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Incineration or Autoclave? A Comparative Study in Isfahan Hospitals Waste Management System (2010)

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ABSTRACT

Introduction: Medical wastes are among hazardous wastes and their disposal requires special methods prior to landfilling. Medical wastes are divided into infected and non-infected wastes and the infected wastes require treatment. Incineration is one of the oldest methods for treatment of medical wastes, but their usage have faced wide objections due to emission of hazardous gases such as CO2 and CO as well as Carcinogenic gases such as Dioxins and Furans which are generated as a result of incomplete combustion of compositions like PVCs. Autoclave is one the newest methods of medical wastes treatment which works based on wet disinfection. **Methods:** The statistical population in this descriptive, comparative study includes hospitals located in Isfahan city and the sample hospitals were selected randomly. To environmentally evaluate the Autoclave method, TST (time, steam, temperature) and Spore tests were used. Also, samples were made from incinerator's stack gases and their analyses results were compared with WHO standards. **Findings:** TST and spore tests results were negative in all cases indicating the success of treatment process. The comparison of incinerator's stack gases with WHO standards showed the high concentration of CO in some samples indicating the incomplete combustion. Also, the incineration efficiency in some cases was less than 99.5 percent, which is the efficiency criterion according to the administrative regulations of wastes management law of Iran. No needle stick was observed in Autoclave method during the compaction of bags containing wastes, and the handlers were facing no danger in this respect. The comparison of costs indicated that despite higher capital investment for purchasing autoclave, its current costs (e.g. maintenance, etc) are much less than the incineration method. **Discussion:** Totally, due to inappropriate operation of incinerators and lack of air pollution control devices, the use of incinerators doesn't seem rational anymore. Yet, despite the inefficiency of autoclaves in treatment of bulky wastes such as Anatomical wastes, their usage seems logic considering the very low amounts of such wastes. Also, considering the amount of generated wastes in Isfahan hospitals, a combination of centralized and non-centralized autoclaves is recommended for treatment of infected wastes. Mobile autoclaves may also be considered according to technical and economical conditions. It must not be forgotten that the priority must be given to the establishment of waste management systems particularly to personnel training to produce less wastes and to well separate them.

Key words: Hospital Wastes, Infected wastes, Wastes Management, Incineration, Autoclave, TST Test, Spore Test.

1. INTRODUCTION

The disposal of medical wastes is an old problem in urban areas. The increasing growth of population has resulted in an increase in the number of patients and it has led to the increase of generated wastes. Hundreds of tones of hospital wastes are daily generated which require appropriate treatment and disposal. Since medical wastes are a source for contamination and pollution, capable of causing diseases and illness to human, special procedures are required for their treatment and disposal (1).

Medical wastes are divided into infected and non-infected wastes. Non infected wastes may be disposed by landfilling the same as municipal wastes (2). But the infected wastes require appropriate treatment processes prior to disposal. Currently, there are two main options for treatment of medical wastes in Iran (3): a) Incineration and moist heat treatment (autoclave); b) Medical wastes treatment means changing the nature of wastes into a non-infected or less infected condition prior to disposal (4).

Incineration is a process in which medical wastes burn and produce combustion gases and non combustible residues (ashes). Produced combustion gases are released to air directly or after treatment through air pollution control devices. The remained non combustible ashes are collected from incinerator and are lanfilled (5). The toxic ash residues sent to landfills for disposal have the potential to leach into groundwater. Medical waste has been identified by US Environmental Agency as the third largest known source of dioxin air emission (6). The air emis-

sions affect the local environment and may affect communities hundreds or thousands of miles away. Dioxin is one of the most toxic chemicals known to humankind. Dioxins have been linked to cancer, immune system disorders, diabetes, birth defects and disrupted sexual development (7).

Autoclave with steam, moisture, heat and pressure is used in order to inactivate the micro-organisms, and to sterilize the medical devices and for medical wastes treatment (8). The BMW (Management and Handling of Wastes) Rules (2000) recommend autoclaving for disposables, microbiological waste and sharps. Typical operating conditions for an autoclave are a temperature of at least 121°C at a pressure of 105 kPa for a period of at least 60 min. The second option for the temperature, etc., is that BMW can be sterilized at 132°C for 30-60 min (9). Anatomical and pathological wastes, low-level radioactive waste, organic solvents, laboratory chemicals, and chemotherapy waste should not be treated in an autoclave (10).

In a recent study also, it has been suggested that alternatives for waste treatment rather than incineration such as a locally made autoclave integrated with a shredder should be evaluated and implemented (11).

One thing is clear and must always be addressed before assessing any technology: "What goes in, must come out (or up)." Development of waste management policies, careful waste segregation and training programs, as well as attention to materials purchased, are essential in minimizing the environmental and health impacts of any technology (12).

From all hospitals in Isfahan city there was only one hospital that had autoclaving system (at the time of our survey) and 2 hospitals with incineration system that just one of them was active. Other hospitals used to store their wastes and give them daily to the municipality systems for further landfilling.

2. MATERIALS AND METHODS

The statistical population in this descriptive, comparative study includes hospitals located in Isfahan. The sample hospitals (5 hospitals) were randomly selected. However, we chose two other hospitals purposefully since they had autoclave system and active incineration system. (To observe data security, we call the first one as "A" hospital and the second one as "F" hospital).

2.1. Data collection

To collect data, a 10 page researcher made questionnaire distributed to 5 hospitals, along with interviews made with health and infection control authorities of hospitals, and reviewing existing documents were used.

2.2. Sampling and analysis

The collection of clinical waste samples and analysis were carried out in December 2008 to April 2010. The waste characterization study was carried out in accordance with WHO guidelines (WHO 1999; WHO 2001). All of the wastes generated in 5 hospitals were segregated and weighed during a period of 3 months, manually. The wastes from hospitals were collected from storage areas. The quantity and composition of the wastes were determined at each hospital. Along with the interviews, the physical compositions of waste in hospitals were determined. Before segregation, the wastes were spread by disinfectant solution (0.5% sodium hypochlorite). Masks and large forceps were used to segregate waste into several types. During segregation, each type of medical waste was discarded into bags. General and medical wastes from outpatient and inpatient services were collected separately. The medical wastes were previously sorted into various components such as serum, syringe and needle (in safety boxes), etc. Following these procedures, the wastes were transported to a special site for storage and final disposal.

To evaluate the efficiency of incinerator in "F" hospital, 20 samples were made from stack gases of incinerator using an IMR 2800. This device could measure up to 6 different gases and their temperatures at the same time.

The treatment efficiency of the pre-vacuum autoclave in "A" hospital was evaluated using Class 6 TST Sterilization Indicator Strips and spore tests. TST test which is a chemical test was performed in every autoclave cycle. If the sensitive orange mark of the test changed into gray, the tests were acceptable. If the color was different, the test was repeated. If results were still unacceptable, then the spore test was performed. Spore test was done every 2 weeks or in emergency conditions. These purple tests contained Bacillus Stearothermophilus. After autoclave process, the tests were incubated for 48 hours in 60 °C. If the color did not change, the test was acceptable.

2.3. Data analysis

The quantities of hospital wastes were presented in terms of kg/day for total amount of waste generation. These data were used to determine the quantities of waste generated by each type of hospital. The data gathered from the questionnaire were compiled using statistical excel and SPSS. Also, the results obtained for costs were compared for two treatment options.

3. FINDINGS

The infected and non infected wastes composition in selected hospitals was characterized using WHO guidelines (WHO 1999; WHO 2001). All of the wastes generated in 5 hospitals were segregated and weighed during a period of 3 months, manually. The results for non infected and infected wastes composition in Isfahan hospitals are shown in Figure 1 and Figure 2, respectively.

At the time of this study, in Isfahan, most of the hospitals did not have any facilities to treat their wastes. They collect their wastes and through a contracted agreement, the urban services organization of the municipality conducts these wastes out of the hospital every two days. These hospitals have a source separation system to separate the infected wastes from non- infected. Unfortunately, this organization performs no treatment on these wastes and buries them in a not well operated landfill

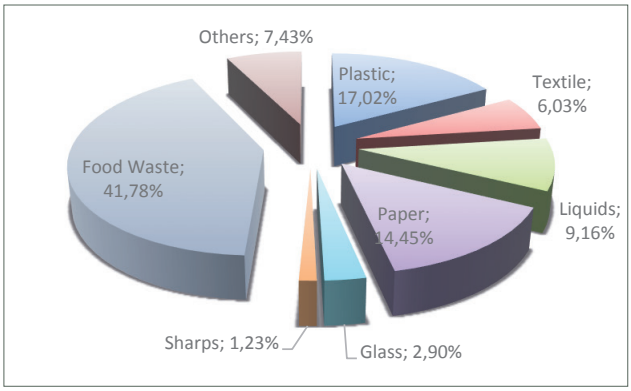

Figure 1. Non Infected waste Composition in Isfahan's Hospitals

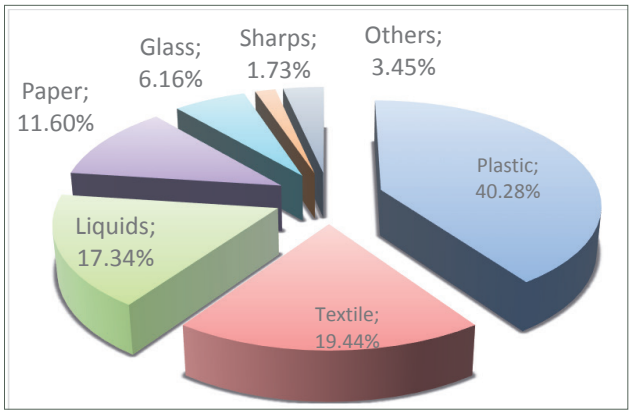

Figure 2. Infected Waste Composition in Isfahan's Hospitals

located at Zainal Neck near Isfahan. There were only an active incinerator in "F" hospital and an automated pre-vacuum autoclave in "A" hospital.

3.1. Autoclave method

As previously mentioned, the treatment efficiency of the pre-vacuum autoclave in "A" hospital was evaluated using Class 6 TST Sterilization Indicator Strips and spore tests. A sample of TST test results are shown in Figure 3. As may be seen, the sensitive part of the strips (the above strip) has changed into grey in all samples, indicating the acceptable performance of the autoclave. The daily capacity of this autoclave is 1000 kg of wastes. In "A" hospital, the amount of infected waste generated was 200 kg/day and the number of safety boxes was 7 per day.

Spore test was performed every two weeks to control the correct performance of the autoclave system and to ensure the right sterilization cycle. These purple tests contained Bacillus Stearothermophilus which are very similar to Anthrax Bacteria in respect of thermal resistance. After autoclave process, the tests were incubated for 48 hours in 60 °C. The tests were then compared with a control sample (Figure 4). No change was observed in the color of tests after incubation.

Figure 3. The class 6 TST test results in the autoclave of "A" hospital

Figure 4. The comparison of spore tests with control sample

3.2. Incineration method

At the time of this study, the only active incinerator in Isfahan province was the one in "F" hospital. Other incinerators were shut down due to their proximity to residential areas and public objections. The average monthly waste generation in this hospital was 10966 kg of which 5088 kg were infected and 5878 kg were non infected wastes. 20 samples were made from stack gases of this incinerator using an IMR 2800, and the results were compared with WHO standard values (Table 1). Unfortunately, the devices to measure the concentration of Furans and Dioxins were not available. Dioxins and Furans are toxic and carcinogenic compositions produced due to incomplete combustion of compositions like PVCs and are the main concerns of incinerators (13).

Gas Type	Number of Samples	Concentration			WHO Standard
		Maximum	Minimum	Average	
CO_2	10	2.5 %	0.9 %	1.8 %	-
O_2	10	19.6 %	17.9 %	18.21 %	-
SO_2	10	0 ppm	0 ppm	0 ppm	55 ppm
Hydrocarbons	10	2.1 %	0 %	0.21 %	-
NOx	10	39 ppm	19 ppm	28.5 ppm	250 ppm
CO	10	179 ppm	6 ppm	32.5 ppm	40 ppm

Table 1. The comparison of incinerator's stack gases analysis results with WHO standard values

Also, the combustion efficiency (C.E) of incinerator was calculated using the equation presented in the medical wastes administrative management regulations of waste management law of Iran (Eq. 1).

$$C.E = \frac{CO_2\%}{CO_2\% + CO\%} \times 100 \quad \text{Eq (1)}$$

3.3. Economic considerations

The information about the purchase cost, maintenance fees, operator's salaries, and water, gas and electricity fees for the two treatment systems were obtained using questionnaires and interviews with responsible authorities. The results are shown in Table 2. Since other costs such as costs for wastes segregation and relocation are the same for two methods, they are not mentioned here.

Autoclave		Incineration	
The cost description	Cost (Rls)	The cost description	Cost (Rls)
Skilled labor (1 person)	3,200,000/ month	Skilled labor (2 persons)	6,400,000/ month
Maintenance (2 times/ year)	400,000/year	Maintenance (3 times/ year)	600,000/year
Energy consumption (water, gas, electricity)	2,600,000/ month	Energy consumption (water, gas, electricity)	5,200,000/ month
Tests (chemical, biological) and special bags (monthly)	300,000/ month	Tests (chemical, biological) and special bags (monthly)	___
Required space cost	180,000,000	Required space cost	540,000,000
Capital Investment	750,000,000	Capital Investment	250,000,000

Table 2. The comparison of costs for two treatment methods

4. CONCLUSION

Comparing the medical, infected and non infected wastes per capita rate in Isfahan with WHO standards, it is seen that the medical waste generation in Isfahan is higher than its standard value for east Mediterranean countries according to the WHO standard (Figure 5). In Isfahan, 40% of wastes are infected which is 15 to 20% higher than WHO standards. According to WHO standards, the amount of non infected wastes in east Mediterranean countries is 75 to 89% of total medical wastes (14).

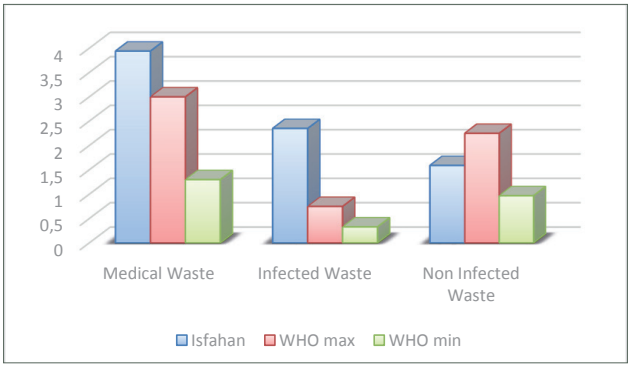

Figure 5. The comparison of waste generation rate in Isfahan with WHO Standard (kg/bed/day)

4.1. Environmental comparison

As previously mentioned, no rejected sample was observed in class 6 TST tests conducted in "A" hospital. Also, all spore tests verified the correct performance of the autoclave system. Since the autoclave system in not equipped with shredder, it cannot be used to treat bulky wastes such as anatomical wastes. However, considering the very low amount of these wastes (<5%), there is not much concern in this respect. Workers and waste handlers use long safety gloves and clothing which protect them against sharps. Safety boxes are compacted during the autoclave cycle, but no needle stick is observed. Also, no leachate was collected in the disposal trolleys.

As may be seen in table 1, the concentration of all pollutants in all of the samples is below the WHO standards. Only the maximum concentration of CO in samples is 4.5 times more than standard values. This high quantity of CO implies the incomplete combustion in incinerator or the lack of oxygen during the incineration process. Since CO is one of criteria pollutants, this high amount of carbon monoxide is environmentally hazardous. As may be seen, WHO has not provided any standards for carbon dioxide, oxygen and hydrocarbons present in incinerator stack gases. However, according to incinerators' emission standards of European Commission, the amount of oxygen present in stack gases must be at least 6% in all times, and thus, there is no problem in this respect.

As mentioned before, the devices to measure the concentration of Furans and Dioxins were not available. Because of the absence of air pollution control devices like wet scrubbers, the high concentration of these toxic and carcinogenic emissions is very probable. Thus, any judge about the stack gases analysis results must be done by care. The C.E for the average concentrations of samples would be 99.82% which is acceptable. In the worst condition (the maximum CO concentration, the minimum CO2 concentration) the C.E is 98.05% and thus, the incineration efficiency is not acceptable. This implies the necessity of usage of air pollution control devices. It must be noted that incinerators emit a significant amount of pollutants to air among them are suspended solids, metals, acid gases, nitrogen oxides, carbon monoxide and organic compounds (15).

4.2. Economical comparison

According to table 2, incineration method needs more workforces to operate than autoclave. Also, its depreciation is higher than autoclave and the maintenance frequency is more. The energy consumption costs, specially the fuel costs, in incineration are much higher than autoclave. The establishment of incinerator requires more space so that to establish an incinerator with the same capacity of an autoclave system, more space is needed (up to 3 to 4 time). The comparison of costs indicates that despite higher capital investment for purchasing autoclave, its current costs (e.g. maintenance, energy consumption, etc) are much less than the incineration method. Comparing two methods of incineration and autoclave, it might be said that each method has advantages and disadvantages over the other one. All in all, it seems that due to significant environmental advantages, autoclave system has over incineration, and its simpler operation and maintenance processes, the autoclave system is the logic option for treatment of hospital wastes in Isfahan. Considering the amount of generated wastes in Isfahan hospitals, a combination of centralized and non-centralized autoclaves is recommended for treatment of infected wastes. Mobile autoclaves may also be considered according to technical and economical conditions.

5. RECOMMENDATIONS

According to results obtained and considering the current situation of medical wastes management in Isfahan, following recommendations are made: a) Primarily, like any integrated waste management system, it is recommended to try to reduce the amount of waste generated using appropriate methods to reduce the wastes disposal costs; b) High percentage of infected wastes indicates the inappropriate waste segregation processes and the lack of knowledge among personnel in this respect. Thus, conduction of training courses for personnel in charge is of great importance; c) Workplace health policies must be implemented and epidemiological studies must be conducted to determine the risks workforces are facing with; d) Financial liabilities must be allocated for integrated medical wastes management and to support internal producers of such facilities.: e) More studies on modern treatment systems and localizing them must be conducted, and separate studies on treatment of hospital wastewaters are required to perform.

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