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SPECIAL ISSUE

REVIEW: MEDICAL WASTE MANAGEMENT FOR COVID19

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Abstract

Introduction*: Medical waste generation during the Covid19 pandemic increased by around 30%. Sources of medical waste generation are health care activities. If medical waste is not appropriately managed, it can pollute the environment and disturb health. The purpose of the review is to identify the potential of medical waste in health-care facilities in Indonesia when the Covid19 pandemic and to review medical waste management in Indonesia. The analysis uses a systematic literature review.* ***Discussion****: The potential of medical waste during the Covid19 epidemic is infectious waste (PPE wastes), sharps waste (syringes), chemical waste (expired medicines), and pharmaceutical waste (the used alcohol bottles when rapid tests). The hazardous waste management system refers to Government Regulation No. 101 year 2014 about Management of Hazardous and Toxic Waste and and Regulation of Minister of Environment and Forestry of Republic Indonesia No. P.56/Menlhk-Setjen/2015 about Procedures and Technical Requirements for Waste Management Hazardous and Toxic From the Health Service Facilities. Infectious waste, sharps waste, chemical waste, and pharmaceutical waste are destroyed with incinerators. Syringe residues were damaged with a needle shredder. Residue and incineration ashes are processed using solidification. If the heavy metal content under the quality standards, then the waste can be landfill.* ***Conclusion****: The potential of medical waste during the Covid19 pandemic is infectious waste, sharps waste, chemical waste, and pharmaceutical waste. Medical waste generated must be appropriately managed. Proper medical waste management can prevent environmental pollution and the spread of disease. One of the processing of potential medical waste is incineration. The incineration system produces residue and ash waste that must further be handled so that it does not pollute the environment and disturb health.*

INTRODUCTION

Indonesia is one of the countries exposed to coronavirus disease (Covid19). The number of people exposed to Covid19 continues to increase. Based on data submitted by the Covid19 handling task force (Communication Team of the Committee for Handling Corona Virus Disease 2019 (Covid19) and National Economic Recovery), the number of people exposed to Covid19 up to August 19, 2020, was 144,945 cases (1). The coronavirus (Covid19) is the Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) virus (2). The coronavirus disease (Covid19) quickly spreads and spreads to all people, including healthcare workers who move as the vanguard.

Healthcare workers have great potential to be exposed to coronavirus disease (Covid19). One example of activities that cause healthcare workers to be potentially exposed to coronavirus disease is when they interact directly with Covid19 patients but do not use Personal Protective Equipment (PPE). Another activity that triggers exposure to Covid19 transmission to healthcare personnel is medical action on Covid19 patients that produce aerosols such as bronchoscopy, nebulisation, tracheal intubation, non-invasive ventilation, tracheostomy, pulmonary resuscitation, manual ventilation before intubation, swab taking, dental examinations such as ultrasonic scaler and high-speed air-driven, throat examination, etc (2). The prevention of Covid19 transmission by healthcare workers is the use of standard Personal Protective Equipment (PPE) based on risk assessment (2). Personal protective equipment (PPE) is a set of tools that serves to prevent users from health hazards, such as exposure to viruses. Personal protective equipment (PPE) used by healthcare workers is surgical masks or N95 masks, eye protectors (goggles), face shields, apron, gloves, head protectors, protective shoes, coverall jumpsuits, medical gown, and hazmat.

The use of Personal Protective Equipment (PPE) causes positive and negative impacts on the surrounding environment. The positive impact is protecting healthcare workers from Covid19 transmission. While the negative impact is an increase in the generation of medical waste (infectious waste). Examples of medical waste that fall into the category of infectious waste (A337-1) are personal protective equipment (PPE) waste that has been used by healthcare workers for caring of Covid19 patients, residual swabs, rapid test residues, syringe wastes, cotton or tissue from patients which is indicated to be infected with Covid19. Medical waste is included in the category of Hazardous Waste (3-4). According to Government Regulation No. 101 year 2014 about Management of Hazardous and Toxic Waste, "Hazardous Waste is the residue of a business and / or activity containing hazardous and toxic material". Therefore, this waste must be specifically managed (5). Hazardous waste if not managed properly can pollute the environment and disturb health (6).

Medical waste is the residue from medical activities. Medical waste is divided into 2 (two) namely solid waste and liquid waste. Solid medical waste is solid waste containing hazardous and toxic materials such as infectious waste, pathological waste, sharps waste, pharmaceutical waste, cytoxic waste, chemical waste, radioactive waste, pressurized container waste, and waste with high heavy metal content (7). Based on data from the Indonesian Hospital Association (PERSI), the estimated amount of medical waste generation in 2018 from 2,813 hospitals is ± 366 tons/day (8). Coverage of hospitals that carry out medical waste management according to standards in 2018 is 33.63% (946 the number of hospitals managing medical waste from 2,813 hospitals) (7). Efforts to manage medical waste according to standards by hospitals continue to increase from year to year. This is evidenced by an increase in the percentage of hospital coverage that conducts medical waste management according to the standard in 2019 (42.64%). There are 1,220 hospitals managing medical waste in 2019 (9). The number of hospitals managing medical waste in 2019 exceeds the strategic plan target of the Health Ministry. The target percentage of hospitals that conduct medical waste management according to standards based on the strategic plan of the Health Ministry in 2019 is 36% (10). Based on the target, it is known that hospitals in Indonesia that manage medical waste below 36% in 2019 are hospitals in the region Aceh (12%), North Sumatra (15.58%), Jambi (27.50%), South Sumatra (12.33%), Riau Islands (27.59%), East Java (17.74%), East Nusa Tenggara (21.88%), West Nusa Tenggara (20.34%), West Kalimantan (14%), South Kalimantan (20.45%), Southeast Sulawesi (17.50%), North Maluku (11.54%), North Sulawesi (2.22%), West Sulawesi (7.14%), Maluku (5.71%) and Papua (1.59%) (9).

Based on Indonesian Health Profile data, it is estimated that the number of hospitals in Indonesia continues to grow. The number of hospitals in Indonesia in 2018 was 2,813 (7), and in 2019 there were 2,861 (9). The hospital number increase in Indonesia affects the amount of medical waste generated (5,11). The condition of the Covid19 pandemic also affects the generation of the medical waste increase generated by health-care facilities. Medical waste has the potential to cause environmental pollution and disturb health if not managed properly (12–14). Besides, medical waste has infectious

characteristics. Hazardous waste (infectious waste), if correctly managed, can have the potential to cause negative impacts, such as causing work injuries, the transmission of diseases (such as nosocomial diseases) (5,11), and environmental pollution (5,13). Infectious waste is waste contaminated with pathogenic organisms that are not routinely present in the environment, and the organism is sufficient in number and virulence to transmit diseases to vulnerable humans (15). The generation of medical waste produced by each health service facility unit continues to increase (5,6,11). It must be accompanied by efforts to manage medical waste. Based on data from the 2019 Indonesian Health Profile, the percentage of hospital coverage that leads medical waste according to standards in 2019 reached 42.64% (9). It means that more than 50% of health service facilities in Indonesia have not carried out standard medical waste management, even though the negative impacts caused by medical waste are quite dangerous, especially during the Covid19 pandemic. The trash is feared to be a coronavirus disease spread media (16). Therefore, there needs to review of medical waste management in health-care facilities in Indonesia. Medical waste management is based on waste characteristics. So another purpose of the review is to identify the potential of medical waste in health-care facilities in Indonesia during the Covid19 pandemic.

DISCUSSION

Identification of the Potential of Hazardous Waste

Health facilities are facilities and infrastructure used to support health services and health cares to the community. Health facilities consist of inpatient facilities, emergency departments, operating and supporting rooms, consultation rooms, waiting rooms, triage, laboratories, registration rooms, cashiers (place of payment for health care), sterilization installations, laundry room, etc. The availability of personal protective equipment (PPE) for healthcare workers in health-care facilities is a problem faced by all countries including Indonesia during the Covid19 pandemic. Therefore, the World Health Organization (WHO), the Centers for Disease Control and Prevention (CDC), and the Health Ministry of Indonesia Republic issued technical guidelines for the use of personal protective equipment (PPE). The technical guidelines issued by the Health Ministry of Indonesia Republic on April 8th, 2020, serve as one of the references for Indonesian healthcare workers in the use of personal protective equipment (PPE) to prevent Covid19 transmission (2). The personal protective equipment (PPE) used in health-care facilities can be seen in Table 1 (2).

Completeness of personal protective equipment (PPE) used by healthcare workers for each activity carried out in the unit of health facilities is different. The use of personal protective equipment (PPE) serves to protect part or all of the body from potential dangers (17). The use of personal protective equipment (PPE) by healthcare workers indirectly affects the production of medical waste generated by each health facility unit. Based on a statement from the Director-General of Waste, Waste and hazardous waste management of the Ministry of Environment and Forestry on May 18, 2020, the generation of medical waste during the Covid19 pandemic has increased by around 30% (18). One of the factors that influence medical waste generation is the number of patients. The higher the number of patients, the medical waste generation will also increase (19). The amount of medical waste generated during the Covid19 pandemic must be accompanied by manage medical waste efforts (hazardous waste). Hazardous waste management according to standard operating procedures (20).

Identify the potential solid medical waste generation is one manage medical waste effort that can be done. The method used to identify potential medical waste is a systematic literature review. The approach to analyzing the potential for medical waste is based on the activities carried out in each health service unit. Identification of potential medical waste aims to determine proper medical waste management. The management of medical waste generated is based on the characteristics of the trash. The potential for solid medical waste during the Covid19 pandemic are infectious groups, sharps, chemicals, and pharmaceuticals. Classification of potential for solid medical waste based on Regulation of Minister of Environment and Forestry of Republic Indonesia No. P.56/Menlhk-Setjen/2015 about Procedures and Technical Requirements for Waste Management Hazardous and Toxic From the Health Service Facilities (15).

Potential infectious waste is personal protective equipment (PPE) waste that is used by healthcare workers when interacting directly with Covid19 patients such as Covid19 patient examination, imaging examination, and non-respiratory specimens examination in patients indicated Covid19 or patients who are positive for Covid19. Personal protective equipment (PPE) waste is surgical masks or damaged N95 masks; damaged goggles; disposable face shield; disposable apron; disposable gloves; disposable head protect; disposable protective shoe coverings, coverall jumpsuits; disposable medical gowns and disposable hazmat. Personal protective

equipment (PPE) that has been used by healthcare workers to carry out medical procedures such as intubation, tracheostomy, bronchoscopy, gastrointestinal endoscopy, autopsy, taking airway specimens for the examination of patients indicated Covid19 or patients who are confirmed positive for Covid19 also includes the infectious waste. The other example of infectious waste is personal protective equipment (PPE) used by healthcare workers in public poly rooms, isolation rooms, consultation rooms when there is direct contact with Covid19 patients. Besides, personal protective equipment (PPE) is used when carrying out activities to clean Covid19 patient rooms, cleaning isolation rooms, washing surgical instruments, handling infectious linen, cleaning consultation rooms with patients indicated Covid19 or patients who are positive for Covid19, ambulance cleansing after removal of patients suspected Covid19, cleaning of medical instruments that have been

Table 1. Types of Personal Protective Equipment (PPE) Used in the Case of Covid119 According to World Health Organization (WHO)

Health Facilities	Health Activities	Personal Protective Equipment (PPE)[**)]
The patient treatment room, the emergency room, and the operating room	Care and direct interaction with COVID-19 patients	Surgical mask Medical Gown Gloves Eye protection (Goggles) Face shield Head protector Protective shoes
	Aerosol-producing actions (such as tracheal intubation, non-invasive ventilation, tracheostomy, cardiac and pulmonary resuscitation, manual ventilation before intubation, nebulation, bronchoscopy, swab taking, dental examinations such as ultrasonic scanners and high-speed air-driven, nose and throat exams, etc.) on COVID-19 patients	N95 mask Medical Gown Gloves Eye protection (Goggles) Face shield Head protector Apron Protective shoes
	Clean the COVID-19 patient room	Surgical mask Medical gown Thick gloves Eye protection (Goggles) Head protector Protective shoes
Other areas used for patient transit (e.g., corridors and wards)	All activities where there is no direct contact with COVID-19 patients	Surgical mask[*)]
The triage	All activities where there is no direct contact with patients who have or have no symptoms of respiratory tract infections	Surgical mask[*)] Head protector Gloves
	Clean the insulation room	Surgical mask Medical Gown Thick Gloves Eye Protection (Goggles) Head Protector Protective Shoes
The laboratory	COVID-19 sample testing	N95 mask Medical Gown Gloves Eye protection (Goggles) Face shield Head protector Protective shoes
The sterilization installation	Washing surgical instruments	Surgical Mask Medical Gown Long Gloves Eye protection (Goggles) Face shield Head protector Apron Protective shoes
The laundry room	Handling the infectious linen	Surgical mask Medical Gown Long Gloves Eye protection (Goggles) Face shield Head protector Apron Protective shoes
The administrative area	Patient registration and payment of health administration (Cashier)	Surgical mask[*)]

Health Facilities	Health Activities	Personal Protective Equipment (PPE)[**)]
The consultation room	The physical examination on the patient	Surgical mask Medical Gown Gloves Eye protection (Goggles) Face shield Head protector Protective shoes
	Bronchoscopy examination, swab taking, dental examinations such as an ultrasonic and high-speed air-driven scaler, nose and throat examination, and eye examination	N 95 mask Medical Gown Gloves Eye protection (Goggles) Face shield Head protector Apron Protective shoes
	Clean the consultation room	Surgical mask Medical Gown Thick gloves Eye protection (Goggles) Head protector Protective shoes
The waiting room	All activities	Surgical mask[*)]
Ambulance	Displacement of the suspected patients that infected coronavirus disease	Surgical mask Medical Gown Gloves Eye protection (Goggles) Head protector Protective shoes
	Clean the ambulance after removal of the suspected patients that infected coronavirus disease	Surgical mask Medical Gown Thick gloves Eye protection (Goggles) Head protector Protective shoes

Source: Ministry of Health of Republic Indonesia, 2020

Information:

[*)] Maintain distance from patients (minimum 1 m)

[**)] After use, Personal Protective Equipment (PPE) must be disposed of in an infectious rubbish bin (yellow plastic) for destroyed in an incinerator.

used by patients who suspected Covid19 or patients who are positive Covid19, and personal protective equipment (PPE) used by ambulance drivers when transferring patients that suspected Covid19 are infectious waste. Controlled syringes, gauze or cotton, and rapid test equipment used during rapid tests also belong to infectious waste. Infusion tubes, plabot/infusion needles, oxygen support tubes used for the treatment of Covid19 positive patients or patients with Covid19 suspects, as well as contaminated tissues, including infectious waste. Waste specimens of confirmed patients with Covid19 or patients Covid19, such as used specimen bags and Covid19 samples used as infectious waste. Whereas, sharps waste are syringes, infusion needles and medicine bottles made of glass such as vials and ampoules. Pharmaceutical waste is broken and expired drugs. The used alcohol bottles used during rapid tests are chemical waste. Table 2 shows the identification of potential medical waste generated by health facilities during the Covid19 pandemic.

Medical Waste Management System in Healthcare Facilities in Indonesia

Medical waste is a hazardous waste (21). Management is a handling process/system (22). "Hazardous Waste Management is an activity that includes reduction, storage, collection, transportation, utilization, processing, and/or landfill." (21). The Hazardous Waste management system, such as medical waste, refers to Government Regulation No. 101 year 2014 about Management of Hazardous and Toxic Waste and and Regulation of Minister of Environment and Forestry of Republic Indonesia No. P.56/Menlhk-Setjen/2015 about Procedures and Technical Requirements for Waste Management Hazardous and Toxic From the Health Service Facilities. The difference between the two conditions is the production of medical waste generated by health-care facilities. The incidence of medical waste increased by around 30% during the Covid19 pandemic (18). Therefore the medical waste management system needs to be improved. The medical waste management system is as follows:

Table 2. Identification of the Potential of Solid Medical Waste during the Covid19 pandemic

Health Activities	The Potential of Solid Medical Waste	Hazardous Waste Characteristics[16]
All activities where there is no direct contact with patients who have or have no symptoms of respiratory tract infections	Disposable head protectors Disposable surgical masks Disposable gloves	Infectious waste
Physical examination in patients with symptoms of respiratory tract infections	Disposable surgical masks Disposable medical gowns Disposable gloves Eye protection (goggles) whose conditions are damaged, opaque, and loose Disposable Face shield Disposable head protectors Disposable shoe cover	Infectious waste
Imaging examination in COVID-19 patients or patients who are indicated to be infected with COVID-19	N-95 mask whose condition is damaged Disposable medical gowns Disposable gloves Eye protection (Goggles) whose conditions are damaged, opaque, and loose Disposable Face shield Disposable head protectors Disposable shoe cover	Infectious waste
Medical actions that trigger exposure to airborne COVID-19 transmissions such as bronchoscopy, intubation, extubation, tracheotomy, gastrointestinal endoscopy, non-invasive ventilation, pulmonary resuscitation, manual ventilation before intubation, nebulation, dental examination such as ultrasonic scaler and high-speed air-driven, nose and throat examination, eye examination) in COVID-19 patients or patients indicated to be infected with COVID-19	N-95 mask Disposable medical gowns Disposable gloves Eye protection (Goggles) Disposable Face shield (face shield) Disposable head protectors Disposable shoe cover Disposable Apron Coverall jumpsuits Intubation hose	Infectious waste
COVID-19 patient care	Disposable surgical masks or N-95 masks that are damaged Disposable medical gowns Disposable gloves Eye protection (goggles) whose conditions are damaged, opaque, and loose Disposable Face shield Disposable head protectors Disposable shoe cover IV line Plabot/Infusion needles Vials/ampoules Oxygen relief hose Infusion needle Syringes Contaminated tissue	Infectious waste Sharps Waste
Taking swab	N-95 mask whose condition is damaged Disposable medical gowns Coverall jumpsuits Disposable gloves Eye protection (goggles) whose conditions are damaged, opaque, and loose Disposable Face shield Disposable head protectors Disposable shoe cover Disposable Apron Swab tools	Infectious waste
COVID-19 sample testing	N-95 mask whose condition is damaged Disposable medical gowns Disposable gloves Eye protection (goggles) whose conditions are damaged, opaque, and loose Disposable Face shield Disposable head protectors Disposable shoe cover Sample specimens Specimen used bag	Infectious waste
Displacement of the suspected patients that infected coronavirus disease	Disposable surgical masks Disposable medical gowns Disposable gloves Eye protection (goggles) whose conditions are damaged, opaque, and loose Disposable face shield Disposable head protectors Disposable shoe cover	Infectious waste

Health Activities	The Potential of Solid Medical Waste	Hazardous Waste Characteristics[16]
Patient registration and payment of health administration (Cashier)	Disposable surgical masks	Infectious waste
Washing surgical instruments	Disposable surgical masks Disposable medical gowns Long disposable gloves Eye protection (Goggles) whose conditions are damaged, opaque, and loose Disposable Face shield Disposable head protectors Disposable shoe cover Disposable Apron	Infectious waste
Clean the COVID-19 patient room	Disposable surgical masks Disposable medical gowns Thick disposable gloves Eye protection (goggles) whose conditions are damaged, opaque, and loose Disposable head protectors Disposable shoe cover	Infectious waste
Clean the insulation room	Disposable surgical masks Disposable medical gowns Thick disposable gloves Eye protection (goggles) whose conditions are damaged, opaque, and loose Disposable head protectors Disposable shoe cover	Infectious waste
Clean the consultation room	Disposable surgical masks Disposable medical gowns Thick disposable gloves Eye protection (goggles) whose conditions are damaged, opaque, and loose Disposable head protectors Disposable shoe cover	Infectious waste
Clean the ambulance after removal of the suspected patients that infected coronavirus disease	Disposable surgical masks Disposable medical gowns Disposable gloves Eye protection (goggles) whose conditions are damaged, opaque, and loose Disposable head protectors Disposable shoe cover	Infectious waste
Handling the infectious linen	Disposable surgical masks Disposable medical gowns Long disposable gloves Eye protection (goggles) whose conditions are damaged, opaque, and loose Disposable Face shield (face shield) Disposable head protectors Disposable shoe cover Disposable Apron	Infectious waste
The Rapid Test	Disposable surgical masks Disposable medical gowns Disposable gloves Eye protection (goggles) whose conditions are damaged, opaque, and loose Disposable Face shield Disposable head protectors Disposable shoe cover Disposable Apron Syringes Contaminated gauze/cotton Alcohol bottles Rapid Test Tools	Infectious waste, Sharps infectious waste, Chemical waste
The pharmacy	Medication is broken and has expired Disposable surgical masks Disposable gloves	Pharmaceutical waste, Infectious Waste

Source: The Minister of Environment and Forestry of the Republic of Indonesia No: P.56 / Menlhk-Setjen / 2015 Regarding Technical Procedures and Requirements for the Management of Hazardous and Toxic Waste Material from Health-care Facilities

Information:

The hazardous waste characteristics based on Regulation of the Minister of Environment and Forestry of the Republic of Indonesia No: P.56 / Menlhk-Setjen / 2015 Regarding Technical Procedures and Requirements for the Management of Hazardous and Toxic Waste Material from Health-care Facilities

Medical Waste Reduction System

Medical waste is a Hazardous Waste (21). Therefore, there is a need for management efforts specifically for medical waste. Reduce medical waste is one management effort that can be made. The reduction of medical waste can be made in several ways, such as sorting medical waste from sources, reuse of medical equipment, minimize the use of dangerous and toxic substances, wise in the procurement of chemicals and pharmaceutical ingredients, and recycling of medical waste. The reduction of medical waste must be carried out by hazardous waste producers (15,21). The reduction of medical waste aims to reduce the amount of medical waste generated from health care activities (5).

Sorting Medical Waste from Sources

Sorting of medical waste from sources is the simplest attempt to reduce hazardous waste. The sorting of medical waste based on type, group, and characteristics of hazardous waste (15). The sorting of waste aims to minimize the contamination of medical waste that has the potential to cause health problems and environmental pollution (23). Besides, sortings also are done on medical waste and non-medical waste from the source. The purpose of sorting medical and non-medical waste is to prevent contamination of medical waste from non-medical waste. Non-medical waste has the potential to contain hazardous and toxic substances if it contaminated with medical waste (5,24-25). Mixing wastes will indirectly lead to the generation of hazardous waste generated by health-care facilities.

The advantages of sorting medical waste are reducing environmental pollution, saving medical waste management costs, improving the image of the hospital (24). Examples of health-care facilities that implement a medical waste sorting system are PB Hospital in Riau Province (24), dr. Saiful Anwar Malang Hospital (25), Dr. Soetomo Surabaya Hospital (5).

Reuse

Reuse of medical equipment that has been used, such as used containers of sterilized chemicals and sterilized personal protective equipment (PPE) (25). The purpose of sterilization of medical equipment that has been used by healthcare workers to eliminate the dangerous and toxic nature so that it is safe for reuse. However, in certain conditions such as medical procedures that produce aerosols (tracheal intubation, non-invasive ventilation, tracheostomy, pulmonary heart resuscitation, manual ventilation before intubation, nebulation, bronchoscopy, swab taking, dental examination such as ultrasonic scaler and high-speed air-driven, the heart examination, nose and throat examination, etc.) in Covid19 patients, personal protective equipment (PPE) waste must be regenerated (26). This matter is due to the fact that PPE waste is infectious waste. PPE that has been used during medical examinations that produce aerosol in Covid19 patients is feared to be a medium for the spread of the Covid19 (27).

Minimize the Use of Hazardous and Toxic Substances (Substitution or Eimination).

Substitution and elimination efforts aim to reduce the use of materials that produce hazardous waste (15,28). An example of the reduction by substitution in the use of medical equipment is to replace the mercury thermometer with a digital thermometer (6,15,28).

Wise in the Procurement of Chemicals and Pharmaceutical Ingredients

One of the efforts to reduce hazardous materials is wise in the procurement of chemicals and pharmaceuticals. The bids can be made by controlling the distribution of drugs and compounds (15,24,28), procurement of drugs and chemicals is carried out with good governance (15), and checking expiration dates medicines and chemicals (24). Another reduction effort that can be done is the procurement of chemicals and pharmaceutical ingredients according to needs (24-25). Wise in the supply of chemicals and pharmaceuticals which aim to avoid the management of chemicals, damaged and expired drugs (6,24-25) and the management of chemical and pharmaceutical waste (28).

Recycling

Recycling is an effort that can be done by healthcare facilities (hospitals, health centers, etc.) in reducing the medical waste generation (5,15,25). Medical waste that has the potential to be recycled is infusion bottle waste, hemodialysis jerry cans (5) jerry cans waste from medicine containers (25). Healthcare workers will usually separate waste for recycling by third parties (5,25).

The causes of not yet optimal handling of medical waste are lack of knowledge of healthcare workers about medical waste reduction (29-30) and lack of enforcement of applicable regulations. Therefore efforts to manage medical waste. The efforts to handle medical waste are periodic training of medical waste management to healthcare workers (31). Training aim to increase knowledge of healthcare workers about medical waste management. Healthcare workers carry out most of the medical waste management in health-care facilities.

Health service activities carried out by health workers produce medical waste. Therefore, it is necessary to increase the knowledge of health workers about medical waste management so that efforts to manage medical waste are maximized (32).

Storage System

Medical waste storage systems based on the type, group, and characteristics of hazardous waste (15). Medical waste containers must be covered with colored plastic. The color determination of the plastic is based on Decree of Minister of Health of Republic Indonesia Nomor 1204/MENKES/SK/X/2004 about Hospital Environmental Health Requirements. Infectious waste containers covered with yellow plastic, chemical and pharmaceutical waste stored in brown plastic covered containers, radioactive waste disposed of in red plastic-covered containers, and cytological disposal containers covered with purple plastic. Especially sharps waste such as syringe waste is stored in a safety box (13,25,33–36). This matter aims to prevent leakage (33) and maintain security and safety for sharps waste collection officers. Medical waste containers must also be equipped with labels and symbols of hazardous waste (15). The use of labels and symbols in hazardous waste containers aims to facilitate the collection of waste based on the type, group, and characteristics of hazardous waste (15). Medical waste storage requirements are strong, rust-resistant, not easily opened or damaged (13,15,34,37-38), watertight (15,33,37,39), not easy to leak and mossy, and have a lid (13,33,39). The capacity of medical waste containers is based on the rate of generation of medical waste generated by health-care facilities.

Problems that occur in the medical waste storage system in several health-care facilities in Indonesia is the color of the plastic used to line medical waste disposal containers does not comply with applicable regulations (38,40–44). Color plastic mismatch is due to the difficulty of obtaining plastic colors by applicable laws (42). The other problem that occurs in the medical waste storage system is medical waste storage containers have no labels and symbols of hazardous (38,41,45). The use of labels and symbols of hazardous on these containers aims to ease health workers and patients to dispose of solid medical waste according to the type, group, and characteristics of hazardous waste (15,33). Containers for the disposal of medical waste are not suitable for their intended purpose is the problems in the medical waste storage system. The example is non-medical waste discharged into medical waste containers (34), infectious waste stored in a cupboard, and used cotton discarded in mineral beverage boxes (46), and syringe waste is stored in drinking bottles (47). It is caused by the lack of awareness in managing medical waste (34).

Collection System

The waste collection system is the process of moving waste carried out by waste collection officers for further management (48). The waste collection process is carried out effectively and efficiently. Time to collect trash from health-care facilities is at least once a day (15) and a maximum of 2 (two) days after the infectious waste is produced (26). If the amount of medical waste generated exceeds the capacity of the available container or if the capacity of the container has filled as much as ¾ of the maximum volume, the collection of medical waste is carried out immediately. Determination of the high capacity of medical waste generation (maximum ¾ of the maximum size) aims to make it easier for medical waste collection officers to bind bags/plastics that filled with medical waste. When collecting waste, a plastic layer in the container will be taken and replaced with a new plastic covering of the same color, label, and symbol. Retrieval of medical waste using medical waste transportation facilities such as wheeled trolleys or wheeled containers (15).

The system of collecting medical waste in several health-care facilities in Indonesia does not meet the applicable regulatory standards, such as the cleaning service collect medical waste by hand (42). The process of medical waste-collecting should use a trolley for wheeled collectors or wheeled containers (15). Furthermore, the officers who collect medical waste are often negligent in using personal protective equipment. The use of personal protective equipment (PPE) aims to maintain safety and health at work. Work accidents that commonly occur when collecting medical waste are injected with needle syringes and exposed to ampoules (34). The time of medical waste collection carried out by health-care facilities based on regulatory standards is least once a day (15). However, there is one health-care facility that collects medical waste about twice a week (41). It is matter caused medical waste produced little by that health-care facility (41). Therefore, the use of PPE is essential before medical waste management activities to prevent work accidents.

Temporary Shelter

A temporary shelter is a place for storing hazardous waste within a specified period. The duration of storage of medical waste such as infectious waste, sharps waste, and pathological waste is 48 hours at the most. However, infectious waste, sharps waste, and pathological waste stored up to 90 days from the waste

generated if the storage has a temperature of ≤ 0°C (15). During the Covid19 pandemic, infectious waste kept in a closed place for a maximum period of 48 hours from the time the waste was produced (26). Determination of the maximum time storage of infectious waste during the Covid19 pandemic aims to prevent transmission of the coronavirus (Covid19). The storage time for chemical waste, radioactive waste, pharmaceutical waste, and cytotoxic waste is no longer than 90 days from being generated (if the waste produced is ≥ 50 kilograms per day) and is kept for a maximum of 180 days since the waste is generated (if the waste produced is <50 kilograms per day for the first category of Hazardous waste) (15).

The hazardous waste temporary shelter building requirements based on Decree of Head of Environmental Imapct Conreol Agency No. 1 year 1995 about Procedures and Technical Requirements for the Storage and Collection of Waste Materials are the exterior roofs and floors specially designed so that rainwater cannot enter the building, has good air circulation, and the building protected from birds or other small animals (49). The other requirement of the hazardous waste temporary shelter building is the exterior of the building has symbols of hazardous waste according to the type, group, and characteristics of hazardous waste. The use of hazardous waste symbols purposes to help the officers know the types, groups, and characteristics of hazardous waste stored (49). The building area is also one of the hazardous waste temporary shelter building requirements. It based on the type, group, characteristics, and generation of hazardous waste (49). If the waste produced is more than 1 (one) type/group/characteristic, so the hazardous waste temporary shelter building has to a separation wall. The use of the separation wall aims to avoid mixing up different types/groups/characteristics of waste (49). Other than that, the building floor of the hazardous waste temporary shelter must sturdy, waterproof, not bumpy, not cracked (49), and easy to clean (34), and equipped with lighting systems and lightning protection systems (49).

Supporting facilities for temporary shelter of hazardous waste are space for waste piles and equipment storage, tank or container, drainage channels, and hazardous waste container (21), emergency response equipment such as fire fighter equipment and first aid kits (21,49), safety fences, and genset (49). The other supporting facilities for temporary shelter of hazardous waste are emergency door, smoke alarms and detectors (49), clean water facilities, cleaning equipment easily accessible, and personal protective equipment (PPE) that is easily accessible (34).

Requirements for the location of hazardous waste temporary shelter are free from natural disasters such as floods (5,28,49), the area is easily accessible by officers and Hazardous waste collection/transport vehicles (34), and the minimum distance between locations and public facilities are 50 meters (49).

Other requirements are that construction of hazardous wastes temporary shelter in health-care facilities must have permission from local government agencies. The license is necessary so that the location and building requirements of the hazardous waste temporary shelter are following Government Regulation No. 101 of 2014 and Decree of the Head of the Environmental Impact Management Agency No. 1 of 1995. Besides, the other requirements are hazardous wastes temporary Shelter cleanliness conditions. The condition aims to maintain cleanliness and health and prevent environmental pollution.

Hazardous waste storage conditions that do not meet the applicable requirements in several health-care facilities, such as the temporary shelter of hazardous waste does not yet have supporting facilities such as smoke detectors, fire extinguishers which are easily accessible, first aid kits, waste collection tanks, and drainage (23-25); The temporary shelter of hazardous waste location in the hospital parking area and basement adjacent to the mortuary (33, 11); Hazardous waste collection/transport vehicles find it difficult to reach hazardous waste temporary shelter (50); The temporary shelter of hazardous waste distance from public facilities <50 meters (24,51); The exterior of the temporary shelter building has not yet been equipped with the symbol hazardous waste (24); Do not have air ventilation so that the accumulation of gas in the storage room (50); Hygiene kits and personal protective equipment (PPE) is out of reach (50); Hazardous waste storage containers do not have covers, and the windows and doors in the Hazardous waste storage room open, making it easier for animals such as insects, flies, birds, etc. to enter the temporary shelter of hazardous waste (52); Duration of Hazardous waste storage > 48 hours (6). Based on these problems, the buildings and locations for hazardous waste storage should meet the applicable requirements. Besides, the supporting facilities for hazardous waste temporary shelter should be complete.

Processing System

The hazardous waste treatment system is a process of reducing or eliminating hazardous properties in waste. The hazardous waste treatment must be carried out by the waste producer or through a third party that has a processing permit (21). The hazardous waste

treatment system most widely implemented by health-care facilities is incineration. Incineration is the process of treating medical waste thermally using an incinerator (Figure 1).

The problems of the medical waste treatment system using incinerators in several health-care facilities in Indonesia are cause air pollution, noise (35), produce residues (the syringe and residue of broken glass), and produce ash that contains heavy metals (28,35,53). The other problems are officers conducting medical waste treatment have not received training on the procedures for using incinerators and the operational costs of treating medical waste using expensive incinerators (54-55). Officers who conduct medical waste treatment do not use personal protective equipment is one of the problems that occurred in several health-care facilities when the medical waste treatment system using incinerators (54). The condition has the potential to damage health (56). The health-care facilities must have permission from the government to treat hazardous waste using incinerators. However, there are health-care facilities that did not get the authority to manage Hazardous waste by the government (11,50). It caused that health-care facilities do not yet have sufficient operational resources (35). Therefore, they use a third party to treat Hazardous waste (50). The role of third parties in treating medical waste is to assist health care facilities that do not have an incinerator / do not have permission to manage hazardous waste using an incinerator. It helps health care facilities enforce the rules for handling medical waste, especially infectious waste. According to Letter of Ministry of Environment and Forestry of Republic Indonesia No. SE.02/PSLB3/PLB.3/3/2020 about Management of Infectious Waste (B3 Waste and Household Waste from Handling Corona Virus Disease (Covid19), infectious waste originating from health care facilities during the Covid19 pandemic is processed using an incinerator facility with a minimum combustion temperature of 800^{0}C (26).

Hazardous Solid Waste Processing Technology

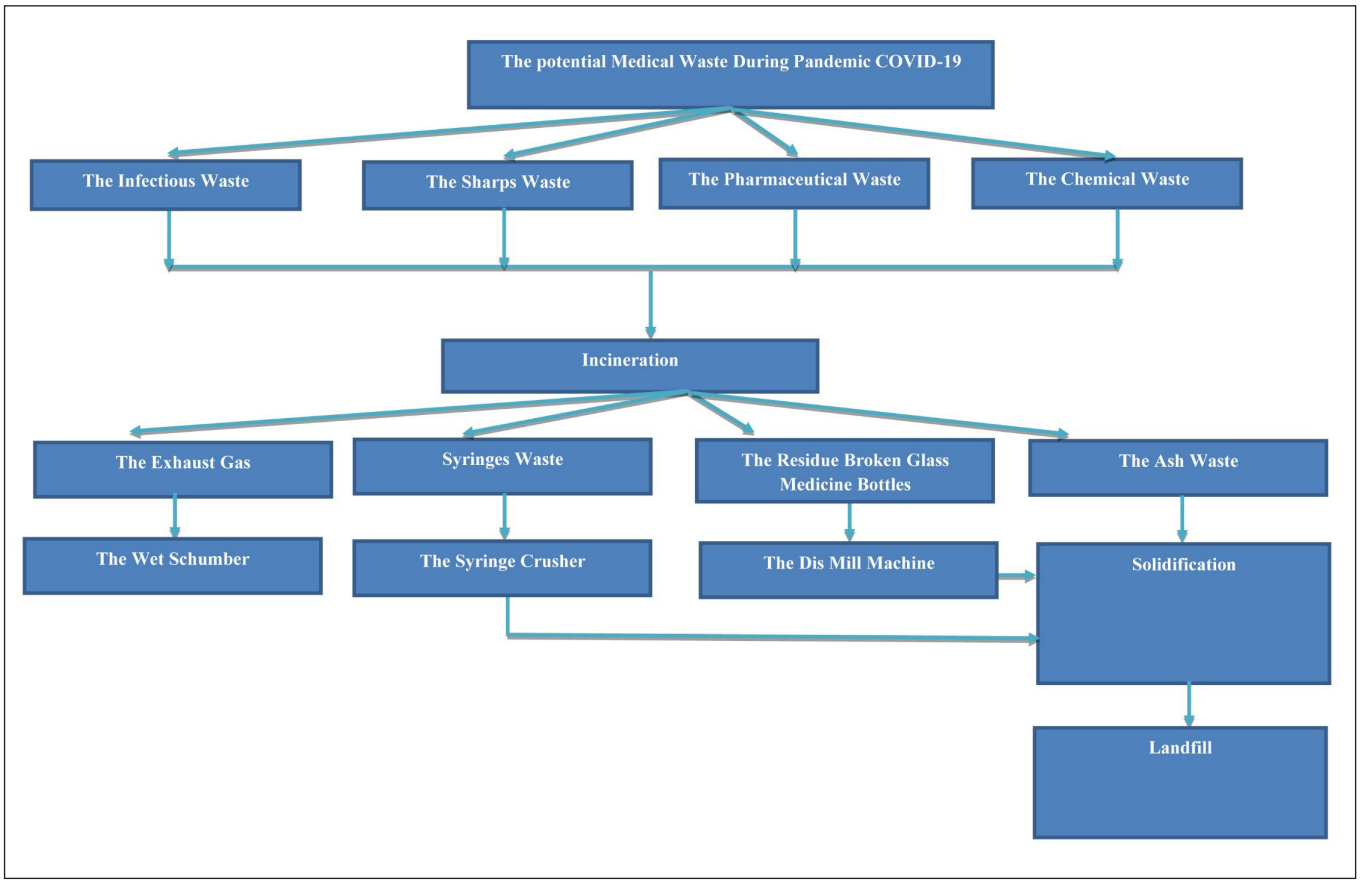

Figure 1. Diagram of The Solid Medical Waste Processing System

The hazardous solid waste treatment is the process of eliminating and or reducing the dangerous and toxic contaminants in hazardous waste (25) one of the technologies for processing the hazardous solid waste is incineration (26,57). The incineration is a technology of treatment of medical organic waste with the thermal systems by high temperatures (58-59). The purpose of medical waste incineration is to destroy medical waste material that is harmful to the environment (3), kill pathogenic bacteria (60), reduce the volume of medical waste to 99.95% (3,15). The results of burning medical waste using an incinerator are gas, unburnt residue, and

ash (3,61). The main components of the incinerator are the combustion chamber, blower, combustion device, temperature indicator and control, wet scrubber, chimney (3,62).

Stages of burning medical waste by using an incinerator are preparation of medical waste, medical waste feed, and burning medical waste (3). The burning process of medical waste is using 2 (two) combustion chambers. The primary combustion chamber has a minimum temperature of 800^{0}C, and the second combustion chamber has a minimum temperature of 1,000^{0}C (15) or 1,050^{0}C (3). The minimum second residence time in the combustion chamber is 2 (two) seconds (3,15).

The next step of the burning medical waste by incineration system is combustion gas processing, treatment of combustion gases using an air pollution control installation (3). Other technologies that can be applied to filter gas and particulate combustion products are wet scrubber (5,14,15) and sprayer (5). Air pollution control devices are located in the chimney incinerator. The working principle of controlling combustion gases is the combustion gases of medical waste containing fine or coarse particles will be absorbed by the blower (centrifugal fan). Then the gas will be filtered by a water jet sprayer located in the upper part of the cyclone. This process occurs continuously with the gravity system. This technology can reduce the content of heavy metals in the combustion gases by using an incinerator. The content of heavy metals (Pb, Hg, Cd, Cr^{6+}, and Cu) on the incinerator emission test results meet the emission air quality standards (5). The condenser is also one of the means of controlling air pollution caused by burning medical waste using an incinerator. The function of the condenser is to condense the gases of combustion (63). The other technology of combustion gas treatment is air pollution control (APC) technology. Air pollution control (APC) technology aims to manage particles and pollutant gases resulting from incinerator combustion. APC technology consists of a quencher, spray drying absorption, filter bag, id fan, and chimney.

The quencher is a technology that occurs due to a decrease in temperature, which causes the rate of dioxin and furan re-formation after the combustion process suppressed. Spray drying absorption (SDA) is a technology used to reduce metals, acid gases, and harmful organic content in flue gases using slaked lime and activated carbon. Bag filter is a tool for filtering dust / fine particles with an efficiency of up to 99%. Pressure drops that occur due to the use of other APC equipment overcome using Fan IDs and Chimneys (64). Besides, the laboratory scale technology that can be applied to treat combustion gases is plasma technology. Plasma technology functions to reduce the pollutants contained in the smoke from burning medical waste using an incinerator. Plasma technology consists of plasma reactors and Direct Curren (DC) high voltage. The plasma reactor used is the Dielectric Barrier Discharge (DBD) plasma reactor. DBD plasma reactors can reduce Total Dissolved Solids (TDS) concentrations by 22.5% with a combustion temperature of 363 K. TDS concentrations reduction is caused by solid pollutant particles contained in combustion fumes deposited on the inner electrodes of the plasma reactor. This event occurs because the pollutant particles that enter the reactor will be loaded by electrons so that the charged particles. The electrodes will attract charged pollutant particles due to electrostatic forces (59).

The last step of the incineration system is the treatment of residual waste (3). One of the residues that result from the incineration process is the syringe. The syringe is processed with the syringe crushing machine. The syringe crushing machine aims to break needle residue into millimeter-sized pieces. The method of destroying syringe residues uses cylindrical grinding stones, where the motor power used is 0.5 HP and rotation of 1,400 rpm (65-66). While the process of crushing the residue of broken glass using the Dis Mill Machine. The Dis Mill machine functions to destroy the residual results of incineration in the form of broken glass into granules such as sand (67). Incinerated ash do not directly dispose of at the Final Processing Site caused still have the hazardous content contained. Therefore, the ash waste from the burning must be further processed.

One of the technologies for processing waste ash from incineration is solidification. Solidification aims to bind heavy metals contained in incineration ash. So the movement of heavy metals obstructed. One of the heavy metal-binding compounds is cement (68). Besides, solidification aims to reduce contaminants, both physically and chemically, by mixing Hazardous waste with binding agents (68). One comparison of incinerator ash solidification is 1 (cement) : 3 Sand: 1 (incineration ash) (53). Then the Toxicity characteristic leaching procedure (TCLP) was tested with 28 days curing (53). If the heavy metal content meets the quality standards of Government Regulation number 101 of 2014, then the waste can be stockpiled. The criteria of the landfill process contain in Government Regulation No. 101 year 2014 about Management of Hazardous and Toxic Waste and Decree of Head of Environmental Imapct Conreol Agency No. 1 year 1995 about Procedures and Technical Requirements for the Storage and Collection of Waste Materials. The hoarding

requirements of processing results, requirements for the location of formed processing, and site of piling of waste from hazardous waste.

Factors that influence the level of removal of medical waste in the combustion process using an incinerator are temperature, the shape of the combustion chamber, medical waste feeding, water content in medical waste, characteristics and types of medical waste, time, and turbulence (3). Temperature is an essential factor in the process of eliminating medical waste using an incinerator. High and stable temperatures will accelerate the process of burning medical waste (3). Fluctuations in combustion temperatures are caused by inconsistent use of incinerators (3). Another factor that causes unstable combustion temperatures is the improper operation of the incinerator, such as the capacity of medical waste burned too much. The incineration material is medical waste and previous incinerator combustion residues (52). The shape of the combustion chamber also affects the temperature produced in the incineration process of medical waste. The shape of the combustion chamber divided into two, namely round and square. The resulting temperature in the round combustion chamber is perfect than the square combustion chamber (3).

Medical waste feeding is part of the combustion stage of medical waste using an incinerator. The process of feeding medical waste that is less precise will affect the level of removal of medical waste. Examples of improper feeding of medical waste are too much medical waste put in the incinerator, and medical waste that inserted into the incinerator before the temperature of the incinerator is reached (3).

Water content in medical waste is one factor that influences the level of removal of medical waste in the combustion process using an incinerator. Too much water content in medical waste Affects humidity levels. The more humid or more water content in medical waste, the longer the process of burning medical waste by using an incinerator (3,69).

The type of waste is an essential factor in the incineration process. Plastic-based personal protective equipment (PPE) will speed up the combustion process because it can increase combustion temperatures. While medical waste that has more water content will reduce the combustion temperature so that the time needed for combustion will be longer (3).

The residence time of medical waste in the incineration process will affect the process of eliminating medical waste so that the resulting residue will be small (60). The length of the combustion of medical waste influenced by the humidity of medical waste. The temperature during incineration is also affecting the duration of medical waste burning (3). The smaller the level of moisture of medical waste burned, the higher the incineration temperature, the faster of the medical waste process burning, and the perfect of the process burning (60).

The contact time of combustion is also an essential factor in the incineration process. Contact time is affected by the humidity of the burned medical waste. The wet waste will require a longer combustion time than dry waste. The vice versa dry waste combustion process will be faster. Even distribution and ideal heat homogeneity in the primary combustion chamber and second combustion chamber are affected by turbulence (3). The turbulence affects the effectiveness of burning medical waste (70). The turbulence that is too large will cause residence time to decrease. It will indirectly affect the level of perfection of medical waste combustion (3).

The weakness of medical waste processing using an incinerator is to generate air emissions that can pollute the environment if not managed properly (71-72). The incineration system also generates combustion residues such as ash that have the potential to pollute the environment if disposed of directly. The resulting ash has the potential to contain heavy metal compounds (53,72). The processing of hazardous waste in several health-care facilities does not use the incinerator caused by the high costs required. These costs consist of investment, operation, and maintenance costs (55,71,73). Besides, temperature indicators and controls are expensive. The use of this tool is very complex in controlling the efficiency of combustion and exhaust gases (71).

The potential hazardous waste generated during the Covid19 pandemic treated using incinerators is the infectious wastes, the sharps wastes, the chemical wastes, and the pharmaceutical wastes (67,74-76). Examples of infectious waste treated using incinerators are ex-personal protective equipment (PPE) used when interacting directly with Covid19 patients, syringes, and contaminated gauze/cotton/tissue. Rapid test equipment, infusion tubes, infusion needles, oxygen support hoses used by Covid19 patients, the used specimen bags, and Covid19 test specimen samples are also infectious waste examples treated using incinerators (74). The sharp waste examples treated using incinerators are syringes, infusion needles, and glass medicine bottles (75,77). While the chemical waste example treated using incinerator is used alcohol bottles used during rapid tests. And pharmaceutical waste examples are broken and expired drugs and remnants of medicines both in pill, liquid, and powder form (67,77). Reduction of the volume of medical waste processed using incineration technology about 99.95% (3,15). Besides, incineration

technology can digest medical waste materials that are harmful to the environment and destroy pathogenic bacteria (3,60). Therefore, incineration is one of the recommended technology for treating medical waste during the Covid19 pandemic.

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CONCLUSION

The potential for medical waste (hazardous waste) during the Covid19 pandemic is infectious waste, sharp object waste, chemical waste, and pharmaceutical waste. Hazardous waste that is not managed correctly can pollute the environment and disturb health. The hazardous waste management system is based Government Regulation No. 101 year 2014 about Management of Hazardous and Toxic Waste and and Regulation of Minister of Environment and Forestry of Republic Indonesia No. P.56/Menlhk-Setjen/2015 about Procedures and Technical Requirements for Waste Management Hazardous and Toxic From the Health Service Facilities. One of the potential medical waste treatments is thermal treatment. The technology for eliminating hazardous waste is incineration. The incineration system can reduce the volume of medical waste by up to 99.95%. Besides, incineration technology can digest medical waste materials that are harmful to the environment and destroy pathogenic bacteria. However, the incineration system has drawbacks. One of the disadvantages is that it produces ash residue and waste, which still contains heavy metals. Therefore, it is necessary to improve incineration management. One of the efforts that can be done is the treatment of residue and ash waste. The residue in the form of syringes is processed using a syringe shredder and the process of crushing the residue of broken glass medicine bottles using the Dis Mill Machine. Ash waste from the incineration process uses solidification. Then the leaching procedure (TCLP) specific toxicity test was performed. If the heavy metal content meets quality standards, the waste landfilled.

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