Medical Waste Treatment Technologies

What is the right choice?

May 2023

The Partnership for Supply Chain Management

Purpose

The document describes the different alternatives for medical waste treatment, including environmentally friendly technologies which advance climate mitigation strategies and help meet commitments in global environmental conventions, and the key considerations helping in making the right choice for the procurement. It is focused on limited-resources settings of low and middle-income countries.

Introduction

In total, 85% of the waste generated by healthcare activities is general, non-hazardous waste comparable to domestic waste; the remaining 15 percent is considered hazardous material that covers a diverse range of materials like:

Infectious waste: waste contaminated with blood and other bodily fluids, cultures and stocks of infectious agents from laboratory work, or waste from patients with infections.

Pathological waste: human tissues, organs or fluids, body parts, etc.

Sharps waste: syringes, needles, disposable scalpels, blades, etc.

Chemical waste: solvents and reagents used for laboratory preparations, disinfectants, sterilants, and heavy metals in medical devices (e.g. mercury in broken thermometers) and batteries, etc.

Pharmaceutical waste: expired, unused, and contaminated medicines and vaccines;

Cytotoxic waste: waste containing substances with genotoxic properties, such as cytotoxic medicines used in cancer treatment and their metabolites.

Radioactive waste: such as products contaminated by radionuclides, including radioactive diagnostic material or radiotherapeutic materials.

Measures to ensure the safe and environmentally sound management of healthcare wastes can prevent adverse health and environmental impacts, including the unintended release of chemical or biological hazards into the environment, thus protecting the health of patients, health workers, and the public.

PFSCM
Partnership for Supply Chain Management

Technology options

There are several alternatives for treating medical waste:

Low-heat thermal processes

Steam-based technologies are commonly used to destroy pathogens contained in infectious and sharp wastes by using thermal energy (heat between 100°C and 180°C). The processes occur in either moist or dry heat environments for a defined period, depending on the load size and the content. The thermal process is commonly performed in an autoclave or steam-based treatment system (WHO 2014).

Microwave treatment is an emerging technology that can help solve most waste treatment needs for developing countries. Microwave is essentially moist thermal processes since disinfection occurs through the action of moist heat generated by microwave energy.

The process must be validated and documented to guarantee the complete decontamination of infectious material. Part of this is regular testing using biological, chemical, and physical test parameters. This is determined by the ability of the heat to penetrate the waste load and inactivate pathogenic organisms at a 6 Log10 reduction or greater. The inactivation can be confirmed using self-contained biological indicators (UNDP 2010).

Besides process validation, chemical indicators should be used to prove the waste decontamination efficiency of each cycle. Chemical indicators show exposure using physical and/or chemical changes and are designed to react to one or more parameters of the decontamination process, such as time of exposure, temperature, and the presence of moisture.

Low-heat treatment can be combined with **mechanical methods** like shredding, grinding, mixing, and compaction to reduce waste volume; the volume reduction does not destroy pathogens. Shredders and mixers before treatment can improve the heat transfer rate and increase the waste's surface area for treatment. Mechanical methods should not be used for pathological, infectious, and sharp waste before the waste is decontaminated, except if the mechanical process is part of a closed system that decontaminates the chamber of the mechanical process and air before it is released into the surrounding environment. Mechanical methods have the advantage of reducing waste volume, which is made unrecognizable and cannot be reused. However, using mechanical treatment increases the investment and operational and maintenance costs. The decontaminated waste ends up in sanitary landfills.

Burning of waste

Incineration is a dry oxidation process that reduces organic and combustible waste to inorganic, incombustible matter and significantly reduces waste volume and weight.

Burning health care waste without flue gas treatment releases a wide variety of pollutants into the atmosphere, according to the composition of the waste. When medical waste is incinerated in conditions that do not constitute the best available techniques or best environmental practices. In that case, there is potential for releasing dioxins and furans in relatively high concentrations. Dioxins and furans are bio-accumulative and toxic.

Pathogens can also be found in solid residues and the exhaust gases and particulates of poorly designed and badly operated incinerators. In addition, the bottom ash residues can be contaminated with dioxins, leachable organic compounds, and heavy metals and should be treated as hazardous waste (UNEP 2012a). To prevent hazardous emissions and the generation of hazardous bottom and fly ash, infectious and sharp waste should be treated and decontaminated by alternative non-burn technologies (UNEP 2003).

What is the right choice?

The choice of the most appropriate treatment system is linked to the operating context and involves the consideration of critical factors, namely:

Relevant international and local environmental regulations including sustainability aspects.

Characteristics and volume of generated waste.

Available space and security for the treatment technology.

Availability of collection and safe disposal of treated waste.

The use of decentralized or centralized waste treatment instructed by national policy for medical waste management.

Budget for capital, operation and maintenance costs.

Calculation of required treatment capacity.

For the waste treatment plant, the site needs careful consideration. Some utilities should be available to operate medical waste equipment:

- Stable electricity source.
- Demineralized water (for steam generation in autoclaves, and wet scrubbers in incinerators.
- Drainage, and good ventilation to maintain a low-level temperature in the working area.

Table 1: Information on the type of waste each technology can treat

Type of waste	Autoclave	Microwave	Incinerator
Sharps	✔	✔	✔
PVC plastic waste	✔	×	×
Radioactive substances and heavy metals like mercury	×	×	×
Pathological wastes	×	×	Specific conditions (extra fuel)
Pharmaceutical waste/ cytotoxic waste	×	×	✔
Infectious and Laboratory waste (except chemical wastes)	✔	✔	✔
Liquid Infectious waste	✔	✔ Except: Volatile and semi-volatile organic compounds	Special design

Table 2: Key considerations for the selection of suitable waste management technology

Considerations	Autoclave	Microwave	Incinerator
Suitable waste	See table 1.		
Waste capacity	Available in small as well as large sizes. Benchtop models of ten liters for up to 5 kg/hour to large models of 500 liters or above with more than 50 kg/hour capacity. Up to 250 liters for a developing hospital. For a hub or waste from many large surrounding hospitals, 250 to 500 liters are commonly used. > 500 liters are used for central treatment plants. **The above-mentioned ranges are indicative. The capacity selection is linked to the generated volume to be treated.**		
Ease of Use	Automatic. Come with pre-installed disinfection programs. Easy.	Similar to the autoclave.	An operator must be trained on the proper operation of the machine, the measure of waste, the calorific value of different waste, and related needed temperatures.
Environmental Impact	Very low pollution of soil and water. discharged effluent may affect water quality. Odors are an issue to close nearby areas if not equipped with a proper ventilation system. Gas and water generated during the process should be treated and then discharged.	No liquid effluent discharge	Emissions vary depending on the type of waste. Carcinogens like dioxins and furans are formed in the presence of halogenated materials, causing air pollution at a high rate. Residual ash should be treated because it contains harmful effluent. New incinerator models with filters can reduce pollution to some extent.
Efficiency	Minimum exposure time and temperature are required for proper disinfection. Reported autoclave efficacy: 6log10 or better. Color-changing strip indicators or biological indicator strips are used to detect efficiency.	Minimum exposure time and temperature are required for proper disinfection. Waste treated by microwaves has no microbe growth (approx. 7 log10 kill or better).	Modern incinerator efficiency 70% to 80% with proper ash, gas emission treatment setup. These measures reduce air pollution standards, but many viable spores of microbes, and heat-resistant bacteria, are found in incinerated wastes.
Infrastructure requirements	Mostly electric-based; Need for reliable electricity supply. Demineralized water. Drainage Good ventilation	Mostly electric-based; Need for reliable electricity supply. Demineralized water. Drainage Good ventilation	Need electricity for fuel pumps, fans, temperature, and other gauges. Good ventilation

Considerations	Autoclave	Microwave	Incinerator
Area requirements for installation	Medium-sized room area. Autoclaves have fewer restrictions on setup location because they don't emit pollutants and have few sound and odor problems.	Similar to autoclaves	Large setup areas for their different sections. Specific consideration • It should be away from the human population. • Wooden areas like forests and valleys ridges are avoided and may cause dispersion. • Hilltops and open fields are favored for their setups.
Capital cost	Cost depends on the type and capacity of the chosen technology.		
Maintenance	All the waste management equipment needs periodic maintenance and repair		
Lifespan	10 to 20 years		5 to 10 years
Some Other factors			
Human resources needed to operate	One operator		
Mass Reduction	No mass reduction		Up to 70% of mass reduction
Volume Reduction	If equipped with a shredder, up to 80% to 90%	Volume of waste can be reduced to 80% by shredder.	90% reduction in volume

Table 3: summary of advantages and disadvantages of on-site waste treatment form an environmental perspective

Technology	Advantages & Disadvantages
There is a rising trend for waste treatment on-site. On-site treatment is beneficial from a supply chain, and sustainability perspective and can aid in emergency and pandemic preparedness.	
Microwave Microwaving is a process that disinfects the waste with moist heat and steam generated by microwave energy. This is the most recent technology developed for waste management.	+ Lower impact on the environment (less emission, no water residue, shredder, enables up to 80% reduction in waste volume). + Ease of use/ operation. – High-investment.
Autoclave A sterilization method that uses high-pressure steam. This technology has existed in the medical environment for a long time but has been adapted to treat medical waste.	+ Limited emissions. + Shredder enables up to 80% reduction in waste volume. – High water consumption and residue.
Incinerator Incineration technology, also called thermal treatment, burns/ combusts waste material at a high temperature, which results in ash and flue gas. This is the oldest technology.	+ Specific conditions (extra fuel) +Widest range of waste treatable. – Emission of combustion by-products (including toxic waste). – Solid residue. – Cleaning waste water, contamination.

Conclusion

Each one of the technologies has its advantages and disadvantages. However, autoclaves and microwaves have the upper hand from an environmental or technological point of view. On the other hand, incinerators represent an economical solution.

This document is based on the WHO guidelines:

World Health Organization. (2019). Overview of technologies for the treatment of infectious and sharp waste from health care facilities. World Health Organization. https://apps.who.int/iris/handle/10665/328146.

References:

- UNDP (2010). Guidance on Microbiological Challenge Testing for Medical Waste Autoclaves. (http://www.lvif.gov.lv/uploaded_files/UNDP/Dokumenti/EN_Guidance_on_Microbiological_Challenge_ Testing_for_Medical_Waste_Autoclaves.pdf accessed August 2017)
- UNEP (2012a). Compendium of Technologies for Treatment/ Destruction of Health care Waste. (https://www.unenvironment.org/ resources/report/compendium-technologies-treatmentdestructionhealth care-waste accessed December 2016).
- UNEP (2003). Technical Guidelines on the Environmentally Sound Management of Biomedical and Health care Waste. (http://archive. References and further information 42 Overview of technologies for the treatment of infectious and sharp waste from health care facilities basel.int/pub/techguid/tech-biomedical.pdf(http://archive.basel.int/ pub/techguid/tech-biomedical.pdf accessed January 2017.
- WHO (2014). Safe management of wastes from health care activities. World Health Organization, Geneva. (http://www.who.int/water_ sanitation_health/publications/wastemanag/en/ accessed January 2017).

pfscm@pfscm.org | www.pfscm.org | +1-571-227-8600

2733 Crystal Drive, 4th Floor
Arlington, VA 22202