Biomedical waste during the covid-19 pandemic in Indonesia: systematic literature review

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Abstract. Since the beginning of the Coronavirus Disease 2019 (COVID-19) outbreak, there has been a significant increase in the quantity of hazardous biomedical waste, which poses a risk to human health and has a negative impact on the environment. There have been no specific studies conducted in Indonesia to assess the potential impact of biomedical waste during the pandemic COVID-19. Therefore, the purpose of this systematic review is to describe the various types of biomedical waste, their implications for health and the environment, as well as the techniques for managing biomedical waste during this pandemic. A total of 141 scientific articles were identified through the Google Scholar database. From these, 17 selected references were systematically analysed. The majority of the studies focused on investigating the environmental impacts of medical waste caused by the COVID-19 pandemic. From the 17 articles, we identified 7 articles that discussed the environmental hazards of biomedical waste, and 4 articles related to health. 6 articles outlined biomedical waste management (BWM) in Indonesia and solutions to implementation issues in BWM. It is recommended to conduct more studies, including meta-analyses, to gain a better understanding of the effects of medical waste on environmental health during the COVID-19 pandemic.

1 Introduction

Since March 11, 2020, the World Health Organization (WHO) has declared COVID-19 a global pandemic, and Indonesia is one of the countries affected by it [1]. There have been over 6.8 million cases in Indonesia with a death toll of approximately 161,000 [2]. The number of cases continues to rise, and new variants of COVID-19 are still emerging. In addition to its impact on health, COVID-19 has consequences in various other aspects of life, including the environment. In the early stages of the pandemic, COVID-19 unexpectedly led to a reduction in pollution levels [3]. By mid-2020, when the government implemented social restrictions, air pollution in Indonesia improved by 42 percent (liputan6.com, 2020). However, in the first year of the pandemic, there has been a significant increase in biomedical waste such as used masks, gloves, bandages, syringes, used infusion sets, used personal

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protective equipment, and more [4]. The amount of waste generated at final disposal sites has also increased. According to data from the Ministry of Environment and Forestry of the Republic of Indonesia (KLHK RI) for the first year period (from March 2020 to July 2021), the amount of biomedical waste in Indonesia reached 18,460 tons, while the national medical waste treatment facilities can only handle a maximum of 458.5 tons of biomedical waste per day [5]. The extreme increase in waste has surpassed the capacity of hospitals and waste banks. Biomedical waste has become a major and concerning threat to public health and the environment [1, 6].

To date, studies on medical waste during the COVID-19 pandemic in Indonesia have primarily focused on evaluating waste management in community healthcare facilities [7, 8]. Other research has concentrated on strategies or guidelines for waste management [9, 10]. As a disclaimer, there has been a previous study that discussed biomedical waste, but on a global scale [11]. Therefore, this research aims to provide a summary of all the studies, publications, and data regarding biomedical waste during the COVID-19 pandemic in Indonesia. This research focuses on potential issues arising from the improper disposal of medical waste, which can make outbreak control much more challenging and increase the risk of people being exposed to various other dangerous diseases. Additionally, policies and corrective actions to address this situation are also discussed.

2 Methods

This study employs the systematic literature review method with a qualitative approach. The study adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Based on Arksey & O'Malley [12], this method consists of five stages: identifying the research question, identifying relevant studies, selecting studies, charting the data, and reporting the results in a narrative format.

2.1 Identifying the research question

The researchers defined the scope of the study and formulated research questions using the PICOC approach (Population, Intervention, Comparison, Outcomes, and Context) proposed by Petticrew & Roberts [13]. There are no standard interventions and comparisons. The research questions established are as follows:

RQ 1: What are the types of biomedical waste generated during the COVID-19 pandemic?
RQ 2: What are the impacts of COVID-19 biomedical waste on the environment in Indonesia?
RQ 3: What are the impacts of COVID-19 biomedical waste on the health in Indonesia?
RQ 4: How is BWM managed during the COVID-19 pandemic in Indonesia?

2.2 Identifying relevant studies

This study utilized a single database, namely Google Scholar. Studies were eligible for inclusion if they met the following criteria: (1) published in English and Indonesian, (2) within the last 4 years, (3) available in full text, and (4) conducted in Indonesia, (5) addressing biomedical waste during the COVID-19 pandemic. The search strategy was developed by an information specialist (K.S). Published literatures were searched using appropriate controlled keywords: “limbah biomedis akibat COVID-19” OR “limbah medis akibat COVID-19” OR “limbah biomedis AND COVID-19” OR “limbah medis AND COVID-19” OR “limbah

farmasi akibat COVID-19" OR "limbah farmasi AND COVID-19". Searches for articles in english, the keywords are translated in english.

2.3 Selecting Studies

All retrieved articles were imported into Mendeley, and duplicates were removed. In the first phase of screening, all study tittles & abstracts were assessed against the review eligibility criteria by second reviewer (K.S.). The remaining studies were retrieved for full text assessment by first reviewer (E.L.).

2.4 Charting the Data

In order to obtain the necessary information to address the research questions, we employed a data collection format using Microsoft Excel by the second reviewer (K.S). The decision was made to extract the following data from the selected individual articles: (1) author's name(s), (2) year of publication, (3) key findings relevant to the systematic literature review questions.

2.5 Reporting Results

The biomedical waste during the COVID-19 pandemic in Indonesia is described in narration. We reported the result of the research in narrative summary to illustrate in a discursive and syntenic way the objectives of the individual studies and their results.

3 Results

Based on the search results on Google Scholar using Boolean logic, 114 articles were found. After removing duplicates, the remaining count was 122 articles. After conducting selection based on inclusion and exclusion criteria, 17 articles were obtained for the analysis of this systematic review (Figure 1).

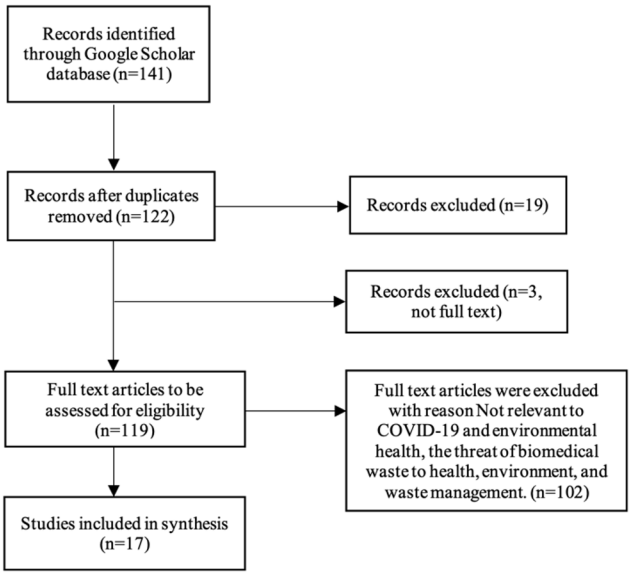

Fig. 1. PRISMA Flow Diagram.

The biomedical waste during the COVID-19 pandemic in Indonesia is described in narration. We reported the result of the research in narrative summary to illustrate in a discursive and syntenic way the objectives of the individual studies and their results.

3.1 The types of biomedical waste caused by COVID-19 in Indonesia

Generally, biomedical waste is categorized based on various coding systems such as letter codes, color codes, or risk codes. The analysis results indicate that there is a slight difference in the coding system for COVID-19 biomedical waste in Indonesia, as shown in Table 1. Out of the 17 studies analyzed, two of them explain the methods of biomedical waste management during the COVID-19 pandemic [10, 14]. One article classifies biomedical waste as infectious and non-infectious waste using yellow and black labels [10]. Nofriyanti's [14] article showed that the focus of their research differentiated the types of biomedical waste during the pandemic as medical and non-medical waste. According to international standards, biomedical waste is typically categorized based on its composition using color codes, where red denotes radioactive waste, yellow indicates infectious and pathological waste, purple represents cytotoxic waste, brown indicates expired chemicals, spills, or packaging remnants, and pharmaceutical waste [6].

Table 1. The types of biomedical waste during the COVID-19 pandemic in Indonesia.

Types of Biomedical Waste	Author(s)	Year	Results
Based on medical and non-medical waste	Nofrianty [14]	2020	Yellow-colored plastic for medical waste and black-colored plastic for non-medical waste
Based on the potential for disease transmission	Nastiti [10]	2022	Classified as infectious and non-infectious

3.2 The Effects of COVID-19 biomedical waste on the environment in Indonesia

Ten articles describe the amount of COVID-19 waste at the national level, while others mention it at the regional or local level in Indonesia. Covid-19 medical waste in Indonesia reached 18,460 tons as of July 27, 2021 [15-18]. Six publications compare the amount of medical waste before and during the COVID-19 pandemic. Prior to the pandemic, the generated medical waste was approximately 366 tons per day from around 2,813 hospitals across Indonesia, with an average waste generation of 87 kg per day per hospital [1,19,20]. During the pandemic, the amount of infectious waste increased by 30-50%, accumulating to 6,417.95 tons from March 2020 to February 2021 [20]. Recent research indicates that these numbers have increased. Two articles discuss the environmental impacts caused by medical waste during the COVID-19 pandemic [22, 22] (Table 2)

Table 2. The impact of COVID-19 biomedical waste on environment in Indonesia.

Biomedical Waste of COVID-19 Affecting the Environment	Author(s)	Year	Results
Incineration of infectious biomedical waste	Suryanto et al. [22]	2022	Some incinerators in Indonesia's hospital are still not equipped with air pollution control systems. The air pollution composition caused by incinerators includes hazardous

			gases such as Nitrogen Oxides (NOx), Carbon Monoxide (CO), Sulfur Oxides (SO2), and Carbon Dioxide (CO2).
The impact of biomedical waste on the environment	Sutrisno & Meilasari [21]	2020	The increasing pollution due to improperly treated medical solid waste. If medical waste is disposed of improperly or not treated correctly, hazardous chemicals or medications contained in the waste can leach into the soil. This can contaminate the soil and pose a threat to soil quality and agriculture.

3.3 The Effects of COVID-19 Biomedical Waste on the Health in Indonesia

In 17 articles, we identified 4 articles that mentioned the effects of COVID-19 biomedical waste on health (Table 3). It was stated that healthcare workers and cleaning service personnel have the highest potential for exposure to medical waste and the possibility of infection [10,14,23]. From these three studies, it was found that used syringes were not properly disposed in safety boxes and were mixed with other waste. Hospitals also did not provide immunization to all staff directly involved in waste management to prevent infection due to occupational accidents. The air pollution composition caused by incinerators includes hazardous gases such as Nitrogen Oxides (NOx), Carbon Monoxide (CO), Sulfur Oxides (SO2), and Carbon Dioxide (CO2) [22]. Those chemicals pose various risks to human health when inhaled. Exposure to NOx can cause respiratory irritation, coughing, shortness of breath, and other respiratory problems. High CO exposure disrupts the blood's ability to carry oxygen, leading to nausea, dizziness, confusion, and even death. Exposure to SO2 causes irritation of the eyes, nose, and throat. Individuals with respiratory disorders, such as asthma, are more vulnerable to the negative effects of SO2. At normal atmospheric levels, CO2 is not hazardous. However, in enclosed spaces or excessive amounts, CO2 displaces oxygen and leads to oxygen deficiency (hypoxia), resulting in dizziness, difficulty breathing, and even loss of consciousness.

Table 3. The impact of COVID-19 biomedical waste on health in Indonesia.

Biomedical Waste of COVID-19 Affecting the Health	Author(s)	Results
BMW affects the health of healthcare workers	Nastiti [10]; Nofrianty [14]; Trisnawati & Suwandana [23]	Healthcare workers providing services at hospitals are responsible for medical waste production and face a high risk of accidents and disease transmission. They are the first individuals directly exposed to medical waste and are at risk of injuries from contaminated sharp objects, such as used syringes.
Health risks of BMW during the pandemic	Suryanto et al. [22]	The air pollution composition caused by incinerators includes hazardous gases such as

		Nitrogen Oxides (NOx), Carbon Monoxide (CO), Sulfur Oxides (SO2), and Carbon Dioxide (CO2). Those chemicals pose various risks to human health when inhaled.

3.4 Solutions for COVID-19 biomedical waste in Indonesia

Among the 15 available articles, there are 6 articles that provide context regarding solutions for COVID-19 biomedical waste (Table 4). These six references discuss recommendations for waste management and preventive measures in handling COVID-19 biomedical waste. It can be concluded that there is a need for synergy among stakeholders and implementers in the field to ensure the ideal management of biomedical waste.

Table 4. The impact of COVID-19 biomedical waste on health in Indonesia.

Solutions	Author(s)	Results
Improve the quality of waste treatment facilities.	Nurwahyuni et al. 2020 [24]; Sumiarsih & Sarumi, 2021 [25]; Anwar & Rochka, 2022 [26]	All community healthcare facilities that have medical waste treatment equipment, whether it be incinerators or autoclaves, even if they do not have operational permits during the COVID-19 pandemic, should still monitor the progress of obtaining operational permits for their waste treatment equipment. This ensures that once the pandemic ends, all medical waste treatment equipment will meet the required standards according to applicable regulations. These equipment can minimize pollution.
Clear regulations with strict sanctions (Stakeholders)	Nurwahyuni et al. 2020 [24]; Saputro & Dwiprigitaningtias, 2022 [27]	The implementation of waste management by the community (application of 3R, separation of organic and non-organic waste, as well as separation of medical and non-medical waste) is considered low. Medical personnel such as nurses, junior doctors, and senior doctors, in their hurried conditions, often dispose of medical waste in non-medical waste bins. This can lead to nosocomial infections, especially for those who are directly involved.
Hospitals and medical personnel must understand	Nofrianty, 2020 [14]	Some medical personnel do not use Personal Protective

that the disposal of Personal Protective Equipment (PPE) waste is crucial.		Equipment (PPE) while on duty, which is very dangerous for themselves and the surrounding environment.

4 Discussion and Conclusion

Globally, numerous studies have indicated a significant increase in medical waste volume during the COVID-19 pandemic. Research by Rajak et al. revealed that medical waste in India due to the COVID-19 pandemic reached 32,996 tons in just the last six months of 2020 [28]. Fadaei's study [29] confirmed that medical waste increased by approximately 350% to 500% in many countries, including Indonesia, as stated in the findings of this research. Waste generation due to the inefficient use of medical equipment during COVID-19 healthcare processes has led to an increase in biomedical waste. In addition to the impact on health, this research has shown that the environment is also significantly affected by the COVID-19 pandemic. The current pandemic has resulted in environmental consequences such as air pollution and waste accumulation [30, 31].

Biomedical waste may contain pathogens or other hazardous substances. From the analyzed articles, several ways can be implemented to address this risk, one of which is by using an incinerator [24-26]. Incinerators are an efficient method for medical waste disposal. Using this tool, the risk of infection transmission can be minimized, protecting patients, healthcare workers, and the general public from potential risks. To address the environmental and health impacts of biomedical waste, incinerators are mandatory facilities for both government and private healthcare institutions. Incinerators can be used to process and eliminate medical waste, including hazardous materials such as used syringes, contaminated bandages, surgical tools, and medical chemicals [11]. By using incinerators, hospitals can ensure that medical waste is safely destroyed, thus preventing disease transmission and reducing the risk of contamination. The high-temperature burning process converts waste into ash and safe gases, helping reduce the volume of medical waste and its impact on the environment. Incinerators also help prevent misuse or accumulation of medical waste, which could pose hazards to the community if not managed properly [25].

Improper waste management during the COVID-19 pandemic has adverse effects on waste handling and increases the probability of virus transmission. Healthcare workers providing services at hospitals are responsible for medical waste production and face a high risk of accidents and disease transmission [10, 14, 23]. Strict procedures and guidelines for the management of COVID-19 biomedical waste should be diligently followed to reduce the risk of virus spread to the environment. The BMW ideally implements infection control principles, such as the use of personal protective equipment like masks, gloves, and lab coats to protect healthcare workers from infection exposure, and the safe disposal of medical waste to prevent contamination and disease transmission [32]. Overall, research on COVID-19 biomedical waste is still limited. We suggest that future studies gather information from studies conducted in various languages and countries.

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