Journal of Environmental Health and Sustainable Development

Cost- Effectiveness Analysis of Infectious Waste Treatment Devices in Hospital

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ARTICLE INFO

ORIGINAL ARTICLE

Article History:
Received:25 July 2018
Accepted: 20 October 2018

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Keywords:
Waste treatment,
Cost effectiveness,
Infectious waste.

ABSTRACT

Introduction: Today, the infectious wastes of hospitals are considered as a public health problem. Considering the huge amounts of hazardous wastes and the disadvantages of incinerators, we need to investigate the non-combustible devices involved in biochemical treatment. This study was carried out with the aim of evaluating the cost-effectiveness of infectious wastes devices.

Materials and Methods: This descriptive-analytical study was conducted to evaluate the cost-effectiveness and economic efficiency of the infectious waste devices in Yazd and Isfahan hospitals. In this study, the total cost of infectious waste treatment systems in hospitals, the Incremental Cost Effectiveness Ratio (ICER), as well as the sensitivity rate for the reduction of infectious wastes were calculated using Treeage software version 2011. In order to calculate the cost effectiveness using the total cost and the amount of produced waste, we applied the discount rate of five percent and the useful life of 10 years for each device.

Results: Based on the results, devices A and F had the highest and the lowest total cost, respectively. In addition, autoclave D with an ICER of 257.20 was more cost effective than other devices. So, device D, with a discount rate of ±5 and a range of 244.244 - 270.06 was chosen as the best option for infectious waste disposal.

Conclusion: The results can be used to explore and outline the future prospects for choosing the best technology for treatment of infectious waste in hospitals. In other words, we have different options on different circumstances and occasions.

Citation: Khashij M, Pakdaman M, Mokhtari M, et al. **Cost- Effectiveness Analysis of Infectious Waste Treatment Devices in Hospital**. J Environ Health Sustain Dev. 2018; 3(4): 645-9.

Introduction

Different types of diseases, modern methods of diagnosis, and development of the applied technologies have led to increase in the number of clients who refer to the medical centers. This in turn, has led to the increase of hygiene and safety problems [1]. According to WHO statistics, 85 percent of the wastes produced in the health centers are non-hazardous or public wastes mostly produced by official activities or in kitchens. The remaining 15 percent of wastes are known as specific or hazardous wastes (infectious, chemical, and radioactive) that include the irreversible dangers [2]. On the other hand, per capitas of hospital waste production in the US and Iran were estimated as 4.8 kg and 4.3 kg for every bed, respectively [3]. According to the waste management laws, medical wastes include all types of infectious and harmful wastes produced in hospitals, medical centers, and medical diagnosis labs and require specific maintenance [4]. These types of wastes require specific management because they include infectious and chemical elements as well as different viruses such as HIV, hepatitis, etc. Inappropriate management of these waste materials has led to irrecoverable damages such as 23 million cases of HIV as well as hepatitis B and C in the individuals who collect the medical wastes [5]. The treatment process is one of the important steps to prevent from such problems. According to the hospital waste management regulations (Iran's Ministry of Health), treatment consists of the logarithmic reduction of microbial agents [6]. The methods of medical waste treatment are incineration, sterilization with chemicals, dry and wet heating, microwaves, and rays [7]. As recommended by WHO, medical wastes should be treated far from the medical site using non-incineration methods [8-9]. In order to fulfill this process, the waste materials should be separated, sterilized, and secured by the waste producers [10]. Compared to incineration, dry or wet sterilization requires fewer individuals as well as less operation and maintenance costs. Considering the economic and environmental aspects of incineration, non-incineration methods such as autoclave, chemiclave, and hydroclave are the alternative methods [11]. These methods are not very costly for the consumers; therefore, estimation of the costs of the devices required for each of these methods and evaluating their benefits can help the decision makers to select the best devices [12]. The objective of this study was to evaluate the devices economically in treatment of infectious wastes of hospitals in cities of Isfahan and Yazd.

Materials and Methods

We conducted this economic evaluation study using cost-effectiveness analysis. We calculated the total expenditure related to the hospitals' treatment systems of infectious wastes and conducted ICER as well as sensitivity analysis in reducing the volume and weight of infectious waste using the Treeage 2011 software. Considering the 5 percent discount rate and 10 years of service life, the cost-effectiveness and ICER were calculated by formula 1.

$$ICER = \frac{Ca - Cb}{Ea - Eb} \qquad (1)$$

In this formula, C and E are the expenditures and consequences, respectively. We initially calculated the additive cost-effectiveness for the nine devices under investigation (autoclave and hydroclave). Due to the intrinsic data uncertainty and in order to increase the precision and accuracy of the calculations, we applied the two-way sensitivity analysis and drew the decision tree. The process of sensitivity analysis determined the sensitivity and generalizability of the results against the fluctuations.

Costs and outputs

Costs, as the inclusion criteria, consisted of the direct costs including the current and investment costs. The investment costs included the construction costs (for the infectious wastes' site and the device operator's office), the investment costs (for buying the land and the required infrastructures to maintain the hazardous devices), the costs of devices and tools for collecting or keeping the wastes (waste collection barrow and waste keeping tools), and the cost of final disposal of the treated waste. The current costs included the costs of consultation, selection and installation of the devices, financial costs (accounting and tax), direct executive costs (special yellow sacks for collecting infectious wastes, sharp and keen objects, energy consumption, fuel, and chemicals), and indirect executive costs (training, repairing, and maintaining the devices and equipment related to the safety of the devices). Finally, the decrease percentage of the wastes' weight and volume were calculated. To evaluate the efficiency and performance of the dvices using the formula 2.

$$E = \%R \times N \times T \times C \times N_b \qquad (2)$$

Where E is Effectiveness value, R is Volume (Weight) reduction percentage of device, N is Hospital bed number, T is Time horizon, C is

Yearly Working days and Nb produced infectious waste per bed.

Ethical issues

This study was funded by the School of public Health of Shahid Sadoughi University of Medical Sciences, Yazd with code of 5571.

Results

costs and efficiency of the treatment devices are mentioned in the Tables 1 and 2. Considering the 10-year service life, devices A and F had the highest and the lowest total costs, respectively.

Table 1: Costs and efficiency of the treatment device per month (Rial (IRR))

Device Cost	A	B	C	D	E	F	G	H	I
Cost of the device	12,162,500	10,833,333	15,000,000	15,000,000	4,166,666	8,333,333	11,666,666	10,000,000	7,500,000
Repair of the devices	8,000,000	1,000,000	2,000,000	1,000,000	2,000,000	2,000,000	7,000,000	1,000,000	4,150,000
Maintenance of the devices	3,000,000	1,200,000	2,000,000	1,500,000	2,350,000	2,300,000	7,000,000	1,200,000	3,000,000
Energy consumption	55,740	55,740	696,780	33,660	32,820	56,370	67,200	73,470	40,149
Personnel	32,000,000	24,000,000	20,000,000	10,000,000	30,000,000	12,000,000	18,000,000	25,000,000	18,000,000
Disposal of waste	3,250,000	6,750,000	4,500,000	5,000,000	6,350,000	3,600,000	3,250,000	3,950,000	4,500,000
Total Cost	58,468,340	43,839,083	44,196,870	32,533,660	44,899,486	28,289,703	46,983,866	41,223,470	37,190,149

Table 2 shows the output efficiency of the treatment devices per month, where the devices F and A with the nominal capacity of 1000 liters turn 24000 and 4200 kg of infectious wastes to normal wastes per month.

Table 2: Outputs of treatment devices per month

Device Output	A	B	C	D	E	F	G	H	I
Efficiency (kg)	4200	3750	4800	7500	2100	24000	1800	2856	4050
Capacity (lit)	1000	500	500	500	800	1000	300	500	600

Table 3 represents the ICER results of the treatment devices. Considering the findings, autoclave D is more cost-effective than the other devices.

Table 3: Cost-effectiveness analysis of the treatment devices

Device Parameters	A	B	C	D	E	F	G	H	I
Cost	58,468,240	43,839,073	44,196,780	32,533,660	44,899,486	28,289,703	4,698,3866	41,223,470	37,550,149
Effectiveness (Kg)	4200	3750	4800	7500	2100	24000	1800	2856	4050
Cost-Effectiveness (ICER)	1524.16	767.87	828.49	257.20	758.43	0	842.07	611.69	464.18
Sensitivity analysis	1447.95	729.47	787.06	244.34	720.50	0	799.96	581.10	440.97
Total	1600.36	806.26	869.91	270.06	796.35	0	884.17	642.27	487.37

[DOR: 20.1001.1.24766267.2018.3.4.6.3]

[DOI: 10.18502/jehsd.v3i4.225]

Discussion

Considering the costs of the treatment devices tabulated in Table 1 and by taking into account the service life of 10 years as well as with the discount rate of 5 percent, devices A and F had the highest and the lowest total costs, respectively. In fact, the total cost of the device A with the discount rate of 5 percent was equal to 58468240 Rials; whereas, device F with the cost of 28289703 Rials had the lowest cost. The device E with 4166666 Rials had the lowest investment cost compared to other devices. In addition, regarding the waste collection and maintenance costs, device D had the lowest cost (1500000 Rials) compared to other devices. However, considering the disposal cost of the treated waste, devices A and G with 3250000 Rials had the lowest costs. The highest cost for disposing the treated waste belonged to device B (6750000 Rials). In comparison between autoclave and hydroclave, device I had the total cost of 37190149 Rials, which was less than the autoclave A cost; i.e., 21278091 Rials. This can be due to the fact that waste treatment was conducted in the temperature 121 °C and under the pressure of 1.1 bars. In other words, lower temperatures require less energy; whereas, the waste treatment in the autoclave devices was performed in 138 °C and 2.2 bars pressure [13-14]. Considering Table 1, the highest and the lowest costs (repair, maintenance, and operation) belonged to device G (14000000 Rials) and device B (2200000 Rials), respectively. In addition, the devices C (696780 Rials) and E (32820 Rials) had the highest and the lowest costs of monthly energy consumption (water, electricity, and gas). Considering the necessity of infectious waste treatment, device F treated the highest weight (24000 kg) of infectious waste. Table 2 shows that device F with the nominal capacity of 1000 liters turned 24000 kg of infectious waste into non- infectious waste per month; whereas, the treatment quantity of device A with the same capacity (1000 liters) was 4200 kg per month. Considering the per capita of infectious waste production in Iran (1-2 kg) [15] and by taking into account the annual 365 working days in Iran, production of 133 - 268 tons of wastes related to personal care can be expected. Therefore, device F had a higher practical capacity in the treatment of infectious waste. Considering ICER, we can observe from Table 3 that autoclave D is more cost-effective than other devices, because it has the lowest amount of ICER, i.e., 257.20. Therefore, device D with treatment of 7500 kg infectious waste per month will be a cost-effective device in a hospital with 163 beds. Considering the sensitivity analysis conducted on the parameters with the highest effects on the cost-effectiveness, we applied the two-way sensitivity analysis [16-17]. Table 3 shows that device D with the efficiency range of 244.34-270.06 is the best option for infectious waste treatment. The second optimal device for waste treatment is device I with the range of 440.97-487.38. The reason for this could be the advantage of using hydroclave technology, in which the treatment is performed by heating the waste and injecting the steam indirectly [18]. In addition, device A with the range of 1447.95-1600.36 is considered as the last option.

Conclusion

Eventually, we can conclude that more expensive devices are not necessarily the more efficient ones. So, in order to select the best technology, various criteria such as price, effectiveness, service life, the methods of infectious waste treatment in a certain time period, number of beds, and the weight of the produced wastes should be taken into account.

Acknowledgements

At the end, the authors appreciate Environmental Health Engineering Department of Shiad Sadoughi University of Medical Sciences for cooperation in conducting this research (Code: 5571).

Funding

This study was funded by the authors.

Conflict of interest

The authors declare no conflict of interests.

References

1. Oli AN, Ekejindu CC, Adje DU, et al. Healthcare waste management in selected government and private hospitals in Southeast Nigeria. Asian Pac J Trop Biomed. 2016; 6(1): 84-9.
2. WHO. Health-care waste. Fact sheet N253. 2015.
3. Minoglou M, Gerassimidou S, Komilis D. Healthcare waste generation worldwide and its dependence on socio-economic and environmental factors. Sustainability. 2017; 9(2): 220-7.
4. Islamic Republic of Iran EPA. Medical waste and waste-related enforcement regulations.Tehran: Iranian Environmental Protection Agency and Department of Health and Medical Education; 2007. Report No.: 1901/56061 [In Persian].
5. La Grega M, Buckingham P, Evans J. Hazardous waste management. United States, Mc Graw Hill Inc. 2010: 40-8.
6. Maamari O, Mouaffak L, Kamel R, et al. Comparison of steam sterilization conditions efficiency in the treatment of Infectious Health Care Waste. Waste Manag. 2016; 49(2): 462-8.
7. Hong J, Zhan S, Yu Z, et al. Life-cycle environmental and economic assessment of medical waste treatment. Journal of Cleaner Production. 2017; 10(174):65-73.
8. Moreira AMM, Günther WMR. Assessment of medical waste management at a primary health-care center in São Paulo, Brazil. Waste Manag**.** 2013;33(1):162-7.
9. Manual Guideline (2005). The resolution of hospital waste management specialized Roundtable. Tehran University of Medical Sciences: 2005. [In Persian].
10. WHO. Definition and characterization of health-care waste. 2017; Available from: http:// www.who.int/water_sanitation_health/medicalwaste/002to019.pdf. [Cited December 11, 2017].
11. Windfeld ES, Brooks MS-L. Medical waste management – A review. J Environ Manage. 2015; 163(2): 98-108.
12. Ökten HE, Corum A, Demir HH. A comparative economic analysis for medical waste treatment options. Environ prot eng. 2015; 41(3)1-10.
13. Bearss JJ, Honnold SP, Picado ES, et al. Validation and verification of steam sterilization procedures for the decontamination of biological waste in a biocontainment laborator. 2017;22(1): 33-7.
14. Ferdowsi A, Ferdosi M, Mehrani MJ. Incineration or autoclave? A comparative study in Isfahan hospitals waste management system 2010. Materia Socio-Medica. 2013; 25(1): 48–51.
15. Farzadkia M, Moradi A, Mohammadi MS, et al. Hospital waste management status in Iran: a case study in the teaching hospitals of Iran University of Medical Sciences. Waste Manag Res. 2009; 27(4):384-9.
16. Vaccari M, Tudor T, Perteghella A. Costs associated with the management of waste from healthcare facilities: An analysis at national and site level. Waste Management & Research. 2018; 36(1):39-47.
17. Hong J, Zhan S, Yu Z, et al. Life-cycle environmental and economic assessment of medical waste treatment. J Clean Prod. 2018; 10(174): 65-73.
18. Health Care Without Harm. Non-Incineration medical waste treatment technologies. 2001; Avaliable from: http://www.bvsde.paho.org/ bvsacd/ cd48/ cap5. Pdf. [Cited February 20, 2017].