RESÍDUOS PLÁSTICOS E SUSTENTABILIDADE: REFLEXOS E IMPACTOS DA PANDEMIA DE COVID-19 NO CONTEXTO SOCIOCULTURAL E AMBIENTAL

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RESUMO

Objetivo: O artigo buscou analisar os impactos e reflexos da pandemia de COVID-19 na gestão dos resíduos plásticos.

Referencial teórico: A preocupação com a COVID-19 resultou em diversas medidas protetivas, como a determinação do uso de EPIs e restrições de circulação nos centros urbanos. Essas mudanças também impactaram padrões de geração e gestão de resíduos sólidos, especialmente de resíduos plásticos, cujos reflexos negativos nos aspectos socioambientais podem emergir, dado seu descarte inadequado.

Método: Foi realizada uma revisão sistemática de literatura, nas bases de dados Scopus, Sage e Web of Science, com utilização do Methodi Ordinatio. Ao total, 22 estudos foram selecionados, compondo o portfólio de pesquisa.

Resultados e conclusão: Os resultados demonstraram uma maior concentração de estudos que relacionam os resíduos plásticos nas regiões costeiras, especialmente provenientes de EPIs, e a poluição por microplásticos. Além disso, há uma preocupação com a geração de resíduos de embalagens pela alteração nos padrões de consumo, com o aumento da procura por serviços de e-commerce e delivery. Além de uma preocupação ambiental, destaca-se um problema de ordem social à longo prazo, devido à quebra de padrões de comportamentos sustentáveis na utilização de plástico descartável.

Implicações da pesquisa: Soluções são propostas no sentido de utilização de plásticos biodegradáveis, reutilização de EPIs e novas tecnologias de tratamento de resíduos, além da mudança no comportamento social.

Originalidade/valor: De um modo geral, o estudo fornece insights e promove reflexões sobre os desafios enfrentados no gerenciamento de resíduos plásticos durante a pandemia de COVID-19.

Palavras-chave: COVID-19; Resíduos sólidos; Plásticos; Sustentabilidade.

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ABSTRACT

Purpose: The article aims to analyze the impacts and reflections of the COVID-19 pandemic on plastic waste management.

Theoretical Framework: The concern with COVID-19 resulted in several protective measures, such as the use of PPE and movement restrictions in urban centers. These changes also affected patterns of generation and management of solid waste, especially plastic waste, whose negative effects on socio-environmental aspects may emerge due to its inadequate disposal.

Method: We conducted a systematic literature review in the databases Scopus, Sage and Web of Science, employing the Methodi Ordinatio. The review selected 22 studies to compose the research portfolio.

Results and conclusion: The results showed a higher concentration of studies on plastic waste in coastal regions, especially from PPE and microplastic pollution. Moreover, there is a concern with the generation of packaging waste by shifting consumption patterns with the increased demand for e-commerce and delivery services. Besides an environmental concern, a long-term social problem stands out regarding the breaking of sustainable behavior patterns in using disposable plastic.

Research implications: We propose solutions involving the use of biodegradable plastics, reuse of PPE, and new waste treatment technologies, besides changes in social behavior.

Originality/Value: Overall, the study provides insights and promotes reflections on the challenges faced in managing plastic waste during the COVID-19 pandemic.

Keywords: COVID-19; Solid waste; Plastics; Sustainability.

1 INTRODUCTION

Since the 1950s, plastics have been essential for society, with applications in many sectors and products to provide more practicality in daily life. However, over the last years, due to their complicated biodegradation, there has been a search for alternatives to replace plastics to eliminate the environmental liabilities caused by their incorrect disposal.

The COVID-19 pandemic, besides entailing public health problems, altered the global dynamic of waste generation and, therefore, aggravated further the concerns with plastic waste generation and management, with impacts on sustainability (Öztürk, 2021; Urban & Nakada, 2021; Mallick, Pramanik, Maity, das & Sahana, 2021). With the outbreak of the novel coronavirus, the consumption of disposable plastics and hospital materials, considered simple and inexpensive solutions to deal with the sanitary crisis, skyrocketed (Stiftung, 2020; Vanapalli et al., 2021).

According to the Brazilian Association of Public Cleaning and Special Waste Companies (ABRELPE, 2021), there was an increase of 25 to 30% in the collection of recyclable materials during the pandemic compared to the previous year. Plastic waste in Brazil totaled 13.35 million tons in 2020. An aggravating factor is that a large part of the collected volume was directly sent to sanitary landfills because of the stoppage or activity reduction in co-ops and triage units (Stiftung, 2020; Urban & Nakada, 2021).

Due to the shifting patterns of plastic waste generation and its entailing problems, the increase in the use of PPE and single-use plastics is an environmental and welfare emergency, especially in developing nations (Öztürk, 2021). Thus, we seek to answer the following research problem: what are the impacts of the COVID-19 pandemic on plastic waste generation and management, considering a sociocultural and environmental approach? It is a relevant point of
To better explain the question, we initially present the theoretical discussion concerning the COVID-19 pandemic and solid waste generation, focusing on plastic waste. After, we describe the methodological procedures employed in the study, followed by the results and their discussion. Finally, we present our final considerations.

2 THEORETICAL FRAMEWORK

This study shows the concerns and the impacts caused by the COVID-19 pandemic related to the overuse of plastics, especially in PPE, for health and safety reasons. Their inadequate disposal harms the environment, as we will see in the following sections.

2.1 The COVID-19 pandemic and solid waste

In December 2019, the city of Wuhan, in China, detected a virus that would soon reach the entire world’s population. With flu-like characteristics, the novel coronavirus (SARS-CoV-2) quickly spread throughout countries (Instituto Butantan, 2021). On March 11, 2020, the World Health Organization (WHO) recognized the severity of the situation and declared COVID-19 a global pandemic (Una-Sus, 2020).

COVID-19 affected several spheres of social life due to the restriction measures adopted by the governments of every nation to stop the virus from spreading. Social distancing policies and movement restrictions are some examples (Khatib, 2020). The virus is highly contagious, so the entire world has adopted preventive measures to control its transmission. One of the most effective measures adopted by the population is wearing face masks (Chowdhury, Chowdhury & Sait, 2021).

During the pandemic, cities instituted lockdown policies, and work became remote in many market segments, leading individuals to spend more time at home. Therefore, the consumption patterns of many families also changed significantly (Tripathi, Tyagi, Vivekanand, Bose & Suthaet, 2020). Online shopping became widespread, and so did delivering orders straight to the consumer’s house (Leal Filho et al., 2021a; Liang et al., 2021a; Saleh, Al-Kahlidi, Abulridha, Banoon & Abdelzaher 2021).

The shift in buying and consuming behavior during the pandemic also affects solid waste generation directly (Urban & Nakada, 2021). Solid waste comprises any material or substance intentionally discarded with no value until proper management, with high potential to affect human life and the environment (Okwesili, Ndukwe & Nwuzor, 2016). Studies show that solid waste
generation increased in the pandemic, not only in residences but also in commercial establishments, due to the increased use of plastic in packaging (Leal Filho et al., 2021b; Chowdhury et al., 2021).

Some studies focus on solid waste generation in healthcare services, in the use of PPE like gloves, masks, face shields, tubes, and other materials employed in the treatment of infected patients and testing of suspected cases (Tsai, 2021). Another point of discussion is the change in the collection services of recyclables because of the concern with the virus spreading from infectious solid waste. Studies, however, have already pointed out that the infections caused by indirect transmission are rare (Lewis, 2021).

The increased solid waste generation during the pandemic, especially infectious waste, must entail alternative forms of treatment and disposal. Given the lack thereof, or poor management, it is possible to observe harmful effects in the environment like soil, air, and water pollution, besides health, security, and economic problems, since remediying the problem is more costly than proper waste management (Hoornweg; Bhada-Tata, 2012; Okwesili et al., 2016; Abdel-Shafy; Mansour, 2018; Das et al., 2019). Albuquerque et al. (2021) state that, even though protecting the population, healthcare system, and economy is the crucial priority during the pandemic, it is an opportunity to improve waste management practices and build an infrastructure from the challenges and lessons learned in this context.

The solution involves consumption reduction and awareness in individual decisions, especially the active engagement of citizens in a public awareness approach (Das et al., 2019). Companies can focus on ecodesign alternatives, while governments can implement and improve public policies like the National Policy of Solid Waste (PNRS), instituted in Brazil by Law no. 12.305/2010, to find systemic and effective solutions that meet the complexity of variables linked to waste management, such as the reach of the productive chain, individual and collective behavior, the varied features of solid waste, among others (Gonçalves-Dias, 2015). The COVID-19 pandemic intensified challenges related to solid waste management due to, for example, the increased solid waste generation. Thus, these challenges require solutions and alternatives to mitigate their adverse effects.

2.2 Plastic Waste

Contemporary society widely uses plastic due to its usability and easiness. However, its long durability after use and consequent resistance to biodegradation in the short term is a problem that affects nature and humanity (Stiftung, 2020; Liang, Tan, Song & Li, 2021b).

It is estimated that, from the 1950s to 2017, 9.2 billion tons of plastic were produced, mostly from single-use packages and products. From this total, less than 10% was recycled (Stiftung, 2020). Borrelle et al. (2020) add that approximately 11% of the plastic waste generated finds a destination in the oceans, harming the ecosystem’s biodiversity.

Predictions considering population and consumption growth rates show that plastic production will double in the next 20 years, which will result in a similar increase in plastic waste post-consumption. This scenario requires a transformation into a circular economy that values and reuses plastic to ensure a positive economic return (Lebreton & Andrady, 2019).

Countries like the United States, United Kingdom, Canada, and South Africa have taken measures to reduce the production and consumption of plastic materials, especially single-use ones. Since 1991, for example, nations have adopted policies to reduce disposable plastic bags, forbidding their sale, charging customers for their acquisition, or taxing the stores that employ them. After 2014, strategies aiming to reduce microplastic pollution started being developed (Xanthos & Walker, 2017).

This mobilization occurs due to the environmental, social, and economic impacts caused by the generation and inadequate disposal of a massive amount of plastic waste. Besides altering ecosystems with air, water, and soil pollution, they cause health and safety problems, greenhouse gases emissions, and high costs in remedial solutions (Okwesili et al., 2016). Microplastic pollution
may affect an ecosystem’s health by entering the animal and human food chain (Golwala, Zhang, Iskander & Smith, 2021). These impacts make waste management a fundamental sustainability question, especially considering the shifting patterns of plastic waste generation and management during the COVID-19 pandemic (Mallick et al., 2021).

The COVID-19 pandemic increased the plastic use by the population, especially considering personal protective equipment like face masks (Vanapalli et al., 2021). This problem is even more noticeable in low-income countries that lack the infrastructure for solid waste management, which entails environmental problems (Chowdhury et al., 2021; Haddad et al., 2021; Mallick et al., 2021). Disposable face masks generate plastic pollution when discarded on streets, seas, and in nature, which demands a strategy from governments to manage these residues, seeing that the pandemic might last for a few more years (Akarsu, Madenli & Deveci, 2021).

During the current pandemic, commercial establishments have increased their plastic use in the packages for customer deliveries and disposable utensils like cups, cutlery, plates, among others (Filimonau, 2020). Another factor is the solid waste generation related to PPE used by the population to deter the virus from spreading, like face shields, masks, and gloves (Chowdhury et al., 2021).

It is also worth discussing the methods of plastic waste management adopted by governments during the COVID-19 pandemic. It is a delicate point, considering the multifaceted conditions linked to the solid waste generated in such a peculiar moment. Discarding face masks with other non-recyclable residues has become a common practice (Tripathi et al., 2020; Albuquerque et al., 2021). Moreover, loosening policies that control single-use plastics may have long-term effects (Vanapalli et al., 2021).

Relying on bioplastics instead of oil-based plastics might be a sustainable change, although it entails additional costs (Vanapalli et al., 2021). Creating a circular economy that recycles plastic waste tends to be the path towards effective management (Liang et al., 2021b). The current pandemic conditions have influenced the collection and final disposal of waste, seeing that nations have adopted policies to prevent virus transmission through the solid waste generated by self-isolated patients and hospitals (Tripathi et al., 2020). Population awareness is also a fundamental factor. Following a protocol of solid waste disposal, especially by those infected, for PPE is one way to ensure the socio-environmental commitment of every individual (Tripathi et al., 2020).

Although the development of vaccines has advanced the fight against COVID-19 significantly, face masks are still widely recommended (Albuquerque et al., 2020; Akarsu et al., 2021). Therefore, this is an opportunity to develop innovative technologies and solutions for sustainable plastic waste management.

3 METHOD

To find the possible environmental impacts and sociocultural reflections of the COVID-19 pandemic on plastic waste management, we conducted a systematic review encompassing the perceptions and findings already published about the theme. The literature review is a method that summarizes, through well-defined rules and systematic procedures, the general views of a knowledge area based on published material, usually relevant papers (Aromataris & Pearson, 2014). This study adopted the Methodi Ordinatio, which selects and assesses the quality of the published material using the InOrdinatio equation, considering the journal’s impact factor, the number of citations, and the paper’s year of publication (Pagani, Kovalski & Resende, 2015; 2017).

The searches employed the descriptors plastic, polymers, COVID-19, pandemic, and solid waste, combined through the Boolean operators OR and AND. We selected the databases Scopus, Sage, and Web of Science because of their relevant content and coverage of the subject. The search criteria included papers only, filtered by title, abstract, and keywords, published from 2020 onward.
The search occurred on August 16, 2021 and returned 55 results, distributed according to Table 1.

### Table 1 – Paper search results per database

<table>
<thead>
<tr>
<th>Database</th>
<th>Search syntax</th>
<th>Papers found</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scopus</td>
<td>TITLE-ABS-KEY (((plastic OR polymers) AND (covid-19 OR pandemic) AND solid AND waste) AND (LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020)) AND (LIMIT-TO (DOCTYPE, &quot;ar&quot;)))</td>
<td>35</td>
</tr>
<tr>
<td>Web of Science</td>
<td>(Plastic OR polymers) AND (COVID-19 OR pandemic) AND solid waste (Abstract)</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>55</td>
</tr>
</tbody>
</table>

Source: The authors (2022).

The information from the selected papers was downloaded and migrated into the Zotero reference manager to remove duplicates. The process eliminated 15 studies, with 40 papers remaining for the analysis of titles, abstracts, and keywords, considering the following selection and exclusion criteria:

- **Selection criteria:**
  a) papers that approach the plastic waste issue in the COVID-19 pandemic context and its implications;
  b) complete studies published by scientific journals.

- **Exclusion criteria:**
  a) papers published in scientific events;
  b) papers centered on chemical experiments;
  c) studies that approach solid waste with no specific focus on plastic waste;
  d) works centered on the potential spread of the novel coronavirus through solid waste;
  e) papers focused only on hazardous medical waste;
  f) studies that do not employ a sustainability approach and its environmental, economic, and social demands.

After applying the criteria, we analyzed the 22 remaining studies through the InOrdinatio equation (Pagani et al., 2015; 2017):

\[
\text{Fator de impacto} = (\frac{F_i}{1000}) + (\alpha^* (10 - (\text{AnoPesq} - \text{AnoPub}))) + (\sum \text{Ci})
\]

In the formula, the impact factor \((F_i)\) uses the Journal Citation Reports (JCR) of 2020, and the total of citations \((\sum \text{Ci})\) corresponds to the results found on Google Scholar. The coefficient \(\alpha^*\) refers to the weighting factor attributed to the relevance of the publication year, ranging from 1 to 10. Given that every paper published about the subject dates from 2020 onward, this factor is not relevant in the calculation and received the value of 1. After the calculation, every study presented an index superior to zero and entered the final portfolio for analysis.
The final portfolio comprised 22 scientific papers. We read them in full, employing the content analysis technique proposed by Bardin (2011). We categorized the analyzed data into Impacts of the COVID-19 pandemic on plastic waste generation, Concerns, and Solutions found in the literature.

The following section presents the research results based on the summary and discussion of the selected studies.

4 RESULTS AND DISCUSSIONS

The results and discussions of the studies are outlined and demonstrated as follows.

4.1 Study characteristics

Chart 1 presents the papers assessed in this review, ranked by the relevance determined by the InOrdinatio equation.

<table>
<thead>
<tr>
<th>Authors/year</th>
<th>Title</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharma et al. (2020)</td>
<td>Challenges, opportunities, and innovations for effective solid waste management during and post COVID-19 pandemic</td>
<td>Discuss the potential sources, destinations, and effects of plastic PPE on the marine environment.</td>
</tr>
<tr>
<td>Aragaw (2020)</td>
<td>Surgical face masks as a potential source for microplastic pollution in the COVID-19 scenario</td>
<td>Assess if surgical face masks are a potential source of microplastic contamination.</td>
</tr>
<tr>
<td>Ardosso, et al. (2021)</td>
<td>COVID-19 pandemic repercussions on plastic and antiviral polymeric textile causing pollution on beaches and coasts of South America</td>
<td>Offer reflections and perspectives on how the COVID-19 pandemic may aggravate plastic pollution at beaches and coastal environments.</td>
</tr>
<tr>
<td>De-la-Torre &amp; Aragaw (2021)</td>
<td>What we need to know about PPE associated with the COVID-19 pandemic in the marine environment</td>
<td>Discuss the potential sources, destinations, and effects of plastic PPE on the marine environment.</td>
</tr>
<tr>
<td>De-la-Torre, et al. (2021)</td>
<td>Occurrence of personal protective equipment (PPE) associated with the COVID-19 pandemic along the coast of Lima, Peru</td>
<td>Report the occurrence and distribution of PPE associated with the COVID-19 pandemic along the coast of Lima, Peru.</td>
</tr>
<tr>
<td>Hantoko et al. (2021)</td>
<td>Challenges and practices on waste management and disposal during COVID-19 pandemic</td>
<td>Present the challenges related to the increase of waste disposal (including plastic waste) during the COVID-19 crisis and its response practices.</td>
</tr>
<tr>
<td>Leal Filho et al. (2021a)</td>
<td>COVID-19 and waste production in households: A trend analysis</td>
<td>Collect international data concerning the consumption increase and subsequent changes in waste generation since the beginning of the COVID-19 pandemic.</td>
</tr>
<tr>
<td>Torres &amp; De-la-Torre (2021)</td>
<td>Face mask waste generation and management during the COVID-19 pandemic: An overview and the Peruvian case</td>
<td>Discuss sustainable alternatives for face masks and paths for recycling and reusing them in the COVID-19 pandemic context; estimate the daily face mask waste generation in Peru.</td>
</tr>
<tr>
<td>Silva et al. (2021)</td>
<td>An urgent call to think globally and act locally on landfill disposable plastics under and after COVID-19 pandemic; Pollution prevention and technological (Bio) remediation solutions</td>
<td>Analyze the pandemic-related challenges in sanitary landfills and discuss the potential environmental and healthcare implications that might distance us from the UN’s sustainable goals for 2030.</td>
</tr>
<tr>
<td>Rakib et al.</td>
<td>Personal protective equipment (PPE)</td>
<td>Determine the PPE amount, features, and...</td>
</tr>
<tr>
<td>Source</td>
<td>Year</td>
<td>Title</td>
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</tbody>
</table>

| (2021) | pollution driven by the COVID-19 pandemic in Cox's Bazar, the longest natural beach in the world | distribution that pollute the longest natural beach in the world, Cox's Bazar, in Bangladesh. |
| 12 Chowdhury et al. (2021) | Estimating marine plastic pollution from COVID-19 face masks in coastal regions | Estimate the yearly use of face masks and plastic pollution caused by incorrect management in the coastal regions of 46 countries. |
| 13 Haddad et al. (2021) | Personal protective equipment (PPE) pollution associated with the COVID-19 pandemic along the coastline of Agadir, Morocco | Monitor PPE pollution associated with the COVID-19 pandemic along the coastline of Agadir, Morocco. |
| 15 Albuquerque et al., (2021) | Fate of disposable face masks in high-solids anaerobic digestion: Experimental observations and review of potential environmental implications | Report the preliminary results of a laboratory experiment conducted with the organic fraction of urban solid waste corrected with disposable face masks. |
| 16 Akarsu et al. (2021) | Characterization of littered face masks in the southeastern part of Turkey | Estimate the number of face masks used during the COVID-19 pandemic in three Turkish cities. |
| 17 Al-Salem, El-Eskandarani & Constantiniou (2020) | Can plastic waste management be a novel solution in combating the novel Coronavirus (COVID-19)? A short research note | Present the possibility of using solid plastic waste as the substrate for employing copper and copper alloys and its nanocomposites and nanodust as a protective surface coating. |
| 18 Xiang et al., (2021) | Polymer composites completely derived from waste: the crystalline structure and the mechanical enhancement effect | Find a solution to the problem of using and generating large amounts of disposable face masks due to the COVID-19 pandemic. |
| 19 Liang et al., (2021a) | Repercussions of COVID-19 pandemic on solid waste generation and management strategies | Analyze the influences of the COVID-19 pandemic on solid waste, including plastic waste. |
| 20 Tsai (2021) | Analysis of plastic waste reduction and recycling in Taiwan | Analyze the changes in the number of regulated plastic packages recycled and the impacts of COVID-19 on the increase of plastic waste in Taiwan. |
| 21 Dissanayake, Torres-Quiroz, Mahato & Park (2021) | Facemasks: a looming microplastic crisis | Investigate how many microplastic fibers were released into the water by face and surgical masks in South Korea. |

Source: Research data.

We observed that 18.2% of the studies were published in 2020 and 81.2%, in 2021, illustrating a growing concern with plastic waste management caused by the COVID-19 pandemic. Countries like the United States, Argentina, Peru, China, Germany, India, Turkey, Taiwan, South Korea, and Iraq constitute the loci of the empirical studies conducted.

The journal Science of the Total Environment stands out with six publications, followed by the Marine Pollution Bulletin, Resources, Conservation and Recycling, and Waste Management & Research, with four, two, and two publications, respectively. The other eight magazines had one publication each. We also identified a small concentration of authors, with De-la-Torre contributing...
to five investigations. Other authors, like Aragaw, Rakib, Pizarro-Ortega, Dioses-Salinas, Leal Filho, Paço, Minhas, Ferreira, and Salvia, took part in two works.

Considering the subject at hand, plastic waste, the studies approach several materials, including plastic PPE (face masks, gloves, bouffant caps, face shields, protective suits, safety shoes), plastic packages, and domestic plastic waste. Moreover, other papers focus on disposable plastic waste without specifics.

4.2 The COVID-19 pandemic, plastic waste, and sustainability

There has been a lot of discussion about the challenges and impacts of the COVID-19 pandemic on solid waste, especially plastic waste, a material that long has been viewed as an enormous burden for the environment due to its resistance to biodegradation, which can surpass 800 years (Saleh et al., 2021). The shifting consumption habits, sociocultural changes related to disposable plastic use, and the need for PPE during the pandemic intensify the existing sustainability concerns with plastic waste management.

The authors Sharma et al. (2020), Hantoko et al. (2021), Leal Filho et al. (2021a; 2021b), Liang et al. (2021a), Saleh et al. (2021), and Tsai (2021) provide a general view of the pandemic influence on plastic waste. They observe an increase, by the consumers, in the use of disposable plastic like bags due to the concern with the virus, seeing the environmental impacts as a lesser factor. Moreover, the start of the outbreak entailed a higher demand for packages of supplies, health products, and packed goods, besides the online shopping and food delivery services, which also generate large amounts of plastic waste, like thin films, foam, and multilayered plastic (Sharma et al., 2020; Liang et al., 2021a; Saleh et al., 2021). Regarding this point, Leal Filho et al. (2021a) found a 53% increase in plastic packages used during pandemic-related restrictions, caused by the longer time people spent at home. Similarly, the growth of medication use and self-medication may have contributed to the increased waste generation, especially blister packs (Saleh et al., 2021).

Studies also expect long-term impacts related to the stagnation of policies that aim to reduce single-use plastics, undermining the global sustainability efforts to reduce plastic pollution (Sharma et al., 2020; Liang et al., 2021a). Saleh et al. (2021) and Liang et al. (2021a) point out that temporarily loosening the plastic bag ban in Iraq, Canada, and the United States might change consumer behavior in the long term, throwing ongoing measures and awareness back. Sharma et al. (2020) complement that this temporary loosening of the disposable plastic ban may break sustainable behavior patterns, creating massive environmental liability. Tsai (2021) stresses this problem considering the reality in Taiwan, which over the years has been achieving positive results in recycling regulated plastics due to circular economy policies. The author states that the pandemic may have an adverse impact, reducing the recycling rates of plastic products regulated in the country.

The increase in PPE use against contagion by COVID-19 is also a concern. Sharma et al. (2020) and Hantoko et al. (2021) point to the excessive use of plastic PPE like gloves, face shields, masks, and other biomedical waste as potential factors of environmental contamination. In this context, face masks, widely used by the global population, stand out and receive the attention of the works by Aragaw (2020), Akarsu et al. (2021), Albuquerque (2021), Dissanayake et al. (2021), and Torres and De-la-Torre (2021). They draw attention to the microplastic pollution caused by face masks. Dissanayake et al. (2021) demonstrated that a single polypropylene face mask might release at least 47 microplastic fibers a day in South Korea, considering the use of one daily mask by 70% of the urban population.

Over time, the studies identified a significant growth in fiber release, which amplifies their potential to affect rivers, lakes, fauna, and flora. Aragaw (2020) found a similar result, pointing to the surgical mask as a potential source of microplastic contamination in the water and waste systems. Other studies estimate the generation of face masks to understand the extension of the possible pollution. Akarsu et al. (2021), for instance, surveyed the number of face masks used in three Turkish cities (Mersin, Adana, and Niğde). The results revealed an average of 182 masks
discarded per Km² and an average production of 10 tons of face masks per day in the three cities, raising the concern with microplastic production. In a single-use scenario, in Peru, Torres and De-la-Torre (2021) estimate a daily generation of 14,983,383 face masks in the country, corresponding to approximately 74.9 tons of plastic waste a day. Albuquerque et al. (2021) present yet another problem associated with face masks waste. In their study, a laboratory experiment revealed that disposable face masks, when mixed with urban solid waste, negatively affect the methane production in digesters (a decrease of up to 18%). Moreover, they do not degrade within 40 days, which affects digestion management practices like composting, soil application, and grounding. They might cause microplastic pollution, as well.

The selected papers also focus on PPE plastic pollution in marine environments (Arduso et al., 2021; Chowdhury et al., 2021; De-la-Torre e Aragaw, 2021; De-la-Torre et al., 2021; Haddad et al., 2021; Rakib et al., 2021). Arduso et al. (2021) and De-la-Torre and Aragaw (2021) reflect on how the COVID-19 pandemic may aggravate plastic pollution in beaches and coastal environments, consequently harming marine species more. In an empirical study, De-la-Torre et al. (2021) found 138 PPE items discarded incorrectly in 11 beaches in Lima, Peru, over 12 weeks of sampling, which raises the concern with the microplastic release, colonization by invasive species, and entanglement or ingestion by predators. Similarly, Rakib et al. (2021) identified numerous PPE items on Cox’s Bazar beach, in Bangladesh, predominantly face masks (97.9%). They found that illegal dumping grounds near the beach, poor practices of solid waste management, and fishing activities, the latter in a lesser proportion, contribute to PPE marine pollution. On the coastline of Agadir, Morocco, a study found a significant increase in PPE density after restriction measures. Most were face masks (96.81%), of which 98.4% were surgical masks found mostly in leisure locations, illustrating a lack of environmental awareness by the population (Haddad et al., 2021). At a larger scale, Chowdhury et al. (2021) estimate that 0.15 to 0.39 million tons of plastic residues might end up in the oceans within a year due to poor solid waste management in coastal regions. They also found that Asian countries generated more plastic waste than European ones and that low-income countries have more marine pollution due to fewer waste management facilities.

Another aspect is the concern with plastic waste discarded in landfills. According to Silva et al. (2021), sanitary landfills receive most COVID-19 plastic waste, especially in developing countries. The authors state that landfills may have been the destination for 3.5 billion tons of masks in the first year of the pandemic, and the biogas, fires, and leached chemicals generated might increase air and water pollution, as well as harm the soil’s ecological integrity.

Studies also raise the question of plastic waste as potentially infectious and demand actions towards proper management (Hantoko, 2021). Analyses point out that the virus stability on plastic surfaces, especially flat ones, may last for seven days (Chin et al., 2020; Corpet, 2021). Despite that, surfaces present a relatively low risk of virus transmission and spread compared to direct contact with infected people (Lewis, 2021).

Finally, the papers indicate possible solutions and paths to manage the plastic waste generated more intensely during the pandemic better. Al-Salem et al. (2020) presented the possibility of using plastic solid waste as the substrate for copper and copper alloys employed as an antiviral surface coating. This solution simultaneously contributes to the environment through plastic waste management and would be a versatile antiviral alternative applicable to day-to-day contact surfaces. Filimonau (2021) seeks plastic waste management solutions in the hospitality sector in a post-pandemic world and points to the investment in more ecological products, emphasizing green innovations like reusable or vegetable-based cutlery instead of disposable plastics. Leal Filho et al. (2021b) propose purchasing package-less food, biodegradable packages, and package reuse as solutions. Torres and De-la-Torre (2021) recommend pretreating face masks before recycling them (disinfection and segregation of plastic materials) and Albuquerque et al. (2021) highlight the need for pre-processing or post-processing masks to improve the efficiency of digesters. Other authors present alternatives for conventional plastics like bioplastics, biodegradable masks, PPE reuse, new treatment technologies, and changes in personal, social, and institutional
behavior as necessary (Haddad et al., 2021; Saleh et al., 2021; Silva et al., 2021; Torres e De-la-Torre, 2021). Figure 2 summarizes the discussions.

**IMPACTS OF THE COVID-19 PANDEMIC ON PLASTIC WASTE**

**CONCERNS**

- Microplastic pollution affecting rivers, lakes, fauna, and flora.
- Pollution of marine and coastal environments – damage to marine species.
- Waste discarded in landfills – consequences in air, water, and soil pollution.
- Indirect infection.

**SOLUTIONS**

- Using plastic waste as a by-product.
- Investments in ecological products.
- Green innovation, bioplastics.
- Biodegradable packages.
- Pre-treatment, pre-processing, and post-processing waste.
- Reusing PPE.
- New waste treatment technologies.
- Changes in personal, social, and institutional behavior.

**Sociocultural changes:**
- Increased use of disposable plastics.
- Loosening policies and restrictions of plastic use globally.
- Breaking sustainable behavior patterns.
- Long-term impacts.

**PPE use:**
- Masks;
- Gloves;
- Face shields and biomedical waste.

**Challenges in consumption habits:**
- Disposable plastic;
- Packaged products;
- Delivery services and online shopping.

Currently, there are no predictions for the end of the COVID-19 pandemic or the preventive measures against the disease. Thus, plastic waste generation, especially single-use and disposable masks, remains a concern. The entailing impacts may have long-term consequences that demand reflecting and seeking alternatives towards more sustainable actions in plastic waste generation and management.

5 **FINAL CONSIDERATIONS**

This study aimed to analyze and present the impacts and reflections of the COVID-19 pandemic on plastic waste management in the sociocultural and environmental context. We conducted a systematic literature review in the databases Scopus, Sage, and Web of Science, employing the Methodi Ordinatio.

The results pointed to the harmful effects of the COVID-19 pandemic, whether to human life or concerning its influence on the environment because of solid waste management. Plastic waste generation has increased due to the higher consumption of packaged products, online shopping, delivery services, single-use plastic use, and PPE.

The studies analyzed are concerned with the possible environmental impacts and sociocultural reflections of the COVID-19 pandemic on plastic waste management. Incorrect disposal, as pointed out by the research, degrades ecosystems through air, water, and soil pollution, and especially harms oceans and marine species through microplastic pollution. In the long-term, the authors estimate a sociocultural impact caused by loosening policies that had been restricting the use of plastic materials globally. In this context, solutions for sustainable management and disposal of this material are a priority, such as developing waste reuse and treatment technologies, green
innovation, and awareness campaigns. The reviewed studies proposed varied solutions and concerns that are not isolated but recurring throughout the world.

The challenges of solid waste management, now expanded by the current pandemic, demand proactive attitudes from citizens and companies that consume, produce, and discard residues. Governments must develop and implement systemic and effective policies to manage solid waste and mitigate its harmful effects on the environment. Rethinking practices and changing habits have always demanded great efforts, but managing life in society has required similar efforts on countless occasions. Society must see the reality entailed by this pandemic as a learning and growth opportunity. We cannot forget that it has been a health catastrophe nor disregard the millions of lives lost, but understand that perfecting life in society is increasingly essential.

Thus, this systematic review serves as an alert for the effective operationalization of the ideas found in the papers reviewed, which need to result in immediate and effective solutions to avoid aggravating the environmental damage caused by plastic waste. It is also possible to observe that the pandemic has induced more awareness related to personal hygiene habits, like washing hands, sanitizing objects, and unnecessary proximity. These behavioral changes can definitely help in the post-COVID-19 scenario by weakening endemics caused by not observing these measures in several countries, especially the developing ones.

This study, guided by the thoughts of several researchers seeking solutions for issues that affect everyone, raised by the complexity of the pandemic, reflects on the primordial search for effective and awareness-raising solutions, aiming to achieve the sustainability ideal. The works reviewed propose advancing plastic waste management, thus advancing scientific knowledge towards the common good. Every discovery opens new paths for science to find effective solutions to the social problems caused by the pandemic.

This study is limited because it considers only the COVID-19 impacts on plastic waste generation and management. Thus, we suggest that future studies approach the subject by observing different types of waste generation that have suffered increases or changes during the pandemic. Furthermore, studies can focus on sustainability transitions to understand the effort to transition into biodegradable plastic or other substitute solutions.

REFERENCES


