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A literature review on environmental management in the textile industry focused on waste management.

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Abstract. The poor management of various types of waste generated by the textile industry has worsened due to the current high demand, negatively impacting the environment. Multiple methods were employed to evaluate 2,275 articles obtained from ScienceDirect and IEEE, all related to environmental management in the textile industry, with a focus on waste management. Rayyan was used to selectively identify the articles most relevant to the research, resulting in 21 selected articles. Additionally, PRISMA was utilized to create a flowchart that outlines the number of included and excluded articles. This study aims to assess various research studies on environmental management in the textile industry, concentrating specifically on waste management. The novelty of this research lies in identifying opportunities for improvement in sustainability practices within the textile sector. Our findings revealed the most significant pollutants the textile industry produces, including chemical products, greenhouse gases, textile waste, and microplastics. Chemical products accounted for 57.1% of the 20 selected articles. The impact of these contaminants is particularly concerning, as 70.8% of the water resources analyzed are primarily contaminated due to the chemical substances used in textile manufacturing. Furthermore, various potential solutions were evaluated. The most frequently mentioned solutions in the articles were management strategies (28.6%) and chemical solutions (19.0%). Additionally, methods aimed at reducing the environmental impact of textile industries were examined, with the circular economy mentioned in five of the selected articles and absorption cited in four articles.

Keywords: textile; textile industry; environmental management; waste management; pollution.

1. Introduction

Textile consumption per capita in the world varies between 7 and 13 kg, but only 15% and 16% of this waste is recycled annually [1]. Also, of 113 million tons of textile material generated, 87% was discarded, influencing between 2% and 8% of global discharges of global warming gases [2]. The textile and clothing industries are highly polluting, using around 1.5 billion liters of water resources and polluting the sea with more than 190 million tons of microplastics [3]. They also use approximately 2000 different chemicals in the form of dyes, and up to 15% of the dye is lost in this process and is discarded in textile wastewater [4]. Also, in 2018, the sources causing thermal gas releases were energy consumption for the textile dyeing and finishing process, which constituted 29% [5]. The demand for textile fibers worldwide has increased over the past 2 decades, with global manufacturing almost doubling from 58 to 113 million tons during 2000 to 2021 [6]. The environmental impacts of textile production depend on the fibers and methods used [7]. Also, some industries that generate post-consumer waste are landfilled or incinerated [8]. The textile industry uses large amounts of chemicals [9]. Mixed waste textiles are highly polluting and difficult to dispose of, the second most environmentally damaging sector [10]. The carbon footprint of collected unsorted textile waste is twice that of sorted waste [11]. Textile waste includes mixtures of natural and synthetic fibers, such as polyester and nylon, which are not biodegradable [12].

A European study evaluated the effects of various proposed policy interventions to manage textile waste, and the research concluded that sustainably managing waste is sufficient to decrease the dispersion of greenhouse gases and reduce pollution [13]. Likewise, it was identified that most companies dedicated to the textile industry in



metropolitan Lima do not have a plan that focuses on collecting and managing the waste they generate; despite this, a digital platform can be developed to improve this problem [14]. In addition, according to research in the city of Medellin, 60% of textile companies produce at least 300 kg per month of waste; as a solution, it was used as stuffing for mattresses, furniture, and rags [15]. Also, in the research carried out in Bogota, it was concluded that initially, the implementation of the SGA had no interest on the part of various political entities and institutional organizations focused on environmental management [16]. On the other hand, the research carried out in the textile company in Guayaquil made it possible to implement an SGA that covered guidelines, operational processes, and control measures to manage the waste generated.

The literature review is a necessary stage in all research since it guides the research and supports the theoretical concepts based on the work that other authors have previously done; it gathers the most relevant research on the subject and allows us to see how the research structures have been carried out in another way [17]. In this sense, its importance is considered in exploring new research fields because although there are already previous works, new research perspectives can still be sought and innovated in developing knowledge [18]. Databases are critical because they yield a large amount of reliable information. The retrieved publications will be critically reviewed and analyzed to extract key findings and insights [19]. ScienceDirect is one of the most popular publications that offers subscription-based access to large databases [20]. ScienceDirect is Elsevier's platform that offers full access to peer-reviewed articles and has over 26,000 books and over 2,500 journals. It also has advanced search and retrieval tools [21]. IEEE Xplore is a flagship digital platform for locating and accessing scientific and specialized material published by the Institute of Electrical and Electronics Engineers in collaboration with publisher affiliations [22]. IEEE is one of the most prominent databases, and it was launched in May 2000. Since its launch, the database has grown significantly, counting more than 400,000 IEEE members. It surpassed 11 million downloads in its first year, reflecting its relevance and usefulness in the academic and professional community [23]. So far, no studies have been reported that address environmental management in the textile sector and focus on waste management. Most existing research has focused on the amount of chemicals used to manufacture garments [24]. At the same time, other studies have addressed how wastewater should be managed to reduce environmental pollution in this sector [25]. Therefore, there is a need to conduct a literature review that focuses on waste management, which will allow us to identify opportunities for improvement in sustainability practices within the textile industry.

The main objective is to evaluate various investigations regarding environmental management in the textile industry, focusing on waste management. To do so, the significant pollutants generated by the textile industry will be presented, the impact produced by pollution in the textile industry will be given, alternative solutions will be examined to reduce the environmental impact caused by the textile industries, and the methods used will be described.

2. Materials and Methods

IEEE and ScienceDirect databases are recognized and trusted by researchers in the academic and scientific fields due to their standardization and high-quality scientific documents. The wide variety of scientific papers reported has shown that the ScienceDirect and IEEE databases are ideal for selecting relevant literature when conducting literature reviews. (see Figure 1). Keywords such as waste, textile industry, and environmental management were used for both databases. In the case of IEEE, a date range of 2020 to 2024 was established. Then, open access documents were downloaded, obtaining 1275 investigations. From the ScienceDirect database, in a date range of 2000 to 2024, 1000 investigations were obtained. A total of 2275 documents were loaded into the Rayyan program, of which 33 were duplicates, and 1611 were also discarded since they were not related to our research because they contained words such as soil, robots, drives, animals, internet of things, agriculture, manufacturing, food waste, plastics, radio, traffic, biotechnology, resources, images, electrical. In addition, they were sometimes discarded because they were not oriented to our objectives. The execution of the entire procedure is observed in the PRISMA flowchart; see Figure 1.

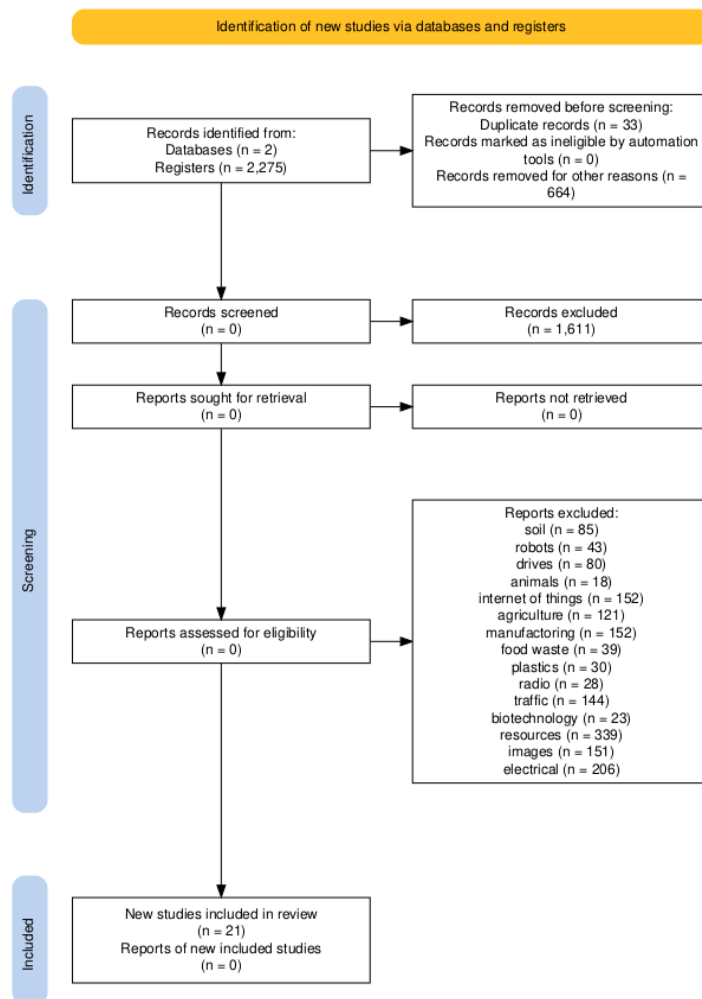


Figure 1. Prisma scheme of the selection of the analyzed documents

As a result of the selection, Table 1 presents all the documents on the subject of waste management in the textile industry that will be used in this research.

Table 1. Analysis of the resources found in the search engines.

N°	Research type	Impact	Pollutant type	Solution type	Solution method
1	Quantitative	Water and energy	Dyes and carbon emissions	Management	Examine the interrelationships between green human resource management and green supply chain management [26].
2	Descriptive	Soil, water and air	Greenhouse gases, microplastics, dyes	Management	Development of a comprehensive methodology to identify environmental impacts, map critical points and establish long-term circular economy objectives for textile products [27].
3	Literature review	Water	Heavy metals, dyes, pharmaceutical and petrochemical waste	Chemical	Development of various adsorbents [28].
4	Experimental	Water	Dyes	Chemical	Hydrogel adsorption [29].

5	Applied	Water	Solid waste	Technological	Smart containers [30].
6	Literature review	Water, soil and air	Carbon emissions	Analytical	Identify findings in the field of CE-TC and highlight existing opportunities and gaps in the sector [31].
7	Applied	Water	Chemical pollutants	Management	GSCM Practices [32].
8	Experimental	Water, soil	Indigo dye	Chemical	Bioremediation and nanofiltration [33].
9	Applied	Cotton	Energy consumption, waste generation	Analytical	Application of 3 methodologies, Partial least squares structural equation modeling, qualitative comparative analysis of fuzzy sets and analysis of need conditions [34].
10	Experimental	Water	Discarded textiles	Physical-chemical	Recycling of wasted cotton textiles for carbon fiber production through a thermal transformation process [35].
11	Experimental	Water	Anionic textile dyes	Physical-chemical	Adsorption by design and synthesis of two composite materials based on basic polyelectrolytes and physically activated carbon [36].
12	Experimental	Water	Dye effluents	Chemical	Use of hydrated ferric oxide waste [37].
13	Qualitative	Water	Textile dyes	Management	Sustainable supply chain design Linking environmental consequences (EC) and the textile value chain (TCV) [38].
14	Applied	Water	Chemical substances	Management	Selection of sustainable suppliers [39].
15	Experimental	Water	Synthetic dye	Electrochemical	Use of Cu/Fe galvanic cells in electrochemical treatment of industrial wastewater [40].
16	Literature review	Water	Organic dyes	Physical-chemical	The use of chitosan (CS) or glycidyl methacrylate (GMA) based sorbents [41].
17	Experimental	Water	Bisazo acid red dye	Physical-chemical	Use of nutraceutical spent industrial coriander seeds (NICSS) [42].
18	Literature review	Water	Textile waste	Analytical	Providing strategies for adoption of green materials, circular economy and sustainable practices. The Shades of Green tool [43].
19	Applied	Water	Textile waste	Management	RFID technology [44]

3. Results and analysis

The results shown in Figure 2 present the numbers of scientific articles evaluated and selected by year, highlighting that most publications belong to 2024, with seven documents representing 33.33% of the total. This is followed by 2023 and 2022, each with six documents (28.57%), and finally, 2021 with two papers (9.52%). The number of articles related to the textile industry has increased over the years; despite the decrease in textile production in 2019 due to the impact of COVID-19, it has increased by 4.1% in GDP in 2020, one-tenth more than in 2019. Likewise, various studies predict that by 2030, it is estimated that the production of textile products will reach 102 million tons, corresponding to a world population of 8.6 billion people. [47].

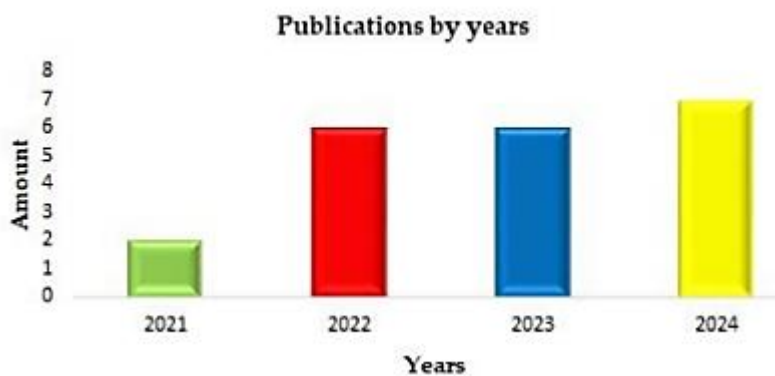


Figure 2. Annual scientific production of articles selected within 2021-2024 on environmental management in the textile industry focused on waste management.

Figure 3 shows the number of analyzed documents published by country out of the total of 21 selected articles; where Bangladesh stands out as the country with the highest number of publications on the topic of environmental management in the textile sector focused on waste management, with a total of 5 publications, which highlights its relevance in the analyzed topic. The United Kingdom ranks second with three publications. India and Finland have two mentions, indicating a moderate interest in their contexts. On the other hand, the remaining countries, such as Egypt, Colombia, Australia, Mexico, France, Germany, Poland, Saudi Arabia, and Vietnam, present one publication each, suggesting that they are less prominent in the analysis. Currently, Bangladesh is among the leading exporters of clothing worldwide. In 2021, clothing exports reached 36 billion dollars, positioning itself as the second largest clothing exporter on the planet. That same year, it was estimated that around 4 million people worked in the garment industry in Bangladesh [48]. Because it is one of the countries with the largest clothing export, it is deduced that they cause a more significant environmental impact. Therefore, it is the country with the most research on waste management.

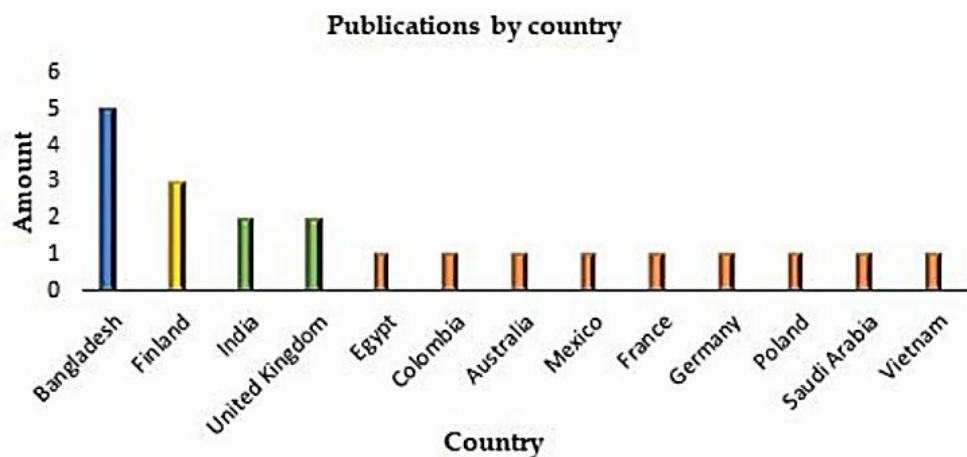


Figure 3. Number of selected publications by country.

The results shown in Figure 4 present 21 articles, including 4 types of pollutants identified as caused by the textile industries. Chemical products (mainly dyes of various kinds) were found among these, representing 57.1%. 19% represent the articles that mention greenhouse gases as pollutants, and the same happens with plastic waste; in the case of microplastics, this is mentioned in 4.8% of the included articles. The textile industries are in high demand worldwide. Still, some processes, including dyeing, require the use of large amounts of water, energy, and chemicals, which, once passed through this process, end up having a high level of pollutants, which end up being harmful to both the environment and health [49]. Likewise, textile waste often ends up in landfills or large open areas; this is worrying because most garments are not biodegradable, which can cause complications in health and biodiversity. It also increases the dispersion of greenhouse gases, and as the exposure time of the garments passes,

they release particles of various chemicals that have a high level of contaminants [50]. Likewise, microfibers, known as microplastics, are generated mainly by the textile industries; the microfibers are primarily released when the garments are washed [51].

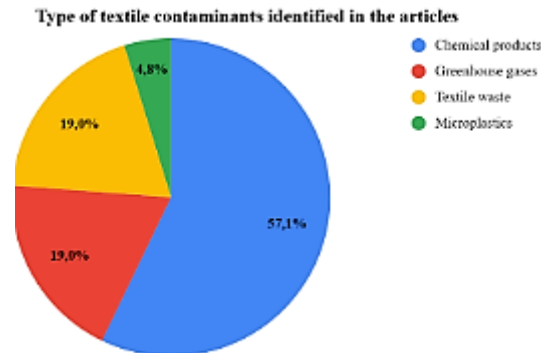


Figure 4. Type of textile contaminants identified in the selected articles.

In Figure 5, we can see that water has the most significant negative impact, with a total of 70.8%; this is mainly because most of the dyes used in the textile industry end up being dumped into rivers and oceans. Likewise, the second most affected resource is soil, with 12.5%, due to the large amount of waste, including fabric scraps and clothing. Finally, each of the energy and air resources accounts for 8.3%. In the textile industry, energy is used only for the operation of industrial machinery. Therefore, it is not considered a high-energy consumption industry [52]. The same happens with water; in the textile industry, water is mainly used to wash, clean, and dye raw materials, which causes the wastewater to contain large amounts of heavy dyes that are difficult to remove; the dyes can be found both in dissolved form and in some cases, it may not be dissolved. Currently, there are several methods for the treatment of this type of wastewater, which can be biological and physicochemical, among others, but mostly the biological method is the most used; this consists mainly of using filters (biological and carbon), ultraviolet disinfection (UV) and tanks to clarify the water. Likewise, another method used for water treatment is advanced oxidation, which is used when wastewater contains toxic and non-biodegradable substances [53]. In the case of floors, approximately 63% of textile products are made from petroleum derivatives, which generate approximately 95TM of waste; in recent years, the amount of waste has increased due to the constant change in the fashion industry [54].

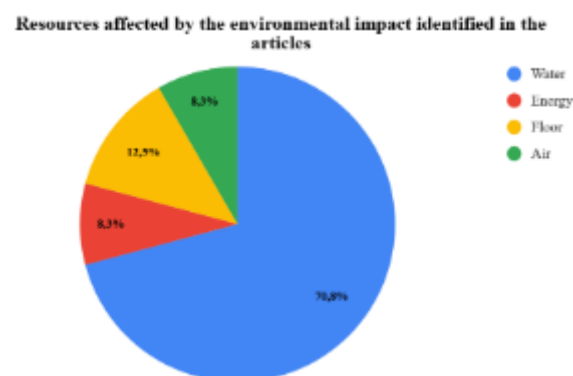


Figure 5. Resources affected by the textile industry's environmental impact, according to the selected articles.

Likewise, Figure 6 presents the types of solutions proposed by the authors to achieve greater sustainability in the textile sector. The figure highlights several categories of solutions. Among them, it can be observed that chemical, analytical and physicochemical solutions are the most mentioned and used by the authors, appearing with the same frequency in the proposals and the least. On the other hand, other categories of solutions are identified with less frequency, such as mathematical, technological and electrochemical solutions. In addition, within the methodologies used in management (See Annex 1) in the supply chain, which have the objective of integrating the aspect of environmental care into companies, in order to minimize the harmful effects produced in manufacturing and purchasing [55]. Likewise, there are various analytical solutions that are used more frequently to identify

effective strategies that promote sustainability in the textile sector. One of the main ones is the implementation of sustainable practices that seek to minimize the environmental impacts of industries [56]. Moreover, technological solutions are less frequently mentioned, but they have great potential to transform traditional textile industry processes towards more sustainable models. One example of this is the creation of defibering machines, which reduce textile waste by allowing the reuse of materials as raw material in the production of new textiles [57].

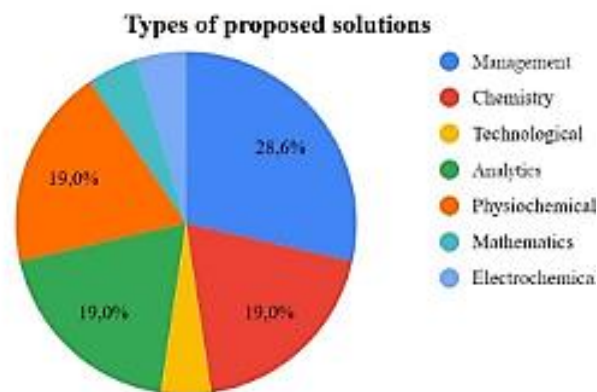


Figure 6. Types of proposed solutions.

According to Figure 7, the most commonly used method by the authors for managing textile waste belongs to the circular economy, the second most widely used is adsorption, and thirdly this management, in that sense, circular economy consists of maintaining the value of active products and services for as long as possible in the economy and promotes sustainable production such as reducing, reusing and recycling [58], the second most commonly used strategy is adsorption which achieves the capture of compounds that are in liquid, solid or gaseous state, which is usually used to be feasible for the retention of polluting agents in effluents [59] also making use of the circular economy it is estimated that the carbon footprint for the production of a virgin polyester t-shirt is 4,702kg of carbon dioxide, the recycled polyester t-shirt emits 1,802kg of carbon dioxide throughout the entire life cycle [60]. This technology has shown more excellent performance than solutions such as activated sludge, photocatalysis, chemical oxidation, and microbial degradation. Among the most commonly used types of adsorbents is activated carbon, which has a high adsorption capacity but is costly and unstable [61].

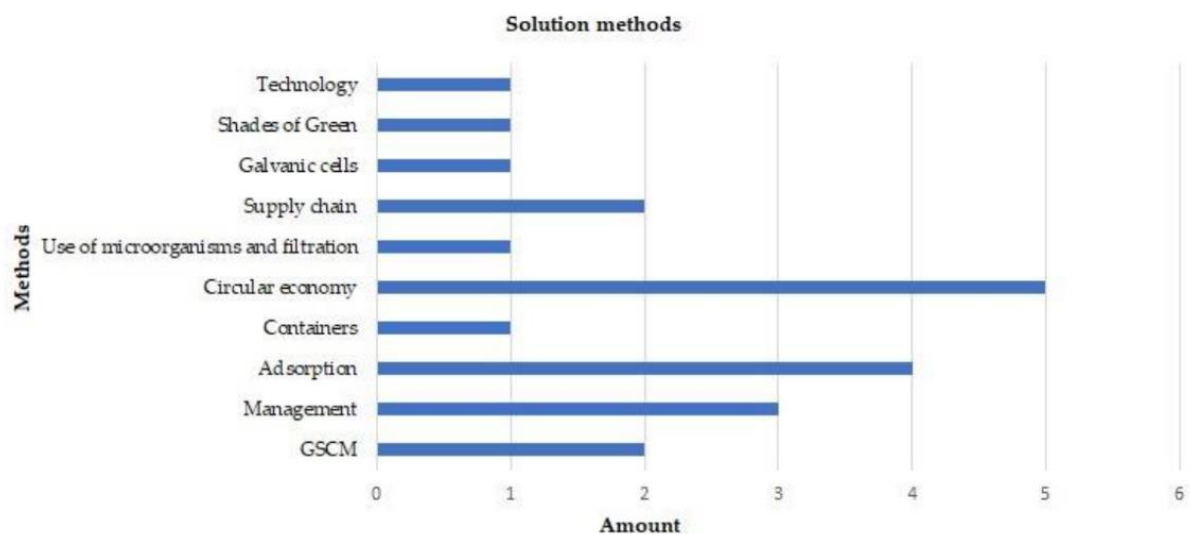


Figure 7. Solution methods used in the selected research.

4. Conclusions

In this paper, various investigations were presented regarding environmental management in the textile industry focused on waste management. This research was carried out with the help of the IEEE and ScienceDirect databases. It was found that the country with the highest number of publications related to the topic is Bangladesh, with five publications out of the 21 selected. In this paper, the significant pollutants generated by the textile industry were exposed to identify the types of contaminants they develop, in which chemical products (dyes, microplastics, heavy metals, among others) had a higher peak of the total of the 21 selected publications. Likewise, the negative impacts produced by the pollution of the textile industry were identified. Water is one of the most affected resources because the dyes used are discarded in rivers and oceans. Also, due to the accumulation of textile waste, the soil not only occupies large areas of land but also releases toxic substances that affect the soil quality. Alternative solutions to reduce the environmental impact were also examined. A total of 7 solutions were examined, with the circular economy being the most commonly used method. Secondly, the absorption method is used for contamination by textile effluents containing various dyes and chemicals. Finally, the fourth objective has shown that, although several viable strategies exist, their implementation is still limited. Recovering materials through recycling, devulcanizing rubber to reuse in other products, and promoting innovative tires to improve durability and reduce environmental impact is essential. However, the key to successful management is greater collaboration between the private sector, government authorities, and civil society to promote stricter policies and raise awareness about recycling and reusing these materials.

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