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Environmental policies for the treatment of waste generated by COVID-19: Text mining review

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Abstract

The rapid transmission of COVID-19 has meant that all economic and human efforts have been focused on confronting it, ignoring environmental aspects whose consequences are causing adverse situations all over the planet. The saturation of the sanitary system and confinement measures have multiplied the waste generated, which implies the need to adapt environmental policies to this new situation caused by the pandemic. It is a review article whose objective was to identify the environmental policies that would facilitate an adequate treatment of the waste generated by the pandemic. It was proposed to analyse the current lines of research developed on this paradigm, applying the text mining methodology. A systematic review of 111 studies published in environmental journals indexed in the Web of Science was carried out. The results identified three areas of interest: knowledge of transmission routes, management of the massive generation of plastics and appropriate treatment of solid waste in extreme situations. Leaders are called upon to implement the contingency plans to sustainably alleviate the enormous waste burden caused by society's adaptation to the restrictions imposed by the pandemic. Specifically, innovation aimed at achieving the reuse of medical products, the promotion of the circular economy and educational campaigns to promote clean environments should be encouraged.

Keywords

Covid-19, waste, text mining, environmental policies

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Introduction

COVID-19 has disrupted human life, affecting multiple economic and social aspects, from the restrictions on movement with the consequent closure of businesses and changes in production rates to the need to regularly wear a mask to try to halt the rapid spread of the virus. The global population has been at war against a virus of unknown properties, while also dealing with major deficiencies that put it at a disadvantage in this battle. This situation has prompted concerns about climate change being pushed to the sidelines. However, the consequences are starting to become apparent. Plastics are currently pouring into rivers and seas around the world. For this reason, countries need an adequate recycling system to address both the growing volume of personal protective equipment (PPE) and the increase in disposable packaging used in food (European Environment Agency [EEA], 2021; Malpass, 2020).

All this has sparked great interest in the scientific community, where numerous studies are being carried out in this area. The role of air quality in the spread of coronavirus has been analysed in different territories: Brazil (Nakada and Urban, 2020), India (Beig et al., 2020; Shehzad et al., 2020; Singh et al., 2020), Italy (Cazzolla-Gatti et al., 2020; Conticini et al., 2020) and China (He et al., 2020; Huang and Sun, 2020; Pei et al., 2020; Wang et al., 2020a; Wu et al., 2021; Yao et al., 2021; Zhao et al., 2020). The influence of meteorological factors on the evolution of the disease has also been studied, focusing on the United States (Dogan et al., 2020; Gupta et al., 2020) or the Eastern Mediterranean (Hochman et al., 2021), with one study even covering a total of 166 countries to draw more precise conclusions (Wu et al., 2020).

The measures taken to control the spread of the virus and deal with the slowdown of economic activities have significant effects on the environment (Rume and Islam, 2020). With all the environmental information about COVID, there is an urgent need for statistical methods to integrate these data into COVID analyses. Specifically, the text mining technique is ideal for analysing the main lines of research currently emerging as a result of the pandemic.

In this context, where economic and social decisions have to be taken immediately, the guidance about climate change provided by the studies carried out represents a valuable tool. Therefore, the objective of this article was to identify the lines of research focusing on COVID-19 and waste, using the text mining

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technique, in order to identify the measures that could be readily implemented by the authorities and the general public.

Over the course of 2020 and 2021, several literature reviews of studies related to COVID-19 and some of its most relevant aspects have been carried out. For example, Kumar et al. (2020a) focus on understanding and summarising all reported findings on coronavirus related to prognosis, pathogenesis, symptoms and so on to discover the possible influence of environmental factors on disease transmission. Franch-Pardo et al. (2020) carry out a geospatial and spatial-statistical analysis of the geographical dimension of coronavirus, based on a review of 63 articles, offering an understanding of the spatio-temporal dynamics of the virus, which is essential for mitigating its spread. Shakil et al. (2020) present a critical analysis of 57 papers on the nexus between COVID-19 and the environment, revealing that environmental degradation, atmospheric pollution, climatological factors and temperature have been the most extensively analysed topics. Similarly, Casado-Aranda et al. (2021) propose a bibliometric analysis to explore the scientific publications on the virus in the environmental field.

Unlike the previous studies, this article focuses on identifying more specific elements, making novel contributions on the waste management issues that may have arisen due to COVID-19: (1) the use of the text mining technique helps ensure the robustness of the findings regarding research lines identified, (2) the systematic review of studies covers the paradigms of the greatest concern to researchers, (3) the conclusions will help decision-makers to implement the necessary changes and be able to curb the environmental consequences of the disease.

Data and method

Specifically, the analysis included 111 articles published in journals indexed in the Web of Science (WoS) whose central focus was environmental topics. However, the text mining method was used to identify the most frequently mentioned terms in environment research papers that study COVID-19 and waste and, next, to detect research lines or groups of the most frequent terms. A statistical analysis was performed using the R environment for statistical computing (R Core Team, 2021).

Data

The procedure to build the database consisted of seven search criteria, which can be summarised as follows (Figure 1).

A search of WoS was conducted on 15 March 2021 for articles written in English containing the terms COVID and waste in the keywords, abstract or title. In line with the aim of this research, the Science & Technology domain and the Environmental Sciences Ecology area were selected in the core collection[1] (the main part of the WoS platform), from which a total of 129 studies were obtained. These studies were reviewed, and finally, only fully informed papers were selected. Applying all the above search criteria yielded a database consisting of 111 research papers published in environmental journals which are indexed in the WoS database (Table 4 of Appendix 1).

Before applying the text mining method, these research papers had to be pre-processed to make them more suitable for computer analysis. Then, to prepare the database, the following actions were taken: conversion of all terms to lowercase so there are no differences between the same terms; removal of punctuation marks, digits and stopwords which are commonly used in English but do not provide information in the text analysis (*a, an, and, that, then, the*, among others) and finally, the application of a stemming process which extracts the roots of the terms to group all derived terms under the same root. Table 1 shows the database in detail with the number of papers published and the quartile corresponding to the journal, ordered from the highest to the lowest frequency.

The Journal of Science of the Total Environment has published the greatest number of articles on research related to COVID and waste (21.62% of all selected papers), followed by the International Journal of Environmental Research and Public Health and Sustainability (8.11%). It is observed that 32 journals have only published one research paper that deals with the COVID-19 pandemic and waste, highlighting an area for environmental researchers to focus their attention on. It is important to mention that half of the database is made up of Journal Citation Reports (JCR) journals ranked in Q1 which means that this study is based on a solid and robust systematic literature review. Finally, the analysis detected four journals that are not JCR, meaning the quartile is not available.

Text mining method

Text analysis, also referred to as text mining, is an interdisciplinary field of activity that combines elements of data mining, linguistics, computational statistics and computer science (Meyer et al., 2008). Its principal aim is to extract high-quality information from a large number of textual documents. After processing the database, the text summarisation technique was used to identify the most frequently mentioned terms in environmental research papers that study COVID-19 and waste. This technique generated a list of all the terms that appear in the database with their frequency, where only the most frequently mentioned repeated terms were selected. Next, the text clustering method was applied to the most frequently identified terms. Clustering is a statistical classification technique used in exploratory data analysis, which has been applied in various disciplines (Carracedo et al., 2021; Han et al., 2019; Täuscher and Laudien, 2018; William and Chang, 2019).

A hierarchical cluster analysis was used, where the Ward's minimum variance method and chi-square distance were applied (Husson et al., 2017). It is based on maximising the similarity between documents and, consequently, minimising the chi-square distance between them. Document clustering groups papers with the smallest chi-square distance to the average vocabulary of the cluster. Finally, the best number of

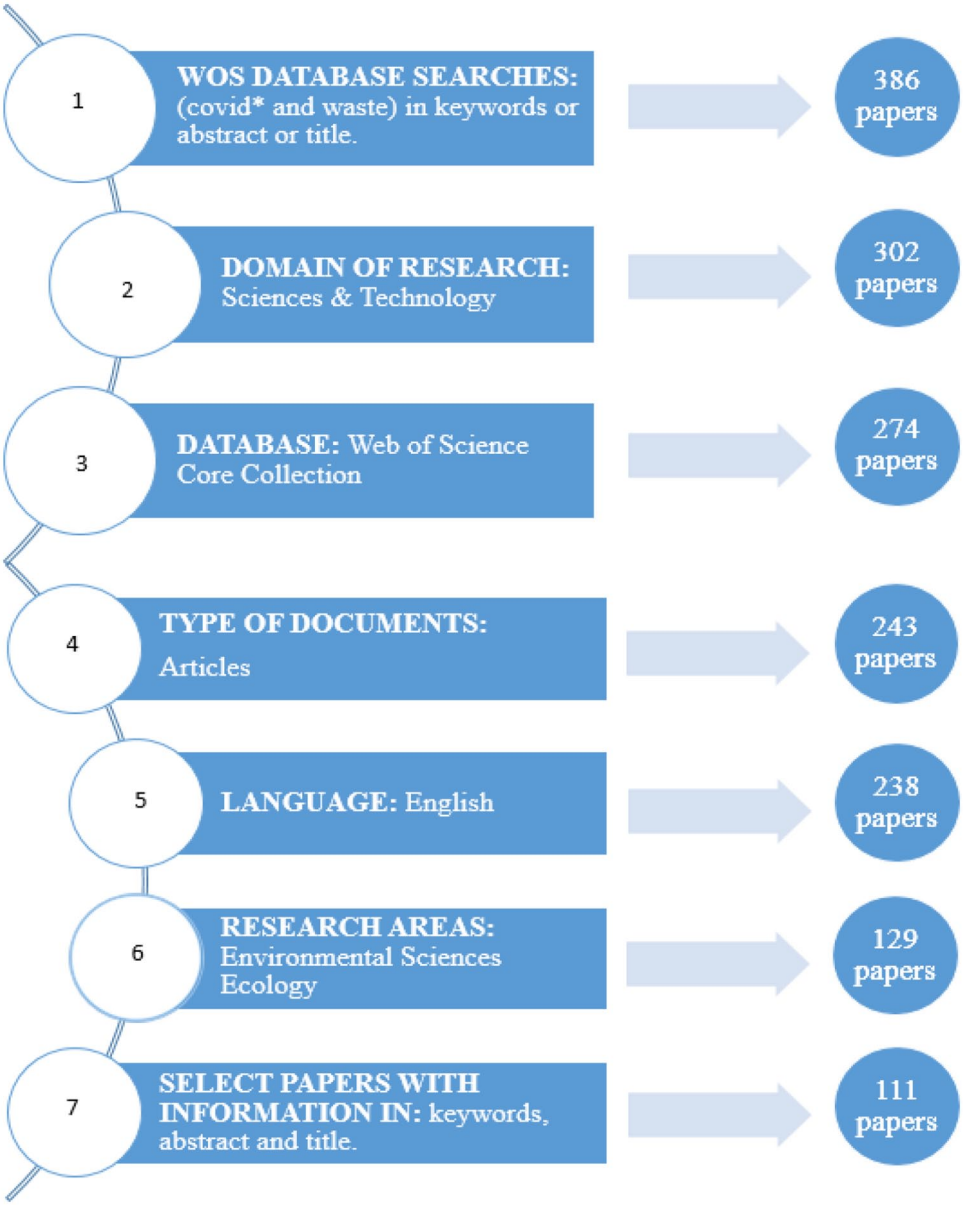

Figure 1. Summary of the review process.

clusters was validated through three popular clustering validity indices.

Average silhouette width. A measure that considers how closely related objects are within the cluster and how clusters are separated from each other. The average silhouette width provides clustering validity and is widely used to select the best number of clusters. Its value ranges between 1 and −1, with a value of 1 indicating a very good cluster (Kaufman and Rousseeuw, 1990; Rousseeuw, 1987).

Average between clusters. A measure of the average distance between cluster centres. It is influenced by the geometry of the cluster centres and increases with the number of clusters (Halkidi et al., 2001). The higher the value, the greater the separation between groups.

Dunn index. High values of this metric indicate compact and well-separated clusters where the means of different groups are sufficiently far apart, considering the internal variance of the cluster (Dunn, 1974; Halkidi et al., 2002).

Results and discussion

Text summarisation technique

The text summarisation technique of text mining is applied to detect the most frequently mentioned terms in environmental research papers that study COVID-19 and waste. The R-output of the database contains 2562 different terms or words in the 111 documents or environmental research papers. The non-/sparse entries are necessary to obtain the sparsity measure, which represents the frequency of the terms in the database. A low sparsity

Table 1. Environmental journals in the WoS database.

Journal	Frequency	%	Quartile
Science of the Total Environment	24	21.6	Q1
International Journal of Environmental Research and Public Health	9	8.1	Q1
Sustainability	9	8.1	Q2
Environment Development and Sustainability	5	4.5	Q3
Environmental Science and Pollution Research	5	4.5	Q2
Journal of Cleaner Production	5	4.5	Q1
Resources Conservation and Recycling	5	4.5	Q1
Environmental Pollution	4	3.6	Q1
International Journal of Hygiene and Environmental Health	3	2.7	Q1
Energy Sources Part A-Recovery Utilisation and Environmental Effects	2	1.8	Q3
Environmental Chemistry Letters	2	1.8	Q1
Global Journal of Environmental Science and Management-Gjesm	2	1.8	
Waste Management	2	1.8	Q1
Waste Management & Research	2	1.8	Q2
Aerosol and Air Quality Research	1	0.9	Q2
Air Quality Atmosphere and Health	1	0.9	Q2
American Journal of Infection Control	1	0.9	Q2
Appetite	1	0.9	Q1
Bulletin of Environmental Contamination and Toxicology	1	0.9	Q3
Cogent Environmental Science	1	0.9	
Drug Development and Industrial Pharmacy	1	0.9	Q3
Ecotoxicology and Environmental Safety	1	0.9	Q1
Environment and Urbanisation	1	0.9	Q2
Environment International	1	0.9	Q1
Environmental Management	1	0.9	Q2
Environmental Research	1	0.9	Q1
Environmental Research Letters	1	0.9	Q1
Environmental Science & Technology	1	0.9	Q1
Environmental Technology	1	0.9	Q3
Eurasian Geography and Economics	1	0.9	Q1
Eurosurveillance	1	0.9	Q1
Frontiers of Environmental Science & Engineering	1	0.9	Q2
Health Research Policy and Systems	1	0.9	Q2
Indian Journal of Biochemistry & Biophysics	1	0.9	Q4
Indian Journal of Community Health	1	0.9	
International Journal of Environmental Health Research	1	0.9	Q3
International Journal of Environmental Science and Technology	1	0.9	Q2
Journal of Environmental Health Science and Engineering	1	0.9	Q3
Journal of Environmental Management	1	0.9	Q1
Journal of Hazardous Materials	1	0.9	Q1
One Health	1	0.9	Q1
Renewable & Sustainable Energy Reviews	1	0.9	Q1
Smart and Sustainable Manufacturing Systems	1	0.9	
Sustainable Development	1	0.9	Q1
Tropical Medicine and Infectious Disease	1	0.9	Q1
World Development	1	0.9	Q1

value means terms are repeated often among the different documents (Dinov, 2018), which implies that the documents that make up the database are very similar. The longest terms, with 17 characters, are multidisciplinary and interrelationship.

The most frequent terms are those that appear at least 55 times in the database (Figure 2). The letter size represents the frequency of the term where the larger the font size, the higher the frequency. In this study, *covid* (772), *wast* (491) and *pandem* (223) are the three most commonly mentioned terms. It should be noted that the name of each term indicates the root obtained in the stemming process (see section 'Data').

Text clustering method

The hierarchical cluster analysis described in section 'Text mining method' is applied to identify research lines. To determine the best number of groups, three popular clustering validity statistics are presented in Table 2. The best number of clusters will be the

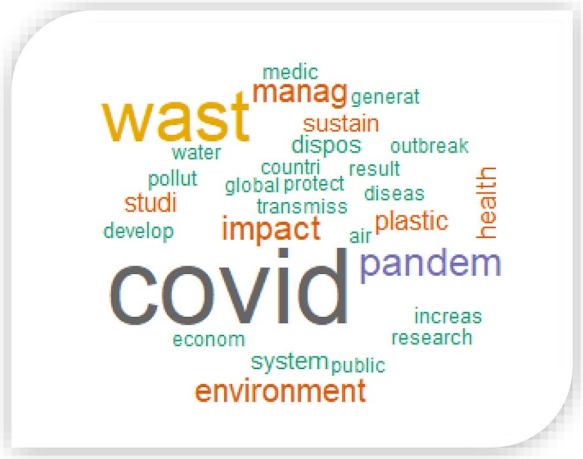

Figure 2. Most frequent terms in the database.

Table 2. Cluster validation statistics.

No. of clusters	Average silhouette width	Average between	Dunn index
2	0.40	3.80	0.81
3	0.37	3.80	0.88
4	0.22	3.00	0.52
5	0.12	2.60	0.34
6	0.12	2.50	0.35
7	0.02	2.30	0.30
8	0.03	2.30	0.31
9	0.04	2.30	0.33
10	0.02	2.30	0.33
11	0.03	2.30	0.34
12	0.05	2.30	0.34
13	0.05	2.30	0.35
14	0.07	2.30	0.35
15	0.07	2.30	0.37

one with the highest value in the average silhouette width, average between and Dunn index measures. It can be observed that Clusters 2 and 3 get the best results, which are very similar. Finally, three clusters are selected to facilitate the interpretation of these groups.

Table 3 shows the composition of each cluster made up of similar papers, that is, papers that share the most mentioned terms. The columns present the number of the clusters, number of papers, number of journals, number of terms in the cluster and finally, the JCR ranking.

Next, Figure 3 shows the graphical representation of the three clusters obtained on a two-dimensional plane. Each term is represented by a triangle where the closeness of terms indicates similarity between them (Lancia, 2008). The distance between each term and the origin (0,0) shows the quality of the terms in the two-dimensional plane, so that the terms farthest from the origin will have more discriminatory power and therefore will be better represented in a cluster (Kassambara, 2017). These three clusters show the most important concerns in the pandemic, revealing the patterns that could guide environmental authorities in the implementation of measures to mitigate and correct the consequences.

Main research lines linking COVID-19 and waste in the environmental field. The methodology applied has revealed three clearly distinct clusters, highlighting the lines of action proposed in the literature (Figure 3). Below, we examine the main ideas that emerge from each cluster.

Cluster 1: Understanding transmission as a means for early detection of COVID-19. This cluster contains 42.6% of all the papers analysed, with 15 of the most frequent terms in the context of the proposed research (Figure 3). Specifically, Cluster 1 is made up of the following: *covid* (26%), *impact* (5.68%), *environment* (5.40%), *health* (4.25%), *sustain* (4.02%), *air* (3.44%), *system* (3.39%), *water* (3.04%), *transmiss* (2.64%), *global* (2.47%), *develop* (2.41%), *research* (2.41%), *econom* (2.41%), *country* (2.30%) and *public* (1.95%), where *covid* has the highest frequency in this group in relation to the total database. The common thread running through these papers is the concern about the environmental impact of the production of plastics, a consequence of the protective products used during the pandemic to prevent infection. Figure 4 shows the papers and the number of citations, grouped in relation to the journal where they were published. Only journals that have more than seven citations have been shown; the remaining journals are grouped in 'Others'. In Figure 4, Science of the Total Environment stands out with more than 320 citations in a total of 10 papers.

This stream of the literature has focused on analysing the possible routes of transmission of the virus to be able to halt its spread and alleviate the human and environmental impacts generated in all countries around the world. Although there is still no proven evidence to confirm the different ways the virus is spread, there are various theories that are being put into practice to curb transmission. The most widespread approaches are minimising direct contact between people and constant sanitising. Both have reduced the viral load and the number of people infected (Kalpana et al., 2020; Rupani et al., 2020). During 2020, lockdown measures and major efforts to disinfect areas with heavy human traffic succeeded in bringing the pandemic under control, producing a notable decrease in cases and thus reducing pressure on hospitals.

Associated with this radical change in economic and social activity, significant environmental effects have been detected. On the one hand, the lockdown of the population and the consequent drop in production helped limit carbon emissions, significantly mitigating environmental pollution (Saadat et al., 2020). However, authors, such as Sarkodie and Owusu (2021) and Mostafa et al. (2021), advise the authorities to adopt the necessary measures to encourage the productive sectors to reactivate the economy.

On the other hand, it has been observed that almost all countries have relegated sustainable practices to the sidelines. Indeed,

Table 3. Characterisation of clusters of environmental research on COVID-19 and waste.

Clusters	No. of papers	No. of journals	Specific terms	Journal Citation Reports ranking
Cluster 1	55	31	15	Q1 (17), Q2 (9), Q3 (2), Q4 (1), not JCR (2)
Cluster 2	12	8	5	Q1 (5), Q2 (1), Q3 (2)
Cluster 3	44	20	9	Q1 (9), Q2 (5), Q3 (5), not JCR (1)

a widespread disregard for waste management can be seen, a possible source of transmission of the coronavirus. In critical situations, such as the one we are currently experiencing, prompted by the need to fight a seemingly endless pandemic, its most immediate consequences should not be overlooked. Nakada and Urban (2020) point out that the accumulation of medical waste and its inappropriate disposal facilitate the spread of the virus. In this regard, Carraturo et al. (2020) call for the appropriate treatment of water and waste, not only in industry but also in the healthcare system, where the massive use of PPE requires a specific procedure for its disposal. Rowan and Laffey (2021) argue there is a need for technological advances that allow the reuse of PPE and the innovative management of biomedical waste, preventing inappropriate processes that can be harmful to human health.

Currently, mass vaccination of the population is the centre of attention of policymakers and researchers, but this effort must be complemented by research into the environmental context to gain an understanding of the role it plays in mass infection. Huraimel et al. (2020) call for sound evidence on modes of transmission to validate what are as yet simply indications. A more intense focus on aerosol and faecal-oral transmission modes is recommended, and on air quality and wastewater for early detection. There is some evidence that the survival of the virus in biosolids and wastewater is low at temperatures above 20°C, and according to Setti et al. (2020), it has a major impact in areas with high concentrations of particulate matter PM10 and PM2.5.

In short, the studies of this cluster suggest that research efforts should be stepped up to obtain solid evidence that confirm the conclusions. The results will help ensure future diseases do not turn into a pandemic as virulent as that of COVID-19. Early detection of possible outbreaks requires an in-depth understanding of the environmental perspective, which is the main driver of the speed of the circulation of viruses. Specifically, the concentration of particulate matter and the climate must be thoroughly explored in light of the existing evidence on the role they play in areas where the effects of the pandemic have been particularly deadly. All this must be supported by policies that bring about a change in standard practices, fostering sustainable development in all areas and thereby ensuring environmentally clean surroundings for the public.

Cluster 2: The accumulation of plastic from products used to tackle the pandemic presents a serious threat to the planet. Cluster 2 comprises 12 studies, representing 9.3% of the total analysed. Following the same criteria as above, the most frequent are the following: *plastic* (21.54%), *pollut* (5.89%), *protect* (3.05%), *increas* (2.85%) and *pandem* (7.32%), where *plastic*, in addition to having the highest frequency in this cluster in relation to the total database, has the highest discriminatory power (Figure 3). There is a strong connection between the terms *increase, protect* and *pandem*, indicating that it would be worthwhile for researchers to focus on protection in the new pandemic-related environment. The common thread running through these papers is the concern about the environmental impact of the production of plastics, a consequence of the protective products used during the pandemic to prevent infection. Figure 5 shows that the papers published in the journal Renewable and Sustainable Energy Reviews are the most cited – a single article has 71 citations (Klemeš et al., 2020) – followed by Science of the Total Environment with 39 citations in five papers.

Pollution from plastic waste is a constant feature of all international agreements on climate change. In March 2019, the European Union adopted very strict directives to combat the plague of plastic invading the planet's oceans: a ban on single-use plastics from 2021 and a 90% collection target for plastic bottles by 2029, with 30% of them recycled by 2030 (https://ec.europa.eu/environment/topics/plastics/single-use-plastics_es). However, COVID-19 has seriously undermined countries' ability to achieve these targets.

Before the pandemic, the use of PPE, gloves or surgical masks was limited to within the healthcare system, so the management of this waste was never considered an environmental problem. Humanity's pressing need to protect itself against the virus has led to the mass use of these products, generating huge amounts of plastic waste and thus triggering urgent calls for effective treatment. According to Prata et al. (2020), an estimated 129 billion masks are used monthly worldwide, along with 65 billion gloves, adding to the PPE and waste from rapid diagnostic tests as real-time polymerase chain reaction (RT-PCR).

Silva et al. (2020) argue against delays to the reinforcement of plastic reduction policies, considering it necessary to combine them with technological advances that facilitate recycling and reuse. Incentives to promote public–private investments should be oriented in this direction: the transition to a circular economy model requires rapid implementation. Authors, such as You et al. (2020) and Parashar and Hait (2021), claim that plastic is a protector that requires appropriate management in terms of reduction, recycling and recovery to prevent harmful leakage into the environment. According to Celis et al. (2021), the way forward should involve the manufacture of biodegradable biomedical products that are free from toxic chemicals.

Current waste management systems do not have the capacity to absorb these new flows (Vanapalli et al., 2021).

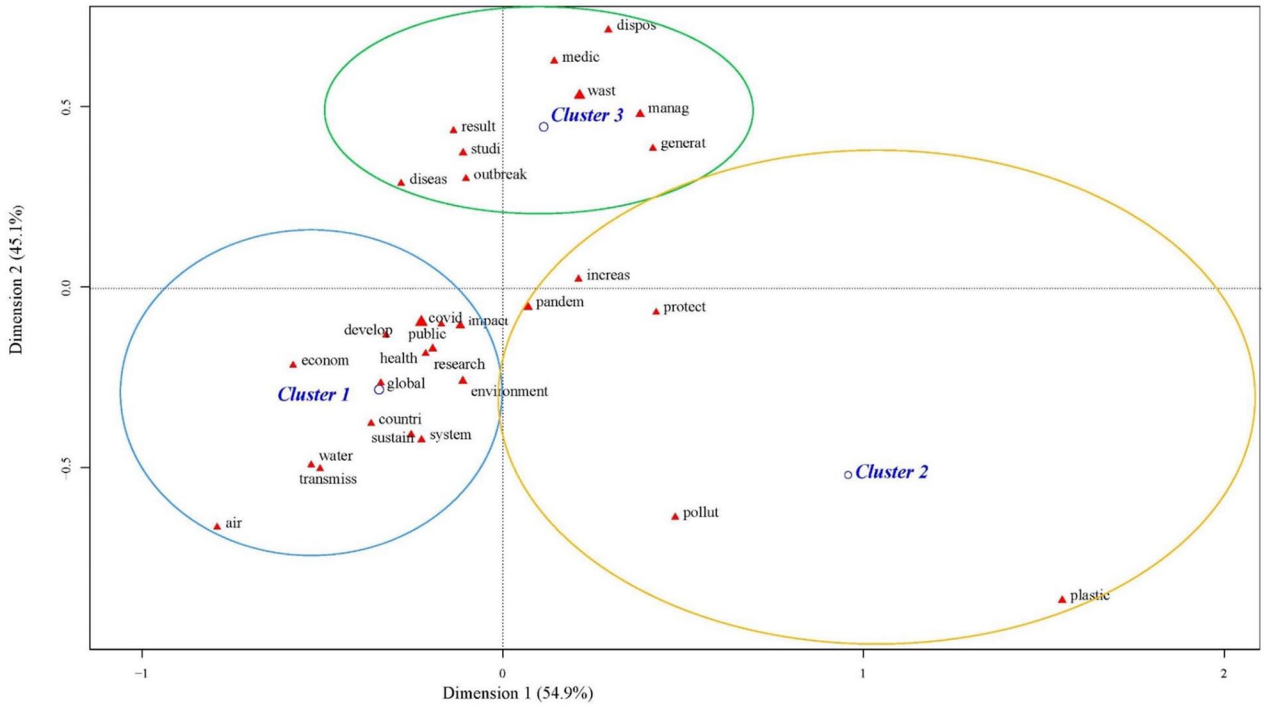

Figure 3. Hierarchical clustering of the most frequent terms in the database.

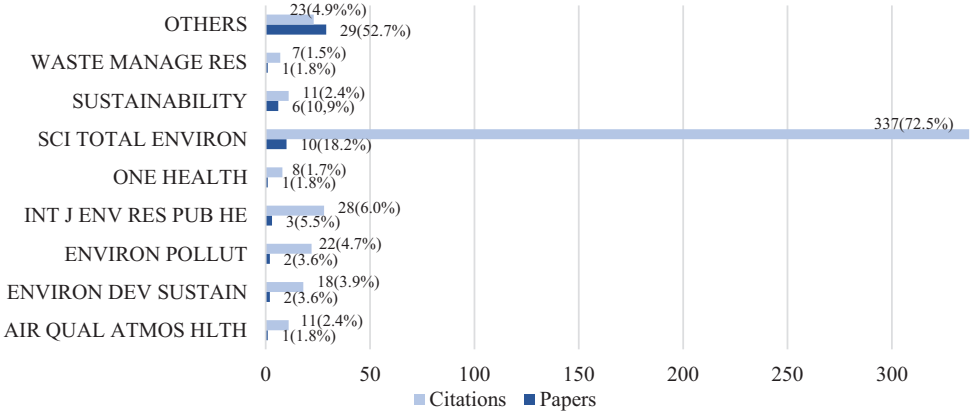

Figure 4. Number of papers and citations of journals in Cluster 1.

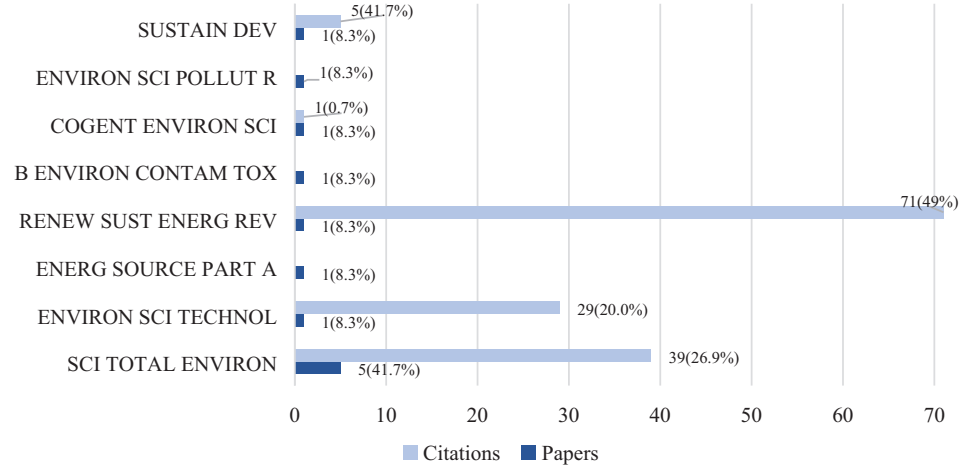

Figure 5. Number of papers and citations of journals in Cluster 2.

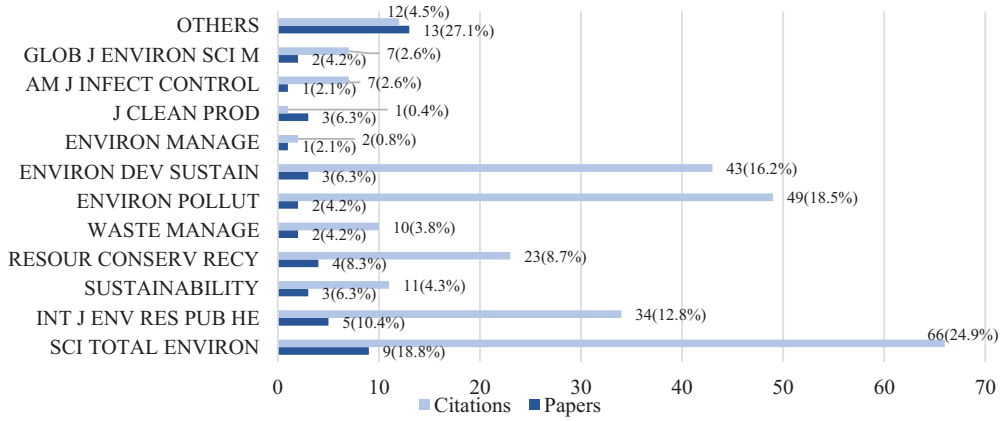

Figure 6. Number of papers and citations of journals in Cluster 3.

In addition to healthcare products, the general public is demanding hyper-hygienic products, hermetically packaged to prevent the transmission of the virus, exacerbating the problem even further. It is not known whether this new demand will be short-lived or if it represents a change in people's behaviour, where protection against possible diseases will mean the environmental disaster, this cause is overlooked. Given the scale of the problem, Klemeš et al. (2020) propose the introduction of the plastic waste footprint to track the environmental footprint of plastics during their life cycle. This would allow abstract environmental burdens to be quantified, providing valuable information to non-specialised people with decision-making power.

Specifically, Ardusso et al. (2021) show that in South America, the lack of appropriate protocols, the inadequate management of the growing volumes of medical waste combined with a lack of collection adapted to the new circumstances, is increasing the pollution of its rivers and beaches. The synthetic nanoparticles in PPE and other protective items pose a growing threat to marine life in this region. In this vein, Liu et al. (2021) call on the Chinese government to simultaneously manage virus containment and environmental protection.

In conclusion, all the authors agree on the importance of applying sustainable strategies and policies that encourage research and thus ensure the appropriate treatment of these new types of waste. It is a problem that threatens the planet as a whole, requiring a proper commitment commensurate with the danger we are facing. Large-scale implementation of circular economy systems, together with citizen awareness and educational campaigns, could help to allay this serious problem.

Cluster 3: Municipal solid waste management must be adapted to the new situation. This cluster revolves around the following nine terms of frequency: *wast* (22.42%), *dispos* (5.00%), *manag* (7.63%), *medic* (3.71%), *studi* (4.32%), *generat* (2.50%), *result* (2.36%), *outbreak* (2.16%) and *diseas* (2.06%), where *wast* has the highest frequency in this group in relation to the total database. Following the same criteria as in Figure 5, Figure 6 shows only those journals that have more than seven citations, with the rest being grouped into 'Others'. It is observed that Science of the Total Environment stands out with more than 66 citations in a total of nine papers.

In line with the previous two clusters, this one also highlights the need of proper disposal of the enormous amount of biomedical waste to prevent the transmission of the disease. It is estimated that the virus can survive for more than 3 days on the masks used by infected patients; Ilyas et al. (2020) thus point to the need for urgent action. Chemical disinfection with 1% NaOCI could be a short-term solution and would even allow recycling and the reuse of PPE and other textiles used in the field of healthcare.

In addition, there has been a widespread lack of concern about the management of municipal solid waste, where improper procedures carry a huge potential risk for whoever is handling it (Kulkarni and Anantharama, 2020). According to Ragazzi et al. (2020), the selective collection rate in Italy has decreased by around 15%, with the authors noting a lack of protocols for lockdown situations. Given this concern, the Italian National Institute of Health set up a working group during the early days of the pandemic to establish guidelines related to solid waste collection, delivery, withdrawal, transport, treatment and disposal (Di Maria et al., 2020). As a result, a temporary stop on waste sorting was recommended, the population was informed about how to package waste, companies were informed about the proper use of PPE and recommendations were provided on the use and sanitation of vehicles.

As a result of a study carried out in Romania, Mihai (2020) recommends using spatial statistics and thematic cartography to monitor the waste generated by COVID-19 in healthcare facilities and places where people are isolating. Similarly, in some cities, such as Isfahan (Iran), the pandemic has led to a ban on waste separation, recycling and composting programmes, with waste being directly disposed of in landfills. Zand and Heir (2021) call for the implementation of protocols to ensure proper management of urban waste. It is necessary to resume the composting practices abandoned as a result of the pandemic, and there is also a need for greater public awareness to prevent the foreseeable environmental impact of this inadequate treatment.

Sharma et al. (2020) claim that lockdown has reduced the generation of food waste, due to a change in people's shopping habits, as they look to buy non-perishable products. However, the lack of warehouse workers to handle the food and the restriction on movement limits transport and can lead to breaks in the supply chain. Only the introduction of innovative processes could resolve situations like these.

In conclusion, the studies in this cluster recommend new regulated action procedures for decision-makers regarding how to manage waste in extreme situations, such as those caused by COVID-19. Public urban hygiene services need to be prepared and know the guidelines to follow. Situations should be avoided where a lack of information causes anxiety for people who have been locked down and barely able to leave their home for weeks or months, and for whom waste disposal is a daily task that needs to be done. In general, there is a need for proper management of facilities for incineration, sterilisation and landfills for the treatment of waste that could have a viral load, representing a possible source of transmission. The introduction of automated processes could be one way of reducing contact with any type of waste.

Conclusion

The healthcare emergency caused by the rapid spread of the virus and its grave consequences for all economic and social sectors has sparked the interest of the scientific community. The research carried out has explored different avenues to determine the extent of the impact and to be as prepared as possible to tackle it. In this study, 111 papers have been analysed, grouping the most frequent terms into three clusters, in which the common thread has been COVID-19 and waste. Each of them has a different area of specialisation: the first focuses on transmission; the second on the concern about the mass production of plastics and the third on the lack of adequate treatment for solid waste in extreme circumstances. However, all the papers analysed converge on the same recommendation: leaders should have contingency plans for waste management in place to be able to deal with situations such as those caused by this pandemic.

Strengths and limitations of the study

After having determined the three lines of study developed in the literature, the authors consider that the guidelines should focus on the following directions:

- There is a need for the introduction of technological advances that allow the reuse of protective medical products, while also avoiding the direct handling of this type of waste.
- The authorities should incentivise research into the transmission of the virus, where certain environmental conditions could accelerate the rate of infection.
- Circular economy systems need to be established in all productive sectors to reduce pollution and ensure full use is made of the waste generated.
- Educational and information campaigns on the guidelines to follow to achieve environmentally clean surroundings must be carried out all over the world.

Only by raising citizens' awareness can pollution – which causes global warming and many of the diseases that afflict humanity – be reduced.

It is worth mentioning two limitations of this study. The first is the database used, which could be expanded with the Scopus database. Furthermore, it would be interesting to carry out a comparative study on the results obtained with the two databases. This information would help researchers and policymakers both in selecting a journal for their research and in having up-to-date information on what is currently being researched. The second is that our objective is specific to COVID-19 and waste in the environmental field, but the analysis could be expanded with other search criteria. Finally, this process should be automated using the programming language provided in R to continuously track all the papers that are published. Any advances and new proposals made by researchers could thus be detected.

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Note

1. It includes six main citation indexes: Science Citation Index Expanded, Social Sciences Citation Index, Arts & Humanities Citation Index, Conference Proceedings Citation Index, Books Citation Index and Emerging Sources Citation Index.

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Appendix 1

Table 4. Paper analysed.

Journal	References
Science of the Total Environment	Huraimel et al. (2020); Aldaco et al. (2020); Di Maria et al. (2020); Franklin and Bevins (2020); Ilyas et al. (2020); Kargar et al. (2020); Kulkarni and Anantharama (2020); Kumar et al. (2020c); Orive et al. (2020); Silva et al. (2020); Ragazzi et al. (2020); Rowan and Galanakis (2020); Saadat et al. (2020); Zambrano et al. (2020); Ardusso et al. (2021 Celis et al. (2021); Hartanto and Mayasari (2021); Parashar and Hait (2021); Rowan and Laffey (2021); Sunkari et al. (2021); Tirkolaee et al. (2021); Urban et al. (2021); Fan et al. (2021); Vanapalli et al. (2021)
International Journal of Environmental Research and Public Health	Jin and Qian (2020); Liu et al. (2020); Mihai (2020); Setti et al. (2020); Yu et al. (2020); Cosgrove et al. (2021); Dabrowska et al. (2021); Lassi et al. (2021); Mahdi et al. (2021)
Sustainability	Ben Hassen et al. (2020); Dombroski et al. (2020); Fleetwood (2020); Giudice et al (2020); Ismail et al. (2020); Kapecki (2020); Qian et al. (2020); Shurson 2020); Tleuken et al. (2021)
Environment Development and Sustainability	Jribi et al. (2020); Kumar et al. (2020b); Sarkodie and Owusu (2021); Aydin et al. (2021); Islam et al. (2021
Environmental Science and Pollution Research	Tabish et al. (2020); Younis et al. (2020); Boroujeni et al. (2021); Praveena and Aris (2021); Quinete et al. (2021)
Journal of Cleaner Production	Chauhan et al. (2021); Manupati et al. (2021); Shah et al. (2021); Thakur (2021); Varbanov et al. (2021)
Resources Conservation and Recycling	Neumeyer et al. (2020); Sharma et al. (2020); Giordano et al (2021); Ikiz et al. (2021); Yang et al. (2021)
Environmental Pollution	Carraturo et al. (2020); Hendryx and Luo (2020); Wang et al. (2020b); Ammendolia et al. (2021)
International Journal of Hygiene and Environmental Health	Mouchtouri et al. (2020); Maher et al. (2021); Pandey et al. (2021)
Energy Sources Part A-Recovery Utilisation and Environmental Effects	Göçmen (2020); Mehran et al. (2021)
Environmental Chemistry Letters	Prabha et al. (2020); Sun and Han (2020)
Global Journal of Environmental Science and Management-Gjesm	Abu-Qdais et al. (2020); Ouhsine et al. (2020)

(Continued)

Table 4. (Continued)

Journal	References
Waste Management	Kalina and Tilley (2020); Richter et al. (2021
Waste Management & Research	Agamuthu adn Barasarathi (2020); Rhee (2020)
Aerosol and Air Quality Research	Liu and Schauer (2021)
Air Quality Atmosphere and Health	Bashir et al (2020)
American Journal of Infection Control	Peng et al (2020)
Appetite	Rodgers et al (2021)
Bulletin of Environmental Contamination and Toxicology	Liu et al. (2021)
Cogent Environmental Science	You et al. (2020)
Drug Development and Industrial Pharmacy	Rahma et al. (2019)
Ecotoxicology and Environmental Safety	Hoseinzadeh et al. (2020)
Environment and Urbanisation	Suter and Luethi (2021)
Environment International	Yuan et al. (2020)
Environmental Management	Belhadi et al (2020)
Environmental Research	Casado-Aranda et al. (2021)
Environmental Research Letters	Greer et al. (2020)
Environmental Science & Technology	Prata et al. (2020)
Environmental Technology	Zand and Heir (2021)
Eurasian Geography and Economics	Cloke (2020)
Eurosurveillance	Wurtzer et al. (2020)
Frontiers of Environmental Science & Engineering	Wang et al. (2021)
Health Research Policy and Systems	Hanney et al. (2020)
Indian Journal of Biochemistry & Biophysics	Chitra et al (2020)
Indian Journal of Community Health	Kalpana et al. (2020)
International Journal of Environmental Health Research	Irfan et al. (2021)
International Journal of Environmental Science and Technology	Rupani et al. (2020)
Journal of Environmental Health Science and Engineering	Torkashvand et al. (2021)
Journal of Environmental Management	Mostafa et al. (2021)
Journal of Hazardous Materials	Ding et al. (2021)
One Health	Trottier et al. (2020)
Renewable & Sustainable Energy Reviews	Klemeš et al. (2020)
Smart and Sustainable Manufacturing Systems	Diaz-Elsayed et al. (2020)
Sustainable Development	Khan et al. (2020)
Tropical Medicine and Infectious Disease	Mahdi et al. (2020)
World Development	Sen (2020)

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