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Research on recycling barriers of biodegradable textile in the clothing industry and the future development

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Abstract. Biodegradable fibers have the advantage of sustainable development from the source. Realizing the sustainable development of the whole life cycle of clothing is the future trend. Nowadays, with increasingly high requirements for an ecological environment, the development of biodegradable fiber will become the mainstream of fiber research and development. However, there are many barriers preventing the total degradation of biodegradable fabrics. This paper explores recycling barriers of biodegradable textiles in the clothing industry, discusses the recycling barriers from four aspects: technical, economic, environmental and social, and analyzes the development direction of biodegradable fabric recycling in the future and puts forward some suggestions, including developing advanced biodegradable fabric recycling technologies; creating economic models conducive to recycling; providing suitable degradation sites; strengthening institutional cooperation and improving consumer recycling behavior. This paper is conducive to promoting the development and application of biodegradable textile in clothing industry, and proposes further research for the widespread and high-quality use of biodegradable fabrics.

Keywords: Biodegradable Textiles, Recycling, Sustainability, Clothing Industry.

1. Introduction

By 2030, global apparel consumption is expected to grow to 102 million tons [1]. Ellen MacArthur Foundation shows that less than 1% of the material used to produce clothing is recycled into new clothing [2]. The current clothing system is extremely wasteful and polluting. Synthetic textiles such as nylon, polyester and many other fibers required by the garment industry are non-biodegradable, remain in nature for many years and are harmful to human health. Therefore, to protect the environment and the health of organisms, the use of biodegradable materials has become an urgent need [3]. Biodegradation processes are one of the first factors in achieving sustainability [4].

Biodegradable textiles refer to those fibers and/or fabrics decomposition naturally using bacteria and fungi [3]. Bao et al. elaborate the research and application status of biodegradable fabrics in the garment industry, and summarized and analyzed the future research and development trend of biodegradable materials [5]. At present, biodegradable fabric have good application prospects in the textile and clothing industry, and some biodegradable fabric for clothing have been successfully applied in clothing products. For example, Liu et al. propose the application of Seaweed Fabric in the field of clothing for the elderly. This means that it will be possible to effectively alleviate the pollution problem in the textile and clothing industry [6]. Kazancoglu et al. mention that recycling challenges in the apparel industry include the

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collection, sorting, and restoration of textiles [7]. Recycling of biodegradable textiles is also difficult, which greatly reduces the sustainability of biodegradable textiles. Therefore, this paper analyzes the barriers to recycling biodegradable fabrics from four aspects: technology, economy, environment, and society, and predicts the development trend of sustainability in the garment industry in the future. This research may promote the widespread use of biodegradable fabrics in the future clothing industry and contributes to realize the sustainable development of the clothing industry and the reduction of environmental pollution.

2. Recycling barriers of biodegradable fabrics

2.1. Technical barriers to biodegradable clothing recycling

The first step in any textile recycling is to scientifically and accurately identify and sort them according to composition, color, weaving method, etc. It is significant to separate waste biodegradable fabrics from other wastes to ensure the smooth implementation of subsequent degradation work. The existing sorting methods of waste textiles mainly include manual sorting, semi-automated sorting and automated textile waste sorting. Manual sorting means that the sorting personnel identifies and sort the ingredients by touching, seeing, burning, smelling, etc.; Semi-automatic sorting is the use of machinery to increase the speed of manual sorting; Automated textile waste sorting uses cameras and sensors to identify and separate the different materials that make up textile waste. The technology includes artificial vision technology, data analysis and NIRS [8].

2.1.1. Biodegradable fabric requirements for recycling technology. The current biodegradable materials for the clothing industry are mainly classified into natural fibers, regenerated fibers, and new synthetic fibers [5]. Biodegradable natural fibers include cotton, silk, wool, etc. Regenerated fibers including Tencel, Modal, Bamboo fiber, Seaweed fiber and so on, which has shown a significant growth trend in recent years. The common biodegradable new synthetic fibers are polylactic acid (PLA), polycaprolactone (PCL) and polyhydroxyalkanoate (PHA). The detection and classification technology of some biodegradable fabrics is mature, but there are still emerging biodegradable fabrics detection technology has undeveloped or the technology is not mature enough. For example, in 2015 Chinese studies demonstrated that FTIR-ATR can identify seaweed fibers quickly and efficiently. Before, the detection standard of seaweed fiber was still blank [9]. Therefore, to effectively recycle biodegradable fabrics, it is necessary to know the different identification technologies of all degradable fabrics in the clothing industry. And with the development of more degradable fabrics, the technology needs to be constantly updated, which will be a huge problem.

2.1.2. The challenge of biodegradable textiles recycling in composite materials. Waste textiles are composed of different materials making bioprocessing difficult [10]. When a fabric contains both biodegradable and non-degradable materials, such as a composite fabric consisting of 80% cotton and 20% polyester, it is almost impossible to degrade the cotton in it. In addition, other materials such as metal zippers, plastic buttons, and other textile material labels are involved in the construction of garments, which makes recycling more difficult. It is feasible to classify Composite Materials manually, but the efficiency and accuracy are low.

Existing recycling technologies include mechanical, physical and chemical recycling. Harmsen et al. raise the possibility of biological recycling as a new recycling technology. The study showed that, in theory, microbes could remove the cotton part from the other fibers, resulting in a cotton-free part. However, to date, biological recycling of textile fabric is nonexisting, and the idea remains theoretical. It also has problems such as slow recycling speed, which hinders the practical application of this technology. In the future, it may become one of the methods of composite material degradation [11].

In addition, the presence of dyes and finishes can inhibit biodegradation, and more work is needed to understand the effects [5]. Some additive substances added during fabric processing, such as adhesives, finishing agents and dyes, can also affect the biodegradation of fabrics, that is, accelerate or

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delay the biodegradation of fabrics. The more chemicals used in clothing production, the longer it takes for the fabric to biodegrade, and even cause environmental pollution, thus losing the meaning of the use of degradable fabrics [3]. Hence, the use of additives is also one of the challenges of recycling biodegradable textiles in composite materials.

In short, in the process of recycling biodegradable fabrics, there are a lot of technical challenges that need to be solved. Effective identification and sorting of biodegradable fabrics is the basis of recycling. Effective extraction or direct degradation of biodegradable textiles from composite materials is one of the problems that need to be developed, which can reduce a part of the landfill incineration and reduce the impact on the environment.

2.2. Economic barriers to biodegradable clothing recycling

Sympany, is a non-profit textile collection and recycling organization. Circularity At Sympany report that it is difficult to develop innovations that can recycle multiple types of textiles on a large scale, because these innovations are capital-intensive [12]. Damayanti et al. also mention the expensive recycling process and high logistics cost as two of the five problems in the summary of recycling challenges [13].

Firstly, Transportation for large-scale recycling requires economic support. Transport from the collection area to the textile recycling plant requires the establishment of convenient transport routes and suitable means of transport. This involves cooperation with other areas and some economic resources support.

Secondly, for any type of textile reuse, it must be collected and sorted separately from other waste. Therefore, there is a need for an economically viable and efficient method to identify and classify textile materials [10]. As mentioned in 2.1, Biodegradable textile recycling requires effective technical support as well as manpower and material resources. This requires the support of relevant personnel, equipment and venues.

Finally, Biodegradable materials need to be fully degraded under the conditions of specific temperature, humidity, chemical environment and microorganisms to produce carbon dioxide and water that are harmless to the environment. If these conditions are not met, the biodegradable material may also become a new pollutant [14]. Therefore, it is necessary to construct an effective degradable environment, and it requires the support of specific areas, technology and resources, to keep the conditions stable.

2.3. Environmental barriers to biodegradable clothing recycling

Environmental barriers can be considered from two aspects, the first is the demand for the environment, and the second is the negative impact on the environment during the recycling process. Firstly, the collection of waste clothing needs space, and even needs to be spread across various communities to provide convenience for residents. This is a large-scale environmental demand. In addition, most biodegradable textile materials, including composites, degrade within 2 weeks to 6 months [15]. Therefore, to ensure the complete degradation of large continuous biodegradable fabrics, a certain number of degradation areas are required. Secondly, due to the energy consumption in the transportation process, it will have a certain negative impact on the environment. This is the unsustainable factor generated in the circular pathway of degradable fabric recycling, which is the only part of the entire closed loop that increases carbon emissions and needs to be addressed in future studies.

2.4. Social barriers to biodegradable clothing recycling

Social barriers can be analyzed separately from consumers and communities. Reports show that only about 12% of textile waste is recycled [16]. The low clothing recycling rate shows that the existing clothing recycling policy is faulty, and consumer attitude towards clothing recycling is not positive. First of all, for consumers, there is no convenient clothing recycling agency, no clothing recycling policy or no attractive clothing recycling incentive program may be the reason for their low recycling enthusiasm. Moreover, the low availability of textile recycling plants on both local and regional levels [13]. It means

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that the existing policies of the society do not have good support for the recycling of biodegradable fabrics. Therefore, to remove social barriers, it is necessary to both increase policy support from the social level and encourage consumers to implement recycling behaviors.

3. Future development of biodegradable textile recycling

Vink et al. propose a vision of ideal sustainable materials. It should have the same role and functionality as the product it replaces, and perform as well or better than existing products; can be obtained at a lower or competitive price; have a low environmental impact on all processes involved; be produced by Manufactured from renewable resources; contains only ingredients that are safe for humans and the environment; should not compromise food or water supplies [17]. There is still a development direction for biodegradable fabrics to become more sustainable materials, one of which is to solve their complete and safe degradation, and comprehensive recycling is the primary issue. The following will provide development suggestions for the future recycling of biodegradable fabrics from four directions.

3.1. Technological development

Ideally, biodegradable plastics should be recycled separately and then concentrated for industrial composting to ensure that the biodegradable fabric can be fully degraded smoothly and with minimal environmental damage. Existing recycling technologies are limited, and recycling systems are labor-intensive and capital-intensive. The development of efficient recycling technology that reduces labor and financial resources may be one of the future directions. For example, radio frequency identification (RFID) tags may be used in the future. The tags can be considered as "wireless USB memory sticks" that can carry data and read it remotely. RFID tags can accurately, conveniently and quickly read clothing fabric information, to classify waste clothing more quickly. However, low-cost RFID tags that can withstand multiple laundry cycles do not exist yet. Therefore, recycling technologies need to be continuously improved to meet the specific requirements of biodegradable fabrics, especially composite fabrics.

3.2. Economic model innovation

More environmentally friendly economic strategies need to be developed at the recycled stage of the biodegradable clothing life cycle. Develop a new closed-loop economic strategy, such as degradable fabric clothing dealers directly setting up recycling departments, using economic incentives to guide consumers to produce positive recycling behavior. The establishment of a closed-loop sales strategy can facilitate consumers to get the recycling channels directly and quickly, and the recycling channels are unified and convenient. Financial incentives such as vouchers can also incentivize consumer behavior, resulting in higher returns for dealers. Innovative economic models that are more conducive to recycling may be better for the economy. Therefore, creating a circular-friendly economic model is one of the research directions of future economic models.

3.3. Environment requirements

The provision of adequate clothing recycling sites, transport pathways and biodegradable fabric degradation sites is necessary to ensure effective recycling of biodegradable fabrics. Establishing clothing recycling stations in the community is convenient for consumers to recycle clothing, which can effectively collect used clothing and avoid environmental pollution caused by littering waste. Developing transport paths for recycled clothing that can safely and efficiently transport used clothing to recycling locations. Minimizing carbon emissions in the process is a problem that needs to be addressed.

3.4. Social support and collaborations

While the textile industry is increasingly focused on recycling, most of the industry still thinks in linear terms. This has led many to believe that top-down enforcement is the only way to make the textile

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industry more circular. However, change should come from all directions, and increased communication about circular issues can increase social support for new innovations in textile recycling.

Park & Ha propose four determinants of recycling intention: attitude, subjective norms, perceived benefit, and personal norms and two antecedents of those determinants: subjective norms and awareness of consequences [18]. Perceived benefit is a significant positive predictor of recycling intentions [19]. Therefore, manufacturers or governments can come up with some programs to encourage consumers to have positive clothing recycling behavior. For example, providing incentives for consumer recycling behavior, such as discount coupons, small gifts, etc.; advertising the benefits of recycling and raising the ethical and responsible value of recycling in the minds of consumers. In addition to the influence of perceived benefit, personal norms also have a significant impact on recycling intention. Individual norms are inevitably influenced by subjective norms. Therefore, the establishment of social recycling system can effectively promote individual recycling behavior.

In order to make the clothing industry more circular, collaborations with multiple stakeholders throughout the clothing industry chain are needed. It is necessary to establish and develop effective cooperation with fellow technological innovators and textile collectors and sorters, educational platforms, and company clusters [20]. for instance, educational platforms can develop programs that positively influence consumer attitudes toward recycling and educate potential users in advance. Comprehensive support from all sectors of society can solve the recycling problems more effectively and quickly.

4. Conclusion

The clothing industry is still facing significant challenges in the sustainable stage. The research and development of biodegradable fabrics is undoubtedly a key part of the clothing industry "cradle to cradle". Society is full of expectations for biodegradable fabrics. But the current situation cannot support the sustainable performance of degradable fabrics. There are technical barriers, economic barriers, environmental barriers and social barriers in the recycling process. Therefore, the research of fabric sorting technology with less manpower, high accuracy and high efficiency, or the development of technology that can directly bio-decompose and degrade composite materials may be the future technical demand. Furthermore, creating a recycling-friendly economic model is also necessary, which may change the recycling pathway from the business perspective. In addition, providing sufficient degradation environment and area for biodegradable fabrics is a requirement for degradation. Finally, all actors in society must learn more about the barriers to biodegradable fabric recycling and the links between them. Strengthening collaboration is necessary at this time of environmental crisis.

This study used only literature analysis. The research channels are limited. In the future, market research can be applied to understand the current situation of biodegradable fabric recycling, and the information obtained will be more accurate and effective. An In-depth exploration of the recycling process and recycling methods will be the focus of future research.

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