IMPLEMENTING THE CIRCULAR ECONOMY IN THE TEXTILE AND CLOTHING INDUSTRY: BARRIERS AND OPPORTUNITIES

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ABSTRACT

The circular economy (CE) model has been widely studied by the scientific community as a viable solution to reconcile economic growth with environmental sustainability. What exists today in the textile and clothing area is a model that extracts, manufactures, uses and discards incessantly. Through the analysis of several recent studies, this work intends to analyze what has been produced in the literature to point out the barriers that prevent the implementation of CE in the textile field, as well as the opportunities to execute it. Mistakes in the manufacturing process, design phase, disregard for the extension of product life cycles, as well as the need for collaboration of those involved in the supply chain, as well as the demand for product tracking, are some of the problems diagnosed. As a result, there is the identification of samples of the mistakes that have been causing environmental disasters around the world. After all, clothes and textiles accompany practically all human beings worldwide and their poor disposal has proven devastating.

Keywords: Circular Economy. Sustainable design. Textile industry.

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INTRODUCTION

For many years, threads and fibers have accompanied the life of the human being. However, this company has charged an exorbitant price. It is not only waste that textile production causes. The process used for its manufacture has serious consequences for the environment, such as excessive use of energy and water, in addition to causing chemical pollution, soil degradation, and emissions of harmful gases (SHIRVANIMOGHADDAM et al., 2020; HUANG et. al, 2021; KAZANCOGLU et. al, 2020).

When linked to the linear system of consumption, the concern with the abundant generation of waste rises in the face of the fact that we have finite resources on our planet. What is seen in this model is the manufacture of products that extract natural resources, are manufactured, little used and discarded (FRANCO, 2017). To this end, environmental capital is disregarded, prioritizing consumption and revenue generation in order to correspond to ephemeral desires.

In this sense, *fast fashion* poses a threat, as it is responsible for about 10% of all global carbon emissions (WEF, 2023). Producing parts in huge quantities, quickly and at an affordable price (CHEN et al. 2021; IKRAM, 2022), contributes to the consumer believing that they are buying disposable products (RATHINAMOORTHY, 2019). This causes clothes and textile products to generate an uncontrollable production of toxic waste, ending up in landfills or being incinerated (FISCHER; PASCUCCI, 2017). For example, companies such as the multinational Zara launch 24 collections per year (KOSZEWSKA, 2018).

However, the literature has been presenting something that seems to be able to put an end to this pattern. The Circular Economy (CE) model has been widely discussed as a way to eliminate these problems, through the zero waste culture (SAHA; DEY; PAPAGIANNAKI, 2021; FISCHER; PASCUCCI, 2017; KAZANCOGLU et al., 2020; KAZANCOGLU et al., 2022; KOSZEWSKA, 2018). This debate goes hand in hand with the need for a more sustainable and environmentally balanced life (KAZANCOGLU, 2020).

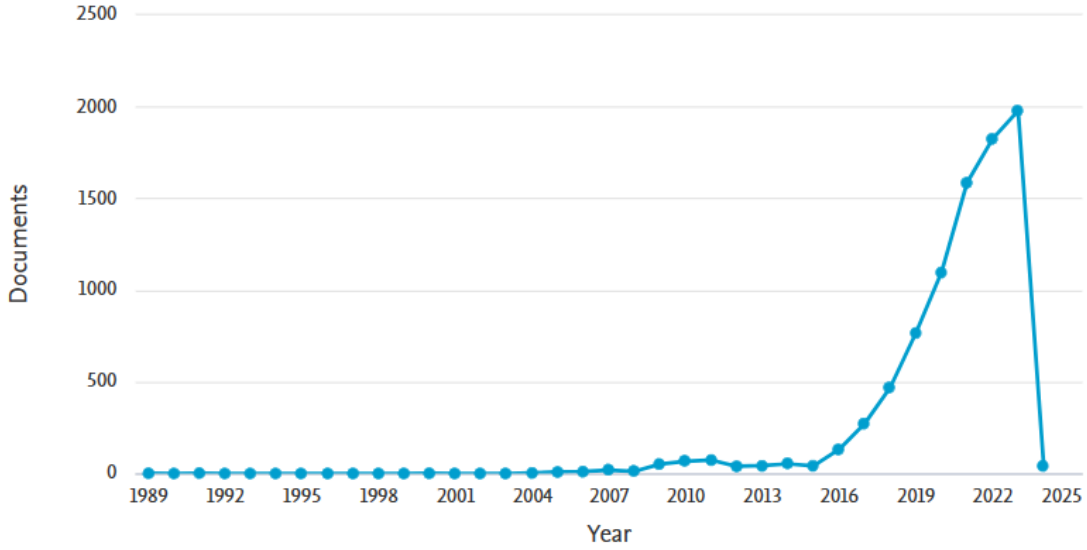
Kirchherr et al. (2023) analyzed 221 definitions of CE to understand what are the current understandings of its concept in the scientific community. They concluded that CE is a regenerative economic system that should replace the concept of end-of-life, among other possibilities, with reuse, with the objective of maintaining value and sustainable development for the benefit of current and future generations. CE is synonymous with a regenerative industrial economy without the use of virgin raw materials (FRANCO, 2017), giving meaning to waste, which becomes a resource (JIA et al. 2020). In view of this, abandoning the linear consumption model seems to be essential.

JUSTIFICATION

The work is justified by the urgency of finding elements that bring a feasible result to a serious problem that has confronted the world as a whole. The implementation of CE can represent a hope that brings strength to the search for a life in a world closer to sustainability. For this, it must be scrutinized and no one better than the scientific community to compile and critically process works that focus on this objective.

The EC study has attracted the attention of researchers around the world. In consultation on the Scopus platform in the title of articles, 8,583 documents were found, 1,979 in 2023 alone.

Figure 1 – Number of papers that contain the term Circular Economy in the title in the Scopus database.

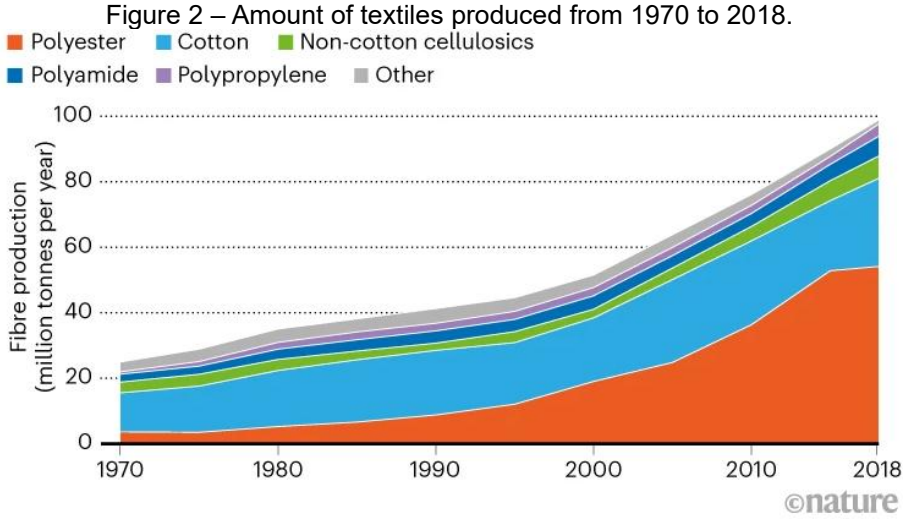


Source: SCOPUS, 2023.

Much of the value of labor lies in the fact that in the last 20 years, the use of textile products has grown from 7kg to 13kg per person annually, representing a total of 100 million tons per year consumed worldwide. However, although these numbers are expressive and apparently financially positive, they contrast with the fact that more than 60% of textile waste is treated as garbage and only 15% is recycled (SHIRVANIMOGHADDAM et.al, 2020). There are about 92 million tons produced every year that end up in landfills or incinerated, which is raw material that could be reused (SAVAGE, 2022). Between 2000 and 2015, world clothing production doubled, but the average number of times garments were worn before being discarded decreased by 36% (NATURE, 2022; WEF, 2023). The textile industry is considered one of the most polluting in the world, along with civil construction, transportation, and the food industry (LEAL et al., 2019). Around 35% of microplastics dumped into the waters come from the textile industry (EUROPEAN PARLIAMENT, 2023).

Globally, textile production has been growing since the 1970s. The fiber that grows the most is polyester (SAVAGE, 2022).

Figure 2 – Amount of textiles produced from 1970 to 2018.



Source: (SAVAGE, 2022).

Not even natural fibers come unaccompanied by harmful effects on the environment. To give a practical example, to make a single cotton T-shirt, 2,700 liters of water are needed, enough to meet the needs of a person for two and a half years (EUROPEAN PARLIAMENT, 2023). The use of pesticides, herbicides and fertilizers in the cultivation of natural fibers is high (FRANCO, 2017; PATTI; CICALA; ACIERNO, 2021). In addition, according to Giacomin, Soares and Pacca (2022), for every 1 million dollars demanded in textile products, there is a global emission of 643.6 tCO2e.

Therefore, generating more and more textile products is incompatible with a healthy life. The world needs to be aware of the fact that linear consumption needs to come to an end, and it is elementary and urgent to close the consumption circuit. The topic has been researched in several renowned scientific journals around the world, as shown in the table below. Hence the need to bring this possibility closer to our reality through existing studies and to follow the unfolding of the world literature.

SYNTHESIS OF THE FUNDAMENTAL BIBLIOGRAPHY

Textile fibers can be divided into two main categories. On the one hand, natural ones, such as cotton, wool, sisal and silk, among others. On the other hand, there are synthetic fibers, such as polyester, *nylon* or acrylic, to exemplify. The latter are not biodegradable and, as they are very small in size, they are more harmful than plastics, and can dump microplastics into waterways (IKRAM, 2022). In addition, synthetic fibers are

extracted from non-renewable sources and use fossil fuels. They represent more than 68% of current fibers (CHEN et al., 2021).

Going further, there seems to be a lack of commitment to fostering initiatives that question the manufacture of textile products. To cite a practical case of this disregard, it is currently easy to find textiles made with mixed fibers on the market. However, mixing them can be harmful. Polyester-based fibers, an umbrella term for petroleum-derived materials (SAVAGE, 2022), commonly come mixed with natural fibers. This makes the recycling process difficult, in order to maintain the quality of this post-consumer waste (FRANCO, 2017; JIA et al., 2020; SANDVIK; STUBBS, 2019; PATTI; CICALA; ACIERNO, 2021; LEAL et al., 2019; KAZANCOGLU et al., 2022; KOSZEWSKA, 2018).

In the case of the mixture of isolated synthetic fibers, it is possible to recycle them through a process that breaks them down chemically. After this, they are fused into new fibers with properties exactly similar to virgin fibers. However, this process is expensive and, therefore, recycled fibers will be priced higher than the original ones (CHEN et al., 2021; DISSANAYAKE; WEERASINGHE; 2021). It is important to note that synthetic fibers are more polluting, dumping three times more carbon dioxide into the atmosphere than natural fibers (RATHINAMOORTHY, 2019; IKRAM, 2022).

The design of the fibers plays an essential role, since it is responsible for its destiny. Commonly, if a product is generated with low-quality characteristics, it loses added value when recycled and has to be used in lower-priced goods, such as elements used in thermal and acoustic insulation, cushion filling, in the production of bricks (SHIRVANIMOGHADDAM et al., 2020; SANDVIK; STUBBS, 2019; DISSANAYAKE; WEERASINGHE; 2021), stuffing for teddy bears, shoe insoles, for carpet bases (LEAL et al., 2019), mattress filling (CHEN et al., 2021) or cleaning cloths (WEF, 2023).

When fabrics have quality in their first life, the greater the possibility of them being used to make new fabrics of greater value (FISCHER; PASCUCCI, 2017). Therefore, thinking about creating durable goods and extending life cycles should be a goal from the beginning of the design of a textile product (FISCHER.; PASCUCCI. 2017; SHIRVANIMOGHADDAM et al., 2020; SANDVIK; STUBBS, 2019; FRANCO, 2017; CHEN et al., 2021, RATHINAMOORTHY, 2019; DISSANAYAKE; WEERASINGHE; 2021). Creating items made to be reused has to be a function of the *designer* from the conception of a good (GOLÇALVES-DIAS; YUMNA; CIPRIANO), since about 80% of the environmental impact of a product is determined in its design stage (DISSANAYAKE; WEERASINGHE; 2021). The ease or difficulty that recycling partners will encounter will be determined from the choice of

materials, dictating their possibility of separation, for example (FRANCO, 2017; KAZANCOGLU et al., 2022; KOSZEWSKA, 2018).

When creating the product, the *designer* must keep in mind that his choices may include his work in the possibility or impossibility of being part of a circular system. The choice of environmentally compatible raw material with recycling and non-hazardous disposal, selection of dyes, solvents and finishes will be decisive in defining their entire life cycle, and may make it less likely that they will end up in landfills (KOSZEWSKA, 2018; JIA et al., 2020). Businesses have to be thought of, from the beginning, to be circular (NATURE, 2022 – author not informed). However, *design* for an extended life or for a second life is rarely taken into account (LEAL et al., 2019). Therefore, the components of a commodity are decisive, affecting the variety of new goods that can be developed with their existing resources (JIA et. al, 2020). It is designing thinking about dismantling (DISSANAYAKE; WEERASINGHE; 2021).

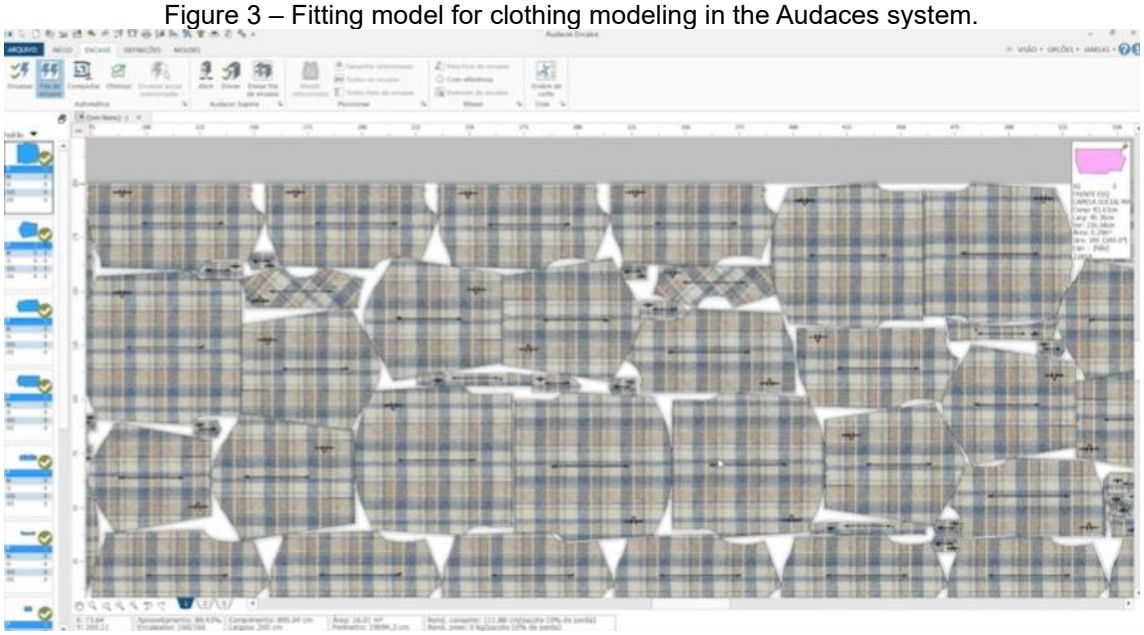
Following this logic, the more components a product has, the more challenging its circularity process will be (KAZANCOGLU et. al, 2020). After all, in addition to fabric, clothes can carry trimmings, zippers and labels that are difficult to recycle (SANDVIK; STUBBS, 2019). It is a complex mixture of materials, not only different natural and synthetic fibers, but also dyes and chemical coatings, which must be separated (SAVAGE, 2022). A bra has fins, fabrics of different compositions, foam cups and rings, for example (FRANCO, 2017). In this way, the need to train specialized personnel is also essential. For Kazancoglu et al. (2022), the textile recycling process requires significant knowledge in order to deal with different components and materials existing in this process.

In this case, only the elements contained after the production of the product are being considered. Before this, the dyeing process pollutes the soil, water, and atmosphere due to the large amount of toxic waste used (LEAL et al., 2019). There are also phases of fiber production, yarn production, pre-treatment, printing and finishing. Again, during them, toxic chemicals, excessive water use, atmospheric emissions, or abundant energy consumption may be present. In addition, companies producing textile materials are often located in countries far from consumers. In order for them to reach their final destination, fossil fuels are used, ensuring more pollution. To make matters worse, it is common for products to come packaged in non-biodegradable plastic bags (PATTI; CICALA; ACIERNO, 2021).

Going further, the fit of the modeling also plays a fundamental role. An elementary process in the manufacture of a garment can be responsible for about 15% of fabric

disposal (DISSANAYAKE; WEERASINGHE; 2021). *Modeling* nesting software such as Audaces Encaixe (AUDACES, 2023) can reduce this waste.

Figure 3 – Fitting model for clothing modeling in the Audaces system.



SOURCE: Audaces, 2023.

In addition to thinking about the concrete manufacture of a fabric, to achieve circularity, there must be collaboration between the supply chain (CS) and the partners involved in it, in order to create innovative materials (JIA et al., 2020). For this, new business models must also be conceived (FRANCO, 2017; LEAL et al. 2019; KAZANCOGLU et al., 2022; KOSZEWSKA, 2018; EUROPEAN PARLIAMENT, 2023; DISSANAYAKE; WEERASINGHE; 2021). To adopt a circular model, companies must establish a relationship with each other, reformulating property rights and laws, jointly identifying sustainable solutions (FISCHER.; PASCUCCI. 2017), in addition to promoting the emergence of industrial, technological and classification standards common to all of them (LEAL et al., 2019). For this to occur, the governmental role can also be decisive, creating laws that encourage standardization to achieve sustainable practices (DISSANAYAKE; WEERASINGHE; 2021).

Textile CS is long and involves different participants. They are *designers*, raw material suppliers, clothing manufacturers, brand owners, merchants and retailers. The improvements that lead to CE require that all those involved, directly or indirectly, are integrated in terms of standardization, collaboration, communication, and coordination, avoiding loss of control or trust among them (KAZANCOGLU et al., 2022).

In order to create standards, initiatives such as Cradle to Cradle (C2C) are welcome. C2C is a certification program conferred by the non-profit organization Cradle to Cradle

Products Innovation Institute for producers who intend to implement CE. Since 2005, when it began, the program has already granted more than 400 certifications for materials, products and systems in the areas of civil construction, interior *design*, paper and textiles, among others, for those who intend to optimize their materials and the *design* of their products (FRANCO, 2017; FISCHER.; PASCUCCI, 2017).

Saha, Dey, and Papagiannaki (2021) highlight that, in addition to the technical and technological difficulties that discourage the implementation of CE, the excessive focus on becoming financially viable intimidates the investor. Low-cost manufacturing is often accompanied by cheap labor in large quantities, in countries that prioritize economic performance over environmental commitment. For Dissanayke and Weerasinghe (2021), many entrepreneurs do not see waste as a resource, since recycling is often more expensive than buying new raw materials.

With a globalized, complex and extremely fragmented CS, with several *stakeholders*, the textile sector needs communication, engagement and commitment among stakeholders (DISSANAYAKE; WEERASINGHE; 2021). After all, there are many cases in which the same textile product is produced in different countries, subject to different laws, which makes it necessary to have a record of the processes that accompanied its design. For example, a chemical component may be allowed in one country and banned in another.

In this sense, product tracking is also a necessity. The use of technology can facilitate this process in order to make it feasible to know the location or condition of an asset, enabling its reverse logistics, wherever it is (FRANCO, 2017; DISSANAYAKE; WEERASINGHE; 2021). This can be done by placing bar codes and radio frequency identifiers (FRANCO, 2017) so that, at the end of the cycle, it is possible to know the composition of the material used and other manufacturing conditions (JIA et al., 2020; KAZANCOGLU et al., 2022). The transparency allowed by digitalization makes it possible to create product identification standards for the moment they are to be recycled (SANDVIK; STUBBS, 2019).

In cases like this, *Blockchain* technology can be a tool capable of providing traceability and transparency to CS (IKRAM, 2022). It allows you to record, in an auditable and secure way, information such as origin, what materials it contains or certifications granted to that product. *Blockchain* is capable of providing *compliance*, transparency, traceability, error reduction, among other advantages such as archiving important information throughout CS (LEAL et al., 2019).

What seems to be a problem, in fact, is a great opportunity. For the European Commission, the reuse of waste through EC can even represent a financial advantage. For

her, the reuse of waste and the "implementation of additional measures to increase resource productivity by 30% by 2030 could increase GDP by about 1%, while creating more than 2 million jobs" (EUROPEAN COMMISSION, 2023).

For all the above, it is clear that it is essential to face the current reality of textile disposal and the possibilities of mitigating losses and knowing the opportunities that it entails. Academic studies on the subject have been produced worldwide, offering the opportunity to research this scenario within academia with current information.

OBJECTIVES

The main objective of the project is to answer the following question: what are the barriers and opportunities for the implementation of CE by the textile industry? Thus, this study intends to scrutinize the literature and studies focused on this purpose, presenting components to find the answer to this guiding question.

After all, there is no more time to learn from mistakes. Otherwise, the consequences can be disastrous. There is no more time to make mistakes. Planet Earth has limited resources and it has responded, in practice, to the aggressions it has been suffering. Climate change is a response to every offense to the environment. The result is constant flooding, drought or excessive heat, for example.

MATERIALS AND METHODS

A systematic review was carried out and the preliminary review pointed out works, mostly in English, all seeking to outline the problems and resources available for the implementation of CE in the textile area. The general objective was to map what has been worked on CE in the textile field worldwide, since, in order to find the solution, it is necessary, first of all, to diagnose this lesion that has affected the whole world in such a resistant way. For this, it is essential to establish possible paths for consumption so as not to cause environmental degradation. The specific objectives are to recognize the general characteristics of the researched field, the world textile scenario, to demonstrate the aggressive potential to the environment of the textile area, to briefly define the CE, as well as to quantitatively contextualize the consumption of textiles in the world.

In view of this, the project, of a descriptive exploratory nature, adopted a systematic literature review method. This type of research allows for a comprehensive, transparent analysis with reflective interpretation (OKOLI; SCHABRAM, 2010). The focus was not to exhaust the bibliometric analysis on the subject, but to know the general characteristics of the problem, as advised by Silva (2017).

For the systematic review of the literature, the Web of Science and Scopus databases were used. The choice for these platforms lies in the fact that they contain a vast number of journals, all peer-reviewed, published continuously, and capable of reaching an international audience. The inclusion and exclusion criteria followed the table below:

Table 3 – Criteria for Systematic Review of the Project's Literature.

FIELDS SEARCHED	*Abstract* and title
SEARCH STRING	*Circular* AND *economy* AND *textile*
INCLUSION CRITERIA	Peer-reviewed articles that dealt with textiles, open access, or were available using VPN, and that were cited more than 50 times.
EXCLUSION CRITERIA	Articles from the materials area.

Source: prepared by the authors, 2023.

As a result, after the systematic review, 11 articles were found, published between 2017 and 2022.

Table 4 – References and number of citations of each article included in the Systematic Review of Literature.

DATABASE	AUTHORS	TITLE	NUMBER OF CITATIONS
Scopus	Saha, K; Dey, P; Papagiannaki, A. (2021)	Implementing circular economy in the textile and clothing industry	55
WoS			58
WoS	KOSZEWSKA, M. (2018)	Circular economy – chalenges for the textile and clothing industry	107
Scopus			132
WoS	Shirvanimogaddam, K.; Motamed, B.; Ramakrishna, S.; Meenu, N. (2020)	Death by waste: Fashion and textile circular economy case	152
WoS	FISCHER, A.; PASCUCCI S. (2017)	Institutional incentives in circular economy transition: The case of material use in the Dutch textile industry	175
Scopus			218
WoS	FRANCO, M. (2017)	Circular economy at the micro level: A dynamic view of incumbents' struggles and challenges in the textile industry	196
Scopus			246
WoS	SANDVIK, I; STUBBS, W. (2019)	Circular fashion supply chain through textile-to-textile recycling	107
Scopus			128
Scopus	PATTI, A.; CICALA, G.; ACIERNO, D. (2021)	Eco-sustainability of the textile production: Waste recovery and current recycling in the composites world	63
WoS	KAZANÇOĞLU, İ.; KAZANCOGLU, Y.; HERO A.; YARIMOGLU, E.; SONI, G. (2022)	Investigating barriers to circular supply chain in the textile industry from Stakeholders' perspective	52
WoS	KAZANÇOĞLU, İ.; KAZANCOGLU, Y.; YARIMOGLU, E.; HERO A. (2020)	A conceptual framework for barriers of circular supply chains for sustainability in the textile industry	60
Scopus			72
Scopus	JIA, F.; YIN, SY.; CHEN, L.; CHEN, X. (2020)	The circular economy in the textile and apparel industry: A systematic literature review	254

WoS	LEAL, W.; ELLAMS, D.; HAN, S.; TYLER, D.; BOITEN, VJ.; PACO, A.; MOORA, H.; BALOGUN, AL. (2019)	A review of the socio-economic advantages of textile recycling	135
Scopus			166

Source: prepared by the authors, 2023.

The authors decided not to use statistics and numbers provided by the authors systematized before 2020, since the year of publication of the articles could compromise their temporal reliability. To this end, material was collected from globally recognized gray literature sources, such as the European Parliament, the World Economic Forum, and the European Commission, all from 2022 to 2023.

It is important to emphasize that the date of publication of the analyzed articles is quite recent, showing the topicality of the theme.

Table 1 – Studies studied in this project, as well as year and journal of publication.

JOURNAL	2017	2018	2019	2020	2021	2022	2023
Nature						2	
Resources, Conservation and Recycling							1
Circular Economy and Sustainability					1		
Journal of Cleaner Production	2		1	1			
Green and Sustainable Chemistry						1	
Sustainable Development					1		
International Journal of Logistics-Research and Application						1	
Materials Circular Economy					1	1	
Autex Research Journal		1					
Polymers					1		
Circular Economy in Textiles and Apparel			1				
Business Strategy and the Environment					1		
Journal of Fashion, Marketing and Management			1				
Science of Total Environment				1			

Source: prepared by the authors, 2023.

CONCLUSION

Linear consumption disregards environmental capital, so it extracts natural resources, manufactures them, and discards them. However, it is essential to replace this model with CE, which allows for the reconciliation of economic growth and sustainable development, since a change in basic logic becomes paramount: garbage must be transformed into a resource. The current textile system represents a huge burden for the whole world.

Globally, since the 1970s, textile consumption has almost quintupled (SAVAGE, 2022). The result is a gigantic generation of non-recycled waste, contamination of the seas by microplastics and aggressive chemicals. According to the World Economic Forum, the

textile and apparel industry is responsible for 4% to 10% of global carbon emissions, which could rise to 26% by 2050 (2023). The disarray, disrespect or ignorance of the producer market causes natural fibers to be mixed with synthetic ones, in a way that makes recycling practically impossible. Low-quality goods are created unlimitedly, resulting in products that, at the end of the first life cycle, are already fated, at best, to be recycled in the form of objects of lesser value, such as pillow filling, for example.

The great contribution of the article is to question new ways of producing, but for this, information and concrete data are needed. For example, the timing of the *design*, as demonstrated, is decisive. The stage of the project is definitive to decide the history of an object, whether its end will be reborn in the form of a new article or whether it will be dumped in a landfill. Product life cycles can be extended and this depends on those who create them. However, little is studied on the subject. The need for collaboration of those involved in the supply chain, in addition to the demand for product tracking, are some of the problems diagnosed. Generating less waste is possible using technology, trained human capital, developing business models that allow reuse or recycling through tools that provide information about the item to be remanufactured, such as *blockchain*.

The general and specific objectives were met, resulting in a frightening panorama. Due to negligence or lack of knowledge or, worse, the union of the two, environmental capital is being despised in a field that is practically omnipresent around the world. Clothing and textiles are embedded in every human being. Therefore, it is necessary to face this reality head-on in order to find ways out of a problem that is planetary. What has happened so far is indifference, as if a textile product or clothing were something superfluous, but they are not.

Finally, it is important to consider the growing awareness of consumers about what they buy. The industry is responsible for manufacturing, but the choice and demand are generated by the customers. Thus, transparency in the sharing of data on SC between them seems to be essential (GIACOMIN; PACCA, 2021).

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