

EMERGING TECHNOLOGIES FOR THE TREATMENT OF MEDICAL WASTE

Considerations for the Commonwealth of Dominica



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ABSTRACT

Concerns regarding emissions from medical waste incinerators, beach wash-ups of medical waste in various countries around the world, and an increased awareness of the occupational hazards of medical waste has lead to the development of alternative treatment technologies to treat medical waste. Many of these technologies are innovative applications of existing processes i.e., microwave, macrowave, chemical, plasma, and pyrolysis. These technologies are still relatively new as compared to the history of the incineration and autoclave but are gaining a track record of experience. Technologies can range from processing 1 needle per cycle to 2,500 kg/cycle. Much information has been gained in the past few years regarding these technologies which can be used in the selection process. Management of medical waste is very much dictated by the prevailing legislation as well as public perception. Economic, environmental, and occupational safety issues also play a key role in the management of medical waste. The Commonwealth of Dominica needs to consider these new alternatives as well as the existing technologies of incineration and autoclaving.

This document presents a general overview of medical waste treatment technologies while the accompanying Health Care Without Harm resource "Non-Incineration Medical Waste Treatment Technologies" provides greater detail.

KEYWORDS: Medical waste management, incineration, autoclave, alternative treatment technologies, microwave, macrowave, chemical, pyrolysis, plasma technology

INTRODUCTION

Incineration and autoclaving have been the most widely employed methods of RMW treatment. The numerous advantages associated with incineration (Table 1) and its long history as an effective method of waste management have lead to its worldwide use as the preferred means of treating and disposing of medical waste. However, growing problems with air pollution, among other disadvantages to its application in medical waste treatment (Table 1), have caused many government and state regulatory agencies to introduce more stringent air-quality standards (Barkely et.al., 1983). Healthcare and other facilities that generate medical waste, have found that to meet these enhanced requirements through retrofitting existing incinerators or purchasing new equipment would be cost-prohibitive and have simply deactivated their incinerators. For example, in 1990, there were approximately 150 medical waste incinerators in operation at hospitals, nursing homes, laboratories, and commercial facilities in New York State. However, by 1999, there were only twelve incinerators in use at healthcare facilities within the state.

Since 1876, when Charles Chamberland built the first pressure steam sterilizer, autoclaves have been used for the sterilization of surgical instruments, medical devices, heat stable liquids, as well as numerous applications in medical laboratories and private industry. Therefore, it was a natural progression to utilize autoclaves to decrease or eliminate the potential bioburden contained in medical waste. While standard autoclaving of medical waste does offer several advantages over incineration, there is a down side to its application in processing both liquid and solid forms of this waste (Table 1). One major concern associated with the use of autoclaves, which has been overlooked until relatively recently, has been the generation of potentially hazardous chemicals. Since pressurized steam is an excellent method of volatilizing organic compounds, and many organic reactions are accelerated at elevated temperatures, a wide variety of organic species maybe emitted depending upon the quantity and composition of the hazardous chemicals contained in the waste. This is an issue applicable to most medical waste treatment systems. Further, standard autoclaves cannot be used to treat a wide variety of waste, e.g., radioactive, chemotherapeutic waste categorized as hazardous waste, and pathologic waste. However, advances in autoclave technology have created a few hydrids systems that have demonstrated their ability to treat pathological waste (see Autoclaves below).

Table 1. Advantages and Disadvantages of Common Medical waste Treatment Systems

Type	Factors	Advantages	Disadvantages
Incineration	Turbulence and mixing Moisture content of waste Filling combustion chamber Temperature and residence time Maintenance and repair	Volume and weight reduction Unrecognizable waste Acceptable for all waste types Heat recovery potential for large systems	Public opposition High investment & operation costs High maintenance cost Significant air pollutants requiring expensive control equipment Bottom and fly ash may be hazardous
Steam Autoclave	Temperature & pressure Steam penetration Size of waste load Length of treatment cycles Chamber air removed	Low investment cost Low operating cost Ease of biological tests Low hazard residue	Appearance, volume unchanged ^a Not suitable for all waste types ^b Possible air emissions Ergonomic concerns
Microwave	Waste characteristics Moisture content of waste Microwave strength Duration of exposure Extent of waste mixture	Unrecognizable waste Significant volume reduction Absence of liquid discharge	Mod -High investment cost Not suitable for all waste types Possible air emissions
Mechanical/Chemical	Concerns for chemicals, temperature, pH Chemical contact time Waste & chemical mixing Recirculation vs flow-through	Significant volume reduction Unrecognizable waste Rapid processing Waste deodorization	High investment cost Not suitable- all waste types Possible Air emissions Need for chemical storage Ergonomic concerns
Plamsa/Pyrolysis	Waste characteristics Temperature Length of treatment cycle	Almost no waste remains Unrecognizable waste Heat recovery potential	Novel technology Air emissions must be treated Skilled operator needed

^a Several autoclave manufacturers incorporate maceration or shredding during the treatment process that results in a volume reduction of up to 80% as well as an unrecognizable waste stream.

^b Two technologies have demonstrated the capability to treat pathological waste.

The reduction in the use of incinerators and the limitations on the application of some autoclaves have created a new industry - alternative medical waste treatment systems. Currently, there are over forty such technologies available from greater than seventy manufacturers within the United States, Europe, the Middle East, and Australia (See Salkin et.al., 2000). While these systems vary in their treatment capacity, the extent of automation, and overall volume reduction, all alternative technologies utilize one or more of the following methods: (1) heating the waste to a minimum of 90 - 95 degrees C by means of microwaves, radio waves, hot oil, hot water, steam, or superheated gases; (2) exposing the waste to chemicals such as sodium hypochlorite (household bleach) or chlorine dioxide; (3) subjecting the waste to heated chemicals; and (4) exposing the medical waste to irradiation sources.

Thermal systems which use heat to inactivate pathogenic microorganisms are the most common alternative technologies for the treatment of medical waste. These systems can be broadly divided into those using low temperatures, i.e., 95 degrees C (moist heat) to 250 degrees C (dry heat) and those that use high temperatures, i.e., approximately 500 degrees C to greater than 6,000 degrees C. The latter systems combust and destroy the waste as part of the treatment process. The most frequently used heat inactivation systems are (see Salkin et. al., 2000 for information on the manufacturers, capacities, treatment cycles, and state's in which the systems are approved to be sited, as well as Joslyn, 1991 and Salkin and Krisiunas, 1998 for additional details):

ALTERNATIVE TREATMENT TECHNOLOGIES

Low-Temperature Systems – Microwaves

Microwaves are defined as those with a frequency in between those of radio and infrared waves in the electromagnetic spectrum. When used in the treatment of medical waste, they stimulate the preshredded and moistened waste to generate heat (95 degrees C or greater) and release steam. It is the combination of the microwaves and moisture which is required to generate the thermal energy to effectively treat the medical waste, e.g., Sanitec – a U.S. based firm that manufactures units in the thru put range of 100 to 250 kg/hour. Meteka is another firm based in Austria that manufactures smaller microwave systems based upon a small batch process (15 kg/40 minute cycle).

Some manufacturers (Sintion – Austria) have used microwaves as the energy source to heat water and to create steam. So in effect, they are more like an autoclave system.

Low-Temperature Systems – Macrowaves

Some systems apply low-frequency radio waves to heat shredded, moistened, compacted medical waste to 90 degrees C for an extended period of time, thereby inactivating microbes contained within the waste, e.g., Stericycle.

Low-Temperature Systems - Dry Heat

Several treatment systems available for large (e.g., hospitals) and small-quantity generators (e.g., physician/dental offices) thermally inactivate potentially pathogenic microorganisms through the use of electrically generated heated air, oil, or molten plastic, e.g., MediWaste.

High-Temperature Systems - Pyrolysis

Pyrolysis involves the high temperature (545 to 1,000 degrees C) treatment of waste in the absence of oxygen. In generating these high temperatures, the systems treat, destroy and reduce the volume of medical waste, e.g., Plasma Energy Pyrolysis System (PEPS).

High-Temperature Systems - Plasma Technology

In a plasma system, an electric current is used to ionize an inert gas (e.g., argon) to cause the formation of an electric arc to create temperatures as high as 6,000 degrees C. The medical waste within the system is brought to temperatures between 1,300 to 1,700 degrees C, destroying potentially pathogenic microbes and converting the waste into a glassy rock or slag, ferrous metal, and inert gases, e.g., Peat's Plasma Arc Reactor System.

Chemical

Chemical treatment systems have an extensive and well-documented history in the medical setting in disinfecting and sterilizing environmental surfaces and medical devices (Jagger et.al., 1989). Inherent in the operation of such systems is the fact that the waste must first be shredded prior to exposure to such agents as sodium hypochlorite, chlorine dioxide, peracetic acid, glutaraldehyde, quaternary ammonium compounds, etc, in order to bring all surfaces of the waste into direct contact with the chemicals. MCM STERIMED (Israel) utilizes a chemical composed of glutaraldehyde, quaternary ammonium compounds, and alcohol (SterCid) to treat medical waste. Some systems, ChemClav, combine heat with the chemicals, sodium hypochlorite to enhance the treatment parameters.

Several companies have also proposed quick lime, Matrix in Australia and Positive Impact Waste Solutions in the U.S. (Odessa, Texas) to treat medical waste. The process appears to be able to treat all forms of waste including pathological material. An issue that must be addressed is an end product with a high pH (10.5-11) that may be considered a hazardous waste in some jurisdictions.

One of the newer chemical systems, Waste Reduction by Waste Reduction or WR², utilizes hot 1 N sodium hydroxide under pressure to treat animal carcasses and reduce this form of pathological waste to bone meal. Additionally, recent information in the literature would indicate that, in theory, the WR²'s use of heated chemicals under pressure would allow for the effective treatment of Prion contaminated waste. If this were verified through scientific investigations, it would mean that the WR² is the only system, including incinerators, which is capable of treating waste generated through treatment of human and animals infected with Prion, e.g., mad cow's disease.

Autoclaves

Even with the numerous alternatives available, autoclaves continue to be one of the most popular methods of treatment because of their history of use and track record within healthcare. A new generation of autoclaves has been developed that may be considered alternative treatment technologies.

These technologies now incorporate maceration or shredding during the treatment process to ensure better penetration of steam. Additionally, these systems achieve significant volume reduction (up to 85%). These technologies include Tempico (US), Hydroclave (Canada), Lajtos (France), and Stericomat (Germany).

SELECTION OF TREATMENT TECHNOLOGIES

The selection of the most appropriate system for Dominica depends upon the composition of the medical waste, the volume of waste to be treated, staffing requirements for the system in terms of both numbers and education levels of employees, support capabilities of the vendor, and initial and continuing operating costs. Several critical factors which should be considered in the selection of an alternative treatment technology are:

Treatment Capabilities

While some treatment systems are specifically designed to process only one type of waste component, e.g., sharps, liquids, animal byproducts, most commercially available systems can treat several different components of the medical waste stream. Obviously, the more types of waste, e.g., pathologic, chemotherapeutic agents, radioactive materials, etc, that can be processed by the system, the simpler it is to operate, since the medical waste stream does not have to be segregated into its specific components for treatment. Consequently, one key criterion in selecting a medical waste treatment system is to match the capabilities of the technology to the types of waste generated by a facility.

Grinding/Shredding

While, as noted, grinding/shredding of medical waste is a necessary first step in chemical treatment systems, other types of treatment technologies may also employ such devices for one or more of the following reasons:

- a. reduce the volume of waste;
- b. remove or reduce physical hazards; and
- c. render the waste unrecognizable.

Although compaction of the waste is used with a few treatment systems, it is generally less efficient than shredding / grinding and must generally be employed after treatment, as the compacting process might generate infectious aerosols.

In addition, an emergency support capability of the vendors is another important selection criterion. In treatment systems that employ grinders / shredders at the end of the cycle, vendors

should be able to provide information and physical assistance, if needed, to store the treated waste until repairs can be completed. If the grinders/shredders are used prior to treatment, vendors must be able to indicate proper decontamination methods for the waste so as to prevent the waste from being a physical and biological hazard to the operators and environment.

Process Capacity

Process capacity may be defined as the volume of waste that may be treated by a system per unit of time. There are commercially available treatment systems with process capacities as low as one syringe per minute to those with capacities as high as 3,000 pounds (approximately 1,360 kilograms) of waste per hour. Further, some systems require a minimum charging capacity, i.e., a minimum volume of waste for the system to operate effectively. In selecting a treatment system, consideration must be given to sizing the technology to the volume of waste generated by the facility.

Throat Capacity

Throat capacity refers to the size and/or volume capacity of the aperture through which the medical waste enters the treatment systems. As in process capacity, treatment technologies vary as to volume, size, and types of waste that can be introduced into the system. Restrictions in a system's throat capacity might require excessive waste handling, which in turn could cause increase operating costs and create safety problems. While an important selection criterion, throat capacity is not often considered in evaluating treatment systems.

Vendor Responsibilities

In selecting a system, vendors should be required to provide efficacy test data to support claims of the technology's treatment capabilities. Prior to accepting a treatment system, the vendors should conduct initial validation tests to demonstrate that the system's on-site capabilities are identical with those found during the technology's initial efficacy tests. Additionally, the vendor should have satisfied all governmental regulatory requirements. Finally, sampling ports, a feature of some treatment technologies, greatly simplify quality control test procedures. These ports provide openings into the system through which samples of the treated or untreated waste may be introduced on a periodic basis for testing to ensure that the technology is operating effectively.

Air Emissions

Particulate and potentially toxic air emissions from incinerators are the primary factors that contributed to the development of alternative treatment technologies. Uncontrolled air emissions may lead to the release of potentially hazardous and/or toxic materials in such a manner that ambient concentrations become excessive. If emissions are generated during the treatment cycle, they should not be hazardous or toxic; or, if these sorts of emissions are released, the treatment system should have abatement equipment to reduce the levels of toxic/hazardous substances. If emissions are vented to the outside, it is critical that they be:

- a) colorless and free from persistent mist or droplets;
- b) odorless as detectable at the boundaries of the facilities; and
- c) vented, when appropriate, through High Efficiency Particulate Air (HEPA) filters.

Proper installation and effectiveness of HEPA filters must be verified using existing standard (DOP; dioctyl phthalate particles) tests and their operations monitored with a magnahelic or other pressure differential measuring device. HEPA filters should only be removed by trained personnel and disposed of as medical waste.

CONCLUSIONS

Interest in alternative treatment technologies has grown during the past decade. Many innovative applications have been introduced. Objective information is now available regarding various aspects of these systems. Bear in mind, selection of one of these technologies will be dictated by a number of items on Dominica including the prevailing legislation, comfort level of end users as well as public perception. Economic, environmental, and occupational safety issues also play a key role in the selection of an appropriate technology.

REFERENCES

- Barkely, W.E., Wedum, A.G., and McKinney, R.W. The hazard of infectious agents in microbiological laboratories. In: Block SS, Ed., *Disinfection, Sterilization and Preservation*, 3rd ed. Lea & Febiger, Philadelphia. 1983.
- Jagger, F., Hunt, E.H., Brand-Elnaggar, J., and Peasron, R.D.. Rates of needle-stick injury caused by various devices in a university hospital. *N Eng J Med*, 319(5):284-288. 1989.
- Joslyn, U. Sterilization by heat. In: Block SS, Ed., *Disinfection, Sterilization and Preservation*, 4th ed. Lea & Febiger, Philadelphia. 1991.
- Salkin, I.F. and Krisiunas, E. Alternatives to medical waste incinerators. *J Solid Waste Tech Manag*, 25(1):9-13. 1998.
- Salkin, I.F. and Krisiunas, E. , and Turnberg, W. in Richmond, J., *Anthology of Biosafety, II. Facility Design Consideration*, American Biological Safety Association, 2000.
- Turnberg, W.L. *Biohazardous waste*. John Wiley and Sons., Inc., New York. 1996.