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Investigating the Health and Economic Evaluation of Health-Care Wastes Disinfection Equipment of Tehran Hospitals in 2016

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ABSTRACT

Introduction: Health-care waste can threaten the health of humans and environment due to dangerous, toxic and pathogenic agents. This study was conducted to investigate the status of disinfection equipment in Tehran hospitals as well as their health and economic evaluation in 2016.

Materials and Methods: In this research, 27 hospitals in Tehran that equipped with disinfection equipment were selected randomly. For health evaluation of chemclave, autoclave and hydroclave disinfection equipment was used respectively form the *Bacillus Atrophies* Indicator, a plastic vial of *stearothermophilus* and a vial of syringe and for economic evaluation a standard checklist was used. Finally, Fisher's exact test was used to analyze the data.

Results: The results of health evaluation showed that the removal rate of indicator organisms in hydroclave, autoclave and chemclave disinfection equipment were 100%, 86.7% and 75%, respectively. The results of the economic evaluation showed that the investment cost of the Autoclave and Hydroclave were over 100 thousand dollars and the chemiclave was below 100 thousand dollars ($P = 0.002$). The most reduction of waste volume after disinfection was related to hydroclave and autoclave devices ($P \leq 0.001$). The highest amount of odor production was in the chemiclave and the minimal was in the autoclave and hydrocollo method ($P = 0.003$). Also, hydroclave and autoclave were the environmentally friendly methods and chemiclave was not ($P = 0.004$).

Conclusions: By comparing health and economical assessments, the autoclave disinfection device at the moment, if resolved the grinding problem, is the best way for health-care waste disinfection.

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Introduction

Nowadays, by increasing population growth, needs, health and medical expectations of human societies, different centers of health-care providers such as hospitals, clinics and specialized laboratories have been developed [1]. Health-care waste is the problem of all hospitals and medical centers [2]. About 75-90% of the health-care wastes are of non-hazardous or general wastes and about 10-25% of them are related to infectious and hazardous wastes [3]. Health-care waste has a high potential risk for patients and hospital staff as well as those involved outside the hospital [4, 5]. In fact, these wastes are of particular importance due to the presence of hazardous, toxic and pathogenic

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agents, including pathological wastes, radioactive, pharmaceutical, chemical, infectious, and utensils and therapeutic products [2, 6]. Furthermore, poor management of medical waste may cause more than 30 significant pathogens, including typhoid, hepatitis B, human immunodeficiency virus (HIV), Escherichia coli, Staphylococcus aureus and Pseudomonas aeruginosa, and etc. [7]. According to international reports, for each hospitalized patient, 1-1.5 kg/d waste is averagely produced which is considerable due to numerous treatment centers in big cities. Based on studies conducted in Tehran, about 70 ton/d infectious and hospital wastes are produced [8]. Health centers wastes account for about 1% of the wastes in Tehran; however, due to their hazardous nature, they are more important than other wastes. Therefore, it is necessary to pay particular attention to the way of controlling, disinfecting, collecting, transporting and disposing health-care wastes and manage them by using methods that are more acceptable in terms of health and environment [9]. By a proper management of collecting waste from departments, safely storing and keeping them in temporary storage, most of hospital wastes can be collected and disposed as other municipal wastes [10]. There are various methods and devices for disinfection of health-care wastes, which include the use of chemicals, wet heat treatment (autoclave, hydroclave), dry heat treatment and use of microwaves [11, 12]. In the chemical method, the pathogenic microbes are destroyed by injecting disinfectant into wastes, thereby reducing the biological risks of infectious wastes [12]. In the wet heat treatment (autoclave, hydroclave), virtually all microorganisms in infectious and sharp wastes are completely disappeared [13]. In this method, the medical waste is disinfected, after grinding and crushing with a grinder machine or without crushing operations in the vicinity of water vapor with a minimum temperature of 121 °C under high pressure and during the sterilization process [14]. In the dry heat treatment, the hospital hazardous waste is compressed and converted into normal wastes after disinfection with dry heat. In this method, as in the case of wet heat treatment, the waste is grinded to a diameter of 25 mm and then placed in the vicinity of the dry heat caused by hot oil flowing at a temperature of about 110 °C to 140 °C for about 20 minutes. In this method, wastes have 80% volumetric and 20 to 35% weight reduction [15]. So far, limited studies have been conducted on the comparison of disinfection equipment. Rashidian, et al. has studied cost-benefit analysis of disinfection equipment of health-care wastes in Iranian hospitals [16]. Soares et al. has investigated the economics of health-care wastes and comparison of microwave, autoclave and chemiclave devices [17]. In another study by Chen et al. on the application of non-burning technologies for disinfection of health wastes in China, non-burning technologies were introduced as the best available technology and best environmental performance [18]. Voudrias has also done a research on the selection of the best technology for disinfection of health-care wastes on the basis of a hierarchical study process [12].

Considering that, comprehensive studies have not been recently carried out on disinfection equipment in Tehran hospitals; the current study was conducted with the aim of determining the way of health-care wastes disinfection and investigating their status of in Tehran and comparing them with considering health and economic items in 2016.

Materials and Methods

This study was a descriptive-cross-sectional study which was carried out to investigate the status of existing disinfection equipment in Tehran Hospital in 2016. Firstly, Yazd University of medical sciences coordinated with the ministry of health and medical education and subsequently, with all three medical universities in Tehran (Tehran University of Medical Sciences, Shahid Beheshti University of Medical Sciences and Iran University of Medical Sciences). By considering security condition and obtaining a license, data pertaining to 136 hospitals were collected. Then, to determine the sample size, the hospitals with disinfection

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equipment were distinguished by type of university, and type of disinfection equipment, autovlave, hydroclave and chemiclave. After that, out of 27 hospitals, 3 hospitals were randomly selected. Afterwards, from each university, 9 microbial samples were obtained depend on the type of disinfection equipment for laboratory examination. By taking at least one repetition, a total of 54 microbial samples were collected and tested. Vialization and microbiological sampling, transfer and cultivation of samples and vials were conducted by the reliable environmental laboratory of Tehran University with confidential coding. Sampling was done completely randomly. In microbial sampling, by placing special vials in the desired packages, after disinfection process and maintaining the sampling conditions, the vials were removed and transferred to the laboratory under laboratory condition. The *Bacillus Atrophus* Indicator was used to evaluate the chemiclave device. After the injection of Percidin and finishing the machine work, the desired bag was opened next to the flame and placed in a 10-cc laboratory tube TSB. Then the indicator had to be detached from its cover without connecting with forceps and in the temperature of 35 °C for 24-48 hr. In the absence of contamination, it is pellucide and, if contaminated, is turbid, indicating the presence of bacteria *Bacillus subtilus*. In order to assess the health of the autoclave, a plastic vial of *stearothermophilus* was used to put it inside the waste bag or place it in its embedded location on the device. After completing the machine work cycle, the vial is removed with a piece of forceps and is placed in a sterile container. Then the glass container inside the vial was broken in the laboratory next to the flame and with pressure and it was placed in the incubator at 55 °C for 24 to 48 hr while shaking. In the event of contamination, the color of the vial is changed from violet to yellow and in the absence of contamination; there will be no change in color. A syringe vial was used to assess the health of the hydroclave device and with a change of color from violet to yellow, the answer was positive and if there was no change in color, the answer was negative.

A checklist was used to evaluate the performance of disinfection equipment of health-care wastes. Questions about general information of the hospital, the status of the staff related to waste, separation, collection, transportation, temporary storage, waste disinfection were included, as well as specific questions regarding the device and costs of investment, operation and maintenance, consumption, and environmental impacts. The checklist was completed by attending hospitals and interviewing with environmental health experts and other staff related to waste management. Finally, after receiving specific information from microbial tests and aggregation of economic evaluation data of the devices, the data was entered into SPSS version 22 and Fisher's exact test was used to analyze the results.

Ethical issues

This article was confirmed by the Ethical Committee (ethical code: IR.SSU. SPH.REC. 1395.162) school of Health of Shahid Sadoughi University of Medical Sciences and Health Services, Yazd.

Results

In this study, a total of 27 devices from hospitals were randomly investigated and compared which were supported by Tehran University of Medical Sciences and Shahid Beheshti University of Medical Sciences in Iran. The removal rate of spore *stearothermophilus* and *bacillus subtilis* in Autoclave, hydroclave, and chemiclave devices is given in Table 1. The results showed that in two sampling steps, the negative samples were only found in the hydroclave device. However, the statistical analysis did not show a significant relationship between spore removal and type of device ($P \geq 0.05$).

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Table 1: The removal rate of spore *stearothermophilus* and *bacillus subtilis* in the studied disinfection equipment

Equipment type	Negative samples in the first stage		Negative samples in the second stage		Positive samples in the first stage		Positive samples in the second stage		Total samples	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Autoclave	13	86.7	15	100	2	13.3	0	0	30	100
Hydroclave	4	100	4	100	0	0	0	0	8	100
Chemiclave	8	100	6	75	0	0	2	25	16	100
p-value	0.658						0.097			

The initial investment cost of the examined devices is given in Table 2. The results showed that the cost of Autoclave and Hydroclave investment was over $ 100,000 and chemiclave less than $ 100,000. There was also a significant relationship between the cost of investment in different devices (P = 0.002). However, six months operating and maintaining costs in all three devices was approximately $ 500 to 1000 and did not differ significantly (P = 0.448). Furthermore, the cost of monthly water and electricity consumption in Autoclave and Hydroclave devices was higher than $ 50 and in chemiclave was below $ 50, and this difference was statistically significant (P1.001).

Table 2: The initial cost of investment in the studied disinfection equipment

Equipment type	$ 25-100		$ 100-175		> $ 175		Total samples		p-value
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	
Autoclave	1	6.7	10	66.7	4	26.7	15	100	
Hydroclave	0	0	2	50	2	50	4	100	0.002
Chemiclave	8	100	0	0	0	0	8	100	

The amount of waste volume reduction in different disinfection equipment is given in Table 3. The results showed that the highest amount of waste volume reduction after disinfection was related to hydroclave device and this difference was statistically significant (P ≤ 0.001). The results also showed that there was a significant relationship between the duration of disinfection in different devices (P ≤ 0.001), in which, chemiclave takes the least time and hydroclave takes the most time.

Table 3: Comparison of the amount of waste volume reduction after disinfection in the studied disinfection equipment

Equipment type	Waste reduction after treatment (%)										p-value
	< 20		20- 30		30- 50		50- 70		> 70		
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	
Autoclave	0	0	8	53.3	1	6.7	5	33.3	1	6.7	
Hydroclave	0	0	0	0	1	25	3	75	0	0	0.000
Chemiclave	8	100	0	0	0	0	0	0	0	0	

Comparisons and investigations showed that there was a significant relationship between the amount of odor production in different devices (P = 0.003). The Chemiclave is in the highest degree of odor production and the hydroclave is in the least degree (Table 4).

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Table 4: Comparison of the odor-based health hazards in the studied disinfection equipment

Equipment type	Risks from odors (%)						Total samples		p-value
	Low		Medium		High				
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	
Autoclave	1	6.7	10	66.7	4	26.7	15	100	0.003
Hydroclave	0	0	2	50	2	50	4	100	
Chemiclave	0	0	0	0	8	100	8	100	

The environmental friendliness of the investigated disinfection equipment is shown in Table 5. The statistical test showed that there is a significant relationship among environmental friendliness in different devices (P = 0.004). The most and the least percentage of environmental friendliness is related to hydroclave and Chemiclave respectively.

Table 5: Comparison of the positive impact of different equipment on the environment

Equipment type	The positive effects of Equipment on the environment (%)						Total samples		p-value
	Low		Medium		High				
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	
Autoclave	1	6.7	3	20	12	80	15	100	0.004
Hydroclave	0	0	0	0	4	100	4	100	
Chemiclave	5	62.5	0	0	3	37.5	8	100	

The results also showed that the most agreement of the experts in environmental health engineering and the operators of devices were related to the centralization of the disinfection site, belonging to the hospitals with chemiclaves and Hydroclaves. The least favorable agreement was related to hospitals with autoclaves (Figure 1).

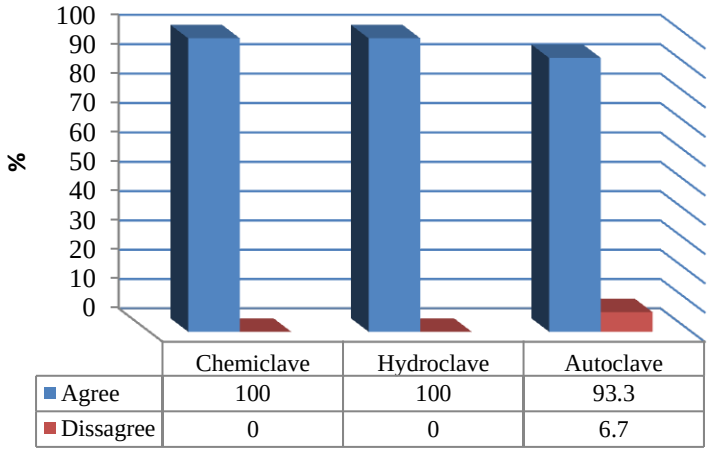

Figure 1: Comparison of the agreement between environmental health experts and the operator of devices regarding the centralization of the disinfection site in Tehran

Discussion

According to the results of the study, the highest removal rate was obtained by hydroclave devices (100%) and then autoclave with a removal percentage of 86.6% and the lowest was by chemiclave devices with 75% removal percentage. The amount of *Bacillus subtilus* spores and *Bacillus stearothermophilus* from hospital wastes

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were most removed in hydroclave devices and had the least removal in chemiclave devices. However, in the study done by Rabbani et al. it was concluded that all four autoclave devices at Alzahra Hospital had 100% sterilizing effectiveness in terms of index and biological indicators, and in terms of index and chemical indicators, had a relatively acceptable performance of 99.80 percent [19].

In examining the cost of initial investment for purchasing devices and associated facilities such as air compressor (wind pump) and water pump and water softening and strong fans for ventilation, press machines, balances, traps (water-to-steam converters) it was found that the investment cost in a hydroclave device is lower than microclave which is only one factor in economic monitoring debates. The cost of operation and maintenance in hydroclave device is more than chemiclave device, since the chemiclave device is lack of accessories and, on the other hand, less dependent on the boycott and economic fluctuations of the society [15, 17]. In comparing the total cost of research equipment, including the cost of consuming water and electricity, personnel and repairs and failures, it can be concluded that in terms of cost of water, electricity and personnel, 100% of hospitals with a chemiclave disinfection were at low cost range and those with hydroclave device were in the average cost range and 93.3% of hospitals with autoclave were in high cost range. Accordingly, the water consumption and the output leachate in the chemiclave device are lower than autoclave and hydroclave respectively. Comparing repairs and failures costs, it was found that the total cost of 75% of chemiclaves was less than 2 million per month and 75% of hydroclves were 2-5 million and 60% of autoclaves were less than 2 million. As a result, maintenance and repair costs in hydroclave devices are more than chemiclave devices. On the other hand, each device is destroyed several times a year, and returns some infected waste, which is an environmental hazard. In this study, the failure rate in Tehran was more in chemiclave, autoclave and hydroclave, respectively. The rate of post-sales services with the exception of failure repetition and device disruption was lower in autoclaves and in hydroclaves due to domestic construction and device assembly and the producer's support. Hospitals using chemical disinfection equipment are less satisfied with the operation, in particular, to address the grinder problem and acid spray pump. Since, these equipment disinfect wastes in less time (with a working cycle of 5 to 7 minutes), and their initial purchase and installation cost are lower, hospital managers are more likely to use them. In this study, due to the proportion of the total number of samples and contaminated items, the highest environmental pollution was observed in the chemiclave device. The autoclave and hydroclave devices create pressure and vacuum, which lead to a deeper steam and heat penetration and better disinfection. Due to the pressure factor in these devices, it not only reduces the volume, but also decreases the cost and risk of shipping, since the waste deformation occurs even without crushing [16]. The results of the study were in line with the results of the study done by Mamery et al. which was concluded that the grinder can improve the performance of waste disinfection process [6]. Based on the health and economic criteria, the autoclave device was selected as the best technology which is in line with the study done by Voudrias on the selection of steam disinfection (autoclave) as the best technology based on environmental, economic, technical and social criteria [12]. Furthermore, the study of Rashidian, et al. in the field of cost-benefit analysis of disinfection equipment for health-care wastes in Iran hospitals, showed that the autoclave was selected as the most economical device, which is consistent with the results of the current study [16]. In the study of Soares et al. in the field of economic evaluation of health-care wastes, the results showed that the microwave machine is not economical; however, in terms of environmental effects as the best device, and the autoclave system was in the second rank. Finally the chemiclave method with lime was introduced as the worst method in terms of economic and

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ecological accounts in comparison with the microwave and autoclave methods [17].

However, the results of this study were not in line with the results of the study by Chan et al. in reducing the effects of medical wastes in China and the process of ozonation. Since less water consumption and greater work capacity was introduced as the best technology for disinfecting the medical waste [18]. Reducing the output volume of waste products is evident in a variety of grinders, but it is more in Ecodas device which has not only high nominal and actual capacities as well as proper tank shape, but also due to the internal grinder, the volume of the waste is reduced and the permeability and change in waste nature in this type of device is more than other types. It is a French device and despite the lower failure, its initial purchase price is higher than all devices, and its post-sales service and parts supply are weak due to boycotting problems. In addition, all of these factors are also available in the Newster model of autoclave except for the nominal and actual capacity of this type of device. In other types of autoclave, there is no grinder, and this is a great weakness for this device. Due to decision of Ministry of Health and Medical Education , some hospitals have started to provide side grinders. Since this important issue is also objected by the environmental organization, it is suggested that it should be considered in hospitals self-report program and followed up until final resolution. Comparing the disinfection equipment in the studied hospitals of Tehran in terms of health problems (odor, gas, and leachate), it was concluded that hydroclave produces the least odor and gas and chemiclave the most, and leachate production was higher in autoclave and less in the chemiclave. In this study, the majority of environmental health experts in hospitals were fully satisfied with the centralization of the disinfection site in Tehran, respecting to health conditions under the Ministry of Health supervision. Rising current costs, falling revenues and shortage of credits in most hospitals reduce this possibility; however, the periodic service of these devices in hospitals, according to the program of proper maintenance and operation, makes hospitals more successful in better operating of these devices. The most important problems of disinfection process is lack of managers' attention to this issue and their lack of cooperation with environmental health experts regarding hospital wastes management, providing inappropriate and low-performance disinfection equipment, failure to select qualified and competent staff for the device operator, as well as the inadequate maintenance and operation of them.

Conclusion

It seems that due to the complexity of health-care waste compounds and advantages and disadvantages of disinfection equipment, no technology can be selected as the best option. However, according to the researchers' findings and the results of this study, the autoclave system is currently being proposed as the best way of disinfecting, although the grinding problem, maintaining and upgrading its position should be solved.

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Conflict of interest

There are not conflicts of interest

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