ENVIRONMENTAL CHALLENGES AND SUSTAINABLE APPROACHES IN THE TEXTILE INDUSTRY

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ABSTRACT: *The textile industry is one of the largest environmental polluters, with a significant impact on water consumption and waste generation. This paper analyzes sustainable approaches in the textile industry, with a particular focus on the use of environmentally friendly materials and the introduction of circular economy principles. Additionally, examples of best practices from the industry, modern technological innovations, and international standards that enable the transition to sustainable production and consumption models are presented. It is concluded that sustainability in the textile industry requires a systemic approach involving producers, consumers, and policymakers. For the complete realization of responsible business practices, broader collaboration between the industry, regulators, and consumers is essential in this transformation process. This paper can serve as a guide for companies in the textile sector on how to improve and advance their existing operations towards a responsible and sustainable business model.*

Keywords: *Textile industry, sustainable development, circular economy, ecological materials, ethical standards.*

EKOLOŠKI IZAZOVI I ODRŽIVI PRISTUPI U TEKSTILNOJ INDUSTRIJI

***APSTRACT**: Tekstilna industrija je jedan od najvećih zagađivača životne sredine, sa značajnim uticajem na potrošnju vode i stvaranje otpada. Ovaj rad analizira održive pristupe u tekstilnoj industriji, sa posebnim fokusom na upotrebu ekološki prihvatljivih materijala i uvođenje principa cirkularne ekonomije. Dodatno su predstavljeni primeri dobre prakse iz industrije, savremene tehnološke inovacije i međunarodni etički standardi koji omogućavaju prelazak na održive modele proizvodnje i potrošnje. Zaključuje se da održivost u tekstilnoj industriji zahteva sistemski pristup koji uključuje proizvođače, potrošače i zakonodavce. Za potpunu realizaciju odgovornog poslovanja neophodna je šira saradnja između industrije, regulatora i potrošača u ovom procesu transformacije. Ovaj rad može poslužiti kompanijama u tekstilnom sektoru industrije kao primer kako unaprediti postojeće poslovanje ka odgovornom i održivom načinu poslovanja.*

***Ključne reči:** tekstilna industrija, održivi razvoj, cirkularna ekonomija, ekološki materijali, etički standardi.*

1. INTRODUCTION

The textile industry is one of the largest sectors of the global economy, with a wide-reaching impact on production, trade, and employment. However, this sector is also one of the biggest polluters in the world, responsible for significant natural resource consumption and waste generation. According to United Nations data, the textile industry accounts for about 10% of global carbon dioxide emissions, and it is estimated that approximately 92 million tons of textile waste are discarded annually [1]. In light of these circumstances, the environmental challenges facing this industry are increasing, and the need for sustainable approaches in production and business is critical for reducing its negative impact on the environment.

Sustainable approaches in the textile industry encompass various strategies such as the use of recycled materials, ethically produced fabrics, the implementation of circular business models, and the optimization of production lines to reduce carbon dioxide emissions and water consumption. Additionally, ethical standards and fair trade play a significant role in ensuring fair working conditions and mitigating the ecological and social negative effects [2].

This paper explores the key environmental challenges faced by the textile industry as well as sustainable approaches that can help reduce its negative impact. Furthermore, it analyzes the role of innovation in production technologies and the importance of corporate social responsibility within sustainable business models. Understanding these approaches not only helps identify challenges but also provides concrete solutions that can contribute to the transformation of the industry towards more environmentally friendly and ethical business practices.

2. USE OF RECYCLED MATERIALS AND ETHICALLY PRODUCED FABRICS

One of the main challenges in the textile industry is reducing the consumption of natural resources and minimizing waste. The use of recycled materials is becoming crucial in achieving sustainable production chains [3]. Recycled polyester, for example, can be produced from old plastic bottles or textile waste, significantly reducing the need for new synthetic fibers and contributing to reduced pollution. Similarly, recycled cotton and wool are becoming popular in fabric production, reducing the need for new raw materials, which in turn decreases CO_2 emissions and water consumption.
Alongside the use of recycled materials, ethically produced fabrics, such as organic cotton, are becoming preferred choices. Organic cotton is grown without the use of synthetic pesticides and chemicals [4], thereby reducing the negative impact on the ecosystem. Furthermore, the production of organic cotton often involves respecting workers' rights and using environmentally friendly practices. This approach not only reduces negative ecological effects but also improves the social conditions of agricultural workers.
Use of organic cotton, hemp, recycled fibers, and biodegradable materials such as Mylo™ and Tencel™ is increasingly favored [5]. Avoidance of synthetic fibers derived from fossil fuels, such as polyester, helps reduce microplastic pollution and non-biodegradable waste [1].

3. RECYCLING AND CIRCULAR ECONOMY

The circular economy represents a sustainable business model based on reuse, recycling, and extending the lifespan of products. In the textile industry, this means creating products that can be recycled, refurbished, or reused, reducing the need for constant intake of new raw materials. Such models not only minimize waste but also reduce the overall ecological footprint of the industry.
One example of a circular model is focusing on design that allows products to be easily disassembled into their core components that can be reused. Companies implementing circular approaches often offer repair, recycling, or even product return services from end-users to avoid textile waste from going to landfills. This model, along with consumer education, can contribute to reducing textile waste and promoting sustainability throughout the entire production chain. Reusing textile waste in new products, designing for recyclability and durability, and applying circular economy principles throughout the supply chain help minimize landfill waste and extend product lifecycles [6].

4. SUSTAINABLE PRODUCTION TECHNOLOGIES

Manufacturing processes often involve large amounts of energy, water, and chemicals, and CO_2 emissions and water pollution are serious issues. Innovations in manufacturing techniques, such as using solar panels, energy-efficient machines, and wastewater recycling, can dramatically reduce the industry’s environmental impact.
One significant step is reducing water consumption in the production of cotton and other textile fibers. Innovative approaches, such as water recycling technologies and minimizing the amount needed for washing and dyeing fabrics, can contribute to substantial resource

savings. Additionally, reducing CO_2 emissions can be achieved through the transition to green energy, optimizing transportation chains, and reducing waste by introducing manufacturing techniques that use fewer materials. Some of the innovative approaches that are transforming the sector by reducing chemical use, conserving water, and lowering energy consumption are:

- Microbiological (Enzymatic) treatments – enzymes are used instead of toxic chemicals [7]
- Digital printing and dyeing – reduces water and chemical consumption compared to conventional methods [8].
- Biodegradable fabrics – such as Mylo™, made from fungal (mycelium) fibers [5].

These innovations not only represent technical advancements but also a response to global sustainability challenges [9]. Their implementation can significantly contribute to reducing the negative environmental impact of the textile industry, provided they are integrated into broader systemic changes – including legislative frameworks, consumer education, and responsible resource management.

4.1. Microbiological Treatments

Microbiological treatments employ natural enzymes as eco-friendly alternatives to harmful chemicals in textile processes. These enzymes act as biological catalysts to facilitate reactions at mild temperatures and neutral pH, decreasing resource use and environmental impact [7,10]. Key applications include:

- De-sizing: Amylases selectively break down starch used for sizing cotton, replacing corrosive acids and high-temperature processes, thus preserving fabric integrity and reducing effluent.
- Scouring and bleaching: Proteases, pectinases, cellulases and laccases clean impurities and prepare fibres for dyeing, significantly cutting water and chemical usage. Pectinases alone reduce water use by up to 67% and energy by 50% compared to conventional treatments.
- Biopolishing and finishing: Cellulases smooth fabric surfaces by removing microfibers (“fuzz”), improving appearance and feel without damaging fibers.
- Effluent treatment: Enzymes like catalase and peroxidase detoxify wastewater by neutralizing residual peroxide and breaking down unused dyes before disposal.

Enzymatic methods offer multiple benefits: reduced water and energy consumption, lower chemical pollution, milder processing conditions, and biodegradable residues [10]. However, higher enzyme costs and compatibility with industrial-scale processes remain challenges to widespread adoption.

4.2. Digital Dyeing

Digital dyeing, often delivered via inkjet or spray-based technologies, represents a revolution in sustainable textile coloration. Instead of bulk dye baths, inks are precisely jetted onto fabrics, drastically reducing water usage and dye waste [8,11].

- Water savings: Digital printing can cut water consumption by up to 90–97% compared to conventional methods.

- Reduced chemical use: Eliminates excess dye baths and rinse cycles, minimizing effluent volume and toxicity.
- Energy efficiency and precision: Offers high-resolution designs with low energy input and waste, ideal for on-demand and localized production.

Industry players like EFI Reggiani and Konica Minolta have released commercial systems boasting up to 90% water and 60% energy reductions, while Alchemie's spray-based digital dyeing entirely eliminates water in the dyeing phase [8,11]. Applications include sustainable silk scarves ("Water Silks") using Epson inkjet, which reduces water use by approximately 97% in printing.

4.3. Biodegradable fabrics

In the modern textile industry, increasing attention is given to the development of materials that combine functionality, aesthetics, and environmental sustainability. One of the most prominent innovative materials in this area is Mylo™, a biodegradable leather alternative made from mycelium which is a root-like structure of fungi [5].

Mylo™ is a product developed by the American biotechnology company Bolt Threads, in collaboration with major fashion brands such as Stella McCartney, Adidas, and Lululemon. The material closely resembles natural leather in both appearance and texture, but is produced without the use of animal-based or synthetic raw materials [13]. It is cultivated under laboratory conditions, where mycelium is grown on organic waste (e.g., sawdust) and transformed into a leather-like structure in just a few days, making it an exceptionally efficient and renewable resource [12].

The environmental benefits of Mylo™ are numerous [5,12]. Unlike conventional leather, its production does not involve livestock farming, thereby reducing greenhouse gas emissions, water consumption, and land use. Furthermore, compared to synthetic "vegan leather," which is often made from plastic, Mylo™ is biodegradable and does not generate long-lasting environmental waste.

Although Mylo™ is still in limited use due to high costs and low production volumes, its emergence represents a significant step toward a more circular and environmentally responsible textile industry. With continued technological development and expanded production capacities, this material is expected to become increasingly present in fashion collections that prioritize sustainability [13].

5. ETHICAL STANDARDS AND FAIR TRADE

Ethical standards and fair trade play a crucial role in ensuring that the textile industry respects human rights, working conditions, and environmental norms. Fair trade implies adhering to fair prices for products, which allows producers in developing regions to achieve stable economic conditions and improve social standards for their workers. In the context of the textile industry, fair trade also involves transparency in production, monitoring supply chains, and collaborating with small-scale farmers and fabric producers who follow social and environmental standards.

Additionally, the textile industry increasingly recognizes the importance of certifications such as Fair Trade, Global Organic Textile Standard (GOTS), and OEKO-TEX standards, which guarantee that products are made in accordance with strict environmental and social norms. These certifications enable consumers to make informed decisions about how and where they purchase products, thereby increasing demand for ethically produced fabrics. Respecting workers' rights, ensuring fair wages and safe working conditions, and adopting certifications such as GOTS, Fair Trade, OEKO-TEX, and Bluesign foster ethical and sustainable supply chains [14].

Key sustainability standards in textiles represent guidelines and certification systems that promote transparency, responsible resource management, respect for human rights, and the reduction of environmental impact throughout the textile production process [9]. These standards help companies align with ecological and ethical principles, and empower consumers to make informed decisions.

Below are listed the most important international sustainability standards and certifications in the textile sector.

Global Organic Textile Standard (GOTS)

Purpose: Certification of organic textiles and socially responsible production [15].

Main Features:

- Covers the entire supply chain: from raw material cultivation to the final product.
- Minimum of 70% materials must be organic, and 95% for the "organic" label.
- Prohibits the use of toxic chemicals, azo dyes, and heavy metals.
- Requires compliance with social criteria according to ILO standards

OEKO-TEX® Standard 100

Purpose: Testing textile products for harmful substances.

Main Features:

- Focused on consumer safety.
- Tests fabrics, dyes, buttons, zippers, etc.
- The “Confidence in Textiles” label indicates the product is safe for skin and health [14,16].

Bluesign®

Purpose: Reducing the harmful environmental impact of the textile industry.

Main Features:

- Strict chemical management throughout the production chain.
- Manufacturers must optimize the use of energy, water, and raw materials.
- Promotes process transparency and traceability across the value chain [14].

Fair Trade Textile Standard

Purpose: Ensuring fair labor conditions and fair pricing in the textile industry.

Main Features:

- Workers receive fair wages and work in safe conditions.
- Promotes workers' rights and prohibits child labor.
- Supports community development through a "Fair Trade Premium" [17].

Cradle to Cradle Certified®

Purpose: Designing products that are fully recyclable or compostable.
Main Features:

- Focus on circular economy: products must be “waste-free”.
- Assessment in five categories: material health, reuse, water stewardship, energy, and social fairness.
- Ideal for brands aiming for a closed-loop production system [18].

ISO Sustainability Standards in Textiles

- ISO 14001 – Environmental management systems.
- ISO 9001 – Quality management systems.
- ISO 20400 – Sustainable procurement
- ISO 26000 – Corporate social responsibility.

These standards are not only technical guidelines but also tools to strengthen consumer trust, protect the environment, and improve ethical practices in the textile industry. By implementing these ISO standards, companies:

- Reduce CO_2 emissions and water usage
- Eliminate hazardous chemicals
- Increase transparency across the supply chain
- Promote ethical labor and social responsibility

6. CONCLUSION

Sustainability in the textile industry is no longer an option, but a necessity. By using eco-friendly materials, applying circular economy principles, and focusing on innovation and global standards, the industry can shift toward more responsible practices. Many real-world examples show that being sustainable can actually provide a competitive edge. However, achieving this shift requires collaboration among the industry, regulators, and consumers. This paper can serve as an example for companies in the textile sector on how to improve and enhance existing operations towards a responsible and sustainable business model. Furthermore, it highlights the importance of continuous innovation and monitoring to ensure long-term success in adopting sustainable practices across the sector.

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