***Carbon to Cloth: Sustainable Fabrics from CO2***

Anisha Sailoni

Department of Information Technology

The K.E.T’s V.G. Vaze College of Science, Commerce and Arts (Autonomous)

Mumbai, India.

[asailoni8@gmail.com](mailto:asailoni8@gmail.com)

Shreya Agrawal

Department of Information Technology

The K.E.T’s V.G. Vaze College of Science, Commerce and Arts (Autonomous)

Mumbai, India.

[shreyaagarwal1811@gmail.com](mailto:shreyaagarwal1811@gmail.com)

**Carbon to Cloth: Sustainable Fabrics from CO2**

**Abstract:**

The fashion industry is a major threat to the environment because it uses the most significant amount of greenhouse gases, and resources, and causes waste. In response, CO2-based textiles have emerged as a promising, sustainable alternative that can help reduce both waste and carbon emissions. This paper explores the potential of CO2-based fabrics, focusing on the technologies that turn carbon dioxide into usable materials for clothing. It looks at processes like carbon capture and mineralization, which are making this idea more feasible. Through case studies of companies and projects leading the way, it examines real-world examples of CO2 fabric production. This paper also discusses the environmental and economic impacts of these fabrics, highlighting benefits like lower carbon footprints and the potential for a circular textile economy, as well as challenges such as cost and scalability. Lastly, the paper looks at the future, considering new trends, research, and potential obstacles to large-scale production. In conclusion, CO2-based fabrics have the potential to play a key role in making the fashion industry more sustainable, but realizing this potential will require ongoing innovation, investment, and collaboration across industries.

**Introduction:**

The fashion industry is responsible for about 5% of global carbon emissions, with pollution occurring at every stage of production. The heavy use of Water for cotton farming and environmental damage caused by leather production deforestation and toxic chemicals only make things worse. On top of that, the use of harmful dyes, synthetic fibers, and the carbon footprint of shipping products worldwide all add to the problem. Climate change is also making things harder, with more extreme weather affecting production.[1]

The CO2-based fabrics provide a solution for some of the major environmental challenges in the fashion industry. This technique will reduce the use of water-intensive crops such as cotton because

carbon dioxide can serve as a primary raw material in producing fiber. Further, it decreases the dependency on harmful chemicals in conventional textile manufacturing. In addition, the fabric has a much lower carbon footprint because it takes less energy to manufacture and emits fewer emissions. Such a technique addresses pollution and resource scarcity: it shall pave the path to a more sustainable future. Considering CO2 fabrics, this holds significant potential in the industry as it works to reduce environmental impacts overall in the fashion industry.

This paper examines textiles made from CO2 and assesses their potential as a sustainable alternative to traditional textiles. It gives a detailed view of the technologies that facilitate the conversion of CO2 into usable materials and highlights case studies of leading companies and initiatives in this area. This paper will also discuss the environmental and economic viability of scaling of CO2-based textile production. Additionally, it addresses the challenges of scaling this technology, including issues related to cost and efficiency. By providing a comprehensive overview, this paper aims to clarify the role of CO2-based textiles in promoting sustainability in the fashion industry while exploring future research and development opportunities.

**Literature Review:**

The concept of using CO2 as a raw material in textual production is quite new but has been a highly popular concept in recent years. For several decades, numerous new methods for capturing and utilizing CO2 has been synthesized and converted into commercial values like chemicals that have been directed into the textile industry.

***Carbon Capture and Utilization Technologies:*** CCU technologies emphasize the capture of carbon dioxide limited in an industrial process that converts this emission into a usable product. Direct capture and industrial sources may prove possible mechanisms by which CO2 will be reduced during the production of textiles.

***Electrospinning:*** It is a very versatile technique for which nanofibers of various materials can be achieved, including polymers obtained from CO2. Through electrospinning, certain conditions can be controlled where the fibers obtained will serve a particular requirement which may include higher surface areas, porosity, or tensile strength.

***Bacterial Cellulose:*** Certain bacteria consume CO2 and produce cellulose, which is a natural polymer. This bacterial cellulose may be processed into textile fibers and is therefore a sustainable alternative to traditional cellulose-based fibers like cotton.

***Technologies in CO2 Conversion:*** Lanza Tech has developed a method of converting industrial carbon dioxide emissions emitted through fermentation into ethanol for further processing into polymer yarn. The viability of such an approach is confirmed in partnerships with companies like Zara and Lululemon. [13][14][8]

Biocatalytic processes are used at Rubi Laboratories to produce carbon-negative cellulose-based fibers from carbon dioxide.[13][16][10]

Zara’s “CarbonSmart” collection employs repurposed emissions and demonstrates the scalability of sustainable fashion. Covestro introduced CO2-derived polymers-made dresses, showcasing its ability to be flexible and beautiful.[13]

***Challenges and opportunities:***

Current challenges include high cost, high energy consumption and the need for high industrial development. However, growing interaction between technology leaders and fashion companies suggests great commercial potential.[11][12][16]

**Research Objective:**

The paper looks to assess the potential of CO2-based textiles as an environmentally sustainable alternative within the textile industry. This paper will focus on

1. exploring the key technologies used to transform CO2 into textile fibers, including carbon capture, electrospinning and bacterial cellulose,
2. assessing the environmental and economic implications of these innovations, especially in terms of reducing carbon emissions, conserving water, and avoiding the depletion of natural resources,
3. exploring specific examples, and case studies from companies like LanzaTech, Rubi Laboratories, and Zara to analyze how CO2-based fabrics are being introduced into the market and their potential for scalability, and
4. analyzing the challenges- such as high production costs, energy requirements, and the need for extensive infrastructure- that must be addressed for these technologies to gain wider acceptance. Ultimately, the research aims to provide insights into how CO2-based textiles could make the fashion industry more sustainable and help establish a circular economy with a smaller environmental footprint.

**Research Methodology:**

1. ***Data Collection:***

* Review of academic journals, patents, and case studies on CO2 conversion technologies.
* Analysis of industry collaborations, such as those between LanzaTech, Zara and Lululemon. [13][12]

1. ***Qualitative analysis:***

* Examining interviews, press releases and reports from companies like Covestro and Rubi Laboratories to understand technological advancements and market impact.[14][15]

1. ***Quantitative analysis:***

* Environmental impact assessments comparing CO2-based fabrics with traditional materials.
* Cost-benefit analysis of adopting CO2-based production.

**Recommendations:**

1. ***Invest in Research and Development***: Continued investment in research and development is crucial to advance the technology and overcome challenges.

1. ***Collaborations and Partnerships:*** Fostering collaborations between academia, industry, and government can accelerate the commercialization of CO2-based textiles.
2. ***Policy Support:*** Implementing supportive policies, such as tax incentives and subsidies, can encourage the adoption of sustainable textile production practices.
3. ***Consumer Awareness and Education:*** Raising awareness among consumers about the environmental benefits of CO2-based textiles can drive demand and market growth.

**Conclusion:**

In conclusion, CO2-based textiles are a transformative opportunity for the fashion industry to address environmental challenges while embracing innovation. It uses technologies such as carbon capture, electrospinning, and biocatalytic processes to provide a sustainable alternative that reduces dependence on resource-intensive materials, conserves water and minimizes greenhouse gas emissions. Case studies from pioneers such as LanzaTech, Rubi Laboratories and Zara demonstrate the potential for these innovations to scale, though challenges such as high costs and energy requirements need to be resolved. To unlock the full potential of CO2-based fabrics, sustained efforts in research, collaboration, and policy support are essential, along with increasing consumer awareness. As the fashion industry shifts toward a circular economy, CO2-based textiles could be the key to paving the way for an even more sustainable and responsible future.

**Future Scope:**

The future of CO2-based textiles is highly promising, with advancements in technologies like Direct Air Capture (DAC) making CO2 collection more efficient and cost-effective. These innovations will help reduce the fashion industry’s reliance on raw materials and lower its carbon footprint by recycling emissions into fabrics. Beyond polyester, CO2 can be used to create diverse materials such as biodegradable fabrics and leather alternatives, expanding its application across industries like construction, automotive and packaging. As more brands like Zara and Lululemon adopt these technologies, production is expected to scale up, lowering costs and increasing availability. Governments could further accelerate adoption through subsidies and environmental policies, while consumer education can drive demand for sustainable CO2-based products Additionally, AI-driven production processes could enhance efficiency and scalability, paving the way for CO2-based textiles to become a mainstream solution in a sustainable fashion.

**References:**

1. [https://www.researchgate.net/publication/377806979\_The\_impact\_of\_the\_fashion\_industry\_on\_the\_climate\_and\_ecolog](https://www.researchgate.net/publication/377806979_The_impact_of_the_fashion_industry_on_the_climate_and_ecology)y
2. <https://www.luxurytribune.com/en/turning-co2-into-fashion-the-future-of-materials>
3. <https://social-innovation.hitachi/en/article/carbon-transformation/#:~:text=useful%20to%20society.-,DAC%20and%20CCU%3A%20Capture%20and%20utilization,CO2%20emissions%20to%20near%20zero>.
4. <https://www.removepaywall.com/search?url=https://www.fastcompany.com/90917190/this-startup-just-turned-co2-into-yarn>
5. <https://www.youtube.com/watch?v=dTulpfiwG8Y>
6. <https://www.imnovation-hub.com/science-and-technology/co2-yarns/>
7. <https://www.ctvc.co/rubi-labs-co2-fashion/>
8. <https://covestro.com/press/dress-with-co2/>
9. <https://carbonherald.com/lanzatech-and-lulemon-deliver-the-first-carbon-capture-fabric/>
10. <https://parisgoodfashion.fr/en/news/soon-clothes-made-of-co2-224/>
11. "Turning CO₂ into fashion: The future of materials" - Luxury Tribune
12. "Capture and utilization: Transforming CO₂ into useful products" - Hitachi Social Innovation
13. "Rubi Labs turns CO₂ into yarn" - FastCompany
14. "LanzaTech and Zara deliver CO₂-based fashion" - FashionUnited
15. "Covestro's dress made with CO₂" - Covestro
16. "CO₂ yarns for sustainable fashion" - Innovation Hub
17. "Rubi Laboratories and Walmart collaboration on CO₂-to-fiber technology" - CTVC
18. <https://impactful.ninja/how-sustainable-are-organic-cotton-fabrics/>
19. <https://therepurposinglife.com/homestead/sustainable/guide-to-sustainable-fabrics/>
20. <https://www.trvst.world/sustainable-living/fashion/sustainable-fabric/>