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The Innovative Recycling Technologies for the Management of Textile Waste

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Abstract

In the textile industry, many fashion trends have led to high consumption of fiber, and consequently the production of waste. Through the years, there has been improved concern concerning the adverse effects of pollution as caused by the textile industry and the disposal of textile products. This increase has led the research activities focus on more sustainable recycling options for the management of the post-consumer textile products. This article also outlines the current and the most advanced technologies along with research studies encompassing the recycling technologies used in the textile sector. Mechanical, chemical, and biochemical recycling of standard fabrics for garments such as cotton, wool, polyester, polyamide 6 6, acrylic are discussed. New developments in recyclability including sophisticated sorting procedures, new chemical processing, and biochemical recyclability are explained. Different techniques for detailed separation of textile wastes and their identification are also presented. From the reviewed studies, the authors found that most of the recycling technologies were experimented on post-industrial textile waste that is often in the aspect of homogenous constituting dyes and fibers in the waste material. It also recommended that post-consumer textiles could be recycled citing chemical and biological methods that can likely turn the waste into higher value.

Introduction

Global fabric manufacturing has steadily increased over recent years, with production expected to continue its upward trend. Fashion trends and styles evolve rapidly, leading to shorter clothing life cycles and, ultimately, faster disposal in landfills. While this drives growth in the textile

industry, it also results in substantial textile waste. Due to limited landfill space, environmental hazards, and the high costs of waste disposal, the disposal of textile waste has become unsustainable. Reducing waste generation and advancing textile recycling can significantly benefit the environment by decreasing reliance on non-renewable fossil resources used in fiber production.

Due to the new fashion trends that have emerged around the new fashion season and rapid growth of fast fashion the textile industry has expanded the production of textiles and cloths amazingly and the end product of this expansion and growth is the increased textile waste. Presently, generation and consumption of textiles are causing severe problems of environmental pollution including fulling up of dump sites and emission of greenhouse gases. Fortunately, recent variations in the concept of recycling present optimistic techniques in managing textile waste. These innovations do not only minimise the ecological impact of the fashion sector but also shed light on innovations for a sustainable fashion forward world.

1. Mechanical Recycling: Giving Fabrics a Second Life:

The most common way of textile recycling include mechanical recycling which involves cutting the waste material into smaller pieces then processing them to form new yarns. There is this process that is favored for cotton and polyester fabrics. For instance, recycled cotton fibers are used mixed with virgin cotton to produce new products with high enduse durability. In addition to being successful, mechanical recycling is not without its setbacks, the main one being the reduction of the fiber strength during processing. That is why more recent innovations affect positively the quality of the delivered fiber that will allow to restore used textilistic products and turn them into new garments and receive new textile waste.

2. Chemical Recycling:

Breaking Down and Rebuilding Chemical recycling is by far more complex in the sense that it completely disassembles textiles so that they may be reassembled into new fibers. This approach is particularly beneficial in synthetic fibres like polyester which can be chemically recycled to give pure raw materials that are as good as virgin polyester. One of them is depolymerisation

recycling that polyesters are recycled infinitely without altering the fiber quality at all. As for the fabrics made of cellulose, including cotton or viscose, there are recently developing potential chemical recycling – Lyocell and Ioncell. They are regenerated fibers which are manufactured by breaking down cellulose and reconstituting them into fibers; these are renewable fibers that are not grown using fertilizers, water, and other chemicals as used in growing conventional cotton.

3. Enzyme-Based Recycling:

Eco-Friendly Breakdown A relatively new method under discussion, which is in the process of becoming popular among recycling enterprises, is the utilization of enzymes to degrade synthetic fabrics and fibers. Enzymatically promoted recycling employs the use of particular enzymes that break down polyester and other synthetic fibres at the molecular level without the extensive energy needs of chemical techniques. This approach holds the promise for waste elimination without the addition of deleterious chemicals into the environment. The latest advancement in enzyme technology currently being practiced by companies such as Carbios is to recycle synthetic fibres such as polyester and upgrade them to virgin standards. Since these processes employ enzymes that selectively degrade textile wastes, these processes are environmentally friendly and energy saving making them suitable for textile waste management.

4. Textile-to-Textile Recycling:

Closing the Loop Wearable-to-wearable recycling is the process of turning worn articles of clothing into new clothing products, without the need for intermediate steps. This new concept is based on a method that involves sorting, processing and recycling of textile waste with the aim of producing new fabrics out of the fiber content. And with enabling technologies of Fibersort and Textile Identification Systems (TIS), fabrics of different types can be sorted and identified in the recycling process much more efficiently. As textile to textile recycling targets natural, synthetic and blended fibers separately, the contamination rate is very low and the recycled fibers are of high quality.

5. Blended Fiber Recycling:

A New Frontier This is true because over the years, the most difficult thing to recycle in textile

has been blended fibers such as the poly-cottons that contain both the natural and artificial products. Conventional techniques prove to be inefficient for sorting such fibers without compromising the quality of the fibers. New technologies are tackling this with some of the separation processes now being capable of separating fibers by using blended ones. For instance, hydrothermal and thermal decomposition techniques can effectively segment cotton and polyester weaving from the blended fabrics where they are interwoven, and then can be recycled separately.

6. Bio-degradable and Bio-Textiles:

The approach is seeing some innovators engage bio-based textiles and biodegradable fibers as long-term solutions to textile waste. New products like polylactic acid (PLA) from cornVerb 3 and bio-based polyester are produced to disintegrate under specific environmental situations thus cutting down landfill heaps. These fibers have both the potential to decrease dependence on fossil fuel and produce fabrics that are not going to languish in a landfill for several decades.

7. Hydrothermal Processing:

Water and Heat: Two Elements for the Separation of Fibers Hydrothermal processing is an innovative technology employing water, heat, and minimum amounts of biodegradable chemicals to disentangle complex textile architectures and individualize synthetic fibers from natural ones. It does this especially for blends such as poly-cotton because the process manages to degrade natural materials like cotton but leaves synthetic material like polyester easily separable and more likely to be recycled. Hydrothermal processing is effective, cheap, and environmentally friendly since it does not use the aggressive chemicals that are normal in fiber separation.

8. Microbial Recycling:

Leveraging of Bacteria and Fungi in Decomposition of Fiber. Microbial recycling involves employing special bacteria and fungi to degrade textile fibers particularly those from synthetic fabric, polyester included. Living organisms are used under laboratory conditions to act upon plastic polymers by breaking them into chemicals that are usable or useful molecules that can be

used to make other materials. Despite still being an early-stage, biomimcry is another promising biotechnology recycling method because of an ideal – natural, low energy recycling process with desirable residual and byproduct implications.

9. Ultrasonic Recycling:

A Journey with the Atomic Design of Materials through Sonic Vibrations Ultrasound method is a highly innovative, non-destructive way of recycling textile by employing sound frequency to disentangle the fibers. This method can be used on blended fabrics to separate the fibers by allowing sound waves that will vibrate water and disintegrate the textile structures by creating micro vibrations. Further, ultrasonic recycling does not harm fibers and enables exceptional material recycling without the use of chemicals. That is why it is a more effective energy-saving solution for the conservation of natural and synthetic fabrics.

10. Solvent-Based Fiber Recovery:

Dispersing and Reforming Fibres Solvent based process involves the use of solvents that dissolve the textile materials in a process of separating fibers from dyes and refractory contaminants. It is most suitable for cellulose containing fabrics such as cotton, viscose and is becoming popular due to its capability in depolymerisation and reforming of fibres without compromising their quality. Of course, there are firms such as Worn Again that has come up with closed –loop solvent systems and whereby the solvents used are recyclable.

11. Blockchain Technology:

Promoting Transparency of Recgycyind Chains Though not a recycling process, blockchain is gradually being applied to trace and authenticate the trajectory of textile goods and the process of their recycling. Blockchain offers the added possibility for companies to follow each link of the textile chain and verify the recycled content in new articles. This reduces cases where substandard products are sold as" recycled" or "sustainable" products in the market. On the same note, blockchain can also fight against greenwashing since brands are required to be responsible for sourcing and recycling.

12. Electrospinning:

Conversion of unwanted waste fibers to wanted nanofibers Electrospinning is a process of using electric field to pull thin fibers from liquid solution thereby producing nano fibre using recycled material. Using this technique, the fibers of textile waste can be reclaimed and recycled for fiber materials with improved performance for application in filtration , medical textiles, and high strength materials. Electrospinning enables fabrication of nanofiber webs with better mechanical strength and very light weight –this makes electrospun recycled textiles products of high value.

13. *Gasification and Pyrolysis*: Waste Conversion Technologies: Waste to Energy and Waste to Chemicals Gasification and pyrolysis are two techniques which involve thermal degradation of liquids and solids, wastewater and textile waste respectively in the absence of oxygen, but at high temperatures so as to convert the waste material into gas, oil and char, without burning them. These processes transform wastes into valuable products for energy, chemicals or material production. Gasification and pyrolysis technologies have the capability of hosting synthetic in addition to contaminated fabrics that cannot be recycled with other techniques and are appropriate for textile waste that cannot be recycled.

Issues for Discussion and Suggestions on the Future Development:

Thus, these innovations can be considered as a great step forward; however, the problem in implementing these technologies on an industrial level is unsolved. Despite otherwise enormous advantages, costs remain high, infrastructures are scarce and the technology difficult to master. Also, the production of more recycled fibers continues to a key area to support these technologies and the fashion industry. A major area of development as the papers discussed here show is to reduce cost of recycling fiber and furthermore, keep the strength of this fiber without adding extra cost as has normally been the value in recycling. Some methods being studied by researchers are also the use of recycled microfiber to enhance new fabric quality, which provides greater utilization of recycled material in the manufacturing of textile with fashionable and functionalities purposes. Companies and governments are coming up with policies and polices which will control the recycling of textiles besides there are incentives which have already been adopted like the European Union's EPR. EPR has to do with assigning the responsibility of

managing waste produced by products to the producers to encourage the use of recyclable material at the production stage.

Conclusion

A Greener Future for Fashion New developments in textile recycling technologies are on the right track in transforming the fashion sector and other industries that deal in fabric materials. Currently the industry is progressing towards better recycling, quality fibers and sustainable material development to support a circular form of economy where textiles are recycled, remade and recycled again. These advancements enable and support both the consumer and the business to appreciate fashion and satisfy their needs without adversely affecting the environment.

References

1. Abbate S, *et al*. Sustainability trends and gaps in the textile, apparel and fashion industries. *Environ Dev Sustain* 2023; 10: 1–28.
2. Damayanti D, et al. Possibility routes for textile recycling technology. *Polymers* 2021; 13: 3834.
3. Echeverria CA, et al. Cascading use of textile waste for the advancement of fibre reinforced composites for building applications. *J Clean Prod* 2019; 208: 1524–1536.
4. Piribauer B, Bartl A. Textile recycling processes, state of the art and current developments: a mini review. *Waste Manag Res* 2019; 37: 112–119.
5. Sakthivel S, et al. Development of nonwoven composites from recycled cotton/polyester apparel waste materials for sound absorbing and insulating properties. *Appl Acoust* 2021; 180: 108126.
6. Sakthivel S, et al. Thermal and sound insulation properties of recycled cotton/polyester chemical bonded nonwovens. *J Eng Fibers Fabr* 2020; 15: 1558925020968819.
7. Stone C, et al. Natural or synthetic–how global trends in textile usage threaten freshwater environments. *Sci Tot Environ* 2020; 718: 134689.

8. Subramanian K, et al. An overview of cotton and polyester, and their blended waste textile valorisation to value-added products: a circular economy approach–research trends, opportunities and challenges. *Crit Rev Environ Sci Technol* 2022; 52: 3921–3942.
9. Zheng J, et al. A comparative study of recyclability between cotton and polyester yarn via inter-fiber frictional force and elongation at break investigation. *Am J Eng* 2021; 12: 1–16.