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Original Article

Cost-Effectiveness Analysis of Health Care Waste Treatment Facilities in Iran Hospitals; a Provider Perspective

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Abstract

Background: Our aim was to make right and informative decision about choosing the most cost-effectiveness heterogeneous infectious waste treatment methods and devices.

Methods: In this descriptive study, decision tree analysis, with 10-yr time horizon in bottom-up approach was used to estimate the costs and effectiveness criteria of the employed devices at provider perspective in Iranian hospitals. We used the one-way and scenario sensitivity analysis to measure the effects of variables with uncertainty. The resources of data were national Environmental and Occupational Health Center Survey (EOHCS) in 2012, field observation and completing questionnaire by relevant authorities in mentioned centers.

Results: Devices called Saray 2, Autoclave based, and Newster 10, Hydroclave based, with 92032.4 ($\pm$12005) and 6786322.9 ($\pm$826453) Dollars had the lowest and highest costs respectively in studied time period and given the 5-10% discount rate. Depending on effectiveness factor type, Newster 10 with Ecodas products and Saray products respectively had the highest and lowest effectiveness. In most considered scenarios, Caspian-Alborz device was the most cost-effectiveness alternative, so for the treatment of each adjusted unit of volume and weight of infectious waste in a 10 year period and in different conditions, between 39.4 ($\pm$5.1) to 915 ($\pm$111.4) dollars must be spent.

Conclusion: The findings indicate the inefficiency and waste of resources, so in order to efficient resource allocation and to encourage further cost containment in infectious waste management we introduce policy recommendation that be taken in three levels.

Keywords: Economic evaluation, Cost-effectiveness analysis, Infectious waste, Treatment devices, Sensitivity analysis

Introduction

The variety of the diseases, changes they have undergone, progress in their diagnosis and treatment methods and development of the technologies employed in hospitals have led to an increase in the number of patients referring to these centers and also to the proliferation of health care waste (1). Medical waste is referred to as all infectious and harmful wastes coming out of healthcare centers that constitute 20 percent of wastes in hospitals. These wastes are categorized as special wastes due to containing a variety of infectious and chemical factors as well as different germs and viruses such as Human Immunodeficiency Virus (HIV), Hepatitis, etc. Another danger of medical wastes is the existence of sharp and cutting objects such as surgical blades and syringes. Paying attention to these objects is crucial for the job safety and health of the staff. The alarming figures published by WHO indicate that, each year about 23 million people get infected with Hepatitis B and C and HIV which are transmitted to them by sharp and cutting objects found in medical wastes (2, 3). The main groups endangered by medical wastes are physicians, nurses and unprofessional workers, patients, visitors and their companions (4).

In recent decades, technologies for the separation and treatment of infectious waste have been improved (5) and in the past three decades, burning has been replaced with thermal and chemical disinfection. Dioxin and Furan carcinogen gases produced during the process of burning medical wastes, alarming rate of waste production and their costly treatment were the main reason for abandonment of the incinerator (6, 7). The main treatment methods of medical wastes are burning, chemical disinfection, dry and wet thermal disinfection, microwaves and burying in landfill sites (8).

According to the regulations in Iran and based on the WHO recommendations, the treatment of medical waste is done in a non-site-way (9, 10). The management of hospital wastes-based on clause 9 of the waste management law in Iran-includes the following stages; classification of medical waste, separation, packaging and implementation, preservation, transportation, disinfection, and treatment. The implementation of these stages is the responsibility of the producers (11).

Compared to grinding and burning, dry and wet thermal treatment methods require much less investment and personnel, and have lowered operational and maintenance costs (12). Unless there are no laws regarding incinerator emissions, non-burning systems such as the Autoclave, Hydroclave and chemical disinfection are more cost saving (13).

Not only in Iran but also in other countries this question that which treatment methods and related devices are most cost- effective, remains unanswered and this study in turn is the first one. Therefore, we studied the cost-effectiveness of medical waste treatment devices in classified groups of Iranian hospitals in different conditions.

Materials and Methods

General plan of study

Economic evaluation based on decision tree analysis for reasons of implicitly perform variable screening or feature selection, require relatively little effort from users for data preparation, nonlinear between parameters do not affect two performance and easy to interpret and explain to executives (14), has been used to estimate the inputs and outputs of the employed devices. Using spreadsheet calculations ad DATA 3.5.7. Software (TreeAge Software, Williamstown, MA). In this study for base case, we have sought the service provider's perspective regarding the devices costs and outputs in question with discount rate (DR) of % 5, 10 years useful life for both and nominal capacity of devices. The data related to the 9 different devices has been gathered from hospitals using them and to prevent any information bias, we have excluded the manufacturers of the mentioned devices and there has also been no relation of any kind between the researchers and them.

Assumptions underpinning the decision-analytical model include; devices safety will not change over time, hospitals have enough and standard land for setting up the treatment devices, Devices effectiveness over 10 years will not be subject to lot fluctuations and only 10 percent is allowed, manufactures and hospital administrators always will act their charge obligations and contract between them about disposal of treated infectious waste still remains upon the volume and weight.

Decision making model

In order to choosing the most optimal available device for treatment of infectious waste by hospital decision makers such as hospital managers and board of trustees, we defined safety and higher cost-effectiveness as the necessary and sufficient conditions, respectively with the focus being on the control of pollutants in the place of production, so only safety devices were economically assessed.

There has been homogeneity neither among the hospitals nor among the devices. All the considered variables were adjusted to be made comparable. With regard to the required devices capacity in treating infectious waste, we based our study on the 10 years useful life in hospitals having 128, 256, 512 beds. The useful life written on the devices' catalogue and the volume and weight capacity of them, as experienced by the centers employing them were considered as the base of our judgment. Therefore, it can be said that, we have taken the average capacity of the each devices in question, which is taken fixed in their useful life.

The studied devices in this investigation include 9, with the names of Newster 10, Caspian Alborz, Ecodas T150, Ecodas T300, Saray 1, Saray 2, Sazgar, KAZU, and Newster. The first two work in a Hydroclave method, the third to seventh in an Autoclave and the eighth and ninth in chemical and dry thermal methods respectively.

Hospitals and devices

Because the hospital decision makers are responsible in purchasing the medical waste treatment device, we considered provider perspective and only related primary costs data were measured. The resources of a large portion of input data such as devices and related equipment costs were National Environmental and Occupational Health Center Survey in 2012 that by a formal request was placed at our disposal. We use field observation and completing questionnaire by relevant authorities in Tehran hospitals to measuring other costs and effectiveness data, so that for any studied devices we are visited two randomly selected hospitals. It should be noted that we have studied all of the most widely used treatment devices in Iran; this note indicates the suitability of devices for treatment of produced medical waste in Iranian hospitals that has been demonstrated over the past time.

Safety

The incinerators utilization due to emission of dangerous pollutants and considerable amount of heavy metals has been decreasing in most countries- including Iran-accordingly (6, 7). Subsequently, new technologies by Regulate Medical Waste (RMW) disposal engineers have been designed and developed (15). Therefore, eliminating the microorganisms, at least to the extent of defined standards and not producing other environmental pollutants with control of pollutants in the source of production can be considered as two appropriate criteria for safe assessments. Considering the biological index of infectious waste (i.e. Mycobacterium phlei and Mycobacterium bovis) must be cleansed and treated to a level of at least 6log10 (16, 17). Some treatment technologies may combine various methods, or to improve the effectiveness of the devices, also employ grinding of the waste. But all these devices must deliver the noninfectious waste to us. Encapsulation, freezing, solidification or squeezing alone does not suffice and wastes must be disinfected (16, 18).

Inputs

Our analysis includes the direct cost of the infectious waste treatment facilities in hospitals including the related capital and current costs. The capital costs include the cost of the site (land, infrastructure, preparing the site and getting the licenses), the construction cost (the devicery building, waste store chamber, and offices), the cost of the devicery, waste transportation cost and the equipment costs (the carts for waste sack collection from wards and refrigerators). The current expenses also consists of the consultants' cost, financial costs (accounting, audit and tax), direct executive costs (yellow sacks with labels for infectious waste, sharp containers, fuel for the devices, the chemical material consumed and the necessary special material) as well as indirect executive expenses (training, replacement, repair and maintenance of the devices, maintenance of the vehicles and safety-related equipment) which have been calculated based on the financial year 2012 with the 5% DR and in a 10 year time horizon, 10 years is the average time of utilize the studied devices. To calculate the indirect cost, we did review the last year financial bills related to mentioned parts of indirect costs that coordinated by correspondence previously. US Dollar (USD) to Iran Rial (IRR) exchange rate at cost data collection time, 2012, on average was 18776.

Output

The two criteria of the percentages of volume reduction and weight reduction have each been taken separately to calculate the effectiveness of the devices. In Iran, healthcare centers' dealings with the municipality are based on the volume and weight of treated infectious waste for landfilling. We have used the average value of effectiveness calculated for the each studied devices in a 10 years period, and measured by the centers using them. We used the primary and secondary data to calculate the devices' effectiveness value by the following equation;

Effectiveness value: Volume (Weight) reduction percentage of device * Hospital bed number * Time horizon * Yearly Working days * Produced infectious waste per bed.

In national literature the produced infectious waste per capita for each bed has been generally calculated as 1-2 (2-3 liters) kilogram (19, 20), that has been approved by studied hospitals.

Sensitivity analysis

Because of the uncertainty surrounding many of the study variables, one–way and scenario sensitivity analysis was performed; varying DR (5-10%), hospital performance capacity (128-512), infectious waste production per capita (2-3 liters), output type and amount of the output (±10%).

Results

Costs

All the devices studied possessed the two required necessary conditions i.e. removing 99/99999% of the waste's microorganisms, and treatment of waste in the place of production. Therefore, having only the sufficient condition can be the criterion for choosing and prioritizing the devices.

The results indicate that the devices of Saray 2 and New Star 10 respectively have the lowest and highest total cost for a 10-year period with a 5-10 percent DR. The total cost of Saray 2 for the 5 and 10 percent DR is 109937.5 and 92032.4 dollars respectively while for Newstar 10 it is about 6786322.9 and 1 billion and 576107.8 dollars respectively (Table 1).

Placing 5 percent as the base discount rate in study, the total expenditure of infectious waste treatment processes from the hospital's perspective for a decade and for hospitals with 128 to 512 beds, ranges between 92032.4 to 576107.8 dollars, with this being heavily dependent on the price of the device itself, to wit Between 70 to 97%. The lowest and the highest amount of expenses related to the device itself are 66143.3 and 482211.6 dollars for the Saray 2 and Newstar 10 respectively.

Sazgar and Ecodas T300 respectively with 2183.6 and 30464.4 dollars for a decade had the lowest and the highest cost of maintenance.

Also the Saray 2 and Ecodas T150 machines with 1011.9 and 7722.6 dollars had the lowest and the highest cost of energy consumption (water, electricity and fossil fuel) respectively.

Because only in the KAZU device, chemical material and special equipment are used in order to treat and clean the infectious waste, some extra expenses are imposed on the hospitals employing it. In 10 years, respectively 2343.4 and 25031.95 dollars are spent on chemical material and special equipment used in the KAZU which results in an increase in the treated waste weight.

Table 1: Devices total costs for 10 years period and 5% discount rate (USD)

Devices	Saray2	Saray1	Caspian Alborz	Sazgar	Kazu	Newster	Ecodas T150	Ecodas T300	Newster 10
Total Cost	92032.4	100234	113709	134054	183053	200895	428632	547774	576108

Percents are shown in parenthesis/Compared with other studied devices**,** Newster 10 respectively with 2556.5, 692.4 and 2556.5 dollars and Sazgar respectively with 10971.5, 1864 and 10971.5 dollars in a 10 year period, had the lowest and the highest cost of parts replacement, vehicle maintenance and safety equipment.

ACER and ICER of the devices studied regarding the waste volume reduction criteria

For hospitals with 128, 256 and 512 beds and a production per capita of 2-3 liter of infectious waste, the amount of waste produced in a 10 year period in tons is as follows: 768-1152, 1536-2304 and 3072-4608 among which the Newster10 device with 90 percent waste volume reduction is the most efficient and Saray 2 with 40 percent is the least efficient (Table 2).

Although Caspian-Alborz device has not had the highest effectiveness or the lowest cost, the combination of these two gives the highest cost-effectiveness for this device. The average cost-effectiveness for this device has been from 33 to 332.9. It means that for treatment of every 1 m^3 of infectious waste by Caspian-Alborz in a 10 year period and in various conditions, 33 to 333 dollars must be spent.

Table 2: Devices related cost- effectiveness results; waste volume reduction

Output Capitation	Devices	128 beds -10% Effectiveness C/E	128 beds -10% Effectiveness ICER	128 beds +10% Effectiveness C/E	128 beds +10% Effectiveness ICER	512 beds -10% Effectiveness C/E	512 beds -10% Effectiveness ICER	512 beds +10% Effectiveness C/E	512 beds +10% Effectiveness ICER
2L/bed	Saray2	399.5	-	239.7	-	99.6	-	59.6	-
	Saray1	652.4	*	326.5	*	163	*	81.5	*
	Caspian Alborz	269	112.9	197.6	112.9	67.1	28.2	49.5	28.2
	Sazgar	348.8	*	249.3	*	87.3	*	62.3	*
	Kazu	265.9	903.3	280.7	903.3	91.6	225.8	70.3	225.8
	New Ster	402.6	*	307.8	*	100.7	*	76.7	*
	Ecodas T150	930.4	*	697.7	*	232.7	*	174.7	*
	Ecodas T300	1189	*	891.6	*	297.2	*	223.2	*
	New Ster 10	937.9	3412	749.9	3412	234.3	852.7	187.5	852.7
3L/bed	Saray2	266.3	-	159.8	-	66.6	-	39.9	-
	Saray1	435.1	*	217.3	*	108.6	*	54.3	*
	Caspian Alborz	179.5	75.1	131.6	75.1	44.7	18.6	33	18.6
	Sazgar	232.7	*	166.2	*	58	*	41.5	*
	Kazu	244.5	602.4	186.9	602.4	61.2	150.7	46.9	150.7
	New Ster	268.4	*	205	*	67.1	*	51.1	*
	Ecodas T150	619.9	*	465	*	155	*	116.1	*
	Ecodas T300	792.5	*	594.4	*	198.1	*	148.6	*
	New Ster 10	625.3	2275	500	2275	165	568.8	125.2	568.8

Undefined values are shown by Udf.

If Saray 2, which had the lowest effectiveness and cost, is chosen as the base device, the lowest ICER amount in all different scenarios and the conducted sensitivity analysis is related to the Caspian-Alborz device, which ranges from 18.6 to 159.8**.** It means that for treatment of every additional m^3 infectious waste in a decade about 18.6 to 160 more dollars yearly must be spent in comparison with Saray 2.

The ICER related to the KAZU device ranges from 150.7 to 965.6 dollars more for reduction of each additional m^3 of infectious waste. While this range for the New Ster10 is 4028 to 568.8. Then other devices are among the dominated devices, which are marked with asterisks.

Although generally the Ecodas T300 is the worst alternative with regard to the mentioned effectiveness index, is the best alternative after Caspian Alborz. With 5% DR, 10% effectiveness below baseline effectiveness and 128 staffed beds, KAZU is the best choice after Caspian-Alborz device, but, ceteris paribus, with an increase in bed number, Sazgar gradually replaces it if we have 10% DR and 10% less than baseline effectiveness, Sazgar device is always the best alternative. In addition, Saray 2 would be the best choice after Caspian-Alborz device if only there be 10% more than baseline effectiveness.

ACER and ICER of the devices studied regarding the waste weight reduction criteria

Ecodas T150 and Ecodas T300 with an 80 percent decrease and Saray 1 without any change in the weight of infectious waste had the highest and lowest effectiveness level respectively. KAZU not only does not decrease the weight of infectious waste, but it also increases it by as much as 10 percent. Its effectiveness has been shown with a minus mark in Table 3 that has been shown the cost-effectiveness analysis results of the devices studied regarding the index of infectious waste weight reduction.

Caspian-Alborz still is the most cost-effective device with its expenses ranging from 61.8 to 740.3 for decreasing every 1 ton infectious waste during a decade. Namely, for treatment of every 1 ton of infectious waste by Caspian-Alborz in a 10 year period and in different conditions, between 61.8 and 740.3 dollars must be spent.

Table 3: Devices related cost- effectiveness results; waste weight reduction

Output Capitation	Devices	128 beds				512 beds			
		-10% Effectiveness		+10% Effectiveness		-10% Effectiveness		+10% Effectiveness	
		C/E	ICER	C/E	ICER	C/E	ICER	C/E	ICER
1kg/bed	Saray2	Udf.	-	1198.3	-	Udf.	-	299.3	-
	Saray1	-2610	*	2610.2	*	-652.4	*	652.4	*
	Caspian Alborz	740.3	141.1	493.7	141.1	184.8	35.2	123.6	35.2
	Sazgar	2327.4	*	997.6	*	581.6	*	249.2	*
	Kazu	2383.9	*	Udf.	*	-596	*	Udf.	*
	New Ster	2616.1	*	1308	*	654	*	327	*
	Ecodas T150	1594.6	2734	1240.4	2734	398.9	683.3	310	683.3
	Ecodas T300	2038.2	*	1585	*	509.7	*	396.2	*
	New Ster 10	3001	*	2143.2	*	749.9	*	535.8	*
2 kg /bed	Saray2	Udf.	-	599.2	-	Udf.	-	149.7	-
	Saray1	-1305.4	*	1305.4	*	-326.5	*	326.5	*
	Caspian Alborz	370.1	70.8	246.6	70.8	92.7	17.6	61.8	17.6
	Sazgar	1164	*	498.5	*	290.8	*	124.6	*
	Kazu	-1192	*	Udf.	*	-297.7	*	Udf.	*
	New Ster	1308	*	654	*	327	*	163.5	*
	Ecodas T150	797.3	1367	619.9	1367	199.2	341.9	155	341.9
	Ecodas T300	1018.8	*	792.5	*	254.6	*	198.1	*
	New Ster 10	1500	*	1071.6	*	375	*	267.9	*

Dominated devices are shown by asterisk
Undefined values are shown by Udf.

Sensitivity analysis has shown that after Caspian Alborz, Ecodas T150 is the best alternative, if we have an effectiveness of 10% less than the baseline, for any number of beds or DR values, with its average cost-effectiveness ranging from 155 to 1655 dollars for decreasing every 1 ton of infectious waste during a decade. With these conditions, Newster 10 device is our last choice.

In situations that we have 10% more than baseline effectiveness with any bed number or DR values, Sazgar and Saray 1 devices are best, and the worst alternative is for Caspian-Alborz.

ICER range for Caspian-Alborz was 17.6 to 199 dollars for reducing each additional ton compared to Saray 1. This range, for Ecodas T150 was between 330.2 and 2734 dollars. Due to KAZU's effectiveness level being negative, its cost-effectiveness level was negative as well. Saray 1 had zero effectiveness in decreasing the waste weight, which using the range of minus $\pm 10\%$ in the sensitivity analysis caused some of its vales to become negative in the table.

Besides these two, Newster10 had the lowest cost-effectiveness level, whose ACER difference in comparison with Caspian-Alborz in a hospital with 256 beds, reaches 586 dollars in decreasing every 1 ton of infectious waste in 10 years.

Discussion

All the studied devices possessed the two required necessary conditions i.e. removing acceptable percent of the waste's microorganisms, and treatment of waste in the production place. Results indicate that in equal conditions and ceteris paribus, the devices of Saray 2 and New Star 10 have lowest and highest total cost for a decade respectively, as much as 63 times. In total for all devices, major portion of treatment process, between 70 to 97 percent, is belonging to device itself. In relation to volume reduction, devices of Newster 10 with 90% and Saray 2 with 40% effectiveness had the most and least efficient respectively, while regards to weight reduction, Ecodas products with 80% and Kazu with -10% had the highest and lowest effectiveness.

Combining the costs and effectiveness results introduced the Caspian-Alborz device as the most cost-effectiveness device. This result not changed in introduced range of employed variables in one-way and scenario sensitivity analysis, but priority rating of other devices is changed. Therefore, to treatment of every $1m^3$ of infectious waste by Caspian-Alborz in a decade and in various conditions, 33 to 333 dollars and in comparison with Saray 2 device about 18.6 to 160 more dollars annually must be spent. Also for treatment of every 1 ton of infectious waste by Caspian-Alborz in similar conditions, between 61.8 to 740.3 dollars and in compared with Saray-1, 17.6 to 199 more dollar must be spent. Of course these results is obtained given to our study assumptions and limitations where in disregarding to effect of sampling method, methodological pattern, perspective approaches and assumptions changes on the results are the limitations of the study. Also because lacking of access, we had studied the about 80% of existing treatment devices in the Iran market, hence study results do not apply for not included devices. High economic fluctuations' in Iran, is the another factor that threat our findings reliability in the future so that will change cost ratios of studied devices directly.

Caspian-Alborz treatment device in compare with other studied devices has 2 relatively advantage; first, low price that is due to its domestic production and resistance against to economic fluctuations. Second, high effectiveness that is because following reasons: use the strong internal grinder, Sterilizes the waste utilizing steam, similar to an autoclave, but with much faster and much more even heat penetration, Removes the water content (dehydrates) the waste, Breaks up the waste into small pieces of fragmented material, do not use the additional chemical materials and finally reduces the waste substantially in weight and volume (21).

Resource allocation and inefficiency

The most economical advantage in the use of Caspian-Alborz device is for bigger hospitals, as the expenses of the studied devices in a 128 bed hospitals, were four times as much as those of a hospital with 512 beds and ICER of this device in a 512 beds hospital in compare with 128 beds is more than 11 times. So the higher the production per capita in a hospital, the lower the average treatment cost and there was a reversed relationship between the average cost and the DR. These results indicate the inefficiency or waste of resources and the importance of designing special devices according to the volume of infectious waste and production capacity of hospitals.

The Caspian-Alborz in compare with the best alternative regarding to reduction in infectious waste volume, KAZU, in terms of ACER and ICER differs 13848 to 95867 and 132 to 805.8 USD respectively. This difference regarding to reduction in infectious waste weight in compare with Ecodas T150 device is gained equal to 93.2 to 1045 and 312.6 to 2534.6 USD respectively.

Policy recommendations

For efficient resource allocation, and to encourage further cost containment in infectious waste management, we introduce policy recommendations in three levels:

1) At the policy makers' level: policy makers by classifying hospitals according to their bed number, should attempt to formulate a comprehensive and transparent guideline including economic indicators to choose the best available systems for treatment of infectious waste. The Ministry of health should also encourage the medical equipment market to become a competitive market.

2) At the ‘producers of treatment devices’ level: These producers should be committed to provide safety, effectiveness and quality and consider the costs of their devices in order to maintain the ability for competition in the market. For example, Sazgar and New Star devices in order to have the same cost-effectiveness as Caspian-Alborz have to reduce 4794 and 8788 dollars of the total cost related to these machines, respectively.

3) At the Hospital decision-makers level: in the first stage, hospital CEOs should reduce their wastes as much as possible and in the next stages limit and manage their waste treatment costs by purchasing cost-effectiveness device with regard to their hospital beds and capability of infectious waste production. These proceedings should be done based on upstream and relevant documents and instructions.

As regards the 883 active hospitals now in Iran, Caspian-Alborz device is used in only 54 hospitals. It is recommended for existing hospitals after their existing devices have passed their useful life, or in newly built hospitals having up to 512 beds.

The study should be repeated in the future with changing the economic conditions and be tested by other perspectives especially social perspective.

Conclusion

The more expensive devise not have the more effectiveness necessarily, and in decision making time for choosing the best alternative, we should considered the multiple criteria about existing and available devices such as price, effectiveness, useful life, treatment method, infectious waste produce in a given time, number of hospital beds, most important effectiveness factor for decision makers and identify the key perspective. This means it is possible that we have more than one cost-effectiveness device for different conditions and times in a country.

Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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