Indonesian efforts to overcome covid-19’s effects on its municipal solid waste management: a review

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Abstract: The COVID-19 pandemic has worsened the solid waste management problem in Indonesia. Lockdowns induced by the pandemic have increased waste generation. Meanwhile, the COVID-19 virus continues to spread through droplets and items exposed to such droplets, including solid waste. Therefore, it is necessary to have exceptional municipal waste management systems in place to ensure these contaminants do not negatively impact the environment, society, or waste workers. We reviewed the municipal waste management systems during the COVID-19 pandemic in Indonesia and suggested remediation of several practices. Several problems exist in the current system, such as increase in solid waste generation (especially food and plastic waste), lack of infectious waste management, many workers not using complete personal protective equipment (PPE) while handling waste, and an inequitable distribution of facilities across different cities. Comprehensive recommendations, such as citizen awareness, PPE use by waste workers and waste pickers, and government policies dealing with urban waste amid the COVID-19 pandemic, are discussed. The findings of this study can serve as a reference for municipal waste management under pandemic conditions in developing countries, as well as for future research.

Subjects: Environmental Issues; Civil, Environmental and Geotechnical Engineering; Waste & Recycling

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The COVID-19 pandemic has become a global issue since a large number of people have been exposed to it and died. The COVID-19 virus can spread through droplets and items that are exposed to the droplets that contain the virus. These items include PPE or medical waste and solid waste, in other words, municipal solid waste. If municipal solid waste is not handled properly, it can endanger waste workers and increase the spread of the coronavirus. The aim of this study is to improve municipal waste management during the COVID-19 pandemic by taking into consideration Indonesian waste workers’ health and safety. A qualitative study was conducted by reviewing peer-reviewed papers in this field of study. This study reveals the generation and composition of waste before and during the pandemic, the types of waste that increased during the pandemic, current MSW management, new regulations, and waste worker behaviors in developing countries.

1. Introduction

The spread of COVID-19 has prompted governments worldwide, including Indonesia, to make quick policy decisions. Several policies that have been implemented in Indonesia in the form of lockdowns since March 2020 include large-scale social restrictions (PSBB), regional quarantine, social distancing, working hours restrictions, and use of face masks. Some of these policies affect the country’s economy, health, and environmental sector. According to Pati (2020), restriction policies have resulted in a 2.97% decline in economic growth as of 17 April 2020, causing a recession with the potential to become an economic crisis. In the health sector (Setiati & Azwar, 2020), Indonesia has ensured improved health facilities and aims to increase the availability of hospital beds, ventilators, hazmat suits, medical face masks, other personal protective equipment (PPE), and COVID-19 test kits. In the environmental sector, lockdowns induced by the pandemic have increased waste generation. Food waste increased by 43% and plastic packaging by 53% during lockdowns. This augmentation occurred largely due to panic buying, as several residents staying at home were forced to modify their regular behavior by shopping online or purchasing take-out meals in excessive quantities. Since March 2020, the purchase of frozen meals has increased as well. Altogether, this has challenged the waste control structures worldwide (Leal Filho et al., 2021).

Furthermore, the mismanagement of increasing waste has led to several environmental issues. Jakarta’s Marunda and Cilincing rivers saw a 5% increase in debris abundance, and a 23–28% reduction in waste weight from March–April 2016 to March–April 2020. This indicates a shift towards lighter debris particles. Plastics continue to dominate river waste, with an abundance of 46–57% by weight. The unprecedented presence of PPE, such as face shields, medical masks, gloves, and hazardous clothes, accounts for 15–16% of daily river waste. The increase in plastic PPE at river outlets has prompted domestic sources to improve medical waste management (Cordova et al., 2021). The gloves, face masks, and infected materials used in the diagnosis, detection, and treatment of COVID-19 along with various other human pathogens are not reusable and become infectious waste. This waste mismanagement causes further health issues (Sangkham, 2020).

COVID-19 survives in aerosols (fine particles of solids or liquids in gas or air, such as smoke and fog) for three hours, cardboard for up to 24 h, and copper surfaces for up to four hours. This virus survives for 3 days on stainless steel and plastic surfaces. The amount of virus that remains on the surface decreases over time. A person may contract the virus through air or after touching a contaminated object (Van Doremalen et al., 2020). A global analysis of coronaviruses, including Middle East respiratory syndrome (MERS), severe acute respiratory syndrome (SARS), and endemic human coronavirus (HCoV), found that these viruses can survive on glass, metal, and plastic surfaces. Moreover, according to Das et al. (2021a), transmission of the COVID-19 virus can
occur through MSW generation and subsequent management. However, the virus particles can be destroyed by applying 62–71 % ethanol, 0.1 % sodium hypochlorite, or 0.5 % hydrogen peroxide solution for approximately one minute (Kampf et al., 2020).

To assist households in managing their infectious waste amid the COVID-19 pandemic, the Ministry of Environment and Forestry (Menlhk, 2020) issued circular No. SE.2/MENLHK/PSLB3/PLB.3/3/2020 concerning the management of infectious waste (hazardous waste) and household waste generated due to the coronavirus disease (COVID-19). Infectious waste consists of discarded PPE, such as masks, gloves, and personal protective clothing (e.g., hazmat suits). According to the MENLHK circular, such waste must first be stored in a closed container labeled “Infectious Waste.” After being packaged, waste is collected by officers from the agency responsible for waste transportation in the environmental, hygiene, and health sectors and then destroyed through hazardous waste processing. The regulation also states that all cleaning officers or waste collectors must be equipped with PPE, especially masks, gloves, and safety shoes, which should be cleaned daily. The government also suggests reducing the generation of mask waste by using reusable masks that can be washed. According to Niman (2020), despite regulations from the Ministry, there are still many scavengers at the Bantargebong Integrated Waste Processing Site (TPST), who ignore health protocols, such as washing hands, wearing masks, and maintaining a safe distance (at least 3 m) from others.

Scavengers are “invisible heroes” for the informal waste management sector because they contribute to the environmental sector and local economy. Given the working conditions, their social status, wages, and protection levels often do not reflect their societal contributions (Carenbauer, 2021). Waste pickers are vulnerable to health problems, especially during pandemics. The persistent and highly contagious COVID-19 virus can infecting MSW workers due to direct exposure to waste with poor PPE (Das et al., 2021a). In Indonesia, more than four million waste pickers have been affected by the COVID-19 pandemic from an economic or health perspective. According to the waste picker association, they are susceptible to the virus that attacks the respiratory tract. These findings reflect a statement made by a Kompas TV journalist that waste pickers are vulnerable to COVID-19 as they often come in contact with medical waste, such as infusion bottles and used syringes. Studies have shown that 12,740 tons of medical waste was generated in Jakarta in the first 60 days after residents were found to be infected with COVID-19. Several developing countries, including Indonesia, have not implemented good solid waste management strategies, so there is potential for contamination from domestic waste treatment (Sangkhram, 2020). This is hazardous to the health of waste pickers who operate waste processing facilities. Transmission can occur through contact with infectious waste, such as tissues, diagnostic swabs, and other medical objects (Organization, 2017).

Before the COVID-19 pandemic, waste pickers were at risk of being exposed to various diseases. This is evidenced by the living conditions of waste pickers around Bantar Gebang TPA, Bekasi City, which are poor because of issues, such as waste odor, abundance of midges and cockroaches, and groundwater pollution. On a daily basis, waste pickers drink and use contaminated water to wash eatables. Additionally, they often consume vegetables and mushrooms grown in landfills (Sasaki et al., 2014). This being the case, there is potential for waste pickers to experience pre-COVID-19 pandemic conditions. The above information suggests that municipal solid waste (MSW) management is still not optimal, even when carried out in accordance with COVID-19 protocols. The standard operating procedures and safety standards are insufficient to protect workers, and further efforts are necessary.

This study conducted a literature review and aimed to improve municipal waste management during the COVID-19 pandemic by considering the health and safety of Indonesian waste workers. This review also includes strategies and recommendations for enhancing MSW management, especially during the COVID-19 pandemic. The results of this study can be used as a reference for further research and as a solution for dealing with MSW, which is fast evolving during the COVID-19 pandemic.
2. Materials and methods

The COVID-19 pandemic has resulted in an increase in municipal waste generation. Owing to this increase, it is necessary to have exceptional municipal waste management systems to prevent waste from negatively affecting the environment, society, and waste workers. This study aimed to evaluate the conditions of municipal waste management during the pandemic and provide practical recommendations for waste management. To achieve this goal, we searched the relevant literature on various sites, such as Scopus and Google Scholar. The literature used in this study was published from 2014 to 2021 in English or Indonesian. In addition, we collected data from local government websites, Indonesian waste authorities, and the news, which are primarily reported in the Indonesian language.

The data included the amount of waste generated, composition of the waste, current state of municipal waste management, and problems related to municipal waste management under pandemic conditions in the six most populous cities in Indonesia namely, Jakarta, Bandung, Surabaya, Semarang, Denpasar, and Medan. The data and literature review are shown in Figure 1. After the necessary data were collected, data analysis was performed. Qualitative descriptive analysis was used in this study.

3. Impact of Covid-19 pandemic on MSW and its composition

3.1. MSW Generation

The COVID-19 pandemic has affected the waste sector. Figure 2 shows that the daily domestic waste generation increased in Indonesia’s six major cities. Jakarta’s daily domestic waste generation increased by 200 tons, Bandung City’s by 26.51 tons, Surabaya City’s by 575.3 tons, Semarang City’s by 25.03 tons, Denpasar City’s (Bali) by 109.42 tons, and Medan City’s by 10.23 tons (Citrasisari et al., 2012). Jakarta generated the highest amount of waste per day: 7,800 tons/day in 2019 and 8,000 tons/day in 2020. Surabaya generated the second highest amount of waste and, with an increase of 575.3 tons, had the largest increase among the six cities. According to (Citrasisari et al., 2012), natural and human factors affect the amount of waste generated. Human factors, including economic activity and waste generation, are affected by the population of a city. Thus, Denpasar (Bali), which generated the least amount of waste, has the lowest population of 725,314 in 2020, according to Bali Statistics 2021.

However, in several cities, including Bandung, waste generation has not changed significantly from 2019 to 2020. This might be due to the city-regional government not updating its data on solid waste generation. All citizens had to perform their activities, including work and schooling, at home. This affected both waste generation and composition. According to Ruslinda et al. (2020), it is relevant that the MSW generation rate has increased due to the COVID-19 lockdowns, such as
the PSBB implemented in Indonesia to prevent its spread. Table 1 shows the municipal waste composition in each of the six cities before (2019) and during (2020) the COVID-19 pandemic.

3.2. MSW Composition

As shown in Table 1, food waste was the dominant component of the solid waste generated in the six cities. Jakarta had the highest percentage of food waste, followed by Medan and Surabaya. Jakarta's food waste percentage increased from 23.02 % to 45.99 %, while Medan's increased by 8.2 %. The other cities whose food waste percentages increased were Surabaya and Denpasar. Bandung City's composition data have not changed as they have not been updated yet; only the total weight of the waste generated has been reported. This observation that food waste increases during lockdowns or when large-scale social restrictions are implemented is supported by the study by Leal Filho et al. (2021), who reported a 43 % increase. This increase occurred due to panic buying, as people had to stay home and modify their behavior by ordering food and shopping online.

The percentage of plastic waste also increased, especially in Jakarta, Surabaya, Semarang, and Denpasar (Table 1). Jakarta's plastic waste percentage increased from 0.92 % to 1.92 %, and the weight of plastic waste increased from 70.2 tons/day to 153.6 tons/day. In Denpasar City (Bali), the plastic waste percentage increased from 13.11 % to 17.15 %, and the weight of plastic waste increased from 97.09 tons/day to 145.775 tons/day. Surabaya's plastic waste percentage increased from 15.03 % to 15.69 %, and the weight of plastic waste increased from 334.37 tons/day to 439.32 tons/day.

3.2.1. Plastic waste

According to the 2020 plastic waste percentages in Table 1, Surabaya generated the most plastic waste by weight, even as its plastic waste percentage decreased from 12.07 % in 2019 to 11.57 % in 2020. Surabaya generated 334.37 tons/day of plastic waste in 2019 and 439.32 tons/day in 2020. The weight of total waste generation increased from 2,224.7 tons/day to 2,800 tons/day. Denpasar (Bali) generated the least amount of plastic waste in 2020, 145.78 tons/day. According to Hapsari and Herumurti (2017), changes in waste generation are influenced by consumption habits. Surabaya produced more plastic waste because its residents used a large amount of plastic. Other factors cause an increase in plastic waste as well. According to Leal Filho et al. (2021), citizens who stayed at home during the lockdown used plastic wrap in the form of packaging for products purchased online, resulting in a 53 % increase in plastic waste. The use of plastic wrap (Lipi, 2020) has increased owing to online shopping. People now shop online approximately 1-10 times a month, up from 1-5 times before the lockdown. Another reason for the high plastic waste generation during the COVID-19 pandemic.
Table 1. Solid waste composition before and during Covid-19 in six cities (Muzdalifah, 2019; SIPSN)

| Solid Waste | Jakarta 2019 | Jakarta 2020 | Bandung 2019 | Bandung 2020 | Surabaya 2019 | Surabaya 2020 |
|-------------|--------------|--------------|--------------|--------------|--------------|--------------|
| Food        | 23.02        | 1,795.56     | 45.99        | 730.32       | -            | 742.60       |
|             |              |              |              |              |              |              |
| Wood/        | 2.97         | 231.66       | 4.34         | 347.20       | -            | 66.43        |
| Twig        |              |              |              |              |              |              |
| Paper/       | 0.18         | 14.04        | 1.62         | 129.60       | -            | 218.81       |
| Cardboard   |              |              |              |              |              |              |
| Plastics    | 0.90         | 70.20        | 1.92         | 274.03       | -            | 278.56       |
| Metal       | 0.08         | 6.24         | 0.78         | 14.73        | -            | 14.98        |
| Fabric      | -            | 2.96         | -            | 78.00        | -            | 218.81       |
| Rubber/      | -            | -            | -            | -            | -            | -            |
| Leather     |              |              |              |              |              |              |
| Glass       | 0.65         | 50.70        | 0.33         | 26.40        | -            | 278.56       |
| Other       | 72.20        | 5,631.60     | 42.06        | 3,364.80     | -            | 334.37       |
| Total       | 100.00       | 7,800.00     | 100.00       | 8,000.00     | 100.00       | 1,628.08     |

(Continued)
| Table 1. (Continued) |
|--------------------|
|                    | By Composition (%) | By Weight (tons/day) | By Composition (%) | By Weight (tons/day) | By Composition (%) | By Weight (tons/day) | By Composition (%) | By Weight (tons/day) |
|                    |                    |                     |                    |                     |                    |                     |                    |                     |
| Solid Waste        |                    |                     |                    |                     |                    |                     |                    |                     |
| Fabric             | 1.97               | 24.66               | 4.94              | 63.07               | 3.45               | 25.55               | 2.72               | 23.12               | 3.34               | 56.91               | 2.80               | 48.00               |
| Rubber/Leather     | -                  | -                   | 1.00              | 12.77               | -                  | -                   | -                  | -                   | -                  | -                  | -                  | -                  |
| Glass              | 0.44               | 25.51               | 1.79              | 22.85               | 1.71               | 12.66               | 1.82               | 15.47               | 1.39               | 23.69               | 1.72               | 29.49               |
| Other              | 9.33               | 116.78              | 2.88              | 36.77               | 14.17              | 104.94              | 5.49               | 46.67               | 5.74               | 97.81               | 5.61               | 96.17               |
| Total              | 100.00             | 1,251.71            | 100.00            | 1,276.74            | 103.00             | 740.58              | 100.00             | 850                 | 100.00             | 1,704.02            | 100.00             | 1,714.25            |
pandemic is the use of PPE. The increase in medical waste, especially due to PPE use, is evident in the increase in plastic waste in the Benowo Landfill, where the plastic waste percentage increased from 12.96% in 2019 to 22.01% in 2020. Additionally, plastic waste containing PPE, such as masks, gloves, and head wraps, as well as various types of medicine, have been found in TPA Sumur Batu, Bantargebang District, Bekasi City, West Java, one of the largest landfills in Indonesia (Mawardi, 2020).

Plastic waste is a complex global problem. However, commonly used plastic products, such as food packaging, bags, and bottles, also have the potential to be reused. One way to recycle plastic is to reuse it to make flower decorations, as has been done by people in the Paeoan, Kendal, and Umbulsari hamlets, who are active in processing plastic waste (Biat et al., 2020). Europe has a target of recycling 55% of its plastic packaging by 2025, while the United Kingdom imposes a tax on the use of non-recycled plastics. The Indian government too prohibits companies from selling single-use plastic. Thus, many companies and organizations worldwide are committing to reducing their plastic use. To help this movement, researchers have been working to develop alternatives to plastic packaging (Delivered, 2019).

3.2.2. Medical waste

Medical waste has increased during the COVID-19 pandemic. Jakarta’s 0.96 kg/bed/day of medical waste increased to 1.62 kg/bed/day. With the spread of COVID-19 in Indonesia, there was a massive increase in medical waste generated in Surabaya’s COVID-19 referral hospitals from April to June 2020. In April 2020, Surabaya’s medical waste generation rate was 0.74 kg/bed/day. Then, in May and June 2020, the generation rates increased to 0.78 kg/bed/day and 0.79 kg/bed/day, respectively (Wardani & Azizah, 2020). This increase was caused by the use of PPE to treat COVID-19 patients, generally made of polymers, such as polyurethane, polypropylene, polycarbonate, low-density polyethylene (LDPE), and polyvinyl chloride.

According to Cordova et al. (2021), debris in Jakarta’s Marunda and Clincing Rivers increased by 5% at both sites, from 9,312 items in March 2016 to 9,768 items in March 2020 and 9696 items in April 2016 to 10,176 items in April 2020. However, this increase in debris was not reflected in the weight. In March and April 2016, there were 2.3 tons/day and 2.19 tons/day of debris in the Marunda and Clincing Rivers, respectively. By March and April 2020, the number of debris had decreased to 1.78 tons/day and 1.58 tons/day, respectively. The weight of the debris decreased while the number of debris items increased because the plastic waste weighed less per item. Plastic waste accounted for 43–47% of waste by abundance and 50–62% by weight. Plastic debris from PPE were not present before the pandemic but constituted 16% of plastic debris by weight or 138 of the 780 items during the pandemic. There was increased diversity in medical waste owing to the introduction of waste from cotton masks, sponge masks, surgical masks, medical gloves, hazmat suits, and face shields. Mask debris is the most common form of PPE waste. By March 2020, masks had accounted for 68 of the 432 items found in the two river mouths each day. In April, they were 102 of the 552 items found. The increase in the amount of PPE waste is further supported by (Kemnaker, 2010), which states that medical waste in Indonesia has increased by approximately 30–50%. In October 2020, 1662.75 tons of medical waste were recorded.

It is reasonable to assume that the amount of plastic waste has increased. The production and demand for medical masks also increased during the COVID-19 pandemic since individuals needed them in their daily lives and medical workers needed them in hospitals. Medical equipment, such as masks, hazmat suits, gloves, and head caps, are made of plastic. Data from the Indonesian Medical Device Manufacturers Association (Aspaki) state that, from July to 3 December 2020.1 billion medical masks were produced in Indonesia, 350.5 million per month.

Indonesia needs 129.8 million medical masks, which means there is an excess of up to 2.97 billion (Lidyana, 2021). Indonesia’s need for medical masks has declined due to the increased demand for cloth masks. In November 2020, the demand for cloth masks increased by 40% (Arief, 2020). The Association of Indonesian Hospitals (PERSI) provides further evidence
of medical waste. Under non-pandemic conditions, Indonesia requires 162 million medical masks every month and has a monthly production capacity of 181 million (KRI, 2020). In comparison (Ranjan et al., 2020), India generated 200,000 tons/day of medical waste during the pandemic, while Wuhan, the city where COVID-19 originated, generated 240 tons/day of medical waste. Since face masks are classified as medical waste, their increased daily use in response to the COVID-19 pandemic has contributed to the increase in medical waste. Since the beginning of the pandemic, the total number of masks used in Asia has reached 2,228,170,832 (Sangkham, 2020). Hadi et al. (2020) reported that medical waste in Hubei province in China increased from 40 tons/day to 240 tons/day, a 600 % increase. Face mask waste can potentially transmit the virus through the contaminated droplets absorbed in them (Theopilus et al., 2020). Furthermore, significant increase in mask use and medical waste creates new problems for the environment. Face mask waste has been reported in the Hong Kong Ocean (Fadare & Okofo, 2020). In addition, Selvaranjan et al. (2021) stated that facemask waste could contribute to microplastic pollution in land as well as marine environments. The significant increase in mask use and medical waste creates new problems for the environment.

Thus, the rapid increase in medical waste during the COVID-19 pandemic endangers the environment because of the presence of plastics in medical waste. The COVID-19 pandemic has caused a complex environmental problem owing to both the plastic in medical waste and the plastic used to wrap packages purchased online during the lockdown. As previously explained, online shopping has increased from one to five times per person to one to ten times per person.

3.2.3. Packaging waste
The lockdown or PSBB in Indonesia changed lifestyles. During the PSBB, many people ordered both food and other products from e-commerce vendors. In addition to the LIPI statement (Lipi, 2020), Greenpeace also stated that plastic waste from packaging increased by 300 % owing to the use of e-commerce services during the lockdown. Plastics used in packaging materials are usually made of high-density polyethylene (HDPE), LDPE, polystyrene (PS), or polyethylene terephthalate (PET). PET and HDPE are commonly recycled, whereas LDPE and PS are rarely recycled (Klemeš et al., 2020).

The total lockdown led to some people panic buying, relying on food delivery, and shopping online. Demand for products, such as plastic shopping bags and plastic packaging, is increasing. Plastic production and use have increased by 14 % in the United States and 40 % in Spain. The use of plastic products is predicted to increase from US$ 909.2 billion in 2019 to US$ 1,012.6 billion (Insider, 2020).

4. MSW management during the Covid-19 pandemic

4.1. Current MSW Management and strategies
MSW management may be a solution to manage and control waste generation. In Indonesia, efforts have been made to control solid waste generation, including waste banks, the 3 R principles (reduce, reuse, and recycle), waste depots, landfills, and household waste. According to Ranjan et al. (2020), the 3 R principles have not been implemented optimally to reduce waste, as their implementation has produced a daily waste reduction of only 22.5 %. Additionally, according to Paramita et al. (2018), only approximately 56.22 % of Jakarta’s waste can be handled, and the landfill processing infrastructure can reduce the total daily waste generated by Jakarta by approximately 30 %. According to Yuanita and Keban (2020), Bandung City’s landfill infrastructure can reduce waste by approximately 14.2 %. As shown in Table 2, the facilities and infrastructure currently available at the TPA are insufficient for managing the generated waste. Moreover, the waste to be processed in landfills must be sorted. Furthermore, implementing the 3 R principles to significantly reduce daily waste generation will be challenging.

During the COVID-19 pandemic, solid waste management faced a new challenge: recycling activities had to be slowed down or stopped owing to the lockdown and social restrictions requiring
people to stay at home. Thus, waste management activities were affected by state government policies requiring physical distancing as a standard procedure to prevent the transmission of the COVID-19 virus (Van Fan et al., 2021). Additionally, according to Chin and Poon (2020), the virus can still be detected on glass and paper on the fourth day after being discarded. On stainless steel, the virus can persist for 7 days. The virus was also detected on medical masks 7 days after use. In Europe, recycling companies are experiencing a crisis due to COVID-19 (Tripathi et al., 2020). This is because of the pandemic-era use of virgin plastics, which are safer than recycled plastics. The COVID-19 pandemic has also caused a crisis in Indonesia’s small waste-recycling industry. According to Wartabromo (2020), approximately 90 % of small business operators have been under pressure since March 2020. Data from the Indonesian Waste Entrepreneurs Association (APSI) state that, of the 90% operators, 50 % chose to close their businesses.

Waste management worsened due to some cases of improper waste management. In Indonesia, there has been a case of used masks being resold by irresponsible individuals. In Bandung, West Java, numerous containers of used masks ready to be distributed to the public were discovered (Reza, 2020). Managing waste in general is difficult, and managing plastic waste, in particular, is especially difficult. During the COVID-19 pandemic, there have been reports from many countries where household medical waste, such as PPE, has not been properly managed. For instance, in Africa, scavengers usually search through piles of waste for potentially recyclable materials, without wearing suitable PPE. In Nigeria, it has been reported that scavengers collect discarded face masks from landfills to resell to the community (Benson et al., 2021).

| Scope/City | Landfill | Facilities | Source |
|------------|----------|------------|--------|
| Jakarta    | Bantargebang | 1. Incinerator; 2. Composting; 3. Open Dumping; 4. Landfill Mining; 5. Sorting; 6. Waste Water Treatment | (Sukwika & Noviana, 2020) |
| Bandung    | Cicabe   | 1. Composting; 2. Controlled landfill; 3. Landfill Mining; 4. Sorting; 5. Waste Water Treatment | (Indartik et al., 2018) |
| Denpasar   | Suwung   | 1. Composting; 2. Sanitary landfill; 3. Landfill Mining; 4. Sorting; 5. Waste Water Treatment | (Putro) |
| Medan      | Terjun   | 1. Composting; 2. Open Dumping; 3. Landfill Mining; 4. Sorting; 5. Waste Water Treatment | (Izharsyah, 2020) |
| Semarang   | Jatibarang | 1. Composting; 2. Open Dumping; 3. Landfill Mining; 4. Sorting; 5. Waste Water Treatment | (Harjanti & Anggraini, 2020) |
| Surabaya   | Benowo   | 1. Incinerator; 2. Composting; 3. Sanitary landfill; 4. Landfill Mining; 5. Sorting; 6. LFG Power Plant/Waste Power Plant; 7. Waste Water Treatment | (Nikmah & Warmadewanthi, 2013) |
Mismanagement of MSW creates the potential for COVID-19 transmission. Hence the waste management sector must improve its handling of medical and household wastes to prevent medical issues. Surabaya’s COVID-19 referral hospitals have the Ministry of Health’s guidelines, “Waste Management for Referral Hospitals, Emergency Hospitals, and Puskesmas for COVID-19 Patient Management.” These policies explain the steps for discarding COVID-19 medical waste.

First, the COVID-19 medical waste is stored in yellow containers labeled “biohazard.” The containers are then sprayed with 0.5 % H₂O₂ disinfectant to prevent the spread of COVID-19, then stored in a temporary hazardous medical waste depot with a maximum storage time of 2 × 24 h. This is done to ensure that there is always space in the temporary hazardous medical waste depots. Once the depots reach three-quarters of their capacity, the COVID-19 medical waste must be transported immediately.

Next, the COVID-19 medical waste is transported to a temporary hazardous medical waste treatment plant and attention must be paid to certain details. The medical waste must be covered to prevent COVID-19 spread. Officers handling it must wear complete PPE, including hazmat suits, goggles, gloves, medical masks, and headwear, at all times. COVID-19 medical waste transportation must be done during low-density hours to prevent the spread of virus particles.

When the COVID-19 medical waste reaches the treatment plant, the trolleys must be disinfected before they are reused. In the final steps of COVID-19 medical waste management, COVID-19 waste is incinerated at 800–1000 °C. The incineration process reduces the volume by up to 90 %. Fly ash and bottom ash from the incineration process are transported to a third-party agency for further treatment.

The same procedure was followed in Malaysia. Malaysia does not have a specific COVID-19 medical waste management system but has adapted the procedure established by the Malaysian Department of Environment under the Environmental Quality Act of 1974.

There are procedure documents available for managing household medical waste in Indonesia. Semarang City’s procedure document specifies that the waste is to be collected from each village and transported to the sub-district office by a fleet of arm roll trucks with closed basins. The procedure for collecting infectious waste is as follows:

- Workers approach trash cans and spray them with disinfectant.
- Workers open infectious trash cans and remove bags filled with infectious waste.
- Infectious waste is placed inside a truck container, which is then closed and sprayed with disinfectant.
- Infectious waste is sent to the district and then to the Semarang City incinerator unit.
- After a delivery, the arm roll truck is sprayed with disinfectant.

Indonesia’s Ministry of Manpower and Transmigration (Kemaker, 2010) states in Article 6, Section 1, of its regulation No. 08/MEN/VII/2010 that, “Workers/laborers and other people who enter the workplace are required to wear PPE according to the potential dangers and risks.”

4.2. Waste worker and waste picker behaviors
The recycling activities of some waste workers who continue recycling because it is their primary job have become highly hazardous. In Indonesia, MSW management cannot be separated from the waste workers and pickers’ informal activities. These activities include scavenging for valuable waste items, utilizing or reselling used goods (such as plastic and cardboard), or reworking them into commodity goods (Hutagalung et al.). Some workers can recycle and create a product by themselves. In addition to plastic and used goods, scavengers pick up leftover food for use as animal feed. Some waste workers and pickers play a role in reducing plastic and paper waste. A large number of scavengers in a landfill could make
a significant difference in the volume of municipal waste, potentially reducing the amount entering the Bandung landfill each day by approximately 12.5 % to 29 % (Febrino & Rahardyan, 2015). However, there has been no satisfactory result for municipal waste management systems, where a large amount is still dumped in landfills. When recycling before the pandemic, especially in the Jatibarang landfill, Semarang, both waste workers and pickers used gloves and boots while working but did not practice social distancing. Currently, despite governments restricting recycling activities in landfills, especially those of waste workers and waste pickers, due to the COVID-19 pandemic, some waste workers have continued to work without any additional equipment, as described in the Ministry of Manpower and Transmigration (Kemnaker, 2010) regulation No. 08/MEN/VII/2010 concerning Personal Protective Equipment. According to the regulations, waste workers and waste pickers must be equipped with masks, gloves and boots, and they must adhere to the distancing recommendation. In contrast to the situation in Indonesia, the 2020 Solid Waste System Operating Manual document of Hennepin County, Minnesota, United States, requires all waste workers to use PPE, such as safety helmets (according to ANSI Z89.1–1997 standards and class G industry category), safety glasses (according to ANSI Z87.1–1989 standards), safety shoes, and reflective vests. Additionally, there are regulations for activities in the field, including warnings against smoking and vehicle speed limits.

The vulnerability of waste workers and pickers to COVID-19 transmission is further evidenced in the news portal Sutrisna (2020) which reported that approximately 300,000 workers and 600,000 waste pickers in Indonesia are being exposed to medical waste (Table 3), such as disposable masks, tissues, and used bottles, which could potentially serve as a medium for the COVID-19 virus transmission. These workers can be infected because many still do not protect themselves by using complete PPE, such as masks and gloves while working. The COVID-19 pandemic requires knowledge and vigilance of workers and scavengers.

Sartika et al. (2020) studied cleaning workers’ use of PPE in the city of Palangka Raya. They concluded that workers are at an elevated risk of contracting diseases that can be transmitted through waste. Therefore, they need to use PPE to protect themselves from potential hazards and work accidents. The following is a comparison of the current levels of compliance regarding the different pieces of PPE at the research location.

Table 4 shows that 92 % of workers do not wear protective aprons or jackets. The type of mask that 38 % of workers routinely use is a single-use mask that has been used repeatedly and so does not comply with health standards. Glove use is routine among 13 % of workers, but the gloves do not adhere to the proper standard since most of them consist of plastic bags pulled over workers’ hands and tied with straps. Routine use of headwear and safety shoes is high, 62 % and 46 %, respectively. However, some officers do not wear safety shoes (Sartika et al., 2020).

According to several statements, there are various precautions that waste workers and pickers can take to continue working safely during the COVID-19 pandemic. The first step in handling infectious waste in the era of COVID-19 is to separate out waste that is likely to be infectious, such as used tissues, masks, handkerchiefs, disposable cloths, and PPE (Acr, 2020). The Ministry of Health of the Republic of

| City       | Number of Workers | Source                                      |
|------------|-------------------|---------------------------------------------|
| Jakarta    | 400,000           | (Kuntoro et al., 2013)                      |
| Surabaya   | 2,500             | (Wijayanti, 2019)                          |
| Semarang   | 245               | (Rifai et al., 2016)                       |
| Medan      | 450               | (Mahyuni, 2012)                            |
| Denpasar   | 231               | (Putri & Subhaktiyyasa, 2018)              |
| Bandung    | 421               | (Balenguru & Triwahyuni, 2017)             |

Table 3. Numbers of workers
Table 4. PPE usage (Sartika et al., 2020)

| Items      | Levels of Compliance (%) | Routine | Not a routine | Not use |
|------------|--------------------------|---------|---------------|---------|
| Safety Mask|                          | 38      | 21            | 41      |
| Safety Gloves |                        | 13      | 15            | 72      |
| Headwear   |                          | 62      | 15            | 23      |
| Apron/Jacket |                        | 3       | 5             | 92      |
| Safety Shoes |                         | 46      | 15            | 39      |
| Waste Clip |                          | 31      | 23            | 46      |

Indonesia recommends that used masks be disinfected by soaking them in a chlorine or bleach solution, and then cutting or shredding them to preempt efforts to recycle them (Kemenkes, 2020). Government policies on handling infectious waste as well as health and safety procedures for cleaning workers who handle infectious waste must be strengthened, requiring all cleaning officers and waste collectors to use PPE, disinfect masks, gloves, and other safety resources daily (Kemnaker, 2010).

Improving the procedures followed by waste workers' during the COVID-19 pandemic is important because for some people it is their primary job. Infectious waste treatment facilities should adopt procedures similar to those used in hospitals.

5. Recommendations for improving MSW management

Based on the results of our literature review, we identified various problems: the increase in solid waste generation (especially food and plastic waste), lack of infectious waste management, many workers not protecting themselves by using complete PPE when working, and disparities across different cities’ facilities. The following suggestions are made to improve the current situation and address different MSW stakeholders: citizens, waste workers, and the government.

5.1. Citizens

Citizens should be more aware of waste management than they currently are. According to Vicente-Molina et al. (2013), environmental awareness can contribute to positive attitudes towards waste reduction. Educated citizens can become more knowledgeable about waste disposal, more responsible for the environment, and more aware of their potentially damaging actions than they were prior to being educated about waste management. The points that citizens must understand to reduce the amount of waste they generate are the 3 R principles of waste management, which will reduce waste generation by 30–40 % (Bir, 2020), household-scale composting, which can reduce total solid waste by approximately 38–55 % (Mbuligwe et al., 2002), meal planning, reusable mask use, and the prioritization of waste prevention whenever possible. To prevent the spread of the virus, citizens must understand the logic behind the separation of medical waste into color-coded biohazard bags, separate collection and disposal of household waste generated by COVID-19 patients, and enhanced personal hygiene standards (ISWA, 2020).

Furthermore, there is a need for community leaders to increase the citizens' interest in waste management. For example, online programs can be implemented in neighborhoods to increase community participation, improve environmental cleanliness, monitor hygiene standards, and provide adequate information regarding COVID-19.

5.2. Waste workers

Waste workers and pickers should improve their personal hygiene, sanitize objects and surfaces regularly, ensure adequate use and frequent changes of PPE (CDC, 2020), and immediately discontinue the manual sorting of mixed waste by substituting the manual stages in mechanical-
manual systems (ISWA, 2020) and avoiding processes, such as shredding waste, until the situation returns to normal (Vanderlaan, 2020).

5.3. Government

The government needs to harmonize policies across the central and local governments. The central government should be active in encouraging local governments and officeholders to take action on waste management amid the COVID-19 pandemic. These actions should include supporting waste management facilities and providing incentives for industries that recycle. Additionally, the government should provide adequate information about COVID-19 risks as well as sanitizing and hygiene materials and supplies (CDC, 2020). Furthermore, the government must facilitate periodic health checks and training procedures for handling waste for waste workers (Das et al., 2021b).

It is necessary that facilities, especially those with thermal technologies for processing medical, plastic, and packaging waste, be equitably distributed across different cities. Thermal processes include incineration, pyrolysis, gasification, plasma gasification, and carbonization (Dharmaraj et al., 2021; Purnomo et al., 2021). Moreover, infectious waste management policies need to be implemented, especially innovations in the manufacture of biodegradable PPE (Septiariva et al., 2022).

6. Conclusion

This study presents the conditions of MSW management during the COVID-19 pandemic in six major cities in Indonesia, and provides recommendations to improve this situation. Before the COVID-19 pandemic, Indonesia already had problems managing MSW. The COVID-19 pandemic has exacerbated MSW management problems, such as the increase in solid waste generation (especially food and plastic waste), mismanagement of MSW, many workers not protecting themselves by using complete PPE when working, and the inequitable distribution of facilities across different cities. Strategies to reduce the spread of the virus through waste exist but are not evenly distributed in all regions of Indonesia.

Based on these findings, recommendations were made to improve the current situation. These recommendations include increasing public awareness of waste management, ensuring waste workers and waste pickers wear full PPE while working, maintaining good personal hygiene, and harmonizing policies across different levels of government. The government should provide all citizens with adequate information about COVID-19 as well as sanitizing and hygiene supplies.

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