Medical Waste Processing Planning on Hospital Ship 124 M

D Jumineti¹,², A Santoso¹ and Mardianto²
¹ Department of Marine Engineering, Institut Teknologi Sepuluh Nopember (ITS) Jalan Raya ITS, Surabaya 60111, East Java, Indonesia
² PT PAL Indonesia (Persero) Ujung, Surabaya 60155, East Java, Indonesia

Abstract. Indonesia is an archipelagic country which has 16,056 islands in 2018. One of the efforts to equalize health facilities in archipelagic areas and accelerate the delivery of health facilities when disasters and accidents occur using hospital ships. The operation of hospital ships will produce hospital waste that needs to be treated to reduce the adverse impact on the environment. Some hospital wastes that are toxic in nature are categorized as B3 waste (Hazardous and Toxic Materials). This waste treatment needs to be regulated so that the ship's medical area and the ship's operational environment remain healthy, clean and well-maintained.

In this study, it is planned to treat hospital ship waste starting from the grouping of waste in the medical area, calculating the amount of waste generated, diagrams of waste treatment to produce a standard operating procedure that is acceptable and applied according to the analysis on the hospital ship. This research was conducted by making a numerical model based on hospital ship data on the BRS (Bantu Rumah Sakit) ship which is currently still under construction at PT PAL Indonesia (Persero). The results of the calculation of medical waste obtained in this study were 318 kg / day with details of non-infectious waste 254.4 kg / day, sharp object waste 3.18 kg / day, chemical and pharmaceutical waste 9.54 kg / day, pathological waste and 47.4% infectious and 3.18 kg / day of broken tube and thermometer waste. Based on the results of this calculation, a suitable waste treatment design and SOP are made that can be applied to the BRS ship.

1. Introduction

Indonesia is a maritime country that has more water areas than land areas. The distribution of Indonesia's population from Sabang to Merauke requires a healthy environment for life and activities. The division of health units also needs to be considered in order to be able to support the provision of health facilities in each region.

One of the efforts to equalize health facilities in archipelagic areas and to provide health assistance facilities when a disaster occurs is by using hospital ships. Hospital ships are health facilities located on the coast or ports that can move from one island to another. An example of using a hospital ship during the March 2020 pandemic is as a quarantine and transport area for covid-19 patients.

The uneven growth of hospitals in Indonesia in each region based on [1] is the reason for the need for ship hospitals in providing health facilities. In addition, the ability of the hospital ship to move is used as a reliable medical vessel when a disaster occurs in a certain area. The main mission of the Navy hospital ships is to provide mobile medical capabilities for deployed military personnel, secondary humanitarian aid and disaster response missions have been at the forefront and centered since the 2004 Asian Tsunami [2].

Health facilities in the medical area of the hospital ship produce medical waste that needs to be treated in order to keep the environment healthy, clean and sterile. The environment is a place for living things in a certain population, a certain time and a certain area. A healthy environment will have an impact on health and good behavior towards life in it. The environment inhabited by living things includes land,
water and air. Apart from environmental health, human health also needs to be maintained by establishing private or government-owned health facilities. Optimizing hospital ships in extending operational time is by increasing the volume of fuel tanks, reliable medical equipment and creating waste treatment systems to reduce waste generated in medical and domestic processes. The management of hospital ship waste needs to be planned starting from the grouping and calculation of the types of medical waste produced to the standard operating procedures for processing it. According to its shape, hospital waste is divided into solid, liquid and gas forms. Treatment of hospital ship waste can be processed on board and on land (according to the IPAL qualifications at the Ministry of Health). Hospital ship waste that can be processed on board can use an incinerator to destroy solid waste and STP (sewage treatment plant) to treat liquid waste before it is discharged into the sea. The objectives of this study are to:
1. Classify and quantify medical waste and accommodation generated on BRS vessels.
2. Creating a diagram of hospital waste treatment and accommodation on the BRS ship.
3. Develop applicable standard operational procedures based on the design of the medical waste treatment system and accommodation on the BRS vessel.

2. Hospital

Hospital is a health service institution that provides complete individual health services that provide inpatient, outpatient and emergency services in accordance with Indonesian Ministry of Health Regulation No.4 of 2018 [3]. Public hospitals are divided into 4 types, namely:
a) Hospital type A
The type A hospital is the central hospital which is the highest referral. Type A hospitals have extensive specialist and subspecialty medical services. For example, the type A hospital in East Java is the DR. Soetomo.

b) Hospital type B
Hospital type B is a hospital that has extensive specialist medical services and limited subspecialty medicine. Type B hospitals exist in every provincial capital. Teaching hospitals that are not included in type A hospitals are categorized as type B hospitals. For example, type B hospitals in Surabaya are Husada Utama Hospital, Adi Husada Undaan Hospital, Bhayangkara Hospital, Surabaya Islamic Hospital, RKZ Hospital Surabaya, Mitra Keluarga Hospital Surabaya, National Hospital, PHC Hospital, Premier Surabaya Hospital, Siloam Surabaya Hospital, Surabaya Surgical Hospital, Undaan Eye Hospital, Soewandi Hospital, Haji Hospital Surabaya.

c) Hospital type C
Type C hospital is a hospital that has limited specialist medical services. The type C hospital is located in the district capital. The specialist services available at the Type C hospital are internal medicine services, surgical services, child health services and obstetrics and gynecology services. For example, type C hospitals in Surabaya are Adi Husada Kapasari Hospital, Al-IrSyad Hospital, Bhakti Rahayu Hospital, Darmo Hospital, Darus Syifa’ Islamic Hospital, Kenjeran Family Partner Hospital, Surabaya Lung Hospital etc.

d) Hospital type D
Hospital type D is a hospital that is transitional in nature with only dental and general services. Hospital type D is able to accommodate referrals from puskesmas [4].

3. Hospital Ship
Hospital ships are included in the type of mobile hospital. A mobile hospital is a hospital that is ready to use and is temporary for a certain period of time and can be moved from one location to another [5]. Indonesia has 17,504 islands separated by the ocean. To flatten health facilities throughout the islands
in Indonesia, a floating hospital is needed in the form of a hospital ship, which has facilities equivalent to hospitals on land. An example of a hospital ship owned by Indonesia is KRI DR Soeharso. KRI DR Soeharso has a function as a hospital ship and as a warship. KRI DR Soeharso is a hospital ship with the ability as a level II hospital which in its management is included in the Indonesian Eastern Region Fleet in the ranks of the auxiliary elements [6]. The international hospital ships that have ever existed are the USNS Mercy belonging to the United States, Mercy Ship which is managed by the charity Mercy Ship etc. Apart from hospital ships, smaller health facilities that can operate in river water areas are the floating puskesmas as a health facility in Kutai barat. The hospital ship data used in this study were the BRS (Bantu Rumah Sakit) ships with the following specifications:

| Project Name                      | Kapal Bantu Rumah Sakit (BRS) TNI-AL |
|-----------------------------------|--------------------------------------|
| LOA                               | 124 m                                 |
| LPP                               | 107.450 m                             |
| Breadth                           | 21.80 m                               |
| Depth                             | 6.700 m                               |
| Speed (Max)                       | 18 knots                              |
| (Cruising)                        | 14 knots                              |
| Operating Range                   | 10 nm                                 |
| M/E at MCR                        | 2 sets x abt. 5400 kW                 |
| Patient                           | 159 persons                           |
| Medical Staff                     | 69 persons                            |
| Crew                              | 280 persons                           |

Figure 1. BRS’s ship elevation View

4. Waste

Waste is waste generated from community, industrial, institutional or private activities. Hospital waste is all waste generated from hospital activities in the form of solid, liquid and gas [5]. The waste produced by the hospital consists of:

4.1. Hospital Solid Waste
a. Solid Medical Waste
Solid waste consisting of infectious waste, pathological waste, sharp object waste, pharmaceutical waste, cytotoxic waste, chemical waste, radioactive waste, pressure container waste and waste with high heavy metal content.
b. Non Medical Solid Waste
Non-medical solid waste is solid waste generated from activities in hospitals outside of medical originating from kitchens, offices, Tama and yards which are reused if there is technology.

4.2. Liquid Waste
Liquid waste is all wastewater including feces originating from hospital activities which may contain microorganisms, toxic chemicals and radioactive which are harmful to health.
4.3. Gas Waste
Gas waste is all waste in the form of gas that comes from burning activities in hospitals such as incinerators, kitchens, generator equipment, anesthetics and disposal of cytotoxic drugs.

4.4. Infectious Waste
Infectious waste is waste contaminated by pathogenic organisms that do not routinely exist in the environment and these organisms are in sufficient quantity and virulence to transmit disease to susceptible humans.

4.5. Highly Infectious Waste
Highly infectious waste is waste originating from culture and stock of highly infectious materials, autopsies, animal organs and other materials that have been inoculated, infected or in contact with highly infectious materials.

4.6. Cytotoxic Waste
Cytotoxic waste is waste from contaminated materials from the preparation and administration of cytotoxic drugs for cancer chemotherapy which have the ability to kill or inhibit the growth of living cells.

Based on the 6 types of waste produced [5], then the types of waste protection are grouped based on [7]. The classification of waste safeguards is divided into: domestic solid waste, hazardous and toxic waste (B3), liquid waste and gas waste. Hospital waste needs to be treated to eliminate infectious properties and minimized it so as not to damage the environment. In addition to regulations from the Ministry of Health, international regulations also regulate waste minimization on ships, this is stated in MARPOL Annex V regarding Garbage Management in waste minimization which recommends that producers, cargo owners, ports and terminals, ship owners and operators and the government consider waste management related to supplies, provisions, and ship cargo as needed to minimize the emergence of waste in all forms [8].

Figure 2. Hospital Ship’s Waste

5. Solid Medical Waste
The solid medical waste treatment system can be destroyed by burning it using an incinerator or stored using a safety box for processing on land. The entire solid waste treatment process is burned using an incinerator. The incineration process stages are generally divided into 4:
Storage process
- Burning process is processed
- Residue combustion handling process
- Process of clearing smoke

The treatment of solid medical waste is basically eliminating infectious properties and minimizing them. The amount of solid waste produced in class C hospitals with beds > 300 is <75 kg / day [9]. To simplify the medical waste treatment process, solid waste needs to be sorted from source using colour coded plastic bags. Plastic bag colour indicator according to[5].

6. Liquid Medical Waste
Liquid medical waste treatment aims to remove contaminants in wastewater so that the processed waste can be reused or not damage the environment when disposed of into the environment[9]. Sources of liquid waste on hospital ships are grouped into:
- Lavatory in the medical area
- Clinic
- Laboratories
- Liquid waste from other medical activities
The output of medical liquid waste that cannot be treated on board is collected in special tanks to be processed onshore. Meanwhile, medical liquid waste that can be processed on ships is processed in the sewage treatment plan (STP) system, where the rest is stored in blackwater, bilge tanks or sludge tank.

7. Calculation of Medical Waste
The calculation of the amount of medical waste uses a reference from a WHO study (1999) which states that the production of daily medical waste generation (TLH) in developing countries is around 1-3 kg /TT.day, while in developed countries (Europe, America) it reaches 5-8 kg / TT. Days. The composition of this medical waste consists of 80% non-infectious waste, 15% pathological & infectious waste, 1% sharp object waste, 3% chemical and pharmaceutical waste, >1% tube waste and broken thermometer [10].

7.1. Daily Medical Waste (TH)
The medical waste generation of the BRS vessel is calculated according to the number of patient beds (TT) provided in 100% average occupancy conditions. The 100% average occupancy is expressed by the notation P = 1

\[ T_H = TLH \times TT \times P \]  
\[ = 2 \times 159 \times 1 \]  
\[ = 318 \text{ kg/day} \]  

7.2. Non-Infectious Waste (TLNI)
Non-infectious waste generation (TLNI) consists of 80% of daily medical waste (TH), then the value is obtained:

\[ T_{LNI} = T_H \times 80\% \]  
\[ = 318 \times 0,8 \]  
\[ = 254,4 \text{ kg/day} \]  

7.3. Pathological and Infectious (TPi)
Pathological and infectious waste generation (TPi) consists of 15% of daily medical waste (TH), then the value is obtained:

\[ T_{Pi} = T_H \times 15\% \]
6

\[ 6 = 318 \times 0.15 \]
\[ = 47.7 \text{ kg/day} \]

7.4. **Sharps Waste (T}_{Bj})**
The incidence of sharp waste (T}_{Bj}) consists of 1\% of daily medical waste (T}_{H}), then the value is obtained:
\[ T_{Bj} = T_{H} \times 1\% \]
\[ = 318 \times 0.01 \]
\[ = 3.18 \text{ kg/day} \]

7.5. **Chemical and Pharmaceutical Waste (T}_{KF})**
Chemical and pharmaceutical waste generation (T}_{KF}) consists of 3\% of daily medical waste (T}_{H}), then the value is obtained:
\[ T_{KF} = T_{H} \times 3\% \]
\[ = 318 \times 0.03 \]
\[ = 9.54 \text{ kg/day} \]

7.6. **Broken Tubes and Thermometers Waste (T}_{TTP})**
The generated waste of tube waste and broken thermometer (T}_{TTP}) consists of 3\% of daily medical waste (T}_{TTP}), then the value is obtained:
\[ T_{TTP} = T_{H} \times 1\% \]
\[ = 318 \times 0.01 \]
\[ = 3.18 \text{ kg/day} \]

The calculation of the amount of waste still needs to be added with accommodation waste and machinery waste if you want to know the amount of waste on the BRS ship as a whole. The share of medical waste from BRS ships is shown in Figure 3.

![Figure 3. Medical Waste’s BRS Ship](image)
8. Designed of Waste Systems
The design of medical waste treatment systems on hospital ships in medical and accommodation areas needs to pay attention to:

- Classification of waste based on the level of hazard and infection.
- For solid wastes which is infectious, it is necessary to take into account the availability of garbage stations for waste that cannot be burned with an incinerator available on board.
- For wastewater, it is necessary to redundant processing equipment such as sewage treatment plants to ensure the system can continue to run during repair conditions.
- A drainage and soil system are provided on each deck to make repairs when a dead end occurs in the pipeline so as not to pollute the accommodation area.
- Reduction of solid waste in garbage stations can be done by burning non-medical waste that does not require a double burner in the incinerator.

9. Conclusion
Based on the results of calculations on the BRS ship with the consideration of patient bed facilities, the calculation results of medical waste in this study were 318 kg/day with details of non-communicable waste 254.4 kg/day, sharp object waste 3.18 kg/day, chemical waste and pharmaceuticals 9.54 kg/day, pathological waste and 47.4% infectious and 3.18 kg/day broken tube and thermometer waste. Based on the results of these calculations, an appropriate waste management design and SOP is made that can be applied to the BRS ship. Waste treatment for solid waste on ships uses a safety box for waste that is not burned in the incinerator and the use of a Sewage treatment plan for treating liquid waste originating from the clinic, operating room, lavatory and funeral room. Standard operational procedures applied to BRS vessels can use solid waste treatment procedures and operational schedules for operation and maintenance of aeration systems at STP for liquid waste. The design of the sewage treatment plant system will become a reference in making a standard operational procedure (SOP). SOP is made by paying attention to the maintenance schedule of the core equipment, namely the Sewage Treatment Plant (STP) according to the maker used and the vacuumator. Making SOP is divided based on usage time in weekly, monthly, annual and every 5 years.

Acknowledgments
In this paper, thank you to PT PAL and Marine Engineering-ITS for allowing us to develop a sewage treatment system on hospital ships. In the future, this research needs to develop a method on how to make a waste treatment system that can be processed 100% onboard efficiently in terms of design, size, operation and availability of materials so that it is possible for Indonesia to equalize Indonesia's health facilities.

10. References
[1] Perhimpunan Rumah Sakit Indonesia, L. Trisnantoro, and E. Listyani, “Jumlah RS di Indonesia-Pertumbuhan RS Publik,” no. April, p. 70, 2018.
[2] D. J. Licina, “Hospital ships adrift? Part 1: A systematic literature review characterizing US Navy hospital ship humanitarian and disaster response, 2004-2012. Hospital Ships Adrift? Part 1: A Systematic Literature Review Characterizing US Navy Hospital Ship Huma,” vol. 28, pp. 2004–2012, 2013.
[3] L. F. Mubin, W. Anggraeni, and R. A. Vinarti, “Prediksi Jumlah Kunjungan Pasien Rawat Jalan Menggunakan Metode Genetic Fuzzy Systems Studi Kasus: Rumah Sakit Usada Sidoarjo,” J. Tek. ITS, vol. 1, no. 1, pp. 1–6, 2012.
[4] W. Purwonugraho, “Desain Hospital Ship (Kapal Rumah Sakit) Untuk Perairan Indonesia,” p. 113, 2015.
[5] Kementerian Kesehatan Republik Indonesia, “Keputusan Menteri Kesehatan No. 1204 Tahun 2004 - Persyaratan Kesehatan Lingkungan Rumah Sakit.” p. 64, 2004.
[6] F. S. Rianto and Purwanto, “Implementation of Hospital Aid Vessels of Kri,” J. Prodi Strateg. dan kampanye Militer, vol. 3, no. 1, pp. 1–23, 2017.
[7] Kemenkes, “Peraturan Menteri Kesehatan Republik Indonesia Nomor 7 Tahun 2019 tentang Kesehatan Lingkungan Rumah Sakit,” *Ayat*, vol. 8, no. 5, p. 55, 2019.
[8] M. Environment *et al.*, “I:\MEPC\71\MEPC 71-17-Add-1.docx,” vol. 295, no. July, pp. 1–30, 2017.
[9] R. Rosita, Luwiharsih, R. Gernpari, H. F. Mansyur, Sukirman, and Dkk, “Pedoman Penatalaksanaan Pengelolaan Limbah Padat dan Cair di Rumah Sakit,” *Jakarta*, pp. 1–125, 2000.
[10] KLH, “Pedoman Kriteria Teknologi Pengelolaan Limbah Medis Ramah Lingkungan,” *Kesehatan*, pp. 1–122, 2014.