

Textile waste in the context of the circular economy

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Abstract. The concept of a circular economy is built in opposition to the traditional linear model where raw materials are used, things are created from them, they are consumed and the leftovers are thrown away. This model relies on large quantities of cheap and accessible materials and energy sources. The textile sector is part of the economies meeting the requirements of the circular economy. What is the real place and importance of waste from textile production and their role for the circular economy, determine the relevance and arouse the interest of the authors in the research. The objective of this paper is to provide a comprehensive overview of the existing situation and to study the textile waste in the context of the circular economy. For the goal fulfillment we use the descriptive-analytical method - theoretical aspects of the studied scientific field are investigated on the basis of current literature research. The information collected is summarized and analyzed; systematic approach; analytical approach; study of the works of authors in the field; comparative analysis; method of observation; determination of relative shares. Current scientific research and economic aspects about textile waste in the context of the circular economy have been explored. The various author collectives work in the field of textile waste, its management and its connection with the circular economy. Research in the field of textiles shows the great importance and fundamental role of textile waste for the realization of the circular economy concept.

1 Introduction

The European Union generates more than 2.5 billion tons of waste annually. It is currently updating its legislation to encourage a shift to a more sustainable model known as the circular economy. EU countries have to increase quality recycling, reduce waste incineration and landfill disposal and limit hazardous chemicals in waste.

The circular economy is a model aimed at extending the life cycle of products. In practice, this means sharing, borrowing, reusing, repairing and recycling existing materials and products as long as possible. When a product reaches the end of its life, the materials from which it is composed continue to be used in another way. This is done over and over again to minimize waste disposal [1].

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In February 2021, Parliament approved its position on the new circular economy plan, calling for further measures to achieve environmental sustainability and carbon neutrality by 2050. Recommendations include tightening recycling requirements and binding targets for material use and reducing the impact of consumption on the environment by 2030. The European Commission presented a first package of measures to accelerate the transition to a circular economy in March 2022. It includes proposals for product sustainability, updating rules and a strategy for textile products

Textiles are at the heart of our daily lives – in clothing and furniture, medical and protective equipment, buildings and vehicles. However, urgent action is needed as their environmental impact continues to grow. Textile consumption in the EU ranks fourth in environmental and climate change impact after food, housing and mobility. It is also the third highest water and land consuming area and fifth in terms of primary raw material use and greenhouse gas emissions [2].

Every year, Europeans use almost 26 kg and throw away about 11 kg of textiles. Used clothes can be exported outside the EU, but in most cases (87%) they are incinerated or landfilled. Globally, less than 1% of clothing is recycled as clothing, partly due to inappropriate technologies [3].

The EU strategy for sustainable textile products, presented by the European Commission in 2020, sets the task that by 2030, textile products on the European market should be long-lasting, recyclable, made as much as possible from recycled materials fabrics and do not contain hazardous substances [4].

The objective of this paper is to provide a comprehensive overview of the existing situation and to study the textile waste in the context of the circular economy. For the goal fulfillment we use *the descriptive-analytical method* - theoretical aspects of the studied scientific field are investigated on the basis of current literature research. The information collected is summarized and analyzed; systematic approach; analytical approach; study of the works of authors in the field; comparative analysis; method of observation; determination of relative shares.

2 Results and discussion

2.1 Trends and perspectives in the circular economy

The circular economy is a growing topic, especially in the European Union, which promotes the responsible and circular use of resources that can contribute to sustainable development. It is a general concept, including different meanings, it becomes defined action plans supported by specific indicators [5].

The circular economy is a multifaceted concept of closing material chains to improved environmental performance that has gained prominence in recent years in government and business policies, as well as in academia. The results of research in this area show that if circular products are perceived as substitutes for conventional products, well-targeted policies can significantly reduce the use of materials [6,7].

A central theme of the circular concept is the valuation of materials within a closed system in order to enable the use of natural resources while reducing pollution or avoiding resource limitations and sustaining economic growth [8]. Moreover, the circular economy is emerging as a way to achieve sustainability.

According to the Circular Gaps Report, globally over 90% of resources used do not go back into production and only 8.6% of the world economy is circular. However, three major trends are emerging to promote the circular economy: ***changing consumer expectations, disruptions in the global supply chain and growing environmental concerns.***

Consumer expectations. Sustainability becomes a key factor in consumer decision making. In this context, a more informed consumer choice, the possibility of detailed information about the whole life cycle of the product, is important.

Supply chain disruptions. The standard supply chain operation should take into account factors related to its optimization through a circular supply chain - disruptions caused by the Covid-19 pandemic (changes in demand for products, insufficient logistics staff, disrupted distribution channels for goods).

Concern for the environment. If we continue to use resources the way we have been used to, by 2050 we will need the resources of three planets like Earth. Resource scarcity and climate change demand a shift from a use-and-throw society to a carbon-neutral, environmentally sustainable, pollutant-free economy. The coronavirus crisis has highlighted the fragility of supply chains and affected small businesses and industry. Developing a circular economy where resources and products are reused and recycled will reduce carbon emissions, stimulate economic growth and create jobs.

In a report adopted in February 2021, Parliament called for the introduction of binding targets for material use and consumption by 2030. In March 2022, the European Commission proposed a first package of measures to accelerate the transition to a circular economy. It is in agreement with the goal of achieving zero carbon emissions by 2050 and includes standards for product sustainability, including updating strategy for textile products.

The European Commission has identified seven key sectors for building the circular economy. They require changes at different stages of the chain - from design through production to their use by end users [4,9]. Key sectors for building circular economy are plastics; textile; electronics and IT; food, water and nutrients; packaging; batteries and vehicles; construction and buildings.

The ambitions of the new circular economy are aimed at reinventing and redirecting the linear economy towards more sustainable approaches. This, according to authors, can be focused on four main parts of the clothing system wheel as follows; (1) materials, (2) production, (3) use and (4) after use. In all sections, massive innovation is paramount given the fact that the textile industry is an old industry whose processes can hardly be changed, which can take the form of; (1) phasing out substances of concern and release of microparticles, (2) increasing utilisation of clothing, (3) improving recycling, and (4) efficient use of resources and switching to renewable raw materials [10].

2.2 Characteristics of textile waste

The main factors driving the increase in the production of textile goods in the current economic environment are the growing world population and the associated diversity of consumer preferences. As a result, there is an unlimited use of production textile materials and an increased amount of textile waste [11].

Although textiles are fundamentally used to protect the body from cold, heat, and light, and to preserve modesty, they have become a reflection of personality, wealth, or interest in fashion. From the sourcing of raw materials to textile production, garment manufacturing, and distribution to retail stores, the textile industries generate huge amounts of waste, which occupy a large place in the municipal solid waste category [12].

Essential for textile waste generation is the idea, created by the fashion industry, that people need new products each season. Large amounts of production and postconsumer fiber waste have been amassed with the growth of the world's population and rising living standards [12].

According to directive "waste" means any substance or object which the holder discards or intends or is required to discard [13].

Textile wastes from the production of all types of textiles and waste textiles from consumption of clothing and technical textiles accompany the fast-growing markets for textiles. Although markets of second-hand clothing have been around for some time, about 80% of old textiles are lost in landfills and incineration, leading to environmental problems [14].

Textile waste is the textile by-product of the manufacturing of garments, fabrics, yarns or fibres that are deemed unusable for its original purpose by the owner. Textile waste can include fashion and textile industry waste, created during fibre, textile and clothing production, and consumer waste, created during consumer use and disposal [15].

Textile waste is the waste from the textile manufacturing process, used fibres, textiles and clothing, divided into 3 main groups: **pre-consumer waste, post-consumer waste and industrial textile waste**. The first group („clean waste“) includes the by-products and fibrous materials from the production process. The second group of textile waste includes so-called household textile waste resulting from end-user use - discarded worn-out, clothing or household textiles with defects (sheets, towels and pillowcases) with no value to consumers beyond their useful life. Industrial textile waste („dirty waste“) result from commercial and industrial activities in the textile sector. An additional factor in the increased generation of textile waste is the consumer’s fast fashion trend [16].

In 2020, synthetic fibers accounted for approximately 62 percent of the global textile fiber output volume. Polyester alone had a market share of 52 percent, while polyamide and other synthetics accounted for five and 5.2 percent [17].

Most clothing around the world is made with polyester, the synthetic fiber derived predominantly from petroleum. It has overtaken cotton as the main textile fiber of the 21st century, ending hundreds of years of cotton’s dominance. The global market for polyester yarn is expected to grow from \$106 billion in 2022 to \$174.7 billion by 2032. Yearly polyester fiber production is projected to exceed 92 million tons in the next 10 years—an increase of 47%.

The polyester is hardy and versatile, used to create everything from athletic clothes to faux fur jackets to silky dresses. It’s been marketed as more sustainable than some natural fibers because the production process doesn’t require as much water or land as growing natural fibers like cotton [18].

Table 1 shows the 2020 consumption of different types of clothing, footwear and household textiles per person in Europe.

Table 1. Apparent consumption of clothing and household textiles, per product type, EU27, 2019-2020.

Example items	EU27 Consumption (kg per person)			
	2010	2015	2019	2020
Shoes	3.4	3.1	3.6	2.7
Total footwear	3.4	3.1	3.6	2.7
Pullovers, cardigans	1.3	1.1	1.3	1.0
Stockings, tights, socks	0.6	0.6	0.6	0.5
Articles of fur	<0.01	<0.01	<0.01	<0.01
Baby clothes, sportswear, scarfs, handkerchiefs	1.3	1.2	1.3	1.3
Blouses, shirts, T-shirts, underpants, pyjamas	2.8	2.5	2.6	2.0
Coats, jackets, trousers, skirts, suits, dresses	1.8	1.2	1.7	0.8
Workwear	0.2	0.3	0.3	0.3
Leather clothes	0.04	0.03	0.02	0.02

Total clothing	7.4	8.1	7.9	6.0
Bed linen, towels, curtains, furnishings, tents, sails	5.1	4.4	5.4	6.1
Total household textiles	5.1	4.4	5.4	6.1
TOTAL (clothing, footwear and household textiles)	15.7	16.8	16.9	14.8

Source: ETC/CE Report 2/2022 [19].

The textiles sector is a major part of the EU economy. Moreover, it is the third largest employer in the world, after food processing and housing, and this is clear from the data [19]. (fig. 1).

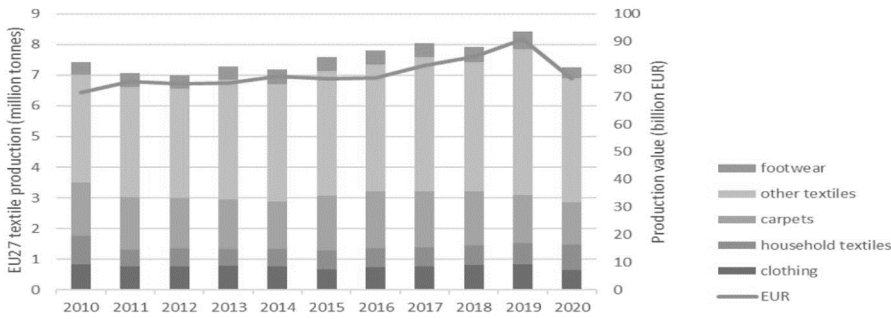


Fig. 1. EU27 production of textile related products, 2010-2020, in million tonnes and billion EUR.

Source: ETC/CE Report 2/2022 [19].

Europe has a massive textile waste problem - currently 7 to 7.5 million tons are generated annually (mainly in private households), but only about 30 to 35 percent is collected separately and less than 1 percent of textile waste is currently recycled into new clothing.

According to the McKinsey study, at least one-fifth of textile waste could become new clothing, and a circular economy for textiles could create 15,000 new jobs in Europe by 2030 and reach a market size of 6 to 8 billion euros. However, this would require kick-off investments of 6 to 7 billion euros by 2030, and this throughout the value chain, for example for collecting and sorting textile waste and the establishment of recycling facilities [20].

An economy that is characterised as climate-neutral and resource-efficient has as its main objective the prevention of waste. A key aspect in research on textile waste generated is its management [21, 22, 23]. A review of the scientific literature found some research studies as follows: textile and fashion industry is credited as world's most wasteful and polluting (second only to oil industry), energy-intensive and an inefficient industry, thanks to the extensive exploitation of natural resources and ever increasing consumption of pesticides, fertilizers and other toxic chemicals. The massive soil degradation, emission of greenhouse gases, increase in carbon footprint and water pollution from the textile and fashion industries are some of the issues that need to be desided [24]; the paper presents a model developed to analyze industrial textile waste streams and develop scenarios for sound waste management [25]; in the research is highlight the challenges and issues involved in managing textile waste concerning environmental concerns and outline methods to increase the usefulness of this resource [26]; as viral crises spread around the globe, the demand for medical textile products have skyrocketed, resulting in significant

growth of the waste stream. Therefore, it is imperative to identify the current situation with particular emphasis on the environmental impact and health hazards of medxzxsical textile waste, and to provide a relevant review of the systematic strategies and approaches of the waste management , with the aims to minimize negative impact of the waste [27].

2.3 Textile waste in the context of the circular economy

Growing awareness of the circular economy of waste motivates valorization strategies to minimize resource consumption and waste production in the private sector. With the rise of various industrial wastes and with the emergence of COVID-19 waste, a sustainable approach was needed to mitigate the growing waste concern [28]. Textile and apparel production in the upstream fashion supply chain generates significant material waste that requires urgent efforts to effectively manage, reduce environmental impact and promote sustainable practices [29].

The importance of reusing or recycling textile waste becomes more prominent when it is considered that for the production of one T-shirt and one pair of cotton jeans, 2720 liters and 10,850 liters of water, respectively, are needed. However, it has been seen that recycling of textile products falls behind recycling of other materials. While 15–20% of textile materials are recycled, 80% of steel, 65% of paper, and 30% of plastics are recycled [12].

According to the National Environment Agency (NEA) [33], In 2021, about 6.94 million tonnes of solid waste was generated, of which 3.83 million tonnes were recycled. Waste generated by the non-domestic and domestic sectors both increased in 2021, from 4.12 million tonnes and 1.77 million tonnes respectively in 2020, to 5.12 million tonnes and 1.82 million tonnes respectively in 2021. Recycled waste attributed to the non-domestic and domestic sectors likewise increased, from 2.81 million tonnes and 0.23 million tonnes respectively in 2020, to 3.58 million tonnes and 0.24 million tonnes respectively in 2021.

2020 was an anomalous year with lower waste generation and recycling rates due to the impact of COVID-19, particularly during the Circuit Breaker period (April to May 2020) when activities were curtailed. The pick up in economic activity, and resumption of business and social activities in 2021 have led to a 10 per cent increase in waste disposal, while 26 per cent more waste was recycled.

Compared to the period before COVID-19 pandemic in 2019, 2021 saw 5 per cent less waste generated and 5 per cent more waste disposed, with the amount of waste recycled being lower by 11 per cent.

With waste generation growing as economic activities ramp up, there is greater urgency to shift from a linear to a circular economy, which is a key part of the Zero Waste Masterplan and the Singapore Green Plan. NEA will continue to engage businesses and consumers to put in place more sustainable practices (table 2).

Table 2. Waste Statistics and Overall Recycling of Textile/Leather (2017 – 2021).

Year	Total Generated ('000 tonnes)	Total Recycled ('000 tonnes)	Recycling Rate (%)	Overall recycling rate	Total Disposed ('000 tonnes)
2017	151	10	6	61	141
2018	220	14	6	62	206
2019	168	6	4	59	161
2020	137	6	4	52	131
2021	189	7	4	55	182

Note: Figures are rounded to the nearest thousand tonnes and percentage point.
Source: National Environment Agency, 2022 [30].

It can be noticed that for the entire period of the study Total Recycled Volumes are very few compared to the generated ones, shown on tabl. 2. Disposal takes precedence in the hierarchy of waste, thereby creating a prerequisite for the accumulation and inefficient use of secondary fibers within the closed cycle provided and demanded by the circular economy. In the composition of waste, textile fibers are a raw material and policies with their disposal after the end of their life cycle should be reconsidered in the context of sustainable textile production that closes the circle.

Textile fibers occupy an extremely small share of the total amount of recycled waste - Paper/Cardboard, Ferrous metal, Plastics, Construction & Demolition (C&D), Food, Horticultural, Wood, Ash & sludge, Used slag, Non-ferrous metal, Glass, Scrap tires, Others (stones, ceramics, etc.).- The data for 2021 are indicative and continue the trends since 2017 (table 3):

Table 3. 2021 Waste Statistics and Overall Recycling.

Year	Total Generated ('000 tonnes)	Total Recycled ('000 tonnes)	Recycling Rate (%)	Total Disposed ('000 tonnes)
Ferrous metal	1,312	1,306	99	6
Paper/Cardboard	1,136	437	39	699
Construction & Demolition	1,013	1,011	99	2
Plastics	982	58	6	924
Food	817	154	19	663
Horticultural	332	277	83	55
Wood	310	234	76	76
Ash & sludge	249	22	9	227
Textile/Leather	189	7	4	182
Used slag	182	181	99	1
Non-ferrous metal	88	87	98	1
Glass	74	9	13	65
Scrap tyres	27	26	95	1
Others (stones, ceramics, etc.)	233	18	8	214
Overall	6.944	3.826	55	3.118

Note: Figures are rounded to the nearest thousand tonnes and percentage point.

Source: National Environment Agency, 2022 [30]

The main problem with waste management is its alternative and reality. The predominant direction of textile waste management in/out of Europe is incineration or landfill, with 85% of the *post-consumer waste*.

The McKinsey& Company analysis indicates that fiber-to-fiber recycling could reach 18 to 26 percent of gross textile waste in 2030. This will require significant investment for capital expenditure in the textile industry, but analyses show that the sector can thus become profitable (1.5 to 2.2 billion euros) by 2030 [31].

The importance of textile waste for the circular economy has been proven in various scientific studies: The study achieved one of the main parameters of the circular economy - carbon footprint reduction and recovery. Authors succeeded in obtaining cotton and polyester fibers through chemical technology of textile waste [32]; The study's results showed that in Romania only a small part of the clothing products no longer used end up in the garbage, still, there is a danger that this quantity will increase in the future, as most citizens have no knowledge about the existence of recycling centres or these centres do not exist in the localities where they live. Even if a relatively high number of respondents are

aware that textile products can be recycled, only a small part of them use this method. It also shows that there is a potential growth of the market for products obtained from the recovery, recycling, and re-use of textiles [33]; in the review are compare different ways of waste wool processing, focused on biotechnological applications [34] in research are presented the recent scientific research, focused on the application of recycled fibers, taken from textile waste, in the field of composite materials to fulfill the ecosustainability requirements of textile manufacturing, and promote actions for a circular economy [35]; in a study identified and described the practices for the management of textile waste after the use of clothing and to analyze them according to environmental, economic and social criteria in the circular economy context [36]; the creation of a circular economy for cellulose based textile waste is supported by the development of an upcycling method for cotton polyester blended waste garments [37]; in this article is made a review summarized the valorisation potential of a textile waste products, especially of flax, hemp and jute fabrics. In this context application of different textile wastes for development of some value added product has been thought of in the paper [38].

The study presents the trends and perspectives in the circular economy, the characteristics of textile waste and the relationship between them through a survey of the scientific literature and economic aspects in the research area. It has been found that a good knowledge of the most current scientific research on textile waste in the context of the circular economy and economic analysis combined can give good results in the research area.

3 Conclusions

In conclusion, it can be summarized that current scientific research and an economic analysis done on textile waste in the context of the circular economy have been explored. The various author collectives work in the field of textile waste, its management and its connection with the circular economy. This is a premise that the obtained scientific results can help with the realization of community/state policies, which have a long horizon of implementation and aim to reduce the harmful ecological footprint of the production of textile goods and discarded textile waste with the development of various activities, such as informing , collection, sorting, recycling, trial of new methods and technologies in the field.

Research in the field of textiles shows the great importance and fundamental role of textile waste for the realization of the circular economy concept. Like other fibers, textile fibers at the end of their life cycle prove to be a valuable raw material for the textile sector. Moreover, textile waste is an excellent example of the manifestation of the circular economy and the possibilities for more efficient utilization and production of products in harmony with sought-after and proclaimed trends within the framework of the only possible economy in modern conditions, such closing the circle.

Future research could be directed towards exploring an even larger number of scientific studies in the field of textile waste, textile waste management, new trends (upcycling) and their connection with the circular economy, which would enable them to be detailed, systematized and grouped the different types and types of studies. The results obtained will provide guidance for future research in line with community/state circular economy policies regarding the textile industry and the textile waste generated by it and consumers.

References

1. The circular economy: what it is and why it matters, European Parliament, (2015). <https://www.europarl.europa.eu/news/bg/headlines/economy/20151201STO05603/krg-hovata-ikonomika-kakvo-predstavliava-tia-i-zashcho-e-vazhna>
2. EU strategy for sustainable and circular textiles, European Commission, (2022). https://environment.ec.europa.eu/strategy/textiles-strategy_en
3. How textile production pollutes the environment (infographic), European Parliament, (2020). <https://www.europarl.europa.eu/news/bg/headlines/priorities/namaliavane-na-otpadtsite/20201208STO93327/kak-tekstilnata-produktsiia-zamrsiava-okolnata-sreda-infoghrafika>
4. Circular economy: how the EU wants to make products more sustainable, European Parliament, (2021). <https://www.europarl.europa.eu/news/bg/headlines/society/20210128STO96607/krgho-va-ikonomika-kak-es-iska-da-napravi-produktite-po-ustoychivi>
5. Moraga G., Huysveld S., Mathieux F., Blengini G.A., Alaerts L., Van Acker K., de Meester S., Dewulf J., Conservation and Recycling **146**, 452-461, (2019), ISSN 0921-3449, <https://doi.org/10.1016/j.resconrec.2019.03.045>.
6. Castro C., Trevisan A., C.A. Pigosso D., Mascarenhas J., Journal of Cleaner Production **45**, 131136 (2022) ISSN 0959-6526, <https://doi.org/10.1016/j.jclepro.2022.131136>.
7. Lahcen B., Eyckmans L., Rousseau S., Dams Y., Brusselsaers J., Ecological Economics **197**, 107451 (2022) ISSN 0921-8009, <https://doi.org/10.1016/j.ecolecon.2022.107451>.
8. Winans K., Kendall A., Deng H., Renewable and Sustainable Energy Reviews **68(1)**, 825-833 (2017) ISSN 1364-0321, <https://doi.org/10.1016/j.rser.2016.09.123>.
9. Nuce M., Three Trends Driving Development of a Circular Economy. (Supply Chain Brain Magazine, 2022) <https://www.supplychainbrain.com/articles/35021-three-trends-driving-development-of-a-circular-economy>
10. Chen X., Memon H.A., Wang Y., Marriam I., Tebyetekerwa M., Materials Circular Economy **3**, 12 (2021) <https://doi.org/10.1007/s42824-021-00026-2>.
11. Denić D., Bošković G., Pavlović A., Jovičić N., Tekstilna industrija **1**, 47-57 (2021)
12. Yalcin-Enis I., Kucukali-Ozturk M., Sezgin H., *Risks and Management of Textile Waste. Nanoscience and Biotechnology for Environmental Applications*. Environmental Chemistry for a Sustainable World, Springer, Cham, **2(22)**, pp. 29-53, (2019), https://doi.org/10.1007/978-3-319-97922-9_2.
13. Directive 2008/98/EC of the European Parliament and of The Council of 19 November 2008 on waste and repealing certain Directives (Text with EEA relevance).
14. Wiesmeth H., Textiles in a circular economy, Implementing the Circular Economy for Sustainable Development **24**, 291-302 (2021)
15. Sourcing textile waste, Redress, 1-28, (2019), https://static1.squarespace.com/static/582d0d16440243165eb756db/t/5dcd14454658fc2b8e087c6a/1573721165094/LEARN_So.
16. Juanga-Labayen J.P., Labayen I.V., Yuan Q., Textiles **2**, 174–188 (2022) <https://doi.org/10.3390/textiles2010010>.
17. Fernández L., Distribution of textile fibers production worldwide in 2020, by type, Statista, (2021), <https://www.statista.com/statistics/1250812/global-fiber-production-share-type/>.

18. Dottle R., Gu J., The Global Glut of Clothing Is an Environmental Crisis (2022) <https://www.bloomberg.com/graphics/2022-fashion-industry-environmental-impact/?leadSource=uverify%20wall>
19. Dils E., ETC/CE Report 2/2022, Textiles and the Environment - The role of design in Europe's circular economy, (2022) <https://www.eionet.europa.eu/etcs/etc-ce/products/etc-ce-products/etc-ce-report-2-2022-textiles-and-the-environment-the-role-of-design-in-europes-circular-economy>.
20. Preuss S., Textile recycling study: “Europe will lead the way”, FASHIONUNITED, (2022). <https://fashionunited.uk/news/business/textile-recycling-study-europe-will-lead-the-way/2022071564153>.
21. European Environment Agency, Progress towards preventing waste in Europe — the case of textile waste prevention, European Environment Agency **15**, 3-71, (2021).
22. Tripa S., Indrie L., Zlatev Z. D., Tripa F., Industria Textilă **73(3)**, 275-281, (2022).
23. Zhou Q., Le Q. V., Meng L., Yang H., Gu H., Yang Y., Chen X., Lam S. S., Sonne C., Peng W., Environmental Technology Reviews **11(1)**, 62-71, (2022), doi: 10.1080/21622515.2021.2017000
24. Dhir Y. J., The Textile Institute Book Series, **2**, 31-58, (2021).
25. Rapsikevičienė J., Gurauskienė I., Jučienė A., Engineering and Management **75(1)**, 43-55, (2019).
26. Pervez M. N., Mondal M. I. H., Cai Y., Zhao Y., Naddeo V., The Textile Institute Book Series **21**, 719-739, (2021), <https://doi.org/10.1016/B978-0-12-821483-1.00002-4>.
27. Yuliana M., Santoso S. P., Putro J. N., Wijaya C. J., Lunardi V. B., The Textile Institute Book Series **26**, 829-864 (2022)
28. Felix C., Ubando A., Chen W., Goodarzi V., Ashokkumar V., Journal of Hazardous Materials **423(B)**, 127215 (2022) ISSN 0304-3894 <https://doi.org/10.1016/j.jhazmat.2021.127215>.
29. Akter M., Haq U., Islam M., Uddin M., Cleaner Environmental Systems **4**, 100070 (2022) ISSN 2666-7894 <https://doi.org/10.1016/j.cesys.2022.100070>.
30. Waste Statistics and Overall Recycling, National Environment Agency, (2022), <https://www.nea.gov.sg/our-services/waste-management/waste-statistics-and-overall-recycling>
31. Scaling textile recycling in Europe—turning waste into value, McKinsey&Company, (2022), <https://www.mckinsey.com/industries/retail/our-insights/scaling-textile-recycling-in-europe-turning-waste-into-value>.
32. Yousef S., Tatariants M., Tichonovas M., Kliucininkas L., Lukošiuūtė S.-I., Yan L., Journal of Cleaner Production **254**, 1-11 (2020)
33. Tripa S. and Indrie L., Environmental Engineering & Management Journal (EEMJ) **20(1)**, 81-87 (2021)
34. Petek B. and Logar R. M., Journal of Material Cycles and Waste Management **23**, 44–54 (2021) <https://doi.org/10.1007/s10163-020-01121-3>
35. Patti A., Cicala G. and Acierno D., Polymers **13(134)**, 1-25 (2021) <https://doi.org/10.3390/polym13010134>.
36. Santos P.S. and Campos L.M.S., Brazilian Journal of Operations & Production Management **18(1)**, 1-17 (2021) e20211084. <https://doi.org/10.14488/BJOPM.2021.004>.

37. Haslinger S., Hummel M., Anghelescu-Hakala A., Määttänen M. and Sixta H., *Waste Management* **97**, 88-96 (2019)
38. Todor M. P., Bulei C., Kiss I. and Alexa V., *IOP Conf. Series: Materials Science and Engineering* **477**, 1-8 (2019)