

## RECYCLING OF PRODUCTION WASTE OF THE TEXTILE AND CLOTHING INDUSTRY IN CIRCULAR ECONOMY CONTEXT

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**Purpose:** The main aim of the research presented in the article was to identify and categorize the main production waste generated in the textile and clothing industry and their impact on the environment in the context of sustainable development, along with presenting recycling as a solution to the problem of production waste. Nowadays, through newly emerging EU directives, growing population, and consumer lifestyles, and, consequently, the huge amount of waste generated, the waste problem will increase, and it will be increasingly important to look for new solutions to this problem.

**Design/methodology/approach:** The research presented in the article used an analysis of the literature on the textile industry and its impact on the environment, along with an analysis of the generated textile waste in the concept of sustainable development.

**Findings:** Textile and clothing industry is an important factor influencing the sustainable development of the economy both in the world and in Poland. In the light of the newly established EU directives, this will be a very important issue in the future, which will require urgent attention to this topic and finding optimal solutions in the context of sustainable development or the circular economy. Based on the report results, there has already been a significant change in the behavior and ecological awareness of Poles over recent years.

**Research limitations/implication:** Future research will continue material recovery during physical and chemical recycling.

**Practical implications:** The article presents a review of research on the diversity of waste from the textile and clothing industry in Poland, which shows the importance and scale of the problem and allows for further research on the management of the generated waste. The author also collected data from a nationwide report on Polish people approach to clothing recycling, which she presented in the article, but they require a broader and more detailed analysis.

**Originality/value:** Based on the analysis of available literature, the article shows the scale of the problem, which is an urgent problem and an important future issue thanks to the new EU directives on sustainable development and the circular economy. Additionally, data was collected regarding a report on Poles' approach to recycling, which highlights the consumer trend in environmental protection.

**Keywords:** textile waste, textile recycling, sustainable development, circular economy.

**Category of the paper:** research article.

## 1. Introduction

Recently, there has been a rapid development of industry, technology, and science, and at the same time an even faster increase in the population. Therefore, the impact of man and his economy on the environment has become very visible, especially from the perspective of the waste he produces. Human activities should be as consistent with nature as possible, should not have any impact on it, and certainly should not irreversibly disturb its operation. However, the amount of waste generated by humans in the 21<sup>st</sup> century is the opposite of the harmony of life with nature. Year by year, people around the world produce more and more waste, which has made it the most burning problem today. Fortunately, society's awareness of caring for and protecting the environment is increasing. The increase in the number of people around the world has contributed to an increase in the demand for various types of goods, and the exhaustion of natural resources makes people think about ecology and the management of such large amounts of waste (Brdulak, 2012; Dorobek, Bursztyński, 2014).

Rational resource management promotes, among others: solving many environmental problems (decrease in the number and availability of renewable sources, environmental pollution, formation of greenhouse gases that reduce the ozone layer, and thus, to global warming) and constitutes one of the most important challenges for Europe.

In the last dozen years, there has been a move away from a linear economy based on the "produce, consume, throw away" model and towards a circular economy "sustainable production, sustainable consumption, upcycling", in which waste can become the basis for the recovery of raw materials; primary, including minerals. Rational use from available raw materials can be a source of significant savings and at the same time contribute to the reduction of waste, the use of secondary raw materials as primary ones and to meet people's demand at least partially for new products (Szołtysek, 2009).

Recycling is a concept that fits into the idea of environmental protection, reducing the amount of waste generated and the circular economy concept. There are many forms of recycling, including plastic, glass, paper, and metal recycling. Each of these forms has its own unique challenges and requires different processing processes, but they all contribute to saving natural resources, reducing waste and reducing greenhouse gas emissions. With the advancement of technology and the growing demand for sustainable products, recycling has also become an important factor in the fashion industry. Clothing recycling allows to use used fabrics and clothes, as well as reduce the negative impact of the fashion industry on the natural environment. This article discusses various aspects of recycling, particularly clothing recycling from the textile industry, including processing processes and also environmental and social benefits.

## 2. Conceptual background

### Textile industry

The textile industry is one of the largest and fastest-developing industries. The rapid development of the clothing and textile industry and the rapid fashion trend among consumers have resulted in a sharp global increase in the amount of textile waste produced. In 1950, FAO reported that 3.7 kg of textile fibers per person was produced, while in 2007 this number increased to 11.1 kg and is constantly growing (Shui, 2011; Bartl, 2011). This huge demand leads to the production of large numbers of textile fibers. In 2007, 70.6 million tons of textile fibers were produced, and in 2014, 90.8 million tons. Therefore, it is expected that the average annual growth rate of the global textile and clothing market will be 3.7% and will exceed 100 million tons in 2025 (Statista, 2016; Tot, 2004; Lenzing, 2016). Such a large expansion of the textile industry has a significant impact on the world economy. In 2002, the world trade in industrial textiles reached \$400 billion, representing 6% of world trade (Vaidya, 2006). However, in 2012, this trade increased to \$1.8 trillion (Comtrade, 2012). The two largest textile producers in the world are China and India. The Chinese textile industry in 2012 accounted for 54% of total world production. However, the largest importer of textile products was the United States; in 2012, the value of textile imports was \$151 billion (Contrade, 2012; Huang, 2012). But over the years, the situation has changed and in 2017, China and the EU were the two leading regions for clothing and textile exports (Tabaraki, 2007). World production of textile fibers amounted to 98.5 million metric tons (MMT) in 2017, and in 2019 it increased to 111 MMT (Wałętrzak, 2016).

### Recycling

Recycling is a waste processing process that aims to reuse it, to reduce the amount of waste stored in landfills and reduce the negative impact on the environment. Nowadays, recycling has become a very important topic due to the growing amount of waste and the need to protect the natural environment (Interreg, 2020). Recycling is not limited only to the use of secondary raw materials but is also a system of full organization of the circulation of materials that can be recycled many times. For the properly system function, it should include elements such as:

- appropriate legislative policy of the country,
- appropriate design of goods (ecodesign),
- development of technologies and techniques related to the processing of materials,
- appropriate labeling system for products, product packaging and their components for easier recognition and segregation,
- spreading pro-ecological education,
- logistics of collecting, sorting, and collecting used goods,
- waste processing and raw material recovery.

There are three types of recycling:

- reuse – using a material or product for the same purpose, e.g., returnable bottles,

- further use – use of waste for new purposes after physical, chemical, or biological processing, e.g., granulate for PET bottles,
- reuse – recovering chemical waste from garbage and reintroducing it into production, e.g., using car wrecks in a steelwork.

Due to the specificity of the technology used, material (mechanical) recycling can be distinguished, including the reuse of waste as a product; raw material (chemical) recycling, allowing the processing of mixed materials; energy recycling (thermal) - combustion with energy recovery and organic (biological) recycling - aerobic or anaerobic treatment.

The benefits of recycling are (Dorobek, Bursztyński, 2014):

- reducing the amount of waste produced by limiting the products purchased, composting waste, giving up packaging,
- giving objects a new life and purpose,
- reducing the amount of stored rainfall,
- energy efficiency,
- creation of new jobs,
- reducing the use of natural resources,
- reducing harmful emissions into the atmosphere and enabling sustainable development.

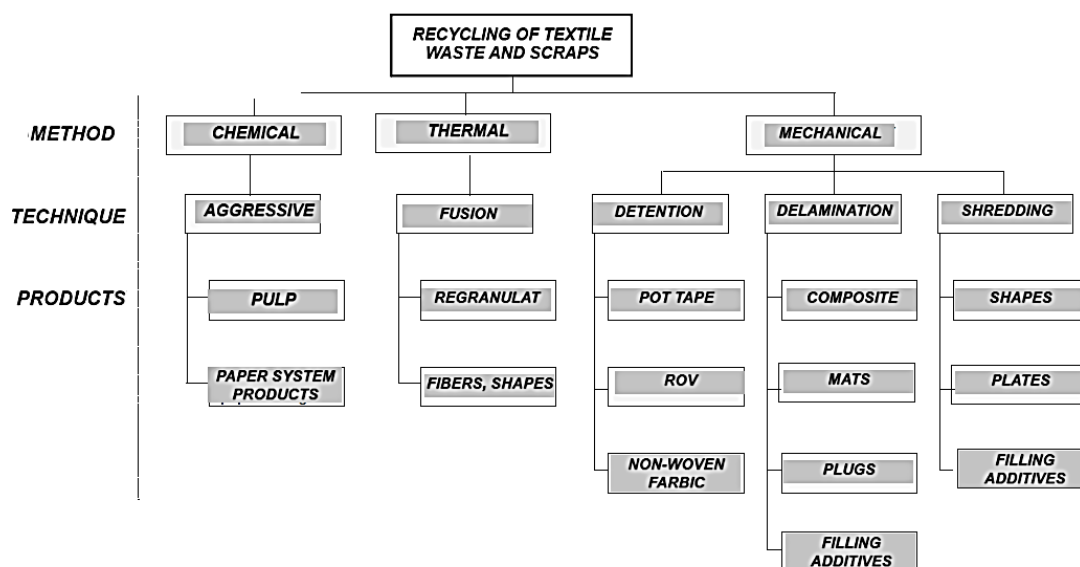
With the advancement of technology and the growing demand for sustainable products, recycling has also become an important factor in the fashion industry. Clothing recycling allows to reuse used fabrics and clothes, as well as reduce the negative impact of the fashion industry on the natural environment.

### **Textile recycling**

Nowadays, textile recycling has become a global challenge because the economy needs a continuous supply of raw material - textiles, especially in the current time of consumerism and fast fashion. On the other hand, in the perspective of growing fashion and the need to move towards sustainable development and a circular economy, there was a need to reduce natural resources. In addition, issues related to waste management, especially recycling, are becoming more and more important due to the shortage of natural raw materials and their unsustainable use. Another problem is the storage of waste, due to the limited amount of space and the relatively high costs of its storage (Chiu, 2021).

For the above reasons, it is necessary to use material recycling not only at the stage of textile production, but also after their production - especially if the consumer intends to get rid of them.

Figure 1 shows three types of material recycling - mechanical, physical, and chemical recycling.



**Figure 1.** Recycling methods and obtained products.

Source: (Moraczewski, 2007).

Mechanical recycling is the most used method of shredding textile waste by cutting and tearing, and finally carding (combing) to loosen the fibers of the materials. The next stage is forming the tape and spinning or forming and consolidating the fleece. During the spinning process, yarns are obtained, while the resulting fleece is mainly used to produce nonwoven fabrics. After recycling, the obtained fibers have deteriorated physical parameters - they are shorter and contain only 2-5% of monofilaments. The fleece is consolidated using various methods, most often by needling, stitching or thermal bonding, i.e., welding. The material produced in this way can be used for cloths and cleaning materials, filling materials, thermal and sound insulation materials, geotextiles and upholstery and automotive textile elements. The most profitable and economically justified concept is the processing of textile waste into disordered fleece (Interreg, 2020).

Physical recycling can be used for thermoplastic materials - textile waste is granulated and can be reused as a raw material. The main criterion for physical recycling is primarily the purity of the final product, therefore waste should be sorted before recycling. Sorting is most often done by machine or manually, depending on the color and chemical structure of the sorted plastics - automatic sorting is most often used. After the sorting process, textile waste is shredded, melted, and processed into granules. Textile polymers such as polyolefins and polyester are recovered in a physical process. Unfortunately, in this process, subsequent temperature processing changes the material properties and makes it difficult to use the materials for the same application. In the process of physical recycling, the quality of the material is lost (worse mechanical properties, change in thermal properties, deterioration of resistance to light exposure) or degradation of the material.

Chemical recycling is the production of chemical products from polymer materials - most often waste. In chemical recycling, there are three methods for recovering polymers. The first method involves depolymerization of polymer chains into monomers with a level of purity that allows the material to be re-polymerized. The second method involves the use of chemical solvents, which are selective polymer solvents - hydrolysis, alcoholics or ammonolysis. The last method is pyrolysis - degradation under the influence of high temperature in the absence of oxygen. The following polymers can be recovered through chemical recycling: cellulose, polyester, polyamide, polyurethane. The advantage of this method is that it can be used to recover various types of polymers from textile waste made from a mixture of polymers or unmixed synthetic textile waste (Interreg, 2020; Moraczewski, 2007).

### **3. Textile recycling in sustaindevelopment context**

“Sustainable development is development in which the needs of the present can be met without compromising the opportunities of future generations to meet their needs” (Report of the World Commission, 1987). One of the main challenges facing the textile and clothing industry is more effective management of natural (non-renewable) resources and increasing the innovation of waste recycling. The changes cover 3 areas of life:

- economic (prosperity) – reducing the costs of raw materials and energy consumption and waste disposal, creating new business networks, which provides a new market of opportunities,
- environmental (planet) - optimization of the use of natural resources, reduction of environmental impact and reduction of gas emissions, avoidance, storage, recovery of energy from waste,
- social (people) – increasing the standard of living, more green jobs (increase in employment).

The eco-design trend fits into the concept of sustainable development. It is an approach to design that considers its impact on the environment throughout the product's life cycle. It concerns design that minimizes the harmful impact of the production and use of products on the environment. The concept of eco-fashion is directly related to the concept of eco-design. Eco-fashion products are characterized by (Muthu, Gardetti, 2016):

- use of organic raw materials grown without pesticides,
- use of textiles without the use of chemicals and bleaches,
- reusing recycled materials or fibers,
- durability and quality so that consumers can keep them for longer,
- considering fair trade principles.

Consumers can also influence the quantity and quality of clothing produced and textile products through (Szewczyk, 2017):

- education and promotion of consumers' minimalist approach to purchased clothing - consumers will buy fewer clothes, their purchases will be more thoughtful, and the clothes they choose will be more universal and functional. This is what is called slow fashion. All these treatments should reduce the amount of clothing produced and, consequently, the amount of waste generated,
- reusing used clothing - it involves extending the life of a given product by repairing, repairing, sewing, or modifying it (shortening, narrowing). There are also companies offering the opportunity to sell and buy your things (e.g., Vinted) and second-hand clothing stores. You can also donate used clothes to the poor (Wtórpol containers, PCK).
- recycling – processing used clothing, fabric scraps, offcuts, and other waste into new fibers of comparable value.

In Poland, as in the entire European Union, various types of clothes and fabrics, but also blankets and other textiles are collected in specialized containers. The textiles that end up there are in various states of wear and tear (wear and cleanliness), so it is very important to segregate them and choose the appropriate method of processing them. There are many companies in Poland that recycle clothes, including: Tesso, PCK, H&M, Reserved, Vive Textile Recycling, Caritas, Wtórpol. In 2021, Wtórpol Company conducted a research report among Poles on clothing recycling and purchasing habits and getting rid of clothes. The study involved 1025 Poles, over 18 years of age, according to the distribution of gender, age, and town size class. According to the report, to the question "Do you think recycling clothes helps protect the environment" only 27.4% of people answered, "Definitely yes", 50.9% "Rather yes", 17.2% answered "I don't know/it's hard to say", and 3.5% answered "Probably not". These results clearly show that some Poles are aware of the fact, that recycling clothes will contribute to environmental protection. 78% of Poles see such a possibility, which is probably the result of numerous campaigns promoting recycling and consumer education in the field of ecology. On the other hand, when asked "Do you know a company or organization that recycles clothes?" only 15.8% of Poles answered affirmatively. This is a very low percentage, which proves that Poles are not interested in what happens to their recycled clothing. Interestingly, when asked about the reasons for environmental pollution, most people selected industrial sewage (29.4%), and only 6.7% selected clothing production. After all, clothing production and the textile industry are the second source of environmental pollution, after the oil industry (Report, 2021).

To summarize the report's results, most Poles (61%) recycle unnecessary clothes. The vast majority of respondents (78%) believe that recycling clothes contributes to environmental protection. Poles' attitude towards buying clothes has also changed, especially after the pandemic. Every third Pole (32%) declares that they buy clothes more consciously, almost the same percentage of respondents (30%) buy new clothes less often. Most changes in

behavior can be observed among women than among men, which may indicate greater ecological awareness among women and the impact of our daily choices on the environment. The majority of respondents (71%) bought second-hand clothes at least once, and 60% of people from this group indicated second-hand stationary stores as the place of purchase.

#### **4. Summary and conclusion**

The world economy has been struggling for many years with problems such as depleting natural resources, environmental pollution, and excessive waste production. The need to introduce changes in the protection of the natural environment is strongly emphasized by the concept of sustainable development. Environmental problems affect many areas of economic life, especially production sectors, e.g., the clothing industry. The clothing industry, after the oil industry, is the second largest consumer of water in the world and a source of pollution. A significant source of environmental degradation are pesticides used in the cultivation of natural fibers. In the next stage of clothes production, a large amount of contamination is created (dye baths containing chemicals and dyes, a large amount of fabric scraps). The next stage of pollution formation is the transport of clothes and their disposal. The clothing industry is inextricably linked with consumerism and fast fashion, which leads to the creation of a huge amount of unused clothes, which are waste. Changing people's awareness and introducing the principles of sustainable development and circular economy can contribute to reducing the amount of waste generated and thus contribute to the protection of the natural environment. Clothing recycling is a very promising solution. Clothing collected from containers, if it is in good condition, goes to poor countries in Africa or Asia. Some of the clothing that is not suitable for shipping is recycled. Carpets are made from wool, cleaning cloths are made from cotton, and other materials are processed into alternative fuel that replaces coal. A large part of clothes is processed into thermal insulation, filler for car seats and animal beds. Through chemical recycling, some fibers can also be recovered for reuse.

Based on the results obtained from the report, there has already been a significant change in the behavior and ecological awareness of Poles over recent years. Ecological, zero waste, eco-design and recycling topics are becoming more and more popular in the media and public discussions, which has a positive impact on the ecological education of society. Of course, there is still a lot to do, as the level of recycling is still quite low in Poland, but looking at the results of the report, the thinking of Polish society is heading in the right direction. Taking care of the environment and the planet is the task of all of us, and it starts with our everyday choices and habits. Starting from buying clothes, through its treatment during use (darning, repairing, patching, sewing) and ending with its disposal, i.e., recycling it or extending its life - selling it, e.g., on Vinted, or giving it to younger siblings.



To sum up, there is still a lot to do when it comes to ecology and recycling, but society is on a much better path than a few years ago. Through various types of educational programs, people's willingness, and attitude towards the subject of care changes about the natural environment.

## References

1. Bartl, A. (2011). Textile Waste. In: D.A. Vallerio (ed.), *Waste*. Boston: Academic Press, pp. 167-179. doi:10.1016/B978-0-12-381475-3.10012-9
2. Brdulak, H. (2012). *Logistyka przyszłości*. Warszawa: PWE.
3. Chiu, Y.T., Li, Y.C., Tsai, Y.P. (2021). Sustainable fashion: A review. *Journal of Cleaner Production*, 306, pp. 272-276.
4. Comtrade, U.N. (2012). *Apparel and Textiles: Trade Statistics*. Michigan State University. <http://globaledge.msu.edu/industries/apparel-and-textiles/tradestats>, 5.11.2023.
5. Dorobek, S., Bursztyński, A. (2014). Recykling surowców w Polsce – ewolucja i rozwiązania logistyczne. *Logistyka*, 6, pp. 526-541.
6. Huang, N. (2012). *China—the king of textile industry*. Businessvibes. <https://www.businessvibes.com/blog/china-king-textile-industry>, 5.11.2023.
7. *Interreg*. <https://iw.lukasiewicz.gov.pl/wp-content/uploads/2021/07/Broszura-ENTER.pdf>, 5.11.2023.
8. Lenzing (2016). *The global fibre market*. <http://www.lenzing.com/en/fibers/the-global-fiber-market>. Html, 5.11.2023.
9. Moraczewski, A., Wiśniewski, M., Wojtysiak, M. (2007). Recykling odpadów tekstylnych za pomocą technik włókninowych. *Problemy eksploatacji*, 1, 197-206.
10. Muthu, S.S., Gardetti, M.A. (2016). *Green Fashion, Vol. 2*. Springer. ISBN-13:978-9811002441.
11. Raport 2022 (2021). *Wiedza Polaków o recyklingu odzieży*. Wtórpol. <https://www.wtorpol.com.pl/wp-content/uploads/2022/08/wiedza-polakow-o-recyklingu-odziezy-raport-badawczy.pdf>, 5.11.2023.
12. Shui, S., Plastina, A. (2011). *A summary of the world apparel fiber consumption survey 2005-2008*. Food and Agriculture Organization of the United Nation (FAO) and International Cotton Advisory Committee (ICAC). Washington, pp. 1-11.
13. Statista (2016). *Worldwide production volume of chemical and fibers from 1975 to 2014*. The statistics portal. <http://www.statista.com/statistics/263154/worldwide-production-volume-of-textile-fibers-since-1975/>, 5.11.2023.

14. Szewczyk, M. (2017). Szanse na rozwój gospodarki okrężnej w przemyśle tekstylno-odzieżowym. *Gospodarka w Praktyce i Teorii*, 3(48), pp. 57-67. <https://doi.org/10.18778/1429-3730.48.05>
15. Szoltysek, J. (2009). *Logistyka zwrotna*. Poznań: Instytut Logistyki i Magazynowania, p. 42.
16. Tabaraki, R., Khayamian, T., Ensafi, A.A. (2007). Solubility prediction of 21 azo dyes in supercritical carbon dioxide using wavelet neural network. *Dyes and Pigments*, Vol. 73(2), pp. 230-238, doi: 10.1016/j.dyepig.2005.12.003.
17. Tot, B.V. (2004). *Textile & apparel industry report*. Available via FPT Securities. [http://fpts.com.vn/FileStore2/File/2014/07/01/Textile%20and%20Apparel%20Industry%20Report%20\(latest\).pdf](http://fpts.com.vn/FileStore2/File/2014/07/01/Textile%20and%20Apparel%20Industry%20Report%20(latest).pdf), 5.11.2023.
18. Vaidya, A.K. (2006). *Globalization: encyclopedia of trade, labor, and politics, vol. 1*. Santa Barbara: ABC-CLIO, pp. 413-432.
19. Wałętrzak, G. (2016). Odpady tekstylne i włókiennicze –wartościowy surowiec czy problematyczna pozostałość. *Logistyka Odzysku*, 4, pp. 18-20, ISSN 2083-6422.
20. *World Commission Report*. Retrieved from: <https://www.gov.pl/web/rozwoj-technologie/zrownowazony-rozwoj>, 5.11.2023.