Evaluation of Medical Solid Waste Management: A Case Study of Two Hospitals in Bogor, Indonesia

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Abstract

Medical solid waste (MSW) is classified as hazardous solid waste based on The Indonesian regulation. However, many hospitals have not properly treated its MSW yet. Therefore, appropriate management is necessary to avoid negative impact on the environment. These research objectives were to measure generation, to classify and to identify the sources of MSW, evaluating MSW management system and to set recommendation to improve it. This research was carried out in two hospitals, namely A and B, located in Bogor Municipality, in West Java Province of Indonesia. MSW was identified for seven days to measure the generation and composition at each source. To evaluate MSW management system, the existing condition was compared with the regulation in Indonesia. The results show that Hospital A was generating 0.17 kg/bed/day, while Hospital B was 0.13 kg/bed/day. Most MSW composition from both hospitals was classified as infectious waste. MSW management on both hospitals did not fully comply with the regulation. Therefore, appropriate improvement of MSW management for both hospitals, including minimization, segregation, collection, storage, treatment and disposal system are important to implement.

Keywords: hospital, medical solid waste, solid waste management, waste generation.

INTRODUCTION

Hospital is a place where interaction between sick people, service provider, visitor and community neighbourhood occur. It is very important to have good hospital sanitation in order to limit the spread of diseases. Hospital activities have potential to generate hazardous waste, such as solid and liquid pathogenic waste, also chemical substances and used medical equipment, besides general waste. Compared to industry, hospital generates relatively fewer hazardous wastes, but 20% of total hospital waste is
infectious one which is potentially contagious [1]. Some of health risks were caused by hospital activities such as contagious disease (influenza, diarrhoea, measles, hepatitis), radiation hazards (cancer, abnormalities of genetic organ) and chemical substances hazard.

According to Indonesian regulation, based on its potential dangers medical wastes are classified into infectious waste, pathological waste, sharps waste, pharmaceutical waste, cytotoxic waste, chemical waste, radioactive waste, high pressure container waste and waste containing high concentrated heavy metal. However, medical waste was categorized as hazardous waste (HW) with code D227 in accordance to Indonesia’s regulation. It is important to point out that the term ‘medical waste’ has often been used interchangeably with other terms such as ‘hospital waste’ and ‘infectious waste’ around the world [2]. In this paper, the term of ‘medical waste’ or ‘medical solid waste’ refers to all wastes which is classified as in Indonesia’s regulation.

Solid waste management is one of environmental problem in most of developing and transitional countries [3] due to its growth and endless generation followed by poor management. In the other hand, medical solid waste (MSW) management doesn’t attract much attention [4] even neglected in the overall solid waste management [5]. In 2005, a study on hospital solid waste was conducted in Bandung, West Java Province of Indonesia. It concludes that hospital waste generation in Bandung was 3,493 tons per year, which 85% was contributed by domestic waste and 15% by MSW (11% infectious waste; 4% others MSW) [5]. Even though, it only generates small amount of waste compared to domestic waste [3; 6], the potential environmental and health hazards of MSW could be harmful if not being recycled and disposed properly since it carries a large number of pathogenic bacteria, especially in developing country [7; 8].

Therefore, to suppress undesirable effects on humans and environment, it is a great importance to evaluate existing MSW management practice in order to meet the requirement. A fundamental prerequisite for the successful implementation of any medical waste management plan is the availability of sufficient and accurate information about the quantities and composition of the waste generated [9]. MSW generation rate varied in each country depending on some factors, such as economic factors, social and health-related factors, multidimensional poverty index (MPI), the life expectancy, the mean years of schooling and the CO$_2$ emissions [10].

MSW management including minimization, segregation, collection, storage area, treatment and disposal system are important to implement. Segregation is the essence of waste management and should be done at the source of generation of Bio-medical waste to prevent contamination of the whole mass of the residues [4; 11].

The objectives of this study were (1) measuring MSW generation; (2) classifying and identifying the sources of MSW in each hospital; (3) evaluating MSW management in hospital A and B; (4) recommend improvement to enhance MSW management for both hospitals.
MATERIAL AND METHODS

This study was conducted at two hospitals (A and B) in Bogor Municipality, West Java Province of Indonesia. Research was carried out by collecting primary and secondary data from field visits on both hospitals to collect information regarding different medical waste management aspects. Primary data were collected including sources and composition of MSW, existing condition of MSW management, such as generation, segregation, transportation, collection and disposal. MSW management was evaluated by comparing the existing condition and Indonesia’s regulation. Secondary data needed were available facilities and number of beds, inpatient occupancy rate [12], organizational structure, hospital blueprint and existing treatment facilities specification.

In the study, the classification criteria were based on potential risks, which are classified into infectious waste, pathological waste, sharps waste, pharmaceutical waste, cytotoxic waste, chemical waste, radioactive waste, high pressure container waste and waste containing high concentrated heavy metal. These categories were weighed separately and the results were then recorded. Tools and equipment used were plastic bags to collect the samples, volume sampling equipment (gauge, container volume 24, 18, 3, 2 and 1 litre) and weight sampling equipment (0-2 kg, 0-5 kg and 0-10 kg), which enable one to calculate the bulk density of the waste, where this result was reported in kg/m$^3$. Sampling was conducted for seven days in order to balance out the daily variations during a week due to holidays or patient visiting [3]. Location of sampling was at all potential MSW sources. Generation rate of general waste was also observed to compare with MSW generation rate. Figure 1 showed the research procedure.

According to Indonesia’s Environmental Health Requirements of Hospital Regulation, disposal or treatment technology and method were fitted to hospital capability and the composition of solid waste generated (incineration or sterilization). Both Hospital A and B using on-site incinerator as treatment technique to disposed their MSW. Performance of the incinerator can be observed by its efficiency (DRE) obtained by using Equation (1). Data was collected from average generation waste for three days.

$$DRE = \frac{W_{in} - W_{out}}{W_{in}} \times 100\%$$

(1)

Where:

$DRE =$ Destruction and removal efficiency (%) \\
$W_{in} =$ Inlet feed mass incinerator (kg) \\
$W_{out} =$ Outlet feed mass incinerator (kg)
RESULTS AND DISCUSSION

1. MSW Generation Rate and Composition

Estimation of MSW generation rate, characterize the volumes and composition of the waste stream was the first step to plan waste management system efficient and economical, including storage, collection, treatment and disposal [2; 9]. Hazardous solid waste which became the focus of this research was categorized as infectious
medical solid waste (MSW). MSW generation was differed from solid waste which disposed in special medical container using yellow bags and safety box for sharps waste. Before the measurement, MSW was sorted as its composition because the MSW container was not segregated based on its composition on both hospitals.

Primary MSW sources on both hospitals were all unit and facilities, including general ward laboratory units, emergency room, operating room, radiology unit, pharmacy, dental clinics and specialist clinics. In addition, there are haemodialysis unit, psychiatric nursing rooms, and drugs infection room in Hospital A, while there are birthing room and medical rehabilitation facilities in Hospital B. MSW composition on both hospitals were similar, i.e. including infectious, sharps, pharmaceutical, chemical substances, infusion bottles, pathological, and high-pressure container waste (Fig. 2). Infusion bottle waste was classified differently due to its large amount of generation and potentially to be recycled after proper treatment.

![Image of waste categories](image)

**Figure 2. Waste composition in Hospital A and B**

The results of the research indicated that the MSW generation rates for hospital A and B are 0.6 kg/bed/day and 0.4 kg/bed/day, respectively (Table 1). It was slightly different with the early research that showed generation rate of MSW in Indonesia was 0.75 kg/bed/day [13]. Generation rate of MSW in Korea was found 0.14-0.49 kg/bed/day [2], while the generation rate based on inpatient occupancy rate for hospital A and B were 0.17 kg/patient/day and 0.13 kg/patient/day, respectively (Table 1).

Medical waste generally consists of many different types of materials. Composition of medical wastes produced from hospitals depends on the size and types of healthcare facilities, the management practices of waste (e.g. handling, segregation and disposal), waste regulations, level of activity (often measured in terms of the number of occupied beds, number of patients per day, and/or number of staff), type of department (e.g. general ward, surgical theatre, office), type or level of facility (e.g. clinic, provincial
hospital), location (rural or urban), regulations or policies on waste classification, segregation practices, temporal variations (e.g. weekday versus weekend, seasonal), level of infrastructure development of the country [2; 7]. Hospital A is a public governmental one which provides wide medical specialists, sub-specialists and more facilities, while Hospital B is a private hospital with fewer facilities and services. In the other hand, general waste often found was mixed at MSW storage besides, there was infectious MSW storage located in corridor near rain fed area which was potentially wet in Hospital B. It was indicated that poor handling in Hospital B affected on MSW generation rate.

<table>
<thead>
<tr>
<th>Hospital</th>
<th>Other MSW (kg/day)</th>
<th>Sharps waste (kg/day)</th>
<th>Total MSW kg/bed/day</th>
<th>kg/bed/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>101.2</td>
<td>2.8</td>
<td>104.0</td>
<td>0.6</td>
</tr>
<tr>
<td>B</td>
<td>36.7</td>
<td>1.7</td>
<td>38.4</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Infectious waste generation rate (Fig. 3) and volumetric rate (Fig. 4) were greater among the other component, both in Hospital A and B. In Hospital A, it was 79.95 kg/day and 161.55 litre/day, respectively. While in Hospital B, it was 20.76 kg/day and 65.59 litre/day, respectively. 54-77% of the generated medical waste is infectious. In contrary, WHO indicated that hazardous-infectious waste represents approximately 10-25% of all medical waste. The reason for this may be because non-infectious medical waste is wrongly classified as infectious. Non-sorting MSW causes contamination of materials with blood, which promotes unnecessary waste items in the waste stream [14]. The consequences were affected negatively to MSW management, including increasing in cost for treatment (e.g. providing the requirements of storage, transport and disposal system), as well creating the risk for people (e.g. medical waste in the municipal waste stream, improper containers) [15]. Furthermore, high-pressure container was only found in Hospital B. Therefore, environmental pollution due to illegal segregation, recycling in the dumpsite should be a main problem in Indonesian hospitals as well.
Figure 3. MSW generation rate in Hospital A and B
The largest specific density waste was infectious waste in Hospital A and pathological waste in Hospital B, which is 460 kg/m$^3$ and 461 kg/m$^3$, respectively. Infectious waste was determined to be 460 kg/m$^3$ at Hospital A and 359 kg/m$^3$ at Hospital B (Fig. 5). This result shows that specific weight on both Hospitals is not varied significantly. Other result in Iran shows that specific weight for hazardous-infectious waste and total medical waste was 96.16 kg/m$^3$ and 99.58 kg/m$^3$, respectively [3]. The reason for such high specific weight in this study could be the high percentage of high moisture content materials such as blood and wet cotton. In addition, liquid from infusion bottle and wet other materials could be spilled in the container.
Figure 5. MSW specific weight in Hospital A and B

General waste is produced from the various activities in the hospitals, such as food preparation, laundry facilities, administrative departments, housekeeping and so on. General waste on both hospitals was determined from all waste disposed in black plastic bags and dumped to municipal waste landfill. The percentage of general waste and MSW generation on both hospitals in this study was presented in Fig. 6. It shows that 94% of the total waste produced by hospitals was classified as general waste and MSW only contributed 6%. This result was supported with study in Iran [3], which reported that general waste contributed 70% of all hospital waste. The WHO has estimated that 75%–90% of the waste produced by health-care providers and hospitals is general health-care waste [7].
2. Management of Medical Solid Waste in Hospital

2.1 Waste Minimization

According to Indonesia’s regulation, waste minimization is performed by recycle, reduce and reuse activities. However, many waste components produced in hospitals might be recycled if they are not infected, contaminated, and not used for medical activities, such as plastics and metals in syringes, infusion tubing and bags, and the glass in tubes and vials [2]. Recyclable materials such as paper, cardboard, plastics, glass, metals, etc. are collected separately, at a rate of 83% in health care service [16].

It was necessary to prevent plastics burning due to dioxin issue. Therefore, it would be needed some efforts to recycle medical PVC plastics, study material substitution of the PVC products, and examine effective treatment methods for medical plastic wastes [2]. Infusion bottle and syringes waste was potentially to be recycled after proper treatment (e.g. shredding, autoclaving). Infusion bottle recycling was done at Hospital B, although it was inefficient due to disposal mixed with other MSW in yellow container since it would have been treated as infectious waste as well.

On both hospitals studied, syringe was discarded to safety box for sharps waste which would treated by incinerator. Proposed system which could be performed was “the deposit-refund system”. This system is basically a mechanism of adding a deposit to purchase prices of a new syringes and returning a refund when the syringe is returned [14] to a third party. It could provide an incentive for segregated handling and disposal of MSW in Indonesia especially for small-medium health care facilities which doesn’t
treat MSW themselves. The system was possibly to perform since there was high awareness to segregate sharps waste with other MSW. However, it would need an extensive education, training and strict regulation to encourage segregation of sharps waste components.

Hospital A performed mercury reuse activity from broken thermometer and sphygmomanometer. Radioactive waste (e.g. fixer, developer, broken film) from Radiology Unit at Hospital A should be reduced by using newest digital technology as used in Hospital B. Rontgen result would be displayed in a computer connected to a printer, so that broken photo would be reduced since only the correct result would be printed.

2.2 Waste Segregation

Hospital A and B have been implementing a standard operating procedure to control their medical waste management. According to Indonesia’s regulation, every composition of MSW should be sorted based on certain colour or symbol in the storage. Hospital A procedure regulates that medical and general waste should be sorted, but didn’t mention detail about general waste, while Hospital B procedure didn’t regulate sorting of solid waste.

Hazardous MSW storage on both hospitals studied only differed into infectious yellow storage and special safety box for sharps waste. On Hospital A procedure, it was not required any symbol at the MSW container, while in Hospital B biohazards symbol should be put on MSW storage. The symbol was commonly used in many countries [2]. Safety box of Hospital A had 5 litres of volume made by hard cardboard, while at Hospital B had 12 litres of volume made by laminated cardboard to prevent liquid leaking. Both hospitals used disposal safety box. In Hospital A, safety box was available at each potential source and the quantity depends on the generation. MSW collector personnel checked the safety box every day to make sure if it was full and subsequently to be incinerated. According to site measurement, Hospital A needs 156 disposable safety boxes.

Safety box handling in Hospital A was riskier to collector personnel. Safety box was emptied to common yellow plastic bags for infectious waste when collecting activity. It was very harmless for the personnel of the punctured risk since reused SB was potentially cause health risk to nurse or another medical provider due to its hazardous characteristic. To minimize cost and hazards, Hospital A could use smaller and non-disposable safety box instead. Therefore, it needs responsibility of the generator i.e. doctors, nurses, technicians etc. (medical and paramedical personnel) to segregate MSW at sources [11].

2.3 MSW Collection and Temporary Storage Area

MSW was collected by two crews at 6.00 AM every day at Hospital A, while collection at Hospital B was done twice a day (7.00 AM and 4.00 PM) by one crew. Collecting
equipment at Hospital A and B was a wheeled trolley that has 400 litres of volume, made from metal and has 400 litres of volume made from wood material, respectively. Wheeled containers should be used to transport the waste/plastic bags to the site of storage/treatment and it should be thoroughly cleaned and disinfected in the event of any spillage. Therefore, it should be made from an easy material to clean and disinfect. In this case, trolley lined internally with stainless steel or aluminium was prefer to use since it provides smooth and impervious surface which can be cleaned [11].

The crews of Hospital A were wearing Personal Protective Equipment (PPE) including wear pack, disposable mask, special gloves and safety shoes, while Hospital B only providing disposable mask and gloves. However, they did not always wear it during on duty because of forget or out of stock. A major issue of many waste handlers was their ignorance of risks, while exposures to medical waste handling are certainly not the primary source of contacting viral blood infections, increases in exposure to these diseases promotes a greater likelihood of risk involved. Therefore, regular and updated training on safe practices in handling of medical waste could appease this problem [14].

MSW collection route was similar to food delivery route as well corridor for patient and visitor. Waste routes should be designated to avoid the passage of waste through patient care areas [11]. However, early MSW collecting time at Hospital A was passed with food trolley since it was risky at Hospital B to meet between MSW trolley and food trolley because of close schedule with snack delivery time.

According to Indonesia’s regulation, temporary storage area for hazardous waste should be protected from rainwater, has good ventilation system, lightning rod system, and adequate lighting system. Hospital A was using an old MSW cart from metal, sized 0.15 m$^3$, without cover but it was put outdoor exposed to rain. Hospital B has an underground temporary storage about 15 m$^3$ located near incinerator. Both hospitals should have built a proper storage area which could store not only MSW but also expired pharmaceutical waste, radioactive waste, chemical substances waste, incinerator ash and sludge. Therefore, it is necessary to design storage separated into some area divided by a wall to prevent waste mixing in order to manage all hazardous waste produced in hospital easily and efficiently. Temporary storage area was used to store all waste collected, waiting for disposal [14].

2.4 MSW Treatment and Disposal

Several medical waste treatment methods, including incineration, steam sterilization (or sanitation), microwave sanitation, chemical disinfection, dry heat disinfection, and disinfection with superheated steam, may be used [2]. However, incineration has been a traditional and widely used treatment method to handle medical waste that typically contains infectious and hazardous materials [2; 13]. It has several advantages when incinerator used to treat medical waste, including a reduction in the waste volume (up to 90%) and weight (up to 75%), the sterilization and detoxification of the waste materials, and the recovery of heat or electricity during incineration, while the disadvantages were including the potential emission of toxic substances into the surrounding area, high operation and maintenance costs, and the requirement of ash
disposal [2; 17].

Treatment of MSW on both hospitals studied was using incinerator. Hospital B already had a treatment permit from government, but Hospital A has not had a permit. Therefore, environmental monitoring was not conducted at Hospital A, while on Hospital B should perform a monitoring every 3 month. All medical waste incinerators should also follow air emission standards for industrial settings to reduce air pollution potential. Many air pollutants in emissions from medical waste incinerators can be significantly reduced by modern air pollution control devices if properly designed and operated, such as cyclones, semi-dry, scrubbers, and bag house filters (or fabric dust removers) [2].

According to Indonesia’s regulation, MSW incinerator should have minimum temperature 1200°C in order to accept all MSW type [18]. Incinerator of Hospital A reached merely 1150°C and Hospital B maximum 1000°C. Destruction and removal efficiency (DRE) indicates performance of an incinerator. The higher DRE, the more efficient combustion performance. DRE of incinerator in Hospital A and B was 86% and 90%, respectively. Those DRE values were expected due to different method performed on both hospitals studied. Hospital B incinerates their MSW gradually as much as 7-8 kg every 20-30 minutes for about 6 hours. The combustion was conducted every 2 days because they should be waiting for incinerator cooling down for minimum 10 hours. This method was proven that it could increase the incinerator’s efficiency although it was hazardous to waste handlers due to exposure to heat and fly ash when charging door opened. Besides, it led to accumulation of untreated MSW stored in temporary storage area. The framework for sustainable operation of medical waste is efficient logistics of waste and balance in the link between waste generation units and treatment facilities [15]. Hospital B incinerated their MSW at once per day, filled up to 70% of furnace volume. It was conducted every day for only 2 hours. Yet it needs improvements to reach efficiency 99.99% based on Indonesia’s regulation. Therefore, one of possible required improvements was repairing incinerator isolation.

Incineration is usually a relatively expensive treatment technique due to environmental and economic impact compared to sterilization and chemical disinfection, respectively, because of the differences in energy consumption [13; 18; 19]. In contrary, it is also an acceptable method to treat the infectious fraction of hazardous medical wastes [13]. Since sterilization usually costs less than incineration, it would be expected that hospitals would rather perform on-site separation instead of incinerating all their medical waste. However, source separation can be also costly, labour intensive and requires proper management techniques [18]. Following sterilization, the sterilized MSW can be disposed of to a regular landfill in order to decrease the payments [16]. However, infectious and toxic wastes that include cytotoxic waste, pathological waste, waste contains heavy metal, chemical substances waste, pharmaceutical waste, should be always incinerated [20].

After incineration, fly ash and bottom ash residual was disposed to sanitary landfill (e.g., liners and leachate collection/treatment) since it was classified as hazardous waste. Hospital A disposed the residual ash through open dumping method in area near incinerator. Incinerator ash can contain concentrations of heavy metals (e.g. lead,
cadmium, mercury, arsenic, copper, and zinc) and organic compounds (e.g. dioxins and furans). When ash is disposed of in a landfill, the metals and organic compounds can leach (i.e. dissolve and move from the ash through liquids in the landfill) and migrate into ground water or nearby surface water, besides it hazards to human health through direct inhalation or ingestion of airborne or settled ash [17].

Hospital A turned over their ash disposal to other company. The incinerator ash was packed in a metal drum before transporting. However, both of studied hospital didn’t have ashes characteristics data, since it may contain a variety of toxic substances. In Korea, bottom ash is characterized by an institution to determine appropriate final disposal methods (hazardous or non-hazardous) [2]. In other hand, it could decrease MSW treatment cost if the ashes non-hazardous evidently.

CONCLUSION

The conclusions that can be obtained from the research are as follows:

1. Waste generation rate at Hospital A was higher than at Hospital B.
2. MSW sources were from ward, laboratory units, emergency room, operating room, pharmacy, dental clinics, specialist clinics and all unit generated MSW. MSW composition on both hospitals was generally similar, i.e. infectious waste, pharmaceuticals, sharps, chemistry substances, pathological, high pressure container and radioactive waste.
3. MSW management improvement on both hospital including minimization, segregation, collecting, storage, treatment and disposal.
4. Improvement recommendations for Hospital A were firstly, built a temporary storage area for MSW and disposed incinerator ash to third party, and secondly, for Hospital B were using smaller non-disposable safety box, collected MSW at sources earlier, and equipping waste handlers with proper PPE.

REFERENCES


