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Original Article

The Impact of COVID-19 Pandemic on Hospital Waste Management: A Bibliometric Analysis

Nabila Astri Nur Kuntari[1], Maria Ulfa[1,2*], Agus Jamal[3]

[1]Master of Hospital Administration, Postgraduate Program, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia
[2]School of Medicine, Faculty of Medicine and Health Sciences, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia
[3]Electrical Engineering, Faculty of Engineering, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia

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***Corresponding author:**
Maria Ulfa,
Email: mariaulfa@umy.ac.id

Abstract
Any used solid, liquid, or gaseous substance will be immediately discarded. Dumped substance waste is generated in various places, including hospitals. The recent problem faced by hospitals is the outbreak of the COVID-19, a novel form of severe acute respiratory syndrome (SARS) that has resulted in a marked escalation in the generation of medical waste. The hospital management system covers hospital waste management. This management allows the hospital to monitor the amount and types of produced waste, thereby minimizing the harmful effects of waste. However, in this area, systematic analytical mapping studies still have numerous research limitations. This study aimed to provide a detailed analysis of the generated additional COVID-19 hospital waste and its impact on the environment and public health. Accordingly, this study applied the qualitative method with a literature study approach. The hospital waste management articles identified from 2020-2022 amounted to 920 publication articles indexed by Scopus, indicating that hospital waste management studies have increased in recent years. The study revealed that the COVID-19 pandemic caused an alarming surge in medical waste, posing a significant threat to the environment. This situation provides an opportunity to enhance healthcare waste (HCW) management systems in a manner that is both ecologically sound and secure.
Keywords: Hospital waste management, COVID-19, Systematic review

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1. Introduction

Healthcare facilities (HCFs) are the primary sources of healthcare waste (HCW), which is commonly referred to as HCW. This term encompasses the waste produced by HCFs and includes medical, biomedical, clinical, and health facility waste (1). It is important to recognize the significance of managing HCWs effectively and efficiently to ensure the safety and well-being of patients, healthcare workers, and the environment. The COVID-19 pandemic led to a double increase in waste, as well as a reduced capacity of healthcare workers to manage waste due to increased patient loads, COVID-19 work, and societal constraints (2). In response to the COVID-19 pandemic, there has been a significant rise in medical waste worldwide (3). Not only does this waste contribute to environmental problems caused by solid waste, but also it creates a potential health hazard for those who handle it (4). This has created a pressing concern for the healthcare industry as the proper management and disposal of medical waste is crucial for public health and environmental protection. The increase in medical waste generation can be attributed to the widespread use of personal protective equipment by healthcare workers, as well as the sharp rise in the number of patients seeking medical attention (5). HCFs must implement effective waste management strategies to mitigate the risks associated with medical waste disposal and to safeguard both public health and the environment.

The World Health Organization (WHO) reports that the generation of tens of thousands of additional tonnes of medical waste puts a great deal of stress on HCW management systems across the globe (6). The recent outbreak of COVID-19, a novel form of severe acute respiratory syndrome (SARS), has resulted in a marked escalation in the generation of medical waste (7). With COVID-19 spreading rapidly and through various pathways (8), disposable protective equipment such as masks, gloves, goggles, and insulating and protective clothing are being consumed at an unprecedented rate, leading to a substantial increase in medical waste in the environment (9, 10). Statistics indicate that over 140

million testing kits have been used since the outbreak of COVID-19, potentially generating 2600 tones of non-infectious waste (mostly plastic) and 731 000 Liters of chemical waste (6). The United Nations Environment Program released a report stating that medical waste generated by HCFs related to COVID-19 has increased to 3.4 kg per person per day globally and approximately 2.5 kg per bed per day in developing countries (11). Globally, a significant proportion of HCFs, specifically three out of every ten currently lack systems for properly segregating waste (2). In the least developed countries, the situation is even more dire, with less than one in three HCFs having access to even basic waste management services. The COVID-19 pandemic has further exacerbated this challenge, with medical waste management becoming a critical issue for health systems worldwide (2).

HCFs need to implement effective waste management practices to safeguard public health and the environment. This includes proper segregation, collection, transportation, treatment, and disposal of waste (2). Failure to do so can result in severe environmental pollution, the spread of infectious diseases, and other health hazards. The importance of addressing potential gaps in solid waste management during the epidemic was highlighted. Hospital waste management, particularly with regard to biological waste, plastic garbage, and food waste, was a heavily discussed topic due to the potential of these waste types to contribute to the spread of illness (7).

Therefore, it is critical that healthcare providers, governments, and other stakeholders take proactive steps to address this pressing issue. This may involve investing in waste management infrastructure, providing training and education to healthcare workers, and promoting public awareness campaigns to encourage effective waste disposal practices (2). By working collaboratively and taking a proactive approach, we can ensure that HCW is managed safely and sustainably, protecting both human health and the environment.

This study aimed to provide a detailed analysis of the additional COVID-19 hospital waste that has been generated and its impact on the environment and public health. It also examined the current hospital waste management systems and their shortcomings and suggested the best-emerging practices and solutions to help reduce the impact of waste on human and environmental health.

2. Methods

To conduct this study, a qualitative literature review methodology was used. This search was limited to peer-reviewed journals with international reputations published between 2020 and 2022, accessible through the Scopus database (scopus.com). The utilized search keywords were "hospital AND waste AND management". We only included documents in English that were published at the final publication stage and met our specific criteria regarding the subject areas of medicine, environmental science, immunology, and microbiology and excluded any subjects beyond these areas.

To eliminate any bias introduced by the expansion of the database, data were gathered in August 2022. Fig. 1 illustrates the detailed study flow diagram generated through the procedures employed in this study. The process of selecting documents followed steps adapted from Page et al (12). Information about study maps was shared through the data being exported in RIS export file format. The Scopus search results were then reviewed using a descriptive method based on the publication year, publishing company, country, publication title, and research topic.

This research employed bibliometric analysis to investigate hospital waste management and offer practical suggestions based on the findings. The Scopus menu search results were scrutinized by VOSviewer, RStudio,

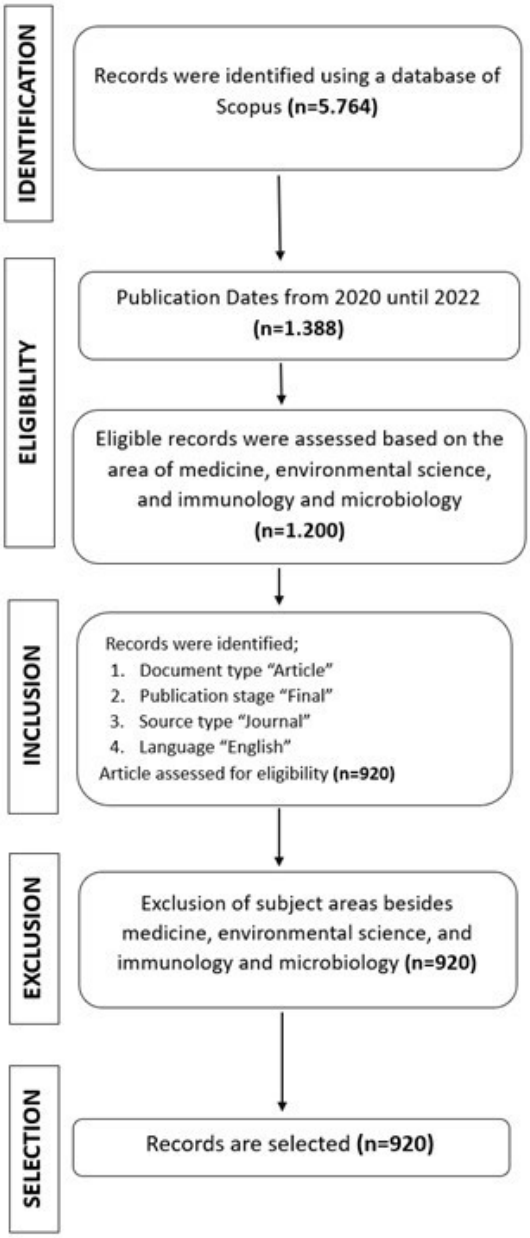

Fig. 1. Flow Diagram on Hospital Waste Management Document Selection Process. *Note.* Source: Adapted from Page et al (12)

and NVivo 12 Plus analytical tools, which culminated in a bibliometric analysis map. VOSviewer was employed to develop a bibliometric map of global research on food safety and security. Then, the collected data underwent numerous refinements to extract pertinent information concerning hospital waste management. The RStudio software offers a user-friendly interface and a set of tools to enhance the productivity of R by visualizing identified keyword trends for each year, making them easy to understand. The NVivo 12 software evaluated the connection between indicators, variables, and keywords used in the chosen studies, resulting in valuable insights for the study.

The researchers performed a comprehensive examination of the research area through bibliometric searches, which involved analyzing mixed citations, co-authorships, and co-occurrences. This enabled us to gain a thorough understanding of the social structure and patterns within the field. We also utilized bibliographic coupling and co-citations to compare references, identify conceptual frameworks, and generate figures and data through various analyses such as keyword co-occurrence analysis, the analysis of significant authors and country distribution, cited sources co-citation analysis, document and organization citation analysis, and co-citation network analysis.

3. Results and Discussion

3.1. Trend by Keywords on Hospital Waste Management

The data presented in Fig. 2 indicated a notable increase in the number of research papers that have been published on the topic of managing hospital waste over the years. This trend has become more pronounced in recent years, with a significant surge in the number of papers published between 2020 and 2022. The current study, which analyzed a vast amount of data, could identify a total of 920 papers published during the COVID-19 pandemic. This finding underscores the importance and urgency of this subject as healthcare institutions worldwide grapple with managing the surge in medical waste generated by the pandemic. Overall, these results indicate that hospital waste management is an area of increasing interest and importance for researchers and one that demands ongoing attention and investment.

The study found that 109 countries conducted research in the relevant field. The United States (146 published papers), India (141 published articles), China (110 published papers), Iran (60 published papers), the United Kingdom (54 published papers), and Brazil, Germany, and Italy (each with 32 published papers) were identified as the leading contributors in this area, as illustrated in Fig. 3.

Fig. 4 presents the results of document analysis conducted by VOSviewer and RStudio. The study identified keyword trends for each year. The document analysis results conducted by VOSviewer and RStudio analysis, depicted in Figure 4, provide valuable insights into the keyword trends observed in the research conducted from 2020 to 2022. The analysis aimed to identify the most common research themes and topics in the field of environmental management.

According to the results, the most notable research keywords in 2020 were coronavirus, disease transmission, and hospital. The research community focused on studying the impact of the COVID-19 pandemic on the environment, especially in terms of disease transmission and organizational management. In 2021, the research trends shifted towards waste management, hospital waste, and wastewater management. Environmental scientists were concerned with the safe disposal of hospital waste, especially during the ongoing pandemic, and wastewater management became a popular research topic due to its critical role in preventing the spread of diseases. In 2022, the research community focused on pollution control, organic carbon, and policy implementation. The focus was on improving environmental policies and implementing effective pollution control strategies to mitigate the adverse effects of human activities on the environment. Further analysis conducted using RStudio revealed that the most frequent keywords from 2020 to 2022 are COVID-19 pandemic (749), waste management (485), hospital (434), hospital waste (308), and wastewater treatment (307). These findings could help researchers and policymakers better understand the most pressing issues in the field of environmental management and focus their efforts on

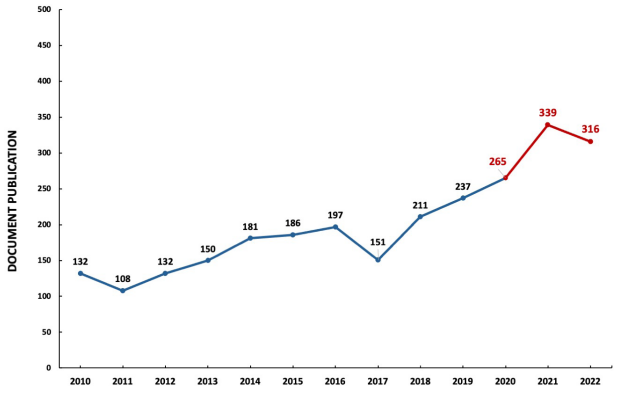

Fig. 2. Documents Publication by Year. *Note*. Source: Scopus

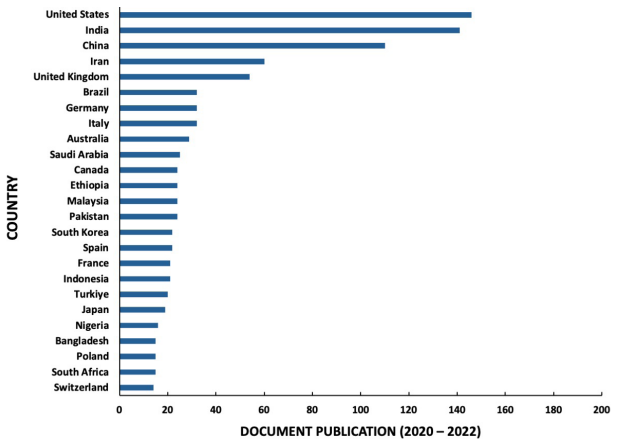

Fig. 3. Documents Publication based on Nation. *Note*. Source: Scopus

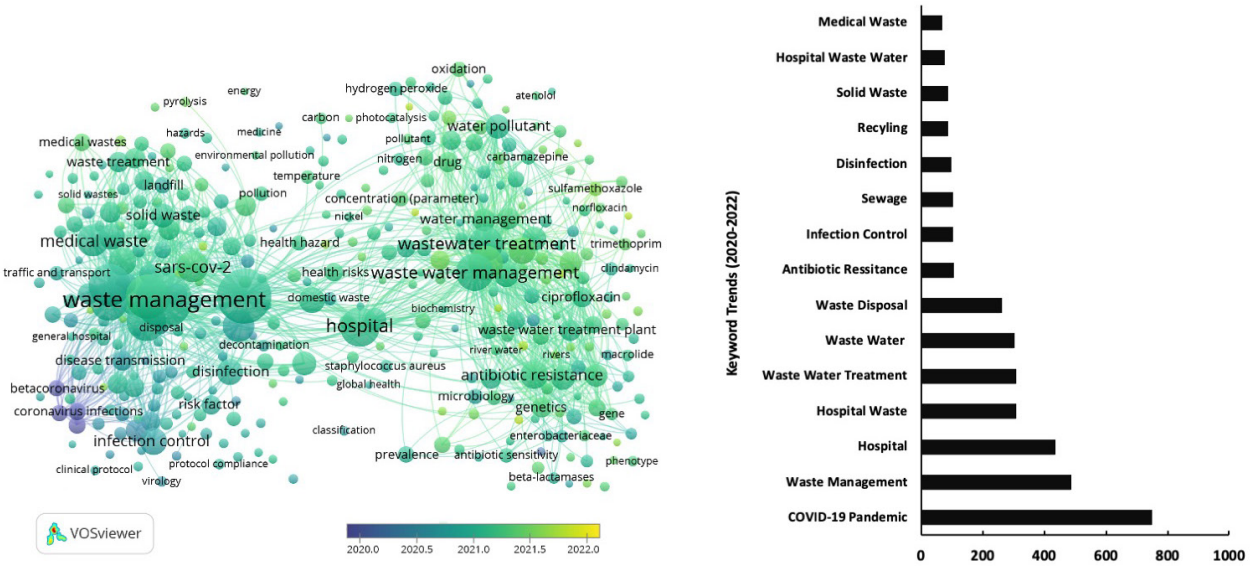

Fig 4. The Keywords Trends in Hospital Waste Management by Year. *Note.* Source: VOSviewer and RStudio

addressing them effectively.

The global spread of COVID-19 affected all aspects of life, including the management of hospital waste. The surge in the number of patients being treated for the virus led to a significant rise in the amount of medical waste generated by hospitals. According to a recent study, countries with high revenue typically produce up to 0.5 kg of hazardous medical waste per hospital bed (13). According to our research findings, the issue became even more intriguing when we examined the obtained data, which indicates a notable rise in the publication of research related to waste during the pandemic. Fig. 2 clearly illustrates the year-by-year increase in the trend of writing research on waste since the outbreak of the pandemic. Figure 3 highlights the top 25 countries globally with the most research articles on hospital waste. The findings of the research showed that the US has the highest number of published papers on hospital waste between 2020 and 2022 (146 articles), followed by India with 141 published articles. Interestingly, a comparison with the pre-Covid era indicates that the US published a total of 357 articles on hospital waste during the 2010-2019 period, while India published 187 articles (Fig. 3).

Moreover, it is possible to gauge a country's commitment to addressing its HCW challenges by examining the number of publications devoted to the topic. A country's level of interest in waste management can be inferred from the number of articles published, particularly when it corresponds with the amount of waste generated in that country. The US produces the greatest amount of HCW per bed per day (8.4 kg), which explains why it also boosts the largest number of HCW-related publications worldwide. Several countries produced different amounts of HCW per bed per day. The top five countries besides the United States are Canada (8.2 kg), Turkey (4,66), Spain (4.4 kg), and China (4,03). This suggests that HCW issues are a significant concern for US-based researchers. However, there may be additional factors that influence a country's publication output.

Based on the results obtained using VOSviewer analysis, there are research keyword trends that experience development every year. The terms coronavirus, disease transmission, and hospital were the most frequent study keywords in 2020, which is in line with the recent emergence of cases of a new disease on the surface which is COVID that immediately caused a global pandemic. Therefore, many researchers were interested to start to identify COVID. Moreover, WHO revealed that the easy transmission of COVID-19 through droplets and aerosol particles will challenge the human health sector, one of which is the environmental sector (14). The COVID-19 pandemic has had a significant impact on the waste management aspect of the environment sector. As a result, in 2021, there was a shift in the most popular research keywords towards managing waste. The research keywords became increasingly specific in 2022, focusing on pollution control, organic carbon, and policy implementation. This is an effort to improve environmental policies and implement efficient pollution control measures.

The researchers conducted a thorough analysis using RStudio and other tools to identify the most frequently used research keywords and determine the pressing issues in the field. The results indicated that the majority of people search for information related to the impact of the COVID-19 pandemic on the environment. To provide a more detailed understanding of the findings, the researchers categorized the discussion into four clusters, each focusing on a specific aspect of the pandemic's impact on the environment, particularly hospital waste. This approach aimed to group the discussions in a more focused manner.

3.2. Cluster Themes on Hospital Waste Management

To assess the retrieved keywords, the VOSviewer application was used. This tool allowed for a thorough

analysis of the keywords and provided valuable insights into the relationships between them. As depicted in Fig. 5, the VOSviewer application generated a visual representation of the keyword connections, facilitating the interpretation of the results. Moreover, a detailed description of the keywords was provided in Table 1, which included various metrics such as their frequency, co-occurrence, and centrality measures. Overall, using the VOSviewer application provided a comprehensive evaluation of the retrieved keywords and helped uncover important patterns and trends in the data. This tool is widely recognized for its ability to construct and showcase bibliometric networks developed by van Eck and Waltman in 2010. Each cluster was thoughtfully labeled using distinct colors, with red assigned to represent hospital waste management, which accounted for 46% of the total clusters. Green was attributed to antibiotic resistance bacteria in Hospital wastewater treatment plant, constituting 28% of the total clusters, blue was designated to signify emerging pollutants in wastewater, accounting for 25% of the total clusters, and finally, yellow was assigned to virus detection, representing only 1% of the total clusters.

The analysis presented in Fig. 6 provides a detailed examination of hospital waste management. The study covers a period of three years from 2020 to 2022 and involves a thorough search of 485 sources. The study's search yielded a total of 920 documents on hospital waste management, which were then analyzed for relevant information. The study found that a large number of authors, specifically 4700, contributed to the literature on hospital waste management, suggesting that this is a topic of significant interest and importance. Furthermore, the study revealed an annual growth rate of 9.2% in publications related to hospital waste management, indicating that this area of research is experiencing rapid growth. These findings highlight the need for continued research and development in hospital waste management to ensure the safe and efficient disposal of medical waste.

Hospitals produce a wide range of waste materials, including solid, infectious, and liquid waste. The COVID-19 pandemic has led to a sharp increase in the amount of waste generated by HCFs, making effective waste management more crucial than ever. However, a significant number of hospitals, three out of every ten, lack proper systems for segregating waste (2). Waste segregation is a crucial stage in determining the effectiveness of hospital waste management. According to Rezaei Kalantary et al (15), the pandemic has increased the types of infectious waste produced by hospitals, making proper segregation of HCW an essential effort to minimize the volume of infectious waste and prevent the spread of diseases. Regardless of the final waste treatment and disposal strategy chosen, separating waste streams is necessary for more effective waste management.

The safe and appropriate handling of HCW is of utmost importance in preventing the spread of diseases, safeguarding the environment, and ensuring the safety of healthcare workers and the general public. It is the responsibility of HCFs to strictly adhere to comprehensive regulations and guidelines in managing the handling, treatment, and disposal of HCWs. The failure to comply with these directives may lead to severe legal and health consequences, as well as irreparable harm to the reputation

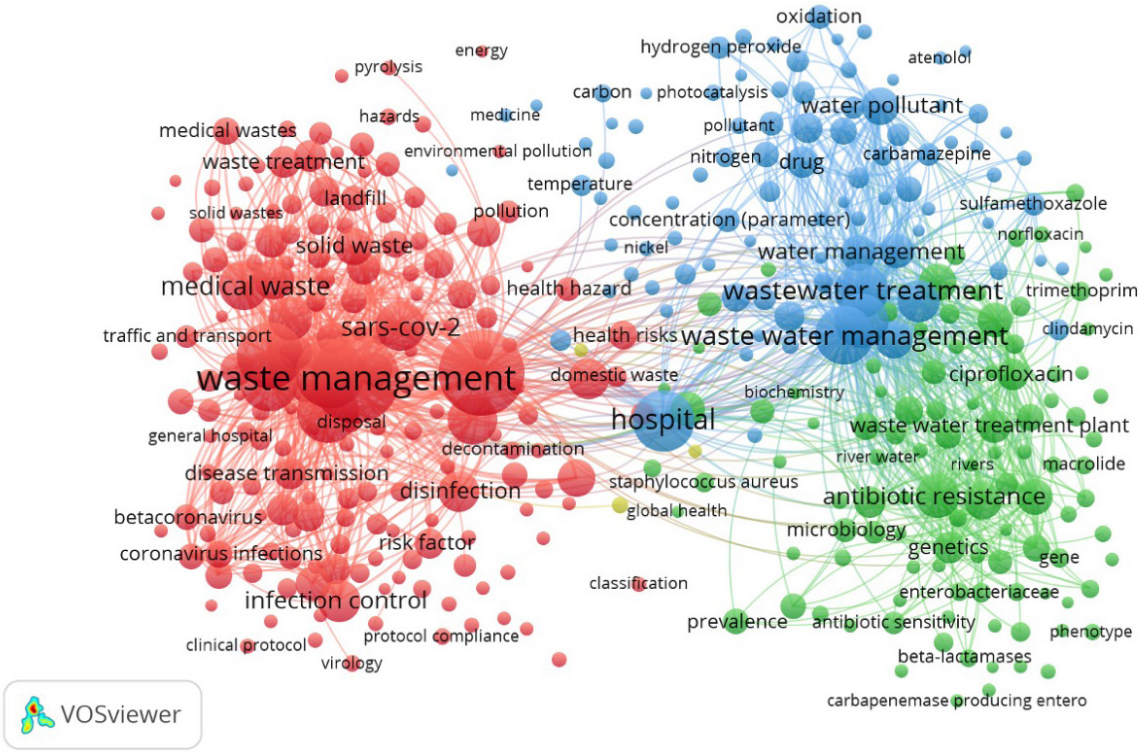

Fig 5. Network Visualization by Keywords Using VOSviewer

Table 1. The Clusters' Themes of Hospital Waste Management Using VOSviewer

Clusters' Theme	Items	Total	Percent
Cluster 1: Hospital waste management	Adverse event, air pollution, attitude, bacterium contamination, beta-coronavirus, biomedical waste, biomedical waste management, biosafety, carbon dioxide, carbon footprint, classification, climate change, clinical protocol, communicable diseases, containment of biohazard, coronavirus, COVID-19, coronavirus infection, coronavirus infections, coronaviruses, cost-benefit analysis, COVID-19, COVID-19 pandemic, cross infection, decontamination, diarrhea, disease outbreaks, disease severity, disease spread, disease surveillance, disease transmission, diseases, disinfectant agent, disinfection, disposal, domestic waste, economic aspect, energy, environment, environmental factor, environmental health, environmental impact assessment, environmental management, environmental policy, environmental pollution, environmental protection, environmental sanitation, environmental sustainability, Ethiopia, fever, food waste, general hospital, greenhouse effect, greenhouse gas, greenhouse gases, hazardous waste, hazards, health, health care, health care management, health care planning, health care policy, health care system, health care utilization, health center, health education, health hazard, health risk, health risks, health service, healthcare, healthcare facility, healthcare waste, healthcare waste management, hospital cost, hospital emergency service, hospital hygiene, hospital management, hospital sector, hospital service, hospital waste, hygiene, incidence, incineration, infection, infection control, infection prevention, infection prevention and control, infection risk, infectious disease, infectious waste, innovation, instrument sterilization, laboratories, landfill, life cycle, analysis, lockdown, management, management practice, medical society, medical waste, medical waste disposal, medical waste management, medical wastes, mortality, municipal solid waste, municipal waste, optimization, organization and management, outcome assessment, pandemic, pathogenicity, patient education, perception, plastic waste, plastics, policy implementation, pollution, pollution control, prevention and control, primary health care, procedures, professional knowledge, protective clothing, protective equipment, protocol compliance, public health, public health service, public hospital, pyrolysis, randomized controlled trial study, recycling, refuse disposal, risk, risk factor, risk factors, risk education, rural area, safety, sanitation, sars-cov-2, sharps disposal, solid waste, solid waste management, solid waters, standardization, sterilization, supply chain management, supply chains, sustainability, sustain development, teaching hospital, tertiary care centers, tertiary health care, traffic and transport, urban population, virology, virus pneumonia, virus transmission, viruses, waste, waste disposal, waste disposal facilities, waste disposal facility, waste generation, waste incineration, waste management, waste treatment, water supply, work environment, and workflow	173	46
Cluster 2: Antibiotic resistance bacteria in hospital wastewater treatment plant	Amides, ampicillin, anti-bacterial agents, antibiotic agents, antibiotic resistance, antibiotic sensitivity, antibiotics, antiinfective agent, antimicrobial activity, antimicrobial resistance, aquatic environment, azithromycin, bacteria, bacteria (microorganism), bacterial DNA, bacterial gene, bacterial genome, bacterial growth, bacterial protein, bacterial strain, bacterium, bacterium culture, bacterium isolate, bacterium isolation, beta-lactamases, biochemistry, carbapenem derivative, carbapenemase production, cefotaxime, ceftazidime, chloramphenicol, ciprofloxacin, clarithromycin, clindamycin, coliform bacterium, colistin, cotrimoxazole, drug effect, effluent, effluent treatment, Enterobacteriaceae, enterococcus faecalis, environmental exposure, environmental risk, enzyme activity, erythromycin, Escherichia coli, Fosfomycin, gene, genetics, gentacimin, geographic distribution, global health, hospital effluent, klebsiella, klebsiella pneumoniae, levofloxacin, macrolide, meropenem, microbial diversity, microbiology, minimum inhibitory concentration, multilocus sequence typing, municipal wastewater, municipal wastewaters, nalidixic acid, norfloxacin, ofloxacin, oxytetracyline, penicillin derivative, phenotype, polymerase chain reaction, prevalence, pseudomonas aeruginosa, quinoline derived antiinfective agent, quinolone derivative, real time polymerase chain reaction, reclamation, resistant bacteria, risk assessment, risk management, river, river pollution, river water, rivers, sewage pumping plants, sewage treatment, sewage treatment plants, staphylococcus aureus, sulfadiazine, sulfonamide, sulfur compounds, surface water, tetracycline, tetracycline derivative, treatment, trimethoprim, vancomycin, waste water treatment plant, wastewater treatment plant, water analysis, water pollution, water quality, water sampling, water treatment plants, whole genome sequencing	106	28

Table 1. Continued.

Clusters' Theme	Items	Total	Percent
Cluster 3: Emerging pollutants in wastewater	Activated carbon, activated sludge, adsorption, ammonia, aqueous solution, arsenic, atenolol, biochemical oxygen demand, biodegradation, bioreactor, bioreactors, bioremediation, cadmium, carbamazepine, carbon, catalyst, chemical composition, chemical oxygen demand, chemical structure, chromium, concentration (parameter), constructed wetland, contamination, cost effectiveness, costs, degradation, diclofenac, drug, ecotoxicology, efficiency, environmental monitoring, environmental temperature, filtration, ground water, groundwater, heavy metal, heavy metals, hospital, hospital wastewater, hydrogen peroxide, iron, isotherm, ketoprofen, liquid chromatography-mass spectrometry, mass spectrometry, medicine, membrane, metabolites, metoprolol, metronidazole, microbial communities, microbial community, microbiota, monitoring, naproxen, nickel, nitrate, nitrogen, organic carbon, oxidation, particle size, pH, pharmaceutical preparation, phosphorus, photocatalysis, physical chemistry, pollutant, pollutant removal, potable water, process optimization, proteobacteria, radioactive waste, sewage, soil, solid phase extraction, sulfamethoxazole, temperature, titanium dioxide, total organic carbon, toxicity, waste component removal, waste water management, wastewater, wastewater treatment, water, water contamination, water management, water pollutant, water purification, water treatment, and zinc	92	25
Cluster 4: Virus detection	SARS, virus, and virus detection	3	1

Note. SARS: Severe acute respiratory syndrome.

Fig. 6. Hospital Waste Management Analysis Using RStudio

of the facility.

The healthcare sector has been identified as one of the most significant sources of pollution globally. Hospitals, in particular, have been recognized as being responsible for a considerable amount of environmental degradation. The issue of HCW management has become a pressing concern, with the need for proper disposal of hazardous medical waste being of utmost importance (16). As such, it is imperative that healthcare organizations adopt sustainable practices to reduce their environmental footprint and minimize their impact on the natural world. The wastewater treatment plants in hospitals are recognized as potential hotspots for spreading antibiotic resistance (17). This poses a serious risk to public health, particularly when reclaimed water is intended for reuse (18). Therefore, it is essential to carefully monitor and manage the wastewater treatment processes in hospitals to minimize the spread of antibiotic resistance and safeguard public health.

It is also important to understand that certain antibiotics we consume are not fully broken down by our bodies and are instead excreted as residual substances that ultimately end up in wastewater. Hospitals can mitigate the emergence of antibiotic resistance in wastewater by implementing advanced wastewater management techniques (19). Furthermore, several recommended wastewater treatment technologies have been proven effective in reducing antibiotic resistance in hospital wastewater treatment plants. These include conventional processes such as chlorine disinfection, anaerobic digestion, ultraviolet radiation, membrane bioreactors, and up-flow anaerobic sludge blanket processes, all of which were found to be successful in removing SARS-CoV-2 RNA from wastewater (19). Additionally, tertiary processes such as membrane filtration, granular activated carbon, and sand filtration, along with disinfection techniques such as ozonation, chlorination, ultraviolet radiation, and peracetic acid, or advanced oxidation processes, can be utilized to control antimicrobial resistance in wastewater (19).

Wastewater treatment involves using microorganisms to remove various types of contaminants, including

organic carbon, nutrients, and micropollutants. The microbial community structure of each treatment system plays a crucial role in this process as it is composed of a diverse range of microorganisms that work together to break down and remove these contaminants (20). Over time, the microbial community structure of a treatment system evolves, adapts to changes in environmental conditions, and introduces new contaminants (21). This ability to adapt and evolve is critical to the effectiveness of the treatment system and its ability to consistently remove contaminants from wastewater. The overuse of antibiotics in healthcare systems has led to the proliferation of antibiotic resistance genes (ARGs) in the environment, which is a major global public health concern (22). The abundance of ARGs has necessitated the development and implementation of effective strategies to combat this growing threat (20). The need for urgent action to mitigate the impact of ARGs on public health, the environment, and the economy cannot be overstated (21). It is thus imperative to prioritize research and development efforts to discover novel antibiotics and alternative solutions to reduce the incidence of ARGs in the environment.

Pollutants in wastewater are typically chemical and biological substances that are not regulated but have the potential to harm the environment and public health. Hospital wastewater containing antibiotic-resistant bacteria can lead to the emergence of new pollutants because antibiotic residues, which are not traditionally monitored, can be considered pollutants. Within hospital wastewater, there exists an array of micro-pollutants, ranging from newly discovered radioactive elements to harmful bacteria such as fecal coliform and pathogens (23). Additionally, there are pharmaceutical chemicals such as hormones, antibiotics, and anti-inflammatory agents that may be present either in their original form or as a metabolite (23). The precise concentration of these pollutants determines their classification as either micro-pollutants, with concentrations ranging between 10−6 to 10−3 mg/L, or macro-pollutants, with concentrations exceeding 10−3 mg/L (23). It is important to note that while some of these pollutants are subject to environmental regulations, others are not.

The emergence of COVID-19 pollutants has had a profound impact on the quality of wastewater in various ways. Apart from the presence of the SARS-CoV-2 virus in untreated water, the usage of hand sanitizers, disinfectants, and different types of pharmaceuticals has considerably increased the organic burden of wastewater. In the absence of adequate treatment, this wastewater can pose severe risks to the environment and public health in the receiving areas. Hence, it is crucial to have a wastewater treatment system that is robust, efficient, and capable of handling these contaminants effectively.

In addition to the prevalence of SARS-CoV-2 in untreated water, an increase in the use of hand sanitizers, disinfectants, and different kinds of pharmaceuticals raised the organic load of wastewater. If there is not a proper and effective treatment, effluents may pose many environmental and public health risks in the receiving environment (24). The new outbreak of COVID-19 has put the risk of virus contamination in water bodies on the horizon of health authorities (24). This presents new challenges faced by wastewater treatment plants due to changes in the number of contaminants and pollutants that appear. More research is thus needed to find out the implications that the new COVID-19 outbreak will have on emerging pollutants.

Hospitals are an indispensable part of our healthcare system, providing essential medical care to people in need. However, the nature of their work means that they generate a large amount of hazardous waste, both in liquid and solid form. This waste includes a wide range of potentially harmful materials such as organic and inorganic pollutants, as well as microbiological agents. When released into the environment without proper treatment, these pollutants can pose a significant risk to human health and the environment. Therefore, it is crucial that hospitals take necessary precautions to manage and dispose of their waste safely and responsibly.

Amidst the ongoing COVID-19 pandemic, the improper disposal of hospital waste and wastewater poses a significant threat to public health. Therefore, it is of utmost importance to accurately categorize hospital waste and choose appropriate disinfection techniques to minimize the risk of infection. Proper waste management and disinfection can help prevent the transmission of infections from hospital waste and wastewater, thereby safeguarding public health. Moreover, during this pandemic, it is crucial to follow specific disinfection protocols to ensure public safety.

The correlation between COVID-19 hospital waste and viral detection is intricate. It serves as a crucial component in acquiring and analyzing patient samples for testing, which facilitates swift identification and isolation of cases. Furthermore, these resources can aid in genomic sequencing and surveillance, enabling the identification of new virus variants and informing public health measures. However, improper handling or disposal of such waste could result in hazardous exposure to infectious materials, impeding safe virus detection and collection.

The COVID-19 pandemic has led to an alarming surge in medical waste, which poses a significant threat to the environment. Regrettably, not all medical facilities are taking the necessary measures to manage their waste efficiently. On the flip side, this situation presents an opportunity to enhance HCW management systems in a manner that is both ecologically sound and secure. Achieving this goal necessitates a comprehensive assessment of the hospital's waste management system, followed by recommendations for best practices and pragmatic solutions. To ensure effective medical waste management, robust national policies and regulations should be established and enforced through regular monitoring, reporting, and heightened accountability.

Moreover, promoting behavioral change and workforce development and increasing funding and financing can enhance HCW management systems to be both safe and sustainable.

4. Conclusion

The COVID-19 pandemic caused a significant increase in hospital waste, which has had a negative impact on the environment and public health. Hence, it is important to implement effective hospital waste management systems to address this issue. Conventional wastewater treatment has been proven to be effective in removing SARS-CoV-2 RNA from wastewater. This study aimed to provide a detailed description of the additional hospital waste produced due to COVID-19 and its effects on the environment and public health. It also analyzed existing hospital waste management systems, highlighted their shortcomings, and suggested emerging best practices and solutions to minimize the impact of waste on human health and the environment.

Authors' Contribution

Conceptualization: Maria Ulfa, Nabila Astri Nur Kuntari.
Data curation: Nabila Astri Nur Kuntari.
Formal analysis: Nabila Astri Nur Kuntari, Maria Ulfa.
Investigation: Nabila Astri Nur Kuntari, Maria Ulfa, Agus Jamal.
Methodology: Nabila Astri Nur Kuntari, Maria Ulfa.
Project administration: Maria Ulfa.
Resources: Nabila Astri Nur Kuntari.
Supervision: Maria Ulfa.
Validation: Nabila Astri Nur Kuntari, Maria Ulfa, Agus Jamal.
Visualization: Maria Ulfa.
Writing–original draft: Nabila Astri Nur Kuntari.
Writing–review & editing: Nabila Astri Nur Kuntari, Maria Ulfa, Agus Jamal.

Competing Interests

The authors have no conflicts of interest to declare.

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