materials through biofabrication with the potential to accelerate a paradigm shift to a circular materials economy, we present nano, micro and macroscale bioengineering strategies for the sustainable production of textile fibres. These strategies have broad application across sectors, including fashion, biomedical, and industrial applications.

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