RISK MINIMIZATION FOR MEDICAL WASTE MANAGEMENT SYSTEM IN BANDUNG CITY, INDONESIA: A LINEAR PROGRAMMING APPROACH

(Minimasi Resiko dalam Sistem Pengelolaan Limbah Medis di Kota Bandung, Indonesia dengan Pendekatan Linear Programming)

Mochammad Chaerul [1]*, Lucky Lie Junpi, Ninda Ekaristi
[1]Faculty of Civil and Environmental Engineering,
Institut Teknologi Bandung, Indonesia
Jalan Ganesha 10, Bandung 40132 Indonesia
Tel./fax: +62-22-253-4187
E-mail: mochammad.chaerul@ftsl.itb.ac.id

Diterima: 1 Juni 2013 Disetujui: 19 Juli 2013

Abstract

A broad range of healthcare services provided by hospital may generate medical waste. Although a large percentage of hospital waste is classified as general waste, which has similar nature as that of municipal solid waste and, therefore, could be disposed in municipal landfill, a small portion of medical waste has to be managed in a proper manner to minimize risk to public health. A medical waste management model is proposed in order to minimize a risk to the public and commercial utilities such as religious facility, bank, office, restaurant, hotel, gasoline station, education facility, mall and shopping center, and park & sport center due to transportation of medical waste and ash and operational of medical waste treatment facility as well. The risk level of each public utility above is determined using Analytical Hierarchy Process (AHP) method. The problem is solved by applying linear programming using optimization software of LINGO®. The model finds optimal medical waste allocation from each hospital to the treatment facility and ash allocation from the treatment to the final disposal site. The result shows that the shortest route may not meet minimum total risk as it is affected also by number and risk level of each public utility passed by medical waste and ash vehicles. Different utilities located surrounding the waste treatment will also generate different total risk.

Keywords: waste allocation, public and commercial utilities, optimization

Abstrak

Berbagai macam pelayanan perawatan kesehatan yang disediakan oleh rumah sakit akan berpotensi menghasilkan limbah medis. Walaupun sebagian besar limbah rumah sakit dapat dikelompokkan sebagai limbah yang tidak berbahaya yang memiliki sifat yang sama dengan sampah rumah tangga dan dapat dibuang ke tempat penimbunan sampah, sebagian kecil dari limbah medis harus dikelola dengan tepat untuk meminimasi resiko terhadap kesehatan masyarakat. Model pengelolaan limbah medis yang dikembangkan ditujukan untuk meminimasi resiko terhadap fasilitas umum dan komersial seperti fasilitas ibadah, bank, perkantoran, restoran, hotel, stasiun pengisian bahan bakar, fasilitas pendidikan, mall dan pusat perbelanjaan, taman dan pusat olahraga/kebugaran, akibat pengangkutan limbah medis dan abu hasil pengolahannya. Tingkat resiko dari setiap fasilitas di atas ditentukan menggunakan metode Analytical Hierarchy Process (AHP). Permasalahan diselesaikan dengan mengaplikasikan linear programming menggunakan software optimimasi LINGO®. Output model berupa optimasi alokasi limbah medis dari setiap rumah sakit ke fasilitas pengolahan dan alokasi abu dari fasilitas pengolahan ke tempat penimbunan akhir. Hasil model memperlihatkan bahwa rute terpendek tidak menghasilkan total resiko terkecil karena dipengaruhi oleh jumlah dan tingkat resiko dari setiap fasilitas yang dilalui oleh kemdaraan pengangkut limbah medis dan abu. Perbedaan fasilitas yang berada di sekitar pengolahan limbah medis juga akan menghasilkan total resiko yang berbeda.

Kata Kunci: alokasi limbah, fasilitas umum dan komersial, optimasi

INTRODUCTION

Although it contributes only (15-20) % of total waste, medical waste is the most dangerous of waste generated from hospital and other healthcare establishments, while the biggest portion is classified as general waste. Medical solid waste is defined as any solid waste that is generated in the diagnosis, treatment or immunization of human beings or animals, in research pertaining thereto, or testing of biological, including but not limited to soiled or blood soaked bandages culture dishes and other glassware (Pruss *et al*., 1999). Medical waste is now recognized as a serious problem that may have detrimental effects either on the environment or human beings through direct or indirect contact. Some of the health impacts originating from exposure to hazardous hospital wastes include mutagenic, tetragenogenic, and carcinogenic effects, respiratory damage, central nervous system effect, reproductive system damage and others (Pruss *et al*., 1999).

In Indonesia, municipality deals only with the general waste, thus the hospital management allows the general one to be collected, transported and disposed of along with other municipal solid waste from households, markets, streets sweeping, etc. In other hand, the medical waste should be handled separately in appropriate manners and It becomes responsibility of the management. Various issues like safety and public health as well as environmental conservation are not so being concerned by the management. As a result, for example, medical waste is mixed with municipal solid waste and disposed of into final disposal site without any treatment prior. Moreover, the open dumping method applied in most cities in Indonesia and waste scavenging at final disposal site worsened the problem (Chaerul *et al*., 2008a). Main objective of this paper is to minimize the risk potential to a variety of public and commercial utilities due to a medical waste management system proposed in Bandung city, Indonesia as a case study.

In Bandung city, medical waste is generated mainly from hospitals with various classes (Figure 1). The hospital's class represents the strength of bed available, number and type of medical specialization offered by hospital. Of all 30 hospitals occur in Bandung city; almost half of them were classified as small size hospital having less than 100 beds.

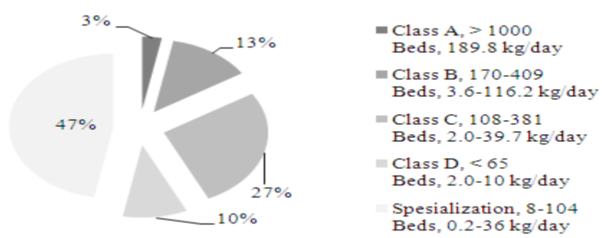

Figure 1. Distribution of hospitals in Bandung city

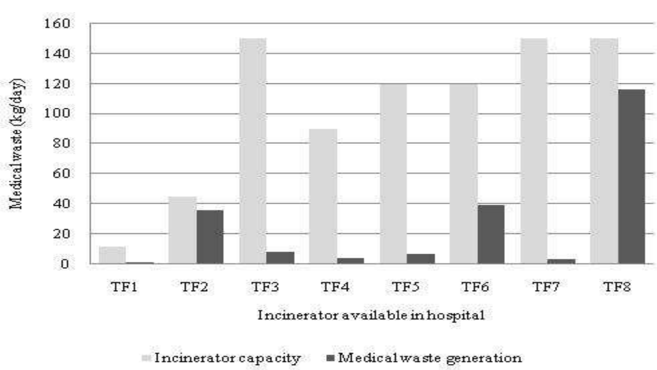

Figure 2. Capacity of incinerators in Bandung City

Figure 1 also presents quantity of medical waste generated by the hospital every day, and the generation varies widely from 0.01 to 1.50 kg/bed/day.

In year of 2004, there were study to measure the medical waste generation from 5 hospitals in Bandung and it was found on 0.284 kg/bed/day (GTZ, 2004). In fact, the medical waste generation is affected not only by health care service provided by hospital but also number of inpatient, demography, economic and public health standard (Chaerul, 2008).

Available treatment technology used for the medical waste in Bandung city is limited to incinerator. There are 8 incinerators with different specification and capacity available in 8 hospitals. From analysis of the existing operational, incinerator in each hospital is not operated on daily basis as the quantity of medical waste generated is so less compared to the capacity of incinerator (Figure 2). In order to meet the capacity the incinerator is used also to treat the general and medical wastes generated by other hospitals. Thus, instead of establishing a centralized treatment facility the study proposes an integrated medical waste treatment system by optimizing capacity of available incinerators in Bandung city.

THE PROPOSED SYSTEM AND MODEL DEVELOPMENT

It is a must to treat completely the medical waste generated from each hospital. The proposed system suggests that the treatment facilities having different specification owned by hospital should be optimized suited to its maximum capacity to treat medical waste. It is logic that a hospital utilizes its own incinerator to treat medical waste generated by the hospital. Thus, there are 22 hospitals (HS1 until HS22) that should transport their medical waste to one or more treatment facilities (TF1 until TF8) and there are 176 possibility solutions for the medical waste flow in the system. Finally, ash generated from each treatment facility should be transported also to final disposals (FD1 and FD2). From this part, there will be 16 possible solutions for the ash flow. The propose system can be seen in Figure 3.

It was realized that medical waste management system has a multiple objectives to be considered such as cost and environmental impact minimization, and safety protection maximization (Chaerul *et al*., 2008b). The proposed system for Bandung city with cost minimization as the objective has been studied (Chaerul *et al*., 2008c). The present paper is trying to put risk minimization as the objective for the same proposed system.

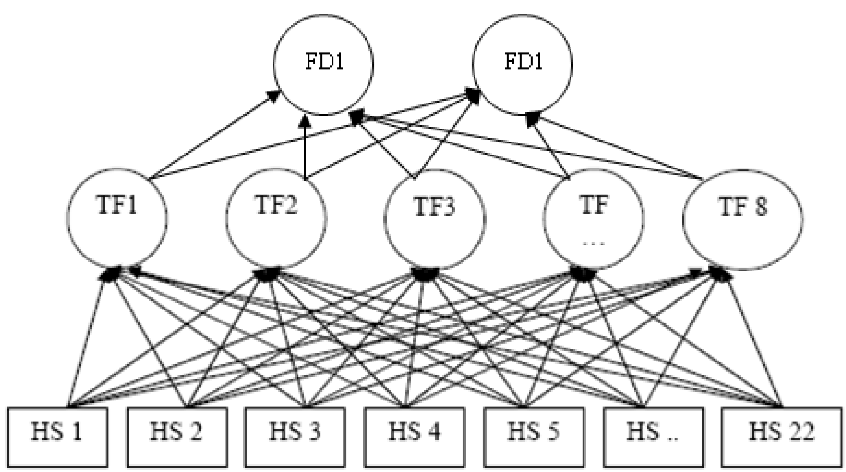

Figure 3. Illustration of medical waste and ash flows

$$\sum_{i=1}^{NHS}\sum_{j=1}^{NTF} A_{ij} * RU1_{ij} + \sum_{j=1}^{NTF}\sum_{k=1}^{NFD} B_{jk} * RU2_{jk} + \sum_{j=1}^{NTF} C_j * RU3_j = \text{MIN } RU \quad (1)$$

Firstly, three possible transportation routes from hospital to treatment facility are determined manually using Bandung city map and assumed that the chosen routes are the shortest and fastest ones. While transporting medical waste generated from hospital to treatment facility a vehicle may pass various public and commercial utilities such as hotel, bank, office, religious facility, school and university, restaurant, mall and shopping center, and gasoline station. Similar consideration is taken for ash transportation from waste treatment facility to final disposal site. Different number and type of the utility surrounding waste treatment facility leads also to different risk. Thus, total risk minimization as the objective could be formulated like equations 1. A_{ij} and B_{jk} represent quantity of medical waste and ash transported to incinerator and final disposal, respectively. While, C_j represents total quantity of medical waste treated in a particular incinerator. $RU1_{ij}$ and $RU2_{jk}$ are risk levels of various utilities passed by medical waste and ash vehicles, respectively. While, RU_j represents risk level due to operational of incinerator to the utilities surrounding the incinerator. The risk level of each utility is determined using Analytical Hierarchy Process (AHP) which is described in the next part.

There are several constraints used in this model. The first constraint guarantees that each incinerator (NTF) receives the total quantity of medical waste generated from hospital(s) (NHS) equal to or less than each incinerator capacity (CS_j). We will refer to this first set of constraint as being the capacity constraint. The second set of constraint, called the medical waste constraint, ensures all medical waste are transported and treated to waste facility treatment. Similarly, ash transported to final disposal (NFD) should be equal to or less than their capacity (CS_k). While, the quantity of ash generated are affected by reduction ratio of each incinerator (R_j, Table 1). Thus, the constraints are formulated using following equations.

$$\sum_{i=1}^{NHS}\sum_{j=1}^{NTF} A_{ij} \le CS_j \quad (2)$$

$$\sum_{j=1}^{NTF}\sum_{k=1}^{NFD} B_{jk} \le CS_k \quad (3)$$

$$B_{jk} = \sum_{j=1}^{NTF} C_j * (1 - R_j) \quad (4)$$

AHP approach was used also to establish and optimize health care waste management systems in rural areas of developing countries by evaluating the way in which the AHP can best be combined with a life cycle management approach, and addressing a main objective of healthcare waste management system, i.e. to minimize infection of patients and workers within the system (Brent et al., 2007).

RESULT AND DISCUSSION

The proposed system above is classified as linear problem, thus a linear programming is applied to solve the problem. There are a variety of software packages to solve optimization problems. Software LINGO® in this study is used to find the minimum total risk to the public and commercial utilities including hotel, bank, office, religious facility, school and university, restaurant, mall and shopping center, and gasoline station.

First output of the model is medical waste allocation from each hospital to available waste treatment facility. Another output is the optimal flow of ash from incinerator to final disposal (Figure 5). Number written in the box of hospital (HS) represents medical waste generated by hospital in kg/day. While, number written in the circle of treatment facility (TF) and final disposal (FD) represent medical waste treated and ash disposed in kg/day. It is clearly observed that all medical waste generated by hospital is transported and treated completely without exceeding capacity of the incinerator. Ash produced by incinerator is also disposed completely into one of disposal site available in Bandung city.

Transportation from hospital to incinerator may pass a variety of utilities and it will generate total risk. Table 2 shows example of risk calculation for medical waste transportation from HS2 to TF6. Then, this value of risk (55.66) is multiplied by weight of medical waste transported from HS2 to TF6 (14.70 kg/day), thus total risk from this path is 818.79 risk index. By considering all constraints defined previously the model could find the optimal medical waste flows from each hospital to the waste treatment(s). Total risk generated from the optimal flow becomes 13,765.63 risk index.

Similarly, risk could be found for ash transportation from incinerators to final disposal sites. Total risk generated from this path is 641.63 risk index. As the incinerator could reduce medical waste treated to produce ash, the total risk becomes so less compared with the risk from medical waste transportation.

Risk due to operational of each incineration is also predicted in this study by considering type and number of utilities located at 5 km-radius of the incinerator. In fact, the emission factor of medical waste incinerator was directly affected by type of incinerator, waste composition and classification, segregation practice and management methodology (Alvim-Ferraz & Afonso, 2003).

As the quality and quantity of emission from incinerator is proportional with quantity of waste treated, the total risk is calculated by multiplying the risk with the quantity of medical waste treated in the incinerator (Table 3). Total risk generated from this portion becomes 49,701.00 risk index.

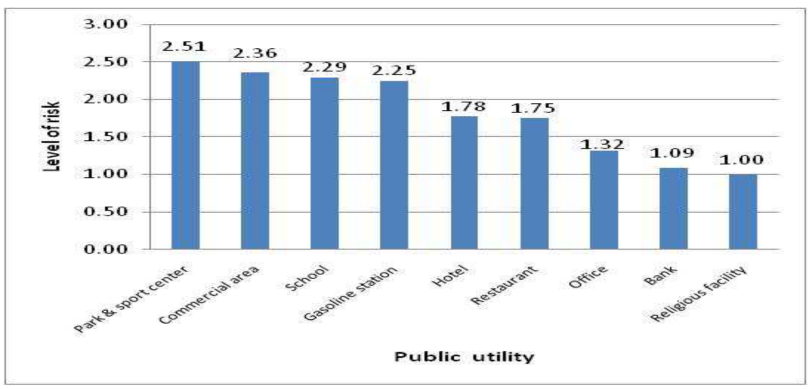

Figure 4. Risk level of each public utility

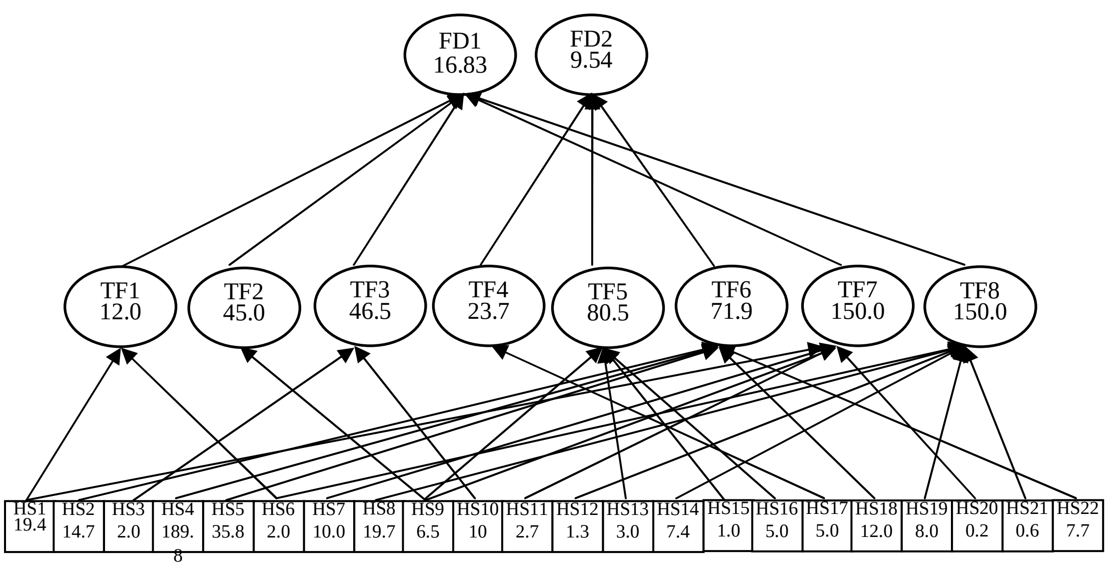

Figure 5. Medical waste and ash allocation

Table 2. Example of risk calculation

Utility	Number of utility passed	Risk level	Total Risk
Religious facility	0	1.00	0
Bank	3	1.09	3.27
Office area	11	1.32	14.52
Restaurant	3	1.75	5.25
Hotel	0	1.78	0
Gasoline station	4	2.25	9.00
School	4	2.29	9.16
Commercial area	4	2.36	9.44
Park & sport center	2	2.51	5.02
Total Risk			55.66

Table 3. Total risk generated by the operational of incinerator

Treatment facility	Risk to public utility	Total waste treated	Total Risk
TF1	125.0	12.0	1,500.0
TF2	60.4	45.0	2,718.0
TF3	27.9	46.5	1,297.4
TF4	28.4	23.7	673.1
TF5	105.9	80.5	8,525.9
TF6	67.7	71.9	4,867.6
TF7	73.8	150.0	11,070.0
TF8	127.0	150.0	19,050.0
Total Risk			49,701.0

CONCLUSION

Instead of a centralized medical waste treatment system, the present study proposes an integrated medical waste management by utilizing as much as possible the capacity of available incinerator in Bandung city. This study develops a model for resolving the obstacle in medical waste management, i.e. the risk to a variety of public and commercial utilities including hotel, bank, office, religious facility, school and university, restaurant, mall and shopping center, and gasoline station.

This model gains the optimum route for medical waste and the ash transportations by considering several constraints to get a minimum total risk to the utilities. The alternative medical waste management could achieve total risk at 64,108.26 consisting 13,765.63, 641.63 and 49,701.00 risk indexes for risk due to medical waste and ash transportations, and due to the operational of incinerator, respectively. The result shows that the shortest route did not meet minimum total risk as it is affected also by number and risk level of the utilities passed by transportation of medical waste and ash.

REFERENCES

Alvim-Ferraz, M.C.M., and Afonso, S.A.V. 2003. Incineration of different types of medical wastes: emission factors for gaseous emissions. *Atmosph. Environ.* 37, 38, 5415-5422.

Brent, A.C, Rogers, D.E.C, Ramabitsa-Siimane, T.S.M., and Rohwer, M.B. 2007. Application of the analytical hierarchy process to establish health care waste management systems that minimize infection risks in developing countries. *Europ. J. of Operation. Res.* 181, 1, 403-424.

Chaerul, M. 2008. Prediction of infectious waste generation in a city: A system dynamics approach. *the International Conference on Environmental Research and Technology*. Malaysia.

Chaerul, M., Tanaka, M., and Shekdar, A.V. 2008a. A system dynamic approach for hospital waste management. *Waste Manage.* 28, 3, 442-449.

Chaerul, M., Tanaka, M., and Shekdar, A.V. 2008b. Resolving complexities in healthcare waste management: a goal programming approach. *Waste Manage. & Res.* 26, 3, 217-232.

Chaerul, M., Lie, L.J., and Ekaristi N. 2008c. Minimization of total cost for medical waste treatment system in Bandung city. *the International Seminar on Sustainable Urban Development*. Indonesia.

GTZ. (Eds.) 2004. Development of a strategic plan for the collection and disposal medical wastes. *Indonesian Ministry of Environment*..

Pruss, A., Giroult, E. and Rushbrook, P. (eds.). 1999. Safe management of wastes from health-care activities. *Geneva: World Bank.*