Steam disinfection, a standard process in hospitals for disinfecting reusable instruments, has been adapted for medical waste treatment. There are two traditional types of equipment used for steam treatment: autoclaves and retorts. Other steam-based systems, sometimes referred to as advanced autoclaves, have been developed in recent years. One unique design of a steam-based process is a microwave unit that achieves disinfection by means of moist heat and steam.

These technologies have one thing in common—steam. As heat is applied to water, its temperature rises until it reaches its boiling point or saturation temperature at which point water is turned into steam. At atmospheric pressure (100 kPa [kilopascals] or 14.7 psia [pounds per square inch absolute]), the saturation temperature of water is 100°C or 212°F. At higher pressures, the saturation temperature is higher. For example, at a pressure of 50 psia, water boils at 281°F (134°C). When steam is at its saturation temperature, the condition is referred to as a saturated condition and the steam is known as saturated steam. Autoclaves and other steam-based systems generally operate at saturated conditions. Engineering handbooks provide tables showing temperatures and their corresponding pressures for saturated steam. Table 5-1 shows selected pressures and corresponding temperatures for saturated steam.

**AUTOCLAVES AND RETORTS**

**Overview of the Technology**

An autoclave consists of a metal chamber sealed by a charging door and surrounded by a steam jacket. Steam is introduced into both the outside jacket and the inside chamber which is designed to withstand elevated pressures. Heating the outside jacket reduces condensation in the inside chamber wall and allows the use of steam at lower temperatures. Because air is an effective insulator, the removal of air from the chamber is essential to ensure penetration of heat into the waste. This is done in two general ways: gravity displacement or pre-vacuuming. A gravity-displacement (or downward-displacement) autoclave takes advantage of the fact that steam is lighter than air; steam is introduced under pressure into the chamber, forcing the air downward into an outlet port or drain line in

<table>
<thead>
<tr>
<th>TABLE 5-1. PROPERTIES OF SATURATED STEAM</th>
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<tr>
<td><strong>ABSOLUTE PRESSURE</strong></td>
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<tr>
<td>kPa</td>
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*KPa=kiloPascal; psia=pounds per square inch (absolute); psig=pounds per square inch (gauge)*

Note: Some technical specifications list pressures in psi without signifying if they are gauge or absolute pressures. Most of the time, the values are gauge pressures. One can determine if the values are gauge pressures (psig) or absolute pressures (psia) by comparing the corresponding temperatures in the table above for saturated steam.
the lower part of the chamber. A more effective method is the use of a vacuum pump to evacuate air before introducing steam, as is done in pre-vacuum autoclaves. Pre-vacuum (or high-vacuum) autoclaves need less time for disinfection due to their greater efficiency in taking out air. Some autoclaves may use pressure pulsing with or without gravity displacement to evacuate air.

A retort is similar to an autoclave except that a retort has no steam jacket. It is cheaper to construct but requires a higher steam temperature than an autoclave. Retort-type designs are found in large-scale applications.

**How It Works**
A typical operating cycle for an autoclave or retort involves the following:

- **Waste collection**: A cart or bin is lined with special plastic liners or large autoclavable bags to prevent waste from sticking to the container. Red bags are then placed in the lined container.
- **Pre-heating** (for autoclaves): Steam is introduced into the outside jacket of the autoclave.
- **Waste loading**: Waste containers are loaded into the autoclave or retort chamber. Periodically, chemical or biological indicators are placed in the middle of the waste load to monitor disinfection. The charging door is closed, sealing the chamber.
- **Air evacuation**: Air is removed through gravity displacement or pre-vacuuming as explained above.
- **Steam treatment**: Steam is introduced into the chamber until the required temperature is reached. Additional steam is automatically fed into the chamber to maintain the temperature for a set time period.
- **Steam discharge**: Steam is vented from the chamber, usually through a condenser, to reduce the pressure and temperature. In some systems, a post-vacuum cycle is used to remove residual steam.
- **Unloading**: Usually, additional time is provided to allow the waste to cool down further, after which the treated waste is removed and the indicator strips, if any, are removed and evaluated.
- **Mechanical treatment**: Generally, the treated waste is fed into a shredder or compactor prior to disposal in a sanitary landfill.

**Types of Waste Treated**
The types of waste commonly treated in autoclaves and retorts are: cultures and stocks, sharps, materials contaminated with blood and limited amounts of fluids, isolation and surgery wastes, laboratory wastes (excluding chemical waste), and soft wastes (gauze, bandages, drapes, gowns, bedding, etc.) from patient care. With sufficient time and temperature as well as mechanical systems to achieve unrecognizability, it is technically possible to treat human anatomical wastes but ethical, legal, cultural, and other considerations may preclude their treatment. Some states and local authorities may allow the treatment of trace-contaminated chemotherapy waste; facilities should check with their regulators (see also “Is Incineration Essential for Certain Types of Waste?” in Chapter 10).

Volatile and semi-volatile organic compounds, bulk chemotherapy wastes, mercury, other hazardous chemical wastes, and radiological wastes should not be treated in an autoclave or retort. Huge and bulky bedding material, large animal carcasses, sealed heat-resistant containers, and other waste loads that impede the transfer of heat should be avoided.

**Emissions and Waste Residues**
Odors can be a problem around autoclaves and retorts if there is insufficient ventilation.

If waste streams are not properly segregated to prevent hazardous chemicals from being fed into the treatment chamber, toxic contaminants will be released into the air, condensate, or in the treated waste. This is the case when waste loads contaminated with antineoplastic drugs or heavy metals such as mercury are put in the autoclave. Thus, poorly segregated waste may emit low levels of alcohols, phenols, aldehydes, and other organic compounds in the air. More independent emission tests of autoclaves operating under typical conditions would be useful.

A study at one autoclave facility by the National Institute for Occupational Safety and Health (NIOSH) found no volatile organic compounds (VOCs) in a worker’s personal air space and work area that exceeded permissible exposure limits set by the Occupational Safety and Health Administration. The highest VOC level in the autoclave facility was 2-propanol, measured at 643 mg/m³. Some autoclaves or retorts may use steam that is treated with corrosion inhibitors or anti-scaling agents (small amounts of neutralizing amines).

There have been dubious claims that dioxin may be created in autoclaves and at levels even higher than those from incinerators. The author is not aware of any scientific paper showing this. Researchers generally agree that dioxins are formed at temperatures between 480 to 840°F (250 to 450 °C), temperatures well above the operating temperatures of autoclaves. Moreover, dioxin formation is believed to be catalyzed by fly ash created during combustion in the presence of metals and a chlorine source.
Both the abovementioned temperature range and fly ash are not found in autoclaves since burning does not take place in an autoclave. However, these conditions along with known precursors (compounds produced by burning that lead to the formation of dioxin) are found in the exhaust downstream from the combustion chambers of incinerators.

Decontaminated waste from an autoclave or retort retains its physical appearance. Some landfill operators may refuse to accept treated waste that is recognizable and several states require unrecognizability. Since steam does not physically alter the waste in any significant way, a mechanical process such as a shredder or grinder is needed to render the waste unrecognizable. Shredding reduces the volume of the treated waste by 60 to 80 percent. In general, as long as organic compounds and inorganic material containing arsenic, barium, cadmium chromium, lead, mercury, silver or other inorganic chemicals are kept out of the waste, the treated waste residue should pass the TCLP test.

### Microbial Inactivation

Autoclaves and retorts require a minimum exposure time and temperature to achieve proper disinfection. Time-temperature recommendations for various conditions are found in a number of references. Often, the exposure times are based on twice the minimum time required to achieve a 6 log$_{10}$ kill of bacterial spores under ideal conditions; equivalent exposure times at different temperatures can be estimated. A common exposure temperature-time criterion is 121°C (250°F) for 30 minutes.

Color-changing chemical indicators or biological monitors (e.g., B. stearothermophilus or B. subtilis spore strips) placed at the center of test loads should be used to verify that sufficient steam penetration and exposure time have occurred.

### Advantages and Disadvantages of the Technology

Autoclaves and retorts have the following advantages:

- Steam treatment is a proven technology with a long and successful track record.
- The technology is easily understood and readily accepted by hospital staff and communities.
- It is approved or accepted as an alternative technology in all states.
- The time-temperature parameters needed to achieve high levels of disinfection are well-established.
- Autoclaves are available in a wide range of sizes, capable of treating from a few pounds to several tons per hour.
- If proper precautions are taken to exclude hazardous materials, the emissions from autoclaves and retorts are minimal.
- Capital costs are relatively low compared to other non-incineration technologies.
- Many autoclave manufacturers offer many features and options such as programmable computer control, tracks and lifts for carts, permanent recording of treatment parameters, autoclavable carts and cart washers, and shredders.

The disadvantages include the following:

- The technology does not render waste unrecognizable and does not reduce the volume of treated waste unless a shredder or grinder is added.
- Any large, hard metal object in the waste can damage any shredder or grinder.
- Offensive odors can be generated but are minimized by proper air handling equipment.
- If hazardous chemicals such as formaldehyde, phenol, cytotoxic agents, or mercury are in the waste, these toxic contaminants are released into the air, wastewater, or remain in the waste to contaminate the landfill.
- If the technology does not include a way of drying the waste, the resulting treated waste will be heavier than when it was first put in because of condensed steam.
- Barriers to direct steam exposure or heat transfer (such as inefficient air evacuation; excessive waste mass; bulky waste materials with low thermal conductivities; or waste loads with multiple bags, air pockets, sealed heat-resistant containers, etc.) may compromise the effectiveness of the system to decontaminate waste. Examples of waste that may need to be collected separately and treated using another technology include evacuated containers and pleurovac machines.

### Other Considerations

Below are some suggestions to consider when selecting autoclave or other steam-based treatment systems:

- Again, make sure that an effective waste segregation plan is in place to keep hazardous materials from being treated in an autoclave or other steam-based system.
- Air evacuation is more effective in autoclaves with a pre-vacuum cycle or multiple vacuum cycles. With higher vacuum levels and more vacuum cycles, the heat penetration is deeper and the heating of the waste load is more uniform.
Certain load configurations, such as placing bags in multi-level racks with sufficient spaces between bags to allow more surfaces to be exposed to steam, are more efficient than other configurations, such as tightly stacked containers or carts piled with red bags.

Facilities should define a standard load and waste configuration for which specific time-temperature parameters have been shown to achieve a 6 log₁₀ kill using B. stearothermophilus spore tests. Operators should then monitor waste loads sizes, load configurations, waste containment and other conditions that may result in less-than-optimal heating conditions; whenever those conditions arise, exposure times and steam temperatures should be increased to provide a margin of safety.

Continuous monitoring of temperature during the exposure time and at various points in the chamber is important in detecting heating problems.

Running a standard cycle with an empty autoclave or retort should be done annually. Any significant changes from the previous years in temperature-time profiles, vacuum, and steam pressure readings indicate a potential problem. Thermocouples and pressure gauges should be tested to ascertain their accuracy.

Maintain records of chemical or biological indicator tests, time-temperature profiles, maintenance activities (such as replacing filters and gaskets), and periodic inspections.

Provide sufficient ventilation to minimize odor problems.

If the cost of hauling and disposal of treated waste is based on weight, the facility might want to consider technologies that dry the waste, thereby reducing weight.

Provide worker training, including: a basic understanding of steam-based treatment systems, standard operating procedures, occupational safety (e.g., ergonomics, proper waste handling techniques, hazards associated with steam and hot surfaces, needle-stick injuries, blood splatter or aerosolized pathogens if red bags are broken or compacted, etc.), record-keeping, identifying waste that should not be treated in the unit, recognizing heating problems, dealing with unusual waste loads and other less-than-optimal conditions, periodic maintenance schedules, and contingency plans (e.g., what to do in case of a spill or power outage).

The following are descriptions of all vendors known to the author as of the time of this publication. While there may be other manufacturers in the market, there was no attempt to make this a comprehensive list. As noted earlier, mention of a specific technology in this report should not be construed as an endorsement by the author nor Health Care Without Harm.

**Bondtech**

**Description**
Bondtech makes insulated retorts/autoclaves, some of which have been in operation for ten years. Their systems are capable of high pressure and high vacuum. Once the waste is loaded, microprocessor controls begin the cycle. A pre-vacuum cycle removes air after which saturated steam between 275 – 305°F is introduced. After exposure, the steam is vented through a condenser and the condensate is drained to the sewer. A post-vacuum is applied to remove residual steam and protect workers, at the same time drying the waste. A chart recorder documents the treatment parameters. Tracks, ramps, ramp lifts, and bin dumpers make it easier to move carts in and out of the treatment system. The company has installed more than 75 units, including commercial systems.

**Models-Capacities**
Bondtech can custom-design the system. Capacities range from 250 lbs (115 kg) to 6,000 lbs (2,727 kg) per cycle and higher.

**Approximate Dimensions**
Models could range from a 3’’ diameter x 4’ long vessel, to a 6’’ diameter x 17’ long vessel. A commercial system might have dimensions of 8’ diameter x 32’ long.

**Typical Installation Requirements**
Steam – 305°F/55 psig; Sewer drain; Electricals

**Features & Options**
In addition to internal tracks and lifts, Bondtech offers optional equipment including medical waste shredders, bins, carts, cart washers, balers, autoclavable bags and liners, bin dumpers, lifters, self-contained compactors and containers, and conveyor systems. Bondtech offers complete turnkey installation and maintenance services.

**Stage of Commercialization**
Fully commercialized.

**Permitting Status**
Retorts and autoclave are accepted or approved in all states.
Approximate Costs
Approximate capital cost ranges from about $90,000 for 100 lbs/cycle; $102,000 for 250 lbs/cycle; $123,000 for 750 lbs/cycle; to $175,000 for 1,500 lbs/cycle. Single-stage shredders range from $50,000 to $78,000; two-stage shredders from $79,000 to $135,000. A self-contained compactor is about $19,000 and a hydraulic bin dumper is $14,500-$16,500. Autoclavable bags are about $18-$163 per 100, depending on size, thickness, and whether they have temperature strips.

Vendor Information
Bondtech, 2400 North Hwy 27, Somerset, KY 42503 Ph. 606-677-2616 or 800-414-4231; Fax 606-676-9157; www.bondtech.net; elsabrown@earthlink.net

Note: Health Care Without Harm does not endorse any specific technology or company. This technology is presented here as an example of a non-incineration treatment technology. Always check with the vendor for the latest and most accurate data and specifications.

Environmental Tectonics Corporation
Description
Environmental Tectonics Corporation (ETC) designs and engineers medical waste autoclaves. They are configured for floor- or pit-mounting with single or double doors and hydraulic power lock doors. Automated loading and unloading systems are also available. The units are adaptable to fit with ancillary equipment such as shredders, compactors, and materials handling systems.

Capacities
Custom volume sizes range from 1 to 19 cubic yards. Standard models range from 4,000 to 13,000 lbs/day.

Stage of Commercialization
Fully commercialized

Permitting Status
Retorts and autoclave are accepted or approved in all states.

Approximate Costs
N/a

Vendor Information
Environmental Tectonics Corporation (ETC), 125 James Way, Southampton, PA 18966-3877; Ph. 215-355-9100; Fax 215-357-4000; www.etcusa.com; info@etcusa.com

Note: Health Care Without Harm does not endorse any specific technology or company. This technology is presented here as an example of a non-incineration treatment technology. Always check with the vendor for the latest and most accurate data and specifications.
Vendor estimates operating costs of about $.06 per pound including labor, utilities, maintenance, autoclavable bags, disposal costs, and amortized capital.

Vendor Information
The Mark-Costello Company, 1145 Dominguez Street, Carson, CA 90746; Ph. 310-637-1851; Fax 310-762-2330; www.mark-costello.com

Note: Health Care Without Harm does not endorse any specific technology or company. This technology is presented here as an example of a non-incineration treatment technology. Always check with the vendor for the latest and most accurate data and specifications.

Sierra Industries

Description
Sierra Industries (formerly, RE Baker Company) makes retorts/autoclaves, some of which have been in operation for more than ten years. They manufacture insulated pressure vessels with hydraulically operated doors and safety interlocks. Their vessels are equipped with built-in ramps, automated controls, and documentation. Red bags are placed in autoclavable bags and loaded into stainless steel carts. The vessel door is opened, the hinged ramp is placed on the ground, and the cart or carts are pushed up the ramp into the vessel. Once the door is locked in place, a start button begins the cycle by injecting steam at 275°F (31 psig) for 45 minutes. The recorder chart documents the temperature. At the end of the cycle, the condensate is discharged and the door can be unlocked. The waste is taken to an optional shredder and compactor, which reduce the volume up to 80%.

Models-Capacities
Sierra Industries makes retorts of varying sizes capable of pressures up to 100 psig and 400°F. Typical designs have 200, 500, and 750 lb per hour capacities.

Approximate Dimensions & Weights
The vessels are cylindrical in shape but are surrounded by water-tight control enclosures, hydraulic pumps, supports, and other structures. Three typical designs might have the following approximate dimensions and weights: 62” high x 70” wide x 112” long, 6,000 lbs; 96” high x 78” wide x 144” long, 7,200 lbs; 96” high x 78” wide x 191” long, 8,500 lbs.

Energy Consumption
Typical natural gas usage for the three typical designs mentioned above: 1.71, 2.71, and 3.46 therms per 60-minute cycle.

Typical Installation Requirements
Steam – ¾” NPT 60 psig; Water – ½” NPT 40 psig; Drain – S/S 2” (2 each); Electrical – 120V 60 Hz 1-phase (for controls) and 208-230/480V 60 Hz 3-phase (for the motor)

Features & Options
Sierra Industries offers a shredding/grinding unit designed for medical waste, with fully automated controls, a semi-automatic cart tipper, and an auger that conveys the shredded waste directly to a compactor. They also offer stationary compactors in a variety of styles and capabilities.

Stage of Commercialization
Fully commercialized

Permitting Status
Retorts and autoclave are accepted or approved in all states.

Approximate Costs
N/a

Vendor Information
Sierra Industries, Inc., 1021 South Linwood Avenue, Santa Ana, CA 92705; Ph. 714-560-9333 or 800-437-9763; Fax 714-560-9339; www.sierraindustries.com; sierra@sierraindustries.com

Note: Health Care Without Harm does not endorse any specific technology or company. This technology is presented here as an example of a non-incineration treatment technology. Always check with the vendor for the latest and most accurate data and specifications.

SteriTech

Description
Red bags are placed in steam-permeable heavy-duty Kraft bags. The treatment system utilizes the facility’s central steam supply. (Alternatively, an internal electrical steam generator can be used.) If the operator uses the optional “sterilization/melting cycle” for sharps containers, the sharps waste is placed on foil-lined shelves of the loading cart and heated to temperatures in excess of 270°F. After steam treatment, the sharps containers are subjected to a heating cycle to melt the plastic sharps containers and syringe barrels making them unusable.

Models-Capacities (in cu ft or lbs/hr)
Model #3016-016 – 4 cu ft or 18 lbs/hr; #3020-020 – 9 cu ft or 40 lbs/hr; #3024-036 – 15 cu ft or 65 lbs/hr; #3024-048 – 20 cu ft or 90 lbs/hr; #3024-060 – 25 cu ft or 115 lbs/hr
Approximate Dimensions (chamber sizes)
Model #3016-016 – 16” x 16” x 26”; #3020-020 – 20” x 20” x 38”; #3024-036 – 24” x 36” x 36”; #3024-048 – 24” x 36” x 48”; #3024-060 – 24” x 36” x 60”

Features & Options
The system has a residual liquid treatment system and an optional patented closed-loop design which allows installation in remote locations without water, drain, or steam lines.

Permitting Status
Autoclaves are accepted or approved in all states.

Vendor Information
SteriTech, P.O. Box 5383, Bloomington, IL 61702-5383
Ph. 309-662-3614

Note: Health Care Without Harm does not endorse any specific technology or company. This technology is presented here as an example of a non-incineration treatment technology. Always check with the vendor for the latest and most accurate data and specifications.

TUTTNAUER

Description
Red bags are placed in an autoclavable bag and manually placed into autoclave baskets resting on a carriage. The full basket is rolled off the carriage into the autoclave chamber. The operator closes the door and pushes a button to automatically start a pre-programmed cycle. Air is removed using a vacuum and heated to 300°F in a heat exchanger prior to discharge in the sewer. Steam is introduced and the waste is exposed for a set period. The vessel can operate up to 279°F/33 psig. After treatment, a high vacuum is used to cool and dry the waste. The basket is then rolled out of the chamber and onto the carriage, where it can be transported to a shredder or compactor. The units are equipped with microcomputer-based controls.

Capacities
Up to 1,500 lbs/hr

Approximate Dimensions
Chamber dimensions are 36” W x 48” H with depths ranging from 72” to 216”.

Features & Options
Tuttnauer also supplies doors at one or both ends, fully automatic sliding doors, baskets, loading carts, and transfer carriages.

Stage of Commercialization
Fully commercialized

Permitting Status
Autoclaves are accepted or approved in all states.

Approximate Costs
Capital costs range from around $100,000 to over $200,000.

Vendor Information
Tuttnauer USA Co. Ltd., 33 Comac Loop, Equi Park, Ronkonkoma, NY 11779; Ph. 516-737-4850 or 800-624-5836; Fax 516-737-0720; www.tuttnauer.com; infor@tuttnauer.com
Tuttnauer Europe, P.O. Box 7191, 4800 GD Breda, The Netherlands; Ph. (31) 77-5423510; Fax (31) 76-5423540

Note: Health Care Without Harm does not endorse any specific technology or company. This technology is presented here as an example of a non-incineration treatment technology. Always check with the vendor for the latest and most accurate data and specifications.

OTHER STEAM-BASED SYSTEMS

Overview of the Technology
In the last few decades, a second generation of steam-based systems have been developed for the purpose of improving the transfer of heat into the waste, achieving more uniform heating of the waste, rendering the waste unrecognizable, and/or making the treatment system a continuous (rather than a batch) process. These new systems have sometimes been referred to as advanced autoclaves.

These systems basically function as autoclaves or retorts but they combine steam treatment with pre-vacuuming and various kinds of mechanical processing before, during, and/or after steam disinfection. The combinations include:
- Vacuum / steam treatment / compaction
- Steam treatment-mixing-fragmenting / drying / shredding
- Shredding / steam treatment-mixing / drying (and chemical cleaning)
- Shredding-steam treatment-mixing / drying
- Steam treatment-mixing-fragmenting / drying
- Pre-shredding / stream treatment-mixing (see note below)
Shredding / steam treatment-mixing-compaction.

Each of these systems operates differently. Nevertheless, they treat the same types of waste and have similar emission characteristics as an autoclave or retort. They also share many of the advantages and disadvantages of autoclaves. Because they are different from standard autoclaves which are accepted in all states, some state regulations require some of these advanced autoclaves to be approved separately as alternative technologies.

Note: As mentioned earlier, pre-shredding or pre-grinding should not be done before disinfection to protect workers from exposure to pathogens released in the air by the mechanical process; some state laws explicitly prohibit this. The exception is when shredding or grinding is an integral part of a closed system designed in such a way that the air stream from the mechanical process is disinfected before being released to the surroundings.

Examples of “advanced autoclave” systems are given below:

Vacuum/Steam Treatment/Compaction
Of the so-called advanced autoclaves, San-I-Pak is one of the more established technologies. Since 1978, they have installed some 700 units in the United States and in about a dozen countries around the world. The technology basically integrates high vacuum/autoclave with a dozen countries around the world. The technology basically integrates high vacuum/autoclave with compaction. The San-I-Pak system was one of the technologies evaluated by the USEPA in 1993 as background material for a report to Congress on medical waste management. In that study, all levels of B. stearothermophilus (up to 10^6) and B. subtilis (up to 10^8), both steam and non-steam exposed spore containers, were inactivated in every treatment cycle tested.

San-I-Pak

Description
San-I-Pak’s old standard design is a rectangular-shaped system, part of which is an autoclave and the other part a compactor. The autoclave cycle begins with a high vacuum to remove air, followed by exposure to 307°F steam. (The evacuated air is mixed with steam to destroy pathogens before being vented out.) The chamber is allowed to reach temperatures of 281-284°F (about 38 psig). After treatment, the steam vents down through a diffuser to condense the steam and the waste is automatically conveyed to the compaction chamber. The compactor section can be used separately for regular trash.

In the mid-1990s, San-I-Pak developed a new line of articulating chambers, a modular design wherein each chamber has three basic positions. In the load position, in which the chamber is tilted with the door facing up, the operator inserts an optional autoclavable liner and loads the waste. The chamber is then rotated to a horizontal position to start the treatment cycle: air is evacuated using a vacuum and 307°F steam is introduced. The waste is exposed to steam for 30 minutes from the time the chamber temperature reaches 270°F and a maximum of 284°F. After treatment, the steam vents down through a diffuser. The operator opens the door and initiates the dump cycle, in which the chamber rotates down, allowing the waste to drop into a compactor where a piston compacts the waste directly into a roll-off container. Units have digital displays and strip printers for documentation.

San-I-Pak offers a wide range of integrated custom designs based on dozens of models. Multiple units can be lined up along a common load platform and waste can be loaded from ground or dock level. Moreover, San-I-Pak offers cart dumpers, conveyors, single- and two-stage shredders, compactors with 4-to-1 and 6-to-1 compaction ratios, bailers, and auto-weighing systems.

Selected Models-Capacities (in lbs/hr)
Capacities range from 25 lbs/hr to 2,240 lbs/hr. Examples: Model #130-2P – 25 lbs/hr; #230-2P – 87; Mark II-N – 106; #241 - 160; #341-230; #352 – 560; #347 – 1,160; #358 – 2,240

Approximate Dimensions (selected models; height based on dump height; excludes stands, load platforms, etc.)
Mark II-N – 85-3/8” H x 114” W x 31’6” D; #241 – 8’1-3/4” H x 4’ W x 6’1” D; #341 – 7’8-3/16” H x 4’7” W x 5’3-5/8” D; #352 – 10’3/4” H x 4’7” W x 6’11-1/16” D; #347 – 7’8-3/16” H x 3’2” W x 5’3-5/8” D; #358 – 10’3/4” H x 36’8” W x 6’11-1/16” D

Typical Installation Requirements
Concrete pad and anchoring; Steam – 1” insulated line with minimum 65 psig steam and maximum 125 psig; Water – 30-100 psi; Drain – floor mount; Electrical – dedicated 120 V, 10 A; may need 208/240/480 V, 3-phase and 220 V, 1-phase service depending on model; Phone line for remote diagnostics

Features & Options
San-I-Pak offers waste audit programs, in-service training, full service contracts, in-house monitoring, and remote messaging systems, among others. San-I-Pak also offers a sharps machine.

Stage of Commercialization
Fully commercialized
**Permitting Status**
Autoclaves are accepted or approved in all states.

**Approximate Costs**
Costs range from around $26,000 for a 25 lb/hr unit to over $500,000 for the largest systems. For example, Model #241 is about $154,000 and #352 is about $286,000.

**Vendor Information**
San-I-Pak, 23535 South Bird Road, Tracy, CA 95376 or PO Box 1183, Tracy, CA 95378-1183; Ph. 209-836-2310; Fax 209-836-2336; www.sanipak.com; sanipak@sanipak.com

*Note: Health Care Without Harm does not endorse any specific technology or company. This technology is presented here as an example of a non-incineration treatment technology. Always check with the vendor for the latest and most accurate data and specifications.*

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**Steam treatment-mixing-fragmenting/drying/shredding**
Tempico installed its first Rotoclave at the Forrest General Hospital in Hattiesburg, Mississippi in 1992. Since then, over 25 units have been in delivered and are in operation. The technology changes the standard autoclave into a rotating drum, thereby combining steam treatment with agitation that serves to break up or fragment the waste. Drying and shredding are added. Three separate microbial inactivation efficacy tests were conducted by the Department of Biological Services at the University of New Orleans and by the Forrest General Hospital between 1991 and 1993. No post-treatment growth of B. megaterium and B. stearothermophilus were detected. In a study prepared for Tempico, Log_{10} kills from 6.7 to 8 were reported for B. stearothermophilus, from 7.4 to 9.1 for B. subtilis, and between 8 to 10 for five other microorganisms. The water-soluble extract from the solid waste and the wastewater or aqueous outflow from the Rotoclave were also tested for mutagenic potential using the Ames test; none showed any detectable mutagenic potential.

**Tempico Rotoclave**

**Description**
The Rotoclave is a pressure vessel with a rotating internal drum. Medical waste bags and boxes are loaded into the drum using an optional cart dumper. The initial step is a vacuum to remove air; the evacuated air is mixed with steam and passed through a condenser and filter to destroy pathogens. The rotating pressure chamber operates at 296°F/50 psig for 30 minutes. The combined effects of the steam and the forces due to rotation, as containers are pushed against the vanes of the rotating drum and fall, cause boxes and bags to break up. The agitation also helps eliminate cold spots. After treatment, the steam is passed through a condenser and the condensate is discharged to the sewer while any residual air is vented through a carbon filter to remove odors. The control system cools the chamber down and dries the waste. Decontaminated waste is then unloaded and conveyed to a post-treatment grinder, which reduces waste volume to about 80 percent. The units are controlled by programmable microprocessors.

**Models-Capacities (in cubic feet per cycle)**
Capacities range from 300 to 750 lbs/hr per vessel. Model #1250-G1 – 109 cu ft per 50-min cycle; #1500-D1 – 212 cu ft per 60-min cycle; #2500-D1 (two vessels) – 424 cu ft per 60-min cycle; #12000-E – 1,038 cu ft per 80-min cycle

**Approximate Dimensions (size of processing vessel excluding grinder, conveyor system, etc.)**
#1250-G1 – 4’ dia x 10’; 1500-D1 – 5’ dia x 12’; 2500-D1 – 5’ dia x 12’ each (two vessels); 12000-E – 8’ dia x 25’

**Typical Installation Requirements**
Concrete pad; Steam – 450 lbs/hr at 60 psig; Water – 75 gpm; Electrical – 30 kWh, 250 A; Air – 5 cfm at 100 psig

**Features & Options**
Tempico offers integrated scale and automatic loading systems, as well as single-stage (D1) or two-stage (D2) grinders. In addition to domestic and international sales, the company also supplies units for regional waste treatment centers.

**Stage of Commercialization**
Fully commercialized

**Permitting Status**
Autoclaves are accepted or approved in all states.

**Approximate Costs**
Approximate capital costs range from $382,000 (for #1250-G1) and higher.

**Vendor Information**
Tempico, Inc., PO. Box 428, Madisonville, LA 70447-0428 or 251 Highway 21 North, Madisonville, LA 70447; Ph. 800-728-9006 or 504-845-0800; Fax 504-845-4411; www.tempico.com

*Note: Health Care Without Harm does not endorse any specific technology or company. This technology is presented here as an example of a non-incineration treatment technology. Always check with the vendor for the latest and most accurate data and specifications.*
**Shredding/Steam Treatment-Mixing/ Drying and Chemical Cleaning**

In the mid-1990s, Sterile Technologies Industries (STI) introduced a treatment system that combined steam and chemical disinfection using sodium hypochlorite (bleach). Between 1995 and 1997, a series of microbial inactivation tests were conducted for STI by three different laboratories (BBI Clinical Laboratories-Connecticut, ViroMed Laboratories-Minnesota, and Dr. E. Jarroll of Cleveland State University) for various test organisms. Log$_{10}$ kills greater than 6 for *B. stearothermophilus* and greater than 8.5 for *B. subtilis* were reported, as well as log$_{10}$ kills greater than 6 for five other microorganisms. TCLP tests in 1996 showed that the solid waste residues could be classified as non-hazardous.14

As the technology evolved, it became primarily a steam treatment unit, using the chemical disinfectant mainly for cleaning the equipment during shutdown or maintenance. The first unit was installed in 1995. Recently, STI was acquired by WR2 (described under chemical-based systems).

**STI Chem-Clav**

**Description**

With the Chem-Clav, the waste is loaded via feed conveyors or cart dumpers into the hopper, where a negative pressure is maintained by drawing air through a high-efficiency particulate air (HEPA) filter. The waste in the hopper drops into a heavy-duty shredding unit, where downward pressure is applied using a ram. The feed mechanism is controlled by an integral process controller. Shredded material enters a rotating auger conveyor where low-pressure steam is introduced through multiple ports maintaining the temperature in the conveyor between 205 to 230°F. Downstream of the conveyor is a dehydration section wherein a steam jacket increases temperatures above 212°F. The steam is discharged through a vent at the very end of the conveyor and through a condenser causing the waste to dry. The decontaminated waste exits the conveyor into a self-contained compactor or roll-off container for transport to a sanitary landfill. A chemical subsystem injects sodium hypochlorite mist for cleaning and odor control. The heavy-duty shredder reduces waste volume up to 90%.

**Models-Capacities**

Chem-Clav models have the following capacities: 600 and 1,000 lbs/hour; larger units of 2,000, 3,000 and 4,000 lbs/hr.

**Features & Options**

The units have touch-screen and self-diagnostic technology. Some units have an aluminum enclosure and are assembled and installed in about a day.

**Permitting Status**

The Chem-Clav is approved, accepted, or has site-specific approval in about 44 states.

**Approximate Costs**

The 600 and 1,000 lb/hr units have capital costs of approximately $367,000 and $427,000 respectively.

**Vendor Information**

Sterile Technologies Industries, Inc., 1155 Phoenixville Pike, Unit 105, West Chester, PA 19380; Ph. 610-436-9980; Fax 610-436-9986; www.stichemclav.com; chemclav@aol.com

*Note: Health Care Without Harm does not endorse any specific technology or company. This technology is presented here as an example of a non-incineration treatment technology. Always check with the vendor for the latest and most accurate data and specifications.*

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**Shredding-Steam Treatment-Mixing/Drying**

In the early 1990s, a Maryland dentist began working on a non-incineration technology that is now called the Steam Sterilization Macerator or SSM-150, nicknamed “WasteWacker.” The new device is sold by The Antaeus Group and combines internal shredding or maceration with steam treatment and mixing, followed by a dewatering process. In 1996, the device was installed and tested at John Hopkins University School of Medicine, and later at Franklin Square Hospital/Helix Health System.

**Antaeus SSM-150**

**Description**

The SSM-150 is a large metal box with an opening that looks like a boat hatch at one end. The operator loads red bags into the unit through the 24” diameter hatch. After closing the hatch, the operator engages a button and the computer controls take over. Hot water and steam at 300°F are injected into the process tank to soak the waste. A pump-grinder then turns on and the waste is “macerated” through a cutter (with 7-inch macerating blades grinding at 1,800 rpm) and the pump impeller, which mixes and recirculates the slurry of material. The temperature of the shredded waste stream is then held at 280°F for a period of time, after which cold water is injected to cool the material. The waste is then sent to a filter-separator that separates the solids from the liquids. Liquid waste passes through another filter and is sent to the sewer. The solids are captured in disposable filter bags and discarded with regular trash. Volume is reduced by up to 80 percent and weight by up to 15 percent.
Model-Capacity
The SSM-150 handles 150 lbs/hr; an operating cycle is about 30 minutes.

Approximate Dimensions & Weight
SSM-150 is 9.5' L x 6.5' H x 4' W, weighs 3,500 pounds; filter-separator is 4' x 5' and weighs 300 pounds.

Approximate Energy Consumption
Water is heated in a 100 kW electric boiler.

Installation Requirements
Sanitary sewer; Hot and cold water; Electrical – 480 V, 60 Hz, 3-phase; Telephone line; Installation takes about 8 hours.

Approximate Costs
Approximate capital cost: about $200,000

Vendor Information
The Antaeus Group, 10626 York Road, Suite D, Hunt Valley, MD 21030; Ph. 410-666-6160; Fax 410-666-6110; www.redbag.com; info@antaeusgroup.com

Note: Health Care Without Harm does not endorse any specific technology or company. This technology is presented here as an example of a non-incineration treatment technology. Always check with the vendor for the latest and most accurate data and specifications.

A recently introduced technology is Ecolotec. It consists of a jacketed pressure vessel fitted with internal knife hammers that rotate up to 3,500 rpm. Ecolotec combines steam treatment with mixing and internal shredding followed by a dehydration process.

Ecolotec

Description
Waste is loaded into the vessel. Steam is injected into the vessel while internal knife hammers rotate to shred the waste. The temperature in the vessel is brought to 270°F. After the treatment period, the vessel is vented through a condenser and filter system. (The filter system has a mechanical pre-filter, high-efficiency particulate air (HEPA) filter, and activated carbon filter.) A vacuum is pulled to remove any residual moisture while cooling the waste to 165°F through evaporative cooling. The vessel is then opened and the dry contents discharged and disposed as regular trash. The Ecolotec uses a programmable logic controller.

Capacity
The unit can handle 300 lbs/hr or more; each cycle is about 15 minutes.

Approximate Dimensions & Weight
8'8" x 3'4" x 8' H; weighs 2,800 lbs

Installation Requirements
Electrical – 230 V 200 A disconnect, 115 V 60 A breaker; Steam – less than 80 lbs/hr at 60 psi; Cold water – 10 gpm, 1" connection; Drain – 4"; Ventilation – standard for computer environment, 10 air exchanges/hr, machine connection to outside vent

Approximate Costs
Approximate capital cost: about $325,000

Vendor Information
Ecolotec LLC, 8 Savannah Court, Union Grove, AL 35175; Ph. 256-498-1114; Fax 256-498-1115; www.ecolotec.com; tmiken@mindspring.com

Note: Health Care Without Harm does not endorse any specific technology or company. This technology is presented here as an example of a non-incineration treatment technology. Always check with the vendor for the latest and most accurate data and specifications.

Steam Treatment-Mixing-Fragmenting/Drying
Hydroclave Systems in Canada has developed a series of steam treatment units that combine the idea of an autoclave (except that steam is applied to an outside jacket only) and agitation in a way that breaks up or fragments the waste for more even heating. Tests conducted for the vendor show inactivation of microbial load greater than $10^6$ equivalent of $B. stearothermophilus$ within 30 minutes at 121°C or 15 minutes at 132°C; results of volatile organic compound analysis are also available from the vendor.

Hydroclave

Description
The Hydroclave is basically a double-walled (jacketed) cylindrical vessel with mixing/fragmenting paddles inside. The waste is loaded through the loading door on top of the vessel. After the door is closed, high temperature steam enters the outside jacket to heat the waste via the hot inner surface. During this time, a shaft and paddles rotate inside to fragment and tumble the waste. The moisture in the waste turns to steam and pressurizes the inner vessel; however, if there is not enough moisture, a small amount of steam is added until the desired pressure
is met. The temperature is maintained at 132°C for 15 minutes (or 121°C for 30 minutes) while the mixing paddles continue to rotate. After treatment, the steam is vented through a condenser while maintaining heat input, causing the waste to dry. The steam to the jacket is shut off, the discharge door is opened, and the shaft and paddles reverse rotation to scoop the waste out through the loading door onto a conveyor or waste container. A strip chart recorder documents the process parameters.

Models-Capacities (lbs/hr including loading and unloading time)
Model #H-25 – 200 lbs/hr; #H-65 – 500; #H-100 – 750; #H-150 – 1,000; #H-200 – 1,500; #H-250 – 2,000

Approximate Dimensions (overall, L x H x W) / Weight
Model #H-25 – 82” x 79” x 48” / 6500 lbs; #H-65 – 139” x 110” x 69” / 15500 lbs; #H-100 – 176” x 102” x 70” / 17800 lbs; #H-150 – 224” x 102” x 70” / 22000 lbs; #H-200 – 249” x 102” x 70” / 23200 lbs; #H-250 – 272” x 102” x 70” / 24400 lbs

Approximate Energy Consumption
Electrical (kWh/h): Model #H-25 – 1.65; #H-65 – 4; #H-100 – 5; #H-150 – 6; #H-200 – 8; #H-250 – 8
Steam (lbs per batch): Model #H-25 – 200; #H-65 – 700; #H-100 – 1,000; #H-150 – 1,800; #H-200 – 2,200; #H-250 – 2,500

Typical Installation Requirements
Electrical – 460 V, 3-phase, 60 Hz for drive motor; Steam – 40 to 60 psi minimum depending on model; Water consumption – 100 to 1,000 gallons per batch, depending on model; Condenser water flow – 10 to 40 gpm, depending on model

Features & Options
Hydroclave offers a shredding system, conveyor, three days commissioning, and one-day operator training.

Stage of Commercialization
Fully commercialized

Permitting Status
The Hydroclave is accepted or approved in most, if not all, states.

Approximate Costs
Capital costs are on the order of $200,000 to over $500,000 depending on the size.

Vendor Information
Hydroclave Systems Corporation, 1371 Middle Road, Kingston, Ontario, Canada K7L 5H6; Ph. 613-545-1933; Fax 613-547-4521; www.hydroclave.com; hydrosys@istar.ca

Note: Health Care Without Harm does not endorse any specific technology or company. This technology is presented here as an example of a non-incineration treatment technology. Always check with the vendor for the latest and most accurate data and specifications.

Pre-shredding/Steam Treatment-Mixing
Aegis Bio-Systems recently developed a mobile treatment system combining pre-shredding and a large (9 cu. yd. capacity) autoclave chamber with internal agitation. Their system is nicknamed “Junk Yard Dog” or JYD.

AEGIS BIO-SYSTEMS JYD-1500

Description
Aegis Bio-Systems has developed JYD-1500, a large mobile treatment system that they sell or offer as a service to health care facilities. The technology handles large volumes, up to 2,500 pounds per batch. It has a two-step shredder: the primary shredder destroys containers, buckets, and other large items; the secondary shredder is a 4-ton machine that reduces the waste further at a rate of 1,500 pounds per hour. Waste volume is reduced by 80 percent or more. The shredded material goes to an autoclave chamber that agitates and treats the waste at 121°C (250°F/15 psig). The mobile system is mounted on a truck and can operate in or near the loading dock of a hospital. JYD-1500 is a relatively new technology with about three completed units.

Model-Capacity
JYD-1500 - minimum capacity of 1,500 lbs/hr

Typical Requirements
Electrical – 480 V 3-phase; Water – ½” connection; Natural gas service; Paved level space large enough for a 48-foot truck

Vendor Information
Aegis Bio-Systems, 409 W. Centennial Boulevard, Edmond, OK 73013; Ph. 888-993-1500 or 405-341-4667; Fax 405-844-9364; www.jyd-1500.com; jrayburn@aegisco.com

Note: Health Care Without Harm does not endorse any specific technology or company. This technology is presented here as an example of a non-incineration treatment technology. Always check with the vendor for the latest and most accurate data and specifications.

Shredding/Steam Treatment-
Mixing-Compaction
Designed by Goldner in Germany, the LogMed Medical Waste Processing System is a new autoclave-based treatment system. Hospital waste is fed into a funnel through a hydraulic lift mechanism and then shredded after the funnel lid is closed. Steam is added. The waste is then carried by a rotating screw that is heated using an oil jacket heating system. The waste is both heated and compressed on its way to the discharge end. Programmable controls set the proper temperature and time needed for disinfection. The LogMed-200 can handle up to 440 pounds per hour (150-200 kg/hr). Installation requirements include electrical (400 V, 50 Hz), and water (1/2", 6 bar). Estimated capital cost is about $950,000. The LogMed is offered by Erdwich Zerkleinerungssysteme GmbH (Kolpingstrasse 8, D-86916 Kaufering, Ph. 08191-9652-0, Fax 08191-9652-16; or Trennso-Technik GmbH, Siemensstr. 3, D-89264 Weissenhorn, Ph. 07309-9620-0, Fax 07309-9620-30).

MICROWAVE SYSTEMS
Microwave disinfection is essentially a steam-based process, since disinfection occurs through the action of moist heat and steam generated by microwave energy.

Microwaves are very short waves in the electromagnetic spectrum. They fall in the range of the radio frequency band, above ultra-high frequency (UHF) used for television and below the infrared range. A magnetron is used to convert high voltage electrical energy into microwave energy, which is then transmitted into a metal channel called a waveguide that directs the energy into a specific area (such as the cooking area of a microwave oven or the treatment section of a disinfection unit).

What makes microwave technology an effective quick cooking device also makes it useful as a disinfection system. The waves of microwave energy cycle rapidly between positive and negative at very high frequency, around 2.45 billion times per second. This causes water and other molecules in the waste (or in food) to vibrate swiftly as they try to align themselves (like microscopic magnets) to the rapidly shifting electromagnetic field. The intense vibration creates friction, which, in turn, generates heat, turning water into steam. The heat denatures proteins within microbial cells, thereby inactivating pathogens. Studies have shown that without water, the lethal effects of microwaves on dry microbial samples are significantly reduced. Studies have also concluded that microbial inactivation was not due to the microwave field as such but because of heat. Thus, microwave treatment systems generally add water or steam into the waste as part of the treatment process.

Microwave units routinely treat sharps waste such as needles and wastes containing pieces of metal. It is a misconception that metals cannot be treated in the microwave disinfection system. Metals that are too large or too hard to go through the shredder, such as steel plates or prosthetic pieces, cannot be treated in the unit, but only because they would damage the shredder.

Overview of the Technology
In general, microwave disinfection systems consist of a disinfection area or chamber into which microwave energy is directed from a microwave generator (magnetron). Typically, 2 to 6 magnetrons are used with an output of about 1.2 kW each. Some systems are designed as batch processes and others are semi-continuous. The microwave treatment system that has successfully established itself in the alternative technology market is manufactured by Sanitec International Holdings. It consists of an automatic charging system, hopper, shredder, conveyor screw, steam generator, microwave generators, discharge screw, secondary shredder (“particulator”), and controls. The equipment includes hydraulics, high-efficiency particulate air (HEPA) filter, and microprocessor-based controls protected in an all-weather steel enclosure.

How It Works
The operation of a microwave unit is as follows, based on a Sanitec Microwave system:

- **Waste loading**: Red bags are loaded into carts that attach to the feed assembly. High-temperature steam is then injected into the feed hopper. While air is extracted through a HEPA filter, the top flap of the hopper is opened and the container with medical waste is lifted and tipped into the hopper.
- **Internal shredding**: After the hopper flap is closed, the waste is first broken down in the hopper by a rotating feed arm and ground into smaller pieces by a shredder.
- **Microwave treatment**: The shredded particles are conveyed through a rotating conveyor screw where they are exposed to steam then heated to between 95° and 100°C by four or six microwave generators.
- **Holding time**: A holding section ensures that the waste is treated for a minimum total of 30 minutes.
- **Optional secondary shredder**: The treated waste may be passed through a second shredder that breaks it into even smaller pieces. This is used when sharps waste is treated in the microwave unit. The optional secondary shredder can be attached prior to operation in about 20 minutes. It is located at the end of a second conveyor screw.

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**Discharge:** The treated waste is conveyed using a second conveyor screw or auger, taking waste from the holding section and discharging it directly into a bin or roll-off container. The bin can be sent to a compactor or taken directly to a sanitary landfill.

**Types of Waste Treated**
The types of waste commonly treated in microwave systems are identical to those treated in autoclaves and retorts: cultures and stocks, sharps, materials contaminated with blood and body fluids, isolation and surgery wastes, laboratory wastes (excluding chemical waste), and soft wastes (gauze, bandages, drapes, gowns, bedding, etc.) from patient care. With sufficient time and temperature as well as mechanical systems to achieve unrecognizability, it is technically possible to treat human anatomical wastes but ethical, legal, cultural, and other considerations may preclude their treatment. Some states and local authorities may allow the treatment of trace-contaminated chemotherapy waste; facilities should check with their regulators (see also “Is Incineration Essential for Certain Types of Waste?” in Chapter 10).

Volatile and semi-volatile organic compounds, bulk chemotherapeutic wastes, mercury, other hazardous chemical wastes, and radiological wastes should not be treated in a microwave.

**Emissions and Waste Residues**
Since the fully-enclosed microwave unit can be installed in an open area and a HEPA filter is used to prevent the release of aerosols during the feed process, the odor problem is somewhat reduced except in the immediate vicinity of the microwave unit. Studies\(^2^1\) by a laboratory group in Connecticut, a research lab in London, and a research institute in Lyon (France) indicated that aerosol emissions are minimized by the design of the Sanitec unit.

If waste streams are not properly segregated to prevent hazardous chemicals from being fed into the treatment chamber, toxic contaminants will be released into the air, condensate, or in the treated waste. An independent study\(^2^2\) by the National Institute for Occupational Safety and Health (NIOSH) found no volatile organic compounds (VOCs) in a worker’s personal air space and work area at a microwave facility that exceeded permissible exposure limits set by the Occupational Safety and Health Administration. The highest VOC level in the autoclave facility was 2-propanol, measured at 2318 mg/m\(^3\). Another study\(^2^3\) of 11 VOCs (including benzene, carbon tetrachloride, chloroform, and other halogenated hydrocarbons) measured around six microwave treatment facilities showed that maximum and 8-hour concentrations were either below detection limits or well below permissible exposure limits.

A toxicity characteristic leachate procedure (TCLP) test of waste residue from a microwave unit, conducted by a laboratory in Florida, showed that the residue could be considered non-hazardous.\(^2^4\) Shredding of waste in the microwave unit not only enhances heat transfer but also reduces the volume of waste by as much as 80 percent. Initially, there may be a slight increase in mass due to some condensed steam. The treated waste is unrecognizable and can be disposed of in a regular sanitary landfill.

**Microbial Inactivation**
A microbiological study\(^2^5\) on treated waste from a microwave unit showed no growth of microorganisms (corresponding to a 7 log\(_{10}\) kill or better) for the following test organisms: *Bacillus subtilis*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Enterococcus faecalis*, *Nocardia asteroides*, *Candida albicans*, *Aspergillus fumigatus*, *Mycobacterium bovis*, *Mycobacterium fortuitum*, and duck hepatitis. No growth was also shown (greater than 3 log\(_{10}\) kill) for *Giardia miura*. Other studies\(^2^6\) show the efficacy of microwave disinfection for other microorganisms under moist conditions.

**Advantages and Disadvantages of the Technology**
Microwave technology has the following advantages:

- Because many people have microwave ovens, it is easy for hospital staff and communities to understand and accept the technology.
- It is accepted or approved as an alternative technology in most states, and several dozen units have been in operation for many years.
- If proper precautions are taken to exclude hazardous material, the emissions from microwave units are minimal.
- There are no liquid effluents from the Sanitec microwave unit.
- The internal shredder reduces waste volume up to 80 percent.
- The technology is automated and easy to use. It requires one operator.

The disadvantages include the following:

- If hazardous chemicals are in the waste, these toxic contaminants are released into the air or remain in the waste to contaminate the landfill.
- There may be some offensive odors around the microwave unit.
The secondary shredder used for sharps is noisy.

Any large, hard metal object in the waste could damage the shredder.

The capital cost is relatively high.

**Other Considerations**

Below are some ideas to consider when selecting autoclave or other steam-based treatment systems:

- Again, make sure that an effective waste segregation plan is in place to keep hazardous materials from being treated in a microwave system.
- Since the shredder is the highest maintenance item, it is important to make sure that no heavy metal objects are included in the waste stream to damage the shredder.
- Unlike autoclaves and other steam-based systems, the Sanitec microwave operates at or below the boiling point of water. Time-temperature disinfection criteria are generally based on temperatures at or above the boiling point. Microbiological tests using *B. stearothermophilus* or *B. subtilis* should be used to verify disinfection levels.
- Sanitec supplies a device to measure microwave energy leakage. Workers should be trained on the use of this instrument and microwave monitoring should be done on a regular basis.
- Periodic inspections should include cleaning around the hopper area at the top of the containment shelter where some debris may accumulate.
- Workers should follow religiously the list of routine preventive maintenance tasks described in detail in Sanitec’s manuals.
- Worker training should include: a basic understanding of microwaves and steam-based treatment systems, standard operating procedures, occupational safety (e.g., ergonomics, proper waste handling techniques, microwave radiation leakage testing), record keeping, identifying waste that should not be treated in the unit, recognizing shredder problems and what to do when soft waste gets stuck in the shredder section, periodic inspections and preventive maintenance, and contingency plans (e.g., what to do in case of a spill or power outage).

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**Sanitec**

**Description**

Sanitec has been in operation since 1990. It was previously a division of Asea Brown Boveri (ABB), a major multi-national engineering company, but is now part of Sanitec International Holdings. There are over 70 units installed in some 20 states and in six other countries. Most units are in hospitals, but about 20 are in commercial treatment centers. (See also description above.)

**Models-Capacities**

Model #HG-A 100 – 220 to 400 lbs/hr; #HG-A 250 – 550 to 900 lbs/hr

**Approximate Dimensions (including height of flap when opened) / Weight**

Model #HG-A 100: 22’ L x 17’9” H x 10’ W / 25,000 lbs; #HG-A 250: 24’ L x 17’ H x 10’ W / 27,000 lbs

**Approximate Energy Consumption**

0.1 kWh per pound of waste treated; peak demand – about 70 kW

**Installation Requirements**

Electrical – 460/480 Vac; 150 to 200 A, 60 Hz, 3-phase; Water – ¾” NPT hookup

**Features & Options**

Sanitec offers assistance in permitting, in-service training, siting, and engineering design. In addition to selling the technology, Sanitec can also offer tailored leasing and financing as well as turnkey installation and operation for large waste streams.

**Stage of Commercialization**

Fully commercialized

**Permitting Status**

The Sanitec microwave unit is accepted or approved as a non-incineration technology in over 40 States.

**Approximate Costs**

Model #HG-A 100 – about $500,000; #HG-A 250 – about $600,000

**Vendor Information**

Sanitec International Holdings, 26 Fairfield Place, West Caldwell, NJ 07006; Ph. 973-227-8855; Fax 973-227-9048; [www.sanitec-inc.com](http://www.sanitec-inc.com); sales@sanitec.net

*Note: Health Care Without Harm does not endorse any specific technology or company. This technology is presented here as an example of a non-incineration treatment technology. Always check with the vendor for the latest and most accurate data and specifications.*
CMB (Christof Group/Maschinenbau und Handels GmbH) in Austria has developed a small microwave unit that can be installed at or near the point of waste generation on a hospital floor or in a clinic. It is automated and simple to operate. The Sintion is designed for small quantities of medical waste.

**SINTION**

**Description**

Waste is placed loosely in a steam-permeable bag (no double bags or closed containers; puncture-proof sharps containers should not be hermetically sealed). The operator lifts the lid and places the waste bag in the disinfection chamber (one waste bag per treatment cycle). The outside of the waste is exposed to steam while micro-wave energy generates heat within the waste. The disinfection chamber operates at 121°C (250°F) but can go as high as 134°C (273°F) if needed. The exposure time can be set, usually between 10 to 30 minutes. A typical treatment cycle is 20 minutes. After treatment, the waste can be removed and passed through an optional shredder or compactor. Sintion uses a self-controlling computer program. It has wheels and can be moved.

**Capacity**

The unit can handle 60-70 liters of waste per cycle (about 12 kg/cycle) or 2.1-2.5 cu ft per cycle (26 lb/cycle), corresponding to about 78 lbs/hr maximum.

**Approximate Dimensions & Weight**

1120 mm D x 840 mm W x 1180 mm H; weighs 430 kg (3.7’ D x 2.8’ W x 3.9’ H; weighs 950 lbs)

**Approximate Energy Consumption**

About 1.5 kWh per cycle; peak demand is 8.7 kW

**Installation Requirements**

Electrical – (standard Euro-power plug) 230/400 V, 50 (60) Hz, 16 A (slow); Water – ¾”, cold water <20°C, 4.5 bar pressure minimum, deionized, about 10 liters per cycle; Drain – 1”; Maximum ambient temperature – 35°C; Good ventilation

**Features & Options**

CMB offers staff training and installation. They also sell plastic bags and containers for internal transport. A shredder is optional.

**Stage of Commercialization**

Initial stage of commercialization

**Approximate Costs**

Approximate capital cost: around $45,000

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**DIELECTRIC HEATING**

Stericycle uses a heating process based on “electro-thermal deactivation.” Waste is placed in containers called “Steritubs” and loaded on a conveyor which have radiation and hydrocarbon detection sensors. The contents then go to feed control rolls that transfer the waste to a size reduction assembly that grinds the material. The ground waste is then carried by high-velocity air to a cyclone where the materials are deposited on a sealed conveyor. (The air passes through a dust collector, HEPA filter, and air wash before being released.) The ground material is sprayed with water and compacted. The compacted waste is subjected to high-voltage electrical fields (low-frequency radio waves; 50 kV/meter, 10 MHz) resulting in dielectric heating to about 194-203°F (90-95°C). The heated vessels are then held for one hour before being loaded by a conveyor into disposal containers. Some of the waste can be used as refuse-derived fuel. If treated waste is used as refuse-derived fuel, the burning would result in emissions associated with combustion. These emissions should be considered in evaluating environmental impact. Load capacities of the ETD range from 1,000 to 6,000 lbs/hr. (Stericycle, Inc., 28161 N. Keith Drive, Lake Forest, IL 60045; Ph. 847-367-5910)

Stericycle operates commercial treatment facilities for medical waste. In recent years, Stericycle was under investigation for possible occupational safety and health problems at its Morton, WA plant. A number of workers were diagnosed with tuberculosis. Health inspectors noted that the flaps on the feed chute leading to the grinder were removed. These flaps were reportedly designed to prevent waste particles from being thrown back into the plant floor in the event that shredding equipment became clogged. Employees reported to the state Department of Labor and Industries that the system would sometimes lose negative pressure, resulting in a “blowback” of air from the processing area to the plant floor. The NIOSH investigation concluded that as a result of these conditions, the employees could have been exposed to pathogens potentially present in the medical waste.

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**Vendor Information**

CMB/Christof Group, Plabuterscherstrasse 115, A-8051 Graz, Austria; Ph. (43-316) 68-55-150; Fax (43-316) 68-55-1510; cmb@sintion.at

Note: Health Care Without Harm does not endorse any specific technology or company. This technology is presented here as an example of a non-incineration treatment technology. Always check with the vendor for the latest and most accurate data and specifications.
A report prepared for Health Care Without Harm provides an in-depth profile of the nation’s largest medical waste firm. Stericycle became the largest medical waste disposal company in the United States after it acquired the medical waste disposal business of Browning Ferris Industries (BFI) in 1999. The purchase included BFI’s medical waste incinerators. BFI had previously announced plans to shut down most of its medical waste incinerators but after the acquisition, Stericycle reportedly did not make the same public commitment.

Stericycle provides medical waste disposal services but does not sell its electro-thermal deactivation technology in the U.S. Hence, a more detailed description of the ETD process is not provided here. Readers interested in more information about Stericycle are referred to the Health Care Without Harm publication cited in the footnote below.

NOTES


3. Based on vendor website and on technical data provided by Bondtech Corporation from July 1995 to August 2000.

4. Based on vendor material provided by ETC from 1993 and 1998.

5. Based on vendor website, technical data provided by Mark Costello from 1998 to 2000, and personal communication with Roger Markle.

6. Based on vendor website, technical material provided by R.E. Baker in 1996, Sierra Industries material from 1998 to 2000, and personal communications.

7. Based on vendor literature obtained in 2000.

8. Based on vendor website, brochures provided by Tutttnauer from 1994 to 1997, and personal communications with Robert Basile.


10. Based on vendor website, brochures and technical data provided by San-I-pak from 1994 to 2000, written responses to technical questions, site visits to San-I-pak installations in California, published data, and personal communications with Karl Oser, Jim Ryder, and Arthur McCoy.


12. G. Braedt, “Treatment of Regulated Medical Waste in Tempico’s Rotoclave produces an output that is sterile and non-carcinogenic.” (no date); report provided to the author by the vendor.

13. Based on vendor website, brochures and technical data provided by Tempico from 1994 to 2000, written responses to technical questions, and personal communications with Sid Alexander.

14. Copies of microbiological test reports by BBI Clinical Laboratories (New Britain, CT), ViroMed Laboratories (Minneapolis, MN), and by Dr. Edward Jarroll, Cleveland State University, as well as air quality and TCLP tests by Waterford Compliance Group (Pottstown, PA) and Blue Marsh Laboratory (Douglassville, PA) were provided by the vendor. These studies were commissioned by Tempico.

15. Based on vendor website, various technical material provided by STI from 1997 to 2000, written responses to questions, and personal communication with Randall McKee.


17. Based on vendor website, vendor material provided in 1999, and personal communications with Wolf von Lersner and Michael Neubauer.


23. Copy of “Mixture TLV Results” from Burlington County, JFK Medical Center, Our Lady of Lourdes, West Jersey, Dover General, and Cooper provided by Sanitec.

24. Copy of “Landfill Acceptability of Waste Residue From ABB Sanitec Microwave Disinfection Unit” by Technical Services, Inc. (Jacksonville, FL) provided by Sanitec.

25. Copy of “ABB Sanitec Microwave Disinfection System Laboratory Test Results” from North American Laboratory Group and Stanford University, provided by Sanitec.


27. Based on vendor website, brochures and technical material provided by Sanitec from 1994 to 2000, written responses to technical questions, technical evaluation of a microwave unit installation in California, personal communication with Mark Taitz, and published data.

28. Based on technical data provided by Sintion from 1997 to August 1999, and personal communication with Carmen Spinotti.
